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UPPER BROMIDE FORMATION AND VIOLA GROUP (MIDDLE AND UPPER ORDOVICIAN) IN EASTERN OKLAHOMA

PART I—WELLING–FITE–CORBIN RANCH STRATA

THOMAS W. AMSDEN

PART II—CONODONT BIOSTRATIGRAPHY OF FITE FORMATION AND VIOLA GROUP

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PART III—THE LATE ORDOVICIAN BRACHIOPOD GENERA *Lepidocyclus* AND *Hiscobeccus*

THOMAS W. AMSDEN

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PREFACE

This report is composed of three papers on the biostratigraphic, lithostratigraphic, and paleoenvironmental relationships of Middle and Late Ordovician strata in the areas extending from the Arbuckle Mountain outcrops in south-central Oklahoma across the Arkoma Basin to the eastern Oklahoma exposures (text-figs. 1, 2). These beds make up the Viola Group and the upper birdseye limestones of the Bromide Formation (Corbin Ranch Submember–Fite Formation). The sequence is composed of open-marine and intertidal carbonates with a combined thickness of about 400 feet (120 m) in the eastern Arbuckle outcrops, which thin to approximately 80 feet (25 m) in eastern Oklahoma. This thinning appears to be due primarily to the loss of pre-Welling Viola strata (Viola Springs Formation) across the Arkoma Basin. These stratigraphic relations are coordinated with the conodont and brachiopod biostratigraphy.

The first paper is by Amsden and describes the lithostratigraphy and lithofacies of late Bromide–Viola strata and discusses the paleoenvironmental conditions represented by these beds. A new stratigraphic unit, the Viola Springs Formation, is described. The second paper is a conodont study by Sweet, which describes the stratigraphic distribution of conodonts in the uppermost Bromide Formation and the Viola Group in the eastern Arbuckle Mountains and in the Fite and Welling Formations of eastern Oklahoma, and which discusses their age and correlation. One new species, *Aphelognathus gigas* Sweet, is described. The final paper is by Amsden and comprises two parts: (1) a taxonomic revision of the brachiopod family Lepidocyclidae Cooper, including a description of a new subfamily, Hiscobeccinae, and a new genus, *Hiscobeccus* Amsden; and (2) a discussion of the biostratigraphic distribution of *Lepidocyclus* and *Hiscobeccus* in the area extending from the Arbuckle Mountains eastward across Arkansas to the Mississippi River.

Acknowledgments.—We wish to express our indebtedness to the following individuals who reviewed this study: Dr. Stig M. Bergström, Ohio State University; Dr. Clifford Jordan, Research and Development Department, Conoco, Inc.; Dr. Gilbert Klapper, University of Iowa; Dr. F. X. Miller, Amoco Production Co.; and Dr. Reuben J. Ross, Jr., Colorado School of Mines.

—T. W. A.
—W. C. S.

Title Page Illustration

Left: *Hiscobeccus capax* (Conrad). Pedicle valve of brachiopod specimen (×1.5), designated the neotype. (See text-fig. 22.)

Right: *Plectodina tenuis* (Branson and Mehl). Sa element of conodont specimen (×100); SEM micrograph. (See pl. 3, fig. 18.)

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UPPER BROMIDE FORMATION AND VIOLA GROUP (MIDDLE AND UPPER ORDOVICIAN) IN EASTERN OKLAHOMA

THOMAS W. AMSDEN[1] and WALTER C. SWEET[2]

PART I—WELLING–FITE–CORBIN RANCH STRATA

THOMAS W. AMSDEN

Abstract—This report presents a sedimentary model for Middle Ordovician (late Champlainian) to Late Ordovician (early–middle Cincinnatian) strata in the region extending from the eastern Arbuckle Mountain outcrops across the Arkoma Basin to the eastern Oklahoma outcrop area. In the Arbuckle Mountains this sequence comprises about 300 feet (90 m) of carbonate strata referred to the Corbin Ranch Submember (Pooleville Member, Bromide Formation), the Viola Springs Formation (new), and the Welling Formation. It is overlain by the Sylvan Shale. The stratigraphic section thins sharply to the east, owing mainly to the loss of the Viola Springs Formation (late Champlainian–early Cincinnatian); over much of the Arkoma Basin it is represented by about 65 feet (20 m) of carbonate strata referred to the Fite Formation (= Corbin Ranch Submember) and upper Welling Formation, which is overlain by the Sylvan Shale. The paleoenvironment represented is shallow marine and intertidal to supratidal.

The Arkoma Basin is a sedimentary-structural basin whose depositional axis must have been located south of the Choctaw Fault in the Ouachita province. Intense structural deformation, combined with a paucity of biostratigraphic control, obscures the stratigraphic relations between the Arkoma Basin and the Ouachita province. However, a stratigraphic model of the Arkoma Basin indicates the following sequence of events: A south-subsiding sedimentary basin developed by Cambrian, possibly pre-Cambrian, time, with its depositional axis located south of the present basin. This pattern continued through deposition of the Simpson sandstones. During deposition of the Corbin Ranch–Fite (Kirkfieldian), basin stresses relaxed, and a more or less stable platform developed. This platform was at times depressed slightly to receive a thin veneer of sediments, and at other times it was elevated slightly above sea level. This pattern continued through Late Ordovician, Silurian, and Early Devonian time. Early in the Middle Devonian the entire region was uplifted and subjected to subaerial erosion, during which period an extensive drainage pattern was developed. In the early Late Devonian the accelerated pattern of southward subsidence of the early Paleozoic resumed, and the Woodford–Chattanooga sea advanced to deposit dark, organic-rich muds.

INTRODUCTION

The Viola Group (= Viola Limestone or Viola Formation of previous authors) and the Bromide Formation make up a carbonate sequence that spans a considerable part of the Middle and Upper Ordovician in the Arbuckle Mountain outcrop area (text-figs. 1, 2). The Viola Group is here divided into two formations, an upper Welling Formation and a lower Viola Springs Formation (new). The underlying Bromide Formation is divided into two members, a lower Mountain Lake Member and an upper Pooleville Member. The latter is a birdseye facies, with the Corbin Ranch Submember locally present at the top. The Viola Springs Formation disappears a short distance east of the Arbuckle Mountain outcrop area, and over most of the Arkoma Basin the Welling Formation rests directly on the Corbin Ranch Submember and its eastern correlative, the Fite Formation. This causes a sharp west-to-east stratigraphic thinning from some 400 feet (120 m) to about 65–80 feet (20–25 m), which is attributed to the chronostratigraphic loss of a considerable part of the lower Cincinnatian and upper Champlainian Series (text-fig. 2).

In the Arbuckle Mountains the Mountain Lake Member of the Bromide Formation is separated

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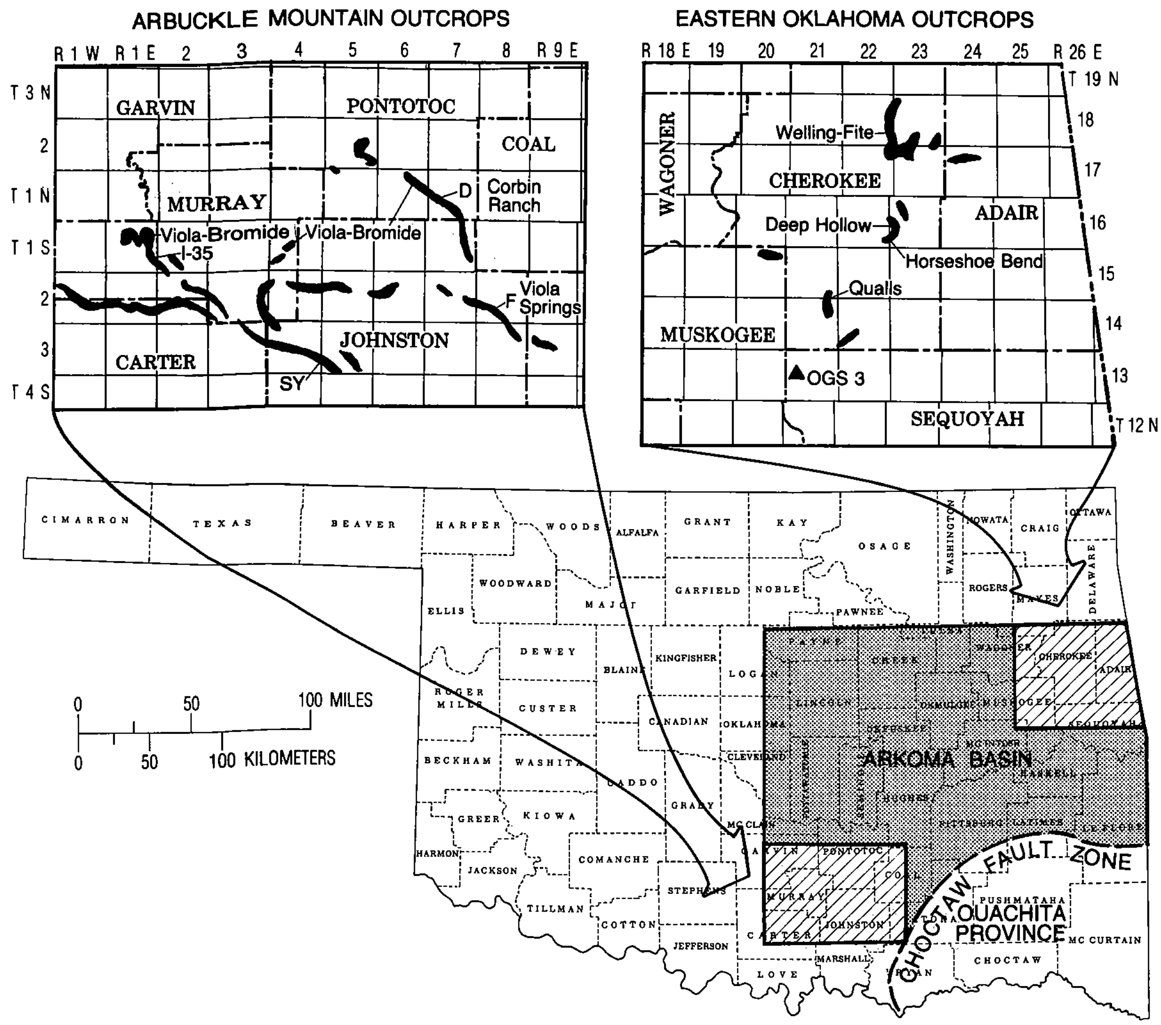
from the Arbuckle Group by a sequence of limestones, shales, and sandstones: in descending order, the Tulip Creek, McLish, Oil Creek, and Joins Formations. In the outcrop area the strata between the Arbuckle Group and the Viola Group (Bromide through Joins) are commonly assigned to the Simpson Group (Harris, 1957, fig. 1); however, over almost the entire Arkoma Basin the late Bromide Corbin Ranch–Fite birdseye limestones are directly underlain by a predominantly shale–sandstone sequence here informally designated as the Simpson sandstones. The exact chronostratigraphic relationship of the pre-Corbin Ranch Bromide carbonates and clastics in the Arbuckle Mountains to the pre-Fite clastics in the Arkoma Basin is uncertain.

My information is derived from a study of these strata in the outcrop areas of eastern Oklahoma and the Arbuckle Mountains, as well as from subsurface investigation based on well cuttings and cores, supported by thin sections. A number of thin sections were point counted in order to obtain



Text-figure 1. Map showing location of area studied and of stratigraphic sections cited in text. Arbuckle Mountain stratigraphic sections include: *D*, type locality for Corbin Ranch Submember, Oklahoma Highway 99, SW¼ sec. 12, T. 1 N., R. 6 E., Pontotoc County; *F*, type locality for Viola Springs Formation, Robertson Creek, NW¼NE¼ sec. 19, T. 2 S., R. 8 E., Johnston County; *SY*, Sycamore Creek, NW¼SE¼ sec. 27, T. 3 S., R. 4 E., Johnston County; *I-35*, east lane, Interstate Highway 35, north flank of Arbuckle Anticline, sec. 30, T. 1 S., R. 2 E., Murray County, Oklahoma. Eastern Oklahoma stratigraphic sections cited in text: Horseshoe Bend area, Illinois River, two stratigraphic sections: one is type locality for Welling Formation on west bank of Illinois River, NE¼NE¼ sec. 36, T. 16 N., R. 22 E., and other is on east bank, NE¼ sec. 31, T. 16 N., R. 23 E., both Cherokee County; Deep Hollow, NE¼ sec. 19, T. 16 N., R. 23 E., Cherokee County; Qualls area, NE¼SE¼ sec. 35, T. 15 N., R. 21 E., Cherokee County; also Oklahoma Geological Survey core hole 3, SE¼SE¼NE¼ sec. 20, T. 13 N., R. 21 E., Sequoyah County, Oklahoma.

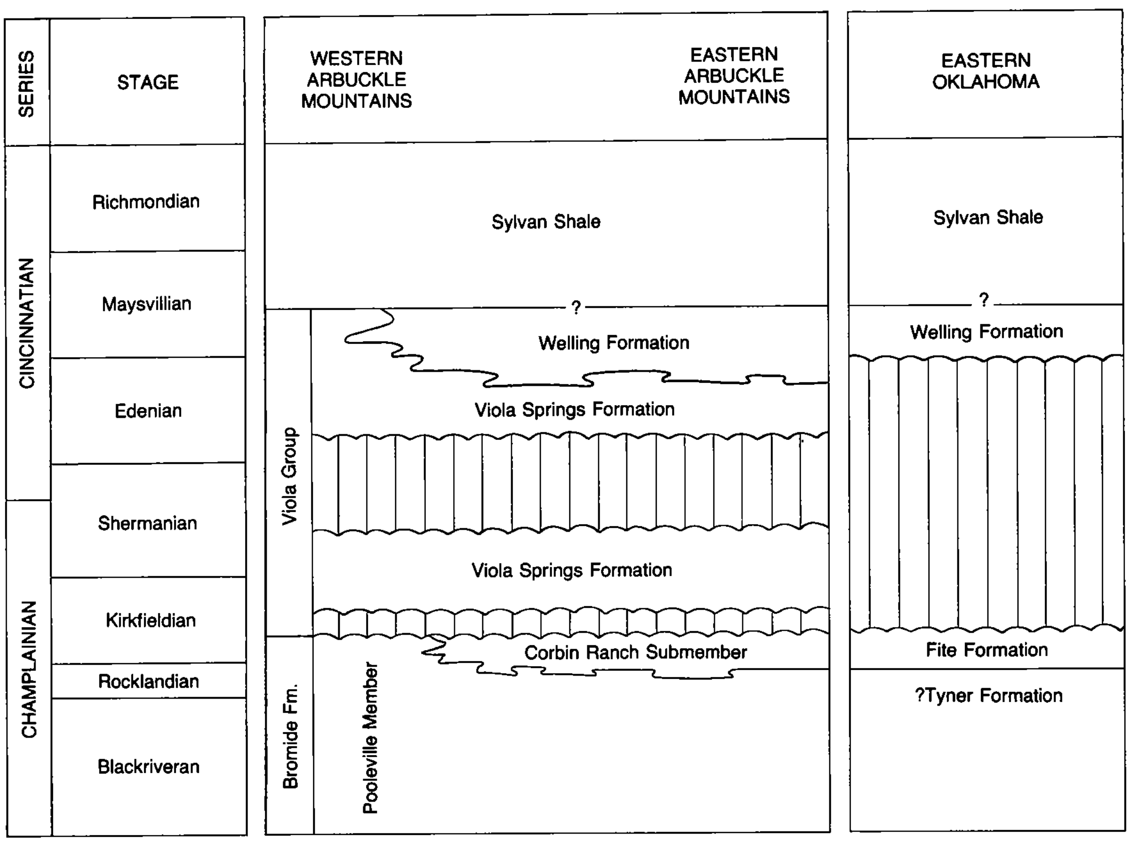
quantitative data on matrix and faunal content, and numerous surface and core samples were analyzed for HCl insolubles, $CaCO_3$, and $MgCO_3$ in the analytical-chemistry laboratory of the Oklahoma Geological Survey. The Viola and Bromide Formations also have been studied by a number of previous investigators, including Wengerd (1948), Harris (1957), Huffman (1958), Frezon (1962), Glaser (1965), Jenkins (1969, 1970), Alberstadt (1967, 1973), Beechler (1974), Longman (1976, 1981), and Amsden (1979). References to other studies can be obtained from the bibliographies included in these reports.

Acknowledgment—In addition to the reviewers who are cited in the preface, I wish to acknowledge the help of Dr. Donald F. Toomey, Cities Service Co., for providing information on Ordovician algae and thin-section textures.

VIOLA GROUP

Throughout most of the Arbuckle Mountains–Criner Hills outcrop area the carbonate sequence between the Sylvan Shale and the Bromide Formation comprises two distinct units: an upper, relatively thin section of organo-detrital limestones and a lower, much thicker section of muddy, irregularly bedded, cherty limestones. Most stratigraphers and biostratigraphers have treated these as distinct formations, referring the lower strata to the Viola Limestone and the upper to the Fernvale Limestone (Twenhofel, 1954, chart 2). The type section for the Viola is near the former village of Viola, Johnston County, Oklahoma, and presents no particular nomenclatorial problems. The type section for the Fernvale, however, is in central Tennessee, and subsequent studies suggest that the Oklahoma "Fernvale" is older than the type Fernvale (Alberstadt, 1973, p. 5). Detailed studies by Glaser (1965) and Alberstadt (1973) proposed to combine these strata into a Viola Formation, divisible into three divisions: stratigraphic units 1, 2, and 3, of which unit 3 is the Fernvale Limestone of previous investigators. Those authors noted that the contact between unit 3 (=Fernvale) and unit 2 is gradational through a few feet of strata.

In 1979 I proposed to replace the name Fernvale with the name Welling (Amsden, 1979, p. 1135–



Text-figure 2. Stratigraphic chart showing inferred correlation and age of late Bromide to Sylvan sequence. Viola Springs Formation is a new stratigraphic unit described in Part I. With exception of Sylvan Shale, age assignments are based on conodont biostratigraphy (see Part II and text-fig. 19). Not to scale in terms of stratigraphic thickness or of time.

1138; 1980, p. 11, panel 3, sections *A–A'*, *B–B'*). The type section is in eastern Oklahoma, but these strata are considered to be correlative with all but the lower part of the Arbuckle Mountain "Fernvale" (see discussion in Part III of this report). The Welling and Viola are distinct stratigraphic units in the Arbuckle Mountains except for the southwestern part, where the Welling tends to lose its lithologic identity by grading into Viola-type limestones (Glaser, 1965, p. 18–30, pl. 7), although even there it retains its faunal identity (Alberstadt, 1973, p. 3, 12).

No systematic study of pre-Sylvan Ordovician strata in the Anadarko Basin has been attempted by me, but an examination of samples and cores from a few wells suggests that the Welling Formation cannot be readily distinguished from the Viola Formation over much of western Oklahoma. For this reason it is convenient to recognize a Viola Group, encompassing all Ordovician strata between the Sylvan Shale and the Bromide Formation, as shown in text-figure 2. This leaves the pre-Welling Viola strata (Viola Limestone of Wengerd, 1948, and others; stratigraphic units 1 and 2, Glaser, 1965, and Alberstadt, 1973) without a name, so it is here proposed that these beds be assigned to the Viola Springs Formation.

The type section is located about a mile and a half southeast of Viola Springs (Connerville NE Quadrangle), in the NW¼ NE¼ sec. 19, T. 2 S., R. 8 E., Johnston County, Oklahoma. This is stratigraphic section F of Glaser (1965, p. 182–183, pls. 6, 8) and Alberstadt (1973, p. 58).

The Viola Springs Formation is about 310 feet (94 m) thick and is exposed in contact with the overlying Welling Formation (stratigraphic unit 3C of Glaser and Alberstadt) and the underlying Pooleville Member of the Bromide Formation. The upper 173 feet (52 m) of the Viola Springs (Glaser and Alberstadt's stratigraphic unit 2) is a light-gray, nodular bedded, muddy limestone with nodular chert in all but the upper 55 feet (17 m); the Viola Springs–Welling contact is poorly defined, for the two formations are gradational through several feet of strata (pl. 9, figs. 1a–1d). The lower 137 feet (41 m) of the Viola Springs Formation (Glaser and Alberstadt's stratigraphic unit 1L) comprises siliceous, laminated calcareous mudstones and bedded cherts containing sponge spicules, graptolites, and other fossils; a sharp contact separates these strata from the underlying fossiliferous limestones of the Pooleville Member of the Bromide Formation. (Viola Springs conodonts are discussed in Part II of this report.)

The Viola Springs Formation attains a maximum thickness of about 800 feet (244 m) in the southwestern part of the Arbuckle Mountains. It thins toward the northeast and is about 300 feet (91 m) thick at the eastern margin of the outcrop area. A short distance east of the outcrop the Viola Springs Formation wedges out beneath the Welling Formation, and throughout most of the Arkoma Basin the Welling rests directly on the Corbin Ranch–Fite Formations (text-fig. 3).

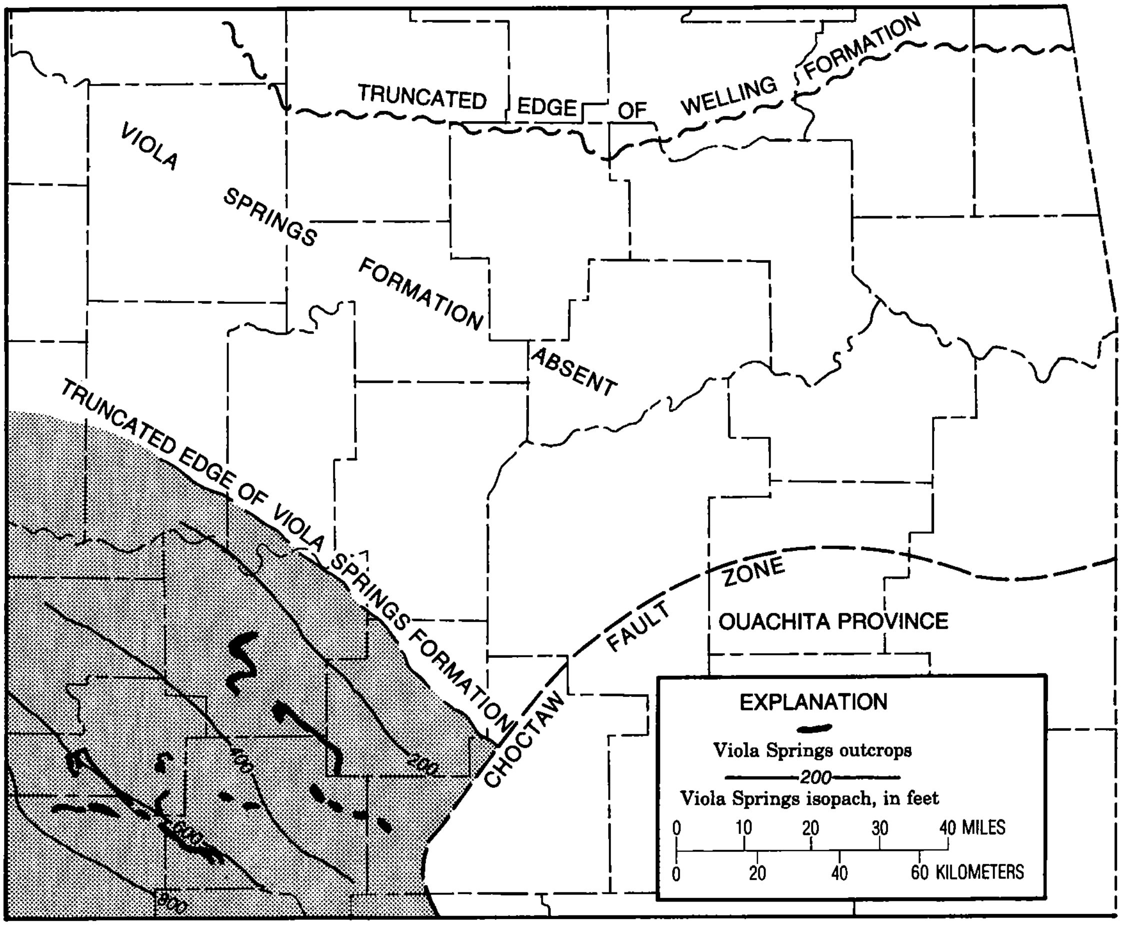
Welling Formation

The Welling Formation is a low-magnesium, organo-detrital limestone (Amsden, 1979, p. 1135–1137). Thin-section point counting shows the total matrix to range from 25 to 38 percent and to average about 30 percent (text-fig. 4). Spar is the dominant element in the matrix, although micritic areas are commonly associated with the spar, and some beds are composed entirely of micrite (pl. 8, figs. 1, 2; pl. 9, figs. 1a, 1b, 2). Disjunct crinoid plates make up a large part of the skeletal debris, and are generally accompanied by a moderate volume of brachiopods and bryozoans. Trilobites also are common, along with a few ostracodes, mostly heavy-shelled types with shell walls thicker than 0.24 mm. No corals or calcareous algae have been observed; if these groups are present, they must be local and sparsely represented. Conodonts and chitinozoans are present in the Welling Formation. Thin sections from both the Arbuckle Mountains and the eastern outcrops studied by point counting (text-fig. 4) show a similar composition, and an examination of numerous thin sections prepared from well samples indicates no significant deviation from this pattern in the subsurface. The counts do suggest a slight increase in matrix volume from east to west, although a much more intense sampling would be needed to confirm this.

No reefs or boundstones have been observed, and the Welling appears to be composed of dissociated organic remains that were spread over the sea floor. Most of the brachiopod shells are disarticulated (pl. 8, fig. 3). Only the rhynchonellids (mainly species of *Lepidocyclus*) are represented by any substantial number of articulated valves, a phenomenon undoubtedly related to their stout teeth and sockets (pls. 4–7). The more delicate organic structures, such as bryozoan fronds, are commonly fragmented, and in some beds breakage is quite intense; however, preservation of the shelly debris suggests that the energy level in the Welling seas was moderate in most areas (pls. 8, 9).

The articulate brachiopods are the only Welling megafaunal group to have been studied in detail (Alberstadt, 1973), and their taxonomy and distribution are discussed in Part III.

The Welling formation is a low-magnesium limestone throughout eastern Oklahoma. Chemical analyses of a core from a boring near Lake Tenkiller dam in Sequoyah County average 0.61 percent $MgCO_3$ (Oklahoma Geological Survey core 3, Amsden and Rowland, 1965, p. 108–113, 162), and the examination of many thin sections



Text-figure 3. Map showing distribution and thickness of Viola Springs Formation in eastern Oklahoma. Thickness data for Viola Springs Formation from Glaser (1965) and Alberstadt (1973).

shows only sparse, scattered dolomite crystals. This is in contrast to the underlying Fite Limestone, parts of which are heavily dolomitized.

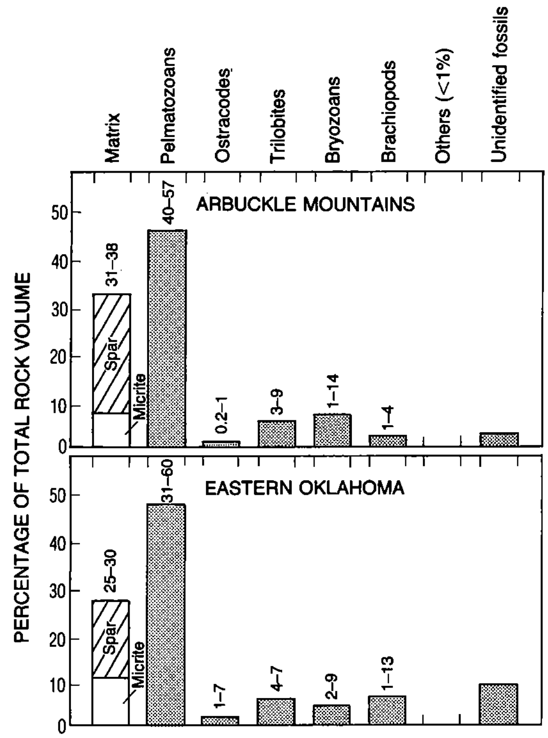
HCl-insoluble detritus is generally low in the Welling Formation. Chemical analyses of the above-mentioned core average 4.1 percent insolubles, and a part of this represents silicification. Scattered, well-rounded detrital quartz grains ranging up to 0.4 mm in diameter are commonly present in the lower part of the formation. These are rarely if anywhere concentrated into beds or seams of quartz sandstone, and, in fact, most of the grains are relatively widely dispersed.

Silicification of fossils in the Welling Formation is common throughout eastern Oklahoma (pl. 8, fig. 3). Block etching and thin sections show this silicification to be highly selective and concentrated predominantly in the brachiopods. The time of silicification is unknown, but it is not related to the present erosion surface.

The Welling Formation makes up a relatively thin sequence of skeletal limestones that attains its maximum thickness in the eastern Arbuckle Mountains, where Glaser (1965, fig. 2) reported 112 feet (33.6 m) (text-fig. 5). The formation gradually thins to the east and north of the Arbuckle Mountain outcrop area. It is less than 25 feet (7.6 m) thick in the eastern Oklahoma outcrops, and a short distance to the north it is truncated by pre-Chattanooga (pre-Woodford) erosion. To the west, in the southwestern part of the Arbuckle Mountains, the Welling organo-detrital limestones grade into Viola Springs-type mudstones and muddy organo-detrital limestones, which probably represent a slightly deeper, more turbid environment. Along the southern margin of the Arkoma Basin the Welling extends to the Choctaw Fault, its disposition south of this structure being poorly understood; to the east it extends into Arkansas, strata of similar texture and age being present in the Batesville district of north-central Arkansas. No strandline has been identified in the area studied. The rounded quartz grains in the lower part of the formation appear to represent a second-generation sand, which could have been derived from the underlying strata; however, the detrital-quartz content of the Fite Limestone, which underlies the Welling Formation throughout the Oklahoma part of the Arkoma Basin lying east of the truncated Viola Springs Formation, would appear to be an inadequate source. The uniform faunal composition of these limestones over large areas, combined with the generally good preservation of the fossils, indicates that the skeletal material was not moved far and suggests that the faunal associations in the Welling are essentially life assemblages. The rich and varied benthic fauna, and the large volume of calcium carbonate represented in the Welling, point to shallow, warm, tropical to subtropical water. The sea floor must have consisted in large part of reasonably well-washed organic sands with clear to only very slightly turbid water. Crinoid thickets occupied much of the area and were accompanied by widespread colonies of brachiopods, bryozoans, and trilobites. Ostracodes were present, and their relatively heavy shells indicate that they were mostly vagrant-benthic types.

Thoughout eastern Oklahoma the Welling Formation rests directly on the Fite Limestone, and the organo-detrital limestones of the Welling are sharply delineated from the birdseye-pellet micrites of the Fite (pl. 12, fig. 1; pl. 14, figs. 2, 4). In the western part of the area under investigation the Viola Springs Formation wedges in between the Fite (=Corbin Ranch Submember) and the Welling, and there the Viola Springs and Welling Formations are gradational through several feet of beds.

Across eastern Oklahoma the Welling Formation is overlain by the Sylvan Shale except where that formation has been removed by post-Ordovician erosion. Because of the easily eroded character of the Sylvan, the Welling–Sylvan contact is rarely exposed at the surface, but many wells penetrate this part of the section and an examination of samples and cores shows this to be a reasonably well-marked lithostratigraphic contact (Amsden, 1980, p. 10). However, in parts of the Anadarko Basin of central and western Oklahoma, the Viola Group–Sylvan Shale–Hunton Group lithostratigraphic sequence is poorly defined, and that suggests that deposition was continuous from Late Ordovician into Silurian time (Amsden, 1980, p. 38–40).



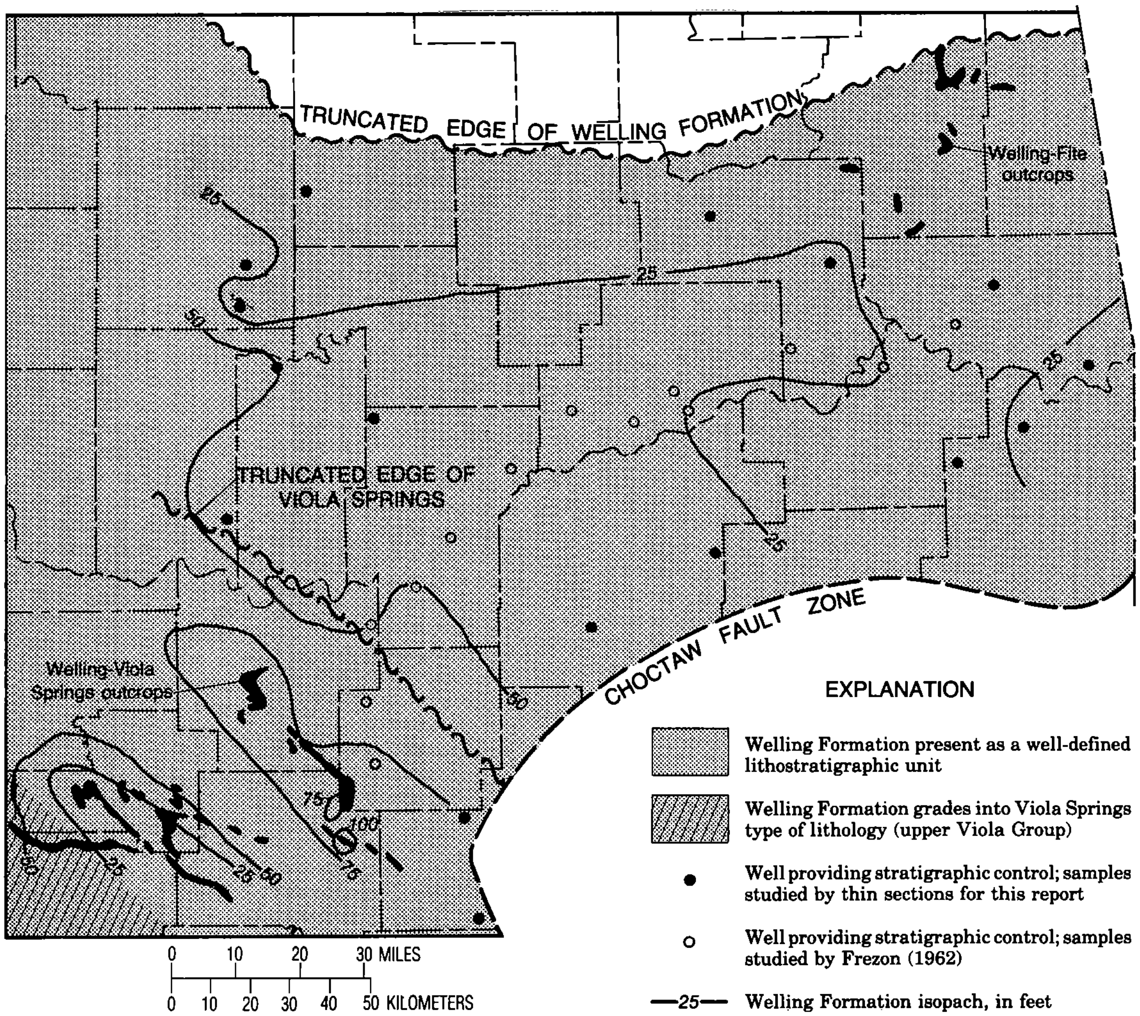
Text-figure 4. Graph comparing distribution of matrix and megafaunal elements in Welling Formation of eastern Oklahoma with same formation in Arbuckle Mountains. Data are derived from point counts of thin sections, each graph representing an average of several thin sections. Numbers above each bar give range in percentage volume. For eastern Oklahoma, thin sections are from specimens collected at outcrops in Horseshoe Bend area, including type section, and Deep Hollow (text-fig. 1; Amsden, 1979, p. 1136–1137); also one count was made of a specimen from Oklahoma Geological Survey core 3 (Amsden and Rowland, 1965, p. 108–113). Thin sections for Arbuckle Mountains are from exposures of the Welling Formation in Lawrence Quarry, Ideal Cement Co., at northeastern end of mountains (Amsden, 1960, panel 2).

LATE BROMIDE STRATA IN EASTERN OKLAHOMA

Fite Formation, Eastern Oklahoma Outcrop Area

The Fite Formation is well exposed in eastern Oklahoma, where it constitutes a distinctive sequence of birdseye limestones and dolomitic limestones overlain by the Welling Formation and underlain by the Tyner Formation. The Fite is not more than 20 feet (6.1 m) thick in the outcrop area, and it thins northward and is truncated by the Chattanooga Shale. The dolomite content is variable. Throughout most of the eastern outcrop the upper part of the Fite is low-magnesium limestone with only scattered dolomite crystals and a few small patches of crystalline dolomite (Amsden, 1980, pl. 12, fig. 3), but the lower 5 to 10 feet (1.5–3 m) is more heavily dolomitized. In Oklahoma Geological Survey core 3 the basal 10 feet (3 m) averages 21.2 percent $MgCO_3$ (text-fig. 6; Amsden and Rowland, 1965, p. 112, 162; Huffman, 1958, p. 24). Insoluble detritus is low, and thin sections show only sparse, widely scattered, fine (less than 0.05 mm), angular quartz grains. Six spot samples from the upper, low-magnesium, part of the Fite in this core average 1.5 percent HCl insolubles.

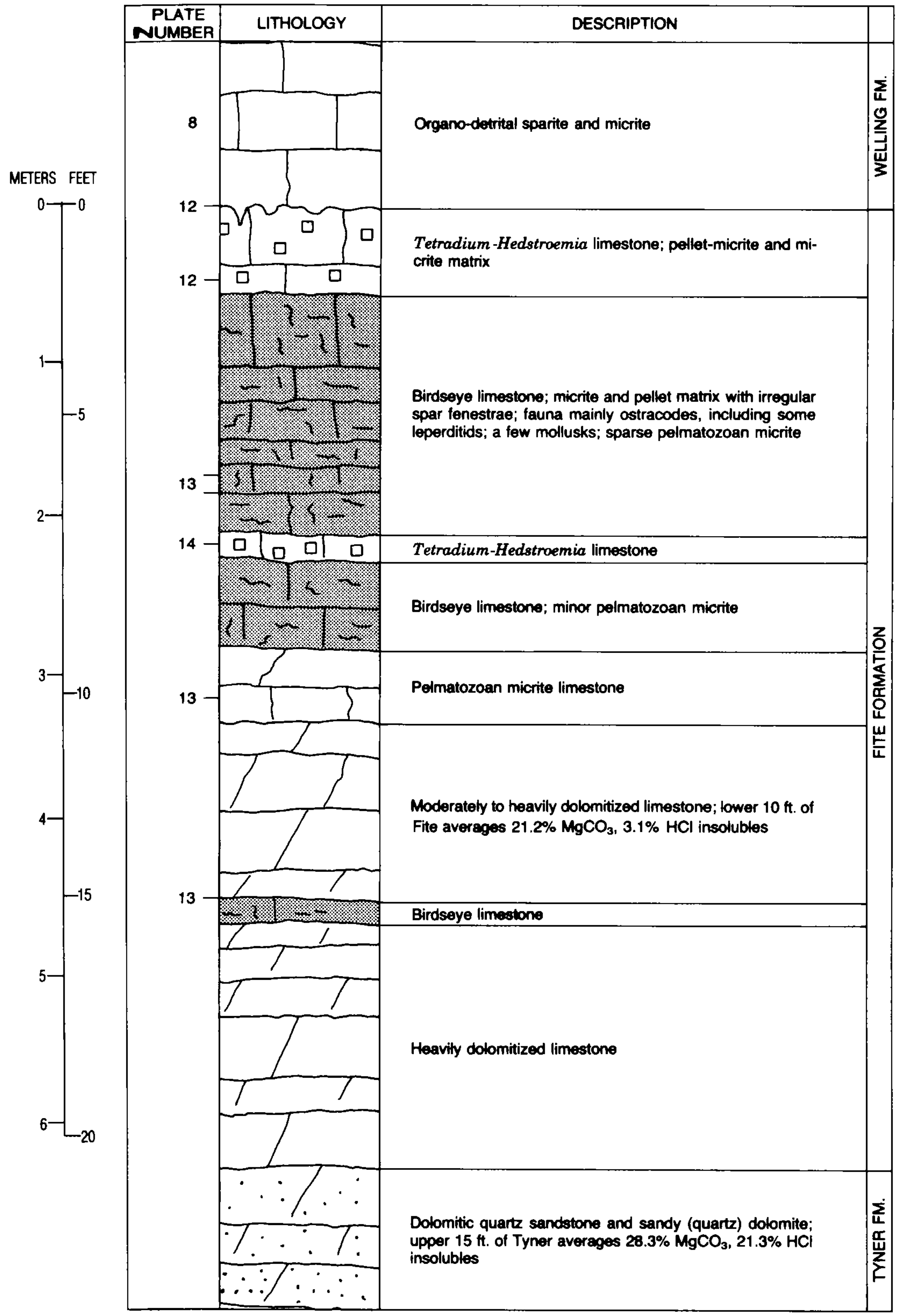
The Fite is mainly a birdseye limestone (fenes-



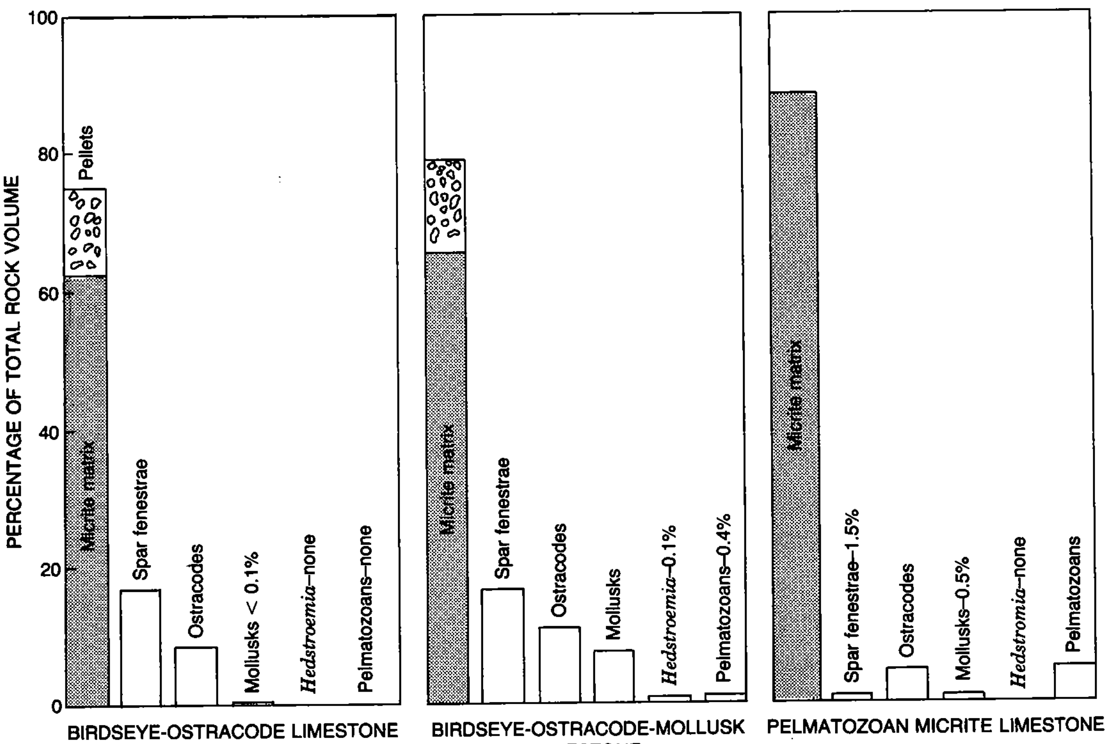
Text-fig. 5. Map showing distribution and thickness of Welling Formation. Data for Arbuckle Mountain region taken from Glaser (1965; Welling equals his stratigraphic unit 3).

tral limestone; Choquette and Pray, 1970, p. 244) in which the matrix is an intimate association of dense, fine-grained micrite and micritic pellets that together make up almost 80 percent of the total rock volume (text-figs. 7, 8). Most of the pellets are less than 0.5 mm in diameter, with a few fragments ranging up to several millimeters; they have a texture identical to that of the micrite (Amsden, 1980, pl. 12, fig. 2). Many pellets have well-defined outlines. Some are set in a matrix of sparry calcite; others, however, have faint outlines and appear to merge into the micrite matrix, where they lose their identity. This suggests that the pellets formed as soft fragments that lost their identity through compaction (Amsden, 1980, pl. 12, fig. 2). The matrix is penetrated by numerous irregular areas of spar (pls. 12–14), which are the fenestrae that produce the birdseye texture (Ginsburg and authors, 1975, p. 198, 234; Hardie, 1977, p. 10, 65, 69, 73; Shinn, 1968, p. 215–233; Choquette and Pray, 1970, p. 244, 246). These fenestrae represent original voids in the sediment that were later filled with spar. The voids originated in a variety of ways, including mud desiccation (pl. 10, figs. 3, 4), the burrowing of organisms (pl. 10, fig. 6), escape of gas bubbles and shrinkage (pl. 10, fig. 2), and represent features commonly associated with sediments alternatively submerged and exposed to the air. The birdseye texture also includes spar that originated as a replacement for skeletal material, especially mollusk shells, and as a cement for the micrite pellets (see Paleoenvironment of the Fite–Corbin Ranch Birdseye Limestones).

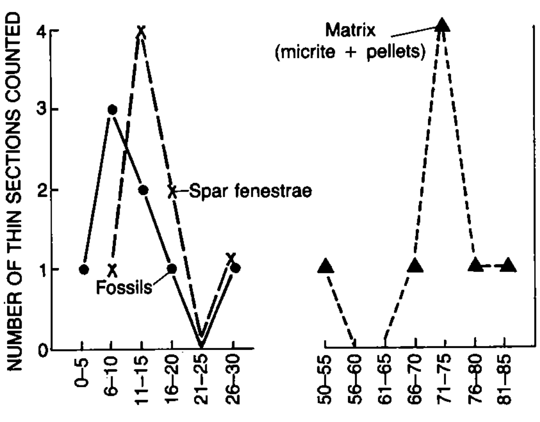
The typical birdseye limestone has a severely restricted megafauna composed almost exclusively of ostracodes, (pl. 12, figs. 3, 4; pl. 14, figs. 3, 5), including leperditids, and here designated



Text-figure 6. Stratigraphic diagram summarizing lithologic and faunal characteristics of lower Welling, Fite, and upper Tyner Formations in Oklahoma Geological Survey core 3 southeast of Lake Tenkiller, SE¼SE¼NE¼ sec. 20, T. 13 N., R. 21 E., Sequoyah County, Oklahoma (Amsden and Rowland, 1965, p. 111–113). Photographs of polished surfaces and thin sections from this core shown on plates 8, 12–14.



Text-figure 7. Graphs showing major matrix and fossil components of Fite birdseye–ostracode limestone, birdseye–ostracode–mollusk limestone, and pelmatozoan micrite limestone. Based on point counts of thin sections: six thin sections for birdseye–ostracode limestones, and two for each of other limestones. Thin sections and polished surfaces of these strata are illustrated on plates 12–14. All of thin sections supplying data for these graphs are from Fite Formation, Horseshoe Bend and Deep Hollow, Cherokee County, Oklahoma.



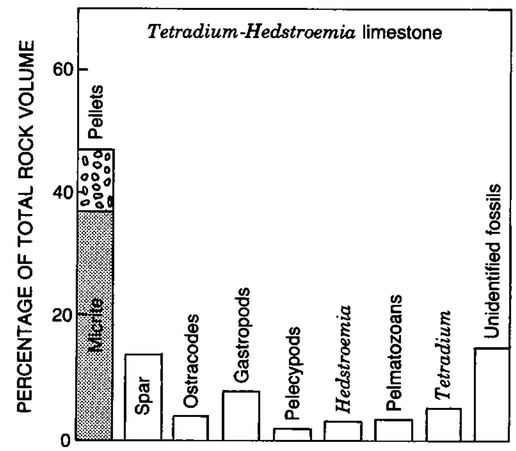
Text-figure 8. Frequency diagram showing range in volume of skeletal material, spar fenestrae, and matrix (micrite plus pellet–micrite) in birdseye–ostracode and birdseye–ostracode–mollusk limestones of Fite Formation in eastern Oklahoma (based on point counts expressed as percentage of total rock volume). More than 99 percent of skeletal debris consists of ostracodes and mollusks, of which some 80 percent are ostracodes.

the birdseye–ostracode facies. The ostracodes may be concentrated along bedding planes, but generally they are scattered through the matrix (pls. 12, 13), and on the average they constitute about 8 percent of the total rock volume (text-fig. 7). Many have thin shells (less than 0.024 mm), and they are both articulated and disarticulated. Relatively large (up to 5 mm), thick-shelled, gently convex leperditids are common, and almost all of them are disarticulated. Gastropods and pelecypods are associated with the ostracodes in some beds, and this assemblage is designated the birdseye–ostracode–mollusk facies (text-figs. 7, 8). Preservation of the shells is generally excellent, with little evidence of fragmentation, and the birdseye facies appears to represent a low-energy deposit. Rare specimens of *Hedstroemia* and a pelmatozoan plate may be present, but these make up an insignificant part of the birdseye fauna. Modest concentrations of relatively small pelmatozoan plates are present in the Fite, but these are confined largely to the nonfenestrate micrites and especially the dolomitized micrites in which they comprise a locally developed litho–biofacies here designated the birdseye pelmatozoan micrite facies (text-fig. 7; Amsden, 1980, pl. 12, fig. 3). Huffman (1958, p. 25) reported the brachiopods *Dalmanella* and *Plectambonites* from the Fite at its type locality northeast of Tahlequah. Conodonts are common in the Fite, and "neurodontiform" elements are numerous in the lower half of the Fite at Horseshoe Bend on the west bank of the Illinois River (locality 78SA; see Part II).

A more varied megafauna with distinct marine elements is represented in the *Tetradium* biofacies, in which the coral *Tetradium* is associated with ostracodes, mollusks, pelmatozoans, bryozoans, and the alga *Hedstroemia* (text-fig. 9; pl. 12, figs. 3, 4). This biota is present in a pellet–micrite matrix in which the typical birdseye fenestrae are much reduced and spar is present mainly as a replacement and filling of the *Tetradium* skeleton. The *Tetradium* colonies and other skeletal elements are commonly fragmented, and this facies appears to represent a fairly high-energy deposit. Specimens of *Hedstroemia* are common, and some of these algae appear to have developed after fragmentation of the *Tetradium* coralla.

The *Tetradium* biofacies differs from the typical birdseye facies in several respects: (1) the *Tetradium* biotic assemblage is more diverse than that of the birdseye facies and includes typical marine elements; (2) the volume of skeletal material, which makes up about 9 percent of the total rock volume in the birdseye ostracode facies, increases to about 20 percent in the birdseye ostracode–mollusk facies and to about 40 percent in the *Tetradium* facies; and (3) the energy level represented by the *Tetradium* facies evidently increased sharply over that of the birdseye facies and resulted in considerable breakage of the shelly debris, which is especially obvious in fragmentation of the coral colonies. I believe that these litho–biofacies changes reflect a shift from the quiet, intertidal environment of the birdseye–ostracode facies to a subtidal environment in the *Tetradium* facies, marked by increased wave and (or) current action, although the restricted biota of the latter suggests that it was not a normal, open-water environment. The *Tetradium* biofacies is widely distributed. It is present in the eastern Oklahoma outcrops (Qualls area and Oklahoma Geological Survey core 3), in the subsurface of the Arkoma Basin (Amsden, 1980, pl. 11, fig. 7), and in the Arbuckle Mountain outcrop area (pl. 11, figs. 2–4). Throughout this region it is closely associated with the birdseye limestones (see sections on Corbin Ranch Submember and Paleoenvironment of Fite-Corbin Ranch Birdseye Limestones).

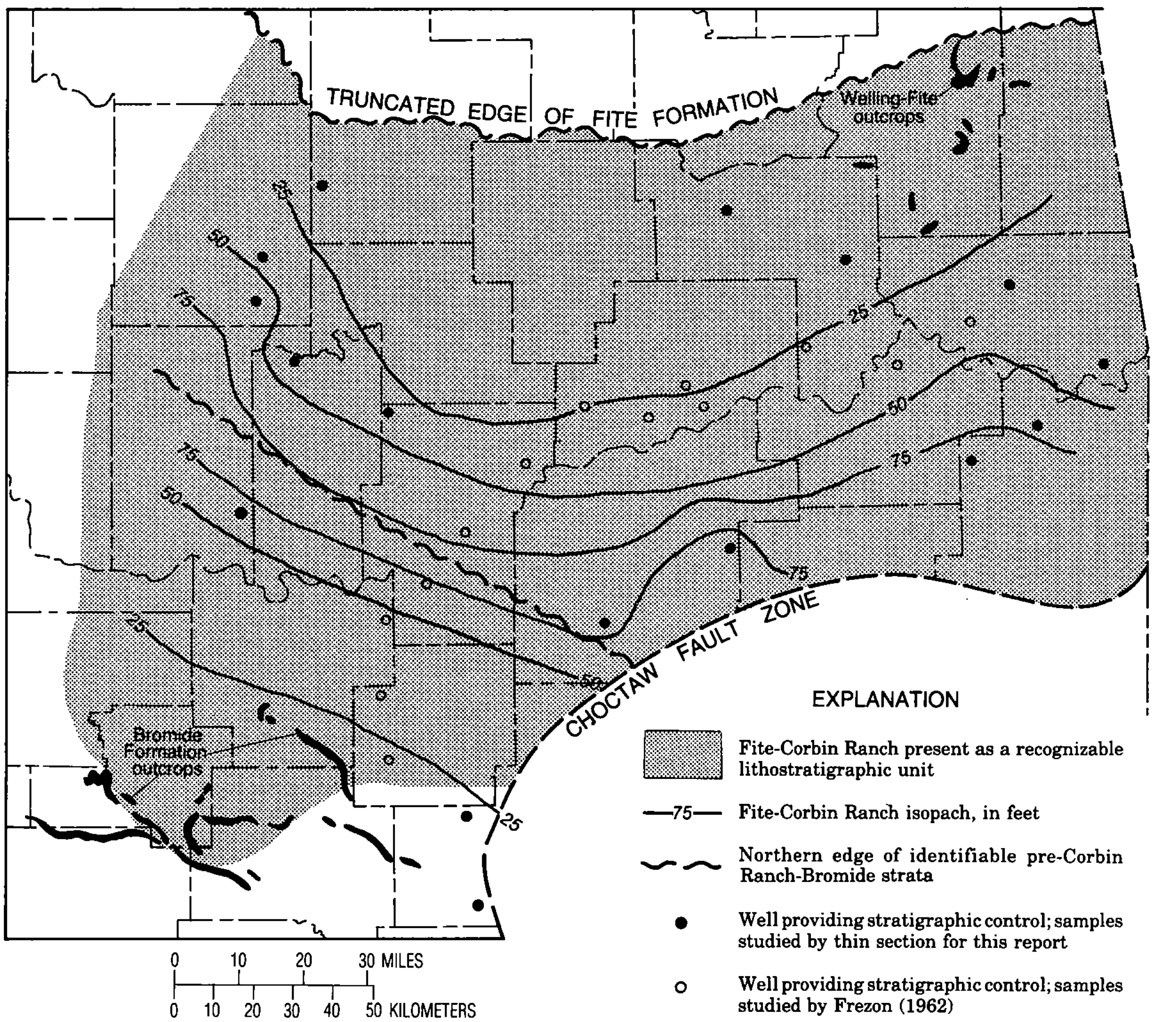
The Welling–Fite contact is well exposed in the Horseshoe Bend area, the Qualls area, and in Oklahoma Geological Survey (OGS) core 3 (Amsden, 1979, p. 1136–1137; Amsden and Rowland, 1965, p. 111–112). It is sharply defined (pl. 12, fig. 1, pl. 14, figs. 2, 4), and the uppermost Fite beds show evidence of pre-Welling induration and solution (see chapter on Stratigraphic Relations of Middle and Upper Ordovician Strata in Eastern Oklahoma). The Fite–Tyner boundary is drawn at the contact between the lower Fite dolomitic beds and the dolomitic sandstones and sandy dolomites of the Tyner Formation. Huffman (1958, p. 25) stated that the Fite rests conformably on the Tyner Formation. However, I have no definitive evidence bearing on this relationship other than to note that in the Horseshoe Bend area, and in OGS core 3, the boundary is reasonably well defined (Amsden and Rowland, 1965, p. 113, 162).



Text-figure 9. Graph showing major matrix and fossil components in *Tetradium–Hedstroemia* limestone, Fite Formation. Based on single thin-section point count; no bryozoans observed in this thin section, but they are present in *Tetradium* beds, Qualls area. Oklahoma Geological Survey core 3, SE¼SE¼NE¼ sec. 20, T. 13 N., R. 21 E., Sequoyah County, Oklahoma; 7 feet below Welling–fite contact.

Fite Formation, Subsurface Distribution in Eastern Oklahoma

Using subsurface samples and electric logs, Frezon (1962) traced the Corbin Ranch birdseye limestone (Bromide "dense") from the Arbuckle Mountain region across the Arkoma Basin into the Fite outcrop area, and my investigation of these strata in the subsurface, based primarily on thin sections prepared from well samples and a few cores, confirms this stratigraphic relationship. My study shows the Fite birdseye limestone to be present throughout the area north of the Choctaw Fault zone and south of the pre-Woodford truncation line, and extending from the Arkansas border westward into the Arbuckle Mountains. Westward from the eastern outcrop area this stratigraphic unit thickens and reaches a maximum of about 75 feet (22.8 m) in the southern parts of Seminole, Hughes, and Pittsburg Counties (text-fig. 10). Throughout the region east of

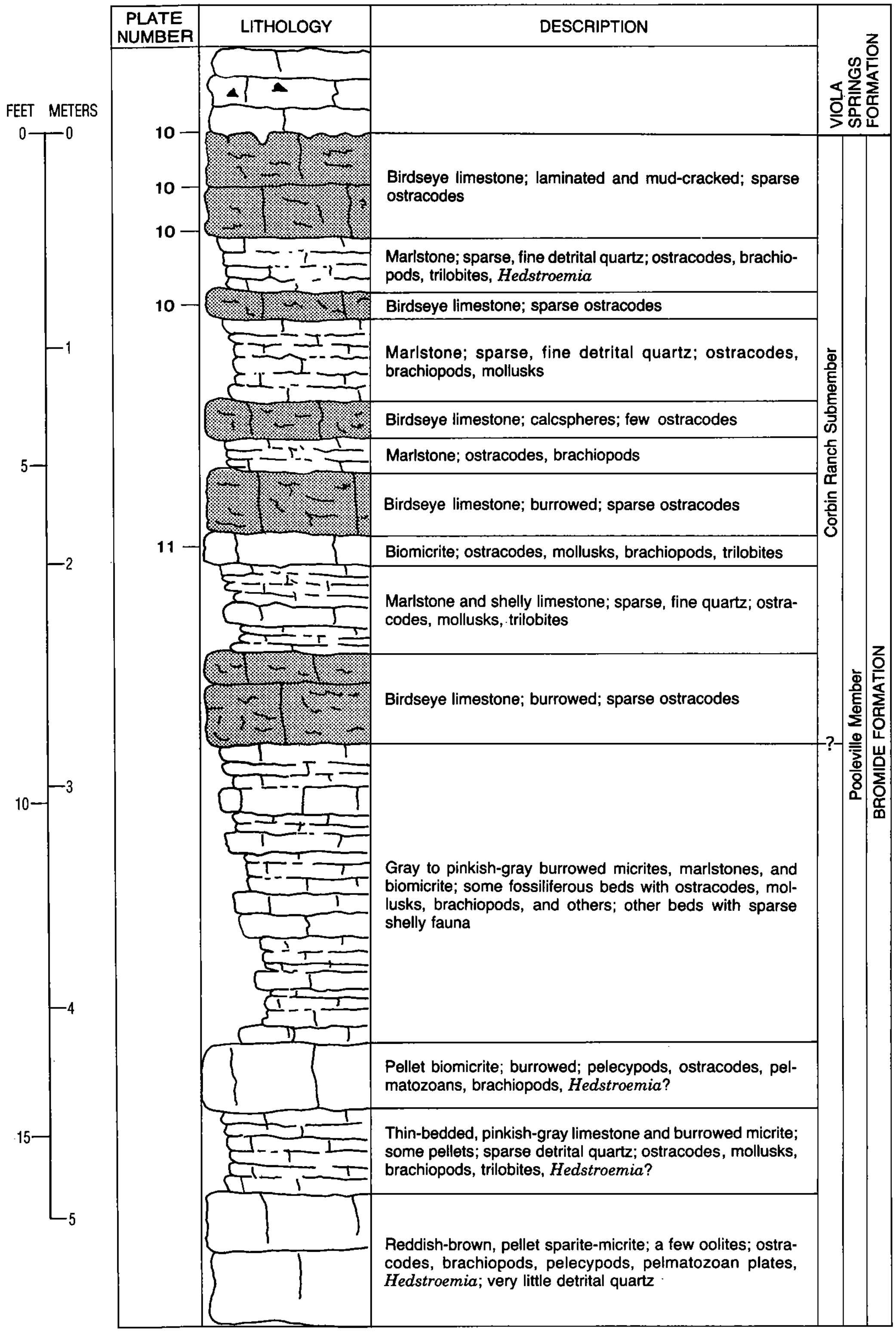


Text-figure 10. Map showing distribution and thickness of Fite Formation and Corbin Ranch Submember (Pooleville Member, Bromide Formation) in eastern Oklahoma. Thinning and disappearance of Corbin Ranch toward southwest is believed due to lateral gradation into different lithofacies. (Arbuckle Mountain area in part from Beechler, 1974, and Longman, 1976.)

the 75-foot isopach the Fite has a fairly uniform birdseye texture that is interrupted only by some local incursions of the *Tetradium* facies. In this belt it is characterized by (1) a restricted fauna dominated by ostracodes (birdseye ostracode facies) and a few specimens of *Tetradium*, (2) a low concentration of detrital quartz, and (3) erratic dolomitization, which is absent in some beds and concentrated into bodies of crystalline dolomite in others (Amsden, 1980, pl. 11, figs. 1, 5–7). From the 75-foot isopach the Fite extends southwestward into the Arbuckle Mountain outcrop area, where it joins the Corbin Ranch Submember (Pooleville Member of the Bromide Formation). In this region the birdseye limestones thin and merge with fossiliferous marlstones and a few skeletal limestones.

Corbin Ranch Submember (Pooleville Member of Bromide Formation) Arbuckle Mountains

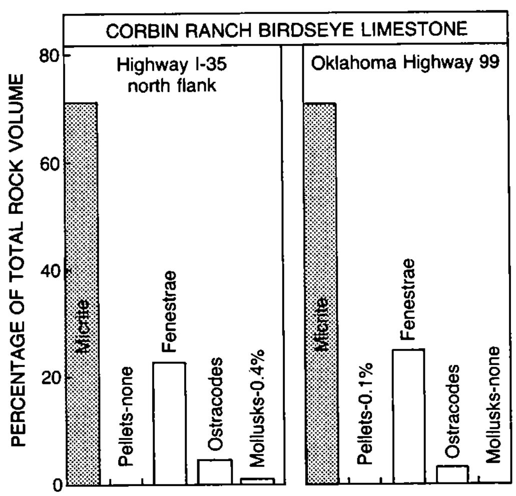
Harris (1957, p. 94–101) named the Corbin Ranch Formation (Bromide "dense") for exposures along Oklahoma Highway 99 in the eastern part of the Arbuckle Mountains (text-fig. 11). This unit apparently includes at least a part of the strata that Ulrich earlier assigned to the Webster in an unpublished chart (later published by Edson; see discussion *in* Harris, 1957). According to Harris, the Corbin Ranch comprises 19 feet of predominantly birdseye limestone, overlain by the Viola Formation (= Viola Springs Formation) and underlain by the Bromide Formation. He identified the Corbin Ranch at one other locality



Text-figure 11. Stratigraphic diagram summarizing lithologic and faunal characteristics of the Corbin Ranch Submember and Pooleville Member of Bromide Formation at type locality on west side of Oklahoma Highway 99, about 3½ miles south of Fittstown, SW¼ sec. 12, T. 1 N., R. 6 E., Pontotoc County, Oklahoma. Illustrations of polished surfaces and thin sections from this outcrop are shown on plates 10, 11. Harris (1957, p. 97) included 19 feet in his original description of Corbin Ranch; however, Amsden restricts it to upper 9 feet of strata, which include beds of typical birdseye limestone. Brachiopod *Ancistrorhyncha costata* Ulrich and Cooper, and trilobites *Bathyurus superbus* Raymond and *Eomononrachus divaricatus* (Frederickson), are present in marlstone beds of Corbin Ranch; see discussion in text.

southwest of Davis in the Arbuckle Mountains. The ostracodes from this unit were reported to be distinctly different from those in the underlying Pooleville (Harris, 1957, p. 101), a difference that is probably paleoecologic rather than phylogenetic (Ludvigsen, 1978, p. 8). Frezon (1962) accepted this stratigraphic classification, but most recent investigators have avoided the use of the term Corbin Ranch. The latest studies on Middle Ordovician strata in the Arbuckle Mountains are those of Beechler (1974) on the Pooleville Member and Longman (1976) on the Bromide Formation. Both authors studied the facies and paleoecologic relations, and provided information on the upper part of the Pooleville Member. Beechler (1974, p. 31–35) and Longman (1976, p. 142–147) recognized the birdseye facies, and their descriptions of this texture are essentially the same as those of the present report. Both authors described stratigraphic sections, including the type Corbin Ranch exposures on Oklahoma Highway 99, although they did not use the name Corbin Ranch for the birdseye beds. Longman (1976, p. 144, 147) expressly rejects Harris' stratigraphic designation because, following the lead of Dr. Robert O. Fay, of the Oklahoma Geological Survey, he regards the Corbin Ranch strata as simply the supratidal facies of the upper Pooleville strata. I agree with Fay (Fay and Graffham, *in* Ham, 1969, fig. 32) and Ludvigsen (1978, fig. 3) that the Bromide "dense" (= Corbin Ranch birdseye limestone) is a lateral facies of the upper Pooleville; however, the birdseye limestones have a much more restricted stratigraphic and geographic development in the Arbuckle Mountains than indicated by those authors; that is, they are confined to the upper few feet of the Bromide in the eastern and central parts of the mountains. I believe it is useful to retain the name Corbin Ranch (reduced to submember status) for the birdseye limestones, for these strata represent the southwestern margin of an intertidal paleoenvironment that occupied most of the Arkoma Basin (see chapter, Stratigraphic Relations of Middle and Upper Ordovician Strata in Eastern Oklahoma).

It is here proposed to restrict the Corbin Ranch Submember to that part of the Pooleville Member that includes birdseye-limestone beds. At the type locality on Oklahoma Highway 99 the Corbin Ranch comprises about 9 feet (2.7 m) of interbedded birdseye limestone and fossiliferous marlstones (text-fig. 11). The birdseye beds of the Corbin Ranch, like those of the Fite, have a mud-supported fabric composed of micrite and pelletiferous micrite matrix, although the latter is much less abundant in the Corbin Ranch. The matrix is penetrated by numerous fenestrae, which represent the filling of burrows, mud cracks, gas bubbles, and other types of voids in the original sediment (pl. 10, figs. 1, 3–5). The acid insolubles in the birdseye beds range from 5.5 to 7.5 percent, and average 6.4 percent. Thin-section point counting shows that the birdseye-limestone beds have a restricted fauna that consists almost entirely of ostracodes and including leperditids, a few mollusks, and conodonts (text-fig. 12). The interbedded marlstones have a mud-supported fabric, in which the matrix is composed of a mixture of lime mud and finely divided insoluble detritus. HCl insolubles range from 9.8 to 20.7 percent and average 13.3 percent. The marlstones contain a sparse marine fauna composed mostly of ostracodes, brachiopods, trilobites, and mollusks (pl. 11, fig. 1). Cooper (1956, p. 622, pl. 127H) described the brachiopod *Ancistrorhyncha costata* Ulrich and Cooper from a bed 5 feet (1.5 m) below the Viola at the type section (text-fig. 12). I have collected a number of specimens of this species from that section, and all of them are from the marlstone beds. The species is especially common in marlstone beds near the top of the Corbin Ranch Submember. Rolf (1978, p. 10–15, figs. 4, 5) described the trilobites *Bathyrurus superbus* Raymond and *Eomonorachus divaricatus* (Frederickson) from the uppermost Bromide strata (Bromide "dense" = Corbin Ranch Submember) at the same locality. The matrix and stratigraphic



Text-figure 12. Graphs showing matrix and fossil components of Corbin Ranch birdseye limestone. Based on point counts of three thin sections from strata exposed on north flank of Arbuckle Anticline (east side, east lane of I-35, near 50-mile marker, Murray County, Oklahoma) and two thin sections from type Corbin Ranch, Oklahoma Highway 99 south of Fittstown (SW¼ sec. 12, T. 1 N., R. 6 E., Pontotoc County, Oklahoma). Birdseye limestones at these two exposures are remarkably uniform in composition: micrite volume ranges from 61.0 to 73.7 percent; only a single thin section contained any pellets, and this was only 0.3 percent; fenestrae ranged from 20.9 to 26.8 percent; ostracodes ranged from 1.8 to 7.2 percent (all thin sections include some leperditids); only one thin section contained any mollusks, and this was 1.1 percent. Illustrations of Corbin Ranch birdseye limestones shown on plate 10.

position ("3½ feet below the Viola contact") indicate that *E. divaricatus* is from a marlstone bed, and this is probably also true for *B. superbus*.

The Corbin Ranch Submember is sparingly represented in the Arbuckle Mountain region. It is present at the type locality south of Fittstown (discussed above), along Interstate Highway 35 (discussed below), and along Sycamore Creek (sec. 27, T. 3 S., R. 4 E.), where Beechler (1974, p. 58) reported 6 feet (1.8 m) of birdseye limestone at the top of the Bromide. Elsewhere in the Arbuckle Mountains and Criner Hills, upper Pooleville strata appear to be represented largely, if not entirely, by marine marlstones, burrowed micrites, and organo-detrital limestones that occupy the same stratigraphic position as the Corbin Ranch beds.

The Corbin Ranch is well exposed on the east lane of I-35, near the north end of the Arbuckle Mountains (text-fig. 13; Beechler, 1974, p. 59; Longman, 1976, p. 275). Birdseye limestones at that locality have a texture similar to those at the type locality (text-fig. 11) and are composed of dense micrites with fenestrae of various types, including filled burrows and mud cracks (pl. 10). Interspersed through the matrix is a sparse megafauna that consists almost entirely of ostracodes and includes some relatively large leperditids (text-fig. 12). The Corbin Ranch birdseye facies as displayed in the I-35 and Oklahoma Highway 99 sections differs from the birdseye of the Fite Formation of eastern Oklahoma in the greatly reduced volume of pelletiferous matrix and in the much reduced volume of ostracodes (text-figs. 7, 12). In the I-35 section the Corbin Ranch birdseye limestones are overlain and underlain by micrites and burrowed micrites with abundant colonies of *Tetradium* and the associated alga *Hedstroemia* (text-figs. 13, 14; pl. 11, figs. 2–4). Some ostracodes, mollusks, brachiopods, bryozoans, trilobites, and other fossils are also present, but the major faunal elements are the specimens of *Tetradium*, which in late Pooleville time formed small reefs that served as the locus for small *Hedstroemia* "heads." This facies, however, shows much evidence of fragmentation, and probably few, if any, of these colonies are in growth position. The faunal assemblage in the *Tetradium–Hedstroemia* Corbin Ranch facies is similar to that in the *Tetradium–Hedstroemia* facies of eastern Oklahoma (text-fig. 9). In both regions these strata include a substantial amount of pellet matrix. (See sections on Fite Formation and on Paleoenvironment of Fite–Corbin Ranch Birdseye Limestones.)

The Corbin Ranch Submember represents the southwesternmost extension of the birdseye limestone facies (text-fig. 10). Eastward, these strata extend across the Arkoma Basin into Arkansas, and to the south and west they grade into the marine limestones of the upper Pooleville. I believe that these facies changes can be observed in the subsurface just east of the Arbuckle Mountains, and in the upper Bromide strata exposed on Oklahoma Highway 99 and on I-35, where the intertidal to supratidal birdseye facies is interbedded with marine marlstones and burrowed micrites. It should be noted, however, that Walter Sweet (personal communication) suggests that upper Pooleville strata at the I-35 section may be older than the Corbin Ranch strata at the Oklahoma Highway 99 section; thus upper Bromide strata may be somewhat time-transgressive. (See section on Paleoenvironment of the Fite–Corbin Ranch Birdseye Limestones.)

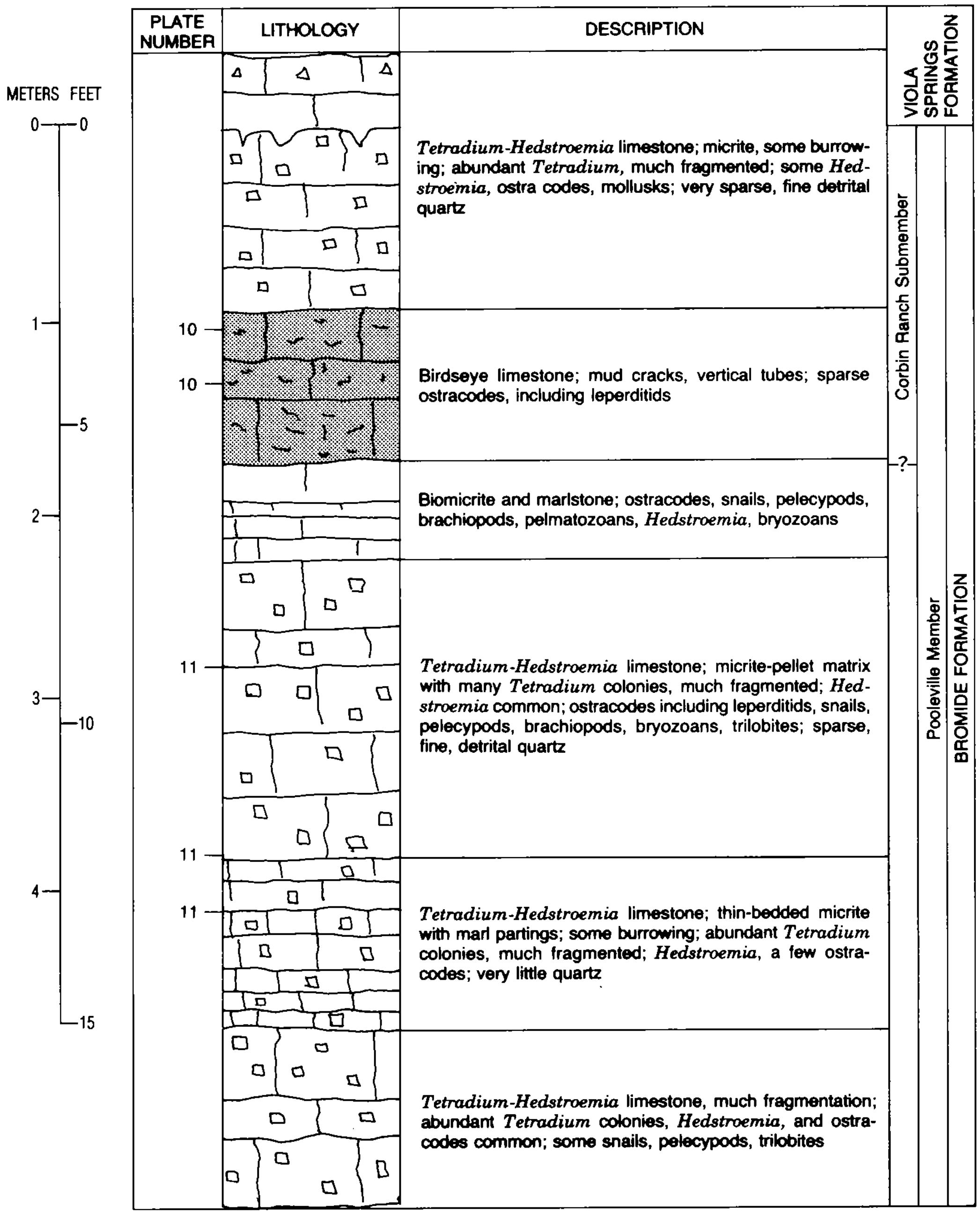
Bromide Brachiopods

Cooper (1956), in his definitive study of Chazyan and related brachiopods, described 78 species of inarticulate and articulate brachiopods from Bromide strata in Oklahoma. This includes 61 articulate species, of which 36 are from the Mountain Lake Member and 25 from the Pooleville Member, with no species common to both members. Cooper referred these articulate species to 29 genera, of which 11 are confined to the Mountain Lake Member and eight to the Pooleville Member; 10 are present in both members. Most of the Pooleville species are from areas in the Criner Hills and Arbuckle Mountains where the Corbin Ranch facies is absent or poorly developed. Cooper (1956, p. 621–622, pl. 127H) did illustrate a specimen of *Ancistrorhyncha costata* Ulrich and Cooper from the Corbin Ranch Submember at the type section (text-fig. 11). He also reported this species from the *Tetradium* beds in the top 10 feet of the Pooleville at a locality southwest of Davis, Murray County, and from three other localities in the Pooleville where the stratigraphic position was unspecified. Cooper (1956, p. 621–622, chart 1) recorded *A. costata* from a number of formations of Porterfieldian–early Wildernessian age distributed over a large area in the eastern United States. He (1956, p. 624, pl. 128B) also described the species *Ancistrorhyncha globularis* Cooper from uppermost Pooleville strata at a locality south and west of Davis; however, I have not identified this species in the Corbin Ranch Submember.

Cooper (1956, chart 1) assigned the Bromide Formation to his upper Ashbyan, Porterfieldian, and lower Wildernessian Stages, with the Pooleville Member representing the upper Porterfieldian and lower Wildernessian Stages. According to Cooper, the Bromide Formation ranges from the upper Chazyan through most of the Bolarian Stages of Kay (*in* Cooper, 1956). Thus the Corbin Ranch Submember, which represents the uppermost facies of the Pooleville Member, is of early Wildernessian age on the Cooper time scale and of late Bolarian age on the Kay time scale. Cooper assigned the Viola (Viola Springs) to the upper Wildernessian–Trentonian Stages and postulated a small time gap between this unit and the underlying Bromide.

Paleoenvironment of Fite–Corbin Ranch Birdseye Limestones

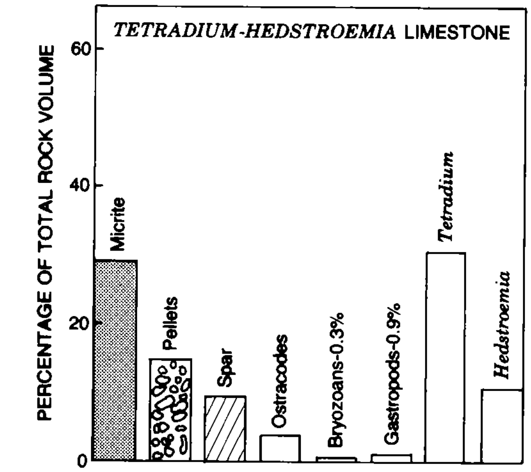
The general textural and faunal characteristics of the Fite–Corbin Ranch strata closely match



Text-figure 13. Stratigraphic diagram summarizing lithologic and faunal characteristics of upper Pooleville Member, including Corbin Ranch Submember, of Bromide Formation on north flank of Arbuckle Anticline, east lane, east side, Interstate Highway 35, south of Davis, Oklahoma (sec. 30, T. 1 S., R. 2 E., Murray County).

those ascribed to birdseye limestones by recent investigators. Most students of recent and ancient carbonate sediments conclude that this facies developed in a tidal environment, but some assign it solely to supratidal environments (Laport, *in* Ginsburg, 1975, p. 245; Beechler, 1974, p. 34–35) and others interpret it as representing intertidal to supratidal environments (Shinn, 1968, p. 215; Read, *in* Ginsburg, 1975, p. 255; Longman, 1976, p. 144). Recently Ginsburg and others (*in* Hardie, 1977, p. 7–11) proposed an *exposure-index* system for quantifying the environment of modern carbonate sediments in the tidal zone. They determined the degree of exposure above sea level for various sedimentary and faunal elements on the tidal flats of northwest Andros Island, Bahamas, and calculated the exposure index as a percentage of time exposed (ranging from 0 to 100 percent exposure). Not enough information is available on the Fite–Corbin Ranch birdseye limestones to quantify them precisely according to this system; nevertheless, a number of the Ordovician birdseye features, such as fenestral laminations, pellets, mud cracks, gas bubbles, and shrinkage cracks, can be matched with reasonable precision to those from Andros Island, and a comparison with the exposure-index graph (Hardie, 1977, p. 10) points to a high intertidal to a supratidal environment. Moreover, the restricted fauna, composed largely of ostracodes, including leperditids, a few mollusks, and conodonts, supports this interpretation (Berdan, 1968).

In places the birdseye limestones are closely associated with the *Tetradium–Hedstroemia* beds. This relationship can be observed in the Qualls outcrops, in OGS core 3 (text-fig. 6), in the subsurface of the Arkoma Basin (Amsden, 1980, pl. 11, fig. 7), and in the I-35 section (text-fig. 13). The *Tetradium–Hedstroemia* limestones appear to represent bioherms or small patch reefs that occupied the outer margin of the birdseye tidal flat. The marine faunal elements seem to mark a low intertidal to subtidal environment, and fragmentation points to strong wave action, which in places was sufficient to move the reef debris well onto the tidal flat. The late Bromide birdseye limestones cover a large area in eastern Oklahoma, and undoubtedly there was some shifting of the strandline with local incursions of the sea introducing a typical marine fauna. Toward the southwest, such incursions became increasingly common, as evidenced by the interbedding of birdseye limestones with sparingly fossiliferous bioturbated micrites, unfossiliferous burrowed micrites, and sparingly fossiliferous marlstones. The relationships are present in parts of the eastern and central Arbuckle Mountains; however, over the southern and western Bromide outcrop area the birdseye facies was replaced by fossiliferous marlstones and skeletal limestones with the varied invertebrate fauna of a subtidal, open-marine environment (text-fig. 15; Beechler, 1974, p. 38).



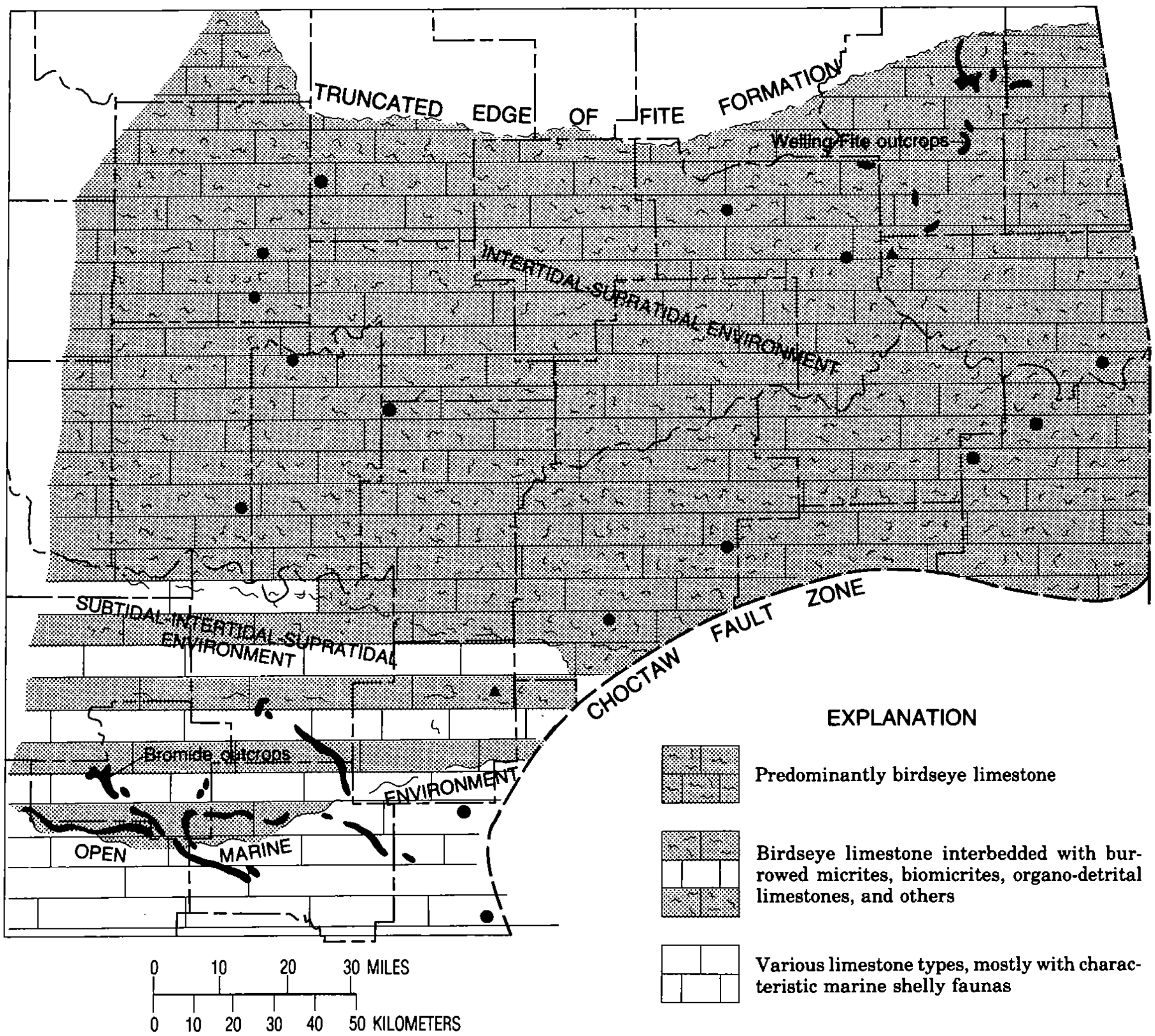
Text-figure 14. Graph showing matrix and fossil components in *Tetradium–Hedstroemia* limestone, upper Pooleville Member of Bromide Formation. Based on point counts of three thin sections from strata 3 to 8 feet below Corbin Ranch Submember; north flank of Arbuckle Anticline, east side, east lane, Interstate Highway 35, near 50-mile marker, Murray County, Oklahoma. (see text-fig. 18, pl. 11, figs. 2–4). Matrix has wide range in composition: micrite from 17.6 to 41.1 percent; pellets, 0.7 percent; spar from 7.5 to 11.6 percent.

The conodont faunas described in Part II indicate that the Fite Limestone of eastern Oklahoma and the Corbin Ranch Submember of the Arbuckle Mountains are older than the Shermanian Stage and that these strata may be correlative. Faunal control is not precise enough, however, to preclude some age difference across the area studied. Even if this environment had been, to some extent, time transgressive, the regional extent of the birdseye limestones over such a large area points to a tidal flat of impressive dimensions.

STRATIGRAPHIC RELATIONS OF MIDDLE AND UPPER ORDOVICIAN STRATA IN EASTERN OKLAHOMA

Welling–Viola Springs–Bromide Relationship

The Welling Formation in the eastern Arbuckle Mountains is an organo-detrital limestone overlain by the Sylvan Shale and underlain by the Viola Springs Formation from which it is separated by a few feet of gradational beds (text-fig. 2). The Viola Springs Formation in this eastern region comprises about 48 m of calcareous mudstones and muddy, organo-detrital limestones with considerable chert. It thickens toward the



Text-figure 15. Map of Fite Formation–Corbin Ranch Submember (Pooleville Member, Bromide Formation), showing inferred paleoenvironments represented.

southwestern part of the mountains, where it attains a maximum thickness of about 815 feet (245 m) (Glaser, 1965; Alberstadt, 1973). The Viola Springs is separated from the underlying Bromide Formation by a sharp lithologic contact that shows evidence of pre-Viola induration and dissolution (pl. 10, fig. 5). There is also biostratigraphic evidence for a hiatus at this point (see Part II of this report; also Cooper, 1956, chart 1). In the southwestern part of the Arbuckle Mountain outcrop area the Welling Formation loses its identity by merging into Viola Springs–type lithology; however, the Welling can be traced eastward across the Arkoma Basin, and it maintains a similar lithology throughout the basin (text-fig. 16). The Viola Springs Formation, which in the Arbuckle Mountains separates the Welling Formation from the upper Bromide Formation (Corbin Ranch Submember), wedges out a few miles east of the outcrop area, so that the Welling is brought into direct contact with the Fite Formation (text-fig. 3). Whereas the Welling–Viola Springs contact is gradational, the Welling–Fite contact is sharply defined, and there is good evidence for pre-Welling induration and dissolution (pl. 12, fig. 1; pl. 14, figs. 2, 4). The Fite birdseye limestones can be traced westward into the Arbuckle Mountains, where they join the Corbin Ranch birdseye limestones. Welling brachiopods from the eastern outcrops are identical to those from the middle and upper parts of the formation in the Arbuckle Mountains, and these strata are regarded as correlative. Conodont faunas discussed by Sweet in Part II indicate that the Welling–Fite sequence of eastern Oklahoma is correlative with the Welling–Corbin Ranch strata of the

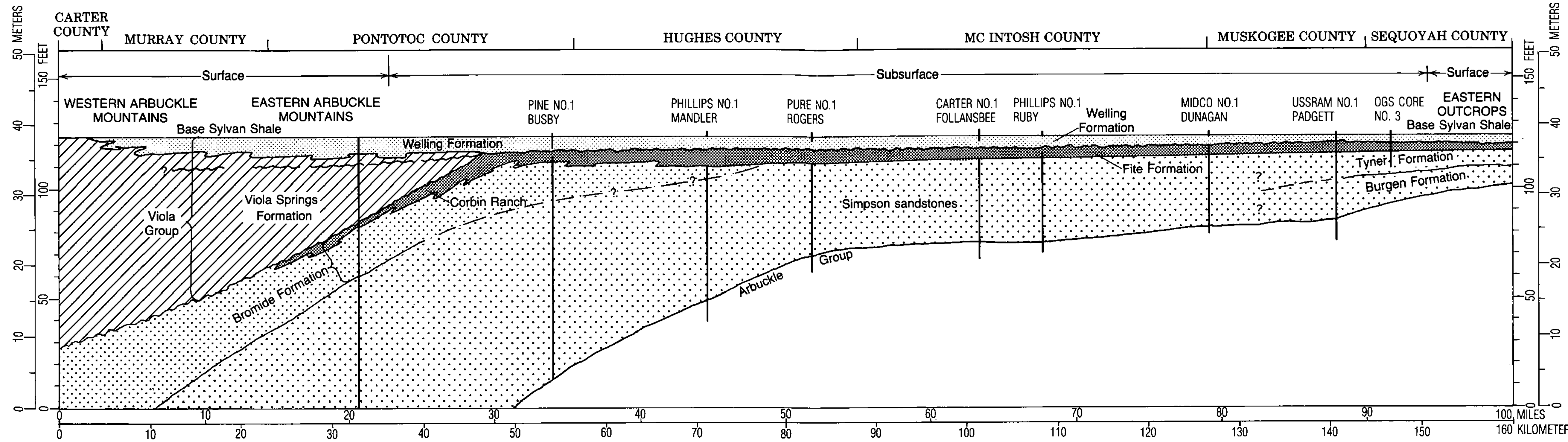
Arbuckle region; and thus both the biostratigraphic and lithostratigraphic evidence points to the loss of the entire Viola Springs Formation, which represents the upper Kirkfieldian through middle Edenian Stages (text-fig. 2). Physical evidence indicates subaerial exposure of the Fite during pre-Welling time, although exposure must have been on a low-lying surface of little relief because truncation of the Fite is moderate and at no place is the Welling known to rest on pre-Fite strata. This explanation is compatible with the interpretation of Fite–Corbin Ranch sedimentation in an intertidal environment.

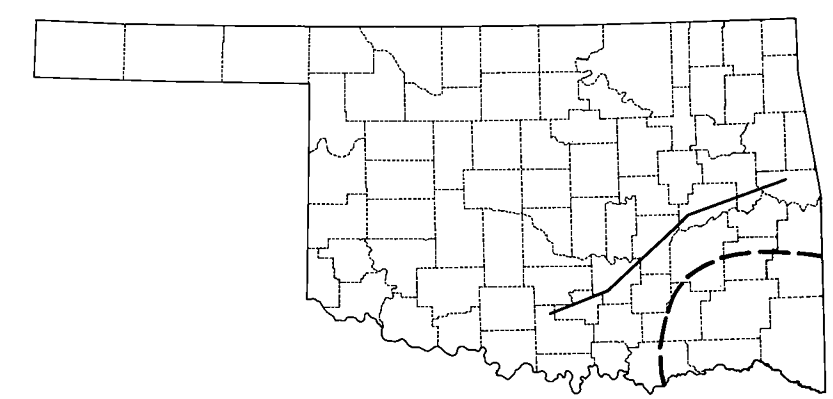
Alberstadt (1967, p. 59, fig. 15) recognized the Welling–Fite unconformity in eastern Oklahoma, but he noted that the "unconformity terminates in the subsurface so that an uninterrupted section is exposed in the outcrop of the Arbuckle Mountains." A different explanation is, however, here suggested to account for these lithostratigraphic–biostratigraphic relations. Glaser (1965, p. 18–23, fig. 3) and Alberstadt (1973, p. 3) postulated a southwestern basin province and a northeastern shelf province, but, except for the merging of the Welling (Glaser–Alberstadt unit 3) into the upper Viola Springs (Glaser–Alberstadt unit 2), which affects only a small part of the Viola Group, they report only minimal lithologic differences between the two provinces. Actually, the principal support for their postulated paleoenvironmental changes is the marked thinning from southwest to northeast (text-fig. 3), mainly affecting the upper Viola Springs (Glaser–Alberstadt unit 2); this can be accounted for by projecting the Welling–Fite unconformity westward into the Arbuckle Mountain region (text-fig. 16). The lithostratigraphic relations and brachiopod biostratigraphic relations (see Part III) seem to preclude placing this unconformity at the Welling–Viola Springs boundary, but the conodont faunas discussed by Sweet in Part II suggest the presence of a hiatus within the Viola Springs Formation. Additional biostratigraphic evidence is provided by Jenkins (1969, p. 34), who studied chitinozoans from the Viola Group, and who reported an important faunal break 40 to 60 feet (12–18 m) below the Viola Springs–Welling (= "Fernvale") contact. According to the explanation suggested in text-figure 16, this faunal break marks the western extension of the Welling–Fite unconformity, with the Viola Springs thinned by truncation beneath an erosional surface. This unconformity is presumed to decrease in intensity toward the southwest. There is solid physical evidence for a depositional hiatus between the Welling and the Fite, but it should be emphasized that no physical evidence for an unconformity within the Welling–Viola Springs sequence has been identified by Glaser, Alberstadt, Jenkins, or any other stratigrapher working on the Viola Group. The discordance between the strata above and below this postulated unconformity is much magnified by the substantial vertical exaggeration in the stratigraphic section illustrated in text-figure 16. Actually, from the Highway 99 outcrop to the Sycamore Creek exposures studied by Jenkins, the thickness of the upper Viola Springs (Glaser–Alberstadt unit 2) increases by about 300 feet (91 m), or at an average rate of only 11 feet (3.3 m) per mile.

The brachiopod zonation described in Part III suggests that the lower beds of the Welling (*Lepidocyclus oblongus* biozone) and the Viola Springs Formation are absent in eastern Oklahoma. According to the stratigraphic model postulated in this report, the absence of lower Welling strata can be explained by assuming that they were lost through onlap onto the old Fite surface, and there is clear physical evidence for a depositional hiatus at this position. In fact, by projecting this onlap southwestward into the Arbuckle Mountain region, it is possible to explain the loss of the entire Viola Springs Formation. Supporting this explanation is the physical and biostratigraphic evidence for a depositional break between the Viola Springs and the Bromide and between the Welling and the Fite. Opposing such a hypothesis is the fact that it requires thinning from the base upward, whereas the lithostratigraphic investigations of Glaser and Alberstadt show that the basal unit of the Viola Springs (their unit 1) undergoes only slight thinning from west to east, with almost all of the loss of section taking place in the upper part of that formation (their unit 2).

Bromide–Simpson Relationship

The Bromide Formation in the Arbuckle Mountains is divided into a lower Mountain Lake Member and an upper Pooleville Member. The latter includes the thin, discontinuous Corbin Ranch Submember at the top (text-fig. 2). The thickness of the Bromide Formation varies, but in the eastern part of the Arbuckle Mountains the Bromide is about 170 feet (52 m) thick. Birdseye limestones of the Corbin Ranch Submember merge with the Fite and extend eastward across Oklahoma, but the underlying part of the Pooleville Member and all of the Mountain Lake Member appear to wedge out as shown in text-figure 16 (see also Frezon, 1962, pl. 2). Throughout eastern Oklahoma, Corbin Ranch–Fite birdseye limestones rest directly on the Simpson, a stratigraphic unit composed predominantly of sandstones and shales with only minor carbonates. These Simpson sandstones include the Tyner and Burgen Formations of the eastern Oklahoma outcrop area. Correlation of the Simpson sandstones of the Arkoma Basin with the pre-Bromide Simpson of the Arbuckle Mountain outcrop area is based on lithostratigraphic relations, for there is little biostratigraphic evidence to support such a correlation. A few fossils





Text-figure 16. Stratigraphic diagram showing inferred distribution and relationships of major pre-Sylvan–post-Arbuckle strata in eastern Oklahoma. (Some stratigraphic distortion in thickness, especially of thinner stratigraphic units.)

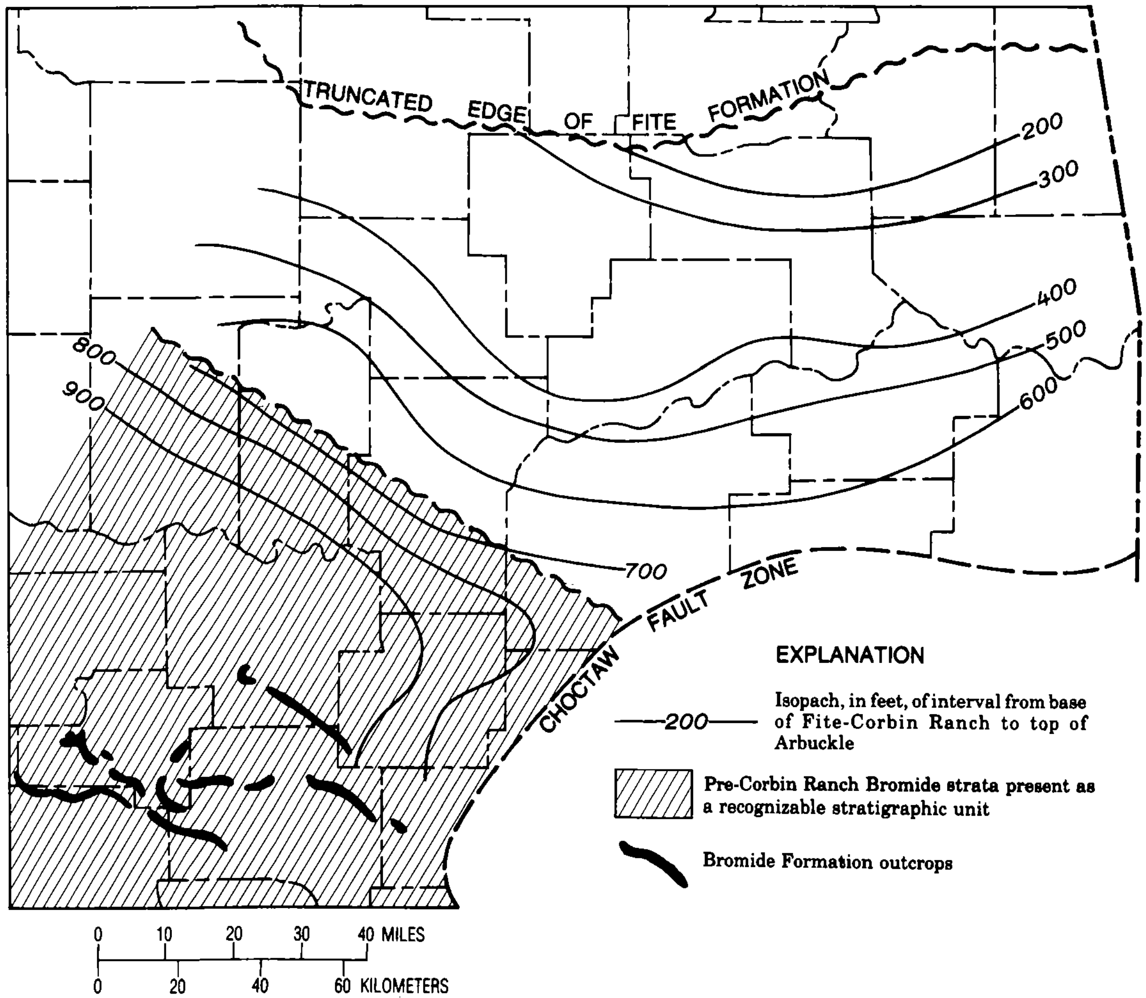
have been reported from the Tyner Formation (Huffman, 1958, p. 23), but, as identified, these contribute little to the solution of age or correlation. The upper part of the Tyner has been correlated with the Bromide, and it is possible that the apparent disappearance of all but the uppermost part of the Bromide (Corbin Ranch Submember) in the eastern part of Oklahoma is the result of partial or complete merging of the Pooleville–Mountain Lake limestones, argillaceous limestones, and sandstones into the predominantly sandstone sequence here designated the Simpson sandstones. Additional biostratigraphic data are needed to resolve this question. Simpson strata rest on dolomite of the Arbuckle Group, and the two are separated by a reasonably distinct lithostratigraphic boundary throughout the Arkoma Basin.

ARKOMA BASIN: MIDDLE ORDOVICIAN THROUGH DEVONIAN HISTORY

The Arkoma Basin is a south-dipping sedimentary–structural Paleozoic basin composed mainly of shallow-water sediments that thicken predominantly toward the south. Middle Ordovician through Devonian strata can be traced with reasonable precision from the truncation line on the north to the Choctaw Fault zone on the south. Undoubtedly the original depositional axis was located within the Ouachita Province; however, stratigraphic relations in that province are obscured by strong structural deformation and meager biostratigraphic control. Therefore, the following discussion is restricted to that portion of the Arkoma Basin north of the Choctaw Fault zone.

The Arkoma Basin was developing by Cambrian time and may have originated in the pre-Cambrian. Lower Paleozoic strata thicken toward the south, with Simpson sandstones increasing from about 150 feet (45 m) in the outcrop area to 715 feet (215 m) near the Choctaw Fault zone (text-fig. 17). Simpson deposition was followed by a distinct change in sedimentation pattern. The Fite and Welling were deposited as thin, intertidal to shallow, subtidal carbonates with no clearly defined basinward thickening (text-figs. 5, 10). These units, whose maximum combined thickness is about 100 feet (30 m), are separated by an unconformity that records a period of uplift, subaerial exposure, and erosion. Carbonate sedimentation was interrupted by deposition of the Sylvan Shale, which began as fine mud and then became increasingly calcareous and dolomitic upward, so that the final sediments include some dolomitic shales. Sylvan thicknesses in the eastern Arkoma Basin are mostly under 35 feet (10 m), and the formation shows no basinward thickening (Amsden, 1980, panel 1). Bottom conditions during Sylvan deposition were such as to preclude almost all benthic organisms; however, factors producing this sterile environment are conjectural (Amsden, 1980, p. 10, 62). The late Sylvan phase of increasing carbonate sedimentation was followed in Late Ordovician (Hirnantian) time by oolite formation (Keel–Pettit Formations), probably with little or no interruption in deposition. The Keel–Pettit oolite banks are erratic in distribution (Amsden, 1980, text-fig. 12) and appear to be entirely subtidal, relatively high-energy deposits. Keel deposition was followed by a period of emergence, representing much of Llandoverian time, which was followed by resubmergence and deposition of the late Llandoverian–Wenlockian Blackgum–Tenkiller–Quarry Mountain (Chimneyhill Subgroup) skeletal limestones, which represent shallow-water, carbonate-shelf deposition (Amsden, 1980, p. 14–30, panels 2, 4). No later Silurian (Henryhouse) or earliest Devonian (Haragan–Bois d'Arc) strata are preserved in the eastern Arkoma Basin, and if such strata were originally laid down, as seems probable, they were completely stripped away by pre-Frisco (middle Early Devonian) erosion. The Frisco Formation is a thin (less than 13 feet or 4 m), high-energy, shallow-water skeletal limestone, the presently restricted distribution of which in the Arkoma Basin is entirely the result of later Devonian erosion (Amsden, 1980, p. 46–49, panel 4). Deposition of the Frisco was followed by a period of uplift and erosion, then by resubmergence and deposition of the late Early Devonian Sallisaw Formation. Sallisaw deposition initiated some changes in the sedimentation pattern, mainly in the sharply increased volume of quartz detritus being transported into the basin. The Sallisaw benthic fauna and texture suggest relatively shallow water, although the energy level was reduced from that of the Frisco. Some time after Sallisaw deposition the entire region (with the possible exception of the deep southwestern part of the Anadarko Basin) was uplifted and exposed to a long period of erosion, during which time major drainage systems were established (Amsden, 1980, p. 61–64, text-fig. 26). In early Late Devonian time the Woodford–Chattanooga sea advanced across this region, and where it encountered residual insoluble debris produced by dissolution of the older carbonates, it incorporated this material as a basal sediment (Sycamore and Misener Sandstones). This sea laid down a blanket of dark, organic-rich muds under conditions that eliminated almost all sessile-benthic organisms. With Woodford–Chattanooga deposition, the basinward pattern of accelerated sedimentation was resumed and continued through Pennsylvanian time.

The stratigraphic relations outlined above suggest that the Arkoma was a Paleozoic basin with a depositional axis situated south of the present



Text-figure 17. Map showing distribution and thickness of strata between base of Fite Formation and top of Arbuckle Group. These strata are designated Simpson sandstones on text-figure 16 (see Introduction to Part I).

Choctaw Fault. Sedimentation was relatively rapid during the early Paleozoic, with a substantial south-accelerated build-up through Simpson time. With inception of Corbin Ranch–Fite deposition, basin stresses relaxed and a more or less stable platform developed, at times depressed slightly to receive a thin veneer of sediments and at other times elevated slightly to expose the surface to subaerial processes. This condition continued through the Silurian and into the Early Devonian, at which time the periods of uplift became more intense and climaxed in the Middle Devonian, when the entire region was uplifted and extensively eroded. With advance of the Woodford–Chattanooga seas in early Late Devonian time, basin stresses were reactivated and a basinward sedimentary build-up was reinitiated. That relationship continued through Pennsylvanian time.

WELLS STUDIED FOR THIS REPORT

Ordovician strata in the following wells were studied primarily by thin sections prepared from cuttings. The stratigraphic terminology is given in text-figures 2 and 16. The Hunton strata for most of these wells are described in Amsden (1980, Appendix).

GRAVES 1-A BARTHOLET (completed 11/18/43 as W. D. Grant 1 Bartlett; later taken over and completed as Graves 1-A Bartholet)—C SW¼SW¼SW¼ sec. 8, T. 14 N., R. 17 E., Muskogee County, Oklahoma; elev. unknown; TD 3,044′ (Arbuckle); compl. 10/4/66; oil production reported, zone uncertain. Tops (all sample depths): Hunton, 2,640′; Sylvan, 2,655′; Welling, 2,695′; Fite, 2,700′; Simpson, 2,720′; Arbuckle, 2,875′. Samples examined from

2,550′ to 3,044′ (TD), good quality; 27 thin sections. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

ARKLA EXPLORATION 1–13 CARR ESTATE—1,650′ FSL and 1,650′ FEL sec. 13, T. 2 S., R. 10 E., Atoka County, Oklahoma; elev. 653′ GL (679′ KB); TD 12,095′ (Arbuckle); compl. 6/21/77; D&A. Tops (all sample depths): Hunton, 8,200′ (−7,521′); Sylvan, 8,440′ (−7,761′); Welling, 8,550′ (−7,871′); Viola, 8,660′ (−8,007′); Bromide(?), 8,890′ (−8,237′); Simpson, 9,330′ (−8,677′); Arbuckle, 10,000′ (−9,347′). Samples examined from 8,060′ to 10,500′, 11,900′ to 12,000′ (last sample). Hunton samples described in Amsden (1980, p. 76), good quality; 89 thin sections (19 Hunton). Samples from OU Core and Sample Library.

TIDEWATER 4 CHILDRESS—C SW¼NW¼ sec. 4, T. 16 N., R. 11 E., Creek County, Oklahoma; elev. 699′ (KB); TD 4,542′ (Reagan); D&A. Tops (all sample depths): Simpson, 2,720′ (−2,021′); Arbuckle, 3,040′ (−2,341′); Reagan, 4,350′ (−3,651′). Samples examined from 2,640′ to 3,300′ and 4,280′ to 4,542′ (TD), good quality; 14 thin sections. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

COOK & GRAY 2 COOK—C SW¼NE¼ sec. 8, T. 12 N., R. 24 E., Sequoyah County, Oklahoma; elev. 640′; TD 1,770′ (Ordovician–Cotter); compl. 1949. Tops: Hunton, 715′ (−75′) SP log; Sylvan, 970′ (−330′) sample depth; "Fernvale," 990′ (−350′) sample depth; Fite, 1,010′ (−370′) sample depth; Simpson (Tyner–Burgen), 1,050′ (−410′) sample depth; Arbuckle, 1,400′ (−760′) sample depth. The Hunton part of this well is described in Amsden and Rowland (1965, p. 133–135); 1 thin section prepared. The pre-Hunton part (715′–1,770′, TD) was examined December 1977; 32 thin sections prepared. Good-quality samples. Samples from OU Core and Sample Library.

PAN AMERICAN 1 DUNN UNIT—SW¼NW¼ sec. 35, T. 9 N., R. 24 E., Le Flore County, Oklahoma; elev. 602′ KB (586′ DF); TD 6,950′ (Arbuckle); compl. 10/18/66; Spiro (Pennsylvanian) gas production reported. Tops: Woodford, 5,646′ (−5,044′) GR log; Hunton, 5,732′ (−5,130′) GR log; Sylvan, 5,874′ (−5,272′) GR log, 5,890′ sample depth; Welling, 5,904′ (−5,302′) GR log, 5,920′ sample depth; Fite, 5,950′ (−5,348′) sample depth; Simpson, 5,962′ (−5,360′) Petroleum Information report; Arbuckle (Cotter) 6,588′ (−5,986′) Petroleum Information report. Samples examined from 5,870′ to 6,950′ (TD); mud drilled to 5,960′; no samples 5,960′ to 6,000′; air drilled 6,000′ to 6,920′; mud drilled 6,920′ to 6,950′; air-drilled samples not studied. One thin section lower Hunton, 3 thin sections Welling and Fite, 3 thin sections lower Arbuckle (6,620′ to 6,650′). Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

HEMBREE (ROBINSON & MARSHALL) 1 HEMBREE—SE¼SW¼SE¼ sec. 19, T. 7 N., R. 5 E., Pottawatomie County, Oklahoma; elev. 927′; TD 5,125′ (Arbuckle); compl. 2/3/54; D&A(?). Tops (all sample depths): Hunton, 3,770′ (−2,843′); Sylvan, 3,805′ (−2,878′); Welling, 3,875′ (−2,948′); Fite, 3,910′ (−2,983′); Bromide (?Mountain Lake Member), 3,980′ (−3,053′); Simpson, 4,300′(?) (−3,373′); Arbuckle, 4,945′ (−4,018′). Samples examined from 3,750′ to 5,125′ (TD), good quality; 41 thin sections. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

MAGNOLIA 1 MANSCHRICK—C SE¼NE¼ sec. 28, T. 6 N., R. 17 E., Pittsburg County, Oklahoma; elev. 963′ KB (950′ GL); TD 12,915′ (Arbuckle); compl. 9/23/54; D&A. Tops (all sample depths): Woodford, 11,412′ (−10,450′); no Hunton present; Sylvan, 11,495′ (−10,533′); Welling, 11,552′ (−10,590′); Fite, 11,580′ (−10,617′); Simpson, 11,682′ (−10,719′); Arbuckle 12,292′(?) (−11,329′); 20 samples missing between Simpson and Arbuckle. Samples and core examined from 11,340′ to 12,600′ and 12,900′ to 12,915′ (TD). No samples 12,254′ to 12,292′; cored (core chips examined) 11,637′ to 12,254′, 12,360′ to 12,600′; 58 thin sections. Samples and core chips from Oklahoma Well Sample Service, Shawnee, Oklahoma.

BUNKER 2 MC ELVANEY—S½NE¼NW¼ sec. 10, T. 12 N., R. 5 E., Lincoln County, Oklahoma; elev. 876′ GL (883′ KB); TD 4,593′ (Simpson); compl. 8/26/75, D&A. Tops: Woodford, 4,250′ (−3,374′) GR log; Misener, 4,314′ (−3,438′) core sample; Hunton, 4,318′ (−3,442′) core sample; Sylvan, 4,375′ (−3,499′) GR log; Welling 4,480′ (−3,604′) sample depth, 4,465′ (−3,582′) GR log; Fite, 4,510′ (−3,627′) sample depth; Simpson, 4,560′ (−3,677′) sample depth. Core and samples examined from 4,300′ to 4,590′ (TD). Hunton strata described in Amsden (1980, Appendix). Good-quality samples; 8 thin sections from Ordovician. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

WHITTAKER 1 MOWDY (originally drilled by Delphi to a depth of 12,063′)—SE¼NE¼SE¼ sec. 10, T. 2 N., R. 11 E., Coal County, Oklahoma; elev. 670′ DF (671′ KB); TD 12,561′ (Arbuckle); compl. 3/22/54; D&A. Tops (all sample depths): Hunton, 11,010′ (−10,340′); Sylvan, 11,055′ (−10,385′); Welling, 11,170′ (−10,500′); Bromide (Corbin Ranch birdseye limestone at top), 11,225′ (−10,554′); Simpson, 11,440′ (−10,769′); Arbuckle, 12,260′ (−11,589′). Samples and core chips examined from 10,900′ to 12,561′ (TD). Hunton section described in Amsden (1980, Appendix). Core chips 11,178′ to 12,561′ (TD); 62 thin sections, 6 from Hunton, 56 from Ordovician. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

CARTER–GRAGG 1 MULLINS—C SE¼SW¼ sec. 29, T. 4 N., R. 14 E., Pittsburg County, Oklahoma; elev. 718′ KB (705′ GL); TD 12,547′ (last sample 12,510′, Simpson); compl. 12/31/61; Cromwell (Pennsylvanian) and Simpson production reported. Tops (all sample depths): Woodford, 11,294′ (−10,576′); Hunton, 11,411′ (−10,693′); Sylvan, 11,430′ (−10,712′); Welling, 11,509′ (−10,791′); Fite, 11,550′ (−10,832′); Simpson, 11,730′? (−11,012′?). Samples examined from 11,370′ to 12,510′ (sample-depth TD). Good-quality samples; 4 thin sections from Hunton, and 24 from Ordovician Hunton section, described in Amsden (1980, p. 94). Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

EXXON 1-A MULLINS—N½S½SE¼ sec. 32, T. 3 S. R. 11 E., Atoka County, Oklahoma; elev. 552′ KB (537′ GL); TD 13,184′ (Arbuckle); compl. 1/18/78; production?. Tops (all sample depths): Hunton, 8,310′ (−7,758′); Sylvan, faulted out(?); Welling, 8,360′ (−7,808′); Viola, 8,440′ (−7,888′); Bromide, 8,710′ (−8,158′), Corbin Ranch birdseye limestone at top; Simpson, ?9,560′ (−9,008′); Arbuckle, ?10,360′ (−9,808′). Samples examined from 8,200′ to 11,000′, and 13,100′ to 13,180′; good quality; 45 thin sections. Samples from Ardmore Sample Cut, Ardmore, Oklahoma.

COKER 1 OLIPHANT—C SE¼SE¼NE¼ sec. 2, T. 9 N., R. 8 E., Hughes County, Oklahoma; elev. 816′ KB; TD 5,040′ (Arbuckle); compl. 3/18/76; Gilcrease and Cromwell (Pennsylvanian) gas production reported. Tops (all sample depths): Hunton, 4,010′ (−3,194′); Sylvan, 4,100′ (−3,284′); Welling, 4,195′ (−3,379′); Fite, 4,230′ (−3,414′); Simpson, 4,260′ (−3,444′); Arbuckle, 4,830′ (−4,014′). Samples examined from 3,900′ to 5,040′ (TD), skip 4,730′ to 4,780′; good quality; 25 thin sections. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

U.S. SMELTING, REFINING & MINING 1 PADGETT—C NW¼NW¼ sec. 29, T. 13 N., R. 20 E., Muskogee County, Oklahoma; elev. 595′; TD 1,550′ (Arbuckle); compl. 3/12/58; Arbuckle(?) production. Tops: Woodford, 884′ (−289′) Petroleum Information report; Hunton, 900′ (−305′) sample depth; Sylvan, 1,020′ (−425′) sample depth; Welling, 1,060′ (−465′); Fite, 1,090′ (−495′) sample depth; Simpson, 1,110′ (−515′) sample depth; Arbuckle, 1,420′ (−825′) sample depth. Samples examined from 890′ to 1,550′ (TD); good quality, 25 thin sections. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

CONTINENTAL 1 REINHARDT—C, SW¼NE¼ sec. 10, T. 10 N., R. 26 E., Sequoyah Co., Okla., elev. 433′ KB (416′ GL); TD 7,357′ (Arbuckle); Spiro (Pennsylvanian) gas production reported. Tops (all sample depths): Woodford, 6,342′ (−5,909′); Hunton 6,374′ (−5,941′); Sylvan, 6,672′ (−6,239′); Welling, 6,710′ (−6,277′); Fite 6,730′ (−6,297′); Simpson, 6,770′ (−6,337′); Arbuckle, 7,350′ (−6,917′). Samples examined from 6,420′ to 7,357′ (TD); 20 thin sections prepared of Ordovician strata, and 7 from Hunton Group. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma. Hunton part of this well described in Amsden (1980, Appendix).

HUMBLE 6 C28 RIDDLE—C N½SE¼SE¼ sec. 35, T. 11 N., R. 6 E., Seminole County, Oklahoma; elev. 928′ KB (920′ GL); TD 5,085′ (Arbuckle); compl. 3/2/61; "Wilcox" (Ordovician) production reported. Tops: Hunton, 4,040′ (−3,112′) SP log; Sylvan, 4,200′ (−3,272′) sample depth; Welling, 4,290′ (−3,362′) sample depth; Fite, 4,340′ (−3,412′) sample depth; Simpson, 4,380′ (−3,452′) sample depth; Arbuckle, 5,025′ (−4,097′) sample depth. Samples examined from 4,100′ to 5,085′ (TD); good quality; 30 thin sections. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

PAN AMERICAN 1 TACKETT UNIT—C SW¼NE¼ sec. 28, T. 8 N., R. 23 E., Le Flore County, Oklahoma; elev. 526′; TD 9,272′ (Arbuckle); compl. 7/11/63; Cromwell (Pennsylvanian) gas reported. Tops: Woodford, 6,147′ (−5,621′) Petroleum Information report; Misener(?), 6,280′ (−5,754′) sample depth; Sylvan, 6,290′ (−5,764′) sample depth; Welling, 6,330′ (−5,804′) sample depth; Fite, 6,350′ (−5,824′) sample depth; Simpson, 6,450′? (−6,924′?) sample depth; Arbuckle, 7,060′ (−6,534′) Petroleum Information report. Samples examined from 6,250′ to 7,020′ and 7,890′ to 7,955′ (TD); samples missing from 7,020′ to 7,890′; good quality except for interval from 6,330′ to 6,450′, where they are very fine (air drilled?); 23 thin sections. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

U.S. SMELTING, REFINING & MINING 2 WHITMORE—SE¼SW¼SE¼ sec. 21, T. 15 N., R. 7 E., Creek County, Oklahoma; elev. 790′ KB (788′ GL); TD 4,469′ (Arbuckle); Simpson production reported. Tops: Woodford, 3,796′ (−3,006′) Petroleum Information report; Sylvan, ?3,829′ (−3,039′) Petroleum Information report; Welling, 3,905′ (−3,115′) sample depth; Fite, 3,930′ (3,140′) sample depth; Simpson, 3,950′ (−3,160′) sample depth; Arbuckle, 4,335′ (−3,545′) sample depth. Samples examined from 3,800′ to 4,470′ (TD); good quality; 25 thin sections. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

U.S. SMELTING, REFINING & MINING 1 YOUNG—NE¼SW¼SW¼ sec. 13, T. 13 N., R. 5 E., Lincoln County, Oklahoma; elev. 801′ DF (795′ GL); TD 4,959′ (Arbuckle); Hunton and Simpson ("Wilcox") production reported. Tops: Hunton, 4,170′ (−3,369′) SP log; Sylvan, 4,260′ (−3,459′) SP log; Welling, 4,345′ (−3,544′) sample depth; Fite, 4,390′ (−3,589′) sample depth; Simpson, 4,430′ (−3,629′) sample depth; Arbuckle, 4,880′ (−4,079′) sample depth. Samples examined 4,100′ to 4,172′; core chips 4,172′ to 4,188′; samples 4,188′ to 4,440′; core chips 4,440′ to 4,515′; samples 4,515′ to 4,959′ (TD); good quality; 37 thin sections. Samples from Oklahoma Well Sample Service, Shawnee, Oklahoma.

PART II—CONODONT BIOSTRATIGRAPHY OF FITE FORMATION AND VIOLA GROUP

WALTER C. SWEET

Abstract—The stratigraphic distribution of more than 18,000 conodont elements in the Corbin Ranch Submember of the Bromide Formation, and in the Fite, Viola Springs, and Welling Formations, is documented for two localities in the Arbuckle Mountains of south-central Oklahoma and four in Cherokee County, eastern Oklahoma. Ranges of 27 conodont species are used to effect a graphic correlation of the two Arbuckle Mountains sections and a composite section that includes data from stratotypes of standard North American Middle and Upper Ordovician stages. That correlation indicates that the Corbin Ranch is latest Blackriveran to Rocklandian in age, that the Viola Springs Formation ranges in age from Kirkfieldian to mid-Edenian, and that the Welling is late Edenian and early Maysvillian in age at Arbuckle Mountain localities but probably entirely early Maysvillian in eastern Oklahoma. Correlations further suggest, but do not prove, the existence within the upper Viola Springs of a hiatus that may represent late Shermanian and early Edenian time, and a Rocklandian or Kirkfieldian age for the Fite Formation of eastern Oklahoma. *Aphelognathus gigas* Sweet, n. sp., is established on the basis of material from the Fite Formation of eastern Oklahoma.

INTRODUCTION

Conodonts have been obtained from the Fite Formation and the basal part of the Welling Formation at four localities in Cherokee County, eastern Oklahoma (text-fig. 1), and from the Welling and subjacent Viola Springs Formation at the type locality of the latter in the Arbuckle Mountains (NW¼NE¼ sec. 19, T. 2 S., R. 8 E., Johnston County, Oklahoma). These conodonts, together with specimens in undescribed collections from the typical Corbin Ranch and material from the lower Viola Springs Formation described by Oberg (1966), constitute the basis for the following interpretation of the conodont biostratigraphy of the Fite, Viola Springs, and Welling Formations.

ARBUCKLE MOUNTAINS

Localities

Conodonts from the Arbuckle Mountains are from two localities, both located precisely and described by Alberstadt (1973). The first, section D of Alberstadt, is a well-exposed sequence of Middle and Upper Ordovician rocks along the west side of Oklahoma Highway 99, 3.3 miles south of Fittstown, in Pontotoc County. Oberg (1966) collected 37 samples from the lower 216 feet (65.9 m) of the Viola Springs Formation at this locality and described and illustrated the conodonts he derived from them in his unpublished doctoral dissertation. Samples from the underlying Corbin Ranch

Submember of the Pooleville Member of the Bromide Formation at this locality were collected in June 1972 by Sweet, with assistance from Stig. M. Bergström and Valdar Jaanusson. Information from the four uppermost samples is used in this study. Those four samples bear the Ohio State University field-register designations 72SJ-20, 21, 22, and 23.

The second Arbuckle Mountain locality from which Viola Group conodonts have been obtained is section F of Alberstadt (1973), which is a natural exposure of virtually the entire Viola Group in and along the west bank of Robertson Creek, Johnston County, Oklahoma. Amsden (this report) designates this section as the stratotype of the Viola Springs Formation. In early 1980, Amsden collected 18 bulk samples for Sweet, and these have been given the Ohio State University field-register designations 80SA-1 through 18. One sample is from the top part of the Corbin Ranch Submember, another is from the basal bed of the Viola Springs Formation, and the remainder are from the upper 60 feet (18.3 m) of the Viola Springs and from the Welling Formation, which overlies the Viola Springs conformably.

Conodonts

The identity and frequency of occurrence of conodonts in samples from Alberstadt's section D are shown in table 1. Comparable information for samples from Alberstadt's section F is given in table 2.

As indicated in tables 1 and 2, conodonts of the Viola Springs and Welling Formations represent 27 species of 17 genera. Two species (*Amorphognathus superbus*? and *A. tvaerensis*?) are only tentatively identified, and three (*Coelocerodontus* sp., *Protopanderodus* sp., and *Staufferella* sp.) are identified in open nomenclature because taxonomically critical elements of their skeletal apparatuses have not yet been recovered, or because they represent undescribed species, or because there are problems in the taxonomy of the groups to which they belong that cannot be solved by study of the specimens at hand. The remaining 22 species, however, are all well-known Middle and Late Ordovician taxa, the majority of which have been thoroughly discussed in the recent literature.

Collections from the Corbin Ranch Submember and the lower part of the Viola Springs Formation at Alberstadt's section D (table 1) have yielded nearly 11,000 specimens, which are assignable to 17 species of 14 conodont genera. Eighty-three percent of these specimens, however, represent *Phragmodus undatus* Branson and Mehl (pl. 3, fig. 12), *Plectodina aculeata* (Stauffer) (pl. 2, figs. 4, 8, 10, 12, 13, 17), and *Plectodina tenuis* (Branson and Mehl) (pl. 3, figs. 10, 14–16, 18, 19), which are characteristic components of late Middle and Late Ordovician conodont faunas in the eastern Midcontinent province of North America (Sweet, 1979a). Of the remaining specimens, 9 percent represent such species as *Belodina compressa* (Branson and Mehl), *B. confluens* Sweet, *Dapsilodus mutatus* (Branson and Mehl), *Drepanoistodus suberectus* (Branson and Mehl), fibrous conodonts, *Panderodus gracilis* (Branson and Mehl), *Polyplacognathus ramosus* Stauffer, *Protopanderodus* sp., *Staufferella* sp. (pl. 2, figs. 1, 3, 6), and *Coelocerodontus* sp. As with species of *Phragmodus* and *Plectodina*, these species are all best known from North American Midcontinent Ordovician faunas.

Eight percent of the Corbin Ranch and lower Viola Springs specimens represent species of *Amorphognathus* (e.g., pl. 3, figs. 3, 6), *Icriodella superba* Rhodes, *Periodon grandis* (Ethington) (pl. 3, figs. 11, 17), and *Rhodesognathus elegans* (Rhodes), which are not uncommon in Middle and Upper Ordovician rocks of the North American Midcontinent province but which are characteristic of, and more widespread in, contemporaneous strata in the North Atlantic province.

Conodonts from Alberstadt's section D represent a faunal association that is essentially identical in its composition to that of the Trenton Group of New York and Ontario (Schopf, 1966); the Lexington Limestone and overlying Cincinnati Group strata of Kentucky, Ohio, and Indiana (Sweet, 1979a); and the Galena Group of northern Iowa and adjacent Minnesota (Ethington, 1959; Webers, 1966).

Collections from the upper Viola Springs Formation and the Welling Formation at Alberstadt's section F (= OSU 80SA) have yielded nearly 5,000 specimens, which represent 24 species of 15 genera (table 2). About 98 percent of the specimens in these upper Viola Group collections are North American Midcontinent forms; the remainder represent typical North Atlantic species (*Amorphognathus superbus*?, *Icriodella superba*, *Periodon grandis*). However, the composition of the Midcontinent component of the upper Viola Group conodont fauna differs substantially from that in the Corbin Ranch–lower Viola Springs. That is, *Phragmodus undatus*, which dominates in the lower Viola Group, is represented by only a single specimen in the upper Viola; *Plectodina tenuis*, which accounts for only 2 percent of the lower Viola Group fauna, accounts for about 40 percent of the upper Viola Group conodonts; *Panderodus gracilis*, which is rare in the lower Viola Group, is represented by some 30 percent of the specimens from the upper Viola; and specimens of *Belodina*, *Culumbodina* and *Pseudobelodina*, which are rare or absent in the lower Viola Group, are present thoughout the upper Viola and constitute more than 11 percent of its fauna.

In the eastern Midcontinent province, faunas

13.4	14.9	16.4	18.0	19.5	21.0	33.8	35.3	36.9	38.4	39.9	41.4	43	44.5	46.0	47.5	49.1	50.6	52.1	53.6	55.1	56.7	58.2	59.7	61.3	62.8	64.3	65.8	67.4	68.9	70.4	71.6
1	—	1	1	1	—	—	8	1	—	—	2	—	—	—	—	—	—	1	—	—	2	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	3	10	3	2	2
—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	2	—	3	7	—	1	—	—	3	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	1	—	—	1	—	—	2	—	—
23	15	11	35	10	—	8	39	2	—	2	7	6	11	57	3	1	18	41	22	5	16	2	6	18	8	20	23	42	11	13	2
—	—	—	—	1	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	1	—	—	—	—	—	—
—	—	—	20	—	6	—	—	—	1	—	—	1	2	6	1	5	6	53	6	—	7	—	10	3	1	6	7	15	2	2	3
4	2	2	2	4	—	—	4	—	—	—	—	—	5	2	—	15	2	25	19	—	6	1	2	3	—	1	3	5	—	—	—
225	269	234	166	226	57	85	681	47	5	21	136	176	95	491	105	40	177	392	145	56	147	11	61	137	113	102	53	129	30	25	1
2	10	3	32	1	11	3	17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	1	5	35	8	13	—	21	—	—	2	18	7	1	—	—	11	4	15	13	—	10	1	1	4	6	11	14	20	—	3	—
—	—	—	—	—	—	—	—	—	—	—	—	2	1	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	5	—	—	1	—	—	—	—	3	1	—	1	—	1
—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	1	1	—	—	1	—	1	—	1	1	—	1	—	—	—	—	—

TABLE 1.—DISTRIBUTION AND FREQUENCY OF CONODONTS IN ARBUCKLE MOUNTAINS SECTION D

(Sample numbers indicate meters above base of section)

Species \ Sample	OSU 72SJ → 0	1.5	3	4.6	Oberg (1966) → 5.8	6.2	6.4	7.3	8.8	10.3	11.9	13.4	14.9	16.4	18.0	19.5	21.0	33.8	35.3	36.9	38.4	39.9	41.4	43
Amorphognathus tvaerensis?	—	—	—	88	183	—	2	—	—	—	—	1	—	1	1	1	—	—	8	1	—	—	2	—
Belodina compressa	—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Belodina confluens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coelocerodontus sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dapsilodus mutatus	—	—	—	—	17	1	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Drepanoistodus suberectus	—	3	—	36	135	—	1	2	1	2	3	23	15	11	35	10	—	8	39	2	—	2	7	6
"Fibrous" conodonts	13	17	4	2	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1	—	—	1	—	—
Icriodella superba	—	—	—	40	301	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Panderodus gracilis	—	—	—	2	11	—	—	1	—	—	—	—	—	—	20	—	6	—	—	—	1	—	—	1
Periodon grandis	—	—	—	7	149	—	3	1	3	1	1	4	2	2	2	4	—	—	4	—	—	—	—	—
Phragmodus undatus	1	9	—	271	3582	11	34	24	48	45	26	225	269	234	166	226	57	85	681	47	5	21	136	176
Plectodina aculeata	—	2	1	—	16	—	—	—	1	1	—	2	10	3	32	1	11	3	17	—	—	—	—	—
Plectodina tenuis	—	—	—	—	—	—	—	—	—	—	—	—	1	5	35	8	13	—	21	—	—	2	18	7
Polyplacognathus ramosus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Protopanderodus sp.	—	—	—	—	7	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—
Rhodesognathus elegans	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Staufferella sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—

TABLE 2.—DISTRIBUTION AND FREQUENCY OF CONODONTS IN ARBUCKLE MOUNTAINS SECTION F

(Same as Ohio State University locality 80SA)

(Sample numbers indicate meters above base of section)

Species \ Sample	0.3	0.6	77	80	83	86	89	92	96	99	102	105	108	111	117	120	123	128
Amorphognathus superbus?	—	—	—	—	11	7	13	—	2	—	1	—	—	—	—	1	1	—
A. tvaerensis?	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Belodina compressa	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B. confluens	—	—	23	24	25	13	16	21	9	3	29	7	7	—	—	3	—	—
Coelocerodontus sp.	—	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Culumbodina occidentalis	—	—	—	1	—	—	—	1	1	—	—	—	—	—	—	—	—	—
C. penna	—	—	—	—	—	3	3	6	6	3	6	2	2	10	—	11	—	—
Dapsilodus mutatus	—	35	9	8	23	9	4	14	—	4	—	1	3	—	—	1	1	—
Drepanoistodus suberectus	3	12	42	44	74	37	51	57	16	57	53	22	63	11	4	58	1	—
Icriodella superba	—	—	—	—	1	—	—	—	—	9	—	—	—	—	—	—	—	—
Panderodus gracilis	—	8	112	126	219	132	164	136	30	51	109	56	90	82	21	124	42	14
P. panderi	1	—	6	16	10	20	16	9	8	—	8	5	23	6	1	28	6	—
Periodon grandis	—	7	4	27	—	—	—	—	—	4	5	—	5	2	—	—	—	—
Phragmodus undatus	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Plectodina tenuis	—	2	212	57	219	285	476	251	34	48	52	64	183	30	14	65	1	—
Protopanderodus sp.	—	8	2	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudobelodina dispansa	—	—	14	13	—	—	—	3	—	—	14	—	11	2	—	3	—	—
P. inclinata	—	—	1	—	5	—	15	16	3	2	—	—	2	9	3	—	3	—
P. kirki	—	—	—	—	—	—	—	—	—	—	5	9	6	—	—	23	—	—
P.? obtusa	—	—	—	1	13	8	7	3	1	—	—	—	7	4	—	—	—	—
P. torta	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—
P. vulgaris vulgaris	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Rhodesognathus elegans	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Staufferella sp.	—	—	14	16	31	5	9	8	—	4	7	—	6	3	1	—	—	—

with *Belodina* and abundant *Panderodus* and dominated by *Plectodina* are characteristic of rocks that accumulated in relatively shallower water than did those with abundant *Phragmodus undatus* (Sweet, 1979a). Species of *Pseudobelodina* and especially *Culumbodina* are rare or unknown in the eastern Midcontinent but are well represented in Late Ordovician rocks of the western Midcontinent province (Sweet, 1979b), which also were deposited in relatively shallow water. Thus the upper Viola Group conodonts form a faunal association that is a mixture of forms characteristic of relatively shallow-water strata in the eastern Midcontinent province and forms typical of the widespread shallow-water carbonates of the western Midcontinent province. In this respect, the upper Viola Group conodont fauna is strikingly similar to that of the Late Ordovician "Fernvale" Limestone of the Batesville district, Arkansas, described by Craig (1968).

Correlation

Previous ideas on the age and correlation of the Viola Group were summarized by Alberstadt (1973), who noted that one group of authors (e.g., Taff, 1903; Ruedemann and Decker, 1934; Decker, 1952; Berry, 1960; Alberstadt, 1973) regarded the Viola Group as a record of continuous sedimentation from early "Trentonian" through Edenian and Maysvillian to early Richmondian time, whereas a second group (e.g., Ulrich, 1911; Wengerd, 1948; Twenhofel and others, 1954) regarded the Viola Springs Formation as wholly "Trentonian" (i.e., post-Blackriveran, pre-Edenian) in age and the Welling Formation (or "Fernvale Limestone") as Richmondian. According to the latter interpretation, of course, there would have to be a gap in the record between the Viola Springs and Welling Formations to account for the absence of rocks of Edenian and Maysvillian ages.

Conclusions of both the groups cited above are necessarily generalized and of relatively low biostratigraphic resolution, for they have been based mostly on broad qualitative comparisons of the distribution of faunal elements such as graptolites or brachiopods between widely separated sections within which the vertical distribution of the faunal elements compared is not known in detail. For the conodonts described in this report, however, and for those known from presumably contemporaneous Ordovician strata elsewhere in the North American Midcontinent province, data on the stratigraphic ranges of species are available in terms of objective linear measure, rather than in terms of aggregate lithostratigraphic units. These data permit a more quantitative approach to correlation of the Viola Group and other Ordovician strata.

The graphic method of correlation is used in this report to effect a correlation between the Viola Group and other Ordovician rocks in the North American Midcontinent province. This method was described in detail by Shaw (1964) and was discussed more recently by Miller (1977) and Sweet (1979b, 1979c). The procedure has not been widely used by stratigraphers, however; hence its application in interpreting the data at hand merits somewhat fuller discussion than might otherwise be necessary.

If data on the range of the same fossil species in two or more stratigraphic sections are available in terms of objective linear measure (e.g., "from 1.5 to 10.5 m above the base of the section"), those data sets can be compared visually by plotting them against one another on a simple two-axis graph. In text-figure 18A, for example, ranges of conodont species in Alberstadt's section D, summarized in the left-hand column of table 3, have been plotted on the Y-axis against data on the ranges of the same species in a "composite standard section," given in the right-hand column of table 3. Derivation of the latter data is explained in a later paragraph. In text-figure 18A, dots are used to plot the positions of range-bases, and crosses to plot range-tops. Numbers by dots and crosses identify the species listed in table 3. Thus, the lowest occurrence of species 4 (*Belodina confluens*) is plotted by a dot at X = 1029, Y = 64.3; the highest occurrence of species 16 (*Plectodina aculeata*) is plotted as a cross at X = 1003, Y = 35.3.

There is a good deal of dispersion in the array of points plotted in text-figure 18A. However, range-tops (crosses) plot on or to the right of, and range-bases (dots) on or to the left of, a line drawn through T16 and B4. This phenomenon is merely the graphic expression of common biostratigraphic experience. That is, ranges of fossil species even in adjacent stratigraphic sections tend to vary considerably in the context of those of the other species with which they are associated. In the example at hand, the section plotted on the X-axis is a summary of information from a large number of local stratigraphic sections; hence the ranges of species in it probably approach the total stratigraphic ranges of those species more closely than do the local ranges established in section D. Therefore, dots above and to the left of the line drawn through T16 and B4 identify the first occurrences of species that appear earlier in the composite standard section than at section D; and crosses below and to the right of the line identify the range-tops of species that range higher in other sections. T16 and B4 have been used to define the linear interface between these groups of points, and this may be taken to indicate that the biologic "epochs" they represent are the ones that are best located in section D, at least in the context of data from the sections that have contributed to the one plotted on the X-axis.

TABLE 3.—RANGES OF CONODONTS IN SECTIONS D AND F OF ALBERSTADT (1973)

(Composite-standard ranges derived by graphic correlation of sections in Cincinnati region (Sweet, 1979a), northern New York (Schopf, 1966), southeastern Minnesota (Webers, 1966), and western Midcontinent province (Sweet, 1979b)

(Ranges are in meters above bases of respective sections)

Species	Section D	Section F	Composite standard ranges
1. *Amorphognathus superbus?*	–	83–123	1028–1148
2. *A. tvaerensis?*	4.6–56.7	0.3	947–1028
3. *Belodina compressa*	4.6–35.3	0.3	887–1027
4. *B. confluens*	64.3–71.6	77–120	1029–1166
5. *Coelocerodontus* sp.	43.0–61.3	0.6	?
6. *Culumbodina occidentalis*	–	80–96	1101–1151
7. *C. penna*	–	86–120	1094–1164
8. *Dapsilodus mutatus*	5.8–68.9	0.6–123	744–1125
9. *Drepanoistodus suberectus*	1.5–71.6	0.3–123	732–1285
10. "Fibrous" conodonts	0.0–39.9	–	–
11. *Icriodella superba*	4.6–62.8	83–99	959–1198
12. *Panderodus gracilis*	4.6–71.6	0.6–128	722–1271
13. *P. panderi*	–	0.3–123	732–1283
14. *Periodon grandis*	4.6–67.4	0.6–111	760–1134
15. *Phragmodus undatus*	0.0–71.6	0.3–120	952–1287
16. *Plectodina aculeata*	1.5–35.3	—	800–1003
17. *P. tenuis*	14.9–70.4	0.6–123	983–1277
18. *Polyplacognathus ramosus*	43.0–46.0	–	931–1030
19. *Protopanderodus* sp.	5.8–71.6	0.6–80	–
20. *Pseudobelodina dispansa*	–	77–120	974–1263
21. *P. inclinata*	–	77–123	1138–1263
22. *P. kirki*	–	102–120	1105–1254
23. *P.? obtusa*	–	80–111	1105–1138
24. *P. torta*	–	108	1105–1166
25. *P. vulgaris vulgaris*	–	89	1103–1270
26. *Rhodesognathus elegans*	41.4–65.8	0.3	978–1180
27. *Staufferella* sp.	35.3–64.3	77–117	–

The straight line defined in text-figure 18A by T16 and B4 is a "line of correlation" (LOC) in Shaw's (1964) and Miller's (1977) terms. It has the equation, $CS = 0.9D + 971$. The slope coefficient of the LOC, 0.9, can be read to mean in this example that each meter of rock in the section plotted on the X-axis (= CS) is represented by only 0.9 m in the section plotted along the Y-axis (= D). The intercept coefficient, 971, can be read to mean that 971 m of rock had already accumulated in the CS section by the time rock accumulation began at D.

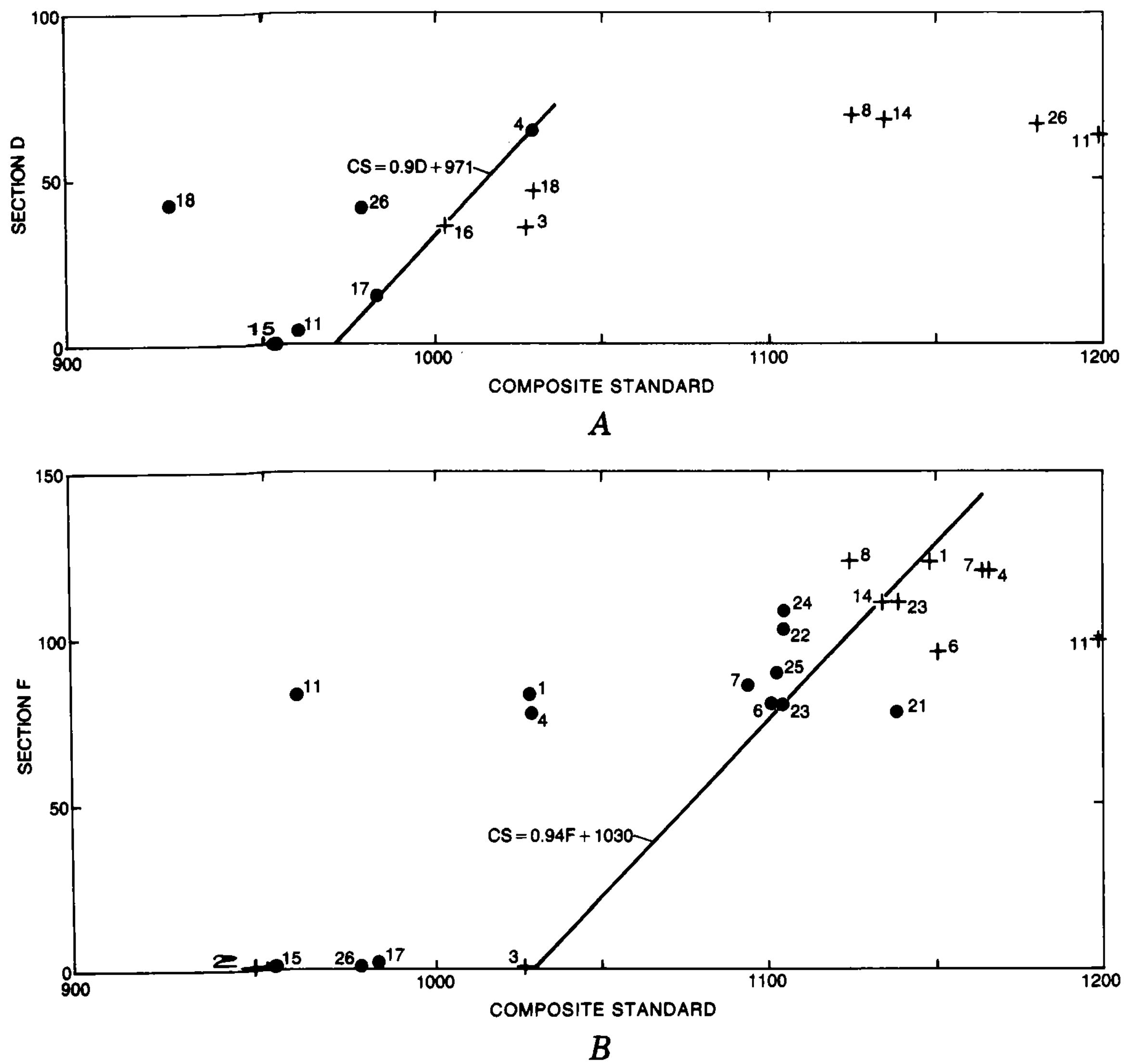
Correlation of section D with the composite standard section can now be stated in terms of values in, or computed from, the equation for the LOC. That is, the base of section D equates with a point in the composite standard section 971 m above its base, and the top of the interval controlled by collections in section D equates with a point 1035.4 m above the base of the composite standard section.

Graphic correlation of section F with the composite standard section is shown in text-figure 18B. In that figure, range-data from table 2 (summarized in the central column of table 3) are plotted on the Y-axis against data on the ranges of the same species in the composite standard section, which are summarized in the right-hand column of table 3. A line through B23 and T14 separates range-bases (dots) and range-tops (crosses). The anomalous position of B21, which plots with the tops, and T8, which plots with the bases, are merely graphic expressions of the fact that, in the context of their faunal associates, species 8 (*Dapsilodus mutatus*) ranges higher in section F than in any of those that have contributed to the composite standard section, and species 21 (*Pseudobelodina inclinata*) makes its debut earlier.

The LOC of text-figure 18B, CS = 0.94F + 1030, indicates that the base of section F equates with a point 1030 m above the base of the composite standard section and that the top of section F equates with a point 1151 m above the base of the composite standard section.

The composite standard section plotted on the X-axis of text-figures 18A and 18B requires some explanation. That is, it is synthetic to the extent that it summarizes range-data that have been compiled graphically from a large number of local stratigraphic sections in the eastern and western parts of the North American Midcontinent province. A detailed discussion of the compilation of the composite standard section is beyond the scope of this report. However, notes on the general mode of its assembly are surely appropriate.

As a first step in compilation of the composite standard section, data on the ranges of conodont species in the sequence of Middle and Upper Ordovician rocks of the Cincinnati region of Indiana, Kentucky, and Ohio given by Votaw (1971) and Sweet (1979a) were plotted against range-data given by Schopf (1966) for the same species in the Middle and Upper Ordovician rocks of northern New York. The equation of the LOC fitted to that graph was then used to convert range-data from the New York section into terms of the Cincinnati-region section. With ranges in the two sections given in terms of the same section, com-

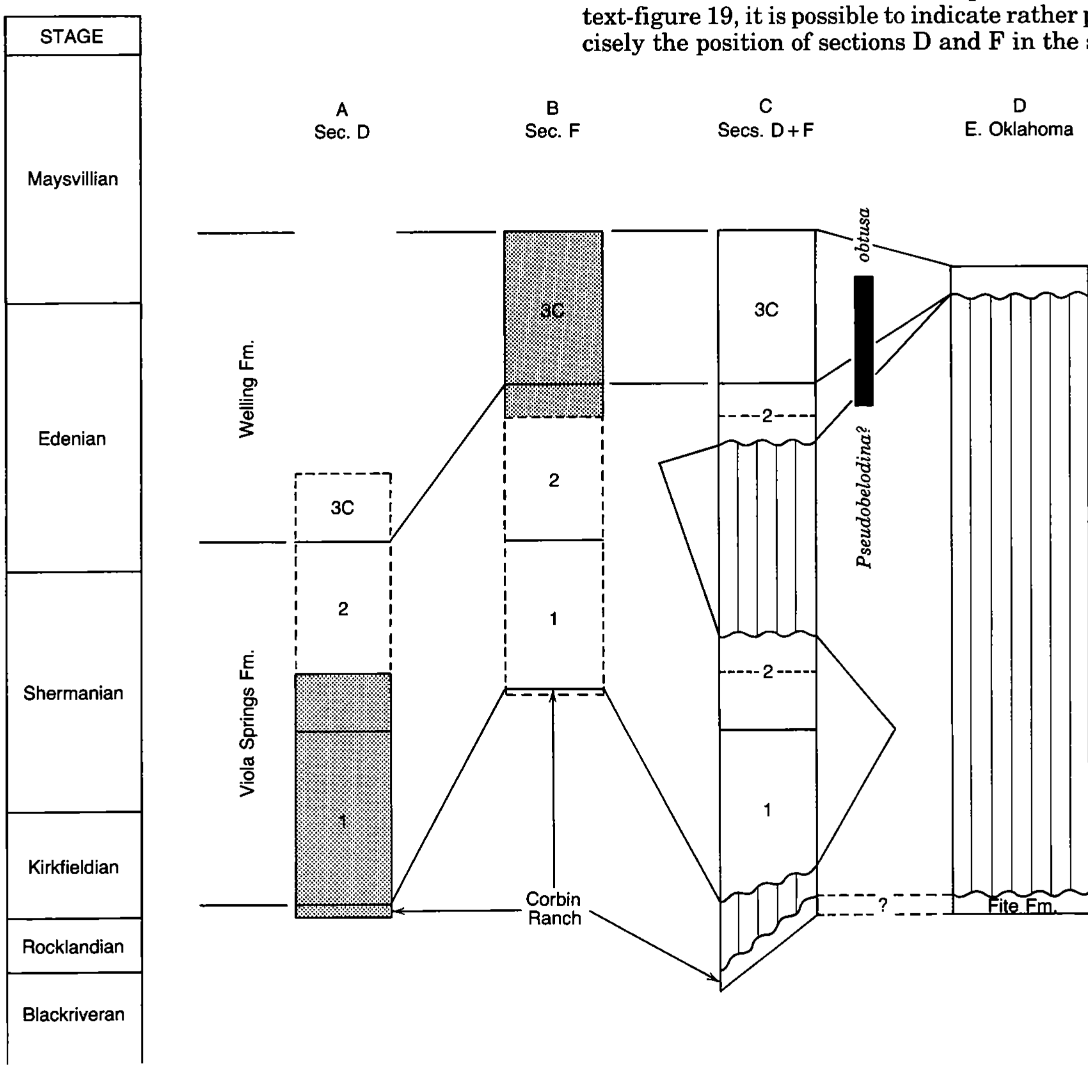


Text-figure 18. Graphic correlation of Arbuckle Mountains sections D (*A*) and F (*B*) and composite standard section, using range-data from table 3. Dots mark range-bases; crosses mark range-tops; numbers by dots or crosses refer to species given those numbers in table 3. Equations are for lines of correlation indicated by arrows. Scales are in meters.

posite ranges were then established by choosing the lowest value for every base and the highest value for every top. The vertical framework of the composite section, of course, was that of the Cincinnati region; but ranges in the composite section were at this stage a combination of values from both the New York and Cincinnati-region sections.

Range-data in the composite section of Cincinnati-region and New York values were then plotted against data given by Carnes (1975) for a section of Middle Ordovician rocks in the Hogskin Valley of eastern Tennessee, chosen because it includes the stratotype of Cooper's (1956) Ashbyan Stage. Subsequently, a composite section including this information was plotted against the one from southeastern Minnesota for which Webers (1966) gave range-data for Middle and Upper Ordovician conodonts. Finally, using the data summarized by Sweet (1979b), information on the ranges of conodonts in Late Ordovician carbonates in South Dakota, Wyoming, Utah, Colorado, New Mexico, and Texas was added to the composite section.

The composite standard section, assembled in the fashion just outlined, not only summarizes range-data for some 94 conodont species but also includes, by projection into a single section, information on the positions of the bases and tops of the stages and series whose stratotypes are included in the various sections compiled. Thus in text-figure 19, it is possible to indicate rather precisely the position of sections D and F in the sta-



Text-figure 19. Correlation of Corbin Ranch and Viola Group strata with stratotypes of Middle and Late Ordovician stages as indicated by graphic correlations in figure 18 (columns *A* and *B*) and figure 20 (column *C*). Right-hand column (*D*) for eastern Oklahoma shows probable stratigraphic position of Fite and Welling Formations discussed in text. Numbered divisions of Viola Springs and Welling Formations in columns *A*, *B*, and *C* are lithic units of Alberstadt (1973).

dial framework customarily used in North America for rocks of late Middle and early Late Ordovician age.

The chronostratigraphic arrangement of sections D and F suggested in text-figure 19 merits careful inspection and additional comment before it is accepted as a reasonable solution to the biostratigraphic problem at hand. First, it should be noted that the intervals closely controlled by collections in the two sections (stippled in text-fig. 19) are mutually exclusive. Consequently, the correlation in text-figure 19 of parts of those sections above or below the controlled intervals depends on two assumptions: (1) that the relative rates of rock accumulation in uncontrolled parts of the two sections were the same as those in the controlled parts, and (2) that each section is a record of uninterrupted deposition.

The assumption that relative rock-accumulation rates were the same, or closely similar, in the uncontrolled and controlled parts of sections D and F cannot be verified from any data at hand. However, the assumption seems reasonable, because the succession of rock types at the two localities is virtually identical and relative rates in the controlled parts of the two sections are closely similar (0.9 and 0.94).

The assumption that sections D and F are records of uninterrupted deposition can be challenged, however. That is, Cooper (1956) and Harris (1957) both interpreted the contact between the Viola Group and the underlying Corbin Ranch Submember of the Bromide Formation as a disconformity that represents a significant hiatus. Jenkins (1969) also identified a significant break in the chitinozoan succession in the upper Viola Springs Formation at a level 40–60 feet (12.2–18.3 m) below the base of the superjacent Welling (or "Fernvale") Formation in a section at Sycamore Creek, in Johnston County, Oklahoma. Jenkins interpreted this break to indicate a "significant hiatus near the top of the Viola–Fernvale unit" and commented that "uppermost Viola–Fernvale strata are substantially younger than the beds immediately below." It is possible, of course, that the reputedly disconformable Corbin Ranch–Viola Springs contact in section D and the postulated hiatus in the upper Viola Springs at a locality near section F are the results of ecologic changes and thus do not signify interruptions in the depositional record. However, it is certainly worth evaluating the effect that either or both of these postulated interruptions might have on the correlations suggested in text-figure 19.

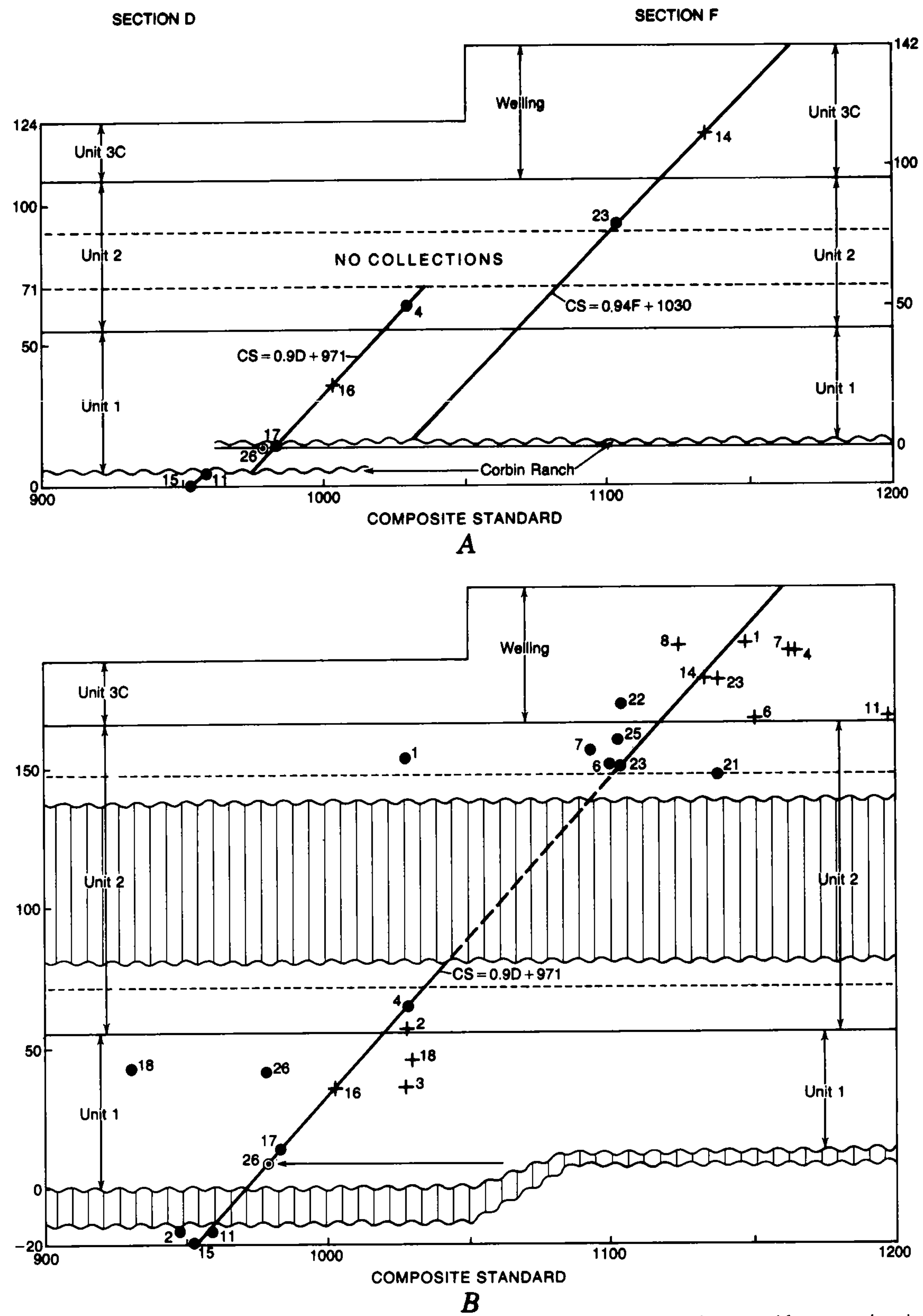
In text-figure 20A, the lines of correlation (LOC's) from text-figures 18 and 19 (and the points that control those lines) are arranged in a single graph. The LOC's are positioned in such a way that the base of Alberstadt's (1973) lithic unit 2 is at the same level in both sections. There is no reason to assume that unit 2 is the same age in the two sections, but it is of the same thickness and lithology at both localities (Alberstadt, 1973) and is thus a convenient datum for comparing the two LOC's.

The LOC's in text-figure 20A are subparallel, but their X-intercepts are separated by 47 m in the composite standard section. This separation may be removed if values that control the LOC for section F are increased by 69 m and the data replotted, as has been done in text-figure 20B. Extension of the LOC from section D now provides a reasonable explanation for the Viola Springs and Welling range-data in sections D and F, but this solution requires a hiatus somewhere in lithic unit 2 for which no physical evidence has yet been described.

If the plotted positions of B15 (*Phragmodus undatus*) and B11 (*Icriodella superba*) in text-figures 18 and 20A are lowered by 20 m, those points also lie on or very close to the downward projection of the LOC from section D. This rearrangement also has been made in text-figure 20B but requires a hiatus between the top of the Corbin Ranch and the base of the Viola Springs in section D. Text-figure 20B also suggests a much more limited gap between the Corbin Ranch and the Viola Springs in section F. That is, the single Corbin Ranch sample from section F contains elements of *Rhodesognathus elegans*, which appears at 978 m in the composite standard section (table 3) and thus sets a lower limit for the top of the Corbin Ranch in section F. The occurrence of *Plectodina tenuis* at the base of the Viola Springs in section F plots almost on the LOC in text-figure 20B, is essentially coincident with the level at which *P. tenuis* appears in section D, and suggests that the base of the Viola Springs in section F is at about 983 m in the composite standard section. Thus the Corbin Ranch–Viola Springs hiatus, if it exists at all, represents less than half as much time at section F as it does at section D.

The arrangement of lithic information, hiatuses, and conodont range-data in text-figure 20B accounts reasonably for the information available from sections D and F; it accommodates the opinions of others on hiatuses at the base of the Viola Springs and within unit 2 of that formation; and it squares with the regional interpretation of Viola Group depositional history presented by Amsden in another section of this report. It should be emphasized, however, that graphic analysis substantiates regional correlation only of the lower 71 m of the Viola Springs Formation in section D and of the upper Viola Springs and Welling Formations in section F. The relations within the currently uncontrolled upper part of the Viola Springs suggested in text-figure 20B appear to be reasonable but will have to be substantiated through study of additional collections.

Text-figure 19 depicts the results of graphic correlation of sections D and F with the composite



Text-figure 20. *A*: Lines of correlation from figure 18 are combined in a single diagram and arranged for comparison by placing base and top of Alberstadt's (1973) unit 2 at same level in both sections. *B*: Points controlling line of correlation of section F and composite standard section are moved upward to lie on projected line of correlation of section D and composite standard section. This maneuver opens a hiatus in Alberstadt's unit 2, although it need not be at position shown. Circled dot labeled *26* marks lowest level possible for top of Corbin Ranch Submember in section F. Corbin Ranch–Viola Group hiatus at section D, indicated in left half of figure, is produced if range-bases of species 11 and 15 are lowered so that they plot on downward extension of line of correlation.

standard section and also includes a column that interprets the rearranged data of text-figure 20B. The portion of the lower Viola Springs Formation controlled in section D by conodont collections is shown to be of Kirkfieldian and early Shermanian age, and the controlled part of the Viola Springs and Welling Formations in section F is shown to be of late Edenian and early Maysvillian age. Rearranged data from text-figure 20B suggest that the Corbin Ranch Submember of the Bromide Formation ranges in age from latest Blackriveran to early Kirkfieldian and that a hiatus representing late Shermanian and early Edenian time may separate the lower and upper parts of lithic unit 2 of the Viola Springs.

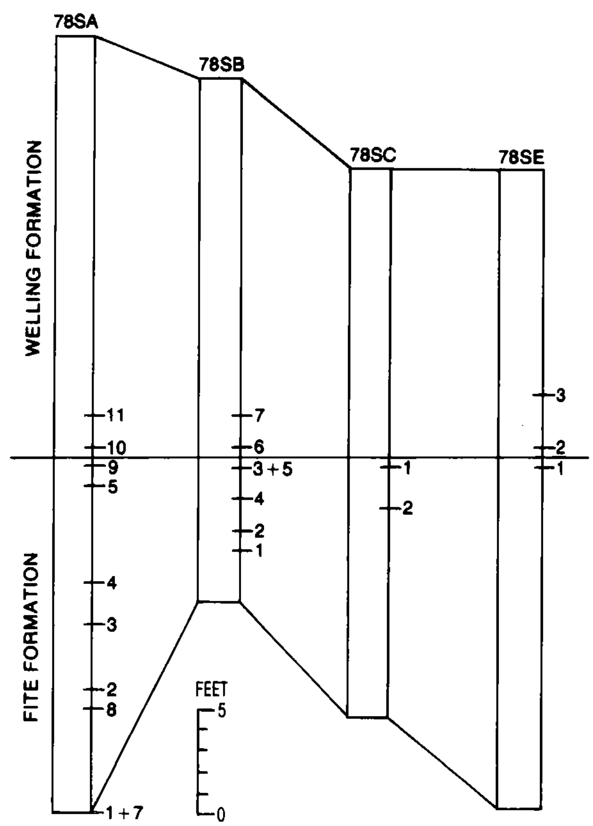
CHEROKEE COUNTY EASTERN OKLAHOMA

The basal meter of the Welling Formation at three localities in Cherokee County, eastern Oklahoma (text-fig. 21) has yielded representatives of the conodont species listed from Welling samples in tables 4 and 5. Most of these species have long stratigraphic ranges in Middle and Upper Ordovician rocks of the North American Midcontinent province, but those starred in tables 4 and 5 are components of conodont fauna 11 of Sweet and others (1971), which is restricted to rocks of mid-Edenian to mid-Maysvillian age (Sweet, 1979b). *Pseudobelodina? obtusa* Sweet, 1979, has the most limited range of all the species starred in tables 4 and 5, and its range is shown schematically in text-figure 19. Although *P.? obtusa* is known from rocks of very early Maysvillian age, it is most abundantly represented in the late Edenian part of the known range of fauna 11. In the Welling Formation of the Arbuckle Mountain localities described in an earlier section of this report, however, *P.? obtusa* is accompanied in all but the uppermost meter of its range by the brachiopod *Lepidocyclus oblongus*, whereas in the basal Welling of Cherokee County, *P.? obtusa* occurs with *Lepidocyclus cooperi*. Because the latter appears in Welling strata above those with *L. oblongus* in the Arbuckles, it is concluded that the basal Welling of eastern Oklahoma is at the top of the range of *Pseudobelodina? obtusa*, and thus that the entire formation in eastern Oklahoma is Maysvillian in age.

Although conodonts are present in all Fite samples processed during this study, they represent an association of species that is difficult to interpret precisely in biostratigraphic terms. *Aphelognathus gigas*, n. sp., *Drepanoistodus suberectus*, *Panderodus gracilis*, and *Plectodina aculeata* range from the base to the top of the Fite. Species with "fibrous" or "neurodontiform" elements are conspicuously represented in the lower half of the formation at locality 78SA (text-fig. 21), but they are not represented in samples from the upper half of the formation. A specifically indeterminate *Oulodus* is apparently the only species restricted to the upper Fite.

Several elements of various "neurodontiform" or "fibrous" species are illustrated on plate 1, but they are not named because the taxonomy of these forms has yet to be worked out in a meaningful way and the material at hand is not suitable for such a study. It is sufficient to point out that species with "neurodontiform" (or "fibrous") elements like the ones illustrated range from the Chazyan through the Edenian and appear to be especially characteristic of very shallow-water, perhaps intertidal or even supratidal, carbonate facies.

Plectodina aculeata (Stauffer) (pl. 2, figs. 4, 8, 10, 12, 13, 17) has a more limited stratigraphic range than the "fibrous" conodonts. It appears first in the lower quarter of the Ashbyan Stage and ranges upward through the Blackriveran and Rocklandian stages to the top of the Kirkfieldian Stage. In the Arbuckles, *P. aculeata* appears some



Text-figure 21. Distribution of conodont-yielding samples in Fite and Welling Formations at four localities in Cherokee County, Oklahoma. Loc. *78SA*: west bank of Horseshoe Bend, NE¼ sec. 36, T. 16 N., R. 22 E. Loc. *78SB*: Qualls area, NE¼SE¼ sec. 35, T. 15 N., R. 21 E. Loc. *78SC*: Deep Hollow, NE¼ sec. 19, T. 16 N., R. 23 E. Loc. *78SE*: east bank of Horseshoe Bend, SE¼ sec. 31, T. 16 N., R. 23 E.

TABLE 4.—DISTRIBUTION AND FREQUENCY OF CONODONTS IN SAMPLES FROM LOCALITY 78SA

(West bank of Horseshoe Bend, NE¼ sec. 36, T. 16 N., R. 22 E., Cherokee County, Oklahoma)

Species \ Sample	1+7	8	2	3	4	5	9	10	11
Amorphognathus sp.	—	—	—	—	—	—	—	2	—
Aphelognathus gigas	15	4	20	71	55	32	—	—	—
Drepanoistodus suberectus	2	2	—	—	—	—	—	7	19
"Fibrous" conodonts	47	32	34	2	—	—	—	—	—
Oulodus sp.	—	—	—	5	—	2	—	—	—
**Panderodus feulneri*	—	—	—	—	—	—	—	66	25
Panderodus gracilis	1	—	2	21	38	15	2	—	—
Panderodus panderi	—	—	—	—	—	—	—	6	7
Plectodina aculeata	6	19	11	10	29	—	5	—	—
**Plectodina tenuis*	—	—	—	—	—	—	—	75	29
**Pseudobelodina kirki*	—	—	—	—	—	—	—	15	23
**Pseudobelodina? obtusa*	—	—	—	—	—	—	—	5	3
Staufferella sp.	—	—	—	—	—	—	—	1	3

*Components of conodont fauna 11 of Sweet and others (1971).

TABLE 5.—DISTRIBUTION AND FREQUENCY OF CONODONTS IN SAMPLES FROM LOCALITIES 78SB, 78SC, AND 78SE

(Qualls area, NE¼SE¼ sec. 35, T. 15 N., R. 21 E., Deep Hollow, NE¼ sec. 19, T. 16 N., R. 23 E., and east bank of Horseshoe Bend, SE¼ sec. 31, T. 16 N., R. 23 E., respectively, all in Cherokee County, Oklahoma)

(Samples 78SB-3 and 78SB-5 are from *Tetradium* bed at top of Fite Formation, but yield conodonts that are mostly typical of Welling Formation above)

Species \ Sample	78SB						78SC		78SE		
	1	2	4	3+5	6	7	2	1	1	2	3
Amorphognathus sp.	—	—	—	1	—	2	—	—	—	—	5
Aphelognathus gigas	115	45	4	—	—	—	36	50	3	—	—
**Belodina confluens*	—	—	—	—	1	2	—	—	—	3	—
**Culumbodina occidentalis*	—	—	—	16	6	—	—	—	—	—	1
**Culumbodina penna*	—	—	—	13	18	4	—	—	—	4	1
Drepanoistodus suberectus	1	2	1	30	10	7	—	1	—	29	—
Oulodus sp.	4	6	8	1	—	—	—	—	3	—	—
**Panderodus feulneri*	—	—	—	114	124	91	—	—	—	43	159
Panderodus gracilis	10	20	8	—	—	—	—	25	3	3	—
Panderodus panderi	—	—	—	4	10	6	—	—	—	5	19
Periodon grandis	—	—	—	—	—	—	—	—	—	1	3
Phragmodus undatus	—	—	—	—	—	—	—	—	—	—	2
Plectodina aculeata	28	6	4	—	—	—	—	—	2	—	—
**Plectodina tenuis*	—	—	—	80	50	46	—	—	—	47	34
**Pseudobelodina kirki*	—	—	—	21	18	9	—	—	—	9	29
**P.? obtusa*	—	—	—	3	2	6	—	—	—	2	—
Staufferella sp.	—	—	—	—	3	1	—	—	—	4	10
Reworked conodonts	—	—	—	18	—	—	—	—	—	—	—

*Components of conodont fauna 11 of Sweet and others (1971).

distance below the base of the Corbin Ranch Submember and ranges upward to a level some 30 m above the base of the Viola Springs Formation.

No species of either *Aphelognathus* or *Oulodus* has yet been described from Middle Ordovician rocks of the North American Midcontinent province older than Rocklandian in age. However, the Fite specimens here assigned to *Aphelognathus gigas*, n. sp. (pl. 2, figs. 16, 18, 19–22), and *Oulodus* sp. (pl. 1, figs. 1–3, 7, 8) are quite different from either *Aphelognathus kimmswickensis* Sweet, Thompson and Satterfield, 1975, or *Oulodus serratus* (Stauffer, 1932), the oldest previously known representatives of *Aphelognathus* or *Oulodus*. Thus it is not possible to assign these species great biostratigraphic importance at this time. It may be of interest to point out, nevertheless, that *A. gigas* appears to be more closely related to the stock within *Aphelognathus* that includes *A. grandis*, the type species, than to the stock typified by *A. kimmswickensis*. The earliest known representatives of the *A. grandis* stock are from rocks of mid-Shermanian age in Kentucky (Sweet, 1979a).

Elements that might have occupied the M positions in the skeletal apparatus of *Oulodus* sp. have not been identified in Fite collections at hand, so that species cannot be compared meaningfully with previously described ones. The species is clearly not *O. serratus*, however, because its apparatus includes prioniodiniform, rather than oulodontiform, elements in the PA position. In that respect,the apparatus of *O.* sp. is closer in its architecture to that of *O. oregonia* (Branson, Mehl and Branson) (including *O. subundulatus*) and related Shermanian and Cincinnatian species than to that of *O. serratus*. The oldest known occurrence of *O. oregonia* is in rocks of early Shermanian age in Kentucky (Bergström and Sweet, 1966; Sweet and Schönlaub, 1975; Sweet, 1979a).

In summary, the occurrence of *Plectodina aculeata* throughout the Fite suggests that the formation is no younger than Kirkfieldian. The presence of *Aphelognathus gigas*, n. sp., and *Oulodus* sp., which represent genera not known in the Midcontinent province before the Rocklandian and which appear to be most closely related to species that make their debut elsewhere in rocks of early to middle Shermanian age, suggests a Rocklandian or Kirkfieldian age for the Fite. None of the Fite conodonts provides very strong evidence for such an age assignment, however, and the formation might well be appreciably older than just suggested. In text-figure 19, the Fite is shown to be a lateral equivalent of the Corbin Ranch Submember of the Pooleville Member of the Bromide Formation. The Corbin Ranch is certainly no older than late Blackriveran, because *Phragmodus undatus* appears at its base; and it can be no younger than earliest Kirkfieldian if the position of the base of the superjacent Viola Springs Formation is where it is placed in text-figures 19 and 20B. Except for *Plectodina aculeata*, however, the Corbin Ranch and Fite have no other stratigraphically significant conodonts in common.

Attention also should be directed to the occurrence of a large number of conodonts in samples 78SB-3 and 78SB-5, from the *Tetradium* bed at the top of the Fite at locality 78SB (text-fig. 21; table 5) that represent species otherwise characteristic of the directly overlying Welling Formation. Because those conodonts are exceptionally well preserved and occur in abundance, it was initially concluded that the top bed of the Fite, like the superjacent Welling, was late Edenian or early Maysvillian in age. Subsequent reexamination of the beds at locality 78SB from which samples 78SB-3 and 78SB-5 were collected has led Amsden to conclude that the conodonts are probably Welling forms that have been introduced into the uppermost Fite along fissures and solution channels that were formed during the interval of exposure and induration that produced the unconformity that now separates the Fite and Welling Formations.

PALEONTOLOGY

Most of the identifiable conodonts in available collections from the Fite, Viola Springs, and Welling Formations represent well-known species that have been adequately described and illustrated in the recent literature. Therefore, illustrations of typical representatives of these species are assembled in plates 1–3, but no descriptions of them are included.

Species with "fibrous" (or neurodontiform) skeletal elements are well represented in samples from the lower half of the Fite Formation of eastern Oklahoma, and a number of typical forms are illustrated in figures 4–6 and 9–21 on plate 1. Taxonomy of the "fibrous" conodonts has yet to be worked out in a meaningful way, however, so no systematic descriptions of the Fite elements are included in this report. It may be noted, nevertheless, that the elements shown in figures 5, 15, 17, 18, and 19 on plate 1 are reminiscent of those that compose the skeletal apparatus of *Erismodus quadridactylus* (Stauffer), which has a wide geographic distribution in the North American Midcontinent province and is known to range stratigraphically from the midpoint of the Ashbyan Stage to the top of the Kirkfieldian Stage.

"Fibrous" elements illustrated in figures 4, 6, 9, 10, 11, 16, and 20 on plate 1 represent the form-genera *Cariodella* and *Curtognathus*, and the originals of figures 12, 13, 14, and 21 on that plate are probably assignable to the form-genus *Polycaulodus*. Obvious similarities in denticulation and in the broad, flat (or slightly convex) basal attachment surfaces of all these elements suggest that they were probably components of the skeletal apparatus of one or two congeneric multielement species. Despite its excellent preservation, however, the Fite material is not extensive enough to serve as the basis for firm judgment about the skeletal architecture or taxonomic assignment of the species represented, which almost certainly form a closely interrelated stock that ranges at least as high stratigraphically as the top of the Kirkfieldian Stage.

Figures 1–3, 7, and 8 on plate 1 are of the components of the skeletal apparatus of a species of multielement *Oulodus* Branson and Mehl. Because the collections available do not include elements that might have occupied the Sa or M positions in the apparatus, it is not possible to identify the species. It is surely not *O. serratus* (Stauffer, 1930) or *O. oregonia* (Branson, Mehl, and Branson, 1951), because the Sc element (pl. 1, fig. 2) is eoligonodiniform (or bipennate) rather than cordylodontiform (or dolabrate). Further, the PA element is prioniodiniform (or angulate), rather than oulodontiform (or digyrate) as is the case in *O. serratus*. These Fite elements thus probably represent an unnamed species, but no name or diagnosis is given, because the material available is incomplete.

Conodonts from the Welling Formation (pl. 2, 3) are mostly assignable to species that have been discussed in detail in a recent report by Sweet (1979b); hence there is no need to repeat here the information summarized in that study. It is sufficient to note that the specimens are generally well preserved, have a color-alteration index (CAI) of 1, and depart in no significant particulars from the types of the species to which they are assigned.

In collections from the Fite Formation, 450 elements form a recurrent group that appears to represent a previously undescribed and unnamed species of *Aphelognathus* Branson, Mehl, and Branson, 1951. A brief diagnosis and discussion of this new multielement species is appended.

Genus **Aphelognathus** Branson, Mehl, and Branson, 1951
emend. Sweet, 1979b

Aphelognathus gigas Sweet, new species
Pl. 2, figs. 16, 18, 19, 20, 21, 22

Diagnosis.—A species of *Aphelognathus* with a seximembrate skeletal apparatus of dichognathiform (or pastinate) PA elements; aphelognathiform (or angulate) PB elements; zygognathiform (or digyrate) M elements; and a symmetry-transition series of trichonodelliform (or alate) Sa elements with a short denticulate posterior process, zygognathiform (or digyrate) Sb elements, and eoligonodiniform (or bipennate) Sc elements. Denticles of all elements are stout, discrete, and peglike, and those of Sa, Sb, and Sc elements tend to be irregularly aligned. Elements in all positions have deep, capacious basal cavities that extend to process extremities.

Discussion.—As presently interpreted, *Aphelognathus* includes two groups of species. In one—including *A. grandis* Branson, Mehl, and Branson, the type species, *A. divergens* Sweet, *A floweri* Sweet, *A. pyramidalis* (Branson, Mehl, and Branson), *A. shatzeri* Sweet, and *A. shoshonensis* Sweet—denticles of skeletal elements are stout, discrete, peglike, and in most species are slightly to conspicuously irregular in their alignment. Furthermore, elements occupying the M position in the skeletal apparatuses of all species in this group are zygognathiform (or digyrate). In the skeletal apparatuses of a second group of species, which includes *A. kimmswickensis* Sweet, Thompson, and Satterfield, *A. politus* (Hinde), and *A. rhodesi* (Lindström), denticles are regularly aligned, compressed, and tend to be discrete only apically; processes are laterally compressed; M elements are eoligonodiniform (or bipennate) or cyrtoniodontiform (or dolabrate); and Sc elements are cordylodontiform (bipennate or dolabrate) and either lack an anterior process or have an adenticulate flange in that position. Pb elements of the skeletal apparatuses of both groups are ozarkodiniform (or angulate) and exhibit the distinctive gap in the denticle profile just anterior of the cusp that is diagnostic of *Aphelognathus*.

Aphelognathus gigas, n. sp., is clearly assignable to, and is thus the oldest known representative of, the first group, the *A. grandis* stock. However, its skeletal apparatus differs from that of any of the species currently recognized in the *A. grandis* stock in having dichognathiform (or pastinate) pectiniform elements in the PA position. In this respect, the skeletal apparatus of *A. gigas* is like that of *A. kimmswickensis*, the oldest known member of the second major *Aphelognathus* stock. Both *A. gigas* and *A. kimmswickensis* make their first appearance in the upper part of the range of *Plectodina aculeata* (Stauffer), which has dichognathiform (or pastinate) PA elements and bipennate or slightly digyrate M elements, and differs basically from *A. gigas* and *A. kimmswickensis* only in having ozarkodiniform rather than aphelognathiform elements in the PB position.

Distribution and material.—Distribution of the 450 identifiable elements of *Aphelognathus gigas*, n. sp., in collections from the Fite Formation is summarized in table 6. Note that the number of "right" and "left" elements in each position is similar and that the total number of Sb and Sc elements is about twice that of elements thought to have occupied the other four positions in the skeletal apparatus. This suggests that the complete skeletal apparatus of an individual of *Aphelognathus gigas* had no fewer than 16 elements: two Sa, four Sb, four Sc, two M, two PA, and two PB.

TABLE 6.—DISTRIBUTION OF FREQUENCY OF ELEMENTS OF *Aphelognathus gigas*, N. SP., IN SAMPLES FROM FITE FORMATION, CHEROKEE COUNTY, OKLAHOMA

	Element type										
		Sb		Sc		M		PA		PB	
Sample	Sa	R	L	R	L	R	L	R	L	R	L
78SA-1+7	4	3	1	1	1	1	1	1	1	—	1
78SA-8	—	1	1	—	—	1	1	—	—	—	—
78SA-2	3	5	1	3	3	1	—	—	—	3	1
78SA-3	10	7	8	11	9	5	6	3	2	5	5
78SA-4	4	5	8	10	8	2	4	6	6	1	1
78SA-5	4	4	4	5	3	3	1	2	2	2	2
78SB-1	13	18	17	6	12	10	10	10	3	10	6
78SB-2	4	8	7	6	4	4	1	2	2	3	4
78SB-4	—	—	1	—	1	—	1	—	—	1	—
78SC-2	6	4	4	5	3	2	2	2	2	3	3
78SC-1	3	7	6	6	7	4	5	2	4	3	3
78SE-1	1	1	—	1	—	—	—	—	—	—	—
TOTALS	52	63	58	54	51	33	32	28	22	31	26

(Locational notation is after Sweet and Schönlaub (1975): *R*, right-handed element; *L*, left-handed element)

Types.—Syntypes, OSU 35501–35506, inclusive, all from Ohio State University sample 78SA-3, which is from a sample 7 to 9 feet (2.1–2.7 m) below the top of the Fite Formation in a section along the west bank of Horseshoe Bend, NE¼ sec. 36, T. 16 N., R. 22 E., Cherokee County, Oklahoma. Types are in the type collections of the Orton Museum of Geology, Ohio State University.

PART III—THE LATE ORDOVICIAN BRACHIOPOD GENERA *LEPIDOCYCLUS* AND *HISCOBECCUS*

THOMAS W. AMSDEN

Abstract—The Family Lepidocyclidae is emended, and two new subfamilies, Hiscobeccinae and Stegerhynchopinae, and one new genus, *Hiscobeccus*, are described. Lepidocyclid biostratigraphy is described for the region extending from the Arbuckle Mountains of south-central Oklahoma to the Mississippi River.

INTRODUCTION

The lepidocyclid brachiopods here referred to the subfamilies Lepidocyclinae and Hiscobeccinae make up a morphologically compact group of Late Ordovician brachiopods that are widely distributed in the continental interior of the United States. This group is especially well represented in the organo-detrital limestone facies, in which they are usually well preserved and commonly silicified. Earlier studies of Howe (1965–69) and Alberstadt (1973), combined with the present investigation, indicate the potential biostratigraphic value of these brachiopods for zonation and suggest that a more intense biostratigraphic study would be profitable. The present study is primarily concerned with the biostratigraphic distribution of *Lepidocyclus* Wang and *Hiscobeccus* (new genus) in the Late Ordovician limestone belt extending from the Arbuckle Mountain region to eastern Oklahoma, across Arkansas, and along the Mississippi River. The main purposes of the following brief taxonomic discussion are to: (1) propose a revision of the genus *Lepidocyclus*, (2) summarize the relation of this group of brachiopods to other lepidocyclids, and (3) outline the presently known geographic and stratigraphic distribution of the Lepidocyclinae and Hiscobeccinae.

Acknowledgments.—In addition to those individuals cited in the Preface, I wish to thank Dr. G. Arthur Cooper, U.S. National Museum, for reviewing and providing helpful information on lepidocyclid taxonomy. I am also indebted to Dr. W. W. Craig, University of New Orleans, for providing information on key stratigraphic sections in the Batesville district, Arkansas, and to Mr. O. A. Wise, Arkansas Geological Commission, for showing me the Ordovician exposures in that area.

LEPIDOCYCLID TAXONOMY

The family Lepidocyclidae is revised to include one new genus, *Hiscobeccus*, and two new subfamilies, Hiscobeccinae and Stegerhynchopinae.

Cooper (1956, p. 657) proposed the family Lepidocyclidae for rhynchonellaceans with concave deltidial plates and a cardinal process. Ager and others (*in* Moore, 1965, p. 554) suppressed this family as a synonym of Rhynchotrematinae Schuchert, 1913, and in 1978 I (Amsden, 1978, p. 26) failed to recognize the prior usage of Lepidocyclidae and proposed Lepidocyclinae as a new subfamily. I here propose to emend the classification of this family as follows.

Family LEPIDOCYCLIDAE Cooper, 1956, emend.
(=Lepidocyclinae Amsden, 1978)

Type genus.—*Lepidocyclus* Wang, 1949.

Diagnosis.—Rhynchonellaceans with a thick posterior ventral shell wall and deeply impressed muscle area; dental plates obscure and teeth supported largely by the thickened shell wall; septiform cardinal process. Late Ordovician to Early Devonian.

Subfamily LEPIDOCYCLINAE Cooper, 1956, emend.

Type genus.—*Lepidocyclus* Wang, 1949.

Diagnosis.—Strongly lamellose lepidocyclids with deltidial plates. This subfamily includes *Lepidocyclus* Wang, 1949, and *Hypsiptycha* Wang, 1949. Late Ordovician.

Subfamily HISCOBECCINAE Amsden
new subfamily

Type genus.—*Hiscobeccus* Amsden, new genus.

Diagnosis.—Strongly lamellose lepidocyclids that lack deltidial plates. This family includes the Late Ordovician genus *Hiscobeccus* Amsden, new genus.

Subfamily STEGERHYNCHOPINAE Amsden
new subfamily

Type genus.—*Stegerhynchops* Amsden, 1978.

Diagnosis.—Nonlamellose lepidocyclids. This subfamily includes *Stegerhynchops* Amsden, 1978, *Latonotoechia* Havlíček, 1961, *Australirhynchia* Savage, 1978, ?*Sicorhyncha* Havlíček, 1961, and ?*Pleurocornu* Havlíček, 1961. Present information indicates a range from Silurian (Wenlockian) into Early Devonian.

Superfamily RHYNCHONELLACEA Gray, 1848

Family LEPIDOCYCLIDAE Cooper, 1956, emend.

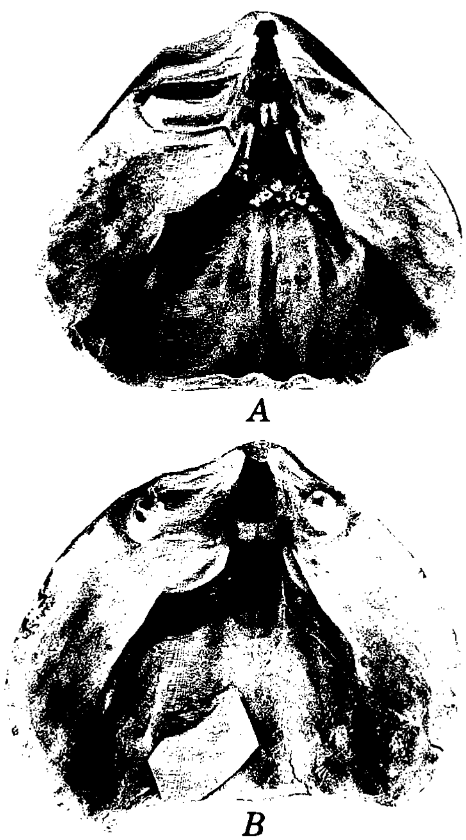
Subfamily HISCOBECCINAE Amsden
new subfamily

Genus **Hiscobeccus** Amsden, new genus

Type species.—*Atrypa capax* Conrad, 1842 (p. 264, pl. 14, fig. 21; text-fig. 22, this report).

Diagnosis.—Strongly costate and lamellose lepidocyclids with deeply impressed ventral muscle scars; dental plates rudimentary or absent; delthyrium open, with no deltidial plates, or rarely with small, incipient plates. Dorsal hinge plate thick, bearing a bladelike cardinal process; supporting septum thick.

Discussion.—The species *capax* has been widely used for Late Ordovician lepidocyclids, although most of these references are too poorly defined to be recognizable. Conrad based his description of *Atrypa capax* on specimens from Late Ordovician strata at Richmond, Indiana. He did not describe or illustrate the internal characters of shells of this species, nor have I been able to locate his type specimen(s). However, I have examined the pedicle interiors from Richmond, Indiana, illustrated by Hall and Clarke (1894, pl. 56, figs. 16, 23; these two valves are shown in text-fig. 22, this report) and here select the specimen figured on their plate 56, figure 23, as the neotype of *Atrypa capax* Conrad, 1842. Hall and Clarke (1894, pl. 56, figs. 17, 18) also illustrated a valve with an open delthyrium, but it is from Iron Ridge, Wisconsin, and is believed to be a representative of *Lepidocyclus*. Howe (1966, p. 263–267, pl. 31, figs. 15–20), who examined numerous specimens from Indiana and Ohio, including topotypes, noted that *capax* has an open delthyrium and a wide delthyrial cavity wholly occupied by the pedicle attachment. He also discussed the external morphology and ornamentation and assigned Oklahoma speci-



Text-figure 22. *Hiscobeccus capax* (Conrad), Richmond, Indiana. Two pedicle valves illustrated by Hall and Clarke (1894, pl. 56, figs. 16, above, *A*, and 23, below, *B*). Specimen shown below (*B*) is here designated the neotype (×2.8). (Field Museum of Natural History, UC 12403, a, b.)

mens from the Welling Formation to *L.? capax*. Alberstadt (1973, p. 53–54, pl. 6, figs. 1–3) described and illustrated Welling specimens from the Arbuckle Mountains and noted that *L. capax* commonly occurs with *Lepidocyclus cooperi* Howe. Alberstadt also discussed the absence of deltidial plates in *capax* but assigned *cooperi* to *Lepidocyclus* without question. *Hiscobeccus capax* is common in the Welling Formation of eastern Oklahoma (Alberstadt, 1973, p. 54; this report, pl. 4, figs. 1a–1c, pl. 7, figs. 2a–2d).

Hiscobeccus is distinguished from other lepidocyclids by its essentially unmodified delthyrium. Both *Lepidocyclus* Wang and *Hypsiptycha* Wang have well-developed deltidial plates (Wang, 1949, pl. 4, fig. D6; pl. 10, fig. B7) that enclose a pedicle tunnel in the postero-ventral part of the valve, whereas *H. capax* has no plate covering the delthyrium (pl. 4, figs. 1c, 1d; pl. 7, fig. 2a; text-fig. 22). In immature specimens of *H. capax* the pedicle beak is nearly erect to slightly inclined (Alberstadt, 1973, pl. 6, fig. 9b; this report, pl. 4, figs. 1a, 1b, 1e), but in large shells the beak is pressed against, or nearly against, the brachial umbo (Conrad, 1842, pl. 14, fig. 21; this report pl. 7, fig. 2d). This contrasts with species of *Lepidocyclus*, such as *L. laddi* Wang (1949, pl. 4, fig. D3), *L. rectangularis* Wang (1949, pl. 5, fig. A3), and *L. cooperi* Alberstadt (1973, pl. 6; figs. 4d, 5b; this report, pl. 4, figs. 2c, 2g), in which the beak is nearly erect. Even in a strongly globose shell, such as *L. oblongus* Howe (1966, pl. 31, fig. 13; this report, pl. 6, figs. 1j, 1s, pl. 7, figs. 1d, 1h, 1j), the beak does not come in contact with the brachial umbo. These differences are undoubtedly related to the presence or absence of deltidial plates.

Species assigned.—*Atrypa capax* Conrad. Many specimens have been referred to this species, but most of these references fail to provide sufficient data for a reliable generic and specific identification. Species from the following formations have been described in enough detail to show their internal and external similarity to *H. capax*: Welling Formation, Arbuckle Mountains and eastern Oklahoma outcrops (Howe, 1966, pl. 31, figs. 15–20; Alberstadt, 1973, pl. 6, figs. 1–3; this report, pl. 4, figs. 1a–1e, pl. 7, figs. 2a–2d); Aleman Limestone, west Texas (Howe, 1967a, pl. 104, fig. 23); "Arnheim" Formation, Tennessee (Howe, 1969, pl. 156, figs. 1–14); Maquoketa Formation, Fort Atkinson Limestone, Iowa, and Richmond Group, Oregonia, Ohio (Howe, 1965, pl. 134, figs. 15, 16, 20).

?Lepidocyclus gigas Wang (1949, p. 16, pl. 10D, figs. 1–5). No internal diagnosis given. I have examined the holotype, which is an articulated shell showing no internal features; because the pedicle beak is pressed tightly against the brachial umbo, this species is provisionally included in *Hiscobeccus*.

Rhynchotrema rowleyi Foerste (1920, p. 201–202, pl. 23, figs. 2A–D), "Maquoketa" Shale, east of Frankford, Missouri. Howe (1969, pl. 156, figs. 21, 22, 23, 24) illustrated the lectotype and two other pedicle interiors, showing an open delthyrium.

Subfamily LEPIDOCYCLINAE Cooper, 1956

Genus **Lepidocyclus** Wang, 1949, emend. Amsden

Type species.—*Lepidocyclus laddi* Wang, 1949 (p. 13, pl. 4D, figs. 1–9).

Diagnosis.—Suboval, generally strongly biconvex lepidocyclids with well-developed deltidial plates.

Discussion.—The deltidial plates are complete, creating a relatively long pedicle tunnel. In at least one species, *L. cooperi* Howe (pl. 4, figs. 2a, 2e, 2k, 2l), the posterior shell wall thickens to further restrict the pedicle opening, perhaps completely closing it in some gerontic individuals. All species presently assigned to this genus are believed to be of Late Ordovician age.

Species assigned..—Lepidocyclus laddi Wang, Maquoketa Formation, Elgin Member, Winneshiek County, Iowa (Wang, 1949, pl. 13, pl. 4D, figs. 1–9; Howe, 1965, pl. 134, fig. 18); Upham and Aleman Limestones, west Texas (Howe, 1967, p. 853, pl. 104, figs. 15, 19, 24).

Lepidocyclus cooperi Howe, Welling Formation, Arbuckle Mountains, Oklahoma (Howe 1966, p. 259–261, pl. 31, figs. 1–6, 8, 9, 10[?]; Alberstadt, 1973, p. 52–53, pl. 6, figs. 4–9); Welling Formation, eastern Oklahoma (Alberstadt, 1973, p. 53; this report, pl. 4, figs. 2a–2l); "Fernvale" Formation, Batesville district, Arkansas (this report, pl. 5, figs. 1a–1g); Cape Limestone, Jefferson County, Missouri (this report, pl. 5, figs. 2a–2c); Cape Limestone, Monroe County, Illinois (this report, pl. 5, figs. 3a–3i); Fernvale Limestone, Davidson County, Tennessee (Howe, 1969, p. 1339, pl. 155, figs. 10–20, 21[?], 22).

Lepidocyclus erectus Wang, 1949, Maquoketa Formation, Brainard Member, Fayette County, Iowa (Wang, 1949, p. 15, pl. 5B, figs. 1–9).

Rhynchotrema manniensis Foerste, 1909 (p. 315, pl. 7, fig. 4). Howe (1966, pl. 31, fig. 7) illustrated the holotype from the Mannie Shale (Upper Ordovician), Riverside, Tennessee. I have examined the holotype, USNM 87053, which does not show the character of the pedicle delthyrium; Howe (1967, pl. 104, fig. 20) illustrated an end view of the holotype and he (1969, p. 1344) stated that the delthyrium is completely closed by deltidial plates. Aleman and Upham Limestones, west Texas (Howe, 1967, pl. 104, figs. 6–10, 21, 22, 25; pl. 105, fig. 12); Maquoketa Formation, Elgin Member, Iowa (Wang, 1949, pl. 5D, figs. 1–12; Howe, 1965, pl. 134, fig. 17).

?*Lepidocyclus notatus* Wang, 1949 (p. 16, pl. 5C, figs. 1–7), Maquoketa Formation, Fort Atkinson Member, Winneshiek County, Iowa (Wang provided no information on the presence or absence of deltidial plates).

Lepidocyclus oblongus Howe, 1966 (p. 261, pl. 31, figs. 11–14; see also this report, pl. 6, figs. 1a–1v), Cape Limestone, Cape Girardeau, Missouri; lower Welling Formation and uppermost Viola Springs Formation, Arbuckle Mountains, Oklahoma (Alberstadt, 1973, p. 54–55, pl. 7, figs. 1–3); "Fernvale" Limestone, Batesville district, Arkansas (this report, pl. 7, figs. 1a–1s).

?*Rhynchonella perlamellosa* (Whitfield, 1878; 1882, p. 265, pl. 12, figs. 23–25), Delafield and Iron Ridge, Wisconsin. Whitfield gave no information on the internal characters, but Hall and Clarke (1894, pl. 51, figs. 17, 18) illustrated a pedicle interior from Iron Ridge, Wisconsin, which has deltidial plates. I have examined the Maquoketa specimen of ?*H. perlamellosus* illustrated by Wang (1949, pl. 6A, figs. 1–5); this is a partial steinkern, and the preservation is not good enough to determine the character of the delthyrium.

Lepidocyclus rectangularis Wang, 1949 (p. 15–16, pl. 5A, figs. 1–8), Maquoketa Formation, Brainard Member, Fayette County, Iowa.

Genus **Hypsiptycha** Wang, 1949

Type species.—Hypsiptycha hybrida Wang, 1949 (p. 17, pl. 10B, figs. 1–9).

Discussion.—As defined by Wang and emended by Howe (1965, p. 1128), *Hypsiptycha* includes small, subtriangular, strongly lamellose lepidocyclids. Wang stated that the dental plates are strong; however, those plates are certainly not conspicuous in the pedicle interior illustrated by him (pl. 10B, fig. 7), nor are they well developed in the pedicle interiors of the various species illustrated by Howe (1965, pl. 134, figs. f-7; 1967, figs. 1, 3, 4). The pedicle scars are not as deeply impressed as in the larger representatives of *Lepidocyclus*, but considering the small size and relatively thinner shell wall of the species referred to *Hypsiptycha*, this genus would seem to be properly included within the Lepidocyclidae. The delthyrium is covered with well-developed deltidial plates, and the brachial valve has a septiform cardinal process. All species presently referred to this genus are assigned a Late Ordovician age.

Species assigned.—Hypsiptycha hybrida Wang, 1949 (p. 17, pl. 10B, figs. 1–9), Maquoketa Formation, Brainard Member, Jackson County, Iowa; Maquoketa Formation, Stockton, Illinois (Howe and Reso, 1967, p. 359).

Rhynchonella anticostiensis Billings, 1865 (1862) (p. 142, fig. 119; Howe and Reso, 1967, p. 359), Vaureal Formation (lectotype), Anticosti Island; Ely Springs Dolomite, Nevada (Howe and Reso, 1967, p. 358, pl. 40, figs. 17–20).

Rhynchonella argenturbicum White, 1877 (p. 75–76, pl. 4, figs. 12a–12e; Howe, 1967, p. 846–847, pl. 103, figs. 1–15, 21, 22), Silver City, New Mexico; Aleman Limestone, west Texas (Howe, 1967, p. 846–847, pl. 103, figs. 1–15).

Rhynchonella neenah Whitfield, 1882 (p. 265, pl. 12, figs. 19–22; Howe, 1967, p. 848, pl. 103, figs. 24, 25), Iron Ridge, Wisconsin; Cutter Limestone.

LEPIDOCYCLID BIOSTRATIGRAPHY OF WELLING, "FERNVALE" AND CAPE FORMATIONS

Welling Brachiopod Faunas

Alberstadt (1973) described and illustrated articulate brachiopods from the Viola Group, based on collections made by him from measured stratigraphic sections in the Arbuckle Mountains. A few of the brachiopods are from the Viola Springs Formation (Alberstadt's stratigraphic units 1 and 2), but most are from the Welling Formation (Alberstadt's stratigraphic unit 3 or "Fernvale"). The following 16 species are represented in the Welling Formation (unit 3) by sufficient specimens to be identifiable with reasonable confidence:

MIDDLE AND UPPER WELLING FORMATION ARBUCKLE MOUNTAINS	WELLING FORMATION EASTERN OKLAHOMA
Hesperorthis rowlandi Alberstadt	X
Glyptorthis glaseri Alberstadt	X
Plaesiomys subquadratus (Hall)	?
P. bellistriatus? Wang	X
P. proavitus (Winchell & Schuchert)	X
Austinella multicostella Alberstadt	X
Platystrophia sutherlandi	X
P. uncinata	X
Diceromyonia cf. *D. tersa* Wang	X
Paucicrura oklahomensis Alberstadt	X
Thaerodonta aff. *T. magna* Howe	X
Strophomena neglecta (James)	
Megamyonia mankini Alberstadt	X
Lepidocyclus cooperi	X
Hiscobeccus capax (Conrad) (=*Lepidocyclus capax*)	X

LOWER WELLING FORMATION AND UPPER VIOLA SPRINGS FORMATION
Lepidocyclus oblongus Howe

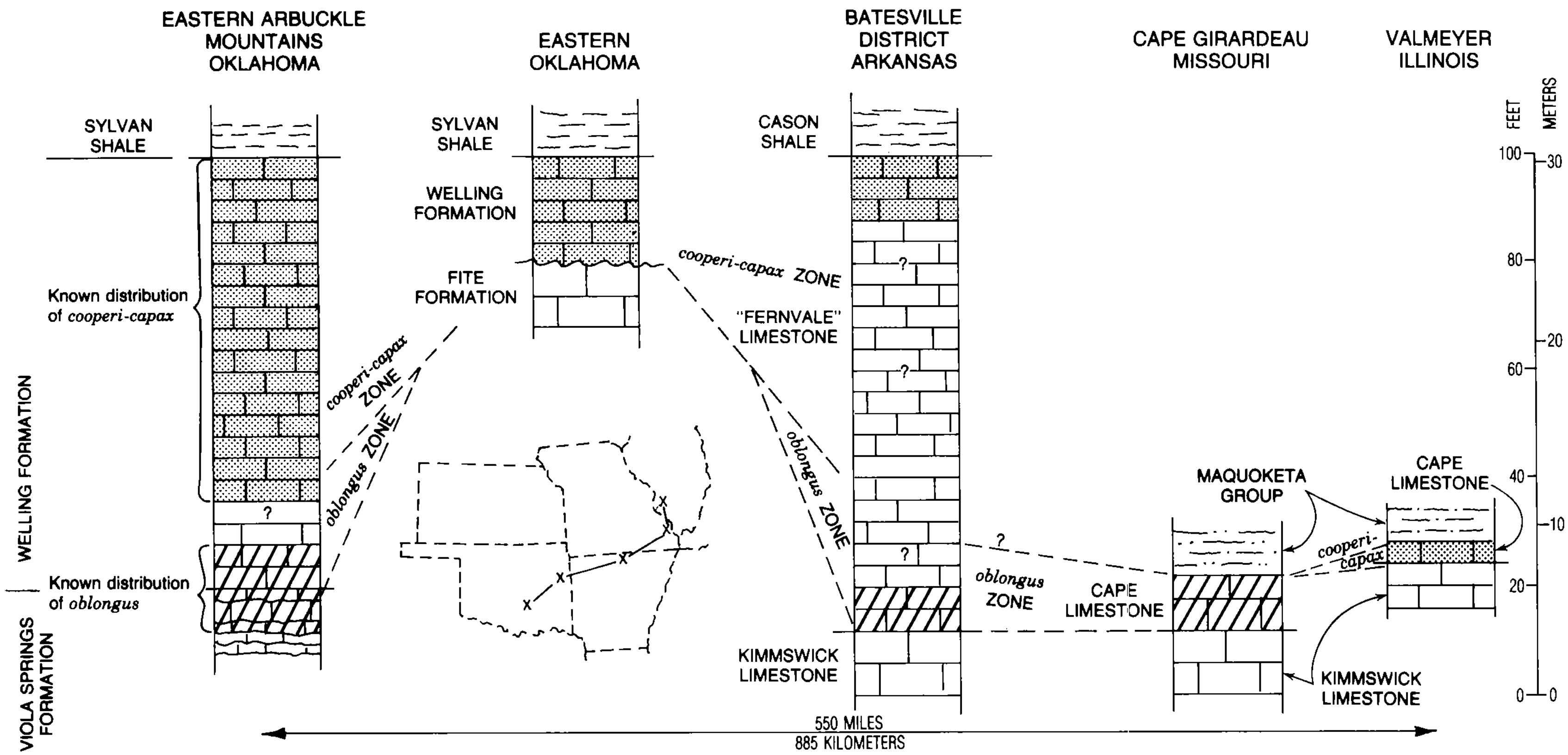
Alberstadt's collections from the middle and upper part of the Welling Formation (unit 3) are from the upper 6 feet of the formation in the eastern Arbuckle Mountains, and from a zone 40 to 60 feet below the top in the western Arbuckle Mountain outcrop area. Thirteen of the species Alberstadt identified were also reported from the Welling Formation (="Fernvale"–Cape Formations) of eastern Oklahoma. *Lepidocyclus oblongus* was found only in the lower 20 feet of the Welling (unit 3) and upper 2 to 3 feet of the Viola Springs (unit 2).

Lepidocyclus–Hiscobeccus Zonation

Hiscobeccus capax (Conrad) was based on specimens from the Richmond Formation, Richmond, Indiana; *Lepidocyclus cooperi* Howe was based on specimens from the Welling Formation ("Fernvale"), Arbuckle Mountains; and *Lepidocyclus oblongus* Howe was based on specimens from the Cape Limestone, Cape Girardeau, Missouri. Alberstadt (1973) described and illustrated specimens of *L. cooperi* and *H. capax* from the middle and upper parts of the Welling Formation, and described and illustrated specimens of *L. oblongus* from the lower Welling and upper Viola Springs, all from the Arbuckle Mountain outcrop area. (I have also collected specimens of *L. oblongus* from the upper Viola Springs Formation at the type locality near Viola Springs; see Part I, Viola Group.) According to Alberstadt (1973, p. 13): "*L. oblongus* occurs only in the basal part of unit 3 [sic] and does not stratigraphically overlap the range of *L. capax* and *L. cooperi*, which occur only in the upper part." Alberstadt did not find *L. oblongus* in the Welling Formation of eastern Oklahoma, but he did collect representatives of this species from the Cape Limestone at Cape Girardeau, Missouri. In addition to *L. oblongus*, the Cape Limestone has a substantial brachiopod fauna that is generically similar to that from the middle and upper part of the Welling beds cited above; however, according to Alberstadt, only two species, *Plaesiomys subquadratus* and *P. proavitus*, are common to both formations.

My collections of brachiopods from the Welling Formation of eastern Oklahoma confirm Alberstadt's observations. A number of well-preserved specimens of *H. capax* and *L. cooperi* (pls. 4, 7) were obtained from several localities by etching blocks of limestone in HCl. No representatives of *L. oblongus* Howe were found, and the basal 1 foot of the Welling Formation yielded a number of specimens of *L. cooperi*. I also collected brachiopods from the Cape Limestone (upper 4 feet) at the type locality in Cape Girardeau, Missouri (Templeton and Willman, 1963, p. 240). Etched blocks from this locality furnished a number of specimens of *L. oblongus* (pl. 6) but no representatives of *H. capax*, *L. cooperi*, or of any other species of lepidocyclid brachiopod were observed.

In 1979 I collected brachiopods from the "Fernvale" Limestone near West Lafferty Creek (NW¼ sec. 10, T. 14 N., R. 8 W.) in the Batesville district of north-central Arkansas. In this stratigraphic section, which was described by Craig in 1975 (p. 66), about 90 feet of "Fernvale" skeletal limestones is overlain by the Cason Shale and underlain by the Kimmswick Limestone. The upper 10 feet of the "Fernvale" has a substantial brachiopod fauna, although the preservation is poor, at least in part as a result of extensive dissolution. Reasonably complete specimens of *Lepidocyclus cooperi* (pl. 5, figs. 1a–1g) can, however, be recovered from these upper strata. The only other representatives of *Lepidocyclus* collected from this section are from the lower 3 feet of the "Fernvale," just above the Kimmswick Limestone. These beds yielded many specimens of *L. oblongus*, along with a sparse representation of strophomenids and orthids (pl. 7, fig. 1s). *L. oblongus* is represented by many well-preserved shells including a number of articulated valves, all of which appear to be typical representatives of that species (pl. 7, figs. 1a–1s). These *oblongus* beds are presumably from the same strata that supplied the lower "Fernvale" conodont Fauna 2 reported by Craig (1975, p. 84). This brachiopod zonation can be extended eastward to Cape Girardeau, where the presence of *L. oblongus* in the upper Cape Limestone beds indicates that the upper *L. cooperi–H. capax* zone is missing (pl. 6, figs. 1a–1v; text-fig. 23). These are the strata from which



Text-figure 23. Chart showing biostratigraphic distribution of *Hiscobeccus capax* (Conrad), *Lepidocyclus cooperi* Howe, and *L. oblongus* Howe in Midcontinent region, extending from south-central Oklahoma to Mississippi River. Light stippling shows known range of *cooperi–capax*, and diagonal lines, known distribution of *oblongus*.

Craig (1975, p. 84) reported a conodont fauna similar to that of Fauna 2 from the lower "Fernvale" in the Batesville district.

I also made small brachiopod collections from the Cape Limestone exposures on Interstate Highway 55 near Barnhart, Jefferson County, Missouri (Thacker and Satterfield, 1977, p. 80) and from a quarry near Valmeyer, Illinois (Templeton and Willman, 1963, p. 238). In both outcrops the Cape is overlain by Maquoketa and underlain by Kimmswick, and in both the Cape is thin, about 2 feet at Valmeyer and about 7 feet on I–55. Silicified specimens of *L. cooperi* were recovered at the Valmeyer and I–55 sections (pl. 5, figs. 2, 3), along with questionable representatives of *H. capax*. No representatives of *L. oblongus* were collected from either section, and, according to the zonation discussed above, the Cape beds at these two sections would represent the upper *cooperi–capax* beds, suggestive of some type of onlapping depositional pattern. More intense sampling of these and other outcrops throughout the Midcontinent region is needed before any final conclusions can be reached concerning the brachiopod biostratigraphy of the Welling–"Fernvale"–Cape strata.

Correlation and Age

The Welling Formation ("Fernvale") commonly has been assigned to the Richmondian Stage (Twenhofel and others, 1954, chart 1), largely on the basis of its brachiopod fauna. As noted by Alberstadt (1973, p. 13), the generic suite is similar to that present in the Richmond Group of the Ohio Valley; however, most of the Welling brachiopods are new species, with *H. capax* being the only well-represented Welling species that is also common in the Richmond.

To my knowledge, there is no recent study of brachiopod biostratigraphy for the Cincinnati region, although, according to the faunal summary given by Caster and others (1969, p. 13), *H. capax* is confined to Richmondian strata. No lepidocyclids have been reported from the Edenian–Maysvillian strata in this region, and all the U.S. National Museum specimens from the Cincinnati area recently examined by me (February 1982) appear to be representatives of *H. capax* and from Richmondian strata. The U.S. National Museum collections do not include any specimens of *L. oblongus* from this region, and this species is currently known only from the Arbuckle Mountains of Oklahoma, from north-central Arkansas, and from southeastern Missouri. Howe reported *H. capax* from the Richmondian of Ohio and Indiana, the Montoya Group of west Texas and southern New Mexico, and the Ely Springs Formation of southeastern Nevada (see Lepidocyclid Taxonomy).

The present investigation of lepidocyclid zonation does not extend into the Cincinnati region, but it does suggest that *H. capax* has a fairly restricted biostratigraphic range. Alberstadt (1973, p. 13) tentatively assigned the *H. capax* beds (upper Welling) to the Richmondian and the *L. oblongus* beds (lower Welling, upper Viola Springs) to the Maysvillian. The conodont biostratigraphy discussed in Part II indicates a slightly older Maysvillian age for the *L. cooperi–H. capax* zone (text-fig. 2). Additional biostratigraphic brachiopod studies are needed in the Midcontinent region in order to provide more precise range data on Late Ordovician species.

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PLATES

Plate 1

Fite Conodonts

Figures are SEM micrographs of specimens coated with gold. Numbers prefixed *OSU* refer to the Catalog of the Orton Museum of Geology, The Ohio State University, where the figured specimens are housed.

Figs. 1–3, 7, 8.——*Oulodus* sp. *1*, PB element (oulodontiform), ×70. *2*, Sc element, ×65. *3*, Sa element?, ×110. *7*, PA element (prioniodiniform), ×120. *8*, Sb element, ×120. 1, 3, 7, 8 from sample 78SB-2; 2 from sample 78SB-4. Fite Formation. OSU 35507–35511, inclusive.

Figs. 4–6, 9–21.——"Fibrous" or "neurodontiform" conodont elements representing various form-species of form-genera *Cardiodella*, *Curtognathus*, *Erismodus*, *Microcoelodus*, and *Polycaulodus*. Multielement taxonomy of "neurodontiform" conodonts has not yet been worked out in detail. *4*, ×60 (78SA-3). *5*, ×63 (78SA-2). *6*, ×130 (78SA-2). *9*, ×75 (78SA-7). *10*, ×72 (78SA-7). *11*, ×45 (78SA-1). *12*, ×100 (78SA-8). *13*, ×75 (78SA-8). *14*, ×100 (78SA-8). *15*, ×85 (78SA-8). *16*, ×70 (78SA-8). *17*, ×80 (78SA-8). *18*, ×80 (78SA-1). *19*, ×58 (78SA-8). *20*, ×70 (78SA-7). *21*, ×85 (78SA-3). Lower half of Fite Formation. OSU 35512–35527, inclusive.

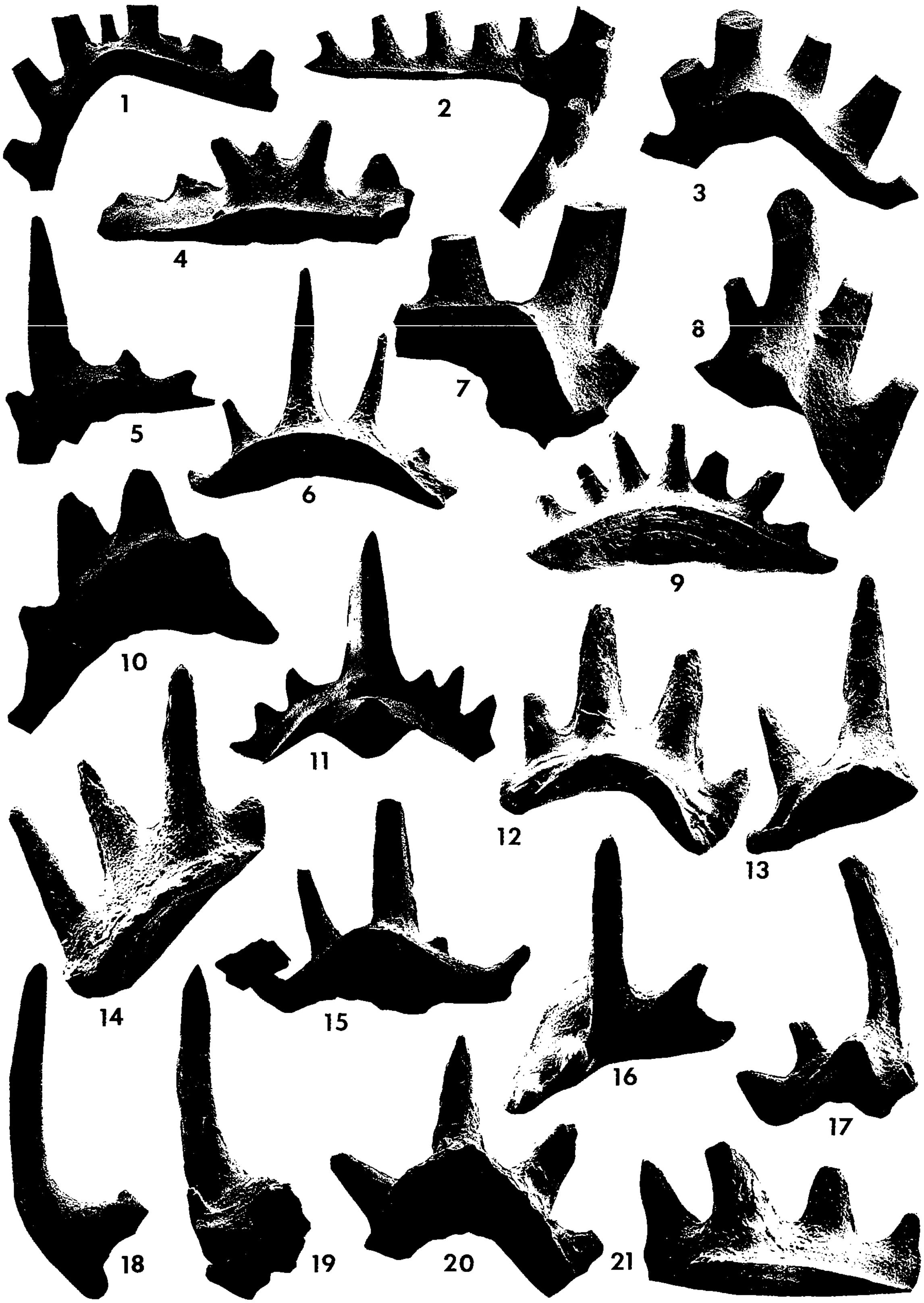

Plate 2

Fite and Welling Conodonts

Figures are SEM micrographs of specimens coated with gold. Numbers prefixed *OSU* refer to the Catalog of the Orton Museum of Geology, The Ohio State University, where the figured specimens are housed.

Figs. 1, 3, 6.—*Staufferella* sp. Three different elements, ×50, ×80, ×65, from sample 78SE-3. OSU 35528–35530, inclusive.

Fig. 2.—*Oulodus* sp. PB element from *Tetradium* Bed of Fite (sample 78SB-3), ×45. OSU 35531.

Figs. 4, 8, 10, 12, 13, 17.—*Plectodina aculeata* (Stauffer). Sc, Sb, Sa, PB, M, and PA elements, ×100, from sample 78SA-1. OSU 35532–35537, inclusive.

Figs. 5, 7, 11, 14, 15.—*Panderodus feulneri* (Glenister). Similiform, falciform, tortiform, asimiliform, and arcuatiform elements, ×60, from sample 78SB-3. OSU 35538–35542, inclusive.

Fig. 9.—*Panderodus panderi* (Stauffer). Falciform element, ×70. Sample 78SB-3. OSU 35562.

Figs. 16, 18, 19, 20, 21, 22.—*Aphelognathus gigas* Sweet, n. sp. Syntypes. *16*, PB element, ×65. *18*, M element, ×75. *19*, Sc element, ×60. *20*, SB element, ×75. *21*, Sa element, ×37. *22*, PA element (dichognathiform), ×80. All from sample 78SA-3 (Fite Formation). OSU 35501–35506, inclusive.

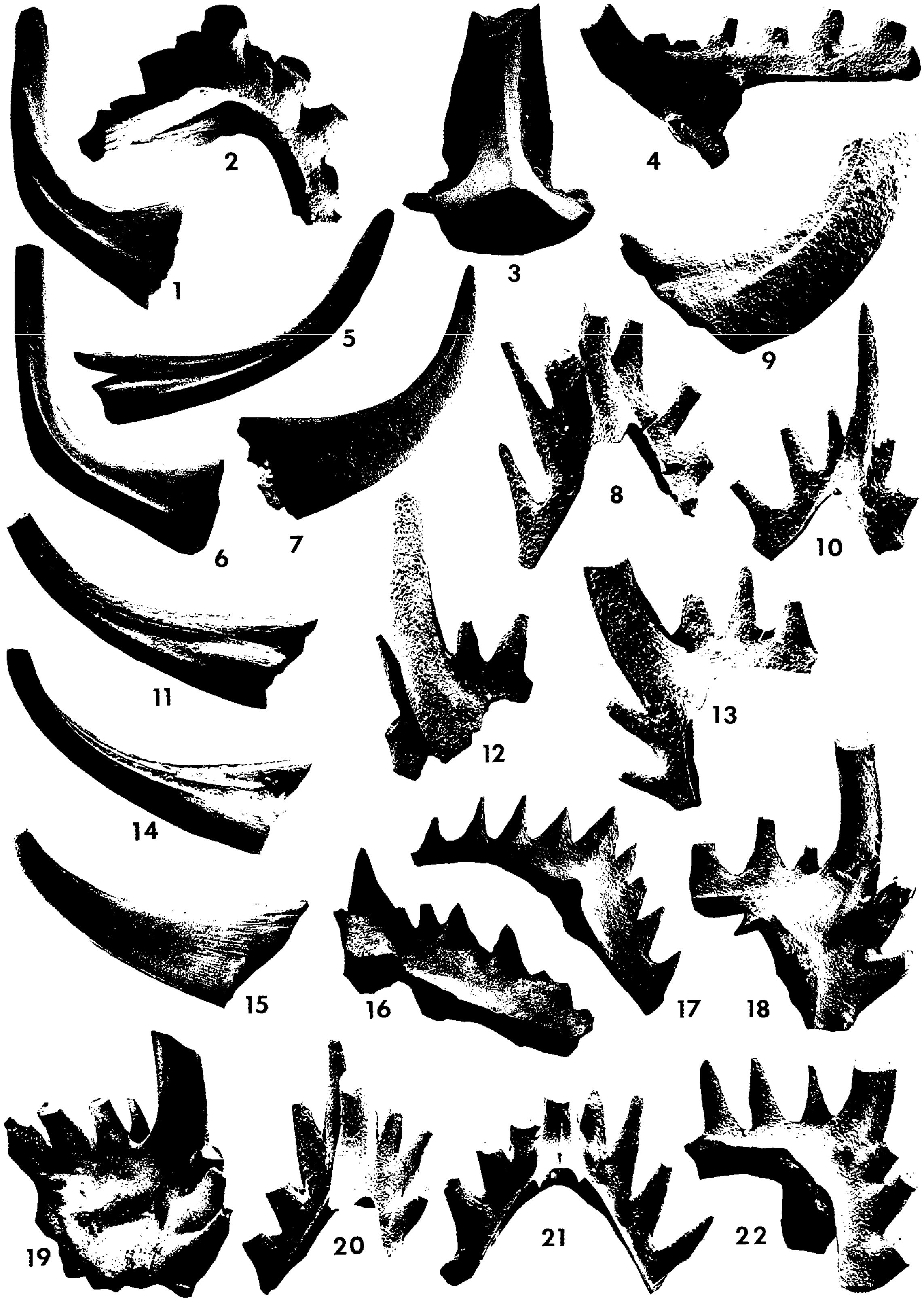
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Plate 3

Welling Conodonts

Figures are SEM micrographs of specimens coated with gold. Numbers prefixed *OSU* refer to the Catalog of the Orton Museum of Geology, The Ohio State University, where the figured specimens are housed.

Figs. 1, 8.—*Culumbodina occidentalis* Sweet. *1*, adenticulate element, ×40, sample 78SB-3. *8*, denticulate element, ×100, sample 78SB-6. OSU 35543, 35544.

Figs. 2, 4, 7.—*Pseudobelodina kirki* (Stone and Furnish). *2*, Sb element, ×55, sample 78SB-3. *4*, P? element, ×80, sample 78SE-3. *7*, Sc element, ×55, sample 78SB-3. OSU 35545–35547, inclusive.

Figs. 3, 6.—*Amorphognathus* sp. *3*, amorphognathiform element, ×100, sample 78SB-3. *6*, ambalodontiform element, ×130, sample 78SE-3. OSU 35548, 35549.

Figs. 5, 9.—*Culumbodina penna* Sweet. *5*, knobbed element, ×70, sample 78SB-6. *9*, rastrate element, ×70, sample 78SB-6. OSU 35550, 35551.

Figs. 10, 14—16, 18, 19.—*Plectodina tenuis* (Branson and Mehl). *10*, PA element, ×65, sample 78SB-6. *14*, PB element, ×90, sample 78SB-6. *15*, M element, ×75, sample 78SB-6. *16*, Sb element, ×140, sample 78SB-7. *18*, Sa element, ×100, sample 78SE-3. *19*, Sc element, ×90, Sample 78SB-6. OSU 35552–35557, inclusive.

Figs. 11, 17.—*Periodon grandis* (Ethington). *11*, prioniodiniform element, ×140, sample 78SE-3. *17*, falodontiform element, ×140, sample 78SE-3. OSU 35558, 35559.

Fig. 12.—*Phragmodus undatus* Branson and Mehl. Phragmodontiform element, ×150, sample 78SE-3. OSU 35560.

Fig. 13.—*Pseudobelodina*? *obtusa* Sweet. Adenticulate rastrate element, ×160, sample 78SB-3. OSU 35561.

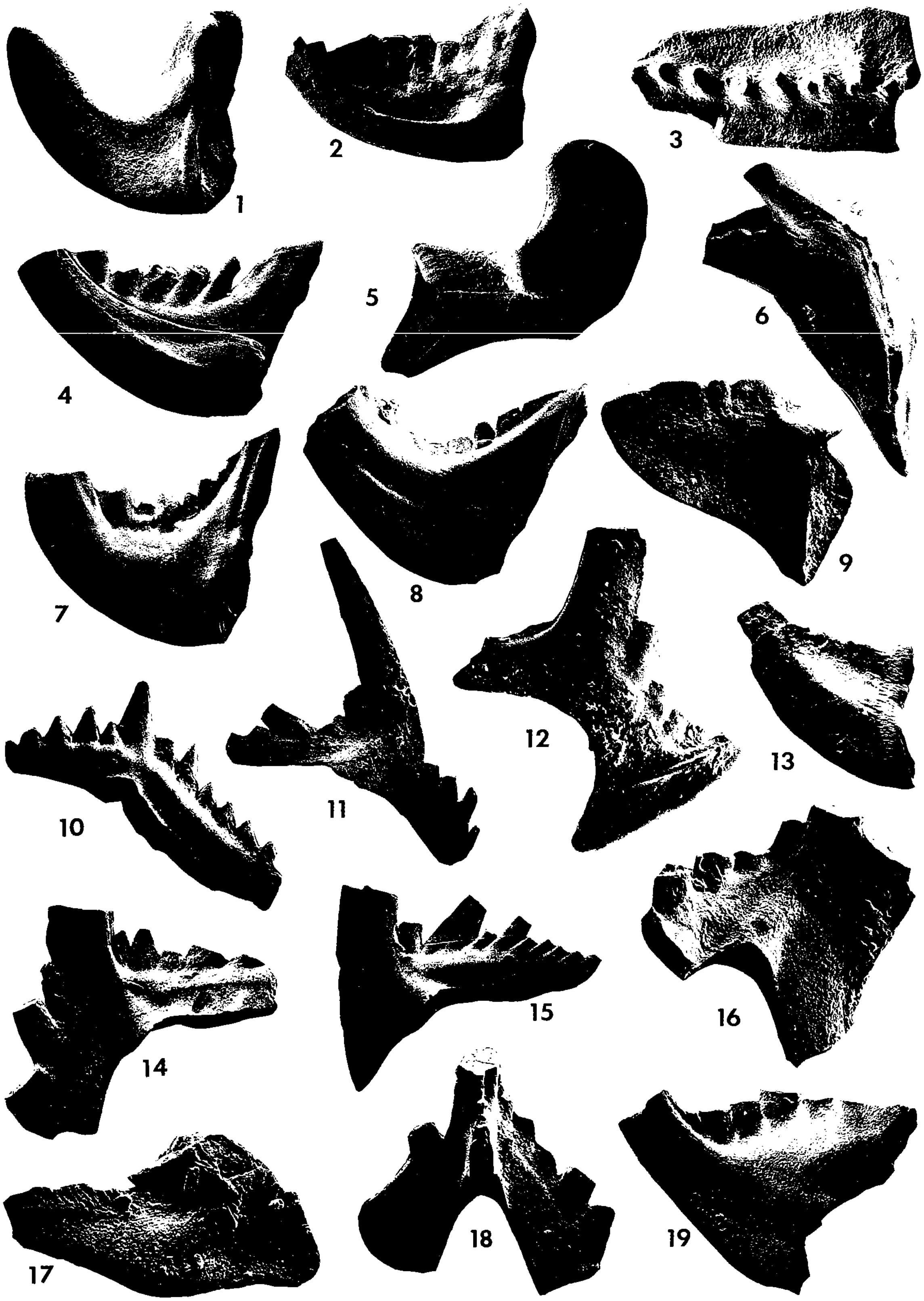
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Plate 4

HISCOBECCUS CAPAX (Conrad), LEPIDOCYCLUS COOPERI Howe

Figs. 1a–1e.—*Hiscobeccus capax* (Conrad). Welling Formation, west bank, Horseshoe Bend, Illinois River, SE¼ sec. 31, T. 16 N., R. 22 E., Cherokee County, Oklahoma.

1a, 1b, 1e, lateral and brachial views (×1) and enlarged view (×3) showing pedicle opening.

1c, pedicle interior (×3), showing open delthyrium.

1d, pedicle interior (×2) of a large valve showing delthyrium and deeply impressed muscle scars.

Other illustrations of *L. capax* on plate 7, figs. 2a–2d.

Figs. 2a–2l.—*Lepidocyclus cooperi* Howe. Welling Formation, west bank, Horseshoe Bend, Illinois River, NE¼ sec. 31, T. 16 N., R. 22 E., Cherokee County, Oklahoma.

2a, pedicle interior (×2), showing pedicle opening, deltidial plates, and deeply impressed muscle scars.

2b–2d, pedicle, lateral, and posterior views (×2) of a moderate-sized shell.

2e, pedicle interior (×2), showing deltidial plates and internal and external openings of pedicle foramen.

2f–2j, posterior, lateral (×2), pedicle delthyrium (×4), anterior, and brachial (×1) views of a large shell.

2k, pedicle interior, showing deltidial plates and muscle scars.

2l, pedicle interior (×4); this is an anterior oblique view to show internal opening of pedicle foramen and its relationship to anterior edge of deltidial plates. Posterior tip of pedicle beak, including part of deltidial plates, is broken.

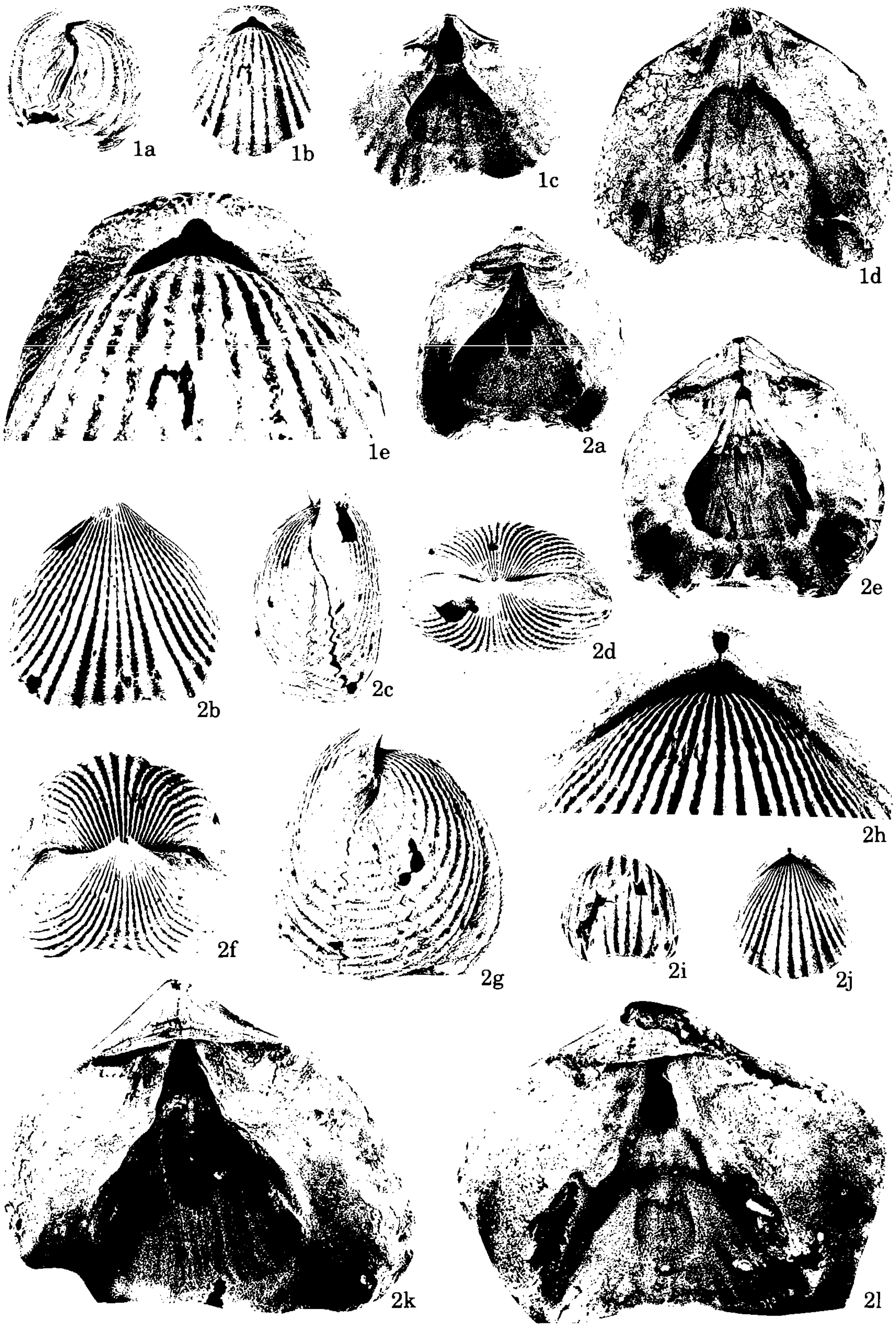
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Plate 5

LEPIDOCYCLUS COOPERI Howe

Figs. 1a–1g.——*L. cooperi* Howe, "Fernvale" Formation, upper 10 feet, east of West Lafferty Creek bridge, SE¼SE¼SE¼ sec. 10, T. 14 N., R. 8 W., Independence County, Arkansas.

1a, 1b, lateral ($\times 2$) and posterior ($\times 1$) views of an incomplete shell.

1c, 1d, 1f, posterior ($\times 1$), lateral, and pedicle ($\times 2$) views of a nearly complete specimen.

1e, pedicle view ($\times 2$).

1g, brachial and pedicle views ($\times 2$) of two valves.

Figs. 2a–2c.——*L. cooperi* Howe, Cape Limestone, upper 3 feet, west side of Interstate Highway 55, 0.6 mile north of Missouri Highway M, Jefferson County, Missouri.

2a–2c, pedicle foramen ($\times 5$), posterior and lateral views ($\times 2$). Specimen illustrated in fig. 2a has complete deltidial plates, of which only outer edge shows.

Figs. 3a–3i.——*L. cooperi* Howe, Cape Limestone, basal 2 feet, Columbus quarry (just above mine entrance), near Valmeyer, Monroe County, Illinois.

3a–3d, 3f, brachial, pedicle, anterior, posterior, and lateral views ($\times 2$) of articulated shell.

3e, pedicle interior ($\times 3$), showing external and internal pedicle opening and deltidial plates.

3g–3i, pedicle, brachial, and lateral views ($\times 2$) of slightly smaller shell.

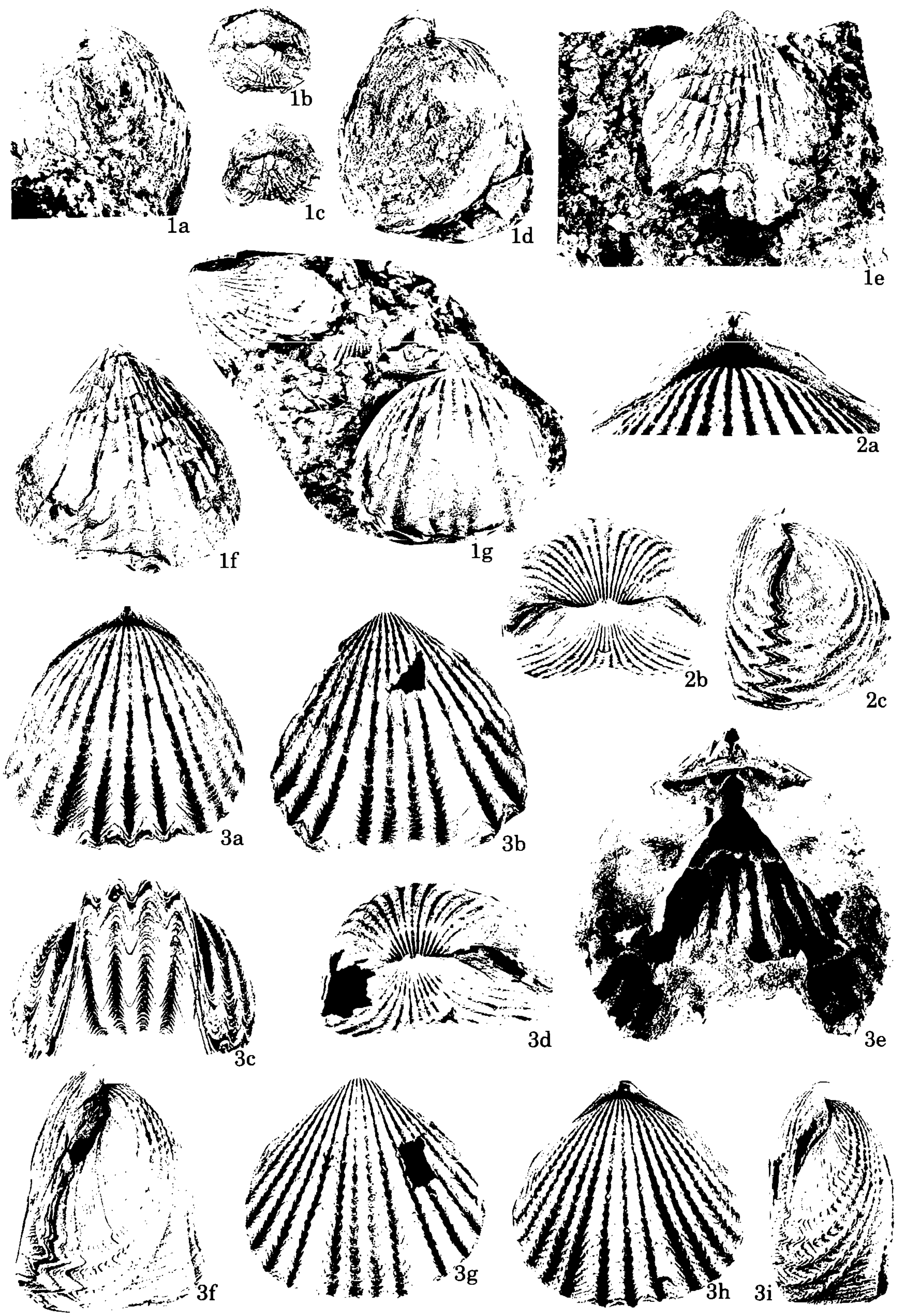
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Plate 6

LEPIDOCYCLUS OBLONGUS Howe

Figs. 1a–1v.—*L. oblongus* Howe, Cape Limestone, upper 4 feet, Main Street, just north of Broadway, Cape Girardeau, Missouri.

1a-1e, brachial, posterior, pedicle, lateral, and anterior views (×1) of large shell.

1f, interior view (×3) of articulated brachial (above) and pedicle valves.

1g, interior view (×3) of pedicle valve, showing deltidial plates, internal and external pedicle openings, and muscle scars.

1h, interior view of pedicle valve (×2), showing deeply impressed muscle field.

1i–1l, posterior, lateral, brachial, and anterior views (×2) of small shell. Lateral view (1j) shows beginning of accelerated lateral growth, which gives this specimen its characteristic inflated profile; compare to figs. 1o, 1n, and 1u.

1m, 1q–1t, posterior, anterior, pedicle, lateral, and brachial views of a moderate-sized shell (×2).

1n, lateral view of small shell (×3), showing greatly accelerated lateral shell growth; compare to figs. 1o and 1u.

1o–1p, lateral and posterior views (×3) of small immature shell. Note erect beak and lack of any accelerated growth lines; compare to figs. 1n and 1u.

1u, enlarged lateral view (×4) of posterior half of large shell, showing development of a greatly accelerated growth pattern as the individual started to mature; compare to figs. 1j, 1n, 1o.

1v, posterior view (×4) of brachial interior, showing sockets, cardinal process, and crura.

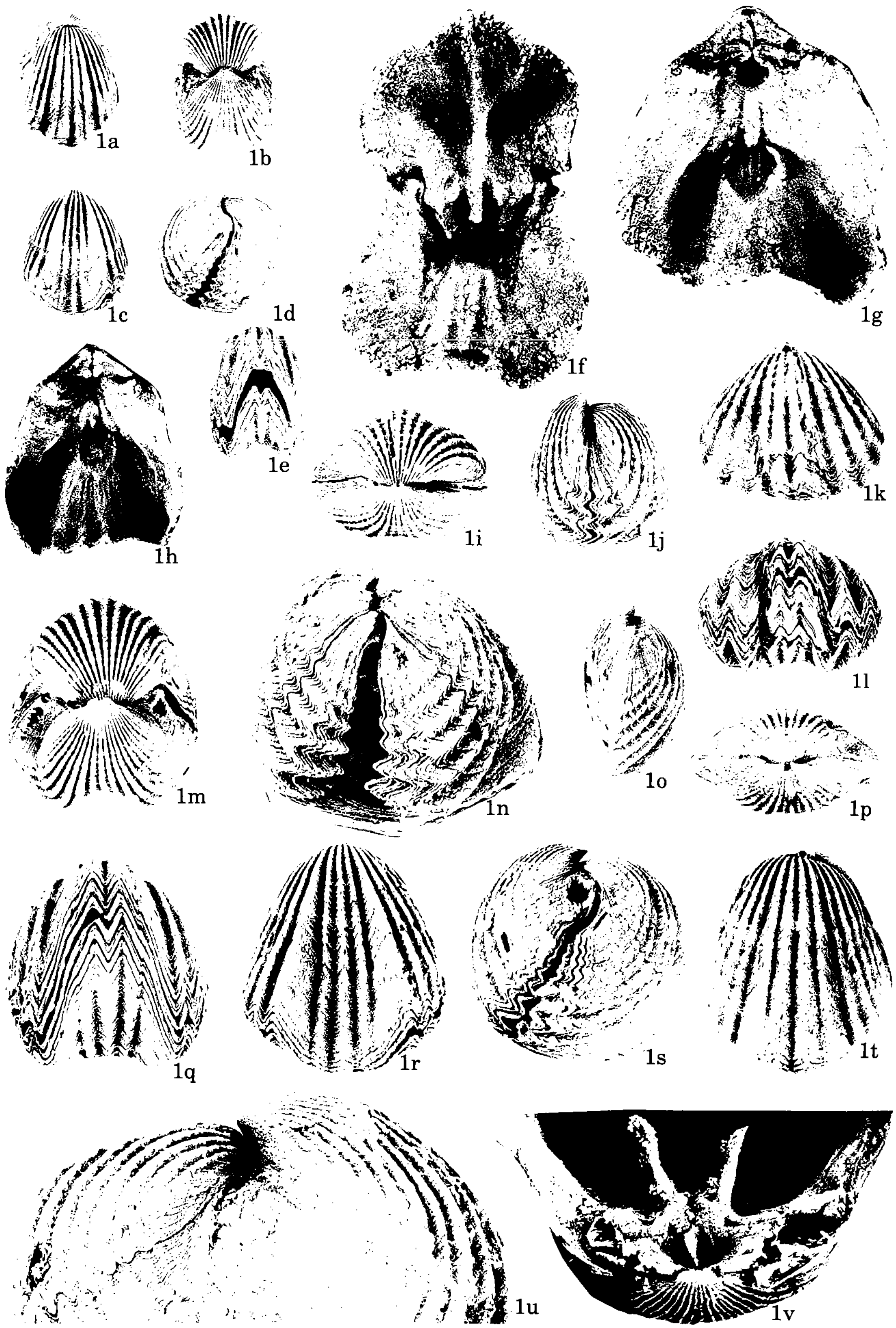
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Plate 7

LEPIDOCYCLUS OBLONGUS Howe, HISCOBECCUS CAPAX (Conrad)

Figs. 1a–1s.—*Lepidocyclus oblongus* Howe, "Fernvale" Limestone, lower 3 feet, east of West Lafferty Creek bridge, SE¼SE¼SE¼, sec. 10, T. 14 N., R. 8 W., Independence County, Arkansas.
- *1a, 1b,* lateral and posterior views (×2).
- *1c, 1d,* posterior and lateral views (×2).
- *1e–1h,* posterior, brachial, anterior, and lateral views, (×2).
- *1i–1k,* brachial, lateral, and anterior views, (×2).
- *1l,* enlarged surface (×5) of pedicle valve, showing surface lamellae.
- *1m–1p,* posterior, pedicle, brachial, and lateral views (×1).
- *1q, 1r,* lateral and anterior views (×1) of one of largest shells from West Lafferty Creek section.
- *1s,* bedding-plane surface (×2), showing scattered shells of *Lepidocyclus oblongus* and a strophomenid brachiopod.

Figs. 2a–2d.—*Hiscobeccus capax* (Conrad), Welling Formation; west bank, Horseshoe Bend, Illinois River, SE¼ sec. 31, T. 16 N., R. 22 E., Cherokee County, Oklahoma. Other views of this species shown on plate 4, figs. 1a–1e.
- *2a,* pedicle interior (×3), showing delthyrium and muscle scars.
- *2b–2d,* pedicle, posterior, and lateral views (×2).

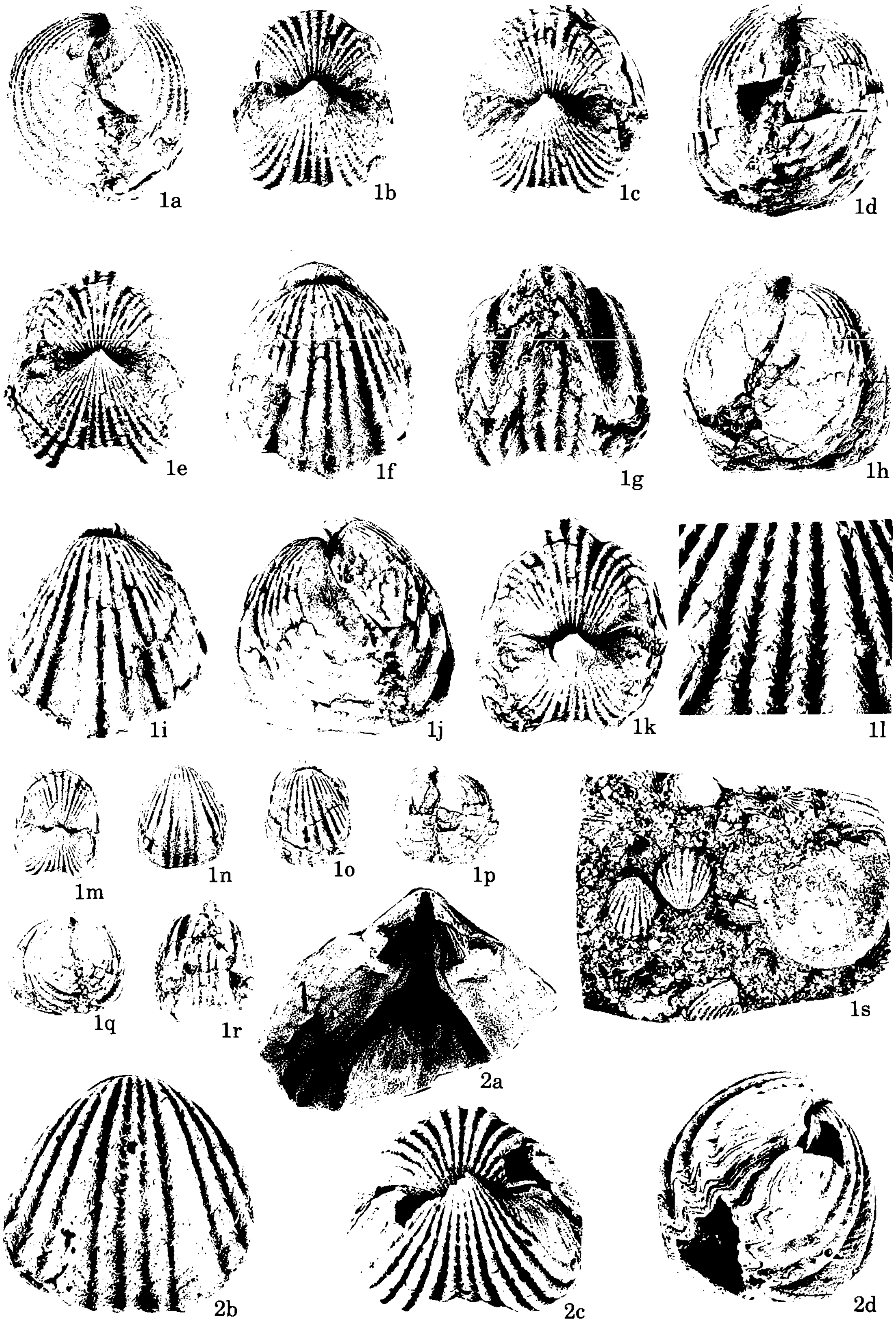
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Plate 8

Welling Formation, Eastern Oklahoma

(Bar = 1 mm)

Fig. 1.—Thin-section photomicrograph (oriented), showing organo-detrital sparite facies of Welling Formation. (See also pl. 12, fig. 2.) Point count shows following composition, expressed as percentage of total rock volume: micrite matrix, 4.3; spar matrix, 25.7; pelmatozoan plates, 36.6; thick-shelled ostracodes (+.024 mm), 2.5; trilobites, 7.0; bryozoans, 1.6; brachiopods, 13.5; unidentified shell debris, 8.8. (Area shown represents only part of area point counted.) Oklahoma Geological Survey core hole 3, 7 feet below Sylvan-Welling contact; SE¼SE¼NE¼ sec. 20, T. 13 N., R. 21 E., Sequoyah County, Oklahoma (Amsden and Rowland, 1965, p. 108).

Fig. 2.—Thin-section photomicrograph, showing organo-detrital micrite facies of Welling Formation. Point count shows following composition, expressed as percentage of total rock volume: micrite matrix, 26.6; spar matrix, 1.7; pelmatozoan plates, 60.0; thick-shelled ostracodes (+.024 mm), 0.7; thin-shelled ostracodes (−0.24 mm), 0.5; trilobites, 4.6%; bryozoans, 1.5; brachiopods, 1.0; unidentified shelly debris, 3.4. (Area shown represents only part of area point counted.) One foot above Welling–Fite contact, Horseshoe Bend, Illinois River, SE¼ sec. 31, T. 16 N., R. 23 E., Cherokee County, Oklahoma.

Fig. 3.—Partially etched block of Welling Formation (×1), showing distribution and varied orientation of silicified brachiopod shells. This is organo-detrital limestone, with only the brachiopods showing any persistent degree of silicification (brachiopod silicification is, to some degree, selective). Horseshoe Bend, Illinois River, SE¼ sec. 36, T. 16 N., R. 22 E., Cherokee County, Oklahoma.


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Plate 9

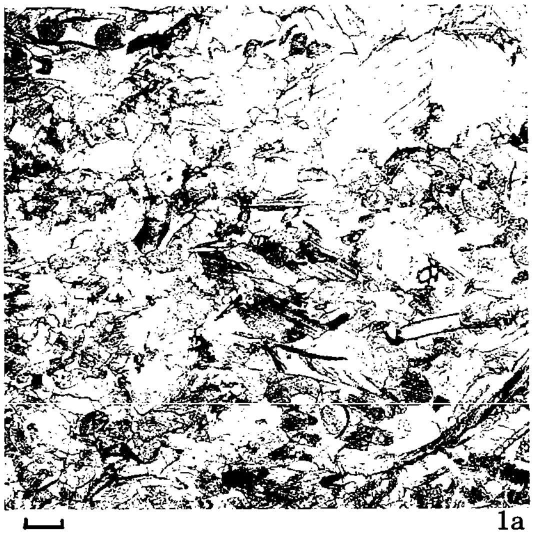
Welling and Viola Springs Formations, Arbuckle Mountains

(Bar = 1 mm)

Figs. 1a–1d.—Thin-section photomicrographs of samples collected from Welling Formation (figs. 1a, 1b) and upper part of Viola Springs Formation (figs. 1c, 1d) at type locality of Viola Springs, NW¼NE¼ sec. 19, T. 2 S., R. 8 E., Johnston County, Oklahoma. At this locality Alberstadt (1973, p. 58) and Glaser (1965, p. 182–183) placed the contact between their stratigraphic unit 3C (= Welling Formation) and stratigraphic unit 2 (= Viola Springs Formation) 112 feet below top exposures of Welling Formation; however, these authors noted that the contact between these units is gradational. The present study confirms this relationship, the organo-detrital limestones of the lower Welling grading into the more micritic, arenaceous (fine quartz detritus) limestones of upper Viola Springs. Although this boundary does appear to be gradational, a fairly well-marked change in insoluble-detrital content occurs at approximately 110 feet, overlying Welling strata averaging 1.1 percent HCl insolubles, and underlying upper Viola Springs beds averaging 4.14 percent insolubles. *1a,* Welling Formation, upper 2 feet. *1b,* Welling Formation, 90 feet below top; note quartz detritus (clear areas); same bed as fig. 3 below; *1c,* Viola Springs Formation, 10 feet below Welling–Viola Springs contact and 120 feet below top of Welling; note quartz detritus. *1d,* Viola Springs Formation, 50 feet below Welling–Viola Springs contact and 160 feet below top of Welling; note quartz detritus. *Lepidocyclus oblongus* collected from lower Welling and upper Viola Springs strata: 70 to 150 feet below top of Welling.

Fig. 2.—Welling Formation, about 20 feet below top; Lawrence Quarry, Ideal Cement Co., sec. 36, T. 3 N., R. 5 E., Pontotoc County, Oklahoma. This illustrates part of thin section that was point counted (expressed as percentage of total rock volume): spar matrix, 37.7; pelmatozoan plates, 40.1; thick-shelled ostracodes (+ 0.24 mm), 0.6; trilobites, 6.2; bryozoans, 8.9; brachiopods 4.4; unidentified fossils, 2.2.

Fig. 3.—Bedding-plane surface (× 1), Welling Formation, showing brachiopods, trilobites, and pelmatozoan plates. Fig. 1b above illustrates part of thin section cut from this bed. Same zone and locality as fig. 1b above.



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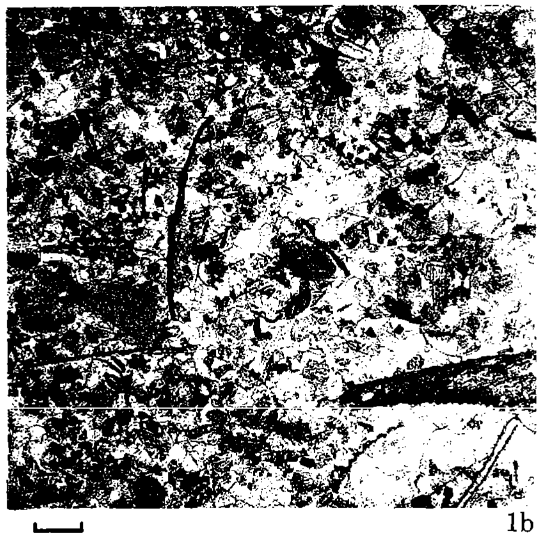

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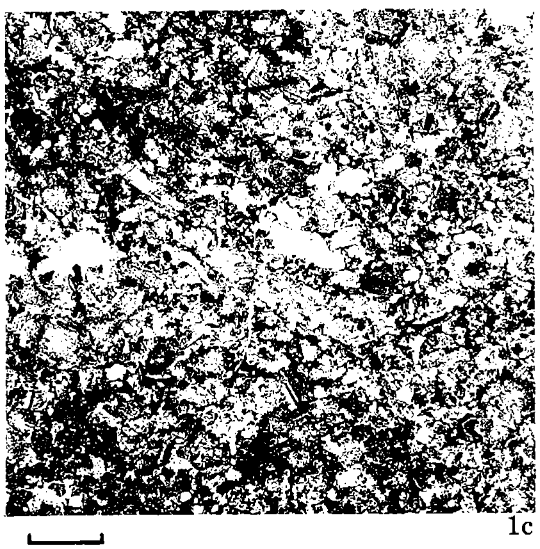

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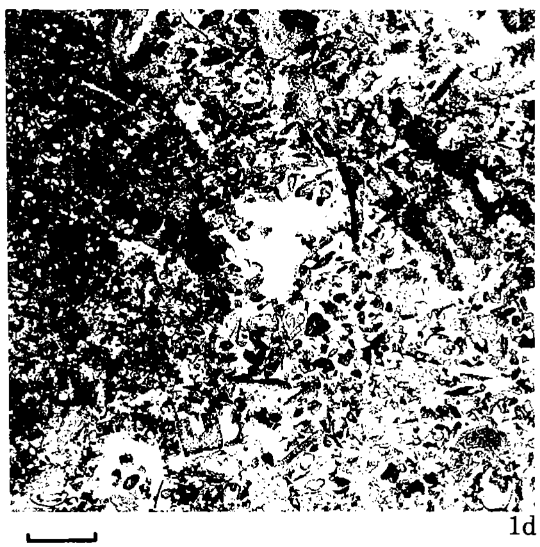

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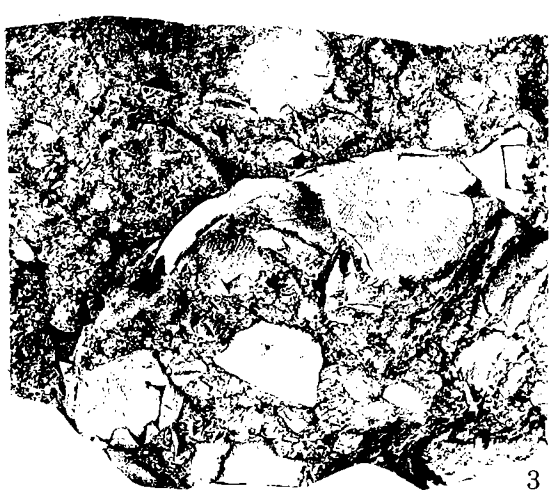

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Plate 10

Corbin Ranch Submember (Pooleville Member of Bromide Formation)
Arbuckle Mountains

Fig. 1.—Polished surface (×1) of the birdseye-limestone facies, showing fenestral laminations (cf. Hardie, 1977, fig. 43, p. 69). One foot below Viola–Bromide contact, west side of Oklahoma Highway 99, NW¼ sec. 12, T. 1 N., R. 6 E., Pontotoc County, Oklahoma (text-fig. 11).

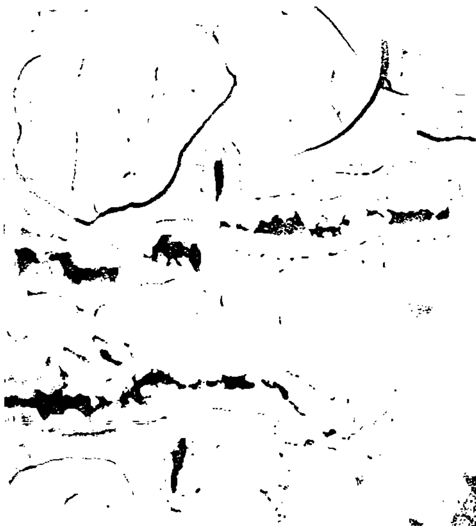
Fig. 2.—Polished surface (×1) of birdseye-limestone facies, showing fenestrae probably representing internal shrinkage cracks and gas bubbles (Shinn, 1968, p. 218). Three and a half feet below Viola–Bromide contact, east lane, east side, Interstate Highway 35, north flank of Arbuckle Anticline, near 50-mile marker (text-fig. 13).

Fig. 3.—Polished surface (×2) of birdseye-limestone facies, showing mud cracks and burrowing. Eighteen inches below Viola–Bromide contact, same locality as fig. 1.

Fig. 4.—Polished surface (×1) of birdseye-limestone facies, showing some burrowing and mud cracks. Two and a half feet below Viola–Bromide contact, same locality as fig. 1.

Fig. 5.—Polished surface (×2), showing Viola Springs–Corbin Ranch (below) contact, same locality as fig. 1.

Fig. 6.—Polished surface (×2) of birdseye-limestone facies, showing fenestrae probably representing burrows and gas bubbles (Shinn, 1968, p. 218). Four feet below Viola–Bromide contact, same locality as fig. 2.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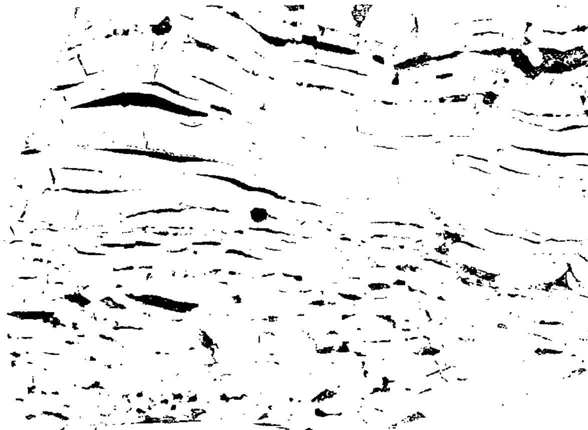
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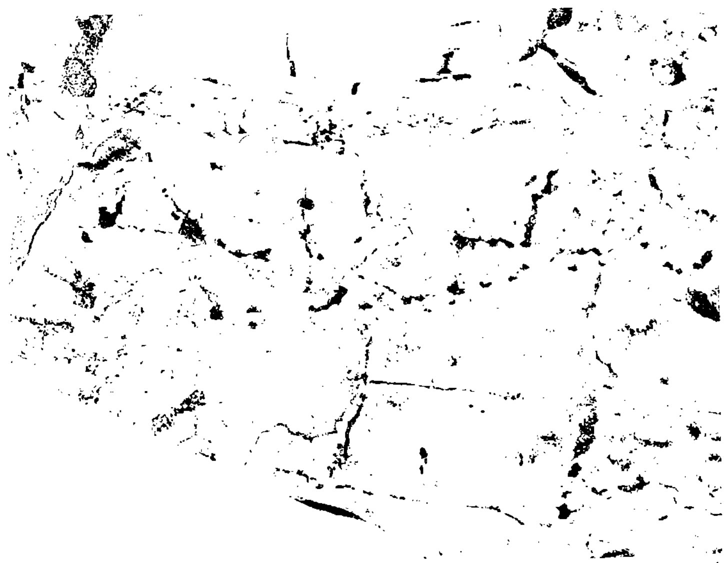
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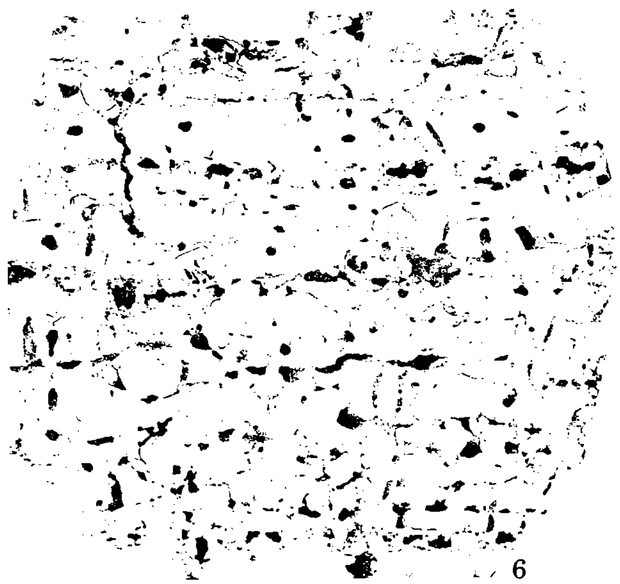
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Plate 11

Corbin Ranch Submember (Pooleville Member of Bromide Formation)
Arbuckle Mountains

(Bar = 1 mm)

Fig. 1.—Thin section (oriented), showing fossiliferous micrite with ostracodes, and articulated pelecypods and brachiopods; brachiopods and ostracodes retain their shell microtexture. Corbin Ranch Submember, Pooleville Member, Bromide Formation, 6 feet 3 inches below Viola–Bromide contact (text-fig. 11); road outcrop, Oklahoma Highway 99, sec. 12, T. 1 N., R. 6 E., Pontotoc County, Oklahoma.

Fig. 2.—Thin section (oriented) of *Tetradium–Hedstroemia* facies, showing colonies of *Tetradium* sp. and *Hedstroemia* sp.; note relatively coarse spar walls of *Tetradium* and fragmentation. Pooleville Member, Bromide Formation, 9 feet below Viola–Bromide contact (text-fig. 13); road outcrop, east lane, east side, Interstate Highway 35, north flank of Arbuckle Anticline, near 50-mile marker, Murray County, Oklahoma.

Fig. 3.—Thin section (oriented) of *Tetradium–Hedstroemia* facies, showing colonies of *Tetradium* sp. Note relatively coarse spar walls and intense fragmentation. Pooleville Member, Bromide Formation, 13 feet below Viola–Bromide contact; same locality as fig. 2 above.

Fig. 4.—Thin section (oriented) of *Tetradium–Hedstroemia* facies, showing fragmented colonies of *Tetradium* sp. Pooleville Member, Bromide Formation, 11 feet 8 inches below Viola–Bromide contact. Same locality as fig. 2 above.

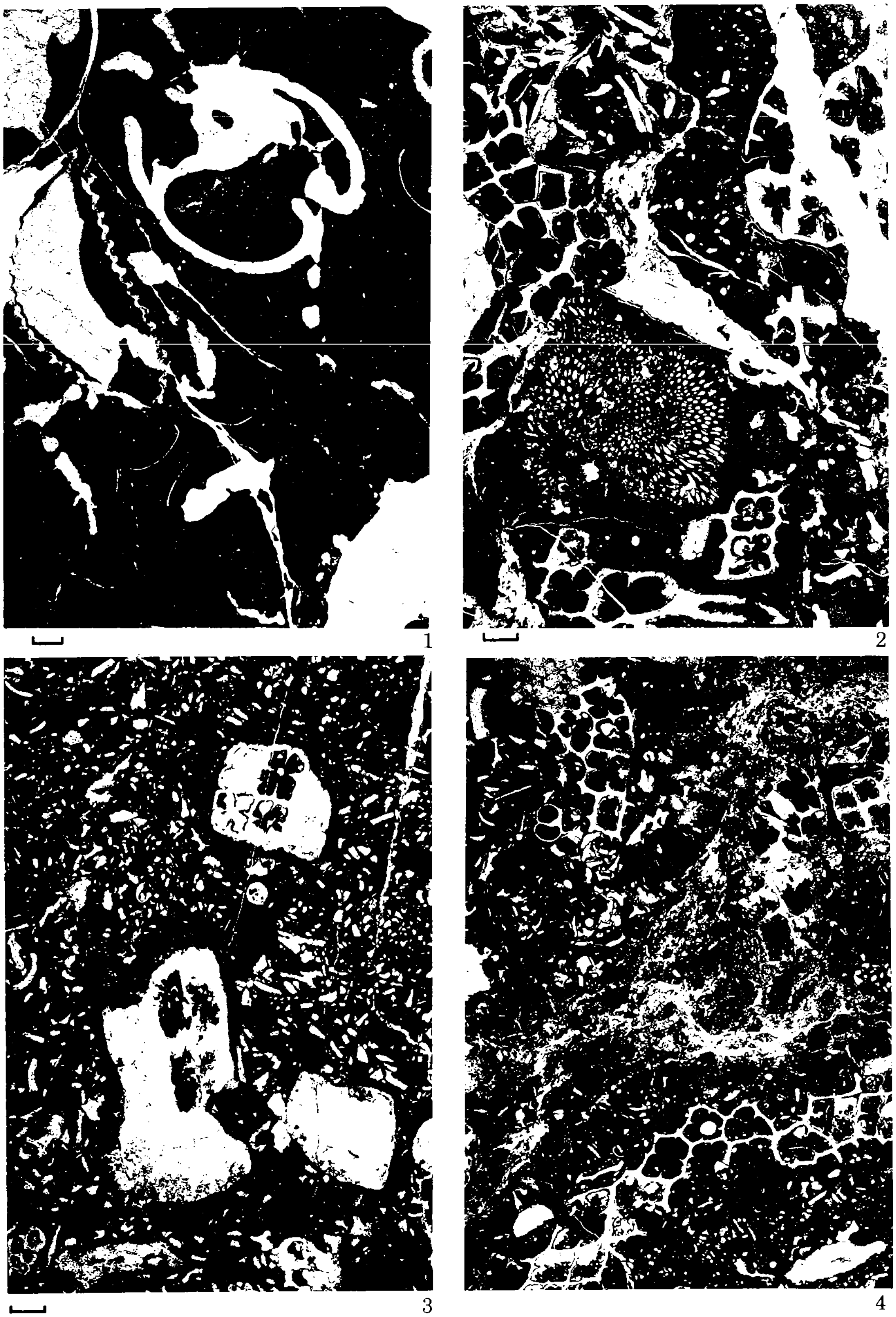

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Plate 12

Welling and Fite Formations

(Bar = 1 mm)

All specimens and thin section from Oklahoma Geological Survey core 3, SE¼SE¼NE¼ sec. 20, T. 13 N., R. 21 E., Sequoyah County, Oklahoma (text-fig. 6; Amsden and Rowland, 1965, p. 108–113).

Fig. 1.—Welling (above)–Fite (below) contact (*C*), polished surface (×2), depth, 207 feet. Note "tongues" of Welling organic detritus (*W*) filling pre-Welling solution channels in Fite.

Fig. 2.—Welling Formation, polished surface (×1) oriented; depth 193 feet, 14 feet above Welling–Fite contact. Thin section from this specimen illustrated on plate 8; point count given in fig. explanation, plate 8.

Figs. 3, 4.—Polished surface (×2, oriented) and thin section (oriented) from same specimen, Fite Formation, *Tetradium–Hedstroemia* facies, depth 208 feet 6 inches (1 foot 6 inches below Welling–Fite contact). This has a micrite–pellet matrix with irregular fenestrae (fig. 4), and a fauna composed mainly of *Tetradium* (fig. 3), ostracodes (figs. 3, 4), mollusks, and *Hedstroemia*.

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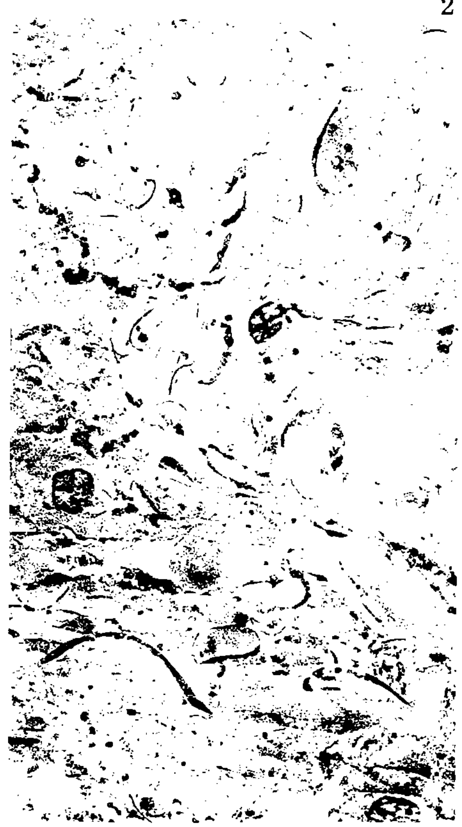

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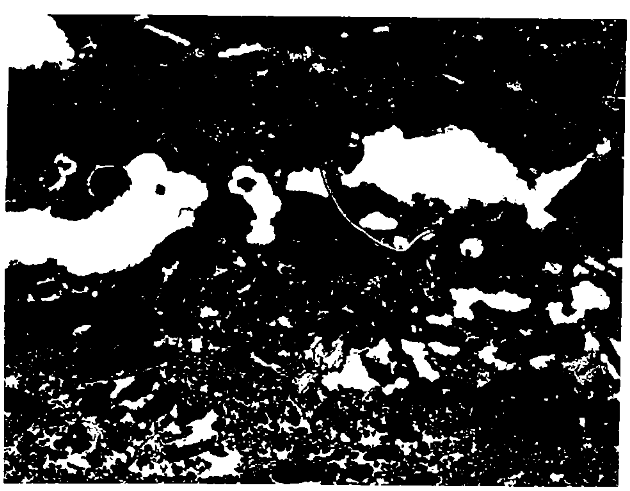

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Plate 13

Fite Formation

(Bar = 1 mm)

All specimens and thin sections from Oklahoma Geological Survey core 3, SE¼SE¼NE¼ sec. 20, T. 13 N., R. 21 E., Sequoyah County, Oklahoma. (Text-fig. 6; Amsden and Rowland, 1965, p. 108–113).

Fig. 1.—Thin section (oriented) of Fite Formation, showing pelmatozoan–micrite, birdseye-limestone facies, composed of weakly dolomitic micrite interbedded with heavily dolomitized micrite; depth, 218 feet, 11 feet below Welling–Fite contact. Fauna of micrite is composed almost entirely of ostracodes, including numerous leperditids, and that of dolomite bed, mostly small pelmatozoan plates.

Fig. 2.—Thin section (oriented) of Fite Formation, birdseye-limestone facies, showing weakly dolomitized micrite with a cross-cutting body of crystalline dolomite; depth, 221 feet, 14 feet below Welling–Fite contact. Sparse fauna composed almost entirely of small, articulated ostracodes.

Figs. 3, 4.—Polished surface (×2) and thin section (oriented) of Fite Formation, birdseye-mollusk facies, showing micrite matrix with calcspar fenestrae, possibly representing burrows; depth, 212 feet 6 inches, 5 feet 6 inches below Welling–Fite contact. Point counted: micrite matrix, 70.0; pellet matrix, 9.2; fenestrae, 9.4; pelmatozoan plates, 0.9; ostracodes, 2.2 (including leperditids); gastropods, 5.6; pelecypods, 2.6; *Hedstroemia* sp., 0.2 (expressed as percentage of total rock volume).

Figs. 5, 6.—Polished surface (×2) and thin section of Fite Formation, birdseye-limestone facies; depth, 216 feet, 6 feet below Welling–Fite contact. Weakly fenestrate micrite with sparse ostracode fauna.

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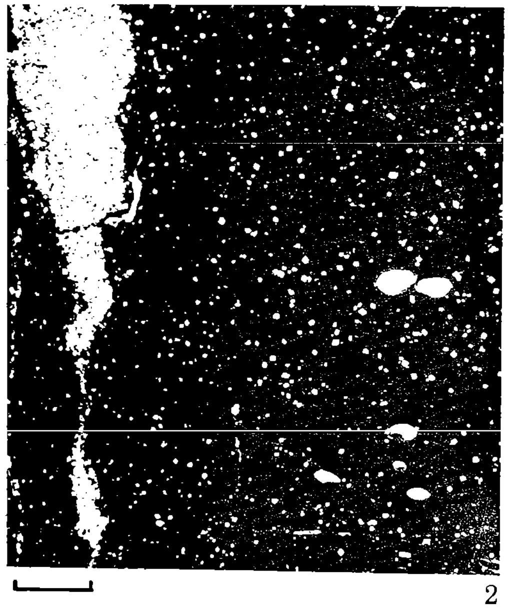

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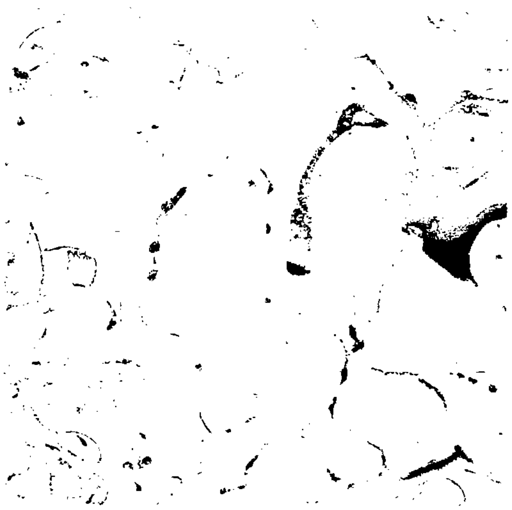

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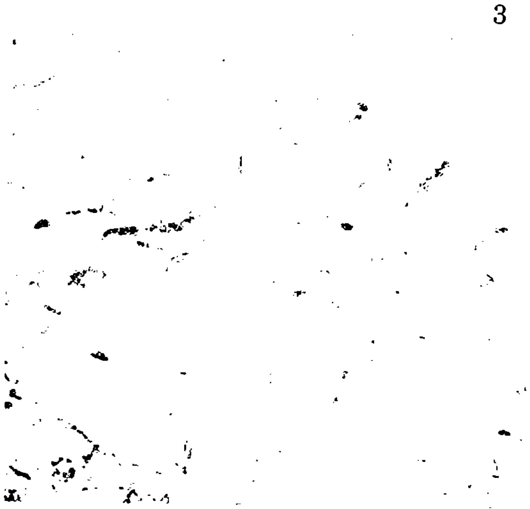

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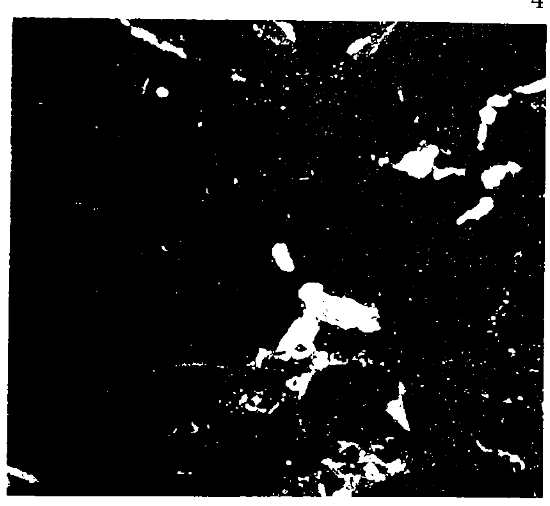

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Plate 14

Fite Formation

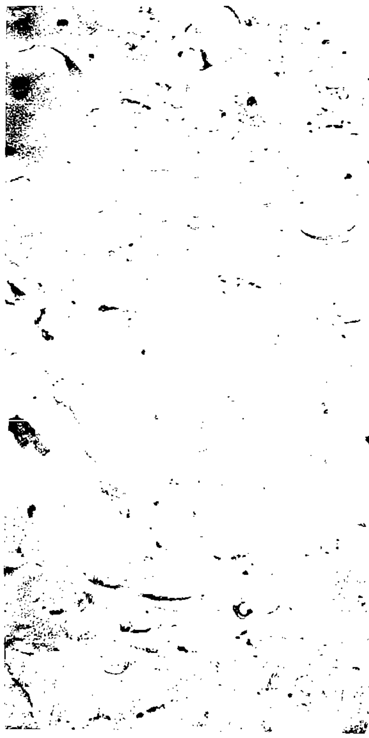
(Bar = 1 mm)

Figs. 1, 3.—Polished surface (×2) and thin section of Fite Formation, birdseye-limestone facies, showing burrowed pelletiferous micrite with sparse ostracode fauna, including some leperditids; 5 feet above Fite–Tyner contact. Thin section point counted: micrite matrix, 67.3; pellet matrix, 8.6; spar fenestrae, 12.0; ostracodes, 11.8; mollusks, 0.4 (expressed as percentage of total rock volume). Horseshoe Bend, Illinois River, NE¼NE¼ sec. 36, T. 16 N., R. 22 E., Cherokee County, Oklahoma.

Fig. 2.—Thin section of Welling (above)—Fite (below) contact (*C*). Note "tongue" of Welling organo-detrital sparite (*W*) filling a cavity, possibly a burrow, in upper Fite; Fite is almost entirely pellet limestone. Horseshoe Bend, Illinois River, NE¼SE¼ sec. 31, T. 16 N., R. 23 E., Cherokee County, Oklahoma.

Fig. 4.—Polished surface of Welling (above)–Fite (below) contact (*C*), showing "tongues" of Welling (*W*) filling pre-Welling burrows and solution cavities in Fite birdseye-limestone facies. Horseshoe Bend, Illinois River, NE¼NE¼ sec. 36, T. 16 N., R. 22 E., Cherokee County, Oklahoma.

Fig. 5.—Thin section (oriented) of Fite Formation, *Tetradium* facies, showing ostracodes, snails, and a few pelmatozoan plates. This is part of a thin section including *Tetradium*, pelecypods, and *Hedstroemia*, which was point counted; Oklahoma Geological Survey core 3; depth, 214 feet, 7 feet below Welling–Fite contact; SE¼SE¼NE¼ sec. 20, T. 13 N., R. 21 E., Sequoyah County, Oklahoma.



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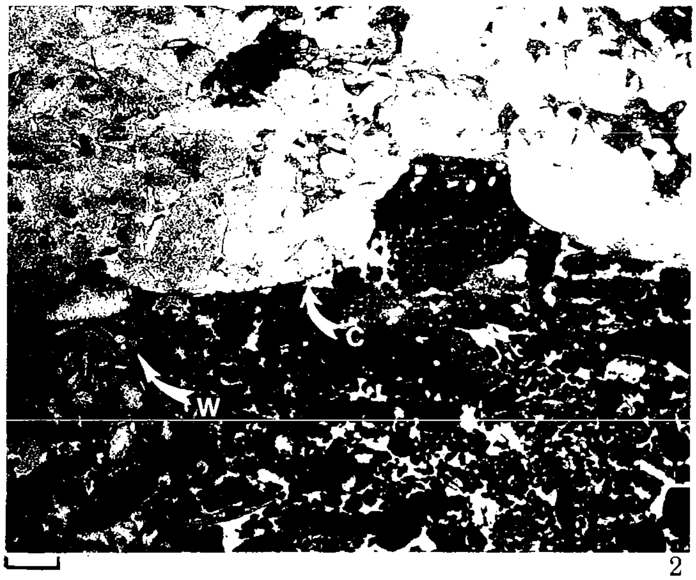

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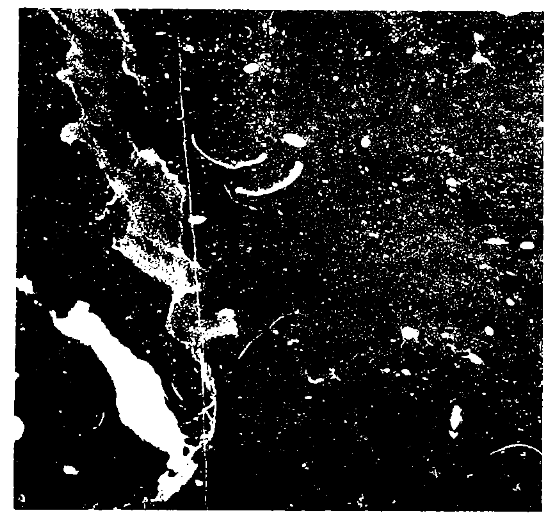

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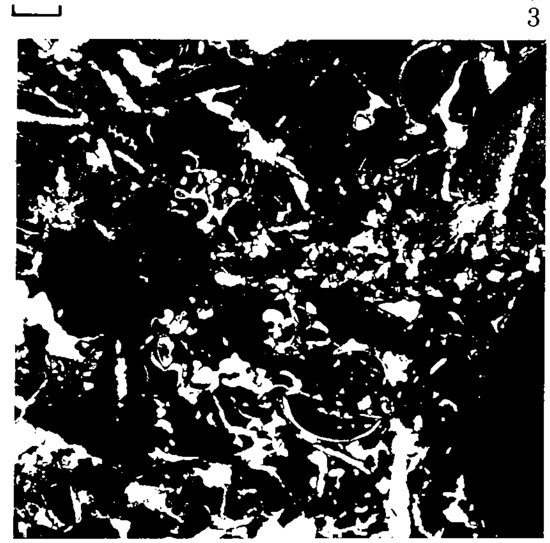

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