Silurian-Devonian Pelecypods and Paleozoic Stratigraphy of Subsurface Rocks in Florida and Georgia and Related Silurian Pelecypods From Bolivia and Turkey

GEOLOGICAL SURVEY PROFESSIONAL PAPER 879

Silurian-Devonian Pelecypods and Paleozoic Stratigraphy of Subsurface Rocks in Florida and Georgia and Related Silurian Pelecypods From Bolivia and Turkey

By JOHN POJETA, JR., JIŘÍ KŘÍŽ, *and* JEAN M. BERDAN

GEOLOGICAL SURVEY PROFESSIONAL PAPER 879

General geologic setting of the Florida and Georgia subsurface Paleozoic; systematics and the biostratigraphic, paleoecologic, and paleobiogeographic significance of the pelecypods

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress Cataloging in Publication Data

Pojeta, John.

Silurian-Devonian pelecypods and Paleozoic stratigraphy of subsurface rocks in Florida and Georgia and related Silurian pelecypods from Bolivia and Turkey.

(Geological Survey professional paper 879)

Bibliography: p.

Supt. of Docs. no.: I 19.16:879

1. Lamellibranchiata, Fossil. 2. Paleontology—Silurian. 3. Paleontology—Devonian. 4. Geology, Stratigraphic—Paleozoic. 5. Geology—Florida. 6. Geology—Georgia. I. Kříž, Jiří, joint author. II. Berdan, Jean Milton, joint author. III. Title. IV. Series: United States. Geological Survey.

Professional paper 879.

QE811.P65 564'.11'09758 74-16046

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington D.C. 20402
Stock Number 024-001-02731-3

CONTENTS

ILLUSTRATIONS

[Plates follow index]

TABLES

SILURIAN-DEVONIAN PELECYPODS AND PALEOZOIC STRATIGRAPHY OF SUBSURFACE ROCKS IN FLORIDA AND GEORGIA AND RELATED SILURIAN PELECYPODS FROM BOLIVIA AND TURKEY

By John Pojeta, Jr., Jiří Kříž, and Jean M. Berdan

ABSTRACT

The subsurface sedimentary Paleozoic rocks beneath northern Florida and adjacent parts of Georgia and Alabama comprise a sequence of quartzitic sandstones and micaceous shales, dark-gray shales, and red and gray siltstones ranging in age from Early Ordovician to Middle Devonian. The Silurian-Devonian pelecypod faunas from four wells (three of which, the Ragland, Cone, and Tillis wells, are in Florida, and one of which, the Chandler, is in Georgia) are described and illustrated. Also described are Silurian pelecypods from one locality in Bolivia and one in Turkey.

Biostratigraphically, the faunas from the American wells range in age from Wenlockian or Ludlovian (Silurian) to Middle Devonian; the Bolivian specimens are probably Ludlovian (Late Silurian); and the Turkish specimens are probably Wenlockian or Ludlovian (Silurian). Paleoecologically, the strata in the American wells represent shallow-water normal marine environments, and all pelecypods known from them belong to one of three life-habit groups—byssally attached, burrowing, or reclining. The Bolivian and Turkish pelecypods likewise belong only to these three life-habit groups. Analysis of the geographic distribution of the Florida Paleozoic pelecypod genera shows that they are closest to the forms found in central Bohemia and Poland; elements of this fauna also occur in Nova Scotia, North Africa, and South America.

INTRODUCTION

This paper is based upon material from four cores from Florida and Georgia and from two small collections, one each from Bolivia and Turkey (figs. 2–4). All six localities have yielded Silurian-Devonian pelecypods, and four of them show affinities to the Late Silurian–Early Devonian pelecypod fauna of Bohemia and Poland.

The four American cores are from the following wells: (1) Mont Warren *et al.* A. C. Chandler No. 1, Early County, Ga.; (2) Coastal Petroleum Co. J. B. and J. T. Ragland No. 1, Levy County, Fla.; (3) Sun Oil Co. J. H. Tillis No. 1, Suwannee County, Fla.; and (4) Humble Oil and Refining Co. J. P. Cone No. 1, Columbia County, Fla.

The Chandler well reached a depth of 7,320 ft; Paleozoic rocks were first encountered at a depth of 6,600 ft. Palmer (1970) described some pelecypods from this well, but none of the mollusk fauna from the other wells has been described previously. The Ragland well reached a depth of 5,850 ft; Paleozoic rocks were first encountered at a depth of 5,792 ft. The Tillis well reached a depth of 3,572 ft, and the first Paleozoic rocks were recorded at a depth of 3,480–3,500 ft. The Cone well penetrated to a depth of 4,444 ft, and the top of the Paleozoic was reached at 3,482 ft.

The taxonomic part of this paper is divided geographically into sections on the southeastern United States, Bolivia, and Turkey, and comparisons are made with Bohemia and Poland where the Silurian and Devonian rocks contain similar or identical faunal elements. Each of the American wells is sufficiently different from the others that its fauna is described separately. The faunas are compared with each other and with those of central Europe.

The pelecypod fauna from the Chandler well is probably Middle Devonian in age, that of the Tillis well is Early Devonian, that of the Cone well is Late Silurian (Pridolian), and the fossils from the Ragland well are Silurian in age (Wenlockian-Ludlovian). The material from Turkey and Bolivia is Silurian in age (Wenlockian-Ludlovian).

Although the pelecypods are taxonomically varied, all belong to one of three life-habit groups: byssally attached, burrowing, or reclining. The abundance of byssate and reclining forms suggests that the enclosing sediments were laid down in relatively shallow water. The abundance of paleotaxodonts in some of the collections also suggests this.

We have plotted the distributions of the pelecypod genera on a reconstruction of the positions of Late Silurian–Early Devonian landmasses and have indicated the probable oceanic surface current patterns. The distribution suggests that the similarity between the faunas of Bohemia and Florida may have been due to the transport of pelecypod larvae by a warm current from central Europe down the east coast of North America.

Responsibility for the general geologic setting section is that of Berdan; Pojeta and Kříž are responsible for the rest of the paper.

ACKNOWLEDGMENTS

We would like to thank the following persons for their help and cooperation: Necdet Özgül, of the Turkish Geological Survey, for collecting the specimens from Turkey and W. T. Dean, of the Geological Survey of Canada, for bringing the Turkish material to our attention; Mario Suárez-Riglos brought the Bolivian specimens to our attention; E. L. Yochelson and John S. Peel and the late Edwin Kirk identified the gastropods and crinoids respectively; Bedřich Bouček, R. H. Flower, P. M. Kier, and G. A. Cooper examined the tentaculites, cephalopods, crinoids, and brachiopods respectively; graptolites were identified by W. B. N. Berry; J. M. Schopf identified the acid-resistant microfossils, and fragments of plant megafossils were identified by F. M. Hueber.

K. V. W. Palmer loaned us the specimens she described from the Chandler well; these specimens are stored at the Paleontological Research Institution (PRI). The Turkish specimens are the property of the Maden Tetkik ve Arama (MTA). All other figured material is deposited in the United States National Museum (USNM).

Preparation of the section on the general geologic setting of the subsurface Paleozoic rocks in Florida and adjacent parts of Georgia and Alabama would not have been possible without the advice and encouragement of P. L. Applin and the late E. R. Applin, who initiated and coordinated much of the work on the Paleozoic of this area. Unattributed remarks in this section on the ages and lithologies of Paleozoic rocks are based on the examination by Berdan of cores and samples provided by numerous oil companies and by the Florida Geological Survey. Special thanks are due the following: the late Herman Gunter and the late R. O. Vernon, both Directors of the Florida Geological Survey; the late D. J. Munroe and the late Louise Jordan, of the Sun Oil Co., who made available the cores of the Chandler, Tillis, and Ragland wells; A. C. Raasch, Jr., and E. T. Caldwell, of the Humble Oil and Refining Co., who made available the cores of the Cone well.

GENERAL GEOLOGIC SETTING OF SUBSURFACE PALEOZOIC ROCKS IN FLORIDA AND GEORGIA

HISTORY OF DRILLING

The first intimations that Paleozoic rocks underlay the Mesozoic section in Florida and adjacent parts of Georgia and Alabama came in the late twenties (Gunter, 1928) and thirties (Campbell, 1939). At that time no fossils had been found; the first wells were drilled by cable tools, and no cores were available, so that Gunter (1928, p. 1108) interpreted the highly micaceous cuttings from Ocala Oil Corp. Clark-Ray-Johnson well No. 1 (fig. 1, well 8, sec. 10, T. 16 S., R. 20 E., Marion County, Fla.) as metamorphic rock and compared them with the metamorphosed Paleozoic formations farther north beneath the Cretaceous. In 1939 (completed Jan. 1940) the St. Mary's River Oil Corp. Hilliard Turpentine Co. No. 1 (fig. 1, well 22, sec. 19, T. 4 N., R. 24 E., Nassau County, Fla.) penetrated 168 ft of dark-gray, non-calcareous, slightly micaceous shale with interbedded siltstone and quartzite. This was also a cable-tool well, and Campbell (1939, p. 1713) suggested that the sequence might represent the Chattanooga Shale. It was not until the period from 1943 through 1950, when many wells were drilled with rotary rigs and cored (fig. 1) that enough fossils were found to provide a tentative framework for the Paleozoic stratigraphy beneath northern Florida and southern Georgia and Alabama. A general outline of the regional setting has been provided by Applin (1951), and a preliminary attempt at correlating the Paleozoic rocks was made by Bridge and Berdan (1952); the latter report, however, requires revision because of subsequent refinements in the identification of some of the fossils and more recent determinations of microfossils.

Because the petroleum companies drilling the wells from which the data on the subsurface Paleozoic were obtained were looking for oil in the overlying Mesozoic section, most of the wells did not penetrate very far into the Paleozoic rocks. Probably in part as a result of the short amount of section penetrated by most wells, no well has encountered more than one assemblage of megafossils, and few have cut more than one lithologic unit. Hence the strati-

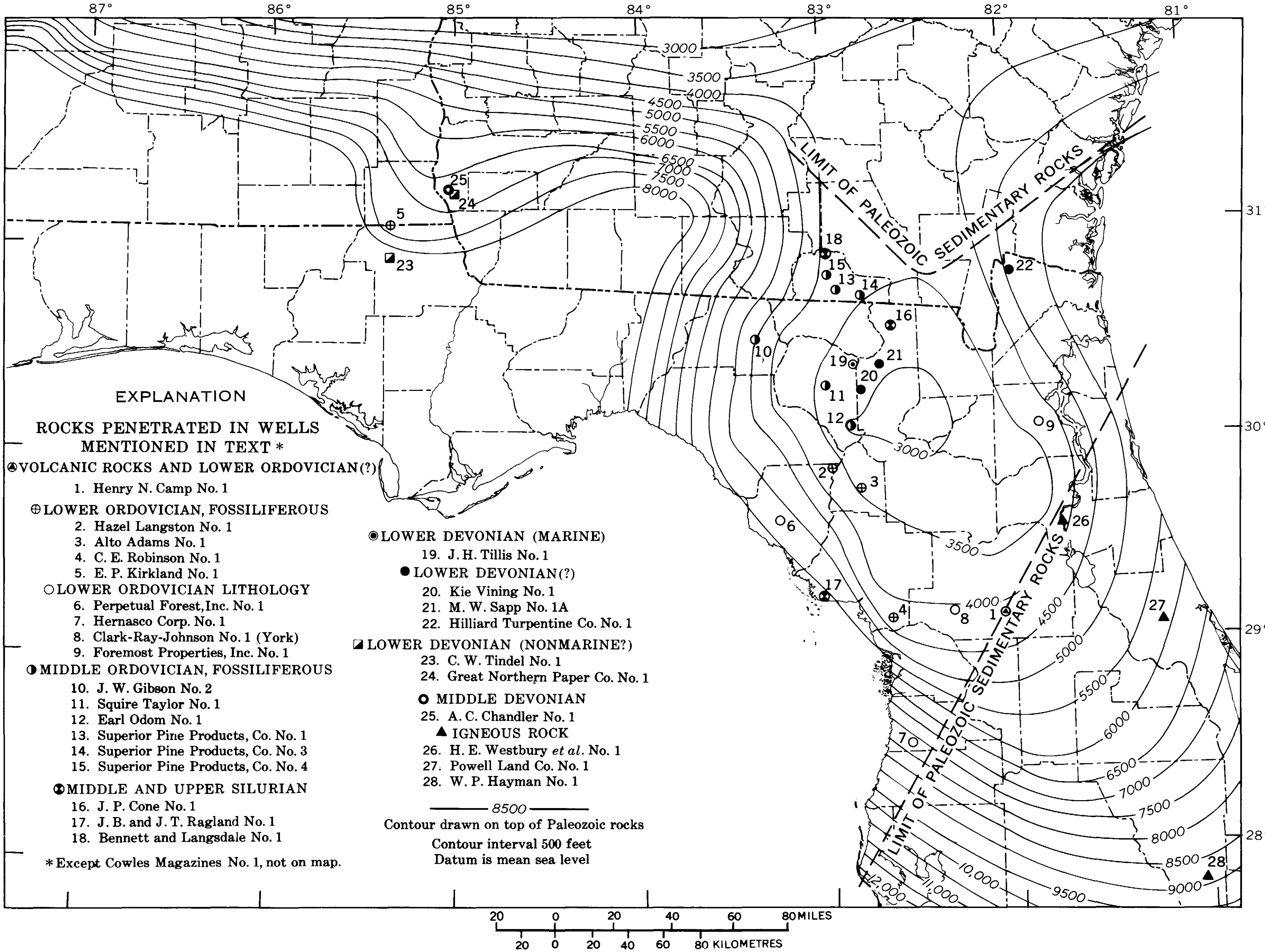


FIGURE 1.—Subsurface distribution of Paleozoic rocks and structure contours on the top of Paleozoic rocks in peninsular Florida and adjacent parts of Georgia and Alabama and locations of wells in Florida, Georgia, and Alabama discussed in text.

graphic position of the rocks penetrated by the wells must be inferred from the fossils; and in cores where fossils are nondiagnostic or absent, correlation between wells has been based to a large extent on the lithology. Of more than 50 wells penetrating Lower Paleozoic sedimentary rocks, 18 have yielded either megafossils or acid-resistant microfossils. Fossils are scarce in the lower part of the sequence, and in many instances there is only one fossil per well; only six wells have yielded moderately diversified faunas, and all but one of these are in the part of the section dated as Silurian or Devonian.

GENERAL SETTING

The sedimentary Paleozoic rocks beneath northern Florida and adjacent parts of Georgia and Alabama comprise a sequence of quartzitic sandstones and micaceous shales, dark-gray shales, and red and gray siltstones ranging in age from Early Ordovician to Middle Devonian. Those in northeastern Florida and southeastern Georgia range in age from Early Ordovician to Early Devonian and occupy a roughly triangular area on the crest of the Peninsular arch (Applin, 1951, p. 3); this area was named the "Suwannee River Basin" by Braunstein (1958, p. 511) which was shortened to Suwannee basin by P. B. King (in Flawn and others, 1961, p. 90). The southeastern boundary of this area extends diagonally across the State from about the north end of Old Tampa Bay on the west coast to a point between Jacksonville and St. Augustine on the east coast (Applin, 1951. p. 13, fig. 1). This boundary roughly parallels a northeast-trending series of magnetic lows (King, 1959, fig. 1). The northern boundary, less well defined and more irregular, trends generally east-west.

This main area of sedimentary Paleozoic rocks is separated from a smaller area at the junction of Florida, Georgia, and Alabama by a deep trough or sag in the pre-Cretaceous surface which was first recognized by Dall and Harris (1892, p. 111) as the "Suwannee Strait," a term later revised by Applin and Applin (1967, p. G30–G31) to Suwannee Saddle. The oldest rock penetrated in this trough appears to be Triassic in age (Applin and Applin, 1965, p. 16, fig. 3). These rocks have been discussed by Applin (in Reeside and others, 1957, p. 1486–1489). They appear to overlap the Paleozoic rocks on both sides of the trough, but as yet no wells in the middle of the trough have passed through the Mesozoic rocks into Paleozoic strata. The youngest Paleozoic rocks in the western, tristate area are Middle Devonian, younger than those on the Peninsular arch.

LOWER ORDOVICIAN SANDSTONES

The oldest Paleozoic sedimentary unit consists of quartzitic sandstones and highly micaceous shales characterized by vertical *Skolithos* borings and inarticulate brachiopods. This unit is present in more than 20 wells and is the most widely distributed of any of the Paleozoic units, occurring in wells from Marion County, Fla., to Houston County, Ala. Howell and Richards (1949, p. 35–36) described one of the linguloid brachiopods from Sun Oil Co. Hazel Langston No. 1 (fig. 1, well 2, sec. 8, T. 8 S., R. 14 E., Dixie County, Fla.) as *Lingulepis floridaensis* and considered it possibly Late Cambrian to Early Ordovician in age and probably not younger than Early Ordovician. The most reliable date for at least part of this unit is Early Ordovician, based on the occurrence of graptolites in Union Producing Co. E. P. Kirkland No. 1 (fig. 1, well 5, sec. 20, T. 7 N., R. 11 W., Houston County, Ala.). These graptolites have been identified by W. B. N. Berry (written commun., 1958) as *Didymograptus deflexus* Elles and Wood and ?*D. protoindentus* Monsen. According to Berry, neither of these graptolites is known from elsewhere in North America, but they do occur together in the zone of *Phyllograptus densus* (=3 b γ of the Lower Didymograptus Shale) in Norway. He states that this zone is about the equivalent of Ross' trilobite zone H in Utah and the Cotter and (or) Powell Formations in the Ozark sequence. While *Didymograptus deflexus* is not known elsewhere in North America, it is found in the lower Arenigian rocks of Wales and northern England, where it is the name giver of the lowest identified Ordovician graptolite zone (Williams and others, 1972, p. 11).

The Kirkland well is correlated with most other wells in peninsular Florida primarily on the basis of the presence of *Skolithos* borings and on general lithologic similarity; it also contains large oboloid brachiopods. The cores from the Langston well and from two other wells in peninsular Florida, the Sun Oil Co. Alto Adams No. 1 (fig. 1, well 3, sec. 15, T. 9 S., R. 15 E., Gilchrist County, Fla.) and Humble Oil and Refining Co. C. E. Robinson No. 1, (fig. 1, well 4, sec. 19, T. 16 S., R. 17 E., Levy County, Fla.) likewise contain fragments or specimens of large oboloid brachiopods.

One well, the Humble Oil and Refining Co. Foremost Properties Corp. No. 1 (fig. 1, well 9, sec. 4, T. 6 S., R. 25 E., Clay County, Fla.), which unfortunately has yielded no body fossils, cored more than 1,500 ft of *Skolithos*-bored sandstone, and another well, Stanolind Oil and Gas Co. and Sun Oil Co. Perpetual Forest, Inc., No. 1 (fig. 1, well 6, sec. 5, T. 11 S., R. 11 E., Dixie County, Fla.), penetrated more than 2,000 ft of the same rock. These thicknesses imply that beds of Cambrian age might be present in the lower part of the section, but because of the lithologic similarity from top to bottom of the *Skolithos* unit, the entire thickness is tentatively considered Early Ordovician.

The Foremost Properties well penetrated about 300 ft of white and reddish sandstone above the *Skolithos* quartzitic sandstone. The former unit is believed to occur in several other wells, in one of which, Ohio Oil Co. Hernasco Corp. No. 1 (fig. 1, well 7, sec. 19, T. 23 S., R. 18 E., Hernando County, Fla.), more than 750 ft of the unit was penetrated. No fossils have as yet been found in this unit, but it also is tentatively considered Early Ordovician in age because of its presumed stratigraphic position between the *Skolithos* beds and the next youngest unit. Carroll (1963, p. A9–A12) recognized three assemblages of heavy minerals in samples from this unit and the *Skolithos* unit; her mineral assemblage A is most common in this unit, although not restricted to it. Carroll (1963, p. A12) has suggested that her mineral assemblages may be useful for correlation; the occurrence of her assemblage A in the Robinson well in quartzite below assemblage C in *Skolithos* beds suggests the possibility that this unit and the *Skolithos* unit are interbedded. Cores from the Foremost Properties well also suggest this possibility, although, because of the spacing of the cores studied for heavy minerals, this is not apparent in Carroll's report. The presence of Carroll's assemblage A in sandstones above volcanic rocks in the Sun Oil Co. Henry N. Camp No. 1 (fig. 1, well 1, sec. 16, T. 16 S., R. 23 E., Marion County, Fla.) adds weight to the interpretation that these sandstones are Paleozoic and equivalent to the white sandstone unit above the *Skolithos* unit. The *Skolithos* unit is not present in this well; its absence may be due to faulting.

MIDDLE OR UPPER ORDOVICIAN CLASTIC ROCKS

A sequence of dark-gray to black shales, with some interbedded gray sandstone, presumably overlies the white sandstone unit. One well, Hunt Oil Co. J. W. Gibson No. 2, (fig. 1, well 10, sec. 6, T. 1 S., R. 10 E., Madison County, Fla.) penetrated 757 ft of dark-gray (*N* 3) shale and white to gray quartzitic sandstone, with shale predominating. Core 2 from this well, from a depth of 5,154 to 5,162 ft, or 231 ft above the bottom of the hole, is a dark-gray shale which contains the trilobite *Colpocoryphe exsul* Whittington, 1953. Whittington (1953, p. 1) considered this trilobite to be of Llanvirnian-Llandeilian Age or early Middle Ordovician. The same core contains a species of *Conularia* and numerous small phosphatic brachiopods which appear to be obolids. Whittington and Hughes (1972, p. 245) have stated that *Colpocoryphe exsul* belongs in their *Selenopeltis* faunal province, which also occurs in Czechoslovakia and northern Africa. Core 2 was the lowest core taken in this well; gray and white quartzite appear in the rotary cuttings at a depth of 5,200 to 5,210 ft, and the amount of quartzite in the cuttings increases to the bottom of the hole. This may indicate that the contact of the black shale sequence with the underlying white sandstone unit was crossed by this well, but without cores it is not possible to determine unequivocally whether the contact was crossed or, if it was, whether the contact is sharp or gradational. Milton (1972, p. 19–20) reported fragments of diabase in the cuttings from 5,200 to 5,210 ft; diabase also occurs at the top of the Paleozoic section in this well.

At least five other wells have penetrated Ordovician shales. Three of these, Sun Oil Co. Earl Odom No. 1 (fig. 1, well 12, sec. 31, T. 5 S., R. 15 E., Suwannee County, Fla.), Humble Oil and Refining Co. Squire Taylor No. 1 (fig. 1, well 11, sec. 25, T. 3 S., R. 13 E., Suwanee County, Fla.), and Hunt Oil Co. Superior Pine Products Co. No. 3 (fig. 1, well 14, lot 532, Land District 13, Echols County, Ga.) have yielded conodonts identified by John W. Huddle (oral commun., 1973) as *Drepanodus* sp.; the genus ranges throughout the Ordovician, but species of this type are most common in the Middle and Upper Ordovician. The Odom-well conodonts came from core 8, at a depth of 3,060 to 3,080 ft, and are associated with phosphatic brachiopods. In addition, Andress, Cramer, and Goldstein (1969) have described chitinozoans from the Odom well from a depth of 3,040 to 3,161 ft, which is the total thickness of Paleozoic rock penetrated by this well. They consider the chitinozoans of their bottommost sample to "indicate a geologic age for this sample which falls at an undeterminable position within the time span from late Arenigian to early Caradocian." (Andress, Cramer, and Goldstein 1969, p. 369). This age range would include that of *Colpocoryphe exsul* from the Gibson well.

The conodont in Superior Pine Products Co. No. 3 came from a depth of 3,670 to 3,680 ft. The cores at this depth are red micaceous shale and sandstone and contain fairly large phosphatic brachiopods. Lower cores in this well, from a depth of 3,892 to 3,895 ft, are dark-gray micaceous shale with some interbedded fine sandstone and contain small phosphatic brachiopods. Two other wells, Hunt Oil Co. Superior Pine Products Co. No. 1 (fig. 1, well 13, lot 364, Land District 13, Echols County, Ga.) and Hunt Oil Co. Superior Pine Products Co. No. 4 (fig. 1, well 15, lot 219, Land District 13, Echols County, Ga.) also contain phosphatic brachiopods of probable Middle Ordovician age. In Superior Pine Products Co. No. 1 the brachiopods are in a dark-gray micaceous shale, but in Superior Pine Products Co. No. 4, which penetrated only 5 ft of Paleozoic rocks, they are in red micaceous shale and sandstone like the upper part of the section in Superior Pine Products Co. No. 3.

SILURIAN AND DEVONIAN SHALES

Presumably overlying the Ordovician shales in peninsular Florida and adjacent parts of Georgia is a sequence of black to dark-gray shales dated by fossils as Silurian to Devonian in age. As yet, no well can be demonstrated to have passed from the Silurian-Devonian shales into the Ordovician shales, and the nature of the contact is unknown. In all, seven wells have penetrated shales of Silurian to Early Devonian age; however, two of these, Sun Oil Co. M. W. Sapp No. 1A (fig. 1, well 21, sec. 24, T. 2 S., R. 16 E., Columbia County, Fla.) and Humble Oil and Refining Co. Bennett and Langsdale No. 1 (fig. 1, well 18, lot 146, Land District 12, Echols County, Ga.) have been dated only on the basis of acid-resistant microfossils identified by J. M. Schopf (written commun., 1959). He identified *Angochitina filosa* Eisenack, *Micrhystridium pavimentum* Deflandre and *Hystrichosphaeridium ramusculosum* Deflandre from core 38 (4,171–4,173 ft, bottom) of the Bennett and Langsdale well, but Cramer (1973, fig. 2) has indicated that *A. filosa* occurs in three of his four chitinozoan zones for the Florida Paleozoic, ranging from Late Silurian into the Early Devonian. The relationship of the rocks penetrated in the Georgia well to those in wells in Florida is not certain, except that they are probably Silurian or Early Devonian. The 65 ft of Paleozoic section penetrated in the Bennett and Langsdale well contains a considerable amount of sandstone, unlike the sections in other wells in the Silurian-Devonian interval, and the sandstone in some cores is crossbedded and shows horizontal trails to the extent that it was originally considered part of the Lower Ordovician *Skolithos* unit (Bridge and Berdan, 1952, p. 35).

The M. W. Sapp No. 1A penetrated only 7 ft of shale, which was gray to pink at the top of the section and dark gray to black in the lower part and at the bottom of the hole. Schopf (written commun., 1959) did not specifically identify any microfossils from this well, but stated that the assemblage that he had recovered from core 22 (3,306–3,311 ft) was the same as that from Gulf Oil Corp. Kie Vining No. 1 (fig. 1, well 20, sec. 2, T. 4 S., R. 15 E., Columbia County, Fla.) from core 43 (3,450–3,470 ft). The Kie Vining well, which cored 117 ft of dark-gray Paleozoic shale, contains arthropod megafossils in addition to the acid-resistant microfossils. Kjellesvig-Waering (1955) described the eurypterid *Pterygotus* (*Acutiramus*) *suwanneensis* and the archaeostracan *Ceratiocaris berdanae* from core 43 of this well, but no other groups of megafossils have as yet been found. Goldstein, Cramer, and Andress (1969, p. 379) listed the chitinozoans from the Kie Vining well from a depth of 3,350 to 3,450 ft, which is above core 43, and considered them the same assemblage as one they found in the Hilliard well at a depth of 4,640 to 4,824 ft. Cuttings from the Hilliard well in the interval 4,700 to 4,800 ft have yielded a fragment of eurypterid integument with semilunar scales suggestive of *Pterygotus* (Applin, 1951, p. 15), which agrees with the correlation between wells proposed by Goldstein, Cramer, and Andress on the basis of the chitinozoans. Cramer (1973, p. 284–285, fig. 2) suggested that the chitinozoans in the Hilliard and Kie Vining wells fall in the age range of Wenlockian to basal early Gedinnian.

The Hilliard and Kie Vining wells were originally tentatively correlated by Bridge and Berdan (1952, table 1) with Sun Oil Co. J. H. Tillis No. 1 (fig. 1, well 19, sec. 28, T. 2 S., R. 15 E., Suwannee County, Fla.) on the basis of the eurypterid remains. Goldstein, Cramer, and Andress (1969, fig. 2), on the basis of chitinozoans, indicated that the Hilliard and Kie Vining assemblages were either younger or older than the assemblage that they found in the Tillis well, and later Cramer (1973, fig. 2) showed the Tillis microfauna as considerably younger than the Hilliard and Kie Vining chitinozoans. The Tillis well passed through 10 ft of brownish-gray, reddish-brown, and red and lavender variegated shale before penetrating 68 ft of black shale; apparently the chitinozoans were obtained both from the variegated shale (core 43, 3,494–3,502 ft) and the lower part of the black shale (core 44, 3,552–3,568 ft) according to Goldstein, Cramer, and Andress (1969, p. 377). The pelecypods described in this paper are all from core 44 in the black shale; no megafossils were found in the variegated shale. In addition to the pelecypods *Nuculites* sp. A, *Nuculites* sp. B, *Arisaigia* cf. *A. postornata*, *Arisaigia* sp., *Actinopteria* sp. A, *Actinopteria* sp. B, *Pterinopecten*?, *Modiomorpha* sp., *Eoschizodus*?, *Pleurodapis* sp., *Prothyris* sp., and pholadomyacean, core 44 contains *Tentaculites*, the gastropod *Plectonotus*, bolliid ostracodes of an undetermined genus, smooth ostracodes, and *Pterygotus floridanus*, described by Kjellesvig-Waering (1950). The fossils are preserved as impressions in the shale, with the exception of some tentaculitids, which are slightly pyritized. The differences in the megafaunal assemblages of the Kie Vining and Tillis wells suggest that Cramer's separation of these wells on the basis of Chitinozoa is probably correct.

The two other wells in peninsular Florida which penetrated the Silurian-Devonian shales are Humble Oil and Refining Co. J. P. Cone No. 1 (fig. 1, well 16, sec. 22, T. 1 N., R. 17 E., Columbia County, Fla.) and Coastal Petroleum Co. J. B. and J. T. Ragland No. 1 (fig. 1, well 17, sec. 16, T. 15 S., R. 13 E., Levy County, Fla.). The Cone well cored through a thickness of 950 ft of dark-gray to black shale and diabase sills (Milton, 1972, p. 13–18). In addition to the pelecypods *Panenka* sp., *Dualina secunda*, *Mytilarca* cf. *M. longior*, *Lunulacardium excellens*, *Lunulacardium* spp., *Cheiopteria bridgei*, *Cheiopteria*?, *Leptodesma carens*, and *Actinopteria migrans*, the Cone well megafauna also includes orthoconic cephalopods with the ornamentation of *Parakionoceras* and *Dawsonoceras* (core 122, 3,562–3,589 ft, core 127, 3,678–3,703 ft), two crinoids, one identified by Edwin Kirk as *Periechocrinus*? sp. (core 126, 3,653–3,678 ft), the other identified by Porter Kier as a member of the Flexibilia which appears to represent a new genus (core 126, 3,653–3,678 ft, middle), small rhynchonellid brachiopods (core 127, 3,678–3,703 ft, top; core 128, 3,703–3,720 ft, middle) and an entomid ostracode (core 135, 3,863–3,888 ft). The most common fossils in the shale, extending as low as core 160 (4,414–4,439 ft), or just above the bottom of the well, are smooth, conical, straight shells which may be either hyolithids or orthoconic cephalopods, but which are not sufficiently well preserved to identify more closely. All the fossils are preserved as impressions in the shales, with the exception of the crinoids, some of which are preserved as calcite. The Cone well penetrated approximately 9 ft of variegated pale-reddish-purple to light-brownish-gray shale which contains an orthoconic cephalopod (core 107, 3,485–3,487.5 ft) immediately overlying the black shale typical of the rest of the well.

Goldstein, Cramer, and Andress (1969, p. 378) recognized three zones of chitinozoans in the Cone well: Zone A from 3,482 to 3,630 ft, Zone B from 3,768 to 3,994 ft, and Zone C from 4,156 to 4,444 ft T.D. Most of the megafossils listed above come from the interval 3,562–3,720 ft, and the pelecypods described in this paper come from the interval 3,562–3,653 ft. The listed megafossils thus overlap part of chitinozoan Zone A and partly fill the gap between Zones A and B. Cramer (1973, fig. 2) has suggested that the chitinozoan zone present in the Kie Vining and Hilliard wells occurs in the gap between Zones A and B in the Cone well. In view of the difference between the arthropod megafauna of the Kie Vining well and the dominantly molluscan fauna of the Cone well, this hypothesis seems unlikely, and the suggestion of Goldstein, Cramer, and Andress (1969, p. 379) that the fauna of the Kie Vining well might be younger than that of the Tillis well is preferred. Unfortunately, the Kie Vining well has not as yet yielded any megafossils suitable for precise age determination.

The Coastal Petroleum Co. J. B. and J. T. Ragland No. 1 (fig. 1, well 17, sec. 16, T. 15 S., R. 13 E., Levy County, Fla.) penetrated about 40 ft of very dark gray to black shale, of which only the bottom 10 ft was cored (Berdan and Bridge, 1951, p. 69). The bottom 10 ft (core 15, 5,840–5,850 ft) contains the pelecypods *Butovicella migrans* and *Actinopteria* sp., crinoid columnals, and poorly preserved orthoconic cephalopods. One of these has the ornamentation of *Dawsonoceras*, and others are smooth and resemble the smooth straight shells in the Cone well. The core in the Ragland well was originally correlated with the upper part of the section in the Cone well because of the general similarity of the faunas in the two wells (Berdan and Bridge, 1951, p. 69). Goldstein, Cramer, and Andress (1969, p. 377) obtained chitinozoans from the Ragland well but did not discuss them because of their poor preservation. The black shale in the Ragland well is overlain by about 18 ft of unctuous yellow, gray, lavendar, and pink variegated well-stratified shale, of which 5 ft was cored (core 14, 5,791.5–5,796.5 ft). No fossils have been found in this variegated shale, but, because of its lithologic similarity to the shale at the top of the Paleozoic section in the Cone well, it is also considered to be Paleozoic.

MIDDLE(?) DEVONIAN CLASTIC ROCKS

Three wells near the junction of the boundaries of Florida, Georgia, and Alabama, on the northwest side of the Suwannee Saddle and about 80 miles (128 km) west of the main area of Paleozoic rocks, have penetrated shales, fine-grained sandstones, and siltstones of probable Devonian age. One of these wells, Humble Oil and Refining Co. C. W. Tindel No. 1 (fig. 1, well 23, sec. 8, T. 5 N., R. 11 W., Jackson County, Fla.) cored 738 ft of gray and grayish-red shales, siltstones, and fine-grained sandstones containing plant fragments from 8,526 to 9,165 ft (cores 101–138). The plant fragments are sporadically distributed, and many of the cores show crossbedding. J. M. Schopf (written commun., 1959) reported that a sample from core 120 (8,737–8,742 ft) contained *Dicrospora* Winslow and *Hymenozonotriletes* Naumova and is probably Middle Devonian in age. Schopf also noted that an abundant fossil mycelium present in the same core indicated an in-situ terrestrial deposit. Fragments of plant megafossils have been identified by F. M. Hueber (oral commun., 1973) as *Hostimella,* which is most common in the Lower and Middle Devonian.

One well in Georgia, Mont Warren *et al.* A. C. Chandler No. 1 (fig. 1, well 25, lot 406, Land District 26, Early County, Ga.), penetrated 459 ft of dark-gray to black shale, reddish-brown shale, and gray siltstone between 6,781 and 7,240 ft (Applin and Applin, 1964, p. 136–148). Core 4 (corrected depth 6,995–7,015 ft) from this well contained *Chevroleperditia chevronalis* Swartz (1949, p. 319–321), undescribed smaller ostracodes (Swartz, 1945, p. 1205), linguloid brachiopods, and small pelecypods described by Palmer (1970) and discussed in this paper. Schopf (written commun., 1958) identified spores from this core as *Archeozonotriletes* of Naumova and considered the sample not older than Middle Devonian. Core 5 (corrected depth 7,015–7,036 ft) contains the same smaller ostracodes present in core 4 but to date lacks the other elements of the assemblage. Swartz (1949, p. 320) suggested that *Chevroleperditia* was Late Ordovician to Early Silurian in age because the combination of characters on which he based the genus was intermediate between those of Ordovician and those of Silurian genera. Swartz's opinion led Bridge and Berdan (1952, table 1) to classify the black shales in the Chandler well as Silurian or Late Ordovician and to suggest (Bridge and Berdan, 1952, p. 34, 35) that the 80 ft of white, quartzitic sandstone penetrated beneath the black shale in this well might be Early Ordovician and equivalent to the white sandstone unit overlying the Lower Ordovician *Skolithos* unit in other wells. This correlation was queried by Applin and Applin (1964, p. 148) and, with the age of the black shale now considered as Middle Devonian, it appears far less probable.

Applin and Applin (1964, p. 146–147) report 181 ft of Middle Devonian(?) weathered(?) reddish-brown and greenish-blue shale and some sandstone overlying the black shale in the Chandler well. As yet no identifiable fossils have been found in this shale, and its age remains uncertain.

Another well, Anderson *et al.* Great Northern Paper Co. No. 1 (fig. 1, well 24, lot 387, Land District 26, 2 miles southwest of Cedar Springs, Early County, Ga.) about 1 mile southeast of the Chandler well, has yielded plant fossils which have been described by McLaughlin (1970). McLaughlin (1970, p. 3) has discussed material from the lowermost 214-foot interval of this well, which he has described as consisting of alternating zones of light- and dark-gray silty shale or siltstone and light- to medium-gray medium- to coarse-grained sandstone. Megafossils consist of psilophytacean fragments and microfossils include acritarchs, microspores, and possibly smaller tasmanitoids. McLaughlin (1970, p. 7) has concluded that some elements of this flora indicate a marine environment of deposition, and others were derived from terrestrial plants, and he considered that this part of the section represents a nearshore, shallow-water low-energy marine deposit into which land plants were washed by streams. The age of the assemblage is believed to be late Early or early Middle Devonian (McLaughlin, 1970, p. 7) and is thus probably slightly older than the assemblage in the Chandler well, although possibly equivalent to that in the Tindel well.

Red shales or variegated shales with reddish tints overlie the Paleozoic black shales of various ages in the Chandler, Tillis, Hilliard, Cone, Ragland, Bennett and Langsdale, M. W. Sapp, Superior Pine Products No. 3, and other wells. The red shale in Superior Pine Products No. 4 is considered to belong in this group, although, as only 5 ft of Paleozoic was penetrated, the presence of black shale beneath the red is not certain. These red and variegated shales lie just below the unconformity between the Paleozoic and overlying Mesozoic rocks and appear to be part of the Paleozoic sequence, as fossils have been found in them in the Cone well and in Superior Pine Products No. 3. Because of their position beneath the unconformity and because different ages of Paleozoic are represented, they are believed to represent possible alteration of formerly black shales at the unconformity. However, Carroll (1963, p. A15) has suggested that they represent a different environment of deposition from that of the black shales in that they had accumulated rapidly in an oxidizing environment with little or no organic matter.

IGNEOUS ROCKS

Southeast of the main area of Paleozoic rocks in peninsular Florida the Mesozoic section is underlain by volcanic and other igneous rocks (Applin, 1951, fig. 1) which have been described by Bass (1969), Milton and Grasty (1969), and Milton (1972). In general, wells just southeast of the Paleozoic terrane have encountered volcanic rocks of rhyolitic composition; Milton (1972, p. 45, fig. 27) has noted the presence of a fragment of an undetermined fossil in ash from a depth of 3,879–3,881 ft in Sun Oil Co. H. E. Westbury *et al.* No. 1 (fig. 1, well 26, sec. 37, T. 11 S., R. 26 E., Putnam County, Fla.). Bass (1969, p. 290–293) considered that Sun Oil Co. Powell Land Co. No. 1 (fig. 1, well 27, sec. 11, T. 17 S., R. 31 E., Volusia County, Fla.) passed through a diorite sill and ended in a hornfels derived from a "clayey volcanic-quartzose sandstone" (Bass, 1969, p. 290). Three wells farther south, one each in Lake, Orange, and Osceola Counties, Fla., entered rock listed by Applin and Applin (1965, p. 10–11) and Bass (1969, p. 289) as granite but considered by Milton (1972, p. 8) to be possible arkose altered by contact metamorphism.

South and west of the wells ending in granitic rocks several wells penetrated volcanic rocks similar to those in the northern part of the igneous terrane. Applin and Applin (1965, fig. 3) have shown the volcanic rocks as surrounding a triangular area of granite and diorite, and they also indicate a separate area of altered igneous rock on the southeastern coast. This represents Amerada Petroleum Corporation Cowles Magazines No. 2, (sec. 19, T. 36 S., R. 40 E., St. Lucie County, Fla.) which has been studied by C. S. Ross (in Applin and Applin, 1965, p. 17–18) and Bass (1969, p. 293–299). Bass (1969, p. 293) considered this well unique in Florida in that it penetrated "schist, gneiss, and amphibolite typical of a regionally metamorphosed terrane."

North of the main area of Paleozoic sedimentary rocks a number of wells have penetrated various kinds of "basement" rocks, which have been described by Ross (1958), Milton and Hurst (1965), and Milton and Grasty (1969). Although there is not complete agreement about the type of rock encountered in some of the wells (Milton and Hurst, 1965, p. 1), in general the wells in southern Georgia immediately north of the sedimentary Paleozoic rocks are rhyolitic tuffs and some basalts that are apparently little metamorphosed. Farther north, in Pierce and Coffee Counties, Ga., three wells entered rock described as either altered granite or arkose. Even farther north, in the belt of counties south of the edge of the Coastal Plain sediments, wells encountered metamorphic and igneous rocks similar to those exposed in the Piedmont area of Georgia.

Obviously, any interpretation of the structural relationships of the Paleozoic sedimentary rocks depends to a considerable extent on the age of the volcanic terranes to the north and south. Milton and Grasty (1969, table 2) list whole-rock potassium-argon ages for samples from five wells in Florida and three in Georgia, and Bass (1969) has provided both potassium-argon and rubidium-strontium ages for samples from three Florida wells, two of which were also dated by Milton and Grasty. Milton (1972, table 2) has summarized all the available evidence bearing on the radiometric dating of these rocks. In general, there appear to be two groups of dates, one ranging from 147 to 191 m.y. (Jurassic to Triassic), mostly obtained from basalts or diabases, and the other centered about 530 m.y. (Cambrian), obtained from various igneous and metamorphic rocks. The older dates have all been obtained from central and southern Florida, with the exception of an age of 303 ± 15 m.y. (late Carboniferous) determined by Grasty for a hornblende schist from a well in Cusseta, Chattahoochee County, Ga., which is considered by Milton and Hurst (1965, p. 16) to be "true basement," that is, an extension of the rocks underlying the Piedmont. The older rocks in Florida all fall within the areas shown by Applin and Applin (1965, fig. 3) as (1) altered igneous rocks of unknown age and (2) Precambrian(?) granite and diorite. Of the younger dates only one, from core at a depth of 8,781–8,781½ ft from Humble Oil and Refining Co. W. P. Hayman No. 1 (fig. 1, well 28, sec. 12, T. 31 S., R. 33 E., Osceola County, Fla.) is from rhyolitic rocks; this core gave an age of 173 ± 4 m.y. (Jurassic) (Milton and Grasty, 1969, table 2).

The two groups of dates indicate two periods of igneous activity, one during the Triassic or Jurassic, and one during the Cambrian. Diabase sills intruding lower Paleozoic sedimentary rocks are probably Triassic in age and belong to the same period of volcanism that produced some of the dated diabases and basalts in the volcanic terrane. Milton and Grasty (1969, p. 2489) consider that the diabases and rhyolites are related and contemporaneous; however, Bass (1969, p. 308) suggests the presence of a rhyolitic belt, undeformed and essentially unmetamorphosed, extending from North Carolina to

Florida with a minimal age of 408±40 m.y. (Ordovician or Silurian), and Sundelius (in Milton and Hurst, 1965, p. 14) noted the similarity of some of the rhyolitic rocks of Georgia to those of the Carolina slate belt, which are as old as Cambrian according to Saint Jean (1965). Additional radiometric dates are needed to determine the age of the rhyolites. The Camp No. 1 passed through presumed Lower Ordovician sandstone and ended in volcanic agglomerate and rhyolitic welded tuff (Milton, 1972, p. 49). Although this might indicate that the volcanic rocks are older than Early Ordovician, the absence of more than a thousand feet of the *Skolithos* unit suggests that a fault of considerable magnitude passes through or near this well.

STRUCTURAL RELATIONSHIPS

Except for the cross-bedded siltstones and claystones in the Tindel well, bedding in all cores from Paleozoic rocks is perpendicular to the axis of the cores, which suggest horizontal bedding or very low dips. The only indication of metamorphism in any of the cores examined by Carroll (1963, p. A12) seems to be low grade and produced by pressure of the overlying rocks. The cluster of wells in Columbia and Suwannee Counties, Fla., which penetrated Devonian and Silurian shales are bordered by wells in Middle Ordovician shales, which in turn are bordered by wells in Lower Ordovician quartzites. This suggests a possible concentric subcrop pattern in the Paleozoic which is offset slightly to the northwest of the Peninsular arch and may indicate a gentle north or northwest dip for the Paleozoic sedimentary rocks in this area. The Silurian cores from the Bennett and Langsdale well in Echols County, Ga., might be explained either by a gentle fold in the Paleozoic sedimentary rocks or by faulting. The Silurian and Devonian shales penetrated by the Ragland and Hilliard wells, respectively, which are on the flanks of and on opposite sides of the Peninsular arch, may be most easily explained by postulating the presence of downdropped normal fault blocks on each side of the arch.

The structural relationships of four wells, three in the Devonian and one in the Lower Ordovician, located near the Florida-Georgia-Alabama boundaries, are not clear because of inadequate data.

SUMMARY

The sedimentary Paleozoic rocks beneath Florida and adjacent parts of Georgia and Alabama lie at a minimum depth of 3,000 ft in a roughly wedge-shaped area bounded both to the north and to the south by volcanic rocks of uncertain age—possibly Cambrian to Precambrian, possibly much younger. The rocks dated by fossils range in age from Early Ordovician to Middle Devonian, the latter being in southwestern Georgia and the Florida panhandle. A composite section based on the logs of individual wells suggests a minimum thickness of 4,000 ft. The rocks are entirely clastic and the lower part of the section, especially the Early Ordovician, shows evidence of shallow-water marine deposition. The most abundant megafossils in the Ordovician part of the section are phosphatic brachiopods and, in the Silurian to Lower Devonian part of the section, mollusks and arthropods. Graptolites are present in only one Lower Ordovician well. Possible upper Lower Devonian and Middle Devonian shales and siltstones separated from the main area of Paleozoic subcrop are dominated by plant fossils and ostracodes. Bedding is generally at right angles to the cores, and metamorphism is low grade except in the vicinity of diabasic intrusive rocks of probable Triassic and Jurassic age.

SYSTEMATIC PALEONTOLOGY

The systematics of the Florida and Georgia subsurface Paleozoic pelecypods is dealt with well by well. Pelecypods have been recovered from the Chandler, Tillis, Cone, and Ragland wells (fig. 2). The Turkish specimens are assigned to the species *Cheiopteria bridgei,* which also occurs in the Cone well core, and are discussed under that species. The Bolivian collection is treated separately following the discussions of the American and Turkish material.

Following is the synoptic classification to the level of genus of the pelecypods considered in this section:

Phylum Mollusca Cuvier
- Class Pelecypoda Goldfuss
  - Subclass Palaeotaxodonta Korobkov
    - Superfamily Nuculacea Gray
      - Family Praenuculidae McAlester
        - Genus *Deceptrix* Fuchs
          - Subgenus *Praenucula* Pfab
    - Superfamily Nuculanacea Adams and Adams
      - Family Malletiidae Adams and Adams
        - Genus *Arisaigia* McLearn
        - Genus *Nuculites* Conrad
        - Genus *Palaeoneilo* Hall and Whitfield
  - Subclass Isofilibranchia Iredale
    - Superfamily Mytilacea Rafinesque
      - Family Modiomorphidae Miller
        - Genus *Modiomorpha* Hall and Whitfield
      - Family Butovicellidae Kříž
        - Genus *Butovicella* Kříž
  - Subclass Pteriomorphia Beurlen
      - Family Praecardiidae Hörnes
        - Genus *Panenka* Barrande

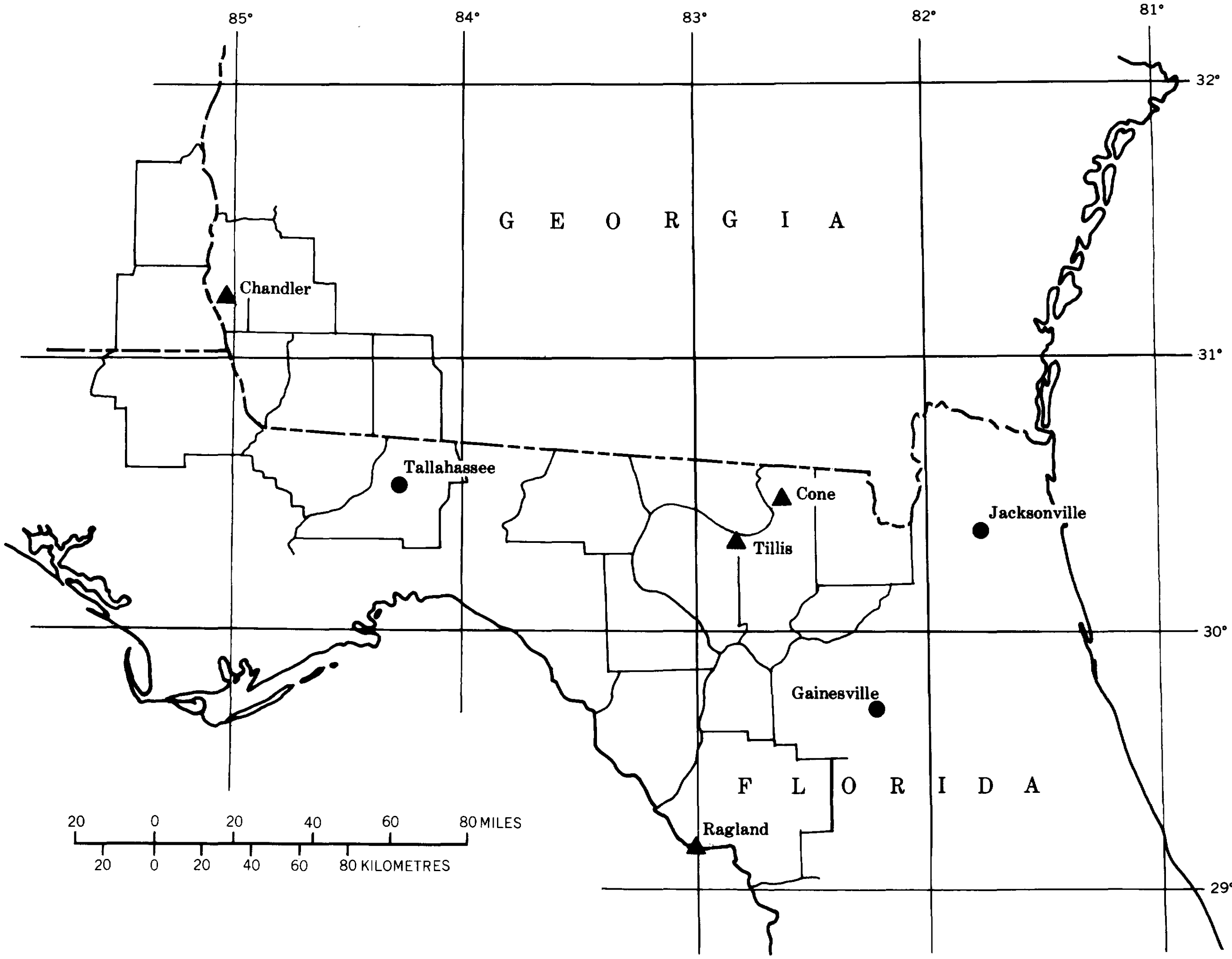


FIGURE 2.—Location of the four Florida and Georgia wells which have yielded Silurian and Devonian pelecypods.

Class Pelecypoda Goldfuss—Continued
Subclass Pteriomorphia Beurlen—Continued
Family Antipleuridae Neumayr
Genus *Dualina* Barrande
Superfamily Ambonychiacea Miller
Family Ambonychiidae Miller
Genus *Mytilarca* Hall and Writfield
?Family Lunulacardiidae Fischer
Genus *Lunulacardium* Münster
Superfamily Pteriacea Gray
Family Pterineidae Miller
Genus *Actinopteria* Hall
Genus *Cheiopteria* n. gen.
Genus *Leptodesma* Hall
Superfamily Pectinacea Rafinesque
Family Pterinopectinidae Newell
Genus *Pterinopecten* Hall
Subclass Heteroconchia Hertwig
Superfamily Trigoniacea Lamarck
Family Myophoriidae Bronn
Genus *Eoschizodus* Cox
Superfamily Carditacea Fleming
Family Permophordae van de Pohl
Genus *Pleurodapis* Clarke

Class Pelecypoda Goldfuss—Continued
Subclass Heteroconchia Hertwig—Continued
Superfamily Solenacea Lamarck
Family Orthonotidae Miller
Genus *Prothyris* Meek
Subclass Anomalodesmata Dall
Superfamily Pholadomyacea Gray
Pholadomyacean genus and species indet.

FLORIDA AND GEORGIA WELLS

CHANDLER WELL

This well was drilled near the tristate boundary of Georgia, Florida, and Alabama (Mont Warren *et al.* A. C. Chandler No. 1, lot 406, Land District 26, Early County, Ga.). Only one new pelecypod specimen (pl. 4, fig. 7) from this well was available to us; we have also examined the specimens from this well (pl. 4, figs. 11, 13, 14) which were figured by Palmer (1970). Pelecypods are known only from Core 4 at a corrected depth of 6,995–7,015 ft.

Genus MODIOMORPHA Hall and Whitfield, 1869

Modiomorpha? sp.

Plate 4, figures 7, 11, 13, 14

Material.—Five specimens, four right valves (PRI 27632, 27633, 27636; USNM 203225) and one left valve (PRI 27633). The left valve (pl. 4, fig. 14, lower part) is 14.7 plus mm long and 7 mm high. The best preserved right valve (pl. 4, fig. 7) is 9.5 mm long and 4.5 plus mm high.

Discussion.—Palmer (1970) called this species *Anthraconauta* cf. *A. phillipsii* (Williamson), and regarded it as a fresh-water Carboniferous form. Although we cannot unequivocally rule out the fresh-water interpretation of these specimens, they are not well preserved and, on the basis of shape and ornament, could also be assigned to the marine genus *Modiomorpha* Hall and Whitfield. *Modiomorpha*? sp. occurs with leperditiid ostracodes which are known to be marine in their occurrence; also present in the sample are plant spores.

The age of *Modiomorpha*? sp. is most likely Middle Devonian rather than Carboniferous. Leperditiid ostracodes are not known from rocks younger than Devonian, and Schopf (written commun., 1958) regarded the plant spores that occur with *Modiomorpha*? sp. to be of Middle Devonian age.

TILLIS WELL

This well was drilled in north-central peninsular Florida (Sun Oil Co. J. H. Tillis No. 1, sec. 28, T. 2 S., R. 15 E., Suwanee County, Fla.) Pelecypods are known only from core 44 at a depth of 3,552–3,568 ft; 12 taxa are recognized.

Genus NUCULITES Conrad, 1841

Most Tillis specimens of this genus have a broad poorly defined posterior buttress (pl. 3, figs. 2, 5) in addition to the sharply defined anterior buttress (pl. 3, figs. 2, 5). Species of this sort are sometimes placed in the genus *Ditichia* (sensu Clarke, 1909); however, the type species of *Ditichia* Sandberger lacks the posterior buttress (McAlester, 1968). As redefined by McAlester (1969) the genus *Nuculites* includes Paleozoic palaeotaxodonts with an anterior buttress.

So far as known all forms with both anterior and posterior buttresses are Late Silurian–Early Devonian in age, for example, *Nuculites elliptica* (Maurer) from the Lower Devonian Moose River Sandstone of Maine (assigned to *Ditichia* by Clarke, 1909); *Nuculites africanus* (Sharpe) from the Lower Devonian of Antarctica, Africa, Bolivia, Uruguay, and Brazil (McAlester, 1965); *Nuculites* n. sp. from the Upper Silurian Moydart and McAdam Brook Formations of Nova Scotia (Bambach, 1969); and probably *Nuculites unisulcus* (assigned to *Cleidophorus* Hall by Korejwo and Teller, 1964) from the Early Devonian of the Chelm borehole of eastern Poland (*Monograptus uniformis* Zone).

The Tillis specimens of *Nuculites* are not placed in any named species. There are many described species of *Nuculites* from the lower Paleozoic and the genus is currently under study by R. K. Bambach, Virginia Polytechnic Institute and State University, Blacksburg, Va.

Nuculites sp. A

Plate 3, figure 10

Material.—One left valve (USNM 203231), measuring 22.5 mm long and 13.7 mm high.

Discussion.—The single known specimen of this species has a very weak posterior buttress, a posteroventrally directed anterior buttress which does not exceed two-thirds of the height of the shell, and a less oblique posterior umbonal slope than does *Nuculites* sp. B. The pits on the posterior part of the umbo of the specimen are not part of its morphology.

Nuculites sp. B

Plate 3, figures 2, 5, 12

Material.—Four right and four left valves (USNM 203232–35); the best preserved specimen (pl. 3, fig. 12) measures 9.4 mm long and 6 mm high.

Discussion.—This form differs from *Nuculites* sp. A in having a more sharply defined posterior buttress, a more oblique posterior umbonal slope, and a longer anterior buttress which is vertical or directed anteroventrally.

Genus ARISAIGIA McLearn, 1918

This genus has previously been reported from the Upper Silurian Doctors Brook and McAdam Brook Formations of Nova Scotia, the Lower Devonian part of the Stonehouse Formation of Nova Scotia (Bambach, 1969), and the Lower Devonian of the Chelm borehole of eastern Poland (*Monograptus uniformis angustidens* Zone; Korejwo and Teller, 1964). The Polish specimens were previously placed in the genus *Parallelodon* Meek and Worthen by Korejwo and Teller, 1964.

Arisaigia cf. A. postornata McLearn

Plate 3, figures 4, 6

Material.—A deformed right valve (pl. 3, fig. 6) and a well-preserved left valve exterior (pl. 3, fig.

4); the latter measures 10.9 mm long and 6.2 mm high. USNM 203236, 203237.

Discussion.—The Florida specimens have the fine overall radial ribbing and subdued posterior plicae of this species; they are smaller than the median height and length of *A. postornata* (Bambach, 1969), but well within the known size range.

Distribution.—This species has previously been reported only from Nova Scotia where it occurs in the Upper Silurian Doctors Brook and McAdam Brook Formations.

Arisaigia sp.

Plate 3, figure 3

Material.—One posterior fragment (USNM 203238).

Discussion.—This fragment has stronger ribbing than *A.* cf. *A. postornata,* and appears to be a part of a more elongate shell; however, it may be a fragment of *A.* cf. *A. postornata* which has undergone some dorsoventral compression.

Genus ACTINOPTERIA Hall, 1884

Actinopteria sp. A

Plate 3, figure 13

Material.—One deformed left valve having a length of 17 plus mm and a height of about 17.7 mm (USNM 203239). The specimen is preserved on the opposite side of the chip on which the specimen of *Pleurodapis* sp. (pl. 3, fig. 11) is preserved.

Discussion.—This is an erect quadrate shell with well-developed anterior and posterior auricles which are clearly separated from the body of the shell.

Actinopteria sp. B

Plate 3, figures 8, 14

Material.—One left (USNM 203240) and one right valve (USNM 203241); the right valve (pl. 3, fig. 14) measures 5.5 mm long and 4.8 mm high.

Discussion.—These small specimens have unusually coarse ribs for their size and do not have the anterior and posterior auricles as clearly separated from the body of the shell as does *Actinopteria* sp. A.

Genus PTERINOPECTEN Hall, 1883

Pterinopecten? sp.

Plate 3, figure 16

Material and discussion.—Many small shells of a pectinacean of the *Pterinopecten* type superimposed upon one another on one chip (USNM 203242).

Genus MODIOMORPHA Hall and Whitfield, 1869

Modiomorpha sp.

Plate 4, figure 8

Material and discussion.—One crushed right valve measuring about 20 mm long with a modioliform shape and prominent commarginal ornament (USNM 203243).

Genus EOSCHIZODUS Cox, 1951

Eoschizodus? sp.

Plate 3, figure 1

Material and discussion.—Four crushed or distorted specimens (USNM 203244, 203245) of which one is articulated; specimens have a schizodiform shape and commarginal sculpture. The figured specimen is 28.6 mm long and 23 plus mm high.

Genus PLEURODAPIS Clarke, 1913

Pleurodapis sp.

Plate 3, figures 9, 11

Material.—Five incomplete specimens (USNM 203246–48), of which three are right and two are left valves. USNM 203247 is on the opposite side of the chip on which *Actinopteria* sp. A (pl. 3, fig. 13) is preserved.

Discussion.—This genus is characterized by the presence of strong angular posterior plicae and in some species a single prominent anterior plica (pl. 3, fig. 15). The Florida material does not show the anterior plica.

Distribution.—In addition to the Florida occurrence, *Pleurodapis* has been reported from the Upper Silurian of Bolivia (Branisa, 1965, pl. 29, fig. 3) and the Lower Devonian of Bolivia (Branisa, 1965, pl. 29, figs. 1, 2), Brazil (Clarke, 1913), Ghana (Saul, Boucot, and Finks, 1963), Germany (Mauz, 1933), and Belgium (Maillieux, 1936).

Genus PROTHYRIS Meek, 1871

Prothyris sp.

Plate 4, figures 5, 6, 9

Material.—Five specimens, four right valves and one left valve (USNM 203251–54). The best preserved specimen (pl. 4, fig. 9) measures 11.4 mm long and 5 mm high. One specimen is preserved on the same chip as the pholadomyacean shown on plate 4, figure 3, and another on the same chip as *Arisaigia* cf. *A. postornata* (pl. 3, fig. 4).

Discussion.—The Tillis specimens have the characteristic shape, ornament, and anterior ridge and auricle of this genus. *Prothyris* is known primarily from upper Paleozoic rocks, but has been reported from the Devonian by several authors including Hall (1885), Whidborne (1896), and Clarke (1913); it is not known from rocks older than the Devonian.

Pholadomyacean genus and species indet.

Plate 4, figures 2–4

Material and discussion.—The incomplete anterior ends of a right (USNM 203255) and a left (USNM 203256) valve; the latter preserves both part and counterpart. These specimens are elongate shells with the characteristic rugose commarginal ornament found in Paleozoic pholadomyaceans.

CONE WELL

This well was drilled in north-central peninsular Florida (Humble Oil and Refining Co. J. P. Cone No. 1, sec. 22, T. 1 N., R. 17 E., Columbia County, Fla.). Pelecypods are known from the 3,562-foot level (core 122) to the 4,330-foot level (core 155), although they are identifiable to genus only from the 3,653-foot level (core 126) to the 4,281-foot level (core 152).

The Cone well is remarkable because of the similarity of all pelecypod taxa to those of the Upper Silurian of central Bohemia; the two regions have several species in common.

Genus PANENKA Barrande, 1881

Panenka sp.

Plate 2, figure 6

Material.—One incomplete right(?) valve from core 126 (USNM 203262), top 5 ft of the 3,653–3,678-foot interval.

Discussion.—This specimen belongs to the *P. humilis–P. bohemica* species group, which has prominent commarginal sculpture that is closely spaced in the mature part of the shell. Species of this group are known from the Upper Silurian (upper Ludlovian)–Lower Devonian (lower Lochkovian) of Bohemia (Barrande, 1881), France (Babin, 1966, pl. 4, fig. 14), and Morocco (Termier and Termier, 1950, pl. 169, fig. 15).

Genus DUALINA Barrande, 1881

Dualina secunda Barrande, 1881

Plate 1, figures 4, 17

Material.—Three specimens, one each from the bottom of core 126, 3,653–3,678 ft (USNM 203263); bottom of core 138, 3,936–3,953 ft (USNM 203264); and top of core 152, 4,256–4,281 ft (USNM 203265). Only USNM 203264 is well preserved (pl. 1, figs. 4, 17); it measures 11.9 mm long and 12.9 mm high.

Discussion.—USNM 203264 shows fine radial riblets on the major ribs (pl. 1, fig. 17), a feature which also occurs on the Bohemian subspecies *D. secunda reticulata* Barrande; the other Florida specimens are not well enough preserved to determine whether or not these riblets are present.

Distribution.—In Bohemia this species is known only from the Upper Silurian Kopanina and Pridol Formations (Ludlovian and Pridolian); the subspecies *D. secunda reticulata* is known only from the Kopanina Formation (Ludlovian). *D. secunda* also occurs in the Upper Silurian of Bolivia and a similar form, *D. convexa* Korejwo and Teller (1964), has been reported from the Lower Devonian (*Monograptus uniformis angustidens* Zone) of eastern Poland.

Genus MYTILARCA Hall and Whitfield, 1869

Mytilarca cf. M. longior (Barrande, 1881)

Plate 1, figure 13

Material.—Two left valves (USNM 203266, 203267) one each from core 127, third 5 ft of the 3,678–3,703-foot interval, and top of core 128, 3,703–3,720 ft. The best preserved of the two specimens is figured; it measures 10 mm long and 12.2 mm high.

Discussion.—*Mytilarca* has a relatively simple external morphology (Pojeta, 1966), and because of this and the numerous named species it is difficult to assign small samples to a species; in general shape the Florida specimens are most like *M. longior* of Bohemia.

Distribution.—*M. longior* occurs in the Pridol (Upper Silurian) and Lochkov (Lower Devonian) Formations of Bohemia. The species *M. lata* Korejwo and Teller and *M. prossera* Korejwo and Teller (1964) from the Lower Devonian of Poland (*Monograptus uniformis angustidens* Zone) are closely similar to *M. longior*.

Genus LUNULACARDIUM Münster, 1840

Lunulacardium excellens Barrande, 1881

Plate 2, figures 1–4, 8, 12

Material.—Over 50 specimens from the second and fourth 5-foot intervals and the general interval in core 127, 3,678–3,703 ft. Most of the specimens are incomplete, but there is a good size range, from under 5 mm to about 14 mm in length, and there are chips covered with juveniles (pl. 2, fig. 4). USNM 203268–78.

Discussion.—*L. excellens* shows a high degree of variability; it is characterized by having two to five secondary ribs between pairs of primary ribs. In both Florida and Bohemia the species is gregarious, covering bedding-plane surfaces.

Distribution.—This species is known only from Florida and Bohemia. In Bohemia it occurs only in the uppermost Silurian (Pridolian).

Lunulacardium spp.

Plate 2, figures 4 (arrow), 5

Material.—Many specimens from several levels; bottom of core 126, 3,653–3,678 ft; core 127, 3,678–3,703 ft; top of core 128, 3,703–3,720 ft;

core 131, 3,768–3,790 ft; top of core 132, 3,790–3,815 ft; top and middle of core 133, 3,815–3,838 ft; and top and middle core 134, 3,838–3,863 ft. Most of the specimens are incomplete, but there is a wide size range from 2 mm to 13 mm in length. Some levels are almost entirely juveniles (3,768–3,790 ft and 3,790–3,815 ft. USNM 203279–90.

Discussion.—The specimens placed in *Lunulacardium* spp. have ribs of equal strength and are most like *L. bohemicum* Barrande and *L. eximium* Barrande, both of which occur in the uppermost Silurian (Pridolian) of Bohemia. A juvenile is figured in the lower left corner of plate 2, figure 4 (arrow).

Genus CHEIOPTERIA Pojeta and Kříž n. gen.

Type species.—*Cardium glabrum* Goldfuss, 1837 (p. 218, pl. 143, fig. 8a, b); *non* Münster, 1840, is herein designated the type species of the new genus *Cheiopteria*. This species name is usually credited to Münster (1840, p. 66, pl. 12, fig. 11), and in fact Goldfuss credits the species to Münster. Münster (1840, p. 66) noted that he had given specimens from Prague to Goldfuss for inclusion in the latter's "Petrefacta Germaniae," and at the same time noted that he had decided that the German material from Elbersreuth was a different species than the Czech material from Prague:

Cardium glabrum *** Von Elbersreuth. Ich habe früher eine bei Prag im Orthoceratitenkalk vorkommende ähnliche Bivalve mit dieser Art verwechselt und die Prager Examplare an Goldfuss für Petrefacten-Werk mitgetheilt, später aber mich überzeugt, dass sie wesentlich verschieden sind und der Prager Muschel wohl zu den Posidonomyen oder Avicula (Monotis) gehören möchte. Translated: (*Cardium glabrum* *** from Elbersreuth. I have earlier mixed up with this species a similar bivalve found near Prague in the Orthoceras Limestone, and conveyed the samples from Prague to Goldfuss for the Petrefacten-Work, but was later convinced that they are essentially different, and that the Prague shell could belong to the posidonomyids or Avicula (Monotis).)

Goldfuss' "Petrefacta Germaniae" was published over a period of 18 years from 1826 to 1844. The Neues Jahrb. Mineralogie Geognosie, Geologie u. Petrefakten-kunde for 1838, p. 106–109, gives the date of publication of v. 2, p. 141–244, pls. 122–146, as 1837. These plates and pages include *Cardium glabrum*. Because Goldfuss used the name *Cardium glabrum* 3 years before Münster, we regard him as the author of the species. Goldfuss clearly states that *Cardium glabrum* occurs at Prague and Elbersreuth and his figures show specimens conspecific with those which occur at Prague (pl. 1, figs. 6, 11 herein). The specimen figured by Münster (1840) under the name *Cardium glabrum* is quite different from those figured by Goldfuss (1837).

Description.—Small equivalved pteriaceans with rugose commarginal ornament; radial ornament absent; auricles only vaguely separated from the body of the shell. Internal features unknown.

Etymology.—*Cheia*—a hole in the ground; *Pteria*—a genus of pelecypods.

Comparisons.—Several names have been proposed for Silurian-Devonian pteriaceans which lack radial ornament. *Leptodesma* Hall and *Joachymia* Růžička (pl. 1, fig. 12) have well-developed auricles, of which the posterior is often elongated into a wing. *Pterochaenia* Clarke (pl. 1, fig. 7) is sometimes classified as a pteriacean; it has a prominent anterior rib which separates the anterior auricle from the body of the shell. *Cheiopteria* is much like *Newsomella* Foerste in external shape and commarginal ornament; however, *Newsomella* has radial ornament between the commarginal rugae of the right valve. *Actinodesma* Sandberger has both auricles elongated into wings and a *Malleus*-like form. *Pterinea* Goldfuss has the anterior auricle sharply delimited from the rest of the shell and has a posterior wing.

Distribution.—In Florida the genus is known only from the Cone well. In Bohemia it occurs in the Upper Silurian Kopanina Formation (Ludlovian), and in Turkey it comes from rocks of probable Wenlockian or Ludlovian Age (W. T. Dean, written commun., 1973).

Cheiopteria glabra (Goldfuss, 1837)

Plate 1, figures 6, 11

1837. *Cardium glabrum* Goldfuss, p. 218.
1840. [*non*] *Cardium glabrum* Münster, p. 66.
1881. *Avicula glabra* Münster. Barrande, pl. 228.
1949. *Pterochaenia* (*Pterochaenia*) *glabra* (Münster). Růžička, p. 4.

Remarks and comparisons.—We figure two topotypes of this species (USNM 203260, 203261) from the upper part of the Kopanina Formation, *Orthoceras* quarry, southwest of Lochkov, Bohemia, Czechoslovakia. This locality is near Prague, and the species occurs widely at this level in the Barrandian. Růžička (1949) placed the species in the genus *Pterochaenia* Clarke.

Cheiopteria bridgei n. sp. is the only other species presently placed in the genus; *C. glabra* differs from this species in having a prominent byssal sinus below the anterior auricle and in that the commarginal rugae are less prominent and angular than in *C. bridgei* (pl. 1, figs. 2, 3).

Cheiopteria bridgei Pojeta and Kříž, n. sp.

Plate 1, figures 2, 3, 5, 14, 15

Description.—*Cheiopteria* lacking a prominent byssal sinus below the anterior auricle and having prominent angular commarginal rugae.

Etymology.—This species is named for the late Josiah Bridge.

Types.—The holotype (pl. 1, fig. 3, USNM 203291) is from the middle of Cone well core 128, 3,703–3,720 ft. Paratypes from the Cone well occur at the top 7 ft of core 128, 3,703–3,720 ft (USNM 203293, pl. 1, fig. 2); middle of core 128, 3,703–3,720 ft (USNM 203292 not figured); bottom of core 128, 3,703–3,720 ft (USNM 203294; 10 specimens not figured); bottom of core 135, 3,863–3,888 ft (USNM 203295; 1 specimen not figured); and bottom of core 142, 4,019–4,039 ft (USNM 203296; 5 specimens not figured).

In addition there are a large number of paratypes (well over 50) from Halevikdere, near Tufanbeyli, a village in the Taurus Mountains about 140 km north of Adana, Turkey (fig. 3), probably from the Yukariyayli Formation. The Turkish specimens were collected by Necdet Özgül of the Maden Tetkik ve Arama and were brought to our attention by W. T. Dean of the Geological Survey of Canada. The Turkish specimens are shown on plate 1, figures 5, 14, 15 (MTA).

Age of the Turkish Material.—W. T. Dean (written commun., 1973) noted that the Turkish specimens occur with an encrinurid trilobite which indicates a Silurian age, probably Wenlockian or Ludlovian.

Dimensions.—The holotype (pl. 1, fig. 3) is 7 mm long and 6.9 plus mm high; the figured Florida paratype (pl. 1, fig. 2) is 7.9 mm long and 7 plus mm high.

Cheiopteria? sp.

Plate 1, figure 1

Materials and remarks.—This form is known from one specimen (USNM 203297) from the middle of core 135, 3,863–3,888 ft. The ornament and outline of this specimen are similar to *Cheiopteria glabra,* except that the intersection of the anterior and posterior margins with the dorsal margin are more angular.

Genus LEPTODESMA Hall, 1883

Leptodesma carens (Barrande, 1881)

Plate 1, figures 10, 16

Material.—Five left valves from the bottom of core 126, 3,653–3,678 ft (USNM 203298–300). The larger of the two figured specimens (pl. 1, fig. 16) measures 17.4 mm long and 11.3 mm high.

Discussion.—The Florida specimens have the same general shape and coarse commarginal ornament as those from Bohemia.

Distribution.—In Bohemia this species occurs in the Upper Silurian (Pridolian) and Lower Devonian (Lochkovian).

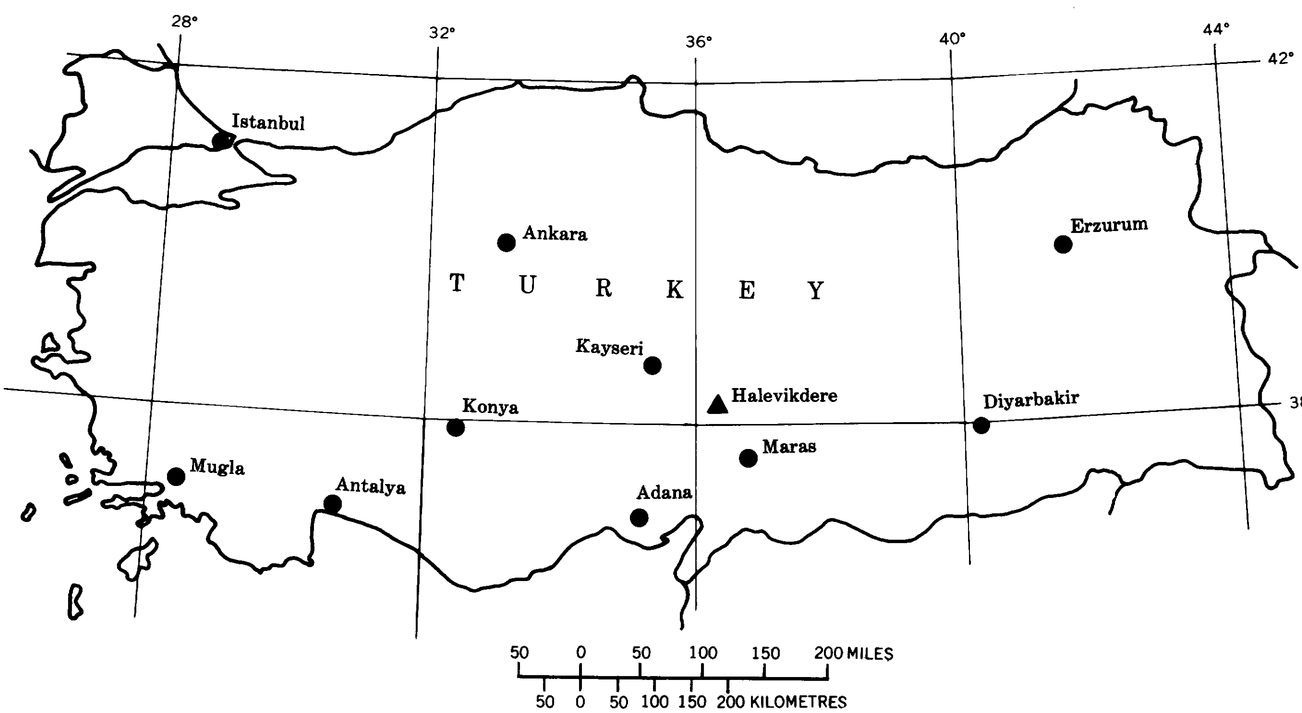


FIGURE 3.—Location of the specimens of *Cheiopteria* from Turkey.

Genus ACTINOPTERIA Hall, 1884
Actinopteria migrans (Barrande, 1881)
Plate 1, figures 8, 9

Material.—Seven left valves, one from core 126, 3,653–3,678 ft (USNM 203301, this specimen is on the same chip with *Periechocrinus*); one from the third 5 ft of core 127, 3,678–3,703 ft (pl. 1, fig. 8, USNM 203302); and five from the middle of core 128, 3,703–3,720 ft (pl. 1, fig. 9, USNM 203303; 203304). All specimens are incomplete or deformed, and none were measured.

Discussion.—The Florida specimens are similar to those from Bohemia in shape, ribbing pattern, and the sharp definition of the anterior auricle.

Distribution.—In Bohemia this species occurs in the Upper Silurian (Pridolian) and Lower Devonian (Lochkovian); it has the same distribution in Poland (Korejwo and Teller, 1964).

RAGLAND WELL

This well was drilled in northwest peninsular Florida (Coastal Petroleum Co. J. B. and J. T. Ragland No. 1, sec. 16, T. 15 S., R. 13 E., Levy County, Fla.). Pelecypods are known only from core 15, at a depth of 5,840–5,850 ft; two taxa are represented.

Genus BUTOVICELLA Kříž, 1965
Butovicella migrans (Barrande, 1881)
Plate 2, figures 9–11

Material.—Three left valves (USNM 203226–28), the best preserved of which measures 4.9 mm long and 3.6 mm high (pl. 2, fig. 11).

Discussion.—All of the Florida specimens show the modioliform shape of the species, and the characteristic ornament which consists of a radially ribbed anterior lobe and moniliform radial ribs over the body of the younger part of the shell.

Distribution.—In Bohemia this species occurs in the upper Liteň (Wenlockian) and Kopanina (Ludlovian) Formations of the Silurian; it is especially abundant on either side of the Wenlockian-Ludlovian boundary. Outside of Bohemia it is known from the Wenlockian of Poland, and the Ludlovian of Germany, Italy, Sweden, Great Britain, France, and Portugal (Kříž, 1969, and herein).

Genus ACTINOPTERIA Hall, 1884
Actinopteria sp.
Plate 2, figure 7

Material.—Five left valves (USNM 203229, 203230), the best preserved of which measures 27.8 plus mm long and 20 plus mm high (pl. 2, fig. 7).

Discussion.—All Ragland well specimens of this form are fragmentary or poorly preserved, and we do not assign them to a species; their association with *Butovicella migrans* shows that *Actinopteria* occurs in rocks as old as the Wenlockian-Ludlovian part of the Silurian.

BOLIVIA COLLECTION

All of the Bolivian material discussed herein is from the Pampa Shale at Huari, Oruro Department, about 110 km south of the City of Oruro (fig. 4).

In discussing the age of the Pampa Shale, Branisa, Chamot, Berry, and Boucot (1972, p. 27) noted:

The Pampa Shale of the Llallagua region has not yet yielded diagnostic fossils, but it is concluded to be of late Llandovery and Wenlock age because of its stratigraphic position.

The new collection from Huari contains the pelecypod *Dualina,* which elsewhere is not known to occur in rocks older than Ludlovian; its presence suggests that at Huari the Pampa Shale is Late Silurian in age.

Genus DECEPTRIX Fuchs, 1919
Subgenus PRAENUCULA Pfab, 1934
Deceptrix (Praenucula) sp.
Plate 5, figures 3, 6, 11, 13

Material.—Twenty-two single valves, 11 right and 11 left, and 2 articulated specimens (USNM 203305–9). The specimen shown on plate 5, figure 6, is 8 mm long and 6.6 mm high.

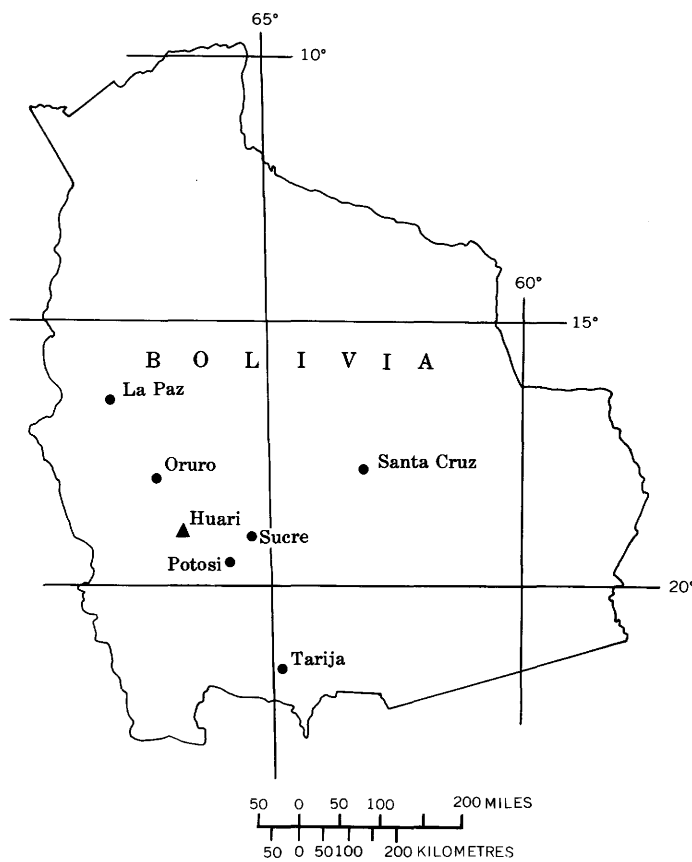


FIGURE 4.—Location of the collection of Silurian pelecypods from Bolivia.

Discussion.—This form differs from *Deceptrix* (*Praenucula*) *pulchella* (Clarke, 1899), in being more equilateral and in having a shorter anterior tooth row. *D. pulchella* is from the Trombetas Formation of Brazil, which according to Lange (1972) is early Llandoverian in age and thus probably older than the Pampa Shale collection from Huari.

Genus NUCULITES Conrad, 1841

Nuculites sp.

Plate 5, figure 4

Material.—A crushed articulated specimen (USNM 203310), one left valve (USNM 203311), and one right valve (pl. 5, fig. 4; USNM 203312). The figured specimen measures 21 plus mm long and 14.6 mm high. The articulated specimen preserves some muscle scars.

Discussion.—As noted previously there are many named species of this genus, and the genus is under study by Bambach. The Huari specimens are most similar to the specimen of *N. pacatus* Reed from the Devonian of Brazil shown by Clarke (1913) on plate 10, figure 23. The other specimens of *N. pacatus* figured by Clarke are different in having an extremely wide anterior buttress.

Genus PALAEONEILO Hall and Whitfield, 1869

Palaeoneilo sp. A

Plate 5, figures 1, 2, 5, 8

Material.—Eleven left valves, 17 right valves, and 10 articulated specimens (USNM 203313–16). The specimen shown in figure 2, plate 5, measures 9.7 mm long and 5.6 mm high.

Discussion.—This is an elongate species in which the dorsal and ventral margins are nearly parallel, the anterior tooth row comes down the anterior face to about the middle of the height and the posterior tooth row occupies at least two-thirds of the dorsal margin posterior to the umbonal peaks. None of the forms described by Clarke (1899, 1900, 1913), Kozłowski (1923), or Branisa (1965) suggests affinities to this species.

Palaeoneilo?

Plate 5, figure 7

Material.—Three left and three right valves (USNM 203317, 203318). The best preserved specimen is figured on plate 5, figure 7, and measures 18.9 mm long and 12 mm high.

Discussion.—This form has the general shape and ornament of the specimen of *P. rhysa* Clarke from the Devonian of Paraná, Brazil, figured by him (1913) on plate 11, figure 5.

Genus DUALINA Barrande, 1881

Dualina secunda Barrande, 1881

Plate 5, figures 15–20

Material.—Two articulated specimens, three flat valves, and six convex valves (USNM 203319–24). The best preserved specimen is shown on plate 5, figure 15; it measures 14.9 mm long and 13.3 mm high.

Discussion.—The Bolivian specimens have the shape, size, and ornament of specimens of this species from Bohemia and Florida; they show the presence of pelecypod faunal elements of the Silurian Mediterranean Biogeographic Province in the Upper Silurian of South America.

Genus ACTINOPTERIA Hall, 1884

Actinopteria sp.

Plate 5, figure 10

Material.—One small incomplete external mold of a left valve (USNM 203325).

Discussion.—This specimen has the shape and ribbing of the genus *Actinopteria.* It is small and had to be photographed under very oblique light; although the figure suggests a right valve, it is an impression of the exterior of a left valve.

Genus MYTILARCA Hall and Whitfield, 1869

Mytilarca sp.

Plate 5, figures 9, 12, 14

Material.—One incomplete left valve (pl. 5, fig. 14; USNM 203326) and two right valves (pl. 5, figs. 9, 12; USNM 203327, 203328). The right valve shown in plate 5, figure 12, measures 20.5 mm long and 21.5 mm high.

Discussion.—None of these specimens is well preserved. They have the general shape of ambonychiids, and because they lack radial ornament are best assigned to *Mytilarca*; however, they are unusually long and quadrate for that genus.

BIOSTRATIGRAPHY

A major difficulty with the biostratigraphic interpretation of the Silurian-Devonian pelecypods of the Florida and Georgia wells is that none of the wells penetrates more than one major faunal unit; thus we do not know the superposition of the units from any single well. In drawing biostratigraphic interpretations from samples of this kind, it is necessary to compare them with those from other areas where the superposition of the faunal zones is known; then a composite picture of the stratigraphy of the four southeastern American wells can be made.

The age of the Chandler well fauna presents the biggest problem. Palmer (1970) interpreted the pelecypods to be fresh-water forms and Carboniferous in age. Swartz (1949) felt the leperditiid ostracode *Chevroleperditia chevronalis* suggested a Late Ordovician or Early Silurian age. The pelecypods occur with the leperditiid ostracodes, a group which is not known from rocks younger than Devonian and which is known only from marine facies. Schopf (written commun., 1958) noted that the plant spores associated with the pelecypods and ostracodes were no older than Middle Devonian in age. It seems best to regard the 6,995–7,015-foot level of the Chandler well (which contains the pelecypods, ostracodes, and plant spores) as Devonian, rather than older or younger, and probably Middle Devonian in age. While we cannot entirely rule out the fresh-water interpretation of the Chandler pelecypods, and certainly fresh-water and marine forms can be mixed in either facies, shells of this shape do occur in marine Devonian environments and are usually placed in the genus *Modiomorpha.* On the basis of the Middle Devonian spores, we regard the Chandler pelecypods as the youngest forms in the four wells studied herein.

Because of the occurrence of *Butovicella migrans* in the Ragland well, the 5,840–5,850-foot level of this well is herein regarded as Ludlovian or late Wenlockian (Silurian) in age. *Butovicella migrans* is most widely distributed in rocks of Ludlovian Age (Late Silurian), but is also known to occur in rocks of late Wenlockian Age (Middle Silurian) in Bohemia and Poland. The Ragland well pelecypod fauna is the oldest from the four wells studied. Thus, the total range of the pelecypods in the four wells is Wenlockian or Ludlovian to Middle Devonian.

Pelecypods from the Tillis well occur in a 16-foot interval (3,552–3,568 ft). The total aspect of the fauna is Devonian, and several taxa are present which are not known from rocks older than the Devonian, for example, *Prothyris, Pterinopecten*?, and *Eoschizodus*?. Forms which are known to range into the Late Silurian are also present—*Arisaigia, Pleurodapis*, and *Nuculites* with a posterior buttress. These taxa are not known from rocks younger than Early Devonian. This mixing of Devonian taxa with genera not known to occur above the Lower Devonian suggests that the Tillis fauna is most likely Early Devonian in age.

The mixing of forms which are not known from pre-Devonian rocks with taxa that range across the Silurian-Devonian boundary suggests that sedimentation in the Florida Paleozoic was continuous across the Silurian-Devonian boundary. This suggestion is also supported by the fauna from the Cone well, which is probably latest Silurian in age. An alternative explanation is that the 3,552–3,568-foot interval of the Tillis well crosses the Silurian-Devonian boundary. At the present time this seems unlikely, as the Tillis forms which are known to range into the Late Silurian also have Early Devonian occurrences elsewhere.

Other mollusks occurring in the Tillis well are the bellerophontacean *Plectonotus* (*Tritonophon*) sp. (pl. 4 fig. 1) and the cricoconarid *Tentaculites* sp. (pl. 3, fig. 7). The bellerophontacean was identified by J. S. Peel and E. L. Yochelson, who noted (written commun., 1970) that species of the taxon occur throughout the Silurian and into the Early Devonian. Fisher (1962) gave the range of *Tentaculites* as "?L. Ord, L. Sil. (Llandov.)–U. Dev. (Mid. M. Frasn.)."

The Cone well fauna is dominated by taxa that are best known from Bohemia, Czechoslavakia. Of the nine taxa recognized from the Cone well, seven occur in Bohemia and an eighth has a closely allied species in Bohemia.

The Cone well fauna is Late Silurian (Pridolian) in age and is probably high in the Late Silurian, just below the Silurian-Devonian boundary. This age is indicated by the presence of *Lunulacardium excellens*, which in Bohemia is known only from the late Pridolian Stage, but is best documented by a comparison of the ranges of the taxa in the Cone well with the occurrence of the same taxa in Bohemia (fig. 5). In Bohemia some of the taxa cross the Silurian-Devonian boundary, but none of them is known to occur only in the Devonian, and most taxa are concentrated near the boundary.

Other mollusks in the Cone well are two fragmentary specimens of nautiloid cephalopods. One is from core 122, 3,512–3,587 ft (pl. 4, fig. 12), and in ornament is most like the Silurian genus *Parakionoceras* Foerste. The other is from core 127, 3,678–3,703 ft (pl. 4, fig. 10), and is ornamented like *Dawsonoceras* Hyatt, a widely distributed Silurian genus.

In the four Florida-Georgia wells which have yielded pelecypods, we see a composite section ranging in age from late Wenlockian or early Ludlovian to Middle Devonian, with each of the four wells having pentrated rocks of a different age. The Ragland well fauna is the oldest, late Wenlockian or early Ludlovian; the Cone well fauna is the next oldest, Pridolian in age; the Tillis well fauna is Early Devonian, about Lochkovian; and the Chand-

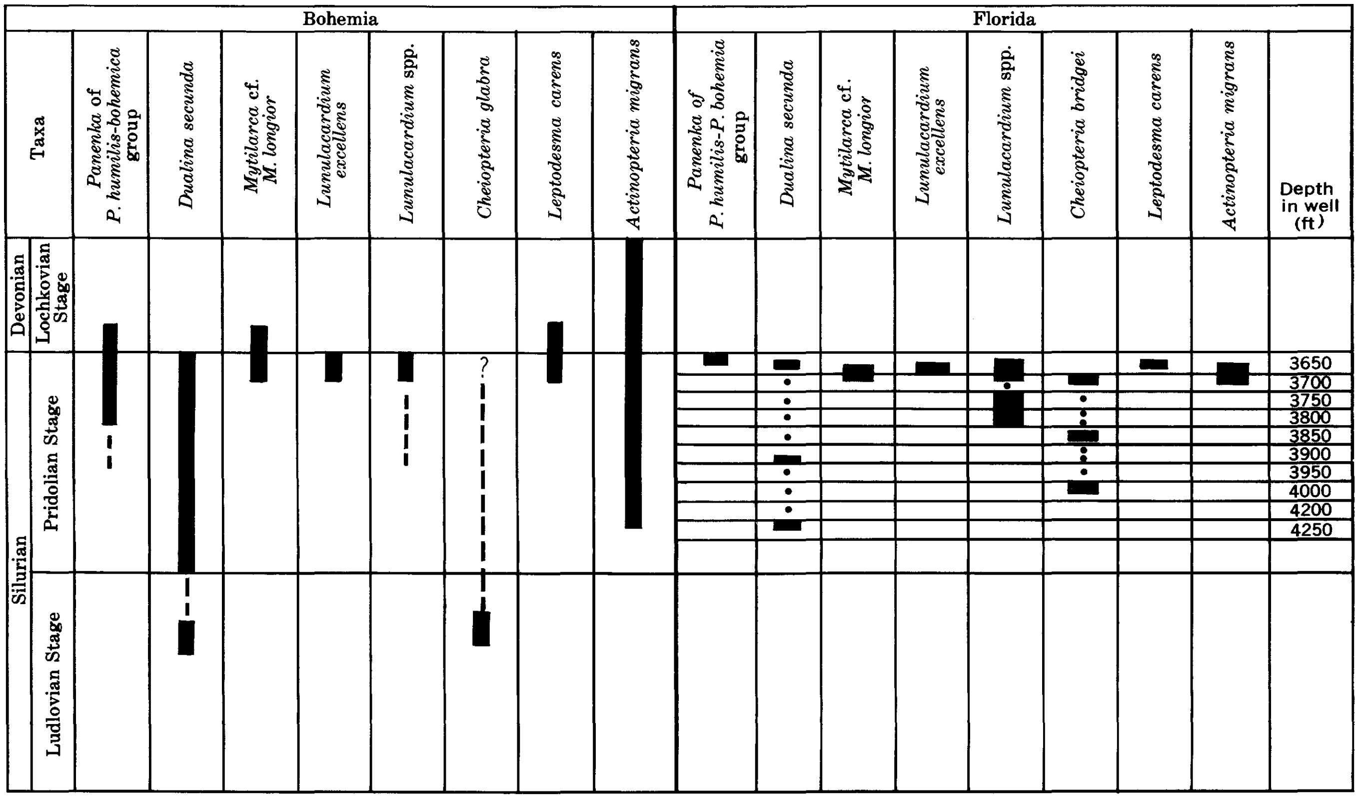


FIGURE 5.—Occurrences of pelecypod taxa in Bohemia and the Cone well of Florida

ler well fauna is Middle Devonian in age.

Kjellesvig-Waering (1950) on the basis of the occurrence of a new species of the eurypterid *Pterygotus* regarded the 3,552–3,568-foot interval of the Tillis well to be Late Silurian in age. Bridge and Berdan (1952) regarded the Tillis fauna to be Late Silurian or Early Devonian in age, the former being more probable, and Berdan (1970) considered that the Cone fauna was more likely younger than the Tillis fauna. Cramer (1973), however, discussed the chitinozoan stratigraphy of four Florida wells, including the Cone and Tillis, and he considered the Tillis fauna to be younger than the Cone fauna, an opinion with which we agree. Both the Tillis and the Cone fauna of this paper fall in Cramer's Zone of *Ancyrochitina fragilis*, which he noted (p. 285) is older than late Gedinnian (Early Devonian); he also noted (p. 284) that the top of the Florida succession is late Ludlovian [Pridolian?] or earliest Gedinnian. We have concluded that the Tillis pelecypod fauna is early Early Devonian in age because forms which are not known below the Devonian are mixed with forms which first occur in the Late Silurian. Also, we conclude that the Cone pelecypods are late Late Silurian, because of their similarity to late Late Silurian species from Bohemia. In effect, the two wells are on opposite sides of the Silurian-Devonian boundary.

As noted, the Late Silurian age of the Bolivian faunule is based on the occurrence of *Dualina secunda*, which elsewhere is not known to occur in rocks older than Ludlovian. The Turkish material is thought to be Wenlockian or Ludlovian in age on the basis of its occurrence with an encrinurid trilobite (W. T. Dean, written commun., 1973). We regard the single Turkish species to be *Cheiopteria bridgei*, which is also known from the Cone well, where it is Pridolian in age.

PALEOECOLOGY AND ENVIRONMENT OF DEPOSITION

Ecology of the various pelecypods.—Stanley (1970) recognized seven life-habit groups in pelecypods. The pelecypods from the American wells, Bolivia, and Turkey, belong to three of these life-habit groups: byssally attached, burrowing, and reclining. Among byssally attached forms Stanley (1972) distinguished endobyssate (semi-infaunal) and epibyssate species—endobyssate forms being those which are partly buried in the substrate and epibyssate forms being those which are entirely epifaunal. The endobyssate category included virtually all forms with a prominent rounded anterior lobe or auricle, a shallow byssal sinus, and an oblique shell; thus many pteriomorphs and isofilibranchs previously regarded as epifaunal are considered to be semi-infaunal by Stanley. Kauffman (1969) did not regard all these forms as being semi-infaunal and explained the external shell morphology of *Modiolus* as an adaptation to an epifaunal mode of life. Stanley's 1972 paper is a bold synthesis with broad deductive conclusions, but it suffers from a small empirical base (Gordon and Pojeta, 1975) which is largely limited to a few species of living mytilids and the pinnids. His conclusions of the modes of life of many extinct forms need verification from field evidence of fossil pelecypods found preserved in living position. Herein we have used Stanley's endobyssate category with the understanding that some of these forms may ultimately be shown to have been epibyssate.

In the Ragland well both known species are byssate forms. Kříž (1969) regarded *Butovicella migrans* as epifaunal, although it has a prominent anterior lobe and is modioliform in shape. He based his conclusions on the observations that the species is most often found in shelly limestones, as the shells provide surfaces for attachment, and in graptolitic shales associated with the alga *Prototaxites*. He regarded the soft bottom in the latter environment as being unsuitable for benthos and suggested that *Butovicella* was epiplanktonic, being attached to floating algae which drifted into the area of graptolitic shale deposition.

The other Ragland species, *Actinopteria* sp., is known only from left valves which are highly oblique and have a small posterior auricle; they have the general morphology of Stanley's (1972, p. 185) endobyssate pteriaceans.

Of the 12 pelecypod taxa known from the Tillis well, 8 are infaunal burrowing forms: *Nuculites* sp. A, *Nuculites* sp. B, *Arisaigia* cf. *A. postornata*, *Eoschizodus*?, *Pleurodapis* sp., *Prothyris* sp., and pholadomyacean genus and species indet.; the first 4 are palaeotaxodonts comparable to living deposit feeders, and the last 4 are suspension feeders. The remaining species are byssate. *Actinopteria* sp. A is an erect shell with a fairly prominent byssal sinus and may have been epifaunal. *Actinopteria* sp. B is more oblique with a broad rounded anterior auricle and a poorly developed byssal sinus; it would fall into Stanley's endobyssate category. *Modiomorpha* sp. has the shell shape of some living endobyssate mytilaceans. *Pterinopecten*? sp. was probably a byssally attached epifaunal pectinacean (Stanley, 1972, p. 192).

In the Cone well there is one infaunal burrowing species, *Panenka* sp. Seven species are byssate: *Mytilarca* cf. *M. longior, Lunulacardium excellens, Lunulacardium* spp., *Cheiopteria bridgei, Cheiopteria* sp., *Leptodesma carens*, and *Actinopteria migrans*. Of the byssate species only *Mytilarca* cf. *M. longior* fits Stanley's criteria of an epifaunal form.

Also occurring in the Cone well is *Dualina secunda*, a markedly inequivalved, inequilateral form which can be right or left convex and which probably was a reclining species. Stanley (1970, p. 8) defined the reclining life habit as: "Occupying a position on or partially buried in a soft substratum and lacking the capacity for attachment." In *Dualina* both valves are convex although one is markedly more so than the other. As in the chamids either valve can be the more convex although there is no sign of cementation in *Dualina*. Thus, either valve of *Dualina* probably could be lowermost and the commissural plane was probably horizontal.

There are a number of inequivalved pelecypod groups which rest on the substrate with the commissural plane horizontal. These include the cemented spondylids, ostreids, chamids, rudists, pseudomonotids, and plicatulids; the byssally attached buchiids, most anomiids, isognomonids, most inoceramids, some pteriids, and many pectinids; and the reclining species of gryphaeids, anomiids, and inoceramids. The great bulk of the forms which have the commissural plane horizontal are pteriomorphs.

Dualina, and antipleurids in general, show no sign of cementation, although they are probably analogous to some chamids in that they could have either valve more convex and lowermost. Little is known of the details of muscle-scar morphology of *Dualina* and antipleurids in general. There is no external sign of a byssus, but its presence cannot be entirely ruled out until we have knowledge of the muscle scars of *Dualina*. Because there is no sign of cementation or byssal attachment we regard *Dualina* as a reclining form analogous to *Placuna* and some gryphaeids and inoceramids.

The Bolivian fauna described herein has four infaunal deposit-feeding species: *Deceptrix* (*Praenucula*) sp., *Nuculites* sp., *Palaeoneilo* sp. A, and *Palaeoneilo*?. There are two byssally attached species: *Mytilarca* sp. and *Actinopteria* sp., the former was probably epifaunal and the latter is too poorly preserved to apply Stanley's criteria. *Dualina secunda* is also present in Bolivia and as noted above was probably a reclining epifaunal species.

Tables 1 and 2 and figure 6 summarize ecological data for the pelecypods from the Tillis and Cone wells and from Bolivia. The Cone well fauna is dominated by endobyssate forms, whereas the Tillis well collection and the one from Bolivia are dominated by infaunal burrowing forms. However, only the Tillis well collection has a strong infaunal suspension-feeding element which forms almost 50 percent of the individuals in the fauna.

TABLE 1.—*Summary of the inferred life habits, by number of species, of the pelecypods from the Ragland, Tillis, and Cone wells and from Bolivia.*

[Note the low occurrence of epifaunal byssate and reclining species. In the Cone well fauna byssate forms dominate, whereas in the Tillis well and Bolivia collections burrowing forms dominate]

Locality	Byssate		Infaunal burrowing		Reclining
	Epibyssate	Endobyssate	Deposit feeding	Suspension feeding	
Ragland well	1	1	0	0	0
Tillis well	2	2	4	4	0
Cone well	1	5	0	1	1
Bolivia	1	1?	4	0	1

TABLE 2.—*Percentage distribution of the life habits of the pelecypods from the Tillis and Cone wells and from Bolivia*

[Note that each locality has a different ecologically dominant group]

Life habit	Tillis well		Cone well		Bolivia	
	Percent of total	Number of specimens	Percent of total	Number of specimens	Percent of total	Number of specimens
Epibyssate	3.3	1, plus several superimposed *Pterinopecten*	2	2	3.5	3
Endobyssate	12.1	4	94	94	1.2	1
Reclining	0	0	3	3	12.8	11
Infaunal deposit feeders	36.3	12	0	0	82.6	71
Infaunal suspension feeders	48.4	16	1	1	0	0
Total	100.1	33	100	100	99.1	86

Environment of deposition of sedimentary sequences in the American wells.—In the four American wells considered herein, the entire sedimentary sequence is clastic; hard slaty black to dark-gray micaceous fissile shale dominates, although there are some thin siltstones (Applin, 1951). Carroll (1963) studied the petrography of the wells; black shales were examined from the Cone and Chandler wells, and red shales from the Tillis and Ragland wells. None of the pelecypods seen by us occur in red shale. For the depth of 3,562–3,587 ft in the Cone well Carroll gave the following analysis of the minerals observed in thin section (1963, p. A7):

Shale consists of very fine grained angular quartz and carbonaceous matter interlaminated with well-crystallized siderite and minor calcite. The siderite is slightly oxidized in places so that reddish-brown rims occur at the edges of the laminae. The clay material occurs as very fine micaceous laths and as indefinite aggregates that exhibit aggregate polarization. A little carbonate also occurs as minute irregular patches in the clay matrix.

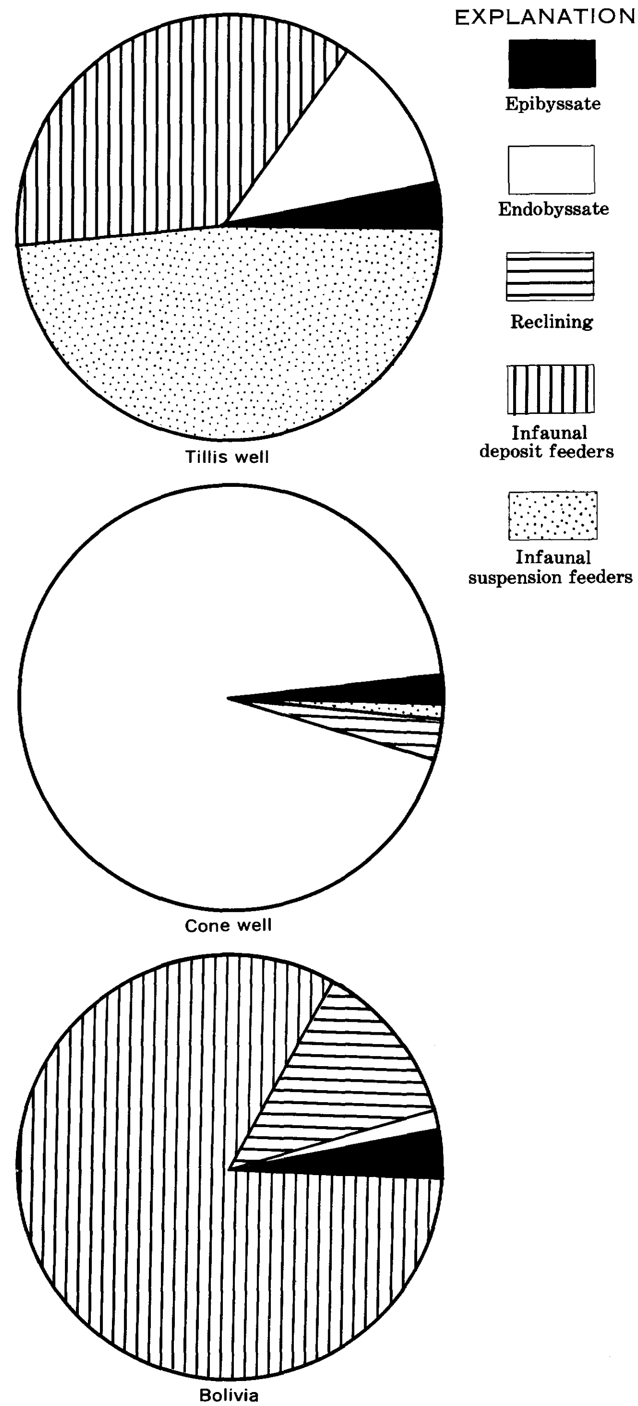


FIGURE 6.—Percentages of various pelecypod ecologic types for the Tillis and Cone wells and the collection from Bolivia.

X-ray examination of the clays showed both kaolinite and illite are present in almost equal proportions. The only heavy mineral from the black shale of the Cone well was pyrite; the Chandler well yielded only opaques.

Bridge and Berdan (1952, p. 29) noted that the Paleozoic strata appear to have been deposited in shallow water. Schopf (1959, p. 1671) considered that the presence of pyrite and abundant carbonaceous material signified deposition in an euxinic environment and postulated a sargassoid environment for microfossils which he had obtained in part from the Cone and Tillis cores. Berdan (1970, p. 150) concluded that the presence of crinoid calices in the Cone fauna suggests fairly normal marine salinity, whereas the eurypterids in the Tillis may indicate a lagoonal environment. Cramer (1973, p. 280–281) stated that

> The presence of the miospores indicates a sedimentary realm not far removed from land; the absence of coarse sediments in the Silurian of Florida suggests an essentially shallow sea in which the areas inhabited by the spore-producing plants must have been flat islands or shoals.

Cramer (1973 p. 286) further commented

> The shales that make up the succession were probably deposited in a fully marine environment, not in a lagoonal one as suggested before. The presence of miospores plus the black shale lithology suggests a low-relief, low energy depositional environment***

To date, most workers have interpreted the cores of the Tillis and Cone wells as representing a shallow water normal marine environment. Bretsky (1969, p. 50–51) noted that pelecypods in the Paleozoic are most abundant and diverse in nearshore situations. The information derived from the study of the pelecypods of these wells agrees with these broad environmental generalizations.

It is likely that the Cone and Tillis well faunas represent near-life assemblages buried with little transportation of the shells. For the Cone fauna this interpretation is supported by the lack of fragmentation of many of the specimens, the well-preserved surface ornament, and the diversity of the fauna at several levels; also, the occurrence of spatfalls on the same bedding plane with larger specimens indicates a lack of size sorting (pl. 2, fig. 4). The Tillis fauna likewise shows a general lack of fragmentation of the specimens, the ornament is well preserved, the fauna is highly diverse, and there are one or two articulated specimens. Although the evidence that we are dealing with near-life assemblages is not overwhelming, it is certainly suggestive of that situation.

The pelecypod faunas from the Ragland, Tillis, and Cone wells and Bolivia and Turkey indicate normal marine environments. They contain several groups of pelecypods which are not known to occur in brackish- or fresh-water environments, including palaeotaxodonts, pteriaceans, and pectinaceans. The occurrence of cephalopods, crinoids, tentaculites, and bellerophontaceans likewise indicates the marine nature of these deposits. As previously noted, the pelecypods from the Chandler well have been regarded as fresh water (Palmer, 1970), but it is our opinion that they are probably marine, as they occur with leperditiid ostracodes.

A low-energy environment for the rocks penetrated by the American wells is indicated by the small grain size of the black shale, the lack of sorting of shells by size, the lack of abrasion of the shells, and the well preserved surface ornament of the shells.

The depth of the water is difficult to estimate on the basis of the pelecypods. Cramer felt that the presence of miospores in the cores indicates a shallow sea near low-lying landmasses. The presence of mica in the rock could suggest fairly close proximity to a crystalline terrane but does not help in estimating depth. McAlester and Rhoads (1967) have dealt with the problem of how to estimate water depth from the pelecypods present in a fossil assemblage. They came to the conclusion that the three primary environmental factors limiting pelecypod distribution are temperature, salinity, and the nature of the substrate, and that the problem of pelecypod bathymetry is one of relating one or more of these primary limiting factors to water depth. Salinity of the marine environment of the sediments in the American wells was normal, and the micaceous organic-rich black shale can occur in both shallow and deep water. Temperature is discussed below.

The total aspect of a pelecypod fauna can give an indication of the depth at which the animals lived. Thus, in the Cone well, the presence of many byssate species, the reclining *Dualina*, the *Lunulacardium* spatfalls and the diversity of the fauna suggest shallow water. Most byssate and reclining pelecypods occur in water of less than 100 fathoms depth. Although the Tillis fauna is quite different from that of the Cone well, one-third of the species are byssate, and they occur with various burrowing forms, many of which have numerous shallow-water representatives today. At the present time, deposit-feeding palaeotaxodonts are most common in nearshore fine-grained organic-rich sediments (Bambach, 1969) comparable to the black carbonaceous shales of the American wells.

McAlester and Doumani (1966) analyzed an Early Devonian pelecypod fauna from Antarctica which contained palaeotaxodonts, *Modiomorpha*, and *Prothyris* and was thus similar to the Tillis fauna; however, the percentages of the various taxa were quite different, and the Antarctic fossils occurred in a dark, poorly sorted, coarse sandstone. They came to the conclusion that in the Early Devonian the Antarctic was a region of relatively cool temperatures. This conclusion is supported by recent reconstructions of Early Devonian paleogeography which show the portion of Antarctica from which their fossils came was about 60° S. lat (Smith, Briden, and Drewry, 1973; Cocks and McKerrow, 1973).

For various reasons explained in the paleobiogeographic section of this paper Pojeta and Kříz regard Florida as having been at about 60° S. lat in the Late Silurian and Early Devonian and thus as having had a relatively cool climate. This climate could have been ameliorated by a warm-water current which would have come by the shores of central Europe and produced the similiar faunas of Bohemia and Florida in the Late Silurian (figs. 7, 8). The Bolivian fauna would be a cold-water assemblage, as it would have been quite close to the South Pole.

PALEOBIOGEOGRAPHY

Paleobiogeographic considerations herein are largely limited to the plotting of our data on the maps of the Late Silurian-Early Devonian published by Cocks and McKerrow (1973) and Smith, Briden, and Drewry (1973); Mercator and South Polar projections are used (figs. 7, 8). On these maps we have included probable surface paleocurrents. These are generalized and obviously depend upon the location of landmasses, which is still an intensely debated subject. As in modern seas we have an equatorial current and a general clockwise circulation of currents in the northern hemisphere and a general counterclockwise movement of currents in the southern hemisphere; no equatorial countercurrent is shown in figure 8.

Figures 7 and 8 show that there is a strong similarity between the pelecypod faunas of Bohemia and Poland and that of Florida in the Late Silurian. Of the eight genera known from the Cone well (*Panenka, Dualina, Mytilarca, Lunulacardium, Cheiopteria, Leptodesma,* and *Actinopteria*) all occur in Bohemia and all except *Panenka* are known from Poland. The Tillis and Cone wells have only the genus *Actinopteria* in common; however, four genera known from the Tillis well also occur in Poland: *Nuculites, Arisaigia, Actinopteria,* and *Pterinopecten*?. Of this Late Silurian–Early Devonian assemblage *Dualina* is also known from Sweden, Bolivia, and north Africa; *Panenka* occurs in France, Spain, north Italy and north Africa; *Lunulacardium* occurs in North Africa and France; *Cheiopteria* is known from Turkey; and *Arisaigia* occurs in Nova Scotia. *Mytilarca* is the most widespread genus, occurring in Nova Scotia, New York, Maryland, Ontario, Siberia, Bolivia, north Africa, and Antarctica (Pojeta, 1966). *Mytilarca* represents an old stock beginning perhaps in the Ordovician, which could explain its wide distribution. *Leptodesma* and *Actinopteria* have distributions similar to *Mytilarca* (although *Leptodesma* is not known from Antarctica) and are not plotted in figures 7 and 8. The genus *Pleurodapis* occurs in Florida, Brazil, Bolivia (Branisa, 1965), western Europe, and west Africa (Saul, Boucot, and Finks 1963).

If, as is assumed in the 1973 paleogeographic reconstructions used herein, Europe north of the Mediterranean Sea were adjacent to North America and straddled the paleoequator and if eastern North America were in the same position relative to the rest of the continent as it is now, then warm-water currents passing Europe and heading south would have warmed the eastern coast of North America and carried pelecypod larvae southward (figs. 7 and 8). This circulation pattern would explain the strong similarity of the Late Silurian–Early Devonian pelecypod assemblage of central Europe and Florida and the presence of some part of this assemblage in Nova Scotia; presumably more of the assemblage should be found in Nova Scotia in the future. *Dualina* in Bolivia could be explained as a eurythermal taxon carried into very high south paleolatitudes by surface currents (figs. 7 and 8), whereas most of the species of the Bohemia-Poland assemblage were not able to tolerate the cold temperatures near the Late Silurian–Early Devonian South Pole. *Pleurodapis* has a distribution comparable to *Dualina* and could be explained the same way.

The occurrence of some elements of the Bohemia-Poland-Florida fauna in north Africa and Turkey is more difficult to explain, but could have been accomplished by dispersal along the shoreline of South America and thence to west Africa and down the shores of west Africa and eastern South America; the two continents are thought to have been nearly contiguous in the Late Silurian–Early Devonian. Alternatively, there could have been a seaway connection between Bolivia and Brazil through Paraguay, and there may have been a dispersal across South America.

Another possible arrangement of the Late Silurian–Early Devonian landmasses was suggested to

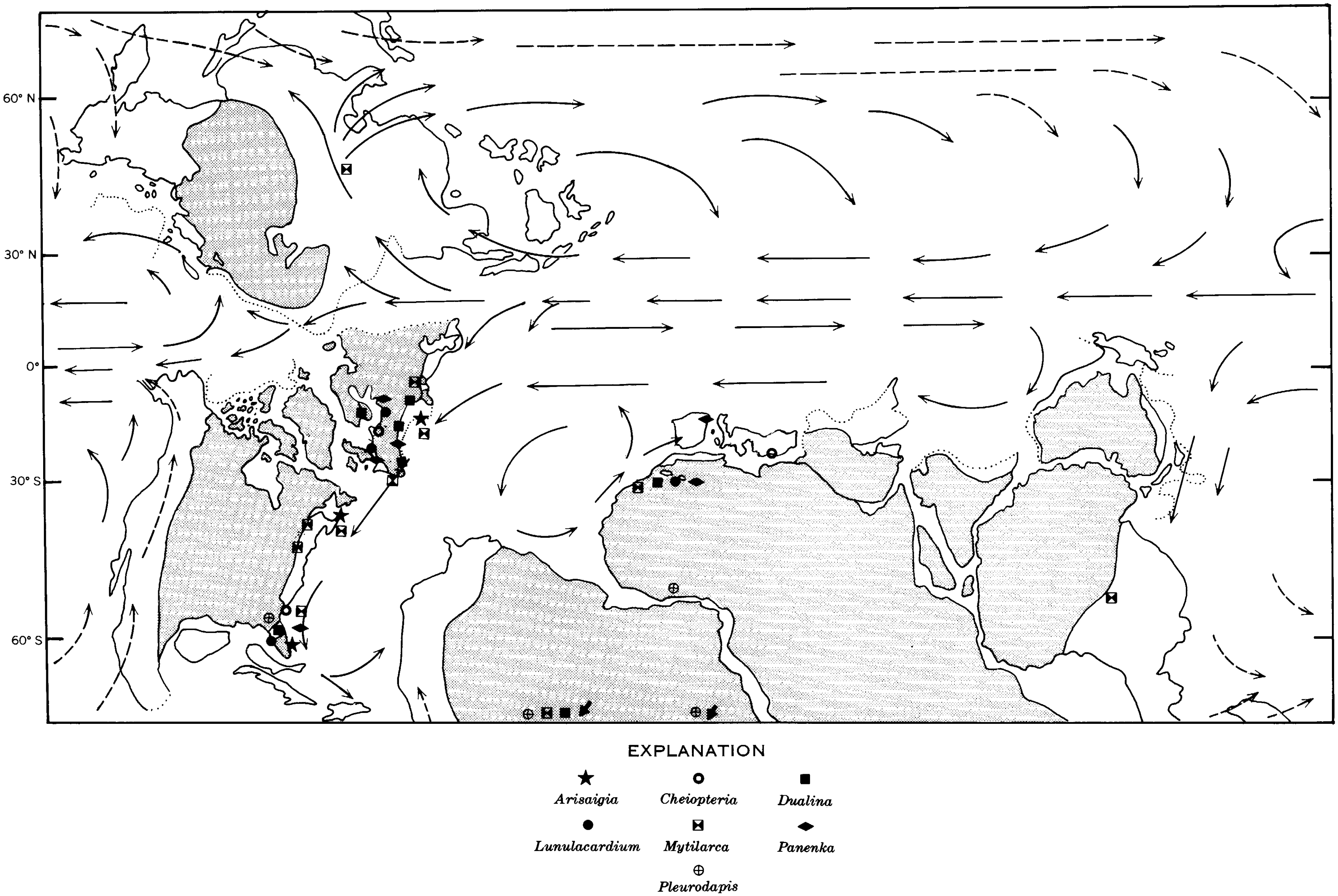


FIGURE 7.—Mercator projection of the position of Late Silurian–Early Devonian landmasses, taken from Cocks and McKerrow (1973) and Smith, Briden, and Drewry (1973). Unpatterned parts of continents represent present-day outcrop areas of Phanerozoic orogenic belts. Indicated on the map are surface paleocurrents and the distributions of various genera which occur in the Cone and Tillis wells of Florida.

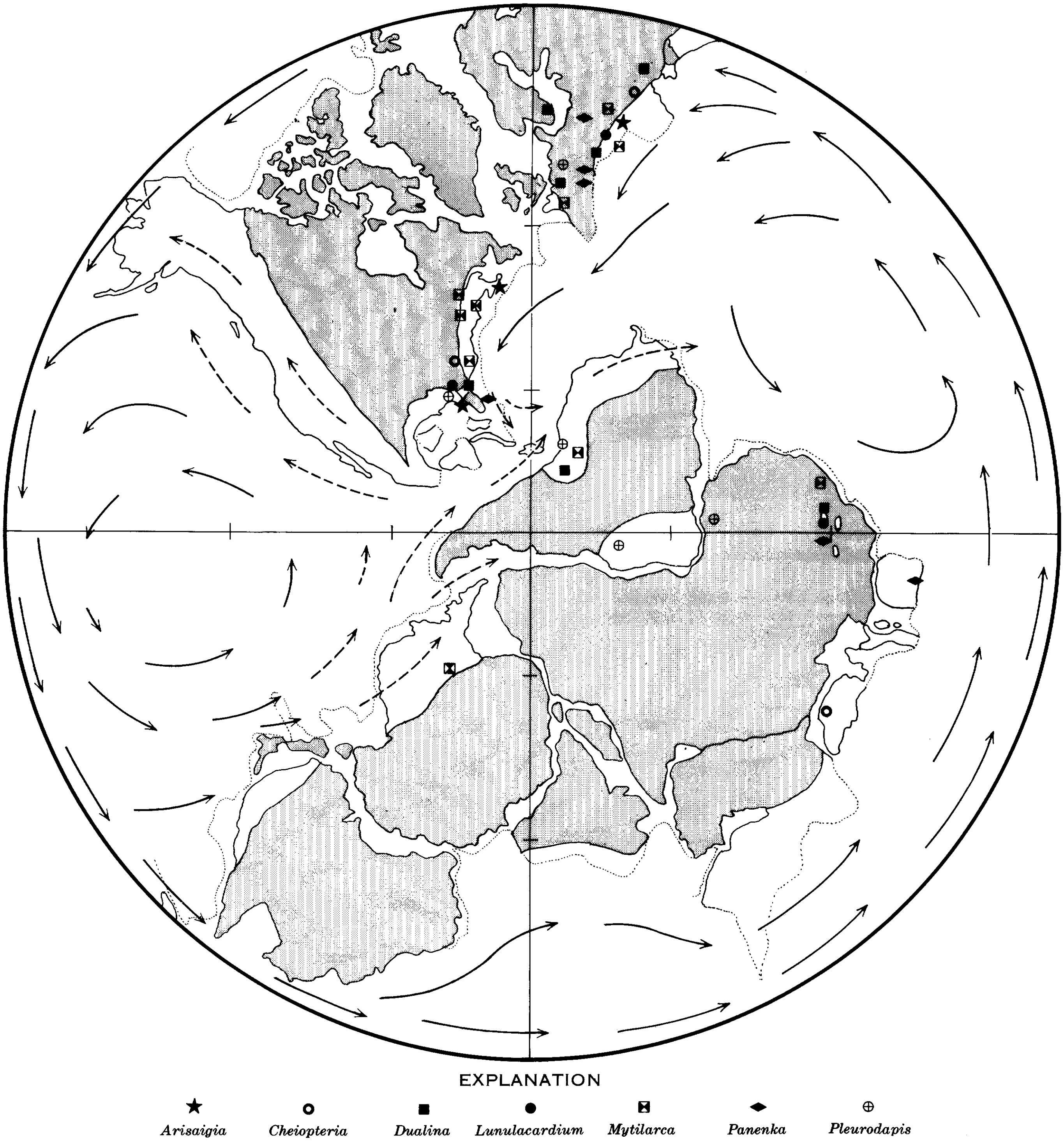


FIGURE 8.—South-polar projection of the position of Late Silurian–Early Devonian landmasses, taken from Smith, Briden, and Drewry (1973). Unpatterned parts of continents represent present-day outcrop areas of Phanerozoic orogenic belts. Indicated on the map are surface paleocurrents and the distributions of various genera which occur in the Tillis and Cone wells of Florida.

us by Warren Hamilton and R. J. Ross, Jr. (oral commun., 1973): Europe south of the Sudetenland would be near north Africa, eastern North America would be separated from the rest of the continent and adjacent to both north Africa and northern South America, with Nova Scotia closest to Iberia and Florida closest to Venezuela and Columbia. This arrangement of the continental blocks is based upon separation along major structural trends and would explain the Ordovician-Devonian similarities of the fauna of middle Bohemia and north Africa and the Bohemia-Florida-north Africa-Turkey Late Silurian–Early Devonian pelecypod similarities. The South American faunal similarities could then be explained by movement along the east and west shores of that continent of eurythermal pelecypod larvae southward into colder high south paleolatitudes. The greatest faunal similarities would occur in a relatively small area and in tropical and subtropical paleolatitudes. This arrangement of the continents would not account for the similarities of the Polish fauna, as Poland is north of the structural trends which would place Bohemia, France, northern Italy, and southern England near north Africa.

Clearly, with at least two such different arrangements of the Late Silurian–Early Devonian landmasses being possible, it is difficult to use the geophysical data to make paleontological deductions. Both arrangements answer a number of paleontological questions, but both leave a residue of unresolved problems. Nonetheless, rearrangement of the continents may better explain the fossil distributions than does plotting these distributions on a map showing the present-day position of the landmasses.

REFERENCES CITED

Andress, N. E., Cramer, F. H., and Goldstein, R. F., 1969, Ordovician chitinozoans from Florida well samples *in* Geology of the American Mediterranean: Gulf Coast Assoc. Geol. Socs. Trans., v. 19, p. 369–375.

Applin, E. R., and Applin, P. L., 1964, Logs of selected wells in the Coastal Plains of Georgia: Georgia Geol. Survey Bull. 74, 229 p.

Applin, P. L., 1951, Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent states: U.S. Geol. Survey Circ. 91, 28 p.

Applin, P. L., and Applin, E. R., 1965, The Comanche Series and associated rocks in the subsurface in central and south Florida: U.S. Geol. Survey Prof. Paper 447, 84 p.

——— 1967, The Gulf Series in the subsurface in northern Florida and southern Georgia: U.S. Geol. Survey Prof. Paper 524–G, 35 p.

Babin, Claude, 1966, Mollusques bivalves et céphalopodes du Paléozoïque Armoricain: Brest, Imprimerie Commerciale et Administrative, 471 p., 18 pls.

Bambach, R. K., 1969, Bivalvia of the Siluro-Devonian Arisaig Group, Nova Scotia: unpub. Ph.D. thesis, Yale Univ., 376 p., 85 pls.

Barrande, Joachim, 1881, Systême Silurien du centre de la Bohême, v. 6, Acéphalés: Paris and Prague, 342 p., 361 pls. (Bound in four volumes.)

Bass, M. N., 1969, Petrography and ages of crystalline basement rocks of Florida—some extrapolations *in* Other papers on Florida and British Honduras: Am. Assoc. Petroleum Geologists Mem. 11, p. 283–310.

Berdan, J. M., 1970, p. 149–150 *of* Florida, southern Georgia, and southeastern Alabama subsurface Silurian, *in* Berry, W. B. N., and Boucot, A. J. eds., Correlation of the North American Silurian rocks: Geol. Soc. America Spec. Paper 102, 289 p.

Berdan, J. M., and Bridge, Josiah, 1951, Preliminary notes on the Paleozoic strata beneath Levy and Citrus Counties, Florida, *in* Vernon, R. O., Geology of Citrus and Levy Counties, Florida: Florida Geol. Survey Bull. 33, p. 68–71.

Branisa, Leonardo, 1965, Index fossils of Bolivia—I, Paleozoic: Servicio Geólogico de Bolivia, Bull. 6, 282 p., 80 pls.

Branisa, Leonard, Chamot, G. A., Berry, W. B. N., and Boucot, A. J., 1972, Silurian of Bolivia, *in* Berry, W. B. N., and Boucot, A. J., eds., Correlation of the South American Silurian rocks: Geol. Soc. America Spec. Paper 133, p. 21–31.

Braunstein, Jules, 1958, Habitat of oil in eastern Gulf Coast *in* Weeks, L. G., ed., Habitat of oil—a symposium. Am. Assoc. Petroleum Geologists, p. 511–522.

Bretsky, P. W., Jr., 1969, Evolution of Paleozoic benthic marine invertebrate communities: Palaeogeography, Palaeoclimatology, and Palaeoecology, v. 6, no. 1, p. 45–59.

Bridge, Josiah, and Berdan, J. M., 1952, Preliminary correlation of the Paleozoic rocks from test wells in Florida and adjacent parts of Georgia and Alabama: Florida Geol. Survey Guidebook, Assoc. Am. State Geologists 44th Ann. Mtg. Field Trip, April 1952, p. 29–38.

Campbell, R. B., 1939, Paleozoic under Florida?: Am. Assoc. Petroleum Geologists Bull., v. 23, no. 11, p. 1712–1713.

Carroll, Dorothy, 1963, Petrography of some sandstones and shales of Paleozoic age from borings in Florida: U.S. Geol. Survey Prof. Paper 454–A, 15 p.

Clarke, J. M., 1899, A fauna siluriana superior do Rio Trombetas and Molluscos Devonianos do Estado do Pará, Brazil: Archivos do Museu Nacional do Rio de Janeiro, vol. 10, p. 1–174, pls. 1–8.

Clarke, J. M., 1900, The Paleozoic faunas of Pará, Brazil, author's English edition, extracted from the Archivos do Museu Nacional do Rio de Janeiro, v. 10, p. 1–174, 1899: Albany, James B. Lyon, State Printer, 127 p., 8 pls.

——— 1909, Early Devonic history of New York and eastern North America, pt. 2; New York State Mus. Mem. 9, 250 p., 34 pls.

——— 1913, Fosseis Devonianos do Paraná: Serviço Geologico e Mineralogico do Brasil Mon. v. 1, 353 p., 27 pls.

Cocks, L. R. M., and McKerrow, W. S., 1973, Brachiopod distributions and faunal provinces in the Silurian and Lower Devonian, *in* Hughes, N. F., ed., Organisms and continents through time: Palaeont. Assoc., Spec. Papers Palaeontology no. 12, p. 291–304.

Conrad, T. A., 1841, Fifth annual report on the palaeontology of the State of New York: New York Geol. Survey Ann. Rept. 5, p. 25–57.

Cox, L. R., 1951, The lamellibranch genus *Schizodus* and other Paleozoic Myophoriidae: Geol. Mag., v. 88, no. 5, p. 362–371.

Cramer, F. H., 1973, Middle and Upper Silurian chitinozoan succession in Florida subsurface: Jour. Paleontology, v. 47, no. 2, p. 279–288, 2 pls.

Dall, W. H., and Harris, G. D., 1892, Correlation papers—Neocene: U.S. Geol. Survey Bull. 84, 349 p.

Fisher, D. W., 1962, Small conoidal shells of uncertain affinities, *in* Moore, R. C., ed., Treatise on Invertebrate Paleontology, Part W, Miscellanea: New York and Lawrence, Kans., Geol. Soc. America and Kansas Univ. Press, p. W98–W144.

Flawn, P. T., and others, 1961, The Ouachita system: Texas Univ. Pub. 6120, 401 p.

Fuchs, A., 1919, Beitrag zur kenntnis der devonfauna der Verse- und Hobräcker Schichten des sauerlandischen faciesgebietes: Preuss. Geol. Landesanstalt, Jahrbuch 1918, v. 29, pt. 1, no. 1, p. 58–95, pls. 5–9.

Goldfuss, G. A., 1837, Petrefacta Germaniae, v. 2, p. 141–224, pls. 122–146: Düsseldorf, Arnz & Comp.

Goldstein, R. F., Cramer, F. H., and Andress, N. E., 1969, Silurian chitinozoans from Florida well samples, *in* Geology of the American Mediterranean: Gulf Coast Assoc. Geol. Socs. Trans., v. 19, p. 377–384.

Gordon, Mackenzie, Jr., and Pojeta, John, Jr., 1975, Pelecypoda and Rostroconchia of the Amsden Formation (Mississippian and Pennsylvanian) of Wyoming: U.S. Geol. Survey Prof. Paper 848–E, 24 p.

Gunter, Herman, 1928, Basement rocks encountered in a well in Florida: Am. Assoc. Petroleum Geologists Bull., v. 12, no. 11, p. 1107–1108.

Hall, James, 1883, Lamellibranchiata plates and explanations: New York Geol. Survey, Palaeontology, v. 5, pt. 1, 20 p., pls. 1–34, 36–41, and 43–80.

——— 1884, Lamellibranchiata 1: New York Geol. Survey, Palaeontology, v. 5, pt. 1, 268 p., pls. 1–33, 81–92.

——— 1885, Lamellibranchiata 2: New York Geol. Survey, Palaeontology, v. 5, pt. 1, p. 269–561, pls. 34–80, 93–96.

Hall, James, and Whitfield, R. P., 1869, Preliminary notice of the lamellibranchiate shells of the Upper Helderberg, Hamilton, and Chemung Groups, with others from the Waverly Sandstones, pt. 2, 80 p.

Howell, B. F., and Richards, H. G., 1949, New Paleozoic linguloid brachiopod from Florida: Wagner Free Inst. Sci. Bull., v. 24, no. 4, p. 35–36, pl. 1.

Kauffman, E. G., 1969, Form, function, and evolution, *in* Moore, R. C., ed., Treatise on Invertebrate Paleontology, Part N, Mollusca 6, Bivalvia, vol. 1, p. N129–N205.

King, E. R., 1959, Regional magnetic map of Florida: Amer. Assoc. Petroleum Geologists Bull., v. 43, no. 12, p. 2844–2854, 4 figs.

Kjellesvig-Waering, E. N., 1950, A new Silurian eurypterid from Florida: Jour. Paleontology, v. 24, no. 2, p. 229–231, pl. 38.

——— 1955, A new phyllocarid and eurypterid from the Silurian of Florida: Jour. Paleontology, v. 29, no. 2, p. 295–297, 2 figs.

Korejwo, Krystyna, and Teller, Lech, 1964, Upper Silurian nongraptolite fauna from the Chełm borehole (eastern Poland): Acta Geol. Polonica, v. 14, no. 2, p. 233–301, 26 pls.

Kozłowski, Roman, 1923, Faune Dévonienne de Bolivia: Annales Paléontologie, v. 12, parts 1 and 2, 112 p., 10 pls.

Kříž, Jiří, 1965, Genus *Butovicella* gen. n. in the Silurian (Bivalvia): Věstníku Ústředního Ústavu Geologického, v. 40, no. 3, p. 207–208, 2 pls.

Kříž, Jiří, 1969, Genus *Butovicella* Kříž, 1965 in the Silurian of Bohemia (Bivalvia): Sborník Geologických Věd, Paleontologie, řada P, no. 10, p. 105–139, 8 pls.

Lange, F. W., 1972, Silurian of Brazil, *in* Berry, W. B. N., and Boucot, A. J., eds., Correlation of the South American Silurian Rocks: Geol. Soc. America Spec. Paper 133, p. 33–39.

Mailleux, Eug., 1936, La faune et l'âge des quartzophyllades siegéniens de Longier: Belgique Mus. Royal Natl. Histoire Mem. no. 73, 140 p., 3 pls.

Mauz, Joseph, 1933, Zur Fauna der Unterkoblenz-Stufe: Senckenbergiana, v. 15, no. 3/4, p. 274–294.

McAlester, A. L., 1965, Bivalves *in* Hadley, J. S., Geology and Paleontology of the Antarctic: Antarctic Research Series, v. 6, p. 261–267, pls. 9–14.

——— 1968, Type species of Paleozoic nuculoid bivalve genera: Geol. Soc. America Mem. 105, 143 p., 36 pls.

——— 1969, Family Malletiidae *in* Moore, R. C., Treatise on Invertebrate Paleontology, Part N, Mollusca 6, Bivalvia, v. 1, p. N231–N235.

McAlester, A. L., and Doumani, G. A., 1966, Bivalve ecology in the Devonian of Antarctica: Jour. Paleontology, v. 40, no. 3, p. 752–755.

McAlester, A. L., and Rhoads, D. C., 1967, Bivalves as bathymetric indicators: Marine Geology, v. 5, no. 5–6, p. 383–388.

McLaughlin, R. E., 1970, Palynology of core samples of Paleozoic sediments from beneath the Coastal Plain of Early County, Georgia: Georgia Geol. Survey Inf. Circ. 40, 27 p.

McLearn, F. H., 1918, The Silurian Arisaig series of Arisaig, Nova Scotia: Am. Jour. Sci., ser. 4, v. 45, p. 126–140.

Meek, F. B., 1871, Descriptions of some new types of Palaeozoic shells: Am. Jour. Conchology, v. 7, p. 4–10, 1 pl.

Milton, Charles, 1972, Igneous and metamorphic basement rocks of Florida: Florida Bureau of Geology Geol. Bull. 55, 125 p.

Milton, Charles, and Grasty, Robert, 1969, "Basement" rocks of Florida and Georgia: Am. Assoc. Petroleum Geologists Bull., v. 53, no. 12, p. 2483–2493, 3 figs.

Milton, Charles, and Hurst, V. J., 1965, Subsurface "basement" rocks of Georgia: Georgia Geol. Survey Bull. 76, 56 p.

Münster, G. G., 1840, Beiträge für Petrefacten-Kunde, h. 3, p. 66, pl. 12.

Palmer, K. V. W., 1970, Paleozoic nonmarine bivalve from a deep well in Georgia: Georgia Acad. Sci. Bull., v. 28, no. 1, p. 45–54, 3 pls.

Pfab, Leo, 1934, Revision der Taxodonta des böhmischen Silurs: Palaeontographica, v. 80, abt. A, p. 195–253, pls. 2–4.

Pojeta, John, Jr., 1966, North American Ambonychiidae (Pelecypoda): Paleontographica Americana, v. 5, no. 36, p. 129–241, pls. 19–47.

Reeside, J. B., Jr., chm., and others, 1957, Correlation of the Triassic formations of North America, exclusive of Canada: Geol. Soc. America Bull., v. 68, no. 11, p. 1451–1514.

Ross, C. S., 1958, Welded tuff from deep-well cores from Clinch County, Georgia: Am. Mineralogist, v. 43, nos. 5–6, p. 537–545.

Růžička, Bohuslav, 1949, Pteriidae Thiele českého siluru a devonu (Lamellibranchiata): Prírodovedecky Sbornik, Ostravkého Kraje, Rocnik 10, Cislo 3, Priloha: Sbornik Výsoké skoly bánské v Ostrave, p. 97–118, 1 pl.

Saint Jean, Joseph, Jr., 1965, New Cambrian trilobite from the Piedmont of North Carolina [abs.]: Geol. Soc. America Spec. Paper 82, p. 307–308.

Saul, J. M., Boucot, A. J., and Finks, R. M., 1963, Fauna of the Accraian Series (Devonian of Ghana) including a revision of the gastropod *Plectonotus*: Jour. Paleontology, v. 37, no. 5, p. 1042–1053, pls. 135–138.

Schopf, J. M., 1959, Sargassoid microfossil assemblage from black shale of Early Paleozoic age in Florida and Georgia [abs.]: Geol. Soc. America Bull., v. 70, no. 12, pt. 2, p. 1671–1672.

Smith, A. G., Briden, J. C., and Drewry, G. E., 1973, Phanerozoic world maps *in* Hughes, N. F., ed., Organisms and continents through time: Palaeont. Assoc., Spec. Papers Palaeontology no. 12, p. 1–42.

Stanley, S. M., 1970, Relation of shell form to life habits of the Bivalvia (Mollusca): Geol. Soc. America Mem. 125, 296 p., 40 pls.

——— 1972, Functional morphology and evolution of byssally attached bivalve mollusks: Jour. Paleontology, v. 46, no. 2, p. 165–212, 34 figs.

Swartz, F. M., 1945, Mid-Paleozoic Ostracoda in exploratory well in Georgia; muscle scars in Leperditiidae [abs.]: Geol. Soc. America Bull., v. 56, no. 12, pt. 2, p. 1205.

——— 1949, Muscle marks, hinge and overlap features and classification of some Leperditiidae: Jour. Paleontology, v. 23, no. 3, p. 306–327, pls. 65–67.

Termier, Geneviève, and Termier, Henri, 1950, Paléontologie marocaine—II, Invertébrés de l'ère primaire, Fasc. III Mollusques: Protectorat de la Republique Française au Maroc, Direction de la Production Industrielle et des Mines, Division des Mines et de la Géologie, Service Géologique, Notes et Mémoires, no. 78, 246 p., pls. 123–183.

Whidborne, G. F., 1892–1907, A monograph of the Devonian fauna of the south of England: Palaeontographical Soc., vol. 2, 222 p., 24 pls.; vol. 3, 247 p., 38 pls.

Whittington, H. B., 1953, A new Ordovician trilobite from Florida: Harvard Mus. Comp. Zoology Breviora, no. 17, 6 p., 1 pl.

Whittington, H. B., and Hughes, C. P., 1972, Ordovician geography and faunal provinces deduced from trilobite distribution: Royal Soc. London Philos. Trans., ser. B, v. 263, no. 850, p. 235–278.

Williams, Alwyn, and others, 1972, A correlation of Ordovician rocks in the British Isles: Geol. Soc. London Spec. Rept. No. 3, 74 p.

INDEX

[Italic page numbers indicate descriptions and major references]

☆U.S. GOVERNMENT PRINTING OFFICE: 1975 O—211-319/36

PLATES 1-5

Contact photographs of the plates in this report are available, at cost, from
U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

PLATE 1

FIGURE 1. *Cheiopteria*? sp. (p. 16).

Right valve from the Cone well, middle of core 135, 3,863–3,888 feet, × 6, USNM 203297.

2, 3, 5, 14, 15. *Cheiopteria bridgei* n. sp. (p. 15).

From the Cone well, core 128, 3,703–3,720 feet, × 5.

2. Paratype, right valve, from top 7 feet, USNM 203293.
3. Holotype, left valve, from middle of interval, USNM 203291.

From near Tufanbeyli, Turkey.

5. Paratype, right valve, × 7. MTA.
14. Chip showing several paratypes including the two shown in figures 5 and 15, × 4, MTA.
15. Paratype, right valve, × 8, MTA.

4, 17. *Dualina secunda* Barrande (p. 14).

4. Hypotype, convex valve from the Cone well, bottom of core 138, 3,936–3,953 feet, × 3.5, USNM 203264.
17. Enlargement of ornament of the specimen shown in figure 4 showing riblets on the main ribs, × 20.

6, 11. *Cheiopteria glabra* (Goldfuss) (p. 15).

From the upper part of the Kopanina Formation, *Orthoceras* quarry, southwest of Lochkov, Czechoslovakia. × 4 .

6. Topotype, right valve, USNM 203260.
11. Topotype, left valve, USNM 203261.

7. *Pterochaenia fragilis* (Hall). (See p. 15).

Hypotype, right valve from the West River Shale Member of the Genesee Formation, 18 Mile Creek, New York, × 5, USNM 101989.

8, 9. *Actinopteria migrans* (Barrande) (p. 17).

Hypotypes, left valves from the Cone well.

8. From third 5 feet of core 127, 3,678–3,703 feet, × 5, USNM 203302.
9. From middle of core 128, 3,703–3,720 feet feet, × 6, USNM 203303.

10, 16. *Leptodesma carens* (Barrande) (p. 16).

Hypotypes, left valves from the Cone well, bottom of core 126, 3,653–3,678 feet.

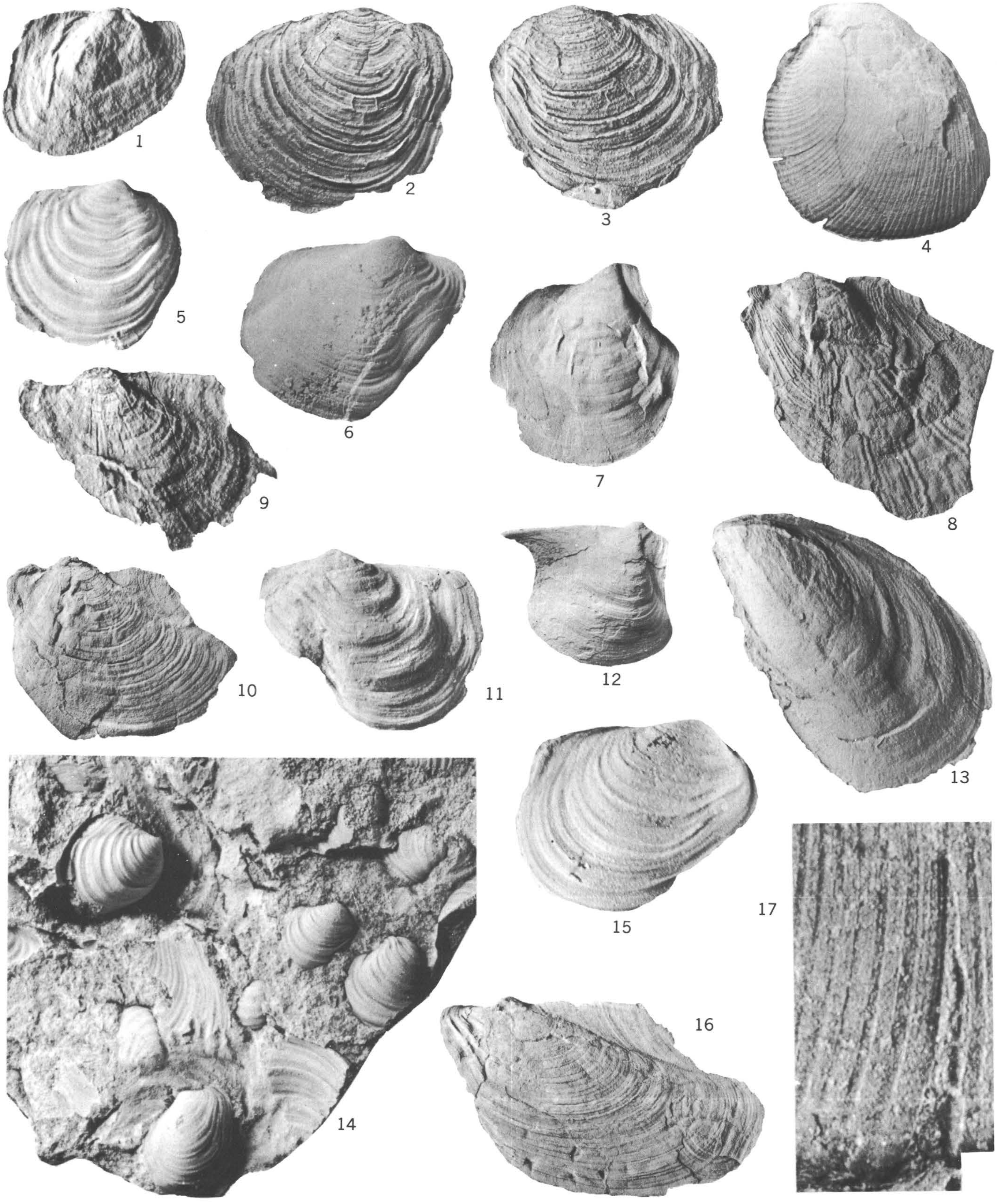
10. × 4, USNM 203298.
16. × 3.5, USNM 203299.

12. *Joachymia falcata* (Barrande). (See p. 15).

Hypotype right valve from Podoli, Czechoslovakia, Pridolian Stage, × 5, USNM 203259.

13. *Mytilarca* cf. *M. longior* (Barrande) (p. 14).

Hypotype, left valve from the Cone well, core 127, third 5 feet of the 3,678–3,703-foot interval, × 4, USNM 203266.



CHEIOPTERIA, DUALINA, PTEROCHAENIA, ACTINOPTERIA, LEPTODESMA, JOACHYMIA, AND *MYTILARCA*

PLATE 2

FIGURES 1–4, 8, 12. *Lunulacardium excellens* Barrande (p. 14).

From the Cone well, core 127, 3,678–3,703 feet.

1-3. Right valves showing characteristic ornament. USNM 203271, 72, 75. 1, 2 × 4; 3, × 5.

4. Chip covered with juveniles (arrow points to specimen of *Lunulacardium* sp.), USNM 203268, × 5.5.

8. Right valve, USNM 203273, × 3.

12. Chip with several valves, USNM 203269, × 2.5.

5. *Lunulacardium* sp. (p. 14).

Right(?) valve showing characteristic ornament from the Cone well, core 133, middle of the 3,815-3,838-foot interval, USNM 203286, × 5.

6. *Panenka* sp. (p. 14).

Right(?) valve from the Cone well, core 126, top 5 feet of the 3,653–3,678-foot interval, USNM 203262, × 1.5.

7. *Actinopteria* sp. (p. 17).

Left valve from the Ragland well, core 15, 5,840–5,850 feet, USNM 203229, × 2.

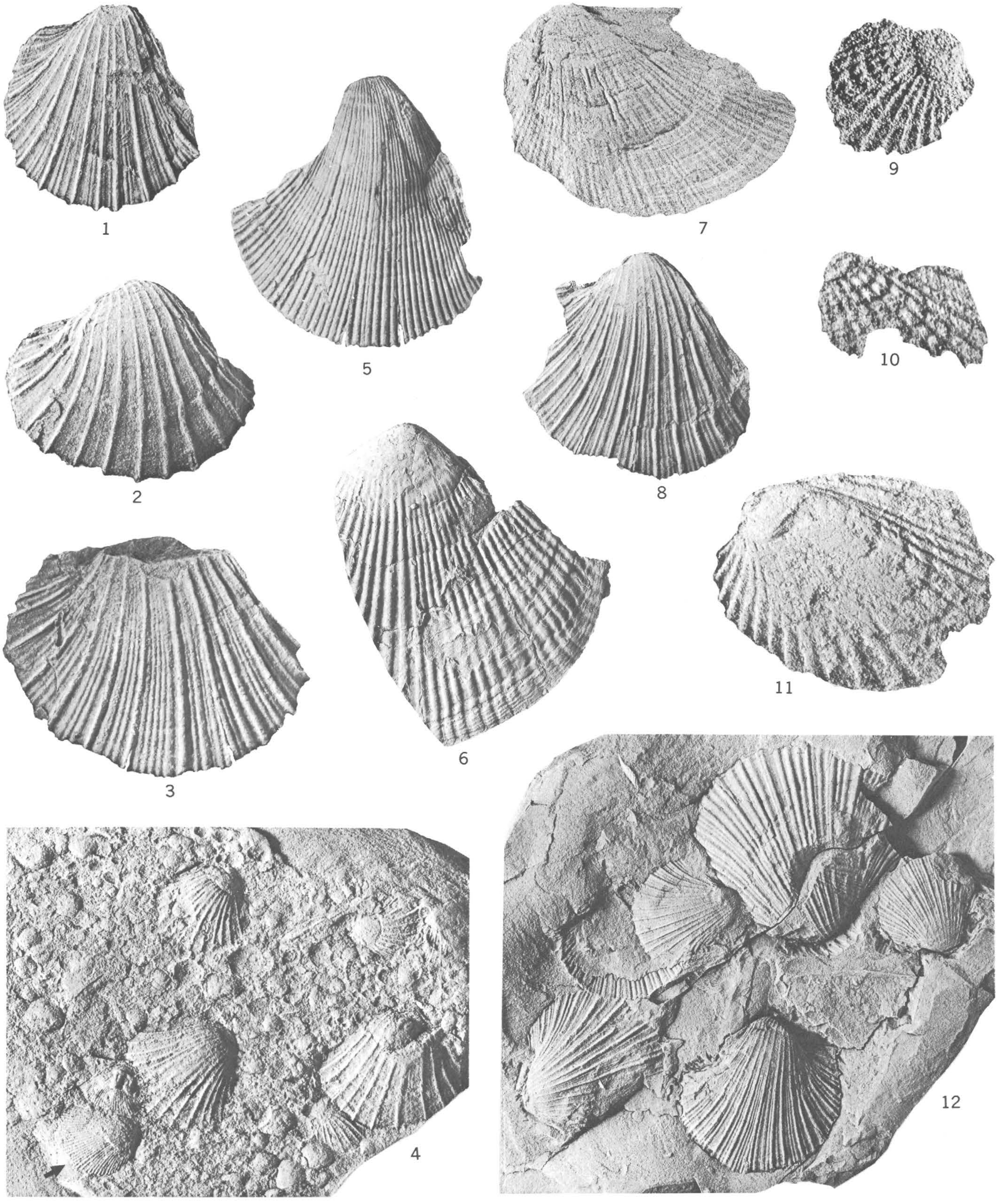
9–11. *Butovicella migrans* (Barrande) (p. 17).

From the Ragland well, core 15, 5,840–5,850 feet.

9. External mold left valve, USNM 203226, × 8.

10. Left valve, USNM 203227, × 7.

11. Left valve, USNM 203228, × 10.



LUNULACARDIUM, *PANENKA*, *ACTINOPTERIA*, AND *BUTOVICELLA*

PLATE 3

[All specimens from the Tillis well, core 44, 3,552–3,568 feet, except fig. 15]

FIGURE 1. *Eoschizodus*? sp. (p. 13).
Right valve, USNM 203244, × 1.5.

2, 5, 12. *Nuculites* sp. B (p. 12).
- 2. Right valve, USNM 203232, × 4.
- 5. Right valve, USNM 203233, × 5.
- 12. Left valve, USNM 203234, × 5.

3. *Arisaigia* sp. (p. 13).
Left valve, USNM 203238, × 3.7.

4, 6. *Arisaigia* cf. *A. postornata* McLearn (p. 12).
- 4. Left valve, USNM 203236, × 4.5.
- 6. Right valve, USNM 203237, × 5.5.

7. *Tentaculites* sp. (See p. 19).
USNM 203249, × 6.

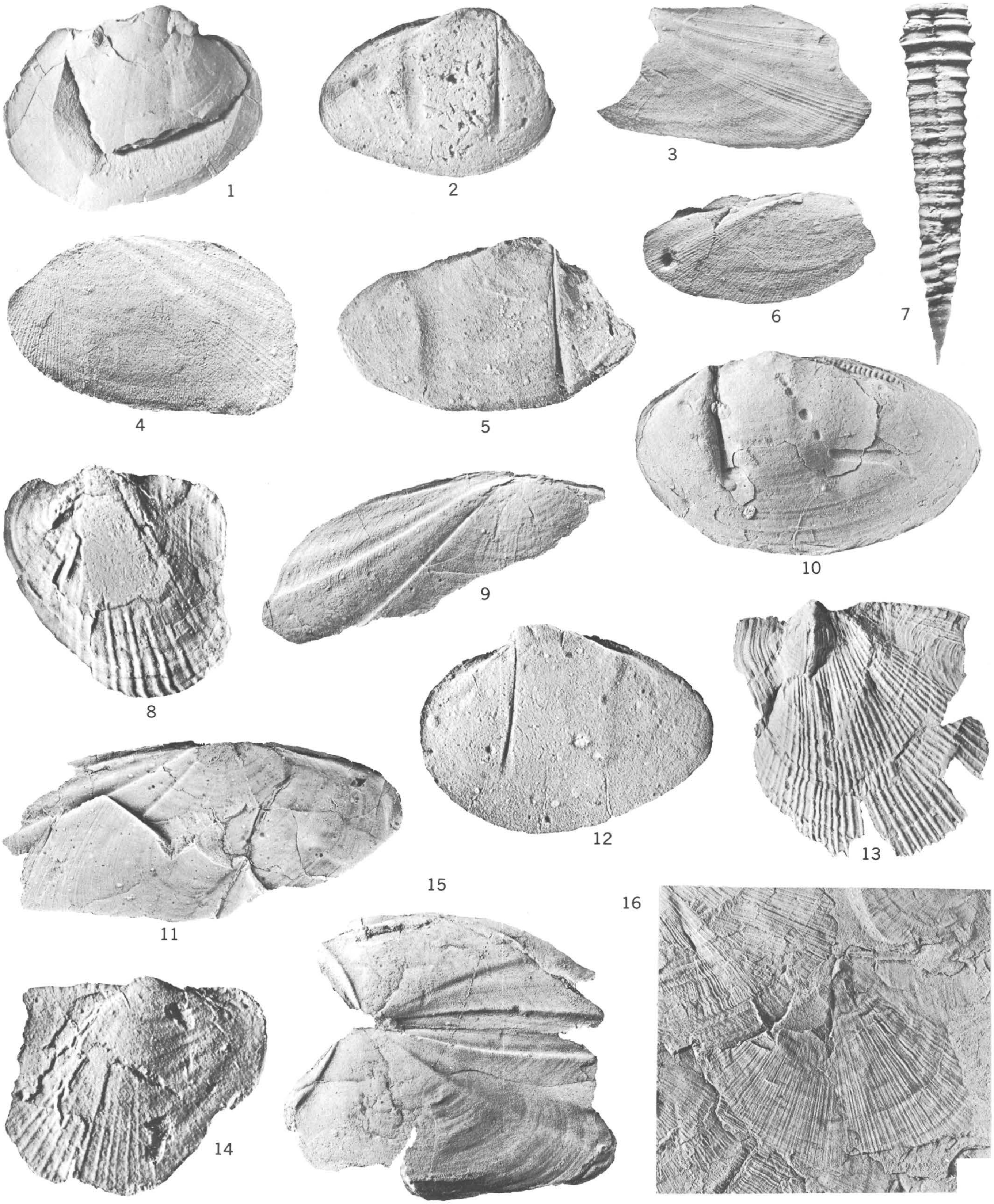
8, 14. *Actinopteria* sp. B (p. 13).
- 8. Left valve, USNM 203240, × 10.
- 14. Right valve, USNM 203241, × 8.

9, 11, 15. *Pleurodapis* sp. (p. 13).
- 9. Right valve, USNM 203246, × 2.
- 11. Right valve, USNM 203247, × 3.5. Specimen preserved on the opposite side of the chip showing *Actinopteria* sp. A (pl. 3, fig. 13).
- 15. Articulated specimen from Devonian rocks, Quebrada Caigua, Aguarague Range, Traija Bolivia, USNM 101905, ×2.

10. *Nuculites* sp. A (p. 12).
Left valve from the Tillis well, core 44, 3,552–3,568 feet, USNM 203231, × 2.7.

13. *Actinopteria* sp. A (p. 13).
Left valve, USNM 203239, × 2.5. Specimen preserved on the opposite side of the chip showing *Pleurodapis* sp. (pl. 3, fig. 11).

16. *Pterinopecten*? sp. (p. 13).
Several valves, USNM 203242, × 3.5.



EOSCHIZODUS?, *NUCULITES*, *ARISAIGIA*, *TENTACULITES*, *ACTINOPTERIA*, *PLEURODAPIS*, AND *PTERINOPECTEN*?

PLATE 4

FIGURE 1. *Plectonotus* (*Tritonophon*) sp. (See p. 19).
From the Tillis well, core 44, 3,552–3,568 feet, USNM 203250, × 2.5.

2–4. Pholadomyacean genus and species indet. (p. 13).
From the Tillis well, core 44, 3,552–3,568 feet.
- 2, 3. Part and counterpart of a left valve, USNM 203256, × 1.5.
- 4. Right valve, USNM 203255, × 1.

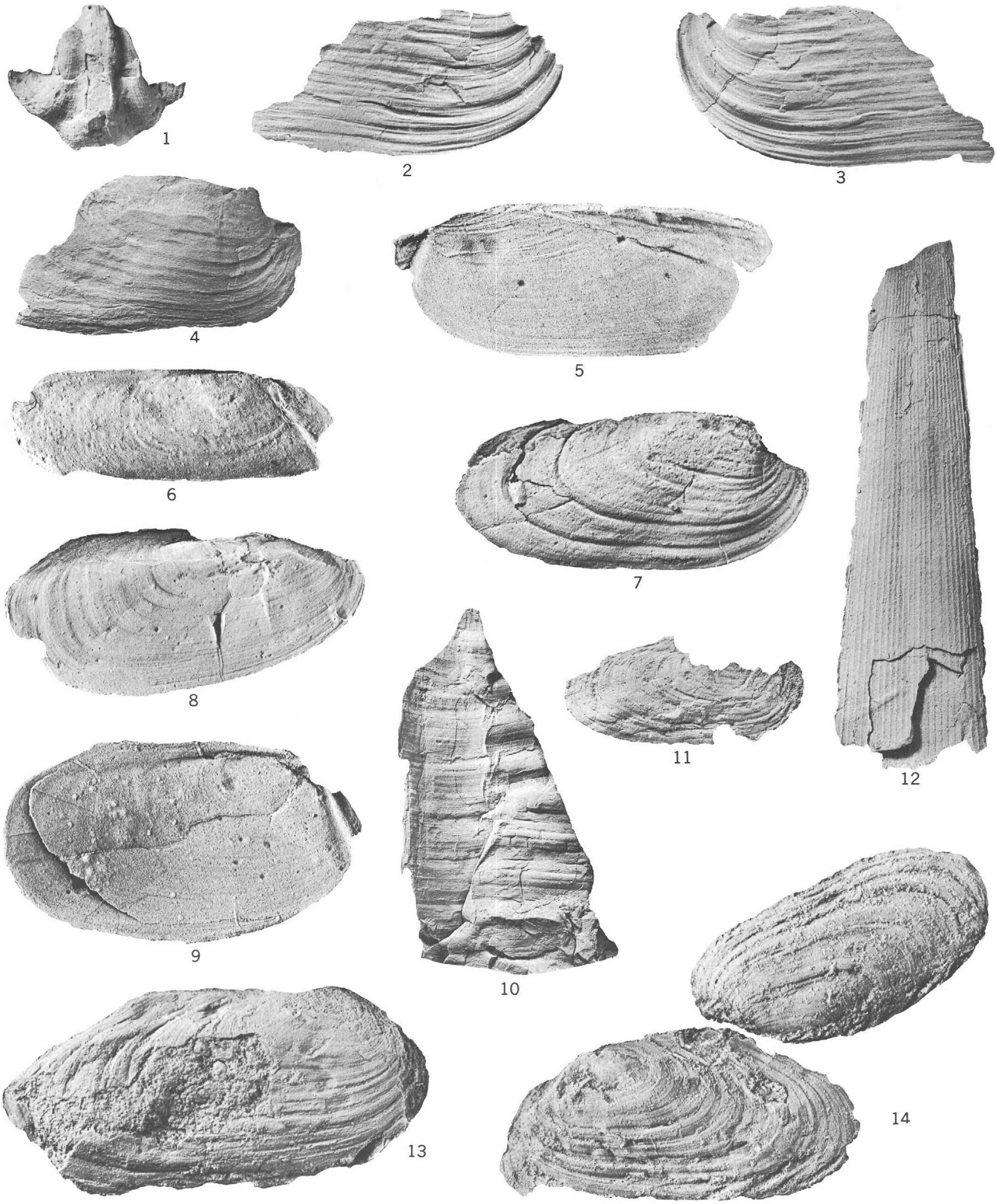
5, 6, 9. *Prothyris* sp. (p. 13).
From the Tillis well, core 44, 3,552–3,568 feet.
- 5. Left valve, USNM 203251, × 4.
- 6. Right valve, USNM 203252, × 4.
- 9. Right valve, 203253, × 6.

7, 11, 13, 14. *Modiomorpha*? sp. (p. 12).
From Chandler well, core 4, 6,995–7,015 feet.
- 7. Right valve, USNM 203225, × 6.
- 11. Right valve, PRI 27632, × 4.
- 13. Right valve, PRI 27632, × 4.
- 14. Left and right valve, PRI 27633, × 4.

8. *Modiomorpha* sp. (p. 13).
Right valve from the Tillis well, core 44, 3,552–3,568 feet, USNM 203243, × 3.

10. *Dawsonoceras* sp. (See p. 19.)
Cone well, core 127, 2,678–3,703 feet, USNM 203257, × 1.

12. *Parakionoceras* sp. (See p. 19.)
Cone well, core 122, 3,512–3,587 feet, USNM 203258, × 1.5.



PLECTONOTUS (TRITONOPHON), PHOLADOMYACEAN, *PROTHYRIS*, *MODIOMORPHA?*, *DAWSONOCERAS*, AND *PARAKIONOCERAS*

PLATE 5

[All specimens from the Pampa Shale, Huari, Bolivia]

FIGURES 1, 2, 5, 8. *Palaeoneilo* sp. A (p. 18).
- 1. Articulated specimen, USNM 203313, × 3.
- 2. Right valve, USNM 203314, × 4.
- 5, 8. Dorsal and lateral views of left valve, USNM 203315, × 4.

3, 6, 11, 13. *Deceptrix* (*Praenucula*) sp. (p. 17).
- 3. Left valve, USNM 203305, × 5.5.
- 6. Right valve, USNM 203306, × 5.
- 11. Right valve exterior, USNM 203307, × 3.
- 13. Right valve, USNM 203308, × 6.5.

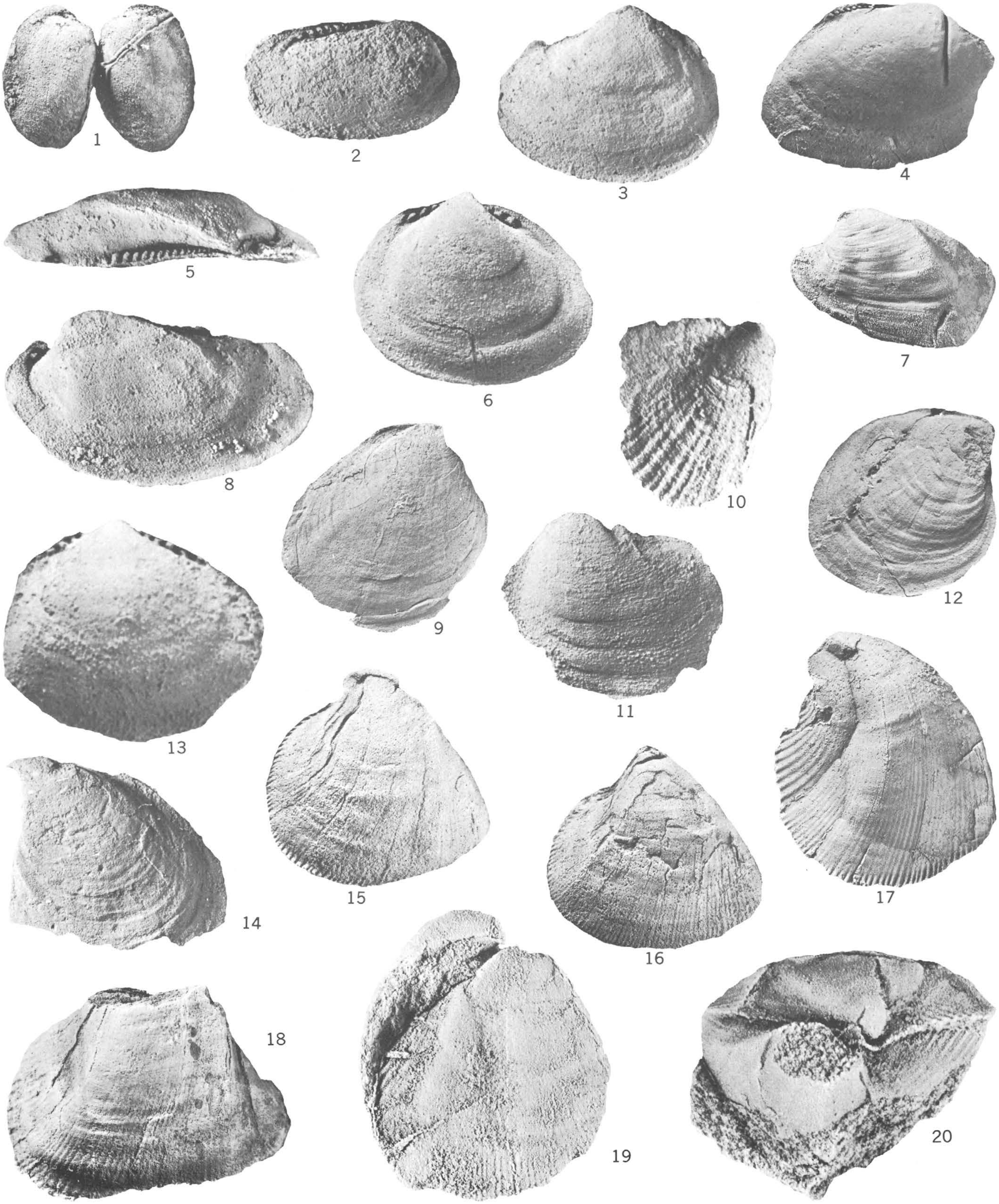
4. *Nuculites* sp. (p. 18).
Right valve, USNM 203312, × 2.

7. *Palaeoneilo*? (p. 18).
Left valve, USNM 203317, × 2.

9, 12, 14. *Mytilarca* sp. (p. 18).
- 9. Right valve, USNM 203327, × 2.
- 12. Right valve, USNM 203328, × 1.5.
- 14. Left valve, USNM 203326, × 2.

10. *Actinopteria* sp. (p. 18).
Left valve exterior mold, USNM 203325, × 10.

15–20. *Dualina secunda* Barrande (p. 18).
- 15. Convex valve, USNM 203319, × 3.
- 16. Convex valve, USNM 203320, × 3.
- 17, 19. Convex and flat valves of an articulated specimen, USNM 203321, × 3.
- 18. Convex valve, USNM 203322, × 3.
- 20. Dorsal view of an incomplete articulated specimen showing convex and flat valves, USNM 203323, × 5.



PALAEONEILO, DECEPTRIX, NUCULITES, MYTILARCA, ACTINOPTERIA, AND *DUALINA*