Paleotectonic Investigations of the Mississippian System in the United States

Part II. Interpretive Summary and Special Features of the Mississippian System

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1010

PART II OF III

Paleotectonic Investigations of the Mississippian System in the United States

Part II. Interpretive Summary and Special Features of the Mississippian System

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Chapters R through W

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By LAWRENCE C. CRAIG *and* KATHARINE L. VARNES

PALEOTECTONIC INVESTIGATIONS OF THE MISSISSIPPIAN SYSTEM IN THE UNITED STATES, PART II: INTERPRETIVE SUMMARY AND SPECIAL FEATURES OF THE MISSISSIPPIAN SYSTEM

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HISTORY OF THE MISSISSIPPIAN SYSTEM — AN INTERPRETIVE SUMMARY

By LAWRENCE C. CRAIG and KATHARINE L. VARNES

INTRODUCTION

This chapter summarizes the history of the Mississippian System in the conterminous United States: the tectonic and paleogeographic history of this system and the characteristics, sources, and environments of deposition of the Mississippian rocks. It was compiled from the information presented in part I of this study and from separate summary material prepared by the authors of part I. Those authors have not been specifically cited extensively in this summary, and some of their manuscript material has been transcribed directly without acknowledgment.

The regions discussed in this chapter are outlined in figure 79. Geographic terms and features used in the text are shown in figure 80.

The Mississippian Period began about 345 m.y. (million years) before the present (Geological Society of London, 1964); it lasted for about 35 m.y., and ended about 310 m.y. ago (Kulp, 1961, fig. 1).

According to current continental drift explanations, the North American Continent during Mississippian time was close to a megacontinental mass, Pangea, whose Gondwana components were located in the southern hemisphere. The South Pole probably lay within southern Africa during the Carboniferous and, as shown by a commonly accepted restoration of the continents, the east coast of the United States was adjacent to the northwest coast of Africa and the west coast of Europe.

The equator of Mississippian time probably cut diagonally across the United States as shown on plate 12. The approximate position of the equator is based on paleomagnetic determinations of the North Pole position from Mississippian rocks of North America. Latitude 35° N., longitude 118° E., in eastern China, was assumed as the position of the North Pole relative to North America in this reconstruction; the position coincides closely with determinations on the Hopewell Group of New Brunswick (Strangway, 1970, table A–4–1, p. 150) and the Maringouin Formation of Nova Scotia (Roy and Robertson, 1968). This pole position, however, is at the western edge of the area of scatter of the numerous determinations on North American Mississippian rocks available in the literature (Strangway, 1970; Cox and Doell, 1960; Roy, 1969). This area of scatter ranges approximately from 30° to 50° N. lat and from 118° to 144° E. long; thus, the position of the equator could be shown in a number of different positions (pt. I, chap. N. fig. 52; Sheldon, 1964, fig. 7) crossing the conterminous United States; most would be farther south than the equator shown on plate 12, but all would similarly cross the United States from southwest to northeast.

TECTONIC HISTORY OF THE MISSISSIPPIAN PERIOD

Many of the structural features that are basic to an understanding of the Mississippian Period were carried over from the Devonian or had their beginnings in even earlier periods. Figure 81 depicts the structural features of the conterminous United States at the end of Devonian time. Likewise, many of the tectonic features of Mississippian time carry over to the Pennsylvanian (fig. 82), although some end with or in the Mississippian Period. The tectonic history of the Mississippian Period is then a single chapter in the tectonic geologic record, following Devonian history and followed by Pennsylvanian history. An attempt is made here to tie into these adjoining records.

STRUCTURAL FRAMEWORK AT THE BEGINNING OF THE MISSISSIPPIAN

The map of the structural framework of the conterminous United States at the end of the Devonian Period

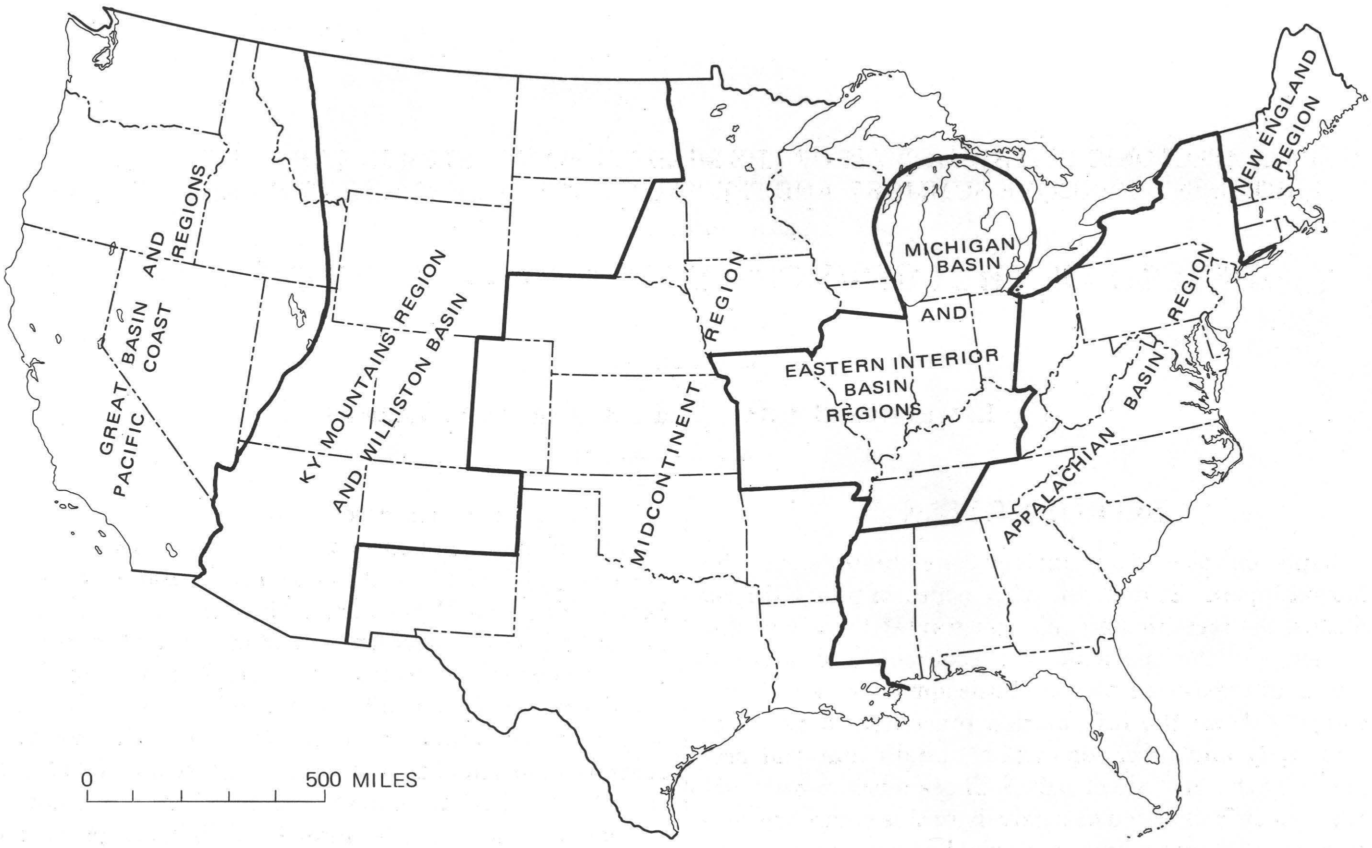


FIGURE 79. — Regions of the United States discussed in this chapter.

and the beginning of the Mississippian Period (fig. 81) shows the continent bounded by roughly north-trending geosynclines on the east and on the west, and having as the main cratonic feature a northeast-trending central positive structure, the Transcontinental arch. Smaller features —basins, arches, domes, and uplifts — are distributed throughout the craton. These features are discussed in this chapter.

NEGATIVE ELEMENTS

During the preceding periods of the Paleozoic, the Appalachian geosyncline had developed — forming a sinuous trough along the eastern margin of the craton (fig. 81) and filling with sediments derived largely from the east. In the latter part of the Devonian coarse materials were shed into the northern part of the geosyncline to form the thick Catskill delta. At least 9,000 feet of relatively coarse detritus was deposited in eastern Pennsylvania during Late Devonian time, but the deposits thin radially to the west and southwest and change from a partly fluvial red-bed sequence to a relatively thin marine black shale facies to the west on the cratonic shelf as well as southward along the trend of the geosyncline. Devonian rocks in the southern part of the Appalachian basin (fig. 79) are thin and subsidence in this part of the geosyncline was slight during the Devonian Period. The black shale facies is thin but surrounds both the Nashville dome and Cincinnati arch (fig. 81) and may have covered both features during Late Devonian. It increases in thickness into the Eastern Interior basin to the west and the central Iowa basin to the northwest, indicating that these basins were subsiding during Late Devonian. The Michigan basin also was a subsiding basin during Devonian time and a maximum of more than 3,000 feet of Devonian rocks is preserved in the middle of the basin. In Late Devonian time, however, a second area of maximum subsidence developed in the western part of the basin, on the northwestern edge of the lower peninsula near Lake Michigan.

The Williston basin — a long-lived negative feature in eastern Montana, western North Dakota, and northwestern South Dakota — subsided throughout the Devonian Period and accumulated a maximum of more than 2,000 feet of Devonian rocks.

Two additional intracratonic basins, one in northwestern Arizona and the other in southeastern Utah and adjacent northeastern Arizona, collected about 1,300 and 700 feet of Devonian rocks, respectively. These are not clearly outlined in the isopach map of up-

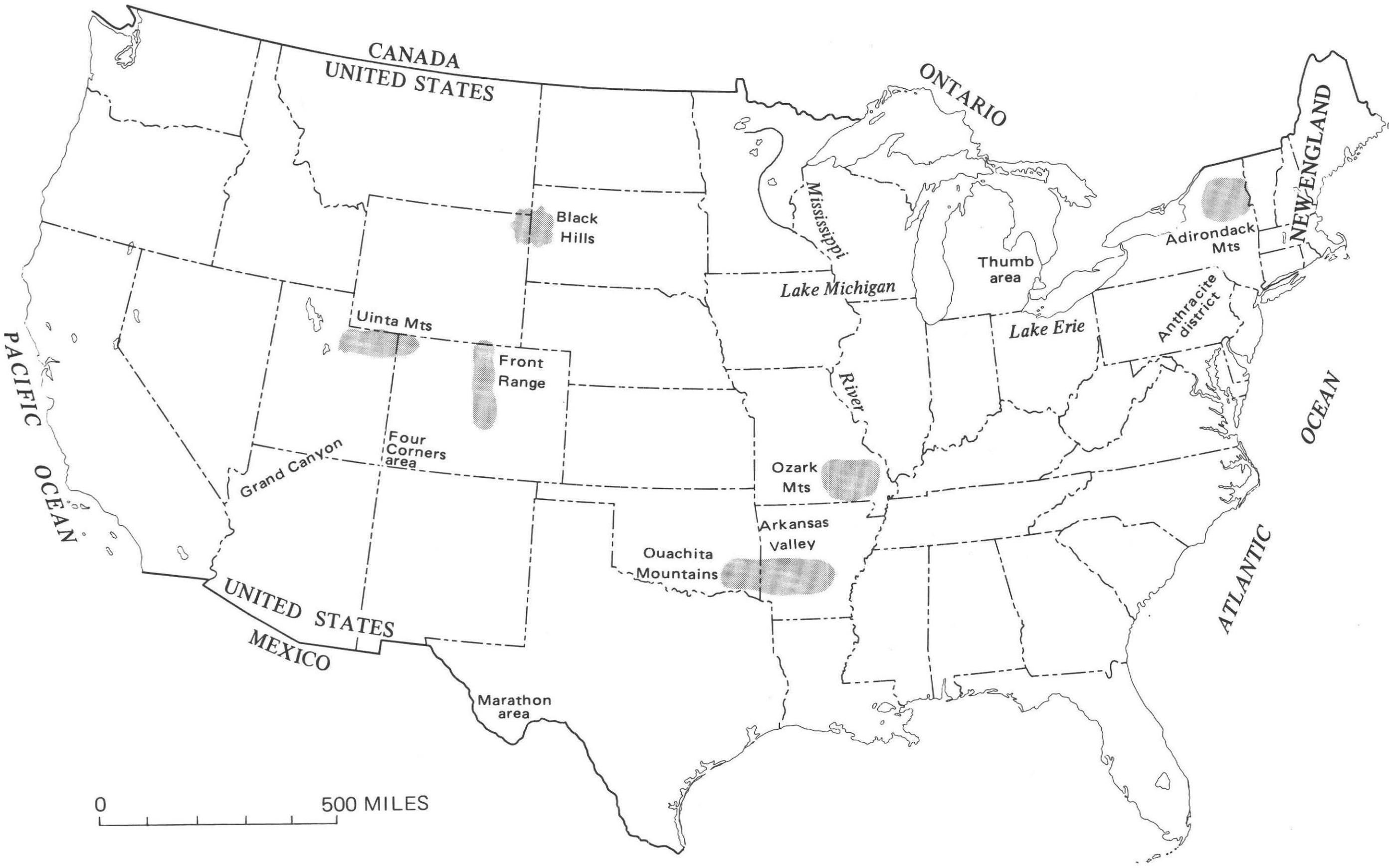


FIGURE 80. — Geographic terms and features used in text.

permost Devonian rocks (Poole and others, 1967, fig. 10) and may not properly be part of the structural setting of the beginning of the Mississippian Period.

Distinctive negative structures of Devonian age are almost lacking in most of the cratonic part of the southern midcontinent region. This lack may be the result of limited distribution of Devonian rocks, and in part the result of pre-Mississippian erosion. However, the area of the ancestral Delaware basin in west Texas did subside, receiving a maximum of about 1,000 feet of Lower and Middle Devonian carbonate rocks and as much as 700 feet of Upper Devonian -Lower Mississippian shale (Amsden and others, 1967, figs. 3, 5).

The Ouachita geosyncline did not develop until after Devonian time. Relatively thin sections of the Arkansas Novaculite in the Ouachita Mountains area of southern Arkansas and southeastern Oklahoma (fig. 80) and of the Caballos Novaculite in the Marathon area of west Texas indicate that at least parts of the area of the future Ouachita trough was subsiding during Devonian time. Little detritus was deposited in these areas, and presumably neither the craton nor the extracratonic areas to the south were sufficiently high to produce much detrital material.

Segments of the Cordilleran geosyncline were actively subsiding during most of the Devonian Period; the alinement of the trough shown in figure 81 is along the axes of maximum thicknesses of the total Devonian (Poole and others, 1967, fig. 6; Sandberg and Mapel, 1967, fig. 5). The eugeosyncline on the west was probably continuous with the miogeosyncline to the east and was limited on the west by piles of volcanic rocks and reefs (Poole and others, 1967, p. 906), perhaps an island arc. The Antler orogeny in Late Devonian time produced a landmass between the geosynclines; eugeosynclinal rocks were thrust eastward over miogeosynclinal rocks in the Antler orogenic belt. Although Upper Devonian rocks show some localized areas of thick sediment accumulation in the miogeosyclinal area, the relative thinness of section may reflect lesser subsidence in response to the compressional stresses in the orogenic belt; a few localized uplifts occurred within the geosyncline.

POSITIVE ELEMENTS

The Acadian orogeny during Middle and Late Devonian time deformed the Appalachian geosyncline in the New England region and produced a highland, the Acadian geanticline (Cumming, 1967, p. 1044). The orogeny was accompanied by granitic intrusion and deformation

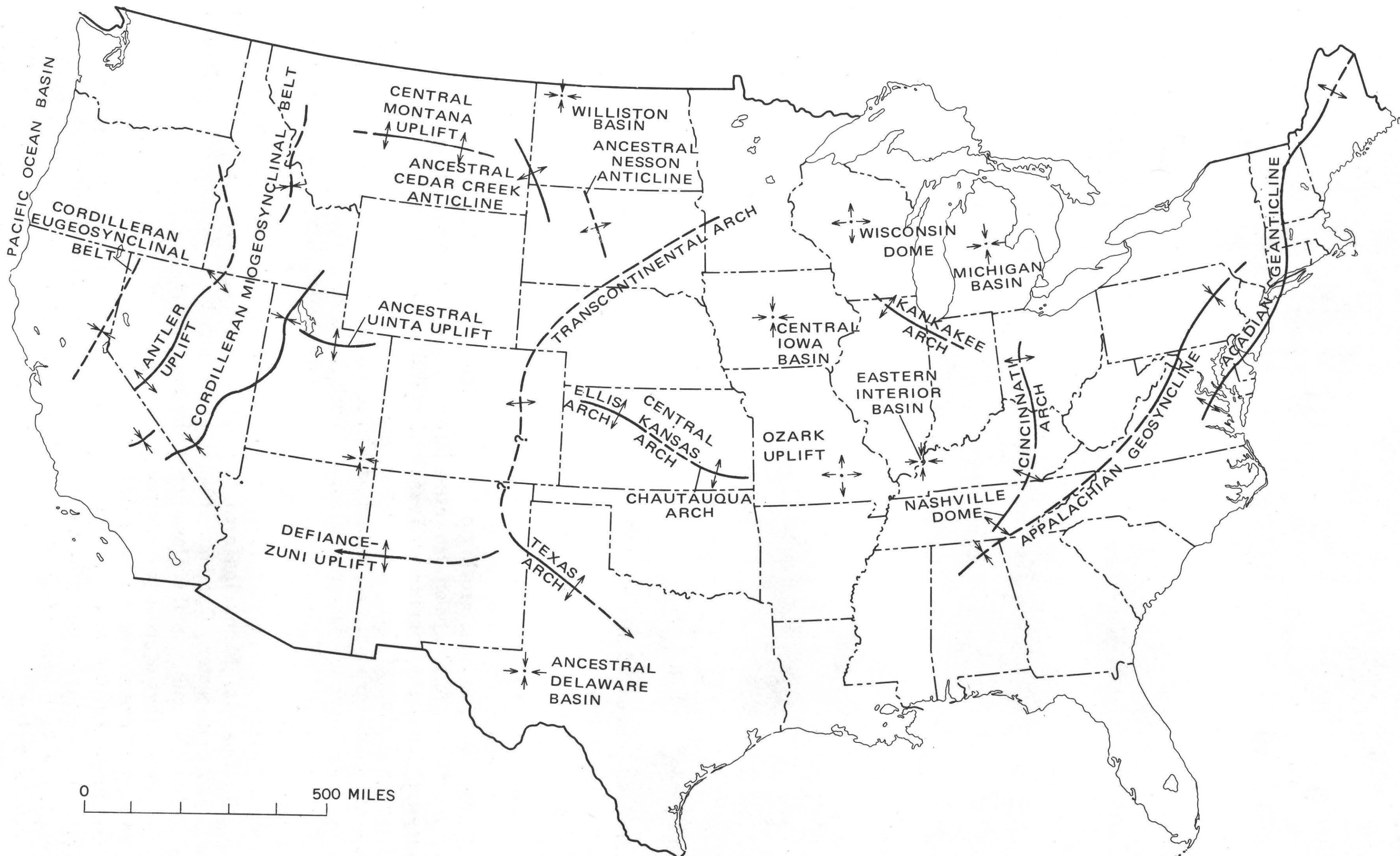


Figure 81. — Structural framework of the conterminous United States at the end of the Devonian Period.

of preorogenic Lower Devonian volcanic and sedimentary rocks. Postorogenic clastic sediments of Late Devonian age were deposited on parts of the area deformed during the Acadian orogeny in Maine and farther north, while the coarse materials of the thick delta of the Catskill Formation were being deposited farther south in the Appalachian geosyncline (fig. 81) in New York, Pennsylvania, and adjoining States to the south.

Although several structural elements in the Eastern Interior region seemed to maintain a positive attitude through most of Devonian time, only the Kankakee arch, the Ozark uplift, and possibly the Cincinnati arch–Nashville dome seemed to retain a positive structural behavior through the Late Devonian. The Kankakee arch appears to have restricted marine access between the Michigan and Eastern Interior basins in Late Devonian time. The Ozark uplift remained as a positive element throughout Devonian time (Collinson and others, 1967, p. 936), and Devonian sediments lapped on to the margins of the uplift. The Cincinnati arch–Nashville dome may have been covered, although probably thinly, by Upper Devonian beds, and the arch may have been positive only in the sense that it subsided less than did the areas on either side.

The Wisconsin dome may have been uplifted in latest Devonian time to serve as source for the fine clastic material of the Saverton Shale in Illinois and its equivalents in Iowa which probably had a source to the north (Collinson and others, 1967, p. 937).

Several positive features were active during the Devonian in the northwestern part of the craton, but only a few seem to have remained active at the beginning of Mississippian time (Sandberg and Mapel, 1967, figs. 9, 10). The distribution of the uppermost Devonian and lowermost Mississippian sediments were affected by the northwest-trending ancestral Cedar Creek anticline in eastern Montana, southwestern North Dakota, and northwestern South Dakota, and faults along the southern extremity of the ancestral Nesson anticline were active either during or immediately after deposition of these beds. The east-trending Central Montana uplift also may have been slightly positive at the end of Devonian time, for it apparently received no uppermost Devonian deposits and served as a low barrier separating or limiting basins of deposition.

In the southwestern part of the craton, the ancestral Uinta uplift was a positive area and no Upper Devonian rocks are preserved on it. Detrital material of Late Devonian age in north-central Utah suggests that the western extremity of the ancestral Uinta uplift was actually raised. The Defiance-Zuni uplift in west-central New Mexico served as a low barrier between Upper Devonian sediments that accumulated to north and south.

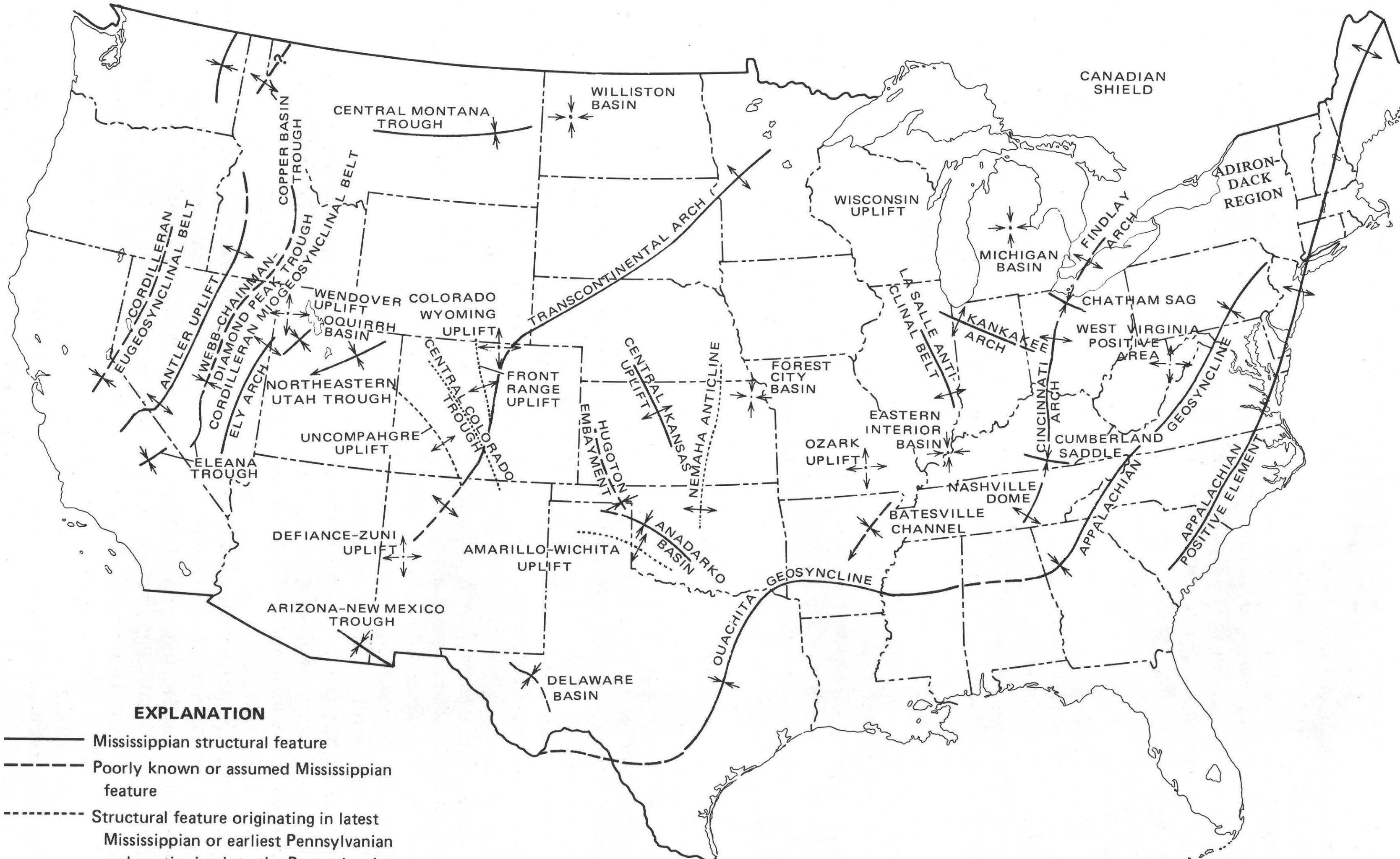
The distribution of Devonian rocks, as well as the distribution of rocks beneath the Mississippian (pls. 2, 13), imply the existence of the Transcontinental arch as a positive structure at the end of Devonian time. Offlap relations of the older Paleozoic rocks marginal to this broad, poorly defined structure suggest that it was uplifted in Late Devonian time and was subjected to widespread erosion and removal of older and older beds proximal to the axis. The axis of this arch at the end of Devonian time extended from Minnesota through western Nebraska into northeastern Colorado (fig. 81). It seems possible that the axis extended into northern New Mexico, with the Texas arch — a broad southeastward-trending positive structure — being a nose extending from northeastern New Mexico into central Texas and with the Defiance-Zuni uplift being a nose extending to the west, as interpreted in figure 81. In latest Devonian time, as a result of epeirogenic subsidence or eustatic rise, the sea readvanced across the beveled surface, and thin units that cross the systemic boundary were deposited in basinal areas on the craton. Although the strandline may have retreated and advanced several times during this episode, the rocks of Early Mississippian age are more widespread than the uppermost Devonian rocks, and this fact indicates the overall continued transgression of the strandline, due to either continued epeirogenic subsidence or eustatic rise. The epeirogenic uplift and folding on the craton during Late Devonian time may have been in response to the vigorous orogenic movements in the flanking geosynclines.

In Late Devonian time the Antler orogeny disturbed the early Paleozoic Cordilleran geosyncline, and thrusting and folding produced the Antler uplift, a highland separating the miogeosyncline from the eugeosyncline. The western margin of the eugeosyncline is little known; volcanic rocks of Devonian age in northern California may imply that a volcanic island arc intervened between the eugeosyncline and the Pacific Ocean basin to the west.

STRUCTURAL DEVELOPMENTS DURING THE MISSISSIPPIAN

INTERVAL A

At the beginning of Mississippian time the northern part of the Appalachian basin consisted of two parts, an eastern geosynclinal segment and a western platform or shelf segment. East of the northern part of the basin, a highland area — the Appalachian positive element (fig. 82), has been uplifted during the Acadian orogeny in Devonian time, possibly as a result of the collision of the North American plate and the European plate, which marked the closure of the northern part of the



EXPLANATION

Mississippian structural feature

Poorly known or assumed Mississippian feature

Structural feature originating in latest Mississippian or earliest Pennsylvanian and continuing into the Pennsylvanian Period

FIGURE 82. — Structural elements of the conterminous United States during the Mississippian Period and at the beginning of the Pennsylvanian Period.

proto-Atlantic Ocean (Iapetus Ocean of some authors). North of the basin the Adirondack region and the Canadian Shield were positive areas that shed sediment into the basin. During interval A detrital materials were shed from the Appalachian positive element into the geosynclinal area, and subsidence of about 500 feet occurred in the geosyncline from southwestern Virginia to northeastern Pennsylvania. Subsidence in southeastern Pennsylvania was greater and may have exceeded 1,500 feet (pl. 10, fig. 1). The earliest Mississippian sediments in this deep part of the trough were warped into open folds and were beveled by erosion prior to deposition of later interval A sediments. Although positive movements of land areas to the north of the basin probably occurred during interval A time and detrital material was carried to the north shelf part of the basin to form the Bedford and Berea deltas (Pepper and others, 1954), subsidence was considerably less than 500 feet in any part of the shelf area.

A small area in east-central West Virginia was a relatively positive area through most of Early Mississippian time. Although surrounded by Lower Mississippian rocks, only a thin layer of lowermost Mississippian red beds (upper part of Hampshire Formation) is preserved. The area may have been uplifted during interval A at about the same time that folding took place in southeastern Pennsylvania.

The Cincinnati arch remained a positive element throughout interval A time and may have been uplifted slightly during the earlier parts of the interval so that it remained as a barrier between the Appalachian basin and the Michigan and Eastern Interior basins. But in late interval A time, the Michigan and Appalachian basins were connected by a seaway through the Chatham sag in southwestern Ontario and northern Ohio (fig. 82). Whether the sag developed as a result of negative structural movement at this time or was simply a relatively low part of the Cincinnati arch that was covered by the advanced stage of the transgressing interval A sea is uncertain.

South of Virginia and Kentucky the basin appears to have been stable. Regional subsidence may have amounted to only a few feet. The geosyncline did not exist south of Virginia. Because of the fine texture of the detrital material, it is inferred that neither highlands nor uplifted source areas were present in the bordering land areas to the east and south.

The Michigan basin subsided to accomodate a maximum of almost 700 feet of sediment during interval A time. The Canadian Shield may have been uplifted slightly during early interval A time to provide the detrital sediments of the Thumb delta in eastern Michigan (fig. 80). In late interval A time, at least an eastern part of the Kankakee arch south of the basin was uplifted enough to form a sill separating normal marine circulation to the south and a restricted euxenic environment to the north in the Michigan basin (pl. 11, fig. 1).

As already noted, the Cincinnati arch was a positive structure during interval A time, and it formed a shoal area or slightly emergent barrier that separated the Appalachian basin from the Eastern Interior basin. Along the southern extension of the Cincinnati arch, the Nashville dome is postulated as a relatively positive area (pl. 10, fig. 1) and is thought to have been emergent during much of interval A time (pl. 12, fig. 1). Southwest of the Eastern Interior basin the Ozark uplift was probably the most active positive element in the region. Late Devonian uplift, perhaps related to the Antler and Acadian orogenies, was sufficient to provide some basal coarse sediments in interval A around the margin of the Ozark uplift. Renewed and, probably, localized uplift in the later part of interval A time provided detritus to the western side of the Ozark area in western Missouri and southeastern Kansas. The La Salle anticlinal belt was a relatively positive structure inherited from the Devonian, and local areas where interval A is missing in eastern Illinois and southwestern Indiana are interpreted here as local structural and topographic high points where interval A was never deposited (pl. 10, fig. 1) and which stood as islands in the Kinderhook sea (pl. 12, fig. 1).

The midcontinent region (fig. 79) was a broad low-lying positive area undergoing erosion at the beginning of interval A time. Only in southeastern Iowa and in the Ouachita Mountains area of Arkansas does sedimentation appear to have been continuous across the basal interval A boundary and appear to imply continuous subsidence. Widespread deposition of interval A was initiated by epeirogenic downwarpings or eustatic rise of sea level.

The Central Kansas uplift may have risen slightly at the beginning of interval A time; at least rocks of only late Kinderhook age are preserved in northern and central Kansas. To the west the Transcontinental arch probably was neutral or slightly positive and probably joined with land areas to the south in New Mexico and Texas that were slightly positive. To the northeast, however, segments of the Transcontinental arch may have been slightly negative (pl. 10, fig. 1) and probably were submerged during interval A time (pl. 12, fig. 1). The Anadarko basin in Texas and Oklahoma was the most conspicuous negative feature of the midcontinent region and it subsided only a few hundred feet. The amount of subsidence in central Arkansas is uncertain.

The Rocky Mountains region and Williston basin appear to have been extremely stable during interval A deposition. The crust apparently foundered gradually to allow the transgression of the sea. The Williston basin continued to subside, and, as the supply of detritus was low, subsidence is interpreted as exceeding deposition. The only possible positive movement in these regions might have been in the area of the Defiance-Zuni uplift of west-central New Mexico which supplied fine-grained detritus southward into the advancing sea in southwestern New Mexico (pl. 10, fig. 1).

In the Great Basin and Pacific Coast regions the Antler uplift (fig. 82) was raised shortly before interval A time and was characterized by extensive low-angle faults of large lateral displacement which telescoped lower Paleozoic eugeosynclinal and transitional facies. The thrusting has been dated as latest Devonian in north-central Nevada (Smith and Ketner, 1968) and possibly as earliest Mississippian in northeastern Nevada (Ketner, 1970). The raising of the Antler uplift was accompanied by the rapid subsidence of the Copper Basin trough, Webb–Chainman–Diamond Peak trough, and, probably, the Eleana trough, all segments of the Cordilleran miogeosynclinal belt during interval A time. These troughs collected dominantly fine-grained detrital rocks derived mostly from the Antler uplift. Between the Webb–Chainman–Diamond Peak trough and the Eleana trough is a relatively thin shallow marine sandy limestone that suggests an embayment in the Antler uplift. Although the limestone contains sand indicating a terrigenous source, the limestone may indicate a part of the geosynclinal belt that did not subside as much as the segments to the north and south, and it may also indicate a part of the Antler uplift that was not elevated as much as segments to the north and south.

Epeirogenic subsidence or eustatic rise of the sea level at the beginning of interval A time caused widespread transgression of the sea eastward from the geosynclines onto the shelf to the east. In mid-interval A time a minor episode of epeirogenic upwarping caused retreat of the sea from west-central Utah, and east-central and southeastern Nevada, terminating deposition and exposing the area to erosion. The sea readvanced and again flooded this shelf area, and bioclastic marine limestone was deposited on the eroded Mississippian and older rocks. Deposition probably continued without interruption in the miogeosynclinal belt during this time. The shelf area was not entirely stable during this interval. In northern Utah two isolated small basins appear to have subsided at least 600 feet, and a shallow trough extended southeastward from the Copper Basin trough in Idaho into this part of northern Utah (pl. 10, fig. 1).

In the Cordilleran eugeosynclinal belt, volcanism took place in northern California (pl. 10, fig. 1) and, possibly, also along the western margin of the Antler uplift in Nevada, as well as elsewhere in the belt. Volcanoes may have formed an island arc in this belt, and, if so, they would have constituted constructional positive features. Positive movement also may have occurred on tectonic blocks. The argillite, graywacke, chert, and lava typical of the eugeosynclinal deposits indicate that subsidence was dominant in the belt.

In northeastern Washington an unnamed limestone and dolomite of Early Mississippian age suggests miogeosynclinal sedimentation in this area. However, nearby Paleozoic rocks are eugeosynclinal facies. The juxtaposition of known Mississippian miogeosynclinal rocks and possible Mississippian eugeosynclinal rocks could be explained by the miogeosynclinal rocks (1) having been faulted in from the east, (2) being in place but surrounded by eugeosynclinal rocks faulted in from the west, or (3) being an isolated anomalous occurrence of limestone within the eugeosynclinal belt. Yet another explanation would be that the miogeosyncline turned northwest in Idaho to include this occurrence. In this case, an extension of the Antler uplift would also trend northwest, providing a major landmass in eastern Washington to the west of the miogeosynclinal occurrence. There is no evidence for such a major landmass and orogenic belt in Mississippian time in this area. Instead, a landmass is postulated to the east in northern Idaho that would have exposed lower Paleozoic sediments that could have provided clasts to conglomerates and could have contributed some of the lutite that is a large component of the dominant eugeosynclinal Paleozoic facies in northeastern Washington.

INTERVAL B

During interval B most of New England remained an area of high rugged mountains formed during the Acadian orogeny. Volcanic activity may have continued off the southeast coast of New England. Fault troughs in east-central Maine may have subsided and collected some interval B sediments, and neutral areas in Massachusetts and Rhode Island may have received volcanic deposits during this time.

During interval B the Appalachian basin was dominated structurally by the Appalachian geosyncline which continued to subside. The belt of great subsidence appears to have extended farther south than during interval A, as far south as northern Georgia (pl. 10, figs. 1, 2). A great volume of coarse-grained clastic rocks was deposited in the geosyncline, indicating that the source area to the east, the Appalachian positive element, was uplifted and eroded. Terrestrial deposits progressively extended farther west over marine deposits, and the restriction of the sea to the western part of the northern Appalachian basin suggests that the source supplied sediment more rapidly than the subsiding geosyncline could accommodate it. The distribution of rock textures indicates that the southern part of the eastern source area was considerably degraded by later interval B time and was not producing much coarse-grained detritus. In contrast, the northern part of the eastern source area continues to supply coarse material well into interval C time, which implies continued uplifts in this area.

In southwestern Virginia the local accumulation of evaporites in the latter part of interval B time is the result of folding and faulting and evaporation in a small basin, and this indicates tectonic disturbance within the basin during interval B.

The small area in east-central West Virginia that was positive during interval A time remained relatively positive during interval B and little or no sediment accumulated on it (pl. 10, fig. 2). The Cincinnati arch was probably submerged during much of interval B time. Near the end of interval B time, however, the northwestern part of the Appalachian basin may have been emergent, perhaps as a result of epeirogenic upwarping, and the area remained positive during the early part of interval C time.

The widespread cherty carbonate in the southern part of the Appalachian basin suggests that the bordering land area was not uplifted and that it provided little or no detrital material to the basin.

The entire Michigan basin continued to subside during interval B, and in at least two parts of the basin, subsidence amounted to more than 1,300 feet. The Kankakee arch appears to have been inactive, but the Findlay arch probably was a positive structure during later interval B time and was elevated sufficiently to prevent detrital material from crossing into Ohio. This uplift might also be part of the emergence noted in the northwestern part of the Appalachian basin in late interval B time.

Similarly, areas of the Eastern Interior basin subsided during interval B but to a lesser extent than in the Michigan basin — about 800 feet in southern Illinois and western Kentucky. Both the Cincinnati arch and Nashville dome seem to have been quiescent and probably were submerged. Minor subsidence, mainly in early interval B time, is indicated by a local basin west of the Ozark area in southwestern Missouri where a maximum of slightly more than 300 feet of interval B accumulated.

The midcontinent region subsided gently during interval B time, and differential tectonic movements appear to have been minimal. A hiatus in much of Kansas at the beginning of interval B indicates a regression of the strandline, gentle epeirogenic uplift, and emergence. The sea readvanced from the south, and interval B eventually covered all the State. Southeastern Iowa also was emergent prior to deposition of interval B (Harris and Parker, 1964), and the hiatus represents a local differential uplift. Subsequently, a broad gentle trough developed, extending from northwest to southeast in southern Iowa, in which interval B is more than 200 feet thick. The only areas of marked subsidence in the midcontinent part of the craton were in the Anadarko basin of the Texas Panhandle and western Oklahoma and its northern extension into Kansas, the Hugoton embayment, and the Delaware basin in southeastern New Mexico and its southern narrow extension into west Texas. In these areas a maximum subsidence of at least 800 feet is indicated by thicknesses of interval B. The Ouachita trough in the Ouachita Mountains region of southern Arkansas probably continued to subside slightly. Deposits in the trough are very thin but are interpreted as formed in deep water. During interval B a small trough, the "Batesville channel," developed as a subsiding northern extension of the Ouachita trough. Deposits in northwestern and north-central Arkansas, although thick relative to deposits in the remainder of Arkansas, were shallow-water carbonate deposits and are interpreted as having formed on a subsiding shelf.

The widespread marine transgression of interval B time appears to have submerged most of the Rocky Mountains region and implies general epeirogenic subsidence. In contrast to much of the craton, considerable differential subsidence took place in the northern part of the region. The Williston basin continued to subside during interval B, and the rate of chemical sedimentation increased so that by the end of interval B shallow-water carbonate rocks were forming in the middle of the basin. An east-trending downwarp, the Central Montana trough, first developed in interval B and connected the Williston basin through central Montana with the Cordilleran miogeosynclinal belt to the west. Another trough, trending northeast through central and northeastern Utah, subsided during interval B time and might be considered related to or a part of the miogeosynclinal belt to the west at this time. In southwestern New Mexico and southeastern Arizona, marked subsidence took place in a trough that projects southeastward into northern Mexico, the Arizona–New Mexico trough (fig. 82). Uplift, if any, was restricted to a limited area of central and eastern Colorado and southeastern Wyoming. This area provided small amounts of detrital materials to the surrounding sea. Perhaps this material was simply reworked residuum from a long-exposed and weathered part of the Transcontinental arch, and little or no uplift was required to transport the detritus. The Texas arch was not a positive structure during interval B and does not reappear as such during Mississippian time. The Defiance-Zuni uplift along the New Mexico–Arizona State line, two small areas in northeastern New Mexico, two in west Texas, and a small area in southwestern Arizona that probably extended into adjacent Mexico are shown as slightly positive during interval B (pl. 10, fig. 2). Depending on the age interpretation of beds in northeastern New Mexico, a part of northeastern New Mexico and probably part of southern Colorado may have been slightly positive during interval B time (Armstrong, chap. K, fig. 40).

Tectonic movements in the Great Basin and Pacific Coast regions appear to have increased during interval B time as compared with interval A. A number of basins or troughs developed marginal to and in the craton east of the main Cordilleran miogeosynclinal belt (pl. 10, fig. 2). In Nevada and Utah these subsided more than 1,000 feet. The Wendover uplift in northwestern Utah was raised slightly during interval B time but is still considered to be part of the craton.

In the miogeosynclinal belt segments of the trough continued to subside actively. In central and eastern Idaho, troughs subsided more than 1,500 feet. Similar amounts of subsidence are indicated in the Webb–Chainman–Diamond Peak and Eleana troughs in northeastern and south-central Nevada. The detrital materials deposited in these troughs suggest that segments of the Antler uplift to the west were being raised during interval B time (pl. 10, fig. 2). Although interval B is poorly known in the eugeosynclinal belt west of the Antler uplift, the belt continued to subside and received detrital materials, as well as the volcanic materials noted in northwestern Nevada and northern California. Volcanoes may have formed an island arc.

In northeastern Washington the unnamed limestone and dolomite of Early Mississippian age mentioned in interval A could belong to interval B as well. The rocks suggest miogeosynclinal sedimentation in this area. However, nearby Paleozoic rocks are eugeosynclinal facies. The juxtaposition of Mississippian miogeosynclinal rocks and possible Mississippian eugeosynclinal rocks was discussed under interval A (p. 362).

INTERVAL C

Tectonic activity was greater during interval C than in preceding intervals, and the sequence of events appears to indicate more differential or independent epeirogenic or orogenic activity from province to province than in preceding intervals.

The sea regressed from the northern part of the Appalachian basin as far south as southwestern Virginia slightly before the beginning of interval C time, probably as a result of differential epeirogenic warping. As a result of epeirogenic subsidence or eustatic rise, the sea gradually readvanced up the Appalachian geosyncline and across the shelf area to the west, eventually extending through much of western Pennsylvania and southeastern Ohio. The geosyncline continued to subside (pl. 10, fig. 3) with maximum downwarp shifting from the northern (Pennsylvania) part of the trough to a segment extending from southwestern Virginia into northeastern Tennessee. A sharp hinge line appears to have bounded this trough segment on the northwest and separated the trough from the shelf area to the west. During interval C, in contrast to preceding intervals, the southern part of the Appalachian Basin region is dominated by limestone, which indicates that the borderlands to the east and south were tectonically quiescent and probably were reduced to areas of low relief in which chemical erosion was dominant. In contrast, the borderlands east of the northern part of the basin continued to be elevated and eroded but at a decreasing rate, as indicated by the smaller volume of detritus that was deposited, primarily on the east side of the geosyncline, as continental sediment. Quartzose detritus in the northwestern part of the Appalachian basin was derived from the north and indicates some uplift in the Canadian Shield during interval C time. The Cincinnati arch appears to have been a relatively positive element separating the Michigan basin from the Appalachian basin but contributed little sediment to the Appalachian basin.

The Michigan basin continued to subside during interval C. Evaporites deposited during the interval suggest that access to the open ocean was limited and that the Findlay and Kankakee arches were positive elements that restricted the mouth of the embayment. Detrital materials were derived from the Canadian Shield to the northeast and from the Wisconsin uplift to the west. Neither the Michigan basin nor the Eastern Interior basin reflects the marine regression at the beginning of the interval that took place in the Appalachian basin. Instead, marine deposition appears to have been essentially continuous in both basins from interval B to interval C. In mid-interval C time minor uplift of the Ozark Mountains area, and perhaps of the Cincinnati and Kankakee arches, combined with minor regression of the sea, perhaps due to slight epeirogenic uplift, produced restricted marine conditions in the Eastern Interior basin (pl. 11, fig. 3) and resulted in the precipitation of evaporites in an area extending from southeastern Iowa to western Kentucky. This episode of restricted environment was followed by widespread transgression, perhaps due to slight epeirogenic subsidence, and by the resumption of deposition in marine water of normal salinity. The Eastern Interior basin was well defined during interval C and subsided a maximum of at least 1,200 feet in southern Illinois and southwestern Indiana.

In most of the midcontinent region, general epeirogenic subsidence appears to have continued from interval B until mid-interval C. During mid-interval C time (early St. Louis), epeirogenic uplift appears to have occurred in northern Iowa and perhaps in much of Nebraska, and in eastern Colorado. This uplift caused regression of the strandline, produced restricted marine conditions in southeastern Iowa and the deposition of evaporites, and caused the erosion and removal of parts or all of lower interval C from northern Iowa, and probably from part of northeastern and central Nebraska. Interval C was probably widespread in Kansas originally, but it has been modified greatly by later erosion and is confined now to the basins on either side of the Nemaha anticline and Central Kansas uplift (fig. 82). The fact that in places middle interval C rocks are more extensive than lowest interval C rocks suggests that most of central and eastern Kansas was not exposed to erosion during the mid-interval C uplift nor to the regression that affected Iowa and Nebraska. However, in western Kansas an intraformational erosion surface has been identified within the St. Louis Limestone. In western Kansas interval C rocks above this surface contain quartz detritus. This sequence suggests that epeirogenic warping caused uplift of the area and a brief regression of the strandline. The quartz detritus in upper interval C suggests that the upwarping also was accompanied by uplift of a segment of the Transcontinental arch to the northwest which then shed detritus to western Kansas. A similar situation also exists in Iowa where quartz detritus is common in the upper part of interval C and indicates that the Wisconsin uplift to the north had been elevated in mid-interval C time. Farther south, in Arkansas, a brief marine regression due to positive epeirogenic movements is recorded in the northern part of the State at the beginning of interval C, but to the south in central Arkansas, the Ouachita trough appears to have subsided continuously and to have received a continuous sequence of detrital marine sediments. This trough extended westward into Oklahoma and connected across a saddle with the Anadarko basin in western Oklahoma. Both troughs subsided during interval C time and collected sediment, dominantly detrital in the Ouachita trough and dominantly carbonate in the Anadarko basin. These negative features were a rejuvenation of tectonic features that had existed intermittently as far back as late Precambrian or Early Cambrian time (Ham and others, 1964, p. 149–150). The subsidence that started during interval C continued until Middle Pennsylvanian time. In the remainder of the midcontinent region no tectonic event interrupted sedimentation from interval B to interval C. Texas, most of New Mexico, and eastern Colorado appear to have been a gradually subsiding shelf. In westernmost Texas and south-central New Mexico, isopachs suggest the existence of a subsiding southward-plunging trough during interval C time (pl. 5-A). During the last part of interval C time much of this shelf region was uplifted sufficiently for the sea to withdraw. Greatest uplift seems to have been in areas along the much later Ouachita fold belt (pls. 3-A, 4-A, 5-A, 6-A) and was sufficient to erode and remove much or all of interval C and interval B.

Interval C in the Rocky Mountains region and Williston basin indicates continued subsidence in the three tectonically negative areas developed during interval B time; the Williston basin subsided to receive more than 1,300 feet of sediment in its deepest part, the Central Montana trough contains as much as 700 feet, and the Northeastern Utah trough received more than 600 feet. The deposition of evaporites in Montana, the Dakotas, and northwestern Wyoming, the distribution of detrital facies in central Wyoming and northeastern Utah, and bedding characteristics in northern Arizona all suggest that deposition was in a regressing sea, which resulted from lowering sea level or epeirogenic uplift. The detrital materials near the margin of interval C in western Wyoming and northeastern Utah suggest localized uplift in north-central Colorado and south-central Wyoming, a segment of the Transcontinental arch.

Uplift took place in late interval C time; in the Williston basin some Meramec rocks were eroded prior to deposition of Chester rocks (interval D); similarly, in Wyoming a karst topography was developed on the top of the Madison Limestone before deposition of the Darwin Sandstone Member of the Amsden Formation (here assigned to interval D). In northwestern Arizona, also, a considerable paleontologic hiatus and probably disconformity occur between the isolated remnant of interval D and the more extensive rocks of interval C.

During interval C time the Great Basin and Pacific Coast regions show increased crustal instability and tectonic differentiation. Segments of formerly stable cratonic areas appear to become distinct parts of the miogeosynclinal belt (pl. 10, fig. 3). The Antler uplift was intermittently active from northern Nevada into southern California, and some segments must have been uplifted a large amount. The relatively thin carbonate rocks of earlier Mississippian intervals along the eastern edge of the highland in the miogeosynclinal belt were uplifted and eroded and then buried by detritus from the rising highland. The Webb–Chainman–Diamond Peak and Eleana trough segments subsided more than in previous intervals. Although the Copper Basin trough in central Idaho continued to subside during interval C time and more than 2,000 feet of sediment accumulated locally, the change from detrital deposition in previous intervals to dominantly carbonate deposition during interval C suggests that the

Antler uplift in Idaho was relatively inactive. Farther south, however, the Wendover uplift was probably a positive element and contributed detritus to northwestern and north-central Utah. Still farther south, in eastern Nevada and adjacent parts of west-central Utah, a north-trending positive area, the Ely arch, developed during interval C but probably shed little detritus to surrounding low areas. On both of these positive elements the shelf carbonates of earlier Mississippian intervals were folded and eroded to form a surface of low relief. The deep subsidence of basins east of the positive elements suggests an expansion of the miogeosynclinal belt at the expense of craton margin to the east.

Eugeosynclinal tectonic history during interval C time is almost as uncertain as in preceding intervals. Volcanics, probably in great volume, were extruded on the western flank of the Antler uplift in Nevada and in northern California, and detrital sediments associated with the volcanics may have been derived from the active Antler uplift and deposited in troughs or basins in the eugeosynclinal belt.

INTERVAL D

Both orogenic and epeirogenic movement continued in interval D time at an increased rate. In general, negative areas appear to have subsided more, and positive areas appear to have been uplifted more than in previous intervals (pl. 10, fig. 4). These tectonic changes are reflected by the dominance of detrital rocks in interval D over most of the country (pl. 6-B), in contrast to the dominance of carbonate rocks in many areas in previous intervals (pls. 3-B, 4-B, 5-B).

Perhaps the most conspicuous tectonic changes in interval D (pl. 10, fig. 4) are the extension of the Appalachian geosyncline to connect with the Ouachita trough and the extension of the Ouachita trough to form a sinuous geosyncline from Arkansas through southeastern Oklahoma and central Texas to west Texas. Subsidence in this combined geosyncline seems to have been less in west-central Alabama than elsewhere along the entire length of the trough; this area might be considered an important discontinuity between the Appalachian and Ouachita troughs. On the other hand, if this area of relatively less subsidence is real, perhaps it was only a sill in the trough and simply did not subside as much as adjacent areas. This stability habit seems to have prevailed in Mississippi and western Alabama through previous intervals of the Mississippian System. The pattern of geosynclinal subsidence in this study clearly shows that trough segments subject to great subsidence are separated by trough segments of lesser subsidence.

Several intracratonic basins or troughs were well defined during interval D time (pl. 10, fig. 4): the Eastern Interior, Anadarko, and Delaware basins in the East and in the southern midcontinent region, and the Northeastern Utah trough, Central Montana trough, and Williston basin in the western midcontinent region. Of these, the Central Montana trough, Northeastern Utah trough, and the Anadarko and Delaware basins seem related to geosynclinal development in that they extend into the craton from the geosynclines; they appear to be located at convex bends of the geosynclines and may have been grabenlike depressions, perhaps taphrogeosynclines (Kay, 1945) or aulacogens (Shatskiy and Bogdanov, 1960), although faulting in Mississippian time has not been demonstrated.

Through interval D time, as in previous intervals, most of New England probably remained uplifted, a mountainous area formed during the Acadian orogeny. Volcanic activity may have continued off the southeast coast to provide volcanics in low neutral areas of Massachusetts and Rhode Island. Fault troughs in east-central Maine may have continued to subside and collect sediments during interval D time.

The Appalachian geosyncline subsided more during interval D time than in preceding intervals; a continuous belt of more than 1,500 feet of subsidence extended from eastern Pennsylvania to eastern Alabama (pl. 10, fig. 4). In the latter part of interval D time, the Appalachian positive element was actively uplifted not only in the northern segment, which had produced detrital materials throughout Mississippian time, but, probably, also as far south as South Carolina. This increase in uplift and southward extension of the Appalachian positive element appears to correlate with the increased subsidence of the geosyncline and its southwestward extension through Arkansas to west Texas. Source areas north of the Appalachian basin appear to have been inactive during interval D time. The Cincinnati arch remained a relatively positive feature separating the Appalachian and Eastern Interior basins, but, probably, it was not uplifted enough to serve as a source for detrital materials in either of these basins. Broad, open folding took place in late interval D time within the Appalachian geosyncline in southwestern Virginia, indicated in part by locally derived pebbles and cobbles within upper interval D. The small area of northeastern West Virginia, which had been either slightly positive or neutral during preceding intervals and which was devoid of earlier Mississippian sediments, appears to have foundered and probably was covered by interval D sediments.

The Michigan basin was uplifted and folded at some time during latest Meramec and Chester time and before earliest Pennsylvanian (Morrow) deposition began. The folds are 3–10 miles long and 2–4 miles wide, and they have 40–200 feet of closure. They trend northwest, except in southwestern Michigan where they trend north. The Eastern Interior basin continued to subside during interval D and received detrital sediments from the uplifted Canadian Shield to the north and northeast and from the Transcontinental arch to the northwest. Some minor tectonic activity took place within the Eastern Interior basin. There was some uplift in the Ozark Mountains area which probably was the source for some of the detrital rocks in northwestern Arkansas. The Ozark uplift may have been connected with the Transcontinental arch by a narrow, slightly positive element during much of interval D.

The Transcontinental arch was a broad uplifted structure trending southwest from Minnesota through western Nebraska, Colorado, and into New Mexico and Arizona. Judging from the distribution of detrital rocks around the margin of this arch, more uplift may have taken place in the Minnesota-Wisconsin area, in north-central Colorado and southeastern Wyoming, and in west-central New Mexico than elsewhere along the arch. South of the arch in Texas and adjacent areas, regional downwarping resumed at the beginning of interval D, and the Ouachita geosyncline, as a rapidly sinking mobile belt, was extended from southeastern Oklahoma southwestward through central Texas to west Texas. The Anadarko basin in western Oklahoma continued to subside during interval D and, as during interval C time, was connected to the Ouachita geosyncline by a trough which subsided less than the Anadarko basin or the Ouachita geosyncline. The Delaware basin in Texas also subsided during interval D and appears to have been connected to the geosyncline to the southeast by a trough of less subsidence. The similarity of the Anadarko and Delaware troughs is striking. Both are subsiding linear elements extending northwesterly into the craton at convex west- or northwest-projecting salients of the Ouachita geosyncline.

In the Rocky Mountains region and Williston basin, the most conspicuous areas of subsidence during interval D time are the Central Montana trough and Williston basin and the Northeastern Utah trough. All these contain some detrital rocks, the detritus having been derived from uplifted segments of the craton. Farther south in Arizona the record of sedimentation is very sparse; but in this area there is no indication of a source for detrital materials, and uplift of cratonic areas must have been slight. The Great Basin and Pacific Coast regions show increased tectonism in the mobile belts during interval D time just as in the Appalachian region. The Antler uplift in central and north-central Nevada was actively elevated; segments of the uplift to the north probably were relatively quiescent; segments to the south probably underwent slight uplift. Although the central Idaho segment of the miogeosyncline subsided to accommodate more than 4,000 feet of carbonate and fine detrital sediment, the Webb-Chainman-Diamond Peak segment of northern Nevada subsided to accommodate only a little more than 2,000 feet of coarse detritus derived from the tectonically active part of the highland. In contrast, the Oquirrh basin in northwestern Utah subsided rapidly and accommodated more than 4,400 feet of dominantly carbonate interval D. Thus, the miogeosynclinal belt in the latitude of northern Nevada and Utah remained as wide during interval D as during interval C. Although the Wendover uplift and Ely arch remained as positive structural features during the deposition of interval D, the sum of movement resulted in a slight subsidence, for interval D thins across these features; rocks of latest Chester age may have completely covered the Wendover uplift.

The eugeosynclinal belt west of the Antler uplift may have continued its general subsidence during interval D time. Detrital sediments no doubt were shed westward from the rising parts of the Antler uplift and probably collected in troughs or basins in this province; elsewhere, shoal areas may have existed, volcanic activity may have continued, and volcanoes may have formed constructional positive features, but the position and size of such features are unknown.

STRUCTURAL FRAMEWORK AT THE END OF THE MISSISSIPPIAN

NEGATIVE ELEMENTS

At the end of the Mississippian Period subsidence and deposition continued in most of the Appalachian-Ouachita geosyncline and in the Cordilleran geosyncline (fig. 82). Two cratonic basins, the Anadarko and at least part of the Delaware basin, continued to subside and collect sediments during the transition from Mississippian to Pennsylvanian time. Four segments of the Appalachian-Ouachita geosyncline subsided large amounts during Chester (Mississippian interval D) time (pl. 10, fig. 4); these segments were in eastern Pennsylvania, western Virginia, across Arkansas into adjacent States, and in west Texas. Although the entire geosyncline from Pennsylvania to west Texas continued to subside during Morrow (Pennsylvanian interval A) time, only a lengthened segment across Arkansas as far east as western Georgia showed major subsidence (McKee, Crosby, and others, 1975, pl. 15*A*, figs. 1, 2). The Anadarko basin also subsided a large amount in Morrow time. The development of the Cordilleran miogeosynclinal belt across the Mississippian-Pennsylvanian boundary is less easily compared. The Webb–Chainman–Diamond Peak and Eleana segments of the Cordilleran miogeosynclinal belt continued to subside from Chester into Morrow time and became the Bird Spring–Ely basin in eastern Nevada, but the northward connection with the central Idaho segment of the trough appears to have been terminated by an eastward-projecting salient of the Antler uplift. The Oquirrh basin continued to subside in Pennsylvanian time and connected to the trough in central Idaho, a negative trend that was evident through Mississippian time. Many of the small basins east of the main miogeosynclinal belt that are evident in latest Mississippian time (pl. 10, fig. 4) are not evident in the earliest Pennsylvanian (McKee, Crosby, and others, 1975, pl. 15*A*, figs. 1, 2).

POSITIVE ELEMENTS

At the end of Chester time most of the cratonic part of the United States was uplifted and gently warped; a generally southward sloping surface appears to have developed through the northern part of the midcontinent region and the Eastern Interior and Michigan Basin regions. Relatively positive features during interval D time — such as the Colorado-Wyoming uplift, the Ozark uplift, the Wisconsin uplift, and the Cincinnati arch — may have been elevated slightly. New tectonic features originated or poorly delineated Mississippian features were reactivated and uplifted. New elements that may have originated at this time were the Uncompahgre uplift, the Central Colorado trough in western Colorado, and the ancestral Front Range uplift in north-central Colorado, the Amarillo-Wichita uplift extending from the Texas Panhandle into southwestern Oklahoma, and the Nemaha anticline in eastern Kansas (fig. 82). Older tectonic features that may have become well delineated at this time were the Central Kansas uplift, the Nashville dome, the Kankakee arch, and the Findlay arch (McKee, Crosby, and others, 1975, pl. 15*A*, figs. 1, 2).

The Appalachian positive element and Antler uplift continued as positive elements into Pennsylvanian time. Active uplift occurred in the southern part of the Appalachian positive element and may have extended as far south as Alabama in Early Pennsylvanian time. Uplift appears to have waned in the northern part of the positive element where uplift had been most active during the Mississippian. In the Antler uplift, active movement continued in the Nevada segments from Mississippian into Early Pennsylvanian time.

SUMMARY OF TECTONIC HISTORY

The structural framework of the continental United States changed markedly during the Mississippian Period. The Appalachian-Ouachita geosynclinal system developed from a limited subsiding area in northeastern United States to an almost continuous subsiding trough extending from Pennsylvanian to West Texas. The Cordilleran geosynclinal system showed increased subsidence through Mississippian time, and the miogeosynclinal area expanded eastward at the expense of the craton. These structural changes are summarized as based on the depositional record provided by the Mississippian rocks and then are interpreted in possible plate tectonic explanations.

STRUCTURAL DEVELOPMENT

During Kinderhook (interval A) time, major subsidence in the Appalachian geosyncline was confined to the northeastern part of the Appalachian basin (pl. 10, fig. 1), and the adjacent borderland was probably highest to the east of this subsiding portion of the geosyncline. During Osage (interval B) and Meramec (interval C) time the geosyncline progressively extended farther south, and large amounts of subsidence took place in different segments along its length from eastern Pennsylvania to southern Georgia (pl. 10, figs. 2, 3). In Meramec time subsidence increased in the Anadarko-Ouachita troughs in Oklahoma and Arkansas.

In some degree the Appalachian positive element paralleled the extension of the geosyncline. Large amounts of uplift are indicated as far south as North Carolina during the Osage. During Meramec time, however, the rate of uplift and subsidence appears to have decreased in the Appalachian system, only to be accentuated (pl. 10, fig. 4) in Chester time (interval D). Subsidence was large along the entire Appalachian geosyncline in latest Mississippian time from Pennsylvania to central Alabama and along the sinuous course of the Ouachita geosyncline proper from eastern Mississippi to west Texas. The only separation between the two geosynclines appears to have been a sill-like area in western Alabama where subsidence, although more than 1,000 feet, was less than to the northeast and to the west. The Ouachita geosyncline continued as a well-defined subsiding trough until mid-Pennsylvanian (Des Moines) time (McKee, Crosby, and others, 1975, pl. 15*B*) when it was uplifted, folded, and faulted by the Ouachita orogeny. The Appalachian geosyncline, on the other hand, continued to subside through Pennsylvanian time and was folded, faulted, and uplifted sometime during the Permian or the early part of the Triassic.

The Cordilleran miogeosynclinal belt developed from a relatively simple subsiding trough east of the Antler uplift during Kinderhook (interval A) time (pl. 10, fig. 1) to a more complex system in succeeding intervals. Positive movement of the Antler uplift continued through Mississippian time and was the result of thrusting of eugeosynclinal rocks eastward over rocks of transitional and miogeosynclinal facies. Beginning in the Osage (interval B), localized basins and troughs (for example, Oquirrh basin) as well as intervening uplifts (Wendover uplift and Ely arch) began to differentiate in the craton margin east of the miogeosyncline (pl. 10, fig. 2) and during the Meramec (interval C) these features were quite mobile, and may be considered a part of the Cordilleran miogeosynclinal belt (pl. 10, fig. 3). These features continued to be active through Chester time (interval D) and into the Pennsylvanian.

In the eugeosynclinal belt west of the Antler uplift little detail of tectonic development is known. Volcanic islands were probably constructional features, and subsiding basins probably existed which collected volcanic sediments as well as detritus from the Antler uplift. The distance of these features west of the Antler uplift is conjectural.

The Williston, Michigan, and Eastern Interior basins prevailed as intracratonic basins throughout Mississippian time, with the exception of the Michigan basin which appears to have been stable or slightly uplifted during Chester (interval D) time (pl. 10, fig. 4). Intracratonic troughs — the Central Montana trough, Northeastern Utah trough, Delaware basin, and Anadarko basin — were subsiding features in Early Mississippian time but were best defined in Chester time when all were subsiding troughs connected to geosynclinal belts (pl. 10, fig. 4). These troughs fit the definitions of taphrogeosynclines (Kay, 1951) or aulacogens (Shatskiy and Bogdanov, 1960) and appear to have developed at bends, convex toward the craton, of the geosynclines.

PLATE TECTONIC INTERPRETATIONS

During the early Paleozoic the North American Continent was probably separated from other continents by oceans, on the east by a proto-Atlantic Ocean (the Iapetus Ocean of some authors). In the area of the present New England States in the Late Devonian, probably as a result of collisions of northeastern North America with northern Europe, an uplift was produced, "Acadia" or "Appalachia", the northern part of the Appalachian positive element of this chapter. This collision, marked by the Late Devonian Acadian orogeny, also resulted in the destruction of the Caledonian geosyncline that, according to recent reconstructions, was continuous from the Eastern United States, through the Maritime Provinces of Canada, and through the northern British Isles to Scandinavia and eastern Greenland (Kay, 1969, p. 971).

The Appalachian geosyncline of both the Mississippian and Pennsylvanian Periods was apparently a southward- and westward-extending segment of the Hercynian geosyncline of central Europe, in spite of the interruption of this trough by the Appalachian positive element in New England.

During the Mississippian Period the destruction of the proto-Atlantic Ocean continued probably as a result of subduction of the oceanic plate beneath encroaching continental plates. The compressional effects were progressive from north to southwest in the United States, first causing the uplift of the southward extension of the Appalachian positive element during the Mississippian and then, in the Early Pennsylvanian, the development of a highland from east to west through Texas.

This compression culminated in the Middle Pennsylvanian (Des Moines time) with the Ouachita orogeny in the Ouachita geosyncline in Arkansas, Oklahoma, and west Texas, and eventually in the Appalachian Revolution during Permian time, which marked the termination of the Appalachian geosynclinal system.

All these compressional events were probably the result of the approach, collision, and adjustment of the African and South American plates with the North American plate and resulted in the destruction of the proto-Atlantic Ocean leaving these continental plates in close proximity at the end of the Paleozoic.

The plate tectonic relations are less clear along the west coast of North America. Presumably the Antler uplift, extending from southern California through central Nevada and western Idaho and possibly into eastern Washington, was the product of compressional forces caused by the encroachment of the North American plate on an oceanic plate. This collision of plates and subduction of the oceanic plate began in the Late Devonian and continued throughout the Mississippian Period with the consequent repeated rejuvenation of the Antler uplift during this time. In view of the large amount of volcanic rocks in the Cordilleran eugeosynclinal belt, it seems likely that the oceanic plate was margined by or contained an arc of volcanoes.

PALEOGEOGRAPHIC SUMMARY

LATE DEVONIAN GEOGRAPHY

At the end of the Devonian Period, mountain building related to the Acadian and Antler orogenies had produced two northerly trending mountainous areas, one along the west coast (the Antler highland) and the other in New England ("Acadia" or the Appalachian positive element).

Minor broad upwarps in the craton, perhaps related to the compressional stresses indicated at both margins of the continent, also occurred near the end of Devonian time. The Transcontinental arch, the Texas arch, and the Ozark uplift appear to have been differentially uplifted and formed low hills and low plains. Although these uplifts caused a minor restriction of the Late Devonian sea, much of the conterminous United States still was covered by broad shallow seas in which deposition from Devonian into Mississippian time appears to have been almost continuous (pl. 13).

MISSISSIPPIAN GEOGRAPHY

INTERVAL A

Rocks assigned to interval A indicate that Kinderhook time was a time of marine transgression. Early in Kinderhook time the sea was moderately restricted, and sizable cratonic areas, marginal to and including the positive elements, were exposed to subaerial erosion. The epicontinental sea expanded later in Kinderhook time and probably had a configuration and areal extent like that shown on plate 12, figure 1. In fact, the sea must have been more extensive than shown in the Colorado, Wyoming, and Utah areas where marine beds of known or suspected Kinderhook age have been mapped arbitrarily with beds of Osage age.

Three different constructions of the paleogeographic map in the Southeastern States seem possible during interval A time. The paleogeographic map indicates that the midcontinent and eastern parts of the United States were an almost landlocked embayment, and that access to open marine waters may have been solely through a broad passageway in South Dakota between the Wisconsin highlands and the Transcontinental lowland and a hypothetical limited passageway in Louisiana. A land area of very low relief may have bordered the embayment on the south through most of the Southeastern States. If this embayment were so landlocked, that fact readily explains the restricted marine environment that existed in late Kinderhook time in the northwestern part of the Appalachian basin and in the Michigan basin where black organic shales accumulated in an euxenic environment. The origin of the phosphate and glauconite in the Kinderhook rocks of the Maury Formation of Tennessee and of the upper part of the Chattanooga Shale of northwestern Georgia and northeastern Alabama could have a bearing on the interpretation of the geography of the southern part of the embayment. Conant and Swanson (1961, pl. 14) showed inferred land through the Southeastern States in latest Devonian and earliest Mississippian time (Chattanooga Shale) and also inferred an isthmus of land connecting northward through northern Mississippi, western Tennessee, and northeastern Arkansas to the Ozark lowland. If this physiography prevailed into interval A time, the phosphate and glauconite of the Maury Formation probably formed from concentration of chemicals indigenous to the water of the embayment during the extremely slow accumulation of the fine detrital material in the Maury. A second possible interpretation of the geography is that the Ozark lowland was isolated as an island in the embayment and that a marine passageway connected from the southern Appalachian basin to the relatively deep water in southern Arkansas. It is possible that phosphorus-rich upwelling currents from the deep carried phosphate to the more shallow areas of the southern Appalachian basin and produced the phosphate deposits of the Maury Formation. Thirdly, it seems possible that additional access to open marine waters may have existed southwest of the Appalachian landmass as one or more passageways southward from the Ouachita Mountains area of Arkansas through Louisiana and Mississippi (as shown on pl. 12, fig. 1) or southward through Georgia and Alabama to join with the open, southern part of the proto-Atlantic Ocean. Again, phosphorus-bearing waters upwelling from the ocean basin might have provided the phosphate contained in the Maury. Either the second or third possibility seems to meet the paleolatitudinal and paleogeographic conditions for phosphate deposition indicated by Sheldon (1964, p. C109–C110); the Maury Formation probably was deposited between lat. 15° and 25° S. within the trade-wind belt. Trade winds would have blown westward from the southern Appalachian basin across the deep water in southern Arkansas, providing proper conditions for upwelling of cool water from the deep.

River systems drained westward from the Appalachian highlands through foothills to cross a swampy plain and form deltaic deposits of coarse clastic material in the Appalachian lowlands (Pepper and others, 1954, pls. 12, 13A–13I). On the northern side of the embayment, deltas, generally of finer grained clastic material, were formed by river systems draining from the Adirondack region, the Canadian Shield, and the Wisconsin highlands. The lower courses of these relatively long rivers probably traversed lands of only slight relief and may have crossed swampy plains to empty into the marine embayment. Within the embayment, Cincinnatia may have been a large island area during early interval A time but may have been almost completely covered by water during the late part of interval A. The Ozark lowland probably was an island, perhaps with centrally located low hills, throughout interval A time; minor uplift during the middle part of the interval produced a marked influx of fine clastic material off the western side of the island. Land areas in Texas, the Transcontinental lowlands, and the Defiance-Zuni hills were undoubtedly of low relief. A part of the lowlands in Texas, in particular, supplied relatively coarse detrital material to the sea in Oklahoma and may have had a central relief of low hills. Segments of the Antler highland formed low hills which shed dominantly fine detrital material to the Eastern Cordilleran Sea and its deeps in southern Nevada, in northern and central Nevada, and in central Idaho. Little is known of the paleogeography of the Western Cordilleran Sea lying west of the Antler highland during interval A, specifically. Detrital material probably was shed westward from the Antler highland, and fine materials may have been transported along the belt by longshore currents. Volcanic rocks in northern California, suggest the possible existence of volcanic islands, perhaps an island arc. The northern extension of the Antler highland is also poorly known. In eastern Washington limestones of Early Mississippian age suggest a miogeosynclinal assemblage, but nearby argillite sequences are of eugeosynclinal aspect. It is possible that the argillites are allochthonous and have been thrust eastward into the miogeosynclinal belt and that the projection of the Antler highland was just to the west of these outcrops. This postulated highland may have extended north to connect with a geanticline in southeastern British Columbia (the Omineca geanticline of Douglas and others, 1970, p. 411–413). By this interpretation, the highland may have been a narrow linear belt of low hills in eastern Washington during interval A time that may have provided the detrital rocks of part of the *Grass Mountain sequence* of northeastern Washington. On the other hand, no evidence of a Mississippian highland has been identified in central Washington, and the thick sequence of detrital rocks may have been derived from a postulated highland in northwestern Montana and northern Idaho (pl. 12, fig. 1). These alternate interpretations may apply throughout Mississippian time, inasmuch as the sparse outcrops of possible Mississippian rocks in Washington cannot be broken down into intervals.

INTERVAL B

Mountainous terrain is again indicated along the central Eastern United States (pl. 12, fig. 2). An elevated landmass extended probably from New England south to North Carolina, flanked on the west by low hills and a swampy coastal plain across which rivers carried detritus which finally was deposited in deltas. Although Osage time marks the maximum transgression of Mississippian seas over conterminous United States, the aggradation by streams draining this eastern source area caused an overall westward retreat of the strandline in the Eastern States. Most areas that had previously been islands, such as Cincinnatia and small islands in the Eastern Interior basin, were all submerged during the interval B transgression. The Ozark lowland might have remained emergent as a small island or a group of islands. The Canadian Shield, Wisconsin highland, and the Adirondack region were still contributing detritus to the embayment from the north. Only marine deposits are known in Michigan and Ohio, thus, the strandline and coastal plain must have been to the north in Canada. Relatively deep water existed in an area extending from southern Illinois southward through southern Arkansas. As during interval A time, the geography of the Southeastern States during interval B is poorly known; a land area of very low relief is postulated to have extended along the southern side of the embayment as far west as eastern Texas, with the exception of a marine passageway possibly through Louisiana.

The Transcontinental lowlands and the lowland in northern and western Texas were mostly submerged during interval B. The Defiance-Zuni hills on the Arizona–New Mexico State line, and parts of northeastern New Mexico, west Texas, and southwestern Arizona all appear to have been island areas of very low relief. A larger island in southeastern Wyoming and central and eastern Colorado may have had some low hills; at least it shed minor amounts of detrital material to the surrounding sea.

In the Far West the Antler highland may have formed a continuous linear land area separating the miogeosynclineal Eastern Cordilleran Sea from the eugeosynclinal Western Cordilleran Sea. Texture and quantity of detritus deposited in the Eastern Cordilleran Sea suggest that land areas of mountainous terrain were uplifted in north-central Nevada and central Idaho. The Wendover highland in northwestern Utah also was uplifted and formed a small island that may have had low hilly relief and shed considerable amounts of detritus. The only area of probable deep water was in the Eleana deep in south-central Nevada. West of the Antler highland the Western Cordilleran Sea area is poorly known. It is visualized as an area containing shoals and both tectonic and volcanic islands, probably with fringing reefs; deeps probably existed in parts of the sea floor.

INTERVAL C

The tectonic instability of Meramec time in the United States is reflected in the paleogeographic interpretations (pl. 12, fig. 3). Marine advance was probably not as extensive as during interval B. The southern part of the Appalachian highlands had been reduced to low hills, but the northern part remained a highland that shed sediments through foothills to an alluvial plain. Maximum marine advance in the Appalachian basin appears to have extended to central Pennsylvania and southeastern Ohio and formed an embayment bounded on the west by a low land, Cincinnatia, and on the north by alluvial plains sloping up toward the Canadian Shield and the Adirondack Mountain area. A low peninsula reflecting the Kankakee arch probaby projected westward from Cincinnatia. A peninsula also projected southeastward from the Wisconsin highland. These two peninsulas served from time to time to restrict the marine waters of the Michigan basin and to cause evaporite deposition. The Ozark lowland in southern Missouri emerged as plains and low hills and was sufficiently large during the mid-interval C regression to combine with Cincinnatia and produce restricted marine waters (pl. 11, fig. 3) and evaporite deposition in the Eastern Interior basin of southeastern Iowa, southern Illinois, and western Kentucky. The only deep water in the major embayment of the eastern part of the United States is presumed to have extended eastward across southern Arkansas from southeastern Oklahoma. Low land is postulated margining this embayment on the south, as far west as southeastern Texas, except for a marine passageway possibly southward through Louisiana. The land areas may have shed some fine detrital materials into the deepwater trough. Volcanoes must have been active in the vicinity, as indicated by the presence of the tuff beds associated with the detrital material deposited in the deep water.

The Transcontinental lowland, connecting with the Wisconsin highland and extending from Wisconsin and Minnesota southwestward through Colorado and Arizona, probably was a land area during most of interval C time, and it probably separated the eastern marine embayment from western marine waters. It must have been a very low barrier, for it produced little detritus to adjacent seas. In the Wisconsin highland area, low hills may have been a source for small amounts of detritus in interval C in southeastern Iowa. Another area of low hills probably existed in western Nebraska and north-central Colorado which served as source for a small amount of detrital material in western Kansas and southeastern Colorado and a larger amount in northeastern Utah (pl. 10, fig. 3). If the combined Transcontinental lowland and Wisconsin highland was a barrier separating eastern and western seas during most of interval C time, the main accessway to open marine waters from the eastern embayment probably would have been through western Texas, southeastern New Mexico, and a possible marine passageway in the Southeastern States.

West of the Transcontinental lowland the most prominent land area was the Antler highland. The southern part was uplifted during interval C time, and high mountains were present in Idaho, in northern Nevada, and in southwestern Nevada and adjacent California. East of the Antler highland, two lowland areas formed islands during most of interval C time, the Wendover higland in northwestern Utah and the Ely lowland, reflecting the Ely arch, in eastern Nevada.

West of the Antler highland, volcanic rocks suggest that volcanic islands, perhaps even a volcanic island arc, may have formed land features, and could have been the only land features in the eugeosynclinal sea.

INTERVAL D

Greater change, both geographically and tectonically, probably took place during interval D time than in any of the preceding Mississippian intervals. The increased instability of both the craton and the marginal belts noted during interval C time continued into interval D time and appears, in general, to have increased through the interval.

The Appalachian highlands along the eastern margin of the Appalachian geosyncline were uplifted and extended southward so that by late Chester time a mountain range probably was continuous from the Canada—New England border almost to Georgia (pl. 12, fig. 4*B*). Detrital material was transported westward through a foothill region and was deposited on alluvial plains that progressively extended westward during the interval causing the westward retreat of marine waters from southwestern Pennsylvanian to southern Ohio. (Compare early Chester, pl. 12, fig. 4*A* with late Chester, pl. 12, fig. 4*B*.) To the southwest an area of low hills flanked by plains are presumed to have extended beyond the end of the mountainous area through the southern parts of Georgia, Alabama, and Mississippi. Some volcanic activity continued in interval D, and volcanoes are again indicated in the south (pl. 10, fig. 4).

To the west, Cincinnatia and the Nashville lowland were emergent areas of very low relief through Chester time. Uplifts in Canada and in the Minnesota-Wisconsin area caused widespread development of deltaic deposition in the Eastern Interior region early in Chester time and caused the consequent general southward retreat of the strandline from its positions in earlier intervals. The Ozark lowland probably was uplifted slightly, and part of it may have been an area of low hills. During at least the latter part of Chester time, the Ozark lowland may have been a peninsula tied by an isthmus of very low land to higher land areas to the west in the Transcontinental lowland.

Thus, the eastern embayment shrank drastically during interval D time, first in the Eastern Interior region and later in the Appalachian basin region.

Shallow-water marine deposition took place in the eastern embayment, but deepwater deposition occurred in both the Ouachita deep and the Anadarko deep. Access to open marine waters must have been through South-Central United States.

The Transcontinental lowland probably was uplifted sufficiently to serve as a northeast-trending barrier between western and eastern marine waters and also to provide a source area for detrital materials along its margins. Higher ground, most likely rolling hills, probably existed in several places along this arch: in northwestern New Mexico, north-central Colorado and southeastern Wyoming, and in Minnesota and Wisconsin.

On the west margin of the Transcontinental lowland, three embayments received some sediment from the lowland itself (pl. 12, fig *4A*). The Williston basin, a prevailing intracratonic basin, was connected to the Eastern Cordilleran Sea through the Central Montana trough. The embayment in western Wyoming, an area of estuarine deposition, was gradually covered by shallow water during the Chester transgression. The structural trough in northeastern Utah (pl. 10, fig. 4) is interpreted to have caused a slight embayment of the coastline in northwestern Colorado.

As in previous intervals, the sea probably was widespread in the Far Western States during interval D time. The Antler highland was the most conspicuous land area and was probably continuous from southern Idaho through Nevada into California. High mountains, however, were probably confined to the part of the highland in northern and central Nevada and in Idaho; the remainder of the highland may have been low hills or plains. West of the highland in the eugeosynclinal belt volcanic islands may have been the only land areas and their position is not known; perhaps they formed an island arc.

END OF THE MISSISSIPPIAN

Marine retreat, probably the result mostly of epeirogenic uplift and warping, reached a maximum at the end of the Mississippian Period. At this time only about 30 percent of the conterminous United States was inundated (pl. 12, fig. *4C*). Marine waters were confined to the southern part of the Appalachian geosyncline but extended at least as far north as northeastern Kentucky (Sheppard and Dobrovolny, 1962; Horne and others, 1974). The Ouachita geosyncline and the Anadarko basin were submerged by marine waters, but the Delaware basin was probably emergent.

In the Western States, the area of the Eastern and Western Cordilleran Seas remained submerged, and a sinuous shoreline probably followed close to the western margin of the craton. Both of the areas of the Williston basin and Central Montana trough were probaby emergent.

The Appalachian highlands probably remained as a mountain range along much of its length at this time, as did the Antler highland in the West, at least in central and northern Nevada and in Idaho. Most of the central land areas of the country were probably flat, perhaps swampy flood plains. Low hills may have been present in the more positive areas of the craton either as erosional remnants or perhaps as areas actively uplifted and eroded at this time. These hilly areas may have been along Cincinnatia, in the Ozark lowland, in the Wisconsin highlands, in the Colorado-Wyoming area, and in the area of the Defiance-Zuni hills.

DEPOSITIONAL AND ENVIRONMENTAL HISTORY OF THE MISSISSIPPIAN SYSTEM

RELATION OF MISSISSIPPIAN SYSTEM TO UNDERLYING ROCKS

Rocks of Mississippian age rest conformably on rocks of Late Devonian age (pls. 2, 13) throughout the Appalachian basin, the Michigan basin, and Eastern Interior basin, as well as most of the Williston basin, Central Montana trough, eastern Ouachita trough, and a central part of the Great Basin region. With only a few exceptions, deposition in these areas seems to have been essentially continuous from Late Devonian into Kinderhook time (pl. 13).

Lithologic changes do not always correspond to the systemic boundary in parts of these areas and the base of the Mississippian System and of interval A has been placed arbitrarily at the nearest regionally identifiable contract. Thus, a thin veneer of beds that are known to be of earliest Mississippian age have been mapped with the Devonian — for example, the Hampshire Formation in the northern Appalachian basin (pl. 15, cols. 4, 5), the Chattanooga Shale of parts of the South-Central States (pl. 15, cols. 70, 72), the Bakken and Englewood Formations in the Williston basin (pl. 15, cols. 98–101). Conversely, some rocks assigned to the Mississippian in this study may be shown (pl. 2) as resting on rocks of combined Mississippian and Devonian age. In all cases these underlying rocks that cross the system boundary are believed to be latest Devonian and earliest Mississippian age.

Mississippian rocks rest disconformably on beds older than Late Devonian in limited areas around the Ozark uplift, marginal to the Williston basin, and marginal to the central part of the Great Basin region. They also are disconformable on older rocks in a broad area extending from eastern Montana through central Wyoming and including much of eastern Colorado, western Kansas, northern New Mexico, northern and central Texas, and all Arizona. In this broad area the Mississippian rocks progressively overlap older systems to rest finally on Precambrian rocks in an irregular central area in northeastern Colorado, and in an irregular area in central and northeastern New Mexico and the adjacent Texas Panhandle. The generalized magnitude of disconformtiy at the base of the Mississippian System is shown on plate 13.

INTERVAL A

Interval A includes rocks that are mostly of Kinderhook age, the oldest provincial series of the Mississippian Period. In places, however, some or all of the rocks of Kinderhook age have been assigned arbitrarily (1) to the overlying unit and mapped as part of interval B, (2) to a combined unit with the overlying rocks and mapped as interval A-B undivided, or (3) to the Devonian and excluded from the maps of interval A. All these arbitrary assignments result from the absence of a distinctive rock unit containing beds exclusively of Kinderhook age. Assignments are shown on plate 15. Cross sections of interval A are shown on plates 9-A, 9-E, 9-F, and 9-G.

Interval A is quite thin over most of its area of deposition relative to the thickness of the succeeding intervals of the Mississippian, and, although widespread originally, interval A forms the least volume of rock of any of the intervals. In general, interval A was deposited in a transgressing sea which covered much of the United States by the end of interval A time. Even if those rocks of Kinderhook age here excluded from interval A were included in this mapping, the interval would still contain the least volume of any Mississippian interval.

APPALACHIAN BASIN

The eastern edge of deposition of interval A must have been considerably east of the axis of the Appalachian geosyncline (pl. 10, fig. 1) in the northern part of the Appalachian basin (fig. 82). The strata of the eastern part of the basin are continental and the featheredge lay well east of the shore of the Early Mississippian sea. Similarly, the northern edge of deposition for the western half of the Appalachian basin lay well north of Lake Erie in Canada.

In the southern extremity of the Appalachian basin, interval A probably reaches a depositional limit in northeastern Mississippi and west-central Alabama (pl. 3-A). Interval A in the southern part of the Appalachian basin mostly consists of a single thin formation, the Maury Formation; in the northern part of the basin, it comprises three formations: the Bedford Shale, Berea Sandstone, and Sunbury Shale and equivalent beds (pl. 15). Along the eastern margin of Mississippian rocks from Pennsylvania to Tennessee, the lower part of the Mississippian cannot be separated, and these formations of interval A pass into the lower part of an undifferentiated sequence of relatively coarse detrital rocks of the Pocono Formation or Price Sandstone. In this area the lower two intervals of the Mississippian are combined and mapped as a single unit, interval A-B, as shown on plates 3, 4, and 9-B.

Interval A is thickest (pl. 3-A) near the axis of the Appalachian geosyncline in eastern Pennsylvania where at least 2,000 feet of continental clastic strata can be referred to the interval on fossil evidence, although lithologically these beds do not differ from the rest of the strata in combined interval A-B. The wedge of interval A strata thins to the west and reaches a near-minimum thickness near the center of the basin in west-central and southern West Virginia. These strata are also thin in south-central Kentucky, Tennessee, and Alabama, where the interval is commonly 5 feet thick or less.

From northeast to west and southwest, the rocks of interval A grade from coarse-grained continental clastics to fine-grained marine rocks (pl. 9-E, sec. *A–A′*). Near the axis of the Appalachian geosyncline in the northeastern part of the region, conglomeratic sandstone is abundant (pl. 3-B); whereas, in the western part of the basin and on the platform to the west, fine-grained dominantly marine sandstone interfingers with and grades laterally into siltstone and shale. Green shale containing phosphate nodules and glauconite grains is the dominant lithology in the southwest part of the basin.

South of Kentucky the Chattanooga Shale contains at most a few feet of beds of Mississippian age; however, the formation has been excluded from interval A, and the base of interval A is mapped at the color change from black shale of the Chattanooga to the green shale of the Maury. The basal contact of interval A is regarded as essentially conformable with underlying strata through almost all of the Appalachian basin (pl. 13). In parts of northeastern Mississippi and northwestern Alabama the Chattanooga Shale and interval A are missing. In the places where both are missing, interval B of the Mississippian rests on rocks of undifferentiated Devonian or probable Middle Devonian age. In limited areas in central Tennessee and northern Alabama, interval A rests on older strata (pl. 2). These isolated areas seem to be areas of localized uplift and erosion prior to Mississippian time and may have been islands during the deposition of the Chattanooga.

Throughout the Appalachian basin the boundary between intervals A and B is conformable and, except in the area where these intervals cannot be separated, is a lithologic contact of convenience (pl. 15).

A major source area for detrital materials lay east of the northern part of the Appalachian basin region and shed coarse materials westward into the Appalachian geosyncline. A second source for detrital material lay in Canada and shed detritus southward into central and eastern Ohio. To the south and west of these sites of coarse deposits, interval A consists of shale and mudstone (pl. 3-B) that is presumed to have been derived mainly from these sources and to have been transported in suspension by marine currents. In the southern part of the basin, however, the fine-grained sediments may have been partly derived from lowland areas inferred to lie to the east and south of the basin (pl. 10, fig. 1; pl. 12, fig. 1).

Large deltas fed by a series of river systems formed along the northern and eastern margins of the Appalachian basin. The subaerial portions of the deltas may have been fringed by beach and tidal flat deposits.

During deposition of the Bedford Shale and Berea Sandstone, the sea appears to have been of normal salinity and oxygen content. But in latest interval A time, during the maximum advance of the sea, when the Sunbury Shale was being deposited, euxenic conditions existed in a large area east of Cincinnatia (pl. 11, fig. 1), and restricted marine conditions are inferred.

A monsoonal climate may have existed in the basin (Pepper and others, 1954, p. 82). Coal beds in the delta formed by the Pocono Formation indicate a climate sufficiently benign to support swamp vegetation.

MICHIGAN BASIN AND EASTERN INTERIOR BASIN

Because of post-interval A and post-Mississippian erosion, the original depositional limits of interval A are not known, but, generally, they were well beyond the present limits of the interval (pl. 3-A; pl. 10, fig. 1) in these regions. The limits of the interval are considered to be depositional limits only locally around the Ozark uplift and in a few places along the La Salle anticlinal belt (fig. 82).

Interval A attains a maximum thickness of almost 800 feet in the Michigan basin (pl. 9-E, secs. $B-B'$, $C-C'$). To the south in the Eastern Interior basin region, interval A (pl. 9-A, secs. $a-a'$ through $g-g'$) is thin compared to thicknesses in the Michigan basin and also compared to thicknesses of succeeding intervals. Thicknesses exceeding 100 feet are mostly lobate tongues of detrital material. Extremely thin but widespread interval A occurs in Indiana and adjoining Illinois and in western Kentucky and western Tennessee.

Interval A in the Michigan Basin and Eastern Interior Basin regions is dominantly fine-grained detrital rock (pl. 3-B) except that carbonate rocks form a belt extending from southwestern Indiana across southern Illinois.

During much of interval A time the Michigan basin was covered with shallow normal marine waters, and deposition in this environment was virtually continuous from the Devonian. In the east a delta in the Thumb area, marked by the Berea Sandstone, tongued southwestward into the Antrim Shale of the central part of the basin. In late interval A time, the delta, if any, retreated northward into Canada (pl. 11, fig. 1); the Sunbury Shale was deposited in much of the basin, and an euxenic environment indicating restricted circulation in the seaway replaced the more normal marine environment of the earlier part of interval A time.

Early interval A time in the Eastern Interior basin region is marked by the westward advance of a delta into eastern Kentucky. Mudstone and sandstone (Bedford and Berea) from source areas east of the Appalachian geosyncline were shed westward into a shallow marine environment. Concurrently, detrital sediments of probable deltaic nature encroached southward and southeastward and were deposited in marine waters in southeastern Iowa, northeastern Missouri, and western and central Illinois, as well as in northwestern Indiana. Muds were also transported, probably southward or westward into the Forest City basin. Early interval A carbonate deposition was mostly restricted to shelf areas in western Missouri. Carbonate environments are interpreted to have spread northward and eastward across areas marginal to the Ozark Mountains area as the supply of detrital sediments from northern source areas diminished.

In late interval A time (pl. 11, fig. 1), deltaic deposition in the eastern part of the region diminished, and environments migrated eastward and northward with the transgression of the sea. Dark organic mudstones were deposited in shallow restricted marine environments along the east side of the Cincinnati arch and north of the Kankakee arch. Weakening of energy to disperse detrital materials in the upper Mississippi Valley area allowed carbonate deposits, already present in western Missouri during early interval A time, to advance eastward and interfinger with detrital sediments in the Mississippi Valley area and finally onlap the detrital sediments throughout most of Illinois and Indiana to the Cincinnati arch. Shallow clear-water marine conditions prevailed in carbonate-dominated areas marginal to the Ozark Mountains area, but quieter and perhaps deeper water conditions are inferred to have existed farther east. The emergent or shoal area along the Cincinnati arch prevented carbonate deposition from reaching eastern Ohio. In late interval A time, deposition of detrital sediments locally in southwestern Missouri and of oolitic limestones in Iowa indicates that a shallow relatively high energy, clear-water environment marked the late stages of interval A deposition.

Source areas for the detrital rocks of the Michigan basin (pl. 10, fig. 1) appear to have been dominantly to the west from the Wisconsin highland and to the northeast from the Canadian Shield. Both of these source areas provided detrital materials to the northern part of the Eastern Interior basin, although the Wisconsin highland appears to have been the dominant source and to have contributed coarser material than that derived from the Canadian Shield. The sandstone and mudstone of eastern Kentucky were derived from the east and northeast; only the distal portions of these detrital wedges occur within the region, and the westward and southward thinning of these lobate tongues indicates the same source direction across the Appalachian basin. The widespread thin phosphatic mudstone (Maury Shale) in the southern part of the region probably was derived from distant eastern and southern sources. The west-trending belt of detrital material in southwestern Missouri (pl. 3-B) was derived from the Ozark uplift.

MIDCONTINENT REGION

In contrast to regions to the east, the base of interval A is a disconformity throughout most of the midcontinent region. Interval A was probably of much greater extent than at present. Interval A seas may have covered the Transcontinental arch in Nebraska and South Dakota, joining the deposits of the midcontinent region with those of the Williston basin.

Interval A exceeds 200 feet in thickness in only a few places in the midcontinent region (pl. 3-A). The irregular thickness distribution appears to be the result both of irregularity of the surface of deposition and pre-interval B or pre-Pennsylvanian erosion or both.

Interval A in the midcontinent region is dominated by carbonate rocks (pl. 3-B; pl. 9-A, secs. *a–a′*, *b–b′*, *c–c′*; pl. 9-E, secs. *D–D′* through *H–H′*, pl. 9-F, secs. *I–I′* through *L–L′*). It contains more than 10 percent chert in large parts of Iowa and westward into easternmost Nebraska. If the interval A part of the Arkansas Novaculite in the Ouachita Mountains area of southern Arkansas had been mapped in this study, it would be shown as carbonate rock containing 10–80 percent silica. Detrital rocks are conspicuous in southeastern Iowa and in the Anadarko basin area of the Panhandles of Texas and Oklahoma and are irregularly distributed in interval A of southwestern Texas and southeastern New Mexico. Rocks of Kinderhook age in the Arkansas Valley through central Arkansas are dominantly shale and would make another patch of detrital rocks on the lithofacies map (pl. 3-B), but they were arbitrarily excluded from interval A and are not shown on the map.

The widespread pre-interval A black shale in the eastern part of these regions, the Chattanooga Shale, represented an euxenic environment of deposition in relatively restricted marine waters. It was succeeded abruptly by normal conditions in a transgressing sea. Earliest deposits of interval A were detrital in many places; basal sandy units in Arkansas, Oklahoma, and western Kansas were derived from reworking of preexisting regoliths which in turn may have been derived in considerable amount from Ordovician rocks. The remainder of interval A is dominated by carbonate rocks through almost all the midcontinent region. These carbonates are oolitic and crinoidal, and with the basal detrital rocks they suggest warm shallow-water normal marine deposition in an environment of moderate energy. A lower energy environment and perhaps deeper water may be indicated by the dark shale and novaculite of central and southern Arkansas. The irregular distribution of interval A in western Texas and southeastern New Mexico suggests that interval A may have filled old valleys in the previous land surface during the advance of the interval A sea from the south.

The detrital materials of southeastern Iowa were derived in part locally from underlying strata and in part from the Wisconsin arch to the northeast (pl. 10, fig. 1); those in the Anadarko basin probably were derived from the Texas arch (fig. 81) to the south, and those in the southwest Texas area may also have been derived from the Texas arch and other land areas in New Mexico and western Texas. The primary source for the carbonate rocks of interval A was organic.

ROCKY MOUNTAINS REGION AND WILLISTON BASIN

Interval A is thickest and most extensive in the northern part of the Rocky Mountains region (pt. I, chaps. M, N; pl. 9-F, secs. *N–N′*, *O–O′*, *P–P′*) and in the Williston basin (pt. I, chap. O; pl. 9-F, secs. *O–O′*, *Q–Q′*). Rocks of interval A include shale and limestone in central and eastern Montana and limestone in North and South Dakota and central Wyoming.

Farther south, beds assigned to interval A are limited in extent. (See pt. I, chaps. J, K, L, M and pl. 9-F, secs. *I–I′*, *M–M′*, *N–N′*.) The age of some beds is poorly known, however, and the age assignments commonly are either equivocal or arbitrary. (See pl. 15.)

The original limits of beds of Kinderhook age were considerably beyond the present limits of the beds assigned to interval A (pl. 3-A) in most of the Rocky Mountains region. As a result of the arbitrary inclusion of certain beds of Kinderhook age with interval B in this study, the land area shown or implied in the interpretive maps (fig. 1 in pls. 10, 11, 12) is considerably exaggerated, particularly in western Colorado, eastern Utah, northeastern Arizona, and northwestern New Mexico. In eastern Colorado, southwestern New Mexico, and southeastern Arizona, the present extent of interval A may approximate the original depositional limit of interval A.

Interval A thins irregularly from a maximum of about 350 feet in western Montana (pl. 3-A). Eastward thinning is probably due partly to onlap during the transgression of the interval A sea. Kinderhook equivalents are thought to be present throughout the Williston basin and to be as extensive there as any of the overlying parts of the system. To the east and southeast of the Williston basin, interval A is beveled by post-Mississippian erosion; consequently, the beds are absent in eastern North Dakota and eastern and southern South Dakota.

In central and eastern Montana, in North and South Dakota, and in northern and western Wyoming, the rocks are dominantly gray fine- to medium-grained thin-bedded limestone and dolomite alternating with thin beds of gray to green calcareous shale or siltstone (pl. 3-B). In the limited exposures of northwestern Arizona, interval A is entirely carbonate. Although these beds in Arizona overlie a regional unconformity at the base of the Mississippian and they probably formed at or near the margin of a seaway, they are almost completely free of terrigenous material. Apparently, any land areas nearby had low relief, and carbonate rock was exposed on most of the surface upon which deposition occurred. The carbonate rock shown (pl. 3-B) as interval A in north-central New Mexico is largely limestone breccia of uncertain origin. (See pt. I, chaps. J and K for differing interpretations.)

If beds arbitrarily eliminated from this map unit (pl. 15) but suspected or known to contain Kinderhook equivalents, were represented on plate 3-B, a limestone pattern would be shown in the Four Corners area, and a sandstone pattern would be shown in central Colorado and in southeastern Wyoming and adjacent northeastern Colorado. These sandstones may indicate that an area in central southeastern Wyoming and north-central Colorado was emergent in Kinderhook time and was high enough to supply small quantities of quartz sand to the surrounding marine shelf.

With the exception of minor detrital sediments — mudstone in the center of the Williston basin and in southwestern New Mexico and basal sandstones in central Colorado and southeastern Wyoming — interval A is dominantly carbonate rock deposited in shallow warm normal marine water (pl. 11, fig. 1) that was clear and free from mud or sand. Calcareous shale in the center of the Williston basin was probably derived from low distant source areas to the east and southeast along the Transcontinental arch. In interval A time the Williston basin area is interpreted as the site of starved-basin deposition under normal marine conditions where very little sediment — mostly silt, clay, and organic matter — was deposited and where water was relatively deep in comparison to later stages of sedimentation. Calcareous mudstone in southwestern New Mexico was probably derived from lowlands to the north in west-central New Mexico.

GREAT BASIN AND PACIFIC COAST REGIONS

Interval A is thought to have been deposited widely on the Great Basin (pl. 9-G, secs. *R–R′* through *U–U′*) and Pacific Coast regions. It was not deposited on the Antler uplift, a belt that was raised in Late Devonian time and extended from central Idaho southward through central Nevada to central and southern California (fig. 82). The uplift separated the Cordilleran geosyncline into two parts, a miogeosynclinal belt on the east and a eugeosynclinal belt on the west. During interval A the uplifted belt was relatively low.

Thicknesses of 1,000 to more than 2,000 feet of interval A were deposited in parts of the miogeosynclinal trough. East of the main trough interval A thins rapidly to shelf sections which range from about 100 feet to local maximums of more than 600 feet. Thicknesses of interval A west of the Antler uplift in the eugeosyncline are not known.

Shale and siltstone are the dominant facies in the miogeosyncline (pl. 3-B); these rocks were derived from the Antler highland (pl. 10, fig. 1) to the west. Locally, in central Nevada, limestone is adjacent to the Antler highland in the miogeosynclinal belt. East of the miogeosynclinal belt, interval A is dominated by limestone. Mississippian rock types in the eugeosyncline are dominantly detrital but include such diverse rocks as bioclastic limestone and mafic lava flows. Rocks probably assignable to interval A include volcanics, shale and chert, and conglomerate in northern California and limestone in northeastern Washington. In the eugeosyncline some of the detritus undoubtedly was derived from the Antler highland to the east, some detritus may have been carried along the geosyncline by longshore currents, but the volcanics and probably much of the coarse detrital material were derived locally from island sources within the eugeosynclinal province.

East of the Cordilleran miogeosynclinal belt through central Nevada and Idaho, carbonate rocks were deposited in clear warm shallow marine waters of normal salinity (pl. 11, fig. 1). Most of the deposition was below wave base, but in southern Nevada and southern

California blue-green algae in micritic limestone suggest that deposition was in a very shallow subtidal, or perhaps intertidal, marine environment. Very little detritus was shed westward from the exposed craton into the shallow epicontinental sea covering the eastern parts of these regions. In the Cordilleran miogeosynclinal belt, mudstone, siltstone, and sandstone, derived from highly weathered lower Paleozoic eugeosynclinal and transitional rocks of the Antler highland, were deposited probably in moderately deep marine water in troughs in central Idaho, in northeastern Nevada, and in south-central Nevada. Elsewhere along the miogeosyncline, limestones appear to be shallow-water marine deposits. Probable Early Mississippian volcanic activity is indicated in northern California. The sparsity of fossiliferous limestone implies that the dominant environments did not support life. The association of bedded chert, graywacke, greenstone, dark argillite, and conglomerate with minor biohermal and reeflike limestone suggests frequent shifts in water depth in the eugeosyncline. The limestones may have been fringing reefs marginal to tectonic or volcanic islands and may have been deposited in shallow marine water; whereas the detrital materials may have been deposited mainly in deeper water and may have been derived in part from the postulated tectonic and volcanic islands.

INTERVAL B

Interval B includes rocks that are mostly of Osage age (pl. 15). In places rocks of Kinderhook age or of Meramec age have been assigned arbitrarily to interval B, in other places some rocks of Osage age have been assigned to either interval A or interval C, and along the eastern Appalachian basin a combined unit, interval A-B, includes rocks of both Kinderhook and Osage age undifferentiated. Most of these arbitrary assignments result from the absence of a distinctive rock unit containing beds exclusively of Osage age.

The marine transgression that began in interval A time continued during interval B, and the present area of the conterminous United States was approximately 80 percent covered with marine waters during this maximum submergence of Mississippian time (pl. 12, fig. 2). Cross sections showing interval B rocks are on plates 9-B and 9-E through 9-G.

APPALACHIAN BASIN

Along the eastern margin of the Appalachian basin, where intervals A and B are not separated, the rocks are composed of relatively coarse detritus which attains thicknesses of more than 1,000 feet. The margin of deposition was probably considerably east of the present extent of these rocks. (Compare pl. 4-A and pl. 10, fig. 2.) As in interval A, interval B shows a continuation of deltaic deposition; presumably, the deltas were fed by streams rising in highlands to the east, which crossed piedmont hills and narrow, probably swampy, coastal plains to deposit material in the deltaic environment. In contrast to interval A, thick sections of interval B rocks appear to have extended continuously in a narrow belt from eastern Pennsylvanian as far south as the northern border of Georgia (pl. 10, figs. 1, 2).

To the west in the northern part of the basin, interval B commonly ranges in thickness from 400 to 600 feet and in the southern part of the basin mostly from 100 to 250 feet. Thus, interval B is much thicker than interval A throughout almost all of the Appalachian basin region. In east-central West Virginia (Dally, 1956, p. 126) rocks equivalent to interval B are thin and locally absent, probably as the result of nondeposition (pl. 10, fig. 2). The original margin of the interval to the north is not known, but it may have extended into eastern Canada. To the south the interval may reach a depositional pinchout (pl. 9-B, sec. *i–i′*) in west-central Alabama.

In general, the rocks of interval B (pl. 4-B) in the northeast portion of the basin are a part of a wedge of quartzose continental detritus that dominated deposition during much of intervals A and B. Locally, coaly shale and coal are intercalated in these coarse-grained rocks. In parts of eastern West Virginia and western Virginia, a sequence of shaly red beds interfingers with and overlies the sandstone facies. In the central part of the basin, interval B is dominated by a shale and siltstone facies in contrast to the sandstone facies which covers much of the northeastern and eastern parts of the basin. From the Kentucky-Tennessee State line southward, the southern part of the basin is dominated by cherty limestone.

The relatively fine detrital rocks in the northwestern part of the basin are mainly the distal marine parts of the deltas to the east, but some of the material in Ohio probably had a northern source in the Canadian Shield (Ver Steeg, 1947). The transition between marine environments on the west and continental environments on the east (pl. 11, fig. 2) lies a short distance west of the boundary between intervals B and A-B (pl. 4; Pelletier, 1958, p. 1055). Coarse well-sorted detritus in western Pennsylvania indicates high-energy marine deposition; whereas to the southwest in eastern Kentucky fine-grained well-laminated detritus indicates a lower energy tranquil marine environment. The carbonate rock and chert in the southwestern part of the basin suggest deposition in a deeper water environment distant from the shore of the expanding delta complex.

MICHIGAN BASIN AND EASTERN INTERIOR BASIN

Thicknesses of interval B in the Michigan basin range from about 600 feet in western Michigan to more than 1,400 feet in northeastern Michigan. In the Eastern Interior Basin region interval B attains a maximum thickness of more than 800 feet in southern Illinois and western Kentucky. In Tennessee and central Kentucky and in Missouri, the interval thins and averages about 250 feet. The original margins of the interval were well outside these regions (pl. 10, fig. 2).

In the Michigan basin interval B consists almost entirely of detrital materials (pl. 4-B). In the Eastern Interior Basin region detrital materials also dominate the interval through much of southern Illinois and southwestern Indiana, but in the remainder of this region the interval is mainly cherty carbonate rocks.

Detrital materials in both regions were primarily derived from the northeast, probably from distant parts of the Canadian Shield. Detrital rocks in central Kentucky appear to be the distal parts of the deltaic wedges in the northern Appalachian basin. In interval B, in contrast to interval A, little detrital material was derived from the Transcontinental arch or the Wisconsin highland, and no clastic material was provided by the Ozark uplift. The sea appears to have transgressed over all, or nearly all, of the Ozark area and probably also over Cincinnatia as well as the other smaller positive elements, such as the Nashville dome, that were interpreted as small island areas during interval A time (pl. 12, figs. 1, 2).

Carbonate rocks (Burlington and Keokuk Limestones) were deposited as shelf deposits in relatively shallow clear marine conditions through the Ozark area and to the north in Missouri. East of these carbonate crinoidal bank deposits, deeper water and more turbid conditions existed (Lineback, 1966, p. 13). From the northeast detrital materials prograded across the Kankakee and Cincinnati arches and were deposited in Illinois as a delta (*Borden Siltstone*). In Indiana and Kentucky the deltaic deposits advanced along a relatively even northwest-trending front. In southern Illinois, western Kentucky, and western Tennessee, fine-grained siliceous carbonates were deposited and lapped onto the delta margins. At the end of the interval fine-grained to crinoidal limestones eventually overlapped earlier deposits throughout the Eastern Interior Basin region. Thus, normal marine environments covered almost all of these regions during interval B time (pl. 11, fig. 2).

MIDCONTINENT REGION

Interval B is quite thin through most of the midcontinent region (pl. 4-A); in only a few places is it thicker than 350 feet, and in most of the region it is less than 250 feet thick. In all parts of the midcontinent region, except in eastern Colorado, the original limit of interval B deposition is thought to have been well beyond the present limit of the interval. In eastern Colorado, Maher and Collins (1949) described a western shoreward facies consisting mostly of finely granular glauconitic and very cherty dolomite, and an eastern or southeastern basinward facies composed of cherty coarsely crystalline crinoidal limestone interbedded with some dolomitic limestone, fine-grained sandstone, and shale. Disconformities at the base of interval B are recognized in southeastern Iowa (Harris and Parker, 1964), where rocks of late Kinderhook and earliest Osage age are missing, and are recognized in Kansas, where the Kinderhook sea withdrew briefly and the Osage sea progressively transgressed from the south. Earliest Osage deposits are restricted to southern Kansas and are progressively overlapped by later Osage deposits to the north.

Interval B of the midcontinent region is dominated by carbonate rocks (pl. 4-B) that are cherty and fossiliferous. Only in an east-west belt across central Arkansas is interval B dominated by detrital rocks. Here a relatively thin sequence of shale and siltstone (equivalent to part of the Stanley Shale) is assigned to interval B.

The carbonate rocks are largely biogenic and reflect some alternation of high and low energy in the widespread clear-water normal marine environment (pl. 11, fig. 2). The belt of fine detrital sediments in Arkansas is thought to have formed on the northern slope of the Ouachita trough. The detritus probably was derived mainly from the northeast, but some may have come from the southeast and was deposited selectively in an area of little or no carbonate deposition.

ROCKY MOUNTAINS REGION AND WILLISTON BASIN

Interval B is about 950 feet thick in central Montana. Isopachs (pl. 4-A) show a linear east-trending downwarp, the Central Montana trough, that received sediments of greater thickness than areas to the north or south. This trough connected thick sections in the Cordilleran geosyncline with thick sections in the Williston basin. In the central part of the Williston basin in western North Dakota, beds of Osage age are more than 1,200 feet thick. These rocks are overlain conformably in this area by beds of Meramec age, and shelfward thinning is depositional. In eastern North and South Dakota, however, interval B is beveled beneath the post-Mississippian unconformity and thins regularly to a featheredge to the east and south. In central South Dakota Osage rocks are absent in a small area, which was probably a small island in the Mississippian sea (Sandberg, 1961, p. 110–111).

In Wyoming, interval B thins irregularly southward. The thickness exceeds 700 feet locally and is less than 300 feet in an arcuate belt in central and southern Wyoming. The zero line is highly irregular.

In western Colorado and eastern Utah, interval B forms a westward-thickening wedge. The rate of thickening increases fairly constantly westward, and the rocks reach a maximum thickness of more than 1,300 feet in central Utah. Isopachs terminate abruptly at the Uncompahgre uplift in western Colorado, indicating that these strata originally were deposited on the site of the uplift and were removed by later erosion. However, gradual thinning takes place near the west margins of the present Front Range in north-central Colorado, which suggests that this area was emergent during interval B time. Isolated areas near the southern margin of the Uncompahgre uplift along the Utah-Colorado State line, where rocks of this map unit are missing, are expressions of blocks uplifted in post-Mississippian time (Baars, 1966). In northern Arizona interval B thins uniformly from a maximum of over 600 feet near the northwest corner of the State to a zero line in northeastern Arizona. In north-central New Mexico the beds assigned here to interval B are irregular in thickness but reach a maximum of about 125 feet.

The original limit of deposition of interval B in these regions was well beyond the present extent of the interval except in the Front Range area of central Colorado and southern Wyoming and in the Defiance-Zuni uplift area of east-central Arizona and west-central New Mexico. In these areas preserved interval B probably approaches a true depositional limit.

Interval B is dominantly carbonate rock and in parts of the region it contains abundant bedded or nodular chert. Only locally does the sequence contain enough argillaceous or sandy material to modify the carbonate symbol on the lithofacies map (pl. 4-B).

In Montana interval B contains less argillaceous or fine-grained detrital material than interval A, and almost pure carbonate was deposited. The rock is massive to thin-bedded and very finely to coarsely crystalline. Dolomite and limestone are interlayered and appear to have been deposited cyclically (Roberts, 1961, p. B294). In the carbonate sequence in southern Montana (pl. 9-F, secs. *O–O′* through *Q–Q′*) a few anhydrite beds occur and chert is common, as are oolite beds, some of which are persistent for miles.

In the Williston basin, lithofacies and thickness trends seem related. Where the map unit is thick in the central part of the basin, it is composed of shaly limestone, but where the unit is thinner on the flanks of the basin and the shelf areas, it is composed of relatively pure carbonate rock. The percentage of dolomite increases from the center of the basin outward. The increase in dolomite generally coincides with the presence of carbonate oolite beds. These beds are most abundant in a roughly circular belt on the flanks of the basin, are less abundant on the shelf area away from the basin flanks, and are absent in the central part of the basin.

In Wyoming, western Colorado, and eastern Utah, interval B consists primarily of carbonate containing minor quantities of sandstone or shale. In southeastern Wyoming, however, a thin basal sandstone composes a large enough fraction to affect the map patterns (pl. 4-B). In north-central Utah and southeastern Idaho a layer of oolitic phosphatic rock occurs in mid-interval B at the base of the Deseret Limestone at a number of localities and is thought to represent a continuous deposit through this area.

In northern Arizona interval B is also carbonate rock; evaporites are absent and detrital sediment of any type is very uncommon either in separate layers or mixed with the carbonate (pl. 9-F, sec. *I–I′*). The only noncarbonate material is chert, which is mainly limited to the Thunder Springs Member and to a thin zone near the top of the Mooney Falls Member of the Redwall Limestone. This chert occurs as discontinuous and irregular layers, each a few inches thick, separated from other chert layers by beds of carbonate rock of similar or somewhat greater thickness.

Interval B in the northwestern corner of New Mexico is largely a light-brown cherty limestone. In north-central New Mexico the rocks assigned here to interval B are characterized by calcarenite with abundant quartz grains and by chert as a distinguishing minor constituent.

The only distinct source of detrital material in the Rocky Mountains region during interval B time appears to be a source area in southeastern Wyoming and central Colorado which provided small amounts of sand to the west, to the northeast, and probably to the south. The widespread cherty carbonate rocks that dominate the interval indicate clear-water marine environments (pl. 11, fig. 2); the rocks are more dolomitic and oolitic in areas of shallow relatively high energy environments. The phosphatic shale of interval B in north-central Utah and southeastern Idaho is considered (Sheldon, 1964) the product of slow deposition in low paleolatitude in relatively shallow warm water adjacent to deep water. Upwelling of cool phosphorus-bearing currents from the deep water is presumed to be the source of the phosphate. The occurrence of a few anhydrite beds in the interval in central and eastern Montana may indicate periodic restriction of circulation in the cratonic sea.

GREAT BASIN AND PACIFIC COAST REGIONS

The greatest known thickness of interval B, more than 2,000 feet, occurs in segments of the Cordilleran miogeosyncline (pl. 4-A) in central Idaho. A thickness of more than 2,000 feet is also shown along this trend in central Nevada, but these rocks may be Meramec in age and should then be assigned to interval C. (See discussion and alternate isopach maps in pt. I, chap. P.) East of the miogeosynclinal belt the interval attains thicknesses of more than 1,000 feet in several relatively small, isolated basins. The interval is absent in northwestern Utah, and, except as clasts in younger rocks, in the area of the Antler highland. To the west an unknown thickness of volcanic rocks may compose interval B in northwestern Nevada, and a part of a metavolcanic and sedimentary sequence may belong to interval B in northern California. In the Pacific Coast region to the north no thicknesses can be assigned specifically to interval B in rocks that here are considered to be Mississippian.

Carbonate rock is the dominant rock type in the eastern part of these regions. Cherty carbonate rock is widespread in southwestern Utah and southern Nevada as well as throughout Arizona. Detrital rocks and carbonate rocks with appreciable detrital content east of the Antler uplift are restricted. These rocks may be characterized as dominantly mudstone, some of which has been altered to phyllite, and minor sandstone and conglomerate, some of which are in the form of mudflows. West of the Antler highland the interval is poorly known; it consists of volcanics interbedded with limestone, shale, and chert on and adjacent to the highland in north-central Nevada. In Oregon and Washington interval B is unidentified specifically. Limestone in northeastern Washington might include rocks of interval B age, and a black argillite sequence not far from these outcrops might also in part be Mississippian. The *Red Mountain sequence* — graywacke, argillite, chert, and mafic volcanic rocks — in northwestern Washington contains fossils of late Paleozoic age and also may include rocks of interval B.

In the Great Basin and Pacific Coast regions, as in the other regions, the original limits of interval B (pl. 10, fig. 2) were probably well beyond present known occurrences of the interval except where detrital rocks indicate uplifted source areas — along the Antler highland from central Idaho to southern California and in northwestern Utah adjacent to the Wendover highland. These detrital sediments probably accumulated close to the source, and the original margin of interval B deposition was nearby.

Deposition in a marine environment of normal salinity dominated most of the Great Basin and Pacific Coast regions during interval B time (pl. 11, fig. 2), but within this broad environment a number of subenvironments can be recognized locally. Exceptions to the normal marine environment are marginal environments, perhaps tidal flats, postulated as along southern parts of the Antler highland, and restricted marine environments in several deeps east of the Antler highland.

In the restricted marine environment, in central Idaho, gray and black carbonaceous shale and mudstone collected in euxenic conditions, a continuation of restricted conditions that started in interval A time. Where normal marine conditions prevailed, fossils from limestone lenses in the detrital rocks of the Webb–Chainman–Diamond Peak trough indicate a warm shallow-water environment; mudflow conglomerates recognized locally may have been catastrophically emplaced during earthquake activity. Downwarping of the troughs seems to have been less than in succeeding Mississippian intervals and sediment accumulation was probably slower. Deposition in the Eleana trough took place under fairly deepwater conditions; convoluted laminae and graded bedding suggest turbidite deposition. The great boulders of quartzite and carbonate rock (Perdido Formation) in southern California can be interpreted as submarine channel rockslide deposits formed along the eastern side of the Eleana trough from a southeastern source (Ridley, 1970). Chert in the limestone to the east of this trough may have been introduced in part by upwelling of the deep sea waters of the trough. The relatively thin noncherty limestone in much of eastern Nevada and western Utah was deposited in warm shallow marine waters as indicated by bioclastic textures and the indigenous faunas.

West of the Antler highland, volcanic activity during interval B time is less well documented than for other Mississippian intervals. Although volcanism may have decreased, normal marine environmental conditions are thought to have continued from interval A through interval B, and volcanic islands may have existed in the eugeosynclinal area.

INTERVAL C

Interval C includes rocks mostly of Meramec age (pl. 15). In a few places arbitrary assignments to or exclusions from interval C have been made. Most of these arbitrary assignments result from the absence of a distinctive rock unit containing beds exclusively of Meramec age.

Interval C in general is less widespread than rocks of previous Mississippian intervals. This restriction is mainly due to post-interval C erosion, but interval C also marks the beginning of a major marine regression from the continental United States. Cross sections of interval C are shown on plates 9-C, and 9-E through 9-G.

APPALACHIAN BASIN

In the Appalachian basin, interval C is thickest in southwest Virginia where it is more than 2,600 feet thick (pl. 5-A). In eastern Pennsylvania it is more than 500 feet thick, and at several places in eastern Tennessee and northern Alabama it approaches or exceeds 500 feet locally. In the northwestern part of the basin the interval is thin, mostly less than 100 feet thick. The small zero area in east-central West Virginia appears to be the result of nondeposition during Meramec time rather than post-Meramec erosion.

In part this thickness distribution reflects the completeness of interval C. Epeirogenic uplift in Northeastern United States at the end of Osage time caused marine withdrawal from the northern part of the Appalachian basin, and marine transgression did not cover this area again until late interval C time. The limit of the marine regression at the end of interval B time was in southwestern Virginia, leaving a more complete marine section of interval C in that area and to the southwest. Continental deposition was essentially continuous and complete in eastern Pennsylvania.

The original margin of deposition of interval C (pl. 10, fig. 3) was beyond the present extent of the unit (pl. 5-A) in most of the basin. The irregular margin of interval C in western Pennsylvania and eastern Ohio is in part depositional but is more the result of pre-Pennsylvanian erosion in Pennsylvania and a combination of pre-Chester and pre-Pennsylvanian erosion in Ohio. In Tennessee the present zero line is the result of recent erosion; the zero line in northeastern Mississippi is probably the result of pre-Chester erosion (Welch, 1959).

Sandy red beds accumulated in eastern Pennsylvania and locally along the axis of the Appalachian geosyncline in West Virginia and Virginia (pl. 5-B). A broad band of calcareous sandstone that grades west into sandy limestone extends from south-central Pennsylvania into northeastern Kentucky. Carbonate strata covered much of the remainder of the basin. Locally, in the southern part of the basin the carbonate rock is cherty.

The red beds in Pennsylvania accumulated subaerially as alluvial deposits derived from an eastern source area (pl. 11, fig. 3). The southern and central parts of the basin were covered by a shallow sea in which accumulated an interbedded sequence of high-energy calcarenite and low-energy calcilutite. Nearshore bar and beach deposits of quartz sand were deposited at the northern end of the seaway late in interval C time. The presence of a large and varied fauna in the Meramec sea strongly suggests a mild benign climate. In contrast, the abundance of red beds in eastern Pennsylvania suggests that some parts of the eastern source area might have been relatively arid. A combination of these data suggests a mild warm marine climate along the seacoast giving way inland to a drier and more extreme climate.

MICHIGAN BASIN AND EASTERN INTERIOR BASIN

Interval C shows a greater range of thickness in the Michigan basin than do preceding intervals because of the differential erosion that took place in post-Meramec and pre-Pennsylvanian time. The greatest thickness of interval C (pl. 5-A), more than 570 feet, accumulated in the center of the basin. In the Eastern Interior basin interval C attains maximum thicknesses of more than 1,100 feet in southern Illinois and southwestern Indiana. The interval thins gradually to the northwest and north in Illinois and is mostly less than 200 feet throughout Missouri. Similarly, it thins eastward in Kentucky and southward in western Tennessee, but in most of these areas the sections of interval C are incomplete as a result of recent erosion.

The present extent of interval C (pl. 5-A) nowhere reaches the original depositional limits. The closest approaches to original limits probably are in western Indiana, where the limit of interval C may be close to the margin of Cincinnatia at this time, and in southwestern Illinois, where interval C extends close to the margin of an expanded Ozark uplift (pl. 10, fig. 3).

The lithofacies distribution of interval C (pl. 5-B) in the Michigan basin is highly diverse in contrast to that of preceding intervals and reflects the variety of rock types in the interval (pl. 9-E, secs. $B-B'$, $C-C'$) and the irregularity of the post-interval C erosion surface. In general, anhydrite and carbonate rocks are most abundant in the western and northern parts of the basin, and fine detrital sediments are more abundant in the eastern and southern parts. In contrast, the Eastern Interior Basin region is dominated by carbonate rocks. Detrital rocks are abundant (pl. 5-B) only in central and western Illinois. Minor amounts of detrital material in dominantly carbonate sequences occur in central Kentucky and in local areas on the margin of interval C in central and east-central Missouri.

The Michigan basin continued to receive detritus from a northeastern source, the Canadian Shield, during much of interval C time (pl. 10, fig. 3). A large number of individual beds of evaporite were deposited during the early part of the interval, and they suggest restricted access to open marine waters to the south, as well as the possibility of an arid climate (pl. 11, fig. 3). To the south in the Eastern Interior Basin region, deposition was dominantly in shallow marine conditions; turbid waters were prevalent during early Meramec, and mostly clear water and a higher energy environment were prevalent during late Meramec time. In mid-Meramec time (early St. Louis) deposition of evaporite beds suggests shallow restricted water conditions in a warm, arid climate. The sparse detrital materials in interval C may have been derived from the Wisconsin highlands to the northwest and from the Michigan basin to the north. Minor detrital contributions were derived from Cincinnatia and from the Ozark uplift.

MIDCONTINENT REGION

Interval C is generally less than 200 feet thick through most of the midcontinent region. Greatest definitely assigned thickness, about 1,350 feet, occurs in the Anadarko basin in northern Texas and western Oklahoma (pl. 5-A). Thick sections extend northward into the Hugoton embayment of southwestern Kansas where as much as 850 feet of interval C is recorded. Isolated thicknesses of about 700 feet also occur southeastward from the Anadarko basin in Oklahoma, and probably greater thicknesses occur in the southeastern corner of the State. Other thicknesses assigned to interval C are 500 feet in the Ouachita trough extending east-west across central Arkansas, more than 400 feet in the Batesville channel in northeastern Arkansas, more than 400 feet in westernmost Texas, and an apparent greater thickening southward into Mexico.

The present extent of interval C (pl. 5-A) in the midcontinent region is much less than the interpreted original extent (pl. 10, fig. 3). By the interpretation in chapter J and shown on plate 10, Meramec beds are close to the original limits of interval C in southwestern and north-central New Mexico, but, by the age assignments of Chapter K, Meramec deposition was probably more widespread. (See chap. K, fig. 41.) In eastern Colorado preserved interval C is near the interpreted margin of deposition. The present restricted extent of the interval is largely the result of post-interval C and pre-Pennsylvanian erosion.

Interval C in two parts of the midcontinent region contains appreciable quantities of detrital sediment (pl. 5-B). These are in central and southeastern Iowa where both muddy and sandy rocks were deposited and in central Arkansas and adjacent southeastern Oklahoma where mudstone patterns dominate and sandstone also was deposited but in lesser amounts. Evaporites form an appreciable part of interval C in a small area in southeastern Iowa where interval C is relatively thick and appears to have been deposited in an extension of the Illinois basin. Carbonate rock is dominant in the remainder of the midcontinent region and is quite cherty in parts of Iowa and Kansas and in northern Arkansas.

The detrital materials in Iowa are mainly in the lower part of interval C and appear to have been derived from the east and from the north and northeast. Restricted marine deposition (pl. 11, fig. 3) is indicated by anhydrite and gypsum in the middle part of interval C in southeastern Iowa (pl. 9-C, sec. *A–A'*). In central Arkansas (pl. 9-E, secs. *F–F'*, *G–G'*) and adjacent southeastern Oklahoma detrital rocks of interval C — mudstone, sandstone, and a few tuff beds — are regarded as largely turbidites formed in relatively deep marine waters of normal salinity and derived in part from the northeast but mostly from the southeast. The volcanic source for the tuffaceous beds is unknown but is postulated to have been to the southeast (pl. 10, fig. 3).

A shoal area east of the Anadarko basin appears to have limited most of the coarse detrital materials to the Ouachita Mountains area; only minor amounts of mud were transported into the Anadarko basin, and these were restricted to the eastern edge of the basin. In general, the carbonate rocks that dominate the remainder of the region reflect relatively high energy normal marine deposition and are in large part biogenic in origin. Silica to form the autochthonous chert in Kansas and Iowa may have been derived from lowland areas to the northwest. On the other hand, chert clasts in interval C of northeastern Oklahoma and northwestern Arkansas were probably derived from nearby lowland areas to the northeast and north.

ROCKY MOUNTAINS REGION AND WILLISTON BASIN

In the Williston basin interval C is a lens-shaped body that is more than 1,300 feet thick in the center of the basin and thins regularly to the east and south to a featheredge, but to the west it extends through the Central Montana trough and attains maximum thicknesses of more than 700 feet in the trough (pl. 5-A). The interval is missing in a large area of north-central Montana and extends only a short distance into Wyoming. It thickens westward toward Idaho and attains a maximum of 650 feet locally along the Wyoming-Idaho boundary. In northeastern Utah the interval thickens southwestward to a projected thickness of almost 1,000 feet; but through the remainder of eastern Utah and through northwestern Arizona it ranges from 0 to less than 300 feet. Through western Wyoming, northwestern Colorado, and southeastern Utah the zero line is quite irregular, and a few isolated occurrences of the interval have been identified east of the zero line. In southeastern Arizona a maximum of slightly over 200 feet of interval C has been identified in very limited occurrences. In north-central New Mexico a maximum of about 50 feet of interval C is shown on plate 5-A (as described in pt. I, chap. J), whereas alternate interpretations would assign as much as 130 feet of beds to interval C in this area (pt. I, chap. K).

Post-interval C and pre-interval D erosion was widespread in these regions, and the present extent of interval C (pl. 5-A) is considerably less than the original extent (pl. 10, fig. 3). The present zero isopach probably most closely approaches the original limit of deposition of the interval in northwestern Colorado, northeastern Arizona, and north-central New Mexico.

The dominant rock type of interval C (pl. 5-B) in these regions is carbonate rock. Detrital rocks are a major constituent of the interval only in the trough in northeastern Utah and are minor constituents in northwestern Wyoming. Evaporites are abundant in the Williston basin and in the Central Montana trough, and they markedly affect the facies patterns. However, the patterns are complicated by the fact that evaporites are mostly peripheral to the basin in the lower part of interval C and mostly in the central part of the basin in the upper part of interval C (pl. 9-F, secs. *O–O′*, *P–P′*, *Q–Q′*). A cumulative thickness of more than 300 feet of halite alone occurs in the central part of the Williston basin.

The only conspicuous source of detrital materials during interval C in these regions appears to have been in north-central Colorado and southeastern Wyoming (pl. 10, fig. 3). The detrital materials in the trough in northeastern Utah and the minor detrital materials in interval C in northwestern Wyoming were probably derived from this source area. The evaporites in the Williston basin and the eastern part of the Central Montana trough indicate restricted marine conditions (pl. 11, fig. 3) and abnormal salinity during interval C time. Restricted marine conditions are also indicated in northwestern Wyoming where local beds of gypsum and anhydrite are present. The carbonate rocks which dominate the interval in the remainder of these regions appear to have formed in relatively shallow marine waters of normal salinity.

GREAT BASIN AND PACIFIC COAST REGIONS

The Cordilleran miogeosynclinal belt shows an increase of mobility during interval C. Troughs containing thick sections of interval C are greater in number and in thickness of sediment contained, and areas of uplift are more numerous than in previous intervals. In the main miogeosynclinal trend, maximum thicknesses of 3,000 feet or more are recorded.

Interval C is absent in the Wendover highland, in northwestern Utah, and it is also absent, or nearly so, on the Ely arch, a larger elongate area to the south in eastern Nevada (pl. 5-A). East of these areas are several areas where interval C is 1,000–1,500 feet thick. The Antler highland extending from north-central to west-central Nevada and into adjacent California probably received no sediment during interval C time. In the eugeosynclinal belt in northwestern Nevada along the western margin of the Antler highland, interbedded volcanics and limestone are assigned to interval C. Volcanic rocks in northern California also probably represent interval C. No meaningful thicknesses may be assigned to interval C in the Pacific Northwest.

Present zero lines of the interval probably approximate the original limits of deposition of the interval around the Antler highland, Wendover highland, and Ely arch. Elsewhere, in the Great Basin and Pacific Coast regions, the interval was probably widespread.

Along the miogeosynclinal belt east of the Antler highland in Nevada and California, detrital sediments are dominant and range in texture from conglomerate to mudstone (pl. 5-B). In central Idaho detrital sediments are less widespread than in preceding intervals, and deposition changed during the interval from dominantly quartzose siltstone and fine-grained sandstone to a cyclic sequence of coarse- and fine-grained limestone.

East of the Wendover highland in south-central Idaho and north-central Utah, interval C is dominantly sandstone interbedded eastward with increasing proportions of siltstone, shale, and cherty carbonate rock, and farther east the interval becomes dominantly dolomite. To the south shale and mudstone dominate the area around the Ely arch. In southwestern Utah, southern Nevada, and southeastern California, the interval is limestone. West of the Antler highland, rocks that are probable or possible interval C contain a typical eugeosynclinal assemblage: volcanic rocks, sandstone, shale, limestone, chert, and minor conglomerate.

The highly fossiliferous limestone of southwestern Utah, southern Nevada, and California indicates a warm subtidal marine shelf environment (pl. 11, fig. 3). Approaching the miogeosynclinal belt these carbonate rocks contain appreciable quantities of chert which may suggest upwelling currents from deep parts of the geosyncline. These chert concentrations may mark the eastern limit of basin deposition and the western margin of the cratonic shelf. The miogeosynclinal trough segments in Nevada and California contain detrital materials derived from the Antler highland. Coarse detritus is limited to a narrow belt along the highland where it may have been deposited in a series of coalescing deltas (pl. 11, fig. 3) formed by east-flowing streams of steep gradient. East of the deltas moderately deepwater deposition prevailed in troughs. Fine detrital sediments around the Ely arch in eastern Nevada were probably derived from the Antler highland as well as from the Ely arch. Volcanism was widespread west of the Antler highland, and the presence of pillow lavas indicates that at least some volcanic rocks were formed in submarine conditions. Limestones associated with the lavas indicate a warm shallow subtidal marine environment. Detrital material at the western margin of the Antler highland was probably derived from the highland. This eugeosynclinal environment appears to have extended through the entire Pacific Northwest and may have contained a volcanic island arc in addition to numerous deepwater troughs or basins in which volcanic rocks and associated sediments accumulated.

INTERVAL D

That interval D rocks are the least widespread of any of the intervals of the Mississippian System is in large part a result of pre-Pennsylvanian erosion and is a result of epeirogenic uplift in the central, cratonic part of the continent and positive orogenic movements in the geosynclinal belts. Interval D also contrasts with the previous intervals in that detrital rocks are much more widespread and abundant.

Interval D contains rocks that are of Chester age, the youngest provincial series of the Mississippian Period (pl. 15), although arbitrary assignments and exclusions have been made in this, as in the earlier, intervals. All these arbitrary assignments result from the absence of a distinctive rock unit containing beds exclusively of Chester age. Cross sections including interval D are shown on plates 9-D through 9-G.

APPALACHIAN BASIN

In the Appalachian basin interval D is thickest (pl. 6-A) along the axis of the basin, where it exceeds 4,500 feet in southwest Virginia (Averitt, 1941) and 5,000 feet in the southern part of the Anthracite district of Pennsylvania (Wood and others, 1962, p. C39). The strata thin rapidly west of the trough and feather out to zero along an irregular line from north-central Pennsylvania to northeast Kentucky. Local outliers are present northwest of the zero line in parts of Kentucky, Ohio, and Pennsylvania.

Once again, the original margin of deposition of the interval was well beyond the present limit of preservation. Continental deposits undoubtedly lay east of the anthracite basins in Pennsylvania, and the interval was undoubtedly more extensive in eastern Ohio and western Pennsylvania. Similarly, in the southern part of the basin some of the thickest sections, 2,000 feet or more, of interval D are in the easternmost outcrops, and originally the interval probably extended a considerable distance to the east and southeast of these. Much of the present restriction of the interval is due to Late Mississippian—pre-Pennsylvanian erosion.

The lower part of interval D is dominated by carbonate rocks in the southern part of the Appalachian geosyncline and in the northwestern shelf area (pl. 9-D, secs. $b-b'$, $c-c'$, $e-e'$; pl. 9-E, sec. $A-A'$). The upper part of the interval is dominated by detrital rocks. In some southern parts of the geosyncline these detrital rocks are so thick that they mask the carbonate component of the lower part of the interval (pl. 6-B), and on the northwestern shelf area of Ohio and adjacent States, the carbonate component dominates mainly because the upper detrital part has been removed by pre-Pennsylvanian erosion. The northeastern part of the Appalachian geosyncline received detrital materials throughout interval D time.

The major source of interval D detrital rocks was the borderland lying east and southeast of the geosynclinal part of the Appalachian basin. Detrital materials in the southern part of the basin were probably derived from the southeast (King, 1950, p. G63); however, some detritus might have been derived from uplifts to the north, the Nashville dome or the Ozark uplift (Thomas, 1967, p. 8, 9). Detrital rocks in northern Alabama and Mississippi could also have been transported by the Michigan River (pl. 12) across the Illinois basin from a source to the north in the Canadian Shield.

Environments of deposition include a wide variety. In the northeastern part of the Appalachian basin, detrital beds are coarse and include red beds that were deposited under terrigenous conditions in a fluvial regime on an alluvial plain (pl. 11, fig. 4). To the south in the geosyncline and over much of the shelf to the west, the lower part of interval D is dominantly cabonate rock formed mainly in high-energy normal marine conditions, but interstratified beds of calcilutite indicate episodes of low-energy marine conditions. In the southern part of the geosyncline, carbonate deposition was followed by fluvial deposition of detrital material as the delta complex extended farther south along the trough.

MICHIGAN BASIN AND EASTERN INTERIOR BASIN

No rocks of interval D are recognized in the Michigan basin. In the Eastern Interior Basin region interval D is limited to central and western Kentucky, southwestern Indiana, and southern Illinois, and to a few isolated erosion remnants in southwestern Missouri. A maximum thickness of almost 1,400 feet of interval D (pl. 6-A) occurs in the deepest part of the basin in southern Illinois.

The original margin of interval D is not known but is interpreted to have been considerably beyond the present limits which are a result of post-interval D erosion. Interval D probably was deposited through southeastern Iowa, in much of northern Illinois, into southern Michigan and through most of Indiana (pl. 10, fig. 4).

Because of averaging, the lithofacies map (pl. 6-B) shows that the dominant rock type of interval D in the Eastern Interior basin is calcareous shale or sandstone. However, interval D is actually composed of a cyclic repetition of detrital- and carbonate-dominated units (pl. 9-D, secs. *a–a′*, *c–c′*).

The detrital material was deposited intermittently in a birds-foot delta by the Michigan River system (pl. 12, figs. 4*A*, 4*B*) which encroached southward into a shallow marine environment (Swann, 1963). Carbonate layers probably indicate times of advance of marine waters and decrease of supply of detrital materials. Westward-flowing marine currents appear to have carried fine detritus to the western edge of the basin and to have allowed dominance of carbonate deposition in clear marine waters in the southeastern part of the basin. In southeastern Kentucky minor detrital beds in lower and middle interval D are interpreted as distal parts of tongues of sediment derived from the Appalachian basin and transported through the Cumberland saddle in the Cincinnati arch, but neither Cincinnatia nor the Nashville dome appears to have been the sources of detrital material during interval D time. In late interval D time large amounts of detrital materials were deposited in eastern Kentucky and transported through the Cumberland saddle into the Eastern Interior basin where they mixed in west-central Kentucky with Michigan River deposits from the north. In the western part of the Eastern Interior basin some late interval D detrital rocks probably were derived from the Transcontinental arch, to the northwest.

The cyclically alternating interval D units reflect shallow marine, shallow deltaic, and, to a lesser extent, continental environments. Depth of water has been calculated as less than 100 feet (Swann, 1964, p. 652–653). Open circulation, normal marine salinity, high-energy directional currents, agitation, and warm temperature conditions are reflected by remains of abundant benthonic organisms, crossbedding of sandstone, oolitic limestone facies, and widespread distribution of relatively pure limestone units. Periods of maximum detrital influx may have been the result of climatic or tectonic oscillations. Numerous fossilized wood remains in sandstones, similar to those in Pennsylvanian rocks, and discontinuous coaly layers in some detrital-dominated units suggest forest vegetation in source areas with humid subtropical or tropical climate. Red mudstones in many detrital units may reflect deposition under oxidizing conditions or may represent transported red soils.

MIDCONTINENT REGION

Interval D is confined to the southern part of the midcontinent region (pl. 6-A) and is limited to the major basins or troughs of interval D time and immediately adjacent areas. In the Ouachita geosyncline in Arkansas, rocks assigned to interval D are more than 5,000 feet thick; farther southwest along the trough, in central Texas, thicknesses in excess of 5,000 and 6,000 feet are recorded. In the Anadarko basin of western Oklahoma interval D is more than 1,700 and possibly almost 2,500 feet thick, and in the Delaware basin in west Texas it is almost 2,000 feet thick. The present limits of the interval are restricted from the original depositional margin (pl. 10, fig. 4). Isolated erosion remnants and sinkhole fillings of interval D rocks occur in southwestern Missouri and southeastern Kansas, north of the continuous interval D in Arkansas and Oklahoma, and provide an indication of the areal restriction of interval D by later erosion.

In the midcontinent region, as in other regions, detrital rocks are a conspicuous part of interval D. Shale or mudstone dominates in the Ouachita geosyncline from Arkansas to western Texas and in the Delaware basin in west Texas. Sandstone is a minor component in the geosyncline in Arkansas. To the west, both sandstone and mudstone pinch out in the eastern part of the Anadarko basin, and carbonate rock is the dominant lithofacies through most of the basin. Carbonate rock also dominates in thin shelf areas in Texas and forms a shelf margin belt that extends east-west across Arkansas north of the Ouachita geosyncline.

Detrital sediments that reflect northerly sources are present in part of northwestern Arkansas, in a small area of northeastern Arkansas, and in the Hugoton embayment of Kansas and the adjacent part of Colorado. These sources are the Ozark uplift, the Michigan River and Eastern Illinois basin, and the Transcontinental arch, respectively. Such cratonic detrital deposits as well as the associated carbonate facies were mainly deposited in shallow-water marine environments. Detrital rocks in the Ouachita geosyncline appear to have been derived from the Eastern Interior basin and from a source south and southeast of the Arkansas part of the trough and probably were transported the length of the geosyncline, through southeastern Oklahoma and Texas, by turbidity currents. Currents were strong enough to spread some of the fine detrital material westward into the eastern part of the Anadarko basin and onto the cratonic shelf areas bordering the Ouachita geosyncline.

ROCKY MOUNTAINS REGION AND WILLISTON BASIN

Interval D has a maximum thickness of more than 1,100 feet in the Central Montana trough and is more than 600 feet thick along most of its length (pl. 6-A). Both north and south of the trough, interval D is cut out by Late Mississippian or Early Pennsylvanian erosion. In the Williston basin, interval D is also of limited extent. It has a maximum thickness of 700 feet in eastern Montana and western North Dakota. In the Dakotas interval D is limited by a pre-Pennsylvanian erosion surface, and overlying Pennsylvanian beds are more extensive than are the rocks assigned to interval D. On the northern and eastern margin of the basin the interval is overlain by Jurassic rocks, and the beveling may be the result of erosion at one or several times between Late Mississippian and Jurassic time.

In western and central Wyoming the rocks assigned to interval D (the Darwin Sandstone Member of the Amsden Formation) have a maximum thickness of more than 200 feet but are considerably less than 100 feet thick over much of the area. The irregular thickness and extent reflect in part the uneven karst surface of interval C on which interval D was deposited. In northeastern Utah the interval has a maximum thickness of more than 800 feet, and it fills a westward-plunging trough; north of the Uinta Mountains it has a recorded thickness of more than 600 feet. The interval thins rapidly to an irregular erosional margin in eastern Utah and northwestern Colorado. A maximum of only $6^{1}/_{2}$ feet of rocks of Chester age was measured in the Grand Canyon area of northern Arizona and is interpreted as an isolated erosion remnant preserved beneath the pre-Pennsylvanian unconformity.

Interval D was originally more widespread (pl. 10, fig. 4) than it is now; present restricted distribution is a result of post-Mississippian erosion. The present limits, however, probably are not very far from the original limits, except east of the Williston basin and in northern Arizona and southern Utah where the interval probably was considerably more extensive.

In the northern part of the Rocky Mountains region, the lithology of interval D contrasts markedly with preceding Mississippian intervals in that detrital material is dominant and carbonate rock is a relatively minor constituent (pl. 9-F, secs. *O–O′*, *P–P′*, *Q–Q′*). The interval is more shaly toward the centers of the Williston basin and the Central Montana trough and more sandy toward the margins (pl. 6-B), reflecting the preservation of the younger more shaly beds in the central areas from post-Mississippian erosion.

In western Wyoming beds assigned here to interval D (Darwin Sandstone Member of the Amsden Formation) are entirely sandstone, and the unit is remarkably homogeneous throughout its extent. In northeastern Utah the facies pattern is related to the shape of the trough in which the rocks were deposited. Muddy carbonate in the central part grades into mudstone on the margins of the trough and into muddy sandstone near the eastern end of the trough. In southeastern Arizona and southwestern New Mexico the few remnants of interval D are dominantly carbonate rock.

The main sources of the detrital sediments in the northern part of the Rocky Mountains region and Williston basin appear to be the exposed Transcontinental arch to the east (pl. 10, fig. 4). Some detritus in the Central Montana trough may have been derived from land areas to the north and south. Alternation of normal marine sediments and brackish water clastics and evaporites indicates that the strandline with its several associated marginal environments (lagoonal, tidal flat, and coastal plain) repeatedly advanced and retreated across these areas (pl. 11, fig. 4). The overall history of interval D in Montana and the Dakotas, however, is one of marine transgression and regression; marine advance was greatest in late interval D time, and the interval terminated with a major regression of the strandline. The sandstone of interval D in western and central Wyoming is considered to be an estuarine or marine embayment deposit covering and filling the karst topography developed on underlying interval C rocks. In northeastern Utah detrital material was derived from an area in north-central Colorado and southeastern Wyoming, a segment of the Transcontinental arch which appears to have been exposed to erosion throughout Mississippian time. The isolated remnants of limestone in Arizona indicate a marine advance across at least part of Arizona, but little can be inferred of the original extent of the sea.

GREAT BASIN AND PACIFIC COAST REGIONS

Interval D is more than 2,500 feet thick in the Webb–Chainman–Diamond Peak segment of the Cordilleran miogeosyncline, and it is commonly 1,500 to 2,000 feet thick along the trough. The greatest thicknesses, more than 4,000 feet, are assigned to interval D in central Idaho in the miogeosyncline and in northwestern Utah in the Oquirrh basin. The interval is absent from a small area in the Wendover highland, of northwestern Utah, and is thin, about 1,000 feet thick, along a belt extending from southern Idaho into east-central Nevada. This relatively thin belt separates the Webb–Chainman–Diamond Peak trough from the

Oquirrh basin. In southeastern Nevada and southwestern Utah the interval is generally less than 1,500 feet thick, and it pinches out to the east of those areas. Interval D is absent on the Antler highland, largely as a result of nondeposition, and from a part of northeastern Nevada, where it was removed by later erosion. To the south the interval probably originally extended beyond the southern tip of Nevada and through much of southern California (pl. 10, fig. 4), but the exact position of the restored zero line is not known. Interval D has not been identified with certainty west of the Antler highland; however, thick sections in north-central and northwestern Nevada and northern California probably contain beds that are of interval D age.

Coarse detrital rocks compose interval D (pl. 6-B) in the miogeosynclinal belt of northern and central Nevada east of the Antler highland. These grade rather uniformly eastward into fine-grained detrital rocks and finally into carbonate rocks in the Oquirrh basin in northwestern Utah. No coarse detrital rocks are present to the north in central Idaho nor to the south in southern Nevada and California. Instead, the rocks in the miogeosynclinal belt are fine-grained detrital rocks that grade eastward in Idaho and southeastward in southern Nevada and California into carbonate rocks. Immediately west of the Antler highland, volcanic rocks of interval D age have not been identified. Possibly, they were present there, however, for eugeosynclinal, dominantly volcanoclastic rocks, probably belonging to interval D, are found in northern California.

The coarse detrital rocks of the miogeosynclinal belt in Nevada were derived from lower Paleozoic rocks exposed on the Antler highland (pl. 10, fig. 4), and they were deposited as deltas marginal to the normal marine environment (pl. 11, fig. 4) that extended to the eastern margin of the region where carbonate deposition prevailed. Marine deposition of the detrital rocks may have been partly by turbidity currents and submarine slides. The fine-grained detrital rocks in the miogeosynclinal belt in central Idaho and in southern Nevada and adjacent California also were derived from the Antler highland. A diverse fauna in the limestones indicates a warm climate during interval D time. Little evidence of sources or environments of deposition is available from the eugeosynclinal belt. Volcanoclastic rocks in northern California indicate some volcanic action; it is presumed that marine deposition was widespread (pl. 11, fig. 4) and that some detrital material was derived from the Antler highland to the east (pl. 10, fig. 4).

RELATION OF MISSISSIPPIAN SYSTEM TO OVERLYING ROCKS

Throughout the United States east of the Mississippi River, Mississippian rocks are overlain by rocks of Early Pennsylvanian (Morrow) age (pl. 8) with the following exceptions: in western Illinois Middle Pennsylvanian (Atoka and Des Moines) rocks rest on Mississippian, in a small area in western Michigan rocks of Jurassic age rest on Mississippian, and in a narrow belt extending along the margin of the present Mississippi embayment from southern Illinois through western Kentucky and Tennessee to northeastern Mississippi, Cretaceous rocks rest on Mississippian rocks.

Inasmuch as Lower Pennsylvanian rocks are resting on uppermost Mississippian rocks (Chester — interval D) through much of the eastern part of the country, the time gap between the systems appears slight. The contact, however, is conformable only in a narrow belt along the eastern and southern margins of the Appalachian basin region. West and north of this narrow belt, the contact is a disconformity of increasing magnitude, and through northwestern Pennsylvania, eastern Ohio, and the Eastern Interior Basin and Michigan Basin regions, the surface shows moderate to great amounts of erosion and is marked in most places by sand-filled scour channels.

In the midcontinent region west of the Mississippi River, virtually continuous sedimentation took place across the systemic boundary in the Ouachita geosyncline from Arkansas to west Texas and in the Anadarko basin of western Oklahoma. In these areas rocks of Early Pennsylvanian (Morrow) age rest conformably on Mississippian interval D (pl. 8). However, throughout most of the midcontinent region rocks of Early or Middle Pennsylvanian age rest disconformably on Mississippian rocks; in narrow belts in eastern Arkansas and eastern Texas, the Mississippian is overlain by Mesozoic and younger rocks as a result of Pennsylvanian folding, uplift, and subsequent erosion; along the northern margin of Mississippian rocks in Iowa, a belt of Cretaceous and Quaternary rocks rests on Mississippian as a result of removal of Pennsylvanian beds by pre-Cretaceous erosion, and later removal from part of the belt of the Cretaceous by pre-Pleistocene erosion.

In general the magnitude of the disconformity at the top of the Mississippian increases to the north and northwest in the midcontinent region. In some areas the base of the Pennsylvanian is marked by a unit of coarse or reworked material.

In the Rocky Mountains region and Williston basin Lower Pennsylvanian (Morrow) rocks rest on Mississippian rocks except in limited areas — mainly near the margins of the Mississippian rocks or in areas of localized structures. Thus, Jurassic rocks rest on the Mississippian through northern Montana and North Dakota and along the eastern part of the Williston basin in central North and South Dakota. Along a narrow belt at the eastern edge of the Williston basin, Cretaceous rocks rest on the Mississippian. Farther south rocks of Middle and Late Pennsylvanian age rest locally on Mississippian in the vicinity of the Black Hills, S. Dak., and around the ancestral Frontrange and Uncompahgre uplifts in southeastern Wyoming and central and western Colorado. In much of southeastern Utah and the southwestern corner of Colorado, Middle Pennsylvanian rocks overlie the Mississippian.

The systemic boundary is a disconformity of differing magnitude throughout the Rocky Mountains region and Williston basin. The least time value of the disconformity is in the central part of the Central Montana trough where the lower part (Morrow age) of the Pennsylvanian Amsden Formation rests on the upper part of the Mississippian Big Snowy Group of late Chester age. Elsewhere in these regions, the magnitude of the disconformity is greater, largely as a result of pre-Pennsylvanian erosion and removal of upper parts of the Mississippian but also as a result of overlap of younger Pennsylvanian rocks beyond oldest Pennsylvanian rocks in limited areas around the margin of Mississippian rocks.

Through much of the Great Basin region east of the Antler highland deposition appears to have been continuous from Mississippian into Pennsylvanian time. In central Idaho and much of eastern Nevada and western Utah, beds of early Pennsylvanian (Morrow) age rest in apparent conformity on beds of late Chester age. Locally, along the eastern margin of the Antler highland in Nevada and adjacent California, Middle and Upper Pennsylvanian, Permian, and Cenozoic rocks rest on the Mississippian. These overlapping relations indicate intermittent and irregular post-Mississippian uplift and erosion along the eastern edge of the Antler highland. Similar instability and uplift and erosion seem to have occurred along the border of the craton in southern Nevada and California and along the border of the Wendover highland in northwestern Utah where Middle Pennsylvanian or Permian rocks rest on Mississippian.

Continuous deposition may have taken place across the systemic boundary in areas away from the Antler highland in the eugeosynclinal belt: in northern California, central Oregon, and northwestern Washington. Close to the west margin of the Antler highland, in northwestern Nevada, a disconformity is indicated where Mississippian is overlain by Middle Pennsylvanian or Permian rocks and suggests an instability similar to that noted along the eastern margin of the Antler highland.

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Paleontologic Zonation of the Mississippian System

By J. T. DUTRO, JR., MACKENZIE GORDON, JR., *and* J. W. HUDDLE

PALEOTECTONIC INVESTIGATIONS OF THE MISSISSIPPIAN SYSTEM IN THE UNITED STATES, PART II: INTERPRETIVE SUMMARY AND SPECIAL FEATURES OF THE MISSISSIPPIAN SYSTEM

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1010-S

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PALEONTOLOGICAL ZONATION OF THE MISSISSIPPIAN SYSTEM

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INTRODUCTION

This chapter summarizes the zonation of the Mississippian rocks of the United States by means of three groups of fossils useful for this purpose. Dutro was responsible for information on the brachiopods, Gordon for that on ammonoids, and Huddle on conodonts. The authors' names are listed above in alphabetical order and coincide with their specialties in generally accepted taxonomic order. The charts prepared for each of these groups also provide information on zonation by foraminifers and by corals, which are discussed briefly in the text.

Until relatively recently, biostratigraphic zonation of the Mississippian in the United States was based mainly on megafaunal studies. For nearly 100 years, from the latter half of the 1800's into the 1950's, brachiopods were the major faunal element analyzed, largely a matter of convenience because they are among the more common and widely distributed of the larger fossils. Corals and bryozoans were studied to a lesser extent, as were molluscs and trilobites. A great many echinoderms were described, especially in the 1800's, but their stratigraphic utility is limited somewhat by facies control.

Goniatites were early recognized for their value in interregional and international correlations (Hyatt 1883, 1893). Although not as frequently found as some other fossils, goniatite-rich sequences were sought out and used as standards in developing a general stratigraphic framework. Unfortunately, for these purposes, classic sequences and type of the Mississippian in the northern midcontinent have yielded few goniatites. The nearest goniatite-rich area is in Arkansas and Oklahoma, and cephalopod zonation developed there must be correlated, in a roundabout fashion, with the type region of the Mississippian to the north (Gordon, 1964b).

Only relatively recently have microfossil studies been applied to biostratigraphic problems in the Mississippian. Early conodont work (Branson and Mehl, 1933, Cooper, 1939, Hass, 1947) was limited by a lack of worldwide study, and correlations with Western Europe were refined only in the last 10–15 years.

Foraminifera were studied in some detail by Zeller (1950, 1957) but biostratigraphic refinement came about mainly through the work of Russian micropaleontologists (Rauzer-Chernousova and others, 1948). In the last few years, a refined biostratigraphic framework for North America has been detailed by Mamet in several papers (Sando and others, 1969; Mamet and Skipp, 1971; Mamet and others, 1971). Mamet's zonal scheme is used in this chapter as a standard against which to plot biostratigraphic data of the other faunal groups.

The first general faunal zonation of the standard Mississippian sequence was outlined by Stuart Weller in 1926. Although not specifically defined, his outline was mainly a sequence of assemblage zones based on the extensive collecting by him and his associates over a period of nearly 20 years in the classical and type Mississippian region. Weller's table is reproduced here (fig. 83) to show the ranges of some of the taxa that he used in his zonation. He listed and discussed 14 zones, 2 of which were designated as subzones. His discussions of the distribution of many forms indicate that he understood well the ideas of acmes, range zones, and occurrence zones. As can be seen by comparing figure 83 with the following discussion, there is a certain amount of overlap in Weller's zonal scheme. This overlap is to be expected when total ranges are taken into account. Weller's zonation was adopted, with only slight modification, in the Mississippian correlation chart (J. M. Weller and others, 1948) to show the range of guide fossils in the type region.

The following list of Weller's zones, with annotations, serves as a basis for understanding subsequent modifications adopted in this chapter.

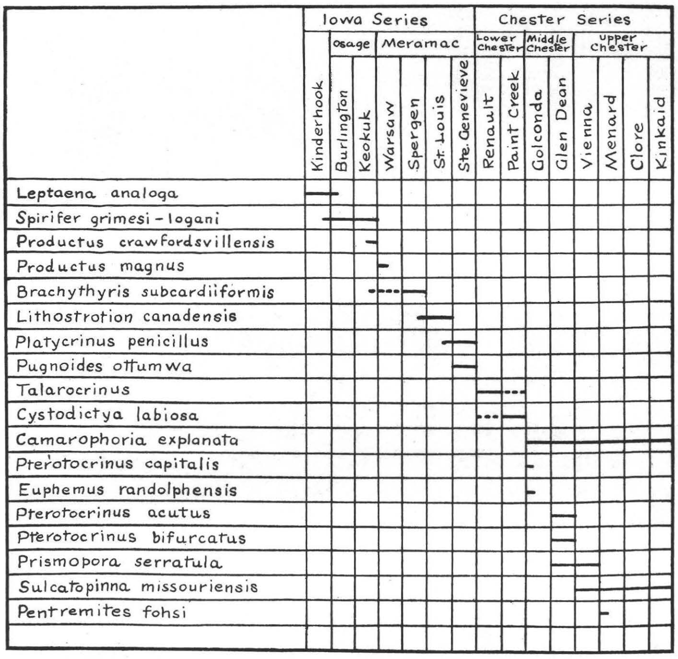


FIGURE 83. — Ranges of some taxa that Stuart Weller used to construct the zonal scheme. Reprinted from Weller (1926, table 1).

I. Zone of "*Leptaena analoga*." — Weller pointed out that this species, now assigned to the genus *Leptagonia*, is simply a name bearer for the assemblage zone that encompasses the Kinderhook. The species itself ranges upward into the lowermost Burlington Limestone. Some of the formations of supposed Mississippian age below the Chouteau Limestone are now considered to be Devonian; therefore, the stratigraphic scope of this zone is considerably reduced from Weller's conception and, indeed, from that shown on the Mississippian correlation chart.

II. Zone of "*Spirifer grimesi-logani*." — This zone ranges through the Osage Series, although early representatives of the *Spirifer* lineage are found in latest Kinderhook beds. *Spirifer rowleyi* occurs in the Fern Glen Limestone and correlative formations; *Spirifer grimesi* is characteristic of the Burlington Limestone; and *Spirifer logani* is found in the Keokuk Limestone. Weller pointed out that many echinoderm subzones occur in this interval, but they are not readily recognizable beyond the type region of the Mississippian. Other species of *Spirifer* are known to occur in younger strata in other parts of the country. These include *Spirifer arkansanus* in the Meramec of the Arkansas-Oklahoma area and *Spirifer brazerianus* in Chester equivalents in the Northern Rocky Mountains province.

III. Zone of "*Productus crawfordsvillensis*." — Weller stated that this is actually a subzone of Zone II and that it has a limited geographic distribution in the upper part of the Keokuk Limestone. Other species commonly associated are *Spirifer mortonanus*, *Orthotetes keokuk*, *Spirifer logani*, and *Rotaia subtrigona*.

IV. Zone of "*Productus magnus*." — This assemblage, whose namebearer is now assigned to the genus *Marginirugus*, is widespread in the lower part of the Warsaw Limestone. Other species that occur with this large productoid are "*Spirifer*" *washingtonensis*, *Syringothyris subcuspidatus*, and "*Aviculopecten*" *amplus*.

V. Zone of "*Brachythyris subcardiiformis*." — This species, recently made the type species of a new genus *Skelidorygma* (Carter, 1974), is highly characteristic of the Salem fauna, although its total range is not limited to the Salem Limestone. An associated, but less common, species is "*Spirifer*" *lateralis*.

VI. Zone of "*Lithostrotion canadensis*." — This coral, now assigned to *Lithostrotionella*, is common in rocks of the St. Louis Limestone although its total range is somewhat longer. It is known in rocks of late Salem age as well.

VII. Zone of "*Platycrinus penicillus*." — One of the more widespread faunas in the midcontinent, this zone also is characterized by *Pugnoides ottumwa*. This assemblage zone in the Ste. Genevieve Limestone also is marked by the "*Lithostrotion*" *harmodites* subzone in its upper part. This coral species is now known as *Siphonodendron genevievensis*.

VIII. Zone of "*Talarocrinus*." — This crinoid genus, with a single exception, is known only from the lower Chester. *Talarocrinus* has its acme in the Renault Formation.

IX. Zone of "*Cystodictya labiosa*." — This zone is essentially coextensive with the *Talarocrinus* Zone, except that the bryozoan has its acme in the Paint Creek Limestone. The two zones of Weller should be considered as a single assemblage zone in the lower Chester. Weller pointed out that neither form is known to exist above the Paint Creek Limestone.

X. Zone of "*Camarophoria explanata*." — As Weller clearly indicated, this zone differs from all others in his scheme in that it is a total range zone, of modern usage. It extends through the middle and upper Chester and includes what he considered four lesser zones. It is not considered significant in a composite assemblage zonal scheme for the Mississippian.

XI. Zone of "*Pterotocrinus capitalis*." — This assemblage from the lower part of the Golconda Formation was considered by Weller to be the most prolific and widespread in the entire Chester Series. The Golconda contains numerous brachiopods, bryozoans, and pentremites, of which many species are restricted to this formation; particularly characteristic are the mollusks "*Euphemus*" *randolphensis* and "*Nucula*" *platynotus*.

XII. Zone of "*Pterotocrinus acutua*" and "*P. bifurcatus*." — This is the Glen Dean fauna which includes, among a number of distinctive forms, *Archimedes laxa*, *Prismopora serratula*, *Pentremites brevis*, and *Pentremites spicatus*. Although the bryozoans have longer ranges, they reach their acme in this zone; and the two blastoids are apparently restricted to this horizon.

XIII. Zone of "*Sulcatopinna missouriensis*." — This assemblage zone encompasses the upper Chester and has a number of local subzones. Associated forms include *Composita subquadrata* and a number of other brachiopods, bryozoans, and blastoids.

XIV. Zone of "*Pentremites fohsi*." — This is a subzone of the *Sulcatopinna* Zone and is apparently restricted to the lower part of the Menard Limestone. Among other associated species, Weller particularly mentioned *Pterotocrinus menardensis*.

To recapitulate, Weller's scheme includes 10 assemblage zones for the type region of the Mississippian. Two of the zones he characterized as subzones; two are here combined to form the *Talarocrinus-Cystodictya* Zone; and the *Camarophoria explanata* Range Zone is set aside because of its different nature.

A detailed zonation of the Kinderhook and pre-Keokuk part of the Osage was presented by Laudon (1931, 1933) and summarized by Moore (1948). While some of these units can be recognized beyond the Iowa area where they were proposed, Weller's more general assemblage zonation retains its practicality for regional use in the midcontinent, as indicated by Moore. Moore's summary of the zonation (1948, fig. 2) is reproduced in figure 84 to show the relationship of Laudon's and Weller's biostratigraphic schemes.

FORAMINIFERAL ZONATION

The distributions of conodonts, brachiopods, and mollusks are plotted against a foraminiferal zonation that was proposed and documented by Mamet and others in a series of papers published during the last 10 years. The most complete documentation of that zonation is in Mamet and Skipp (1971).

CORAL ZONATION

As was pointed out in the introduction, corals were early used as zonal indicators in the Meramec part of the sequence. However, because of their relative rarity in older and younger beds, they were seldom used in other parts of the Mississippian. Exceptions are the two zones shown in figure 84 (Moore, 1948) for the Gilmore City (upper part) and Fern Glen Limestones.

In 1951, Parks proposed a zonation based on coral distribution in the Upper Mississippian of northern Utah. Subsequently, Sando and Dutro initiated a study of megafaunal distribution in the Madison Group and equivalent strata in the Northern Rocky Mountains region and developed a series of zones in which corals play a leading role. The history of that study, together with a complete zonal scheme, is fully presented in Sando and others (1969).

The two Waverlyan coral zones of Moore (1948) are correlated with the C_1 Zone of Sando, although that zone apparently has a greater stratigraphic range in the Northern Rocky Mountains region than in the midcontinent. Corals at this level were discussed in some detail by Bowsher (1961) and significance of distributions was summarized by Sando (1969).

Relationships of these megafaunal zones to the zonations and ranges of the conodonts, brachiopods, and mollusks discussed in this paper are indicated in the charts. For fuller details concerning occurrences, ranges, and biostratigraphic usefulness, see Sando and others (1969).

BRACHIOPOD ZONATION

As was natural for a paleontologist who specialized in the group, Weller heavily weighted his zonation toward brachiopods, especially in the lower part of the Mississippian. Chester faunas reflect increasing endemism that developed within the midcontinent embayment in the latter half of Mississippian. Therefore, any modern synthesis of brachiopod distribution and biostratigraphic zonation must lean heavily on information from other regions. Specifically, the Arkansas-Oklahoma area and the Northern Rocky Mountains region provide supplemental data that are essential to such a compilation.

Stratigraphic distributions in terms of generic and specific ranges are shown in figure 85. Ranges are drawn from several regions and cannot be considered applicable in all areas of Mississippian outcrop. Modern generic names are used where revisions have been made. For this compilation, a number of sources have been used. Chief among these are the works on Mississippian brachiopods by Weller (1900, 1909, 1914), Mackenzie Gordon's analysis of the evolution of the

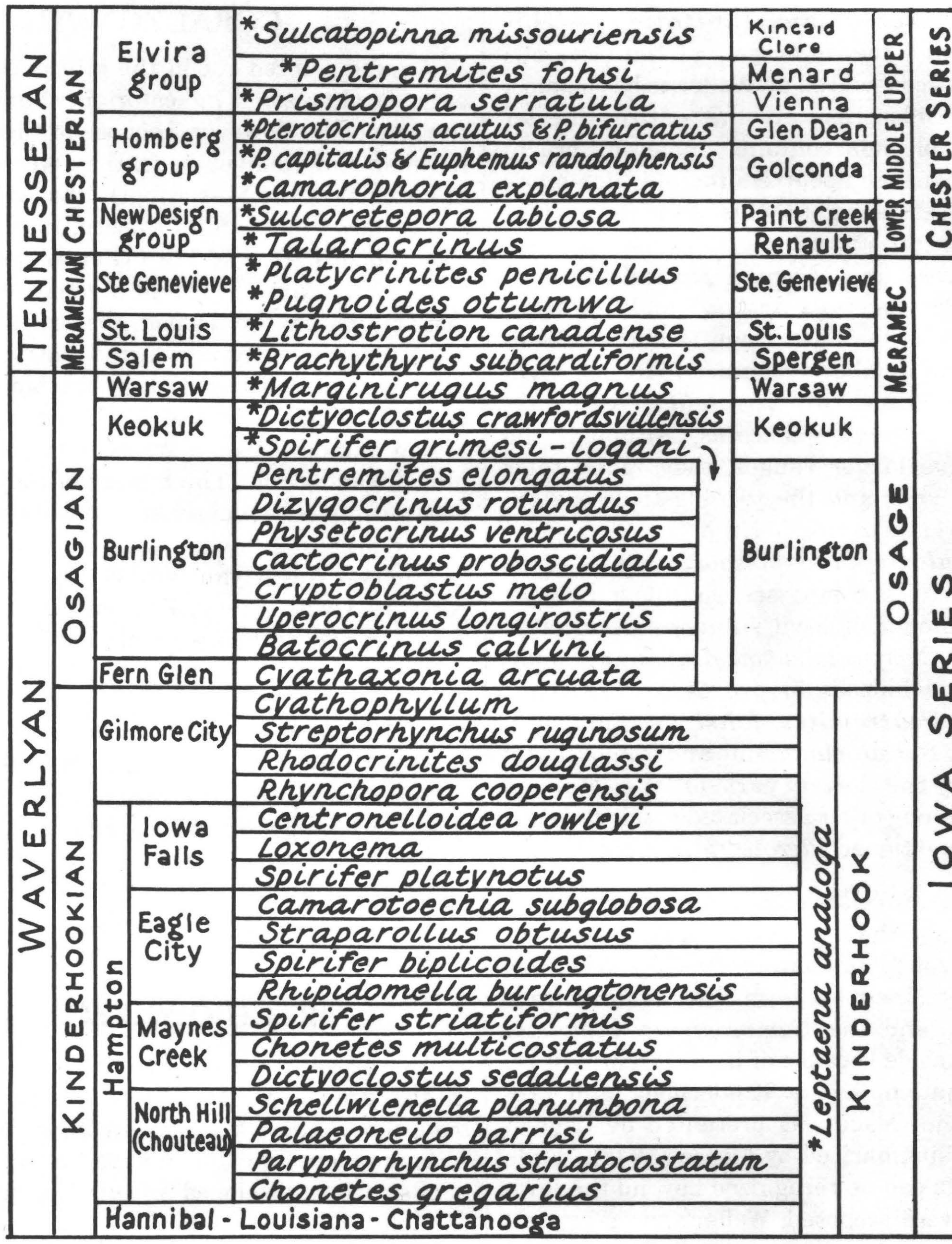


FIGURE 84. — Paleontological zones in American Mississippian rocks. The stratigraphic classifications shown at right and the zones indicated by asterisks are according to Stuart Weller (1926). The stratigraphic classification at left is based on Van Tuyl, Laudon, and Moore. Paleontological zones below the Keokuk Limestone (except *Cyathaxonia arcuata*) are from Laudon (1931, 1933). Reprinted from Moore (1948, fig. 2).

Productidae (1971a) and stratigraphic summaries by Gordon (1971b, 1962), studies of Early Mississippian faunas by Carter (1967, 1968, 1971, 1972), and work in the northern Rocky Mountains by Dutro (1963a, b; in Sando and others, 1969).

BRACHIOPOD ASSEMBLAGE ZONES

The following seven brachiopod assemblage zones, particularly the lower four zones, are similar to those used by Weller and others. The genera and species considered significant are those shown in figure 85. There are, of course, many other species in the total brachiopod fauna at any stratigraphic level, but full documentation of these brachiopod faunas is not the purpose of this study. The reader is referred to the taxonomic literature for details; a good introduction to this vast amount of material is given by Carter and Carter (1970).

Leptagonia *Assemblage Zone.* — This zone encompasses the Lower Carboniferous part of the original Kinderhook Group. For practical purposes it includes the Hannibal Shale and Chouteau Limestone and their correlatives. The base of the Mississippian is discussed further in the section on conodonts. In terms of the sequence in the Kinderhook type area, the contact is approximately the base of the Hannibal Shale or *McCraney Limestone* or *English River Formation*, as discussed by Straka (1968, fig. 5). Two subzones are indicated: (1) the *Paraphorhynchus* Subzone that includes the faunas of the Hannibal equivalents, and (2) the *Rhytiophora* Subzone for the Chouteau and equivalent faunas.

Spirifer grimesi-logani *Assemblage Zone.* — This zone, which coincides with Osagean Stage, is almost precisely as defined and used by Weller.

Brachythyris subcardiiformis *Assemblage Zone.* — This zone is a combination of two of Weller's zones and his "*Productus magnus*" zone is here considered a subzone — the *Marginirugus* Subzone. As indicated in figure 85, the upper part of this zone is missing in many parts of the Western United States.

Marginicinctus *Assemblage Zone.* — This new brachiopod zone includes, essentially, the fauna of the St. Louis Limestone and equivalent strata. This is the "*Lithostrotion canadensis*" Zone of Weller and is, for all practical purposes, correlative to Mamet's Foraminiferal Zones 13–14.

The remaining Upper Mississippian zones are named from taxa that are not found in the type region of the Chester. Most of Weller's original zones in the Chester were based on fossils other than brachiopods. In addition, Weller stated that only the faunas in the limestones were useful for zonation purposes. Consequently, most of those zones, while useful in the midcontinent, are actually highly endemic facies-controlled occurrence zones that have little application on an interregional scale.

Striatifera *Assemblage Zone.* — This fauna characterizes strata correlative with the Ste. Genevieve Limestone in western North America. It is approximately correlative with Mamet's Zones 15 and early 16_i. The name-bearing genus is commonly found together with many brachiopod species and characteristic coral genera.

Spirifer brazerianus *Assemblage Zone.* — This zone includes the faunas in strata equivalent to Mamet's Zones 16_i (late)–18 (early) in the northern Great Basin, Idaho, western Wyoming, and southwestern Montana.

Rhipidomella nevadensis *Assemblage Zone.* — This zone, proposed by Sadlick (1955) in the Great Basin of Utah and Nevada, includes Mississippian faunas in beds of late Zone 18 and Zone 19 age. Most of the interval is missing in the type Chester, but it is commonly present in the Big Snowy Group, lower part of the Amsden Formation, lower part of the Ely Limestone, and equivalent strata in many parts of Nevada, Utah, Idaho, western Wyoming, and Montana (Gordon, 1971b).

The Mississippian-Pennsylvanian boundary is difficult to place in western sequences. For the purposes of this study, it is considered to be the boundary between Foraminiferal Zones 19 and 20. Although its placement is not easy to determine on the basis of brachiopods, Gordon (1971b) placed the boundary between his *Rhipidomella nevadensis* and *Rugoclostus* assemblages in the Ely Limestone of the Diamond Peak area, Nevada. Similar relationships are noted in several of the western areas.

AMMONOID ZONATION

Approximately 45 genera of ammonoids are known in the Mississippian rocks of the United States. Because most of them have relatively short stratigraphic ranges and are widely dispersed geographically, they are useful as guide fossils. Their usefulness, however, is partly limited by their normal restriction to a Culm facies habitat — predominantly of dark-gray shales and limestones — or to a molluscan limestone facies. They are generally absent in limestone sequences that contain coral-brachiopod faunas. They are inclined to sporadic distribution in pockets and in limestone concretions, but they occur locally in some abundance. Mississippian ammonoids have been found in about half of the 50 States. The stratigraphic distribution of the Mississippian ammonoid genera in the United States is shown in figure 86.

In Europe, ammonoids have provided the main basis, during the last 50 years, for subdividing the Carboniferous into a number of zones and stages. The two principal zonal schemes are those of Bisat (1924), based on the Carboniferous section in the north of England, and of Schmidt (1925), based on the sequence in western Germany; both are shown in figure 86. Most of the major European zones of late Visean and Early Namurian age can be recognized in the Upper Mississippian of the United States, represented by related species and, in some places, by the same species. Some important European genera are absent, most notably *Homoceras* and related genera. Lower Mississippian ammonoid occurrences do not seem to equate with the European succession, except in a broad general way.

A zonal scheme for the American Mississippian, based on ammonoids, has been a relatively recent development in comparison to that in Europe, and part

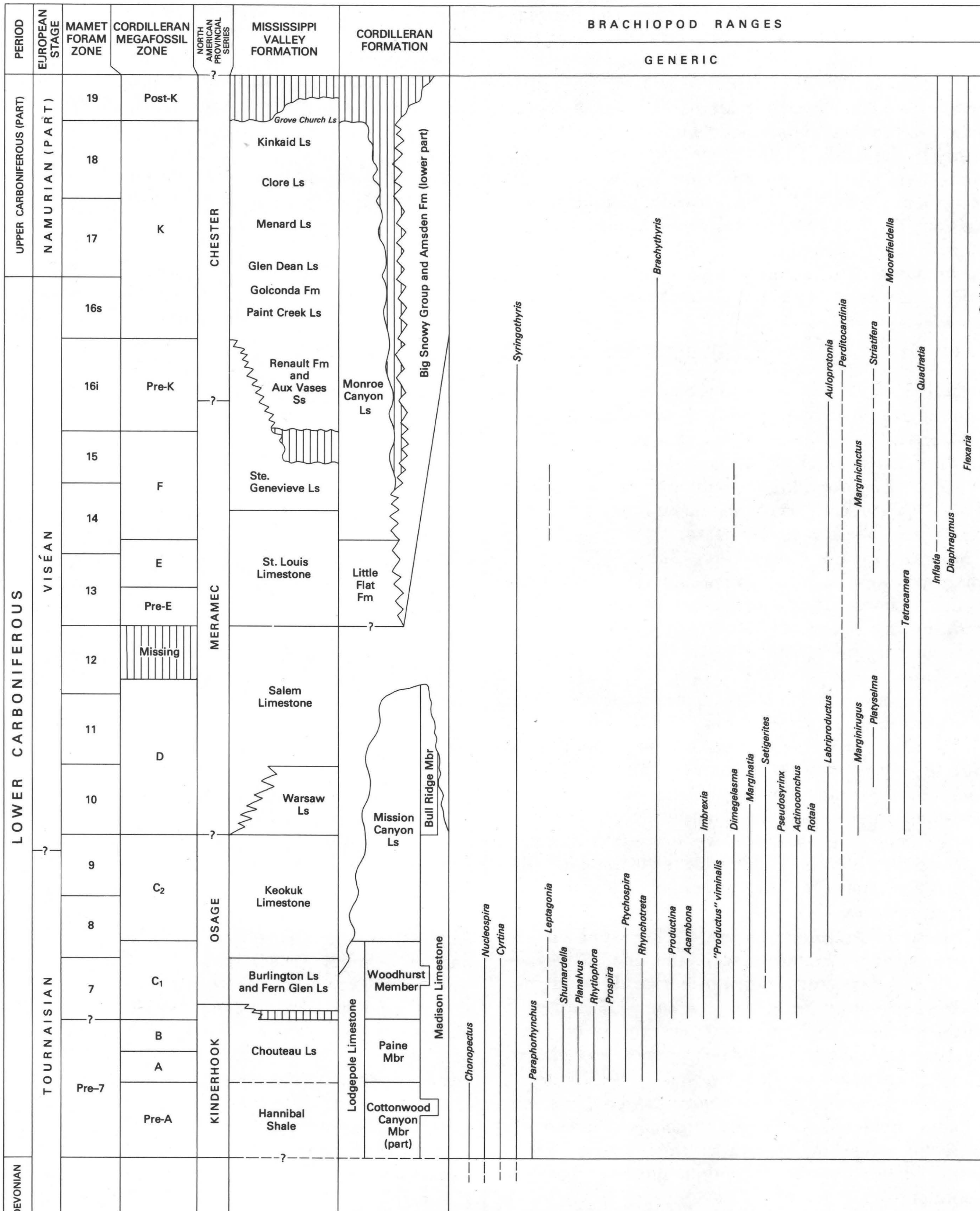
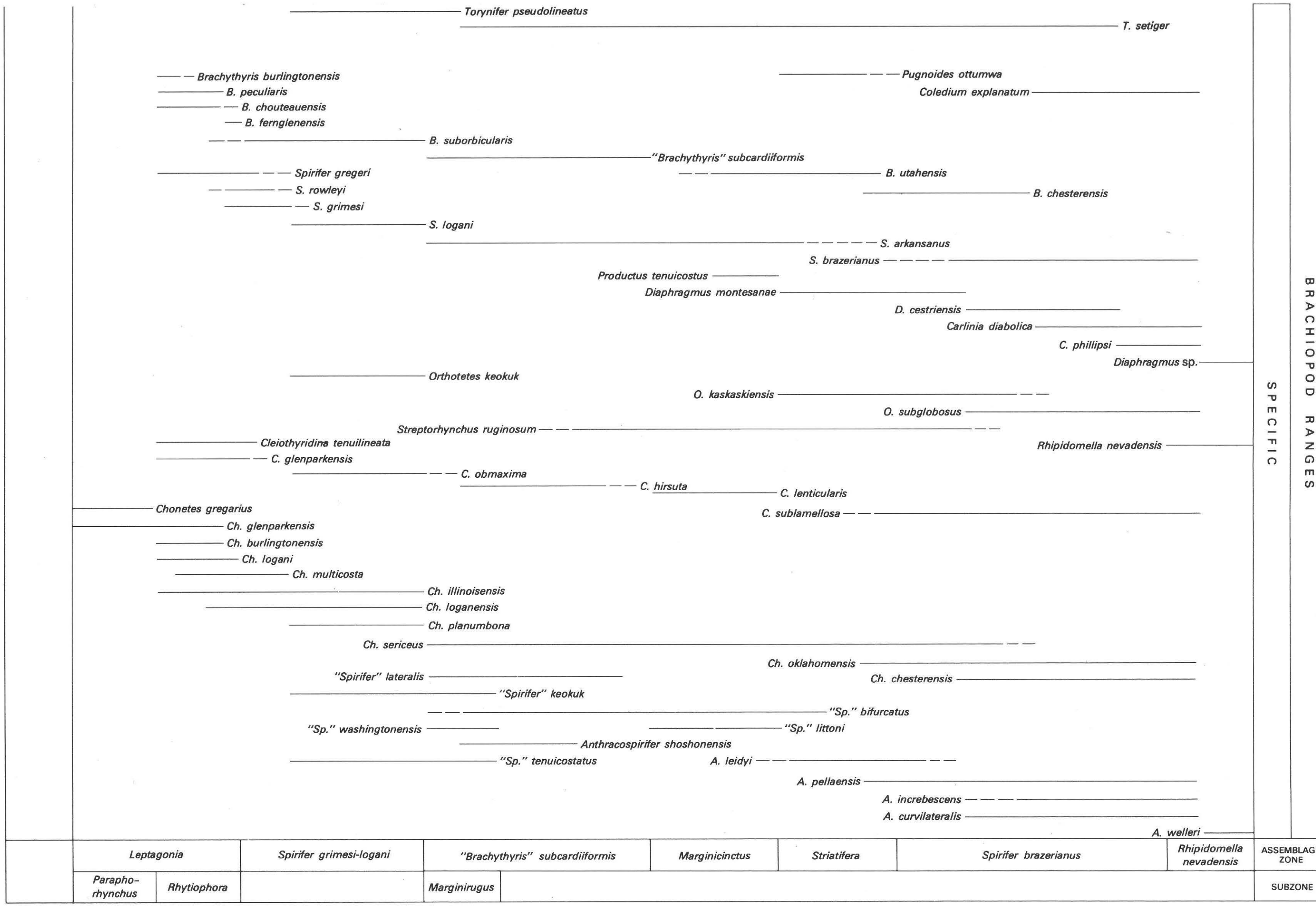


FIGURE 85. — Stratigraphic distribution of selected brachiopod



genera and species in the Mississippian of the United States.

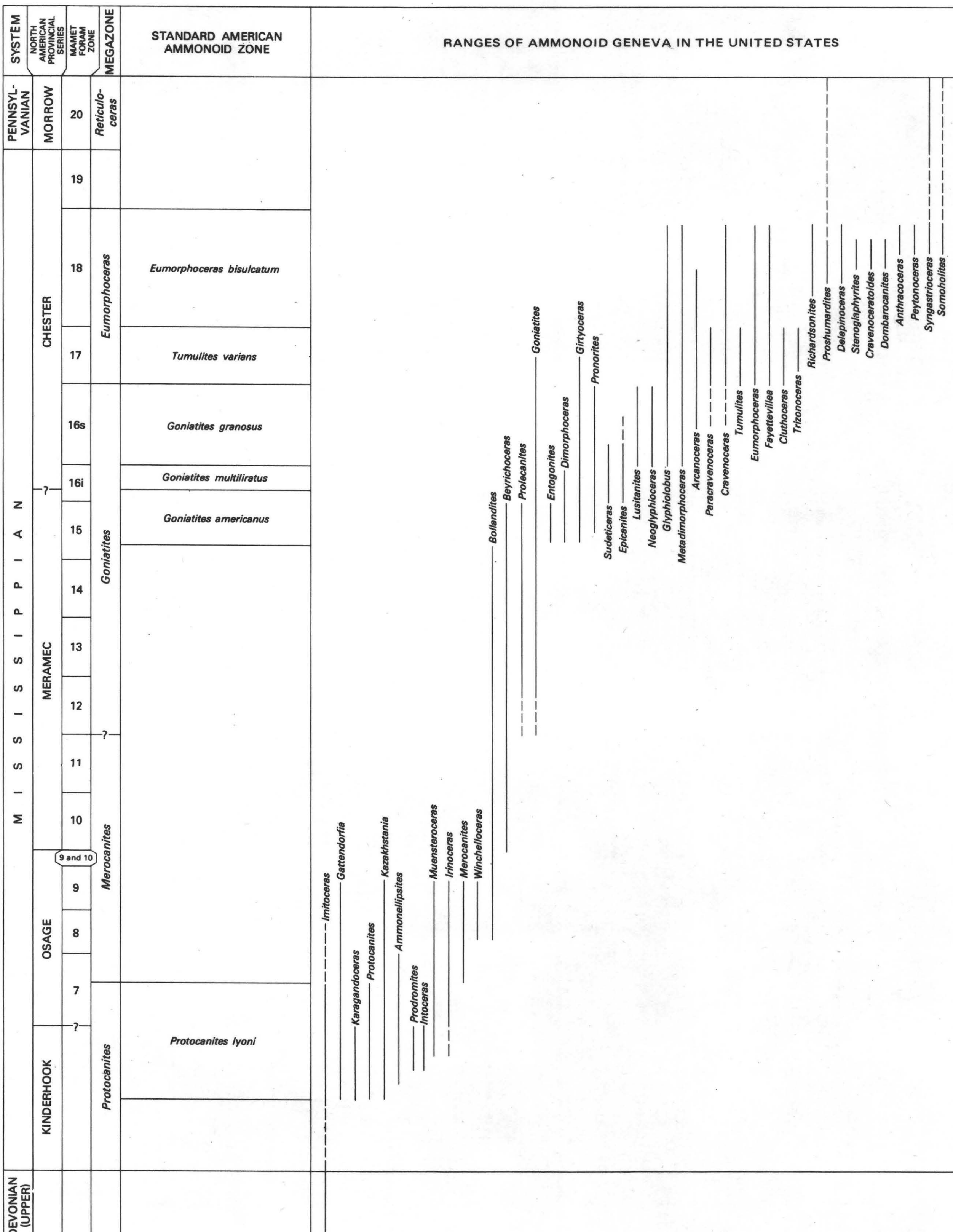
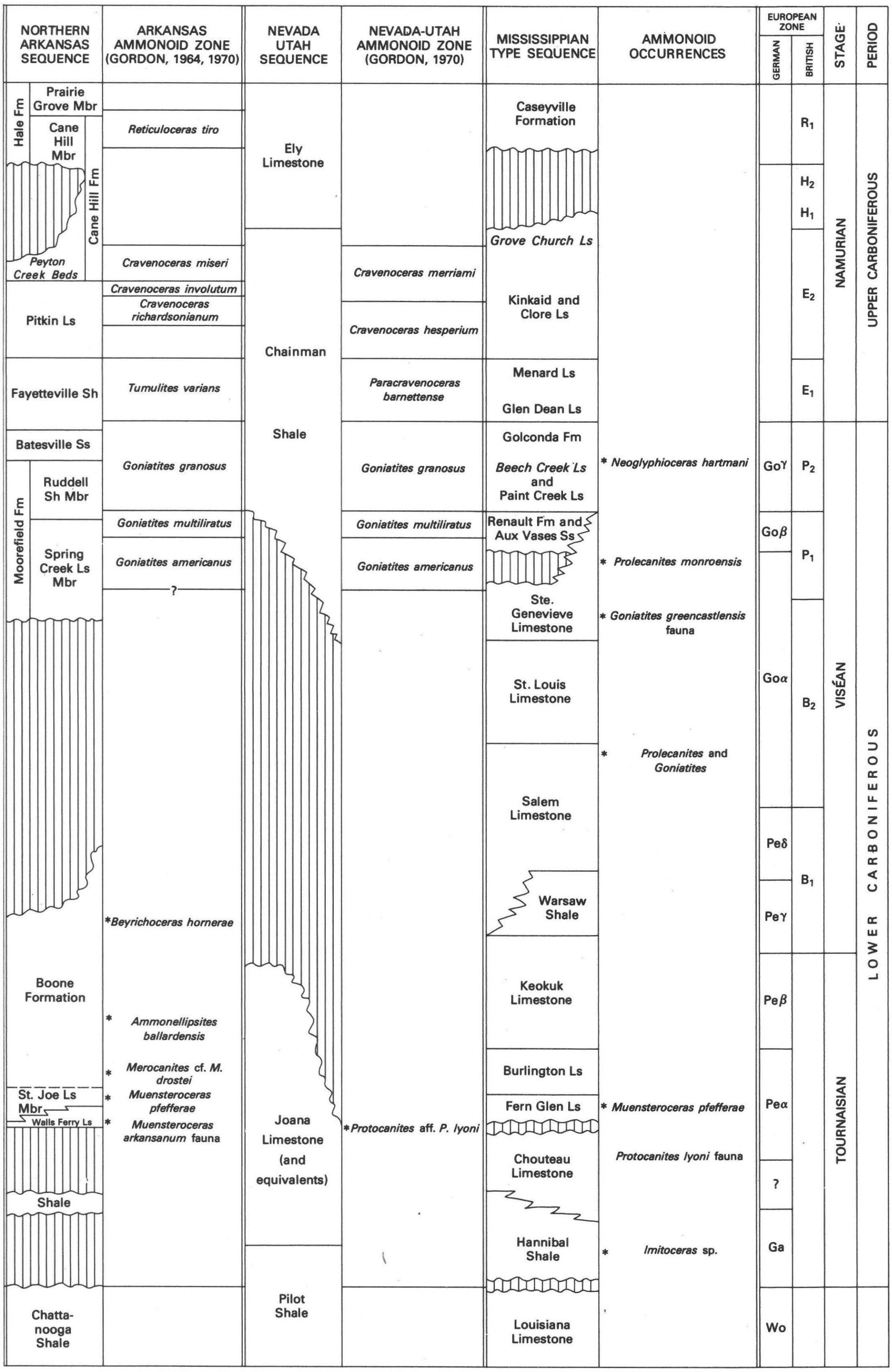


FIGURE 86. — Ammonoid zones and ranges.



*, occurrence is approximately located.

of it is still in a state of flux. Perhaps the earliest designation of a formal ammonoid zone in the Mississippian was that of Kindle (1899, p. 100), who proposed the *Muensteroceras oweni* Zone to include the fauna of the Rockford Limestone of Indiana, which he regarded as the lowest Eocarboniferous fauna in Indiana and Kentucky, equivalent stratigraphically to part of the Marshall Sandstone of Michigan. Smith (1903, p. 18, 27, 114, pl. 2), supporting a concept of interregional zonation, proposed the zone of *Aganides rotatorius* to include the Rockford ammonoids and a similar fauna in the Upper Tournaisian of Belgium; he also suggested extending the *Goniatites striatus* Zone of Europe to the United States to include the fauna of the "St. Louis-Chester Stage". These proposals, however, have not been followed in recent years.

In connection with the Mississippian correlation chart of the Geological Society of America (J. M. Weller and others, 1948), Miller (1947b; in J. M. Weller and others, 1948) proposed that three principal goniatite zones be recognized in the United States: (1) a zone of *Protocanites* equating approximately with the Kinderhook Series, (2) a zone of *Beyrichoceras*, approximately with the Osage Series, and (3) a zone of *Goniatites*, with the Meramec and part of the Chester Series. In more recent years, a fourth broad zone, of *Eumorphoceras*, adopted from the British zonal scheme, has been added above the *Goniatites* Zone by cephalopod specialists.

Although the British recognize an extensive *Beyrichoceras* Zone below that of the *Goniatites*, or *Posidonia* (P_1 and P_2) Zone, the genus *Beyrichoceras* is rare in the Western Hemisphere. At the time Miller proposed his *Beyrichoceras* Zone, he had just described the first specimen of this genus ever found in the United States (Miller, 1947a). It came from beds of the Boone Formation of Missouri that Miller believed were of Burlington age, but Gordon (1964b, p. 13, 14) suggested a late Keokuk or early Warsaw age for the chert that contained this fossil. Gordon (1957) has also described several specimens of *Beyrichoceras* from the latest Meramec in northern Alaska. The name *Beyrichoceras* Zone, therefore, seems inappropriate as a broad term for the ammonoid faunas found in the Osage Series. We are substituting for it the name *Merocanites* Zone.

In summary, it seems reasonable to divide the Mississippian ammonoid faunas into four megazones, each denominated by a characteristic genus. In ascending order, these are the *Protocanites*, *Merocanites*, *Goniatites*, and *Eumorphoceras* megazones. Although these approach being range zones, there is some present uncertainty as to limits of ranges and some overlap; so it is more correct to consider them broad assemblage zones.

ZONATION PROBLEMS

Some limitations of the stratigraphic and geographic distribution of the Mississippian ammonoids have complicated the task of erecting a series of zones that would serve the entire United States and equate with the European succession. A virtual absence of ammonoids exists at three levels: in rocks of early Kinderhook, late Osage-early Meramec, and latest Chester ages. European equivalents of the lowest and highest of these intervals are replete with ammonoid faunas, but the middle one is likewise poorly represented in Europe.

During Mississippian time, moreover, the Transcontinental arch extended, peninsulalike, southwestward from the Canadian Shield (fig. 87), dividing the shallow shelf seas of the eastern and western parts of the craton. Although some migration of faunas was possible around the southern end of the arch, which was relatively unstable, at certain times migration was greatly impeded and considerably different groups of species developed within the same zone at either side of the arch. This fact led Gordon (1970) to recognize two partly different sets of zones: one for the Great Basin region, characterized by sections in western Utah, and the other for the Southern Midcontinent region, based on sections in northern Arkansas (Gordon, 1964b). The location of these two ammonoid zonal sequences is shown in figure 87, which also shows in simplified form the principal structural regions and the areas of greatest encroachment of the Mississippian seas.

STANDARD AMERICAN ZONES

The standard zones shown in figure 86 are, for the most part, well established and are based on well-known faunas. These zones can stand alone, but they can also be considered subdivisions of the generic megazones, each name-bearing species belonging in, or very closely related to, the genus that gives its name to the megazone.

Local zonal hierarchies and their relation to the formations are shown also for the Arkansas and Utah sections. Several of these local zones differ in name from the standard zones, where the genera are represented by species other than those of the standard zone and a precise correlation has not yet been demonstrated.

PROTOCANITES MEGAZONE

This zone occupies much of the Kinderhook Series, as well as the lower part of the Osage Series. The lower boundary is uncertain, but it is assumed to lie at or near the base of the Mississippian, by analogy to the Lower Carboniferous section in northwestern Europe. In the Mississippi Valley the Louisiana Limestone of Missouri used to be considered Early Carboniferous in age. This

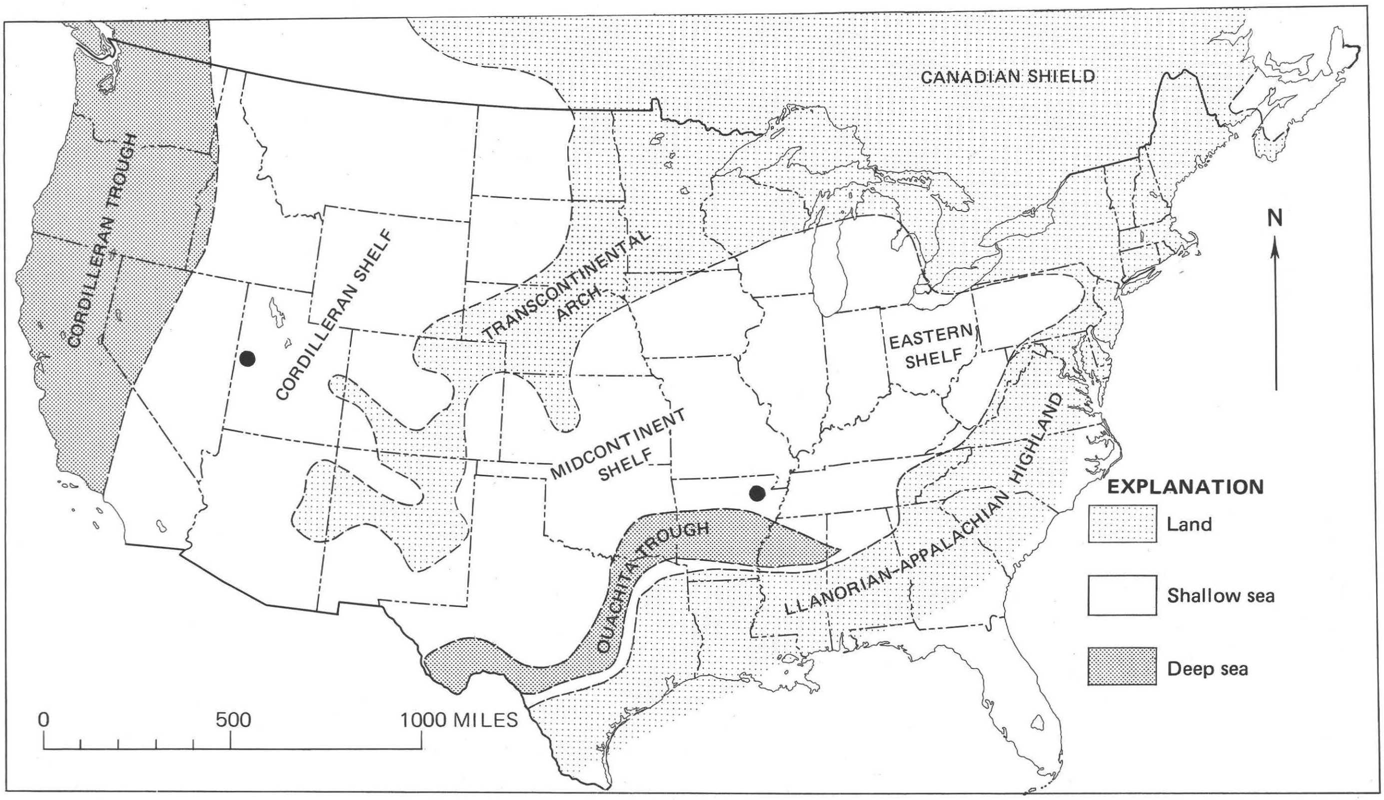


FIGURE 87. — Map of the conterminous United States showing locations of the two most complete ammonoid zonal sequences (black dots) and their relation to principal paleogeographic features during maximum transgression of the seas in Mississippian time. (After Mackenzie Gordon, Jr., 1974)

was mainly because it contains an ammonoid described originally as *Goniatites louisianensis*, based on immature shells; this species was referred to *Protocanites* by Schmidt (1925, p. 537). More recently, *G. louisianensis* has been shown to represent the early stages of an *Imitoceras*, an ammonoid genus that ranges from the Late Devonian through much of the Early Mississippian (Furnish and Manger, 1973, p. 19, 20). The Louisiana Limestone is now classified as very late Devonian in age by conodont workers. So far as we now know, no ammonoids occur in the lower part of the Kinderhook Series.

PROTOCANITES LYONI ZONE

In the United States *Protocanites* makes its earliest appearance in the upper part of the Kinderhook. Ammonoids are common locally in this part of the Kinderhook Series and in the lower part of the Osage Series, within the range zone of *Protocanites lyoni*. Approximately 30 species have been described from these beds. Ammonoids of this zone are typically developed in the Chouteau Limestone of Missouri, concerning which Miller and Collinson (1951, p. 458) have stated, in part:

> the ammonoids of the Chouteau are part of an early Lower Carboniferous fauna that is essentially worldwide in its distribution. The most diagnostic and widespread species of this fauna is *Protocanites lyoni*, nowhere abundant but almost invariably associated with numerous specimens of *Imitoceras* and *Muensteroceras*. Other ubiquitous genera such as *Gattendorfia* and *Pericyclus* occur sporadically in this zone.

It might be argued as to whether formal proposal of an ammonoid zone was intended by this statement, but it defines clearly the *Protocanites lyoni* Zone cited by Gordon (1964b, p. 72; 1970, p. 818) and employed in the same sense. It has recently been established, however, that this zone straddles the Kinderhook-Osage boundary (Manger, 1978).

That part of the *Protocanites lyoni* Zone within the Kinderhook Series is characterized by predominance of *Imitoceras* and the presence of *Karagandoceras* and *Prodromites*. The last two genera are, however, not particularly common and have not been found in the Western United States. Species typical of this part of the zone occur in the Chouteau Limestone of Missouri (Miller and Collinson, 1951), the Rockford Limestone of Indiana (Gutschick and Treckman, 1957), and what is now known as the *Wassonville Limestone* of Iowa (Smith, 1903, p. 36, 39). These include: *Imitoceras discoidale, I. jessieae, I. lentiforme, Gattendorfia alteri, G.* aff. *G. bransoni, G. mehli, Intoceras osagense, Ammonellipsites (Pericyclus) blairi, Protocanites lyoni,* and *Prodromites gorbyi.*

The Northview Shale of southwestern Missouri has a slightly different fauna (Miller and Collinson, 1951): *Imitoceras brevilobatum, I. rugilobatum, Gattendorfia minisculum, Muensteroceras medium, Ammonellipsites* (*Pericyclus*) cf. *A.* (*P.*) *blairi, Protocanites gurleyi,* and *P. lyoni.* The presence of *Muensteroceras* is considered unusual in Kinderhook ammonoid assemblages (Manger, oral commun., 1975).

The upper part of the Cuyahoga Shale of Ohio contains *Imitoceras sciotoense, Kazakhstania colubrella,* and one species each of *Gattendorfia, Karagandoceras,* and *Muensteroceras* (Manger, oral commun., 1975). The overlying *Berne* and *Byer Members* of the Logan Formation have yielded *Imitoceras sciotoense, Kazakhstania colubrella, Gattendorfia andrewsi, Karagandoceras bradfordi,* and *Protocanites lyoni* (Hyde, 1953; Manger, 1971, p. 34). All three units are regarded as late Kinderhook in age.

Strata of Kinderhook age from the Western United States have yielded additional ammonoids, principally *Gattendorfia* and *Ammonellipsites* (*Pericyclus*). From the *Caballero Formation* of south-central New Mexico, Miller and Youngquist (1947) have described *Gattendorfia bransoni* and *Pericyclus* cf. *P. blairi.* At least two species of *Ammonellipsites* (*Pericyclus*) are represented in connections from this formation in the U.S. National Museum. In the basal Lodgepole Limestone in the Little Rocky Mountains in north-central Montana *Imitoceras, Gattendorfia, Ammonellipsites* (*Pericyclus*), and a form having nodose umbilical shoulders resembling *Hammatocyclus* are present. Accompanying conodonts identified by Huddle (written commun., 1970) are late Kinderhook forms.

The early Osage part of the *Protocanites lyoni* Zone is characterized by an abundance of the genus *Muensteroceras* and absence of *Karagandoceras* and *Prodromites.* The Rockford goniatite fauna, represented in the collections of many museums, is now known to have come from the basal part of the New Providence Shale (Manger, oral commun., 1975), which overlies the Rockford Limestone in Indiana. It includes the following ammonoids: *Imitoceras rotatorium, Muensteroceras oweni, M. parallelum, and Protocanites lyoni.* These ammonoid-bearing beds are early Osage in age and the ammonoids do not belong in the Kinderhook Series as previously believed. Rockford fauna ammonoids have been figured by J. E. and B. M. Conkin (1975, p. 51, 51, pl. 3) from northwestern Tennessee in what they have identified as the *Jacobs Chapel Shale,* a phase of the Rockford Limestone.

A related fauna believed to represent approximately the same zone was described from the Walls Ferry Limestone of Arkansas by Gordon (1964b) and referred to the local *Muensteroceras arkansanum* Zone, named for its most abundant species. This fauna included *Muensteroceras collinsoni, M. arkansanum, Imitoceras sinuatum,* and *Protocanites* cf. *P. lyoni,* as well as forms referred to *Gattendorfia, Ammonellipsites* (*Pericyclus*), and *Irinoceras.* (See Weyer, 1972, p. 338, 341.) Conodonts from the Walls Ferry Limestone were studied by Thompson and Fellows (1969, p. 76, 2-3, 224) and determined to be of early Osage age.

Judging in part from their stratigraphic position, the occurrence of *Muensteroceras eshbaughi* in the Fern Glen Limestone of Missouri (Miller, Downs, and Youngquist, 1949, p. 604) and *M. pfefferae* from the same formation and in the St. Joe Limestone Member of the Boone Formation in Missouri (Miller and Werner, 1942; Miller and Collinson, 1952) probably represent the upper part of the *Protocanites lyoni* Zone.

Isolated occurrences of *Protocanites lyoni,* as recorded in the Price Formation of Virginia (A. K. Miller, 1936, p. 70) and from an unnamed shale in northeastern Nevada (Furnish, Miller, and Youngquist, 1955, p. 186) need reassessment by means of associated fossils to determine which part of the *Protocanites lyoni* Zone is represented.

MEROCANITES MEGAZONE

The recorded occurrences of *Merocanites* in the United States are all in Osage rocks, and most seem to be in the lower part of this series. In Europe, however, this genus ranges upward into beds that probably are equivalent to the lower part of the Meramec Series. No formal zones have been proposed within this megazone, partly because most of the ammonoid occurrences are isolated, and generally limited to one or at most two species. About 20 species are known in this megazone.

The most varied cephalopod fauna attributable to this megazone is found in the Michigan basin (Winchell, 1862, 1865, 1870; Miller and Garner, 1955). It occurs in the Marshall Sandstone and, in part, in the underlying Coldwater Shale. Associated with *Merocanites houghtoni* and *M.* (*Michiganites*) *marshallensis* are *Imitoceras rotatorium, Gattendorfia andrewsi, G. stummi, G.? shumardiana, Irinoceras romingeri, Kazakhstania americana, Muensteroceras oweni, M. pergibbosum, M.? pygmaeum,* and *Winchelloceras allei.* In this area, however, the genus *Merocanites* seems to have a very limited range within the Marshall Sandstone. As the stratigraphic position of the Michigan Lower Mississippian ammonoid-bearing beds is not known in terms of the standard Osage section of the Mississippi Valley, it would appear premature to base a standard zone on the Michigan sequence.

Isolated species that belong also in this megazone include *Merocanites drostei* from the *Brodhead Formation* of Kentucky (Collinson, 1955), *M.? greenei* and

Gattendorfia brownensis from the *Knobstone Group* of Indiana (S. A. Miller, 1892, p. 700; 1894, p. 330), *Ammonellipsites* (*Stenocyclus*) *ballardensis* from the Grand Falls Chert Member of the Boone Formation in Kansas (Gordon, 1964b, p. 174), *A.* (*Fascipericyclus*) *polaris* from pre-Kogruk shale in Alaska (Gordon, 1957, p. 33), and *M. mitchelli* and *M. rowleyi* from the Burlington Limestone of Iowa (A. K. Miller, 1935; Miller and Furnish, 1958).

Whether the unique occurrence of *Beyrichoceras hornerae*, in chert probably derived from the upper part of the Boone Formation in Missouri (Miller, 1947a), belongs in this megazone cannot be determined at present. The occurrence seems to be well below the first appearance of *Goniatites* in the section and may be within the range zone of *Merocanites.*

GONIATITES MEGAZONE

The *Goniatites* zone, as at present known, begins in the upper part of the Salem Limestone of the Mississippi Valley and continues upward through the Golconda Formation. It thus includes about two-thirds of the Meramec Series and the lower third of the Chester Series. *Goniatites* and *Prolecanites* are characteristic genera of this megazone. Its top approximates the Viséan-Namurian boundary of Europe. The upper half is well developed, but much of the lower half is missing in the Arkansas and Utah sequences. Three standard zones are recognized within this megazone, one in the Meramec Series and two in the Chester. More than 35 species of ammonoids are known from this megazone.

An ammonoid assemblage typified by *Goniatites greencastlensis* occurs near Greencastle, Ind. As the stratigraphic relations of the rocks containing this fauna are incompletely understood, no formal zone has been proposed, even though the fauna is clearly Meramec in age and resembles those of the upper *Beyrichoceras* (B_2) Zone of the British Carboniferous section (Gordon, 1964b, p. 78). Early records referred these beds to the "St. Louis (Meramec) Group" (Miller and Gurley, 1896), and later ones (Miller and Garner, 1953), to the Salem Limestone. Collinson (1955, p. 437) and Gordon (1964b, p. 78, 79) have suggested that the fossils may have come from the oolitic Ste. Genevieve Limestone that encircles Greencastle, and this has been confirmed by Knapp (1965), who has studied the fauna. The ammonoids include *Bollandites* sp., *Goniatites greencastlensis,* and *Prolecanites americanus* and occur with several nautiloids.

Recently, a similar though presumably earlier fauna has been found at the south edge of Bedford, Ind., at the top of the Salem Limestone; Gordon has examined material collected by Jack Donahue. The total thickness of the rocks containing these ammonoids is not known. Further studies will be necessary before it can be determined if the goniatites from the upper part of the Salem Limestone should be included in a zone with the *Goniatites greencastlensis* fauna.

GONIATITES AMERICANUS ZONE

The zone was proposed by Gordon (1970, p. 818, 821), and the type locality in Utah was later elaborated by him (Gordon, 1971c, p. C39). The thickness of strata containing ammonoids of this zone at the type locality was given as 55 feet, but more recent fieldwork in 1974 indicates that it exceeds 80 feet. The Utah fauna is not yet described in full, but *G. americanus* occurs with *Entogonites borealis* and species of *Girtyoceras, Dimorphoceras,* and *Prolecanites.*

In northern Alaska, the *G. americanus* fauna occurs in the black chert and shale member of the Alapah Limestone in association with Zone 15 foraminifers (Armstrong and Mamet, 1977). *Beyrichoceras micronotum, Bollandites bowsheri, Goniatites americanus, Girtyoceras arcticum, G. endicottense, Entogonites borealis,* and *Dimorphoceras algens* are typical northern representatives of this zone. Also, from isolated Alaskan outcrops, possibly belonging in this zone, are *Bollandites killigwae, B.* cf. *B. sulcatus, Goniatites crenistria,* and *Pronorites* sp. (Gordon, 1957).

The *G. americanus* Zone also has been recognized, mainly through the presence of the species for which it was named in the Caney Shale of Oklahoma and the Moorefield Formation of Arkansas (Gordon, 1971c, p. C40, C41) and more recently from specimens found by U.S. Geological Survey geologists in the Diamond Peak Formation of east-central Nevada (where the ammonoids are associated locally with Moorefield-like brachiopods of late Meramec age and, rarely, with corals of the *Faberophyllum* (F) Zone, and in the lower part of the Paradise Formation in southwestern New Mexico).

GONIATITES MULTILIRATUS ZONE

This zone is approximately 50 feet thick in the section at Moorefield, Ark. It is also recognized in the lower part of the Caney Shale in southeastern Oklahoma and in the Chainman Shale in Nevada and Utah (Gordon, 1970, p. 821). Characteristic species are *Goniatites multiliratus* and *Girtyoceras meslerianum.* This zone correlates with the upper part of the lower *Posidonia* (P_1) Zone of the British Carboniferous section. It probably equates with the sandstone containing *Goniatites sphaericostriatus* (described as *G.* cf. *G. sphaericus* by Gordon, 1957, p. 45, 46) in the eastern De Long Mountains, Alaska, and the beds in the Alapah Limestone that yielded *Sudeticeras alaskae* (Gordon, 1957); these are believed to lie within foraminiferal

Zone 16i of very early Chester age, according to Mamet and Armstrong (1975).

GONIATITES GRANOSUS ZONE

The upper *Posidonia* (P_2) Zone of Great Britain, which is equivalent to the Goγ Zone of Germany, is also known as the *Goniatites granosus* Zone. Under this name it has been recognized in many parts of the United States (Gordon, 1957, p. 47, 49; 1964b, p. 72, 73; 1970, p. 818, 821). In northern Arkansas it includes the Ruddell Shale Member, Batesville Sandstone, and, locally, the lower part of the Fayetteville Shale. The zone reaches a maximum thickness of approximately 400 feet in the vicinity of Batesville, where it was divided by Gordon (1964b, p. 72, 73) into four subzones on the basis of species he assigned to *Neoglyphioceras: N. newsomi, N. subcirculare, N. caneyanum,* and *N. crebriliratum,* in ascending order. Elsewhere, it is thinner, and the subzones have not been distinguished.

Ammonoids of this zone have been described in the Calico Bluff Formation of Alaska (Gordon, 1957), the Chainman Shale of Utah (Miller, Youngquist, and Neilsen, 1952), the Caney Shale of Oklahoma (Girty, 1909; Gordon, 1962, 1964b), the Barnett Formation of Texas (Miller and Youngquist, 1948), the Floyd Shale of Georgia (Miller and Furnish, 1940, p. 366–369; Allen and Lester, 1954 *fide* Drahovzal, 1972, p. 35), the Pride Mountain Formation of Alabama (Drahovzal, 1972, p. 34, 35), and from an unknown formation near Crab Orchard, Ky. (Miller, 1889; Miller and Faber, 1892; Drahovzal, 1972, p. 34).

Characteristic ammonoids of this zone include *Goniatites choctawensis, G. granosus, Lusitanites subcircularis, Neoglyphioceras caneyanum, N. cloudi, N. cloudi utahense, N. crebriliratum, N. hyatti, N. georgiensis, N. newsomi, Ferganoceras elegans, Girtyoceras limatum, G. ornatissimum, Glyphiolobus pseudodiscrepans, G. edwini,* and *Pronorites baconi.* Probably representing this zone in the *Beech Creek Limestone* of Illinois is *Neoglyphioceras hartmani* (Furnish and Saunders, 1971).

Drahovzal (1972, p. 23) has also listed *Cravenoceras scotti, Paracravenoceras ozarkense,* and *Paradimorphoceras wiswellense* from the Ruddell Shale Member, but as these are species previously believed to be confined to the overlying *Tumulites varians* Zone and as no particulars of the occurrence have been provided, this considerable extension of range downward must be regarded as tentative.

EUMORPHOCERAS MEGAZONE

The beds referred to this zone in the United States begin where the *Goniatites granosus* fauna is replaced abruptly in ascending sequence by a fauna in which *Cravenoceras* and *Paracravenoceras* are the dominant genera. The zone extends upward to include the highest occurrences of *Eumorphoceras.* This megazone thus roughly approximates the range zone of *Eumorphoceras.* Stratigraphically lower occurrences of *Cravenoceras* and *Paracravenoceras* have been reported in the United States (Ruzhencev and Bogoslovskaya, 1971, p. 42, footnote; Drahovzal, 1972, p. 23) but not yet documented. Several species of *Cravenoceras* are likewise associated with ammonoids related to the *Goniatites granosus* fauna in the U.S.S.R. (Ruzhencev and Bogoslovskaya, 1971). Moreover, the genera *Goniatites, Lusitanites, Neoglyphioceras,* and *Girtyoceras* range upward from the *Goniatites* megazone some few tens of feet into the *Eumorphoceras* megazone locally in the United States (Miller and Youngquist, 1948, p. 652, 656; Gordon, 1964b; Drahovzal, 1972; Drahovzal and Quinn, 1972). So there exists some overlap of genera at either side of the lower contact of the zone.

This megazone is divided into two major standard zones that correspond to the lower *Eumorphoceras* (E_1) and the upper *Eumorphoceras* (E_2) Zones of northwest Europe. Some 50 species of ammonoids are known in the megazone.

TUMULITES VARIANS ZONE

This zone was proposed by Gordon (1964b, p. 73) under the name *Eumorphoceras milleri* Zone, but a delay in the publication of Gordon's report resulted in prior publication of the name-bearing species as *Tumulites varians* McCaleb, Quinn, and Furnish (1964, p. 30). Gordon (1970, p. 818) therefore changed the name of the zone to conform. In Arkansas this zone is present in the Fayetteville Shale; at Marshall, Searcy County, where the formation is approximately 300 feet thick, it extends from the bottom to the top of this formation. At other Arkansas localities it begins a few feet to a few tens of feet above the base of the Fayetteville.

Ammonoids of this zone include *Cluthoceras glicki, C.? pisiforme, Cravenoceras fayettevillae, C. incisum, C. lineolatum, C. scotti, Paracravenoceras ozarkense, Fayettevillea planorbis, Girtyoceras jasperense, Eumorphoceras plummeri, Tumulites varians, Arcanites furnishi, Trizonoceras typicale,* and *Metadimorphoceras wiswellense.* Ammonoids from this zone have been described also from the Caney Shale (Girty, 1909) and the Goddard Shale (Elias, 1952) of Oklahoma, and from the upper part of the Barnett Formation of Texas (Miller and Youngquist, 1948). This zone is well developed in the Great Basin, where it reaches a thickness slightly in excess of 400 feet in western Utah. Gordon (1970, p. 821) gave it the local name *Paracraveno-*

ceras barnettense Zone based on the one common species. Present also are *Cravenoceras kingi, Eumorphoceras plummeri,* and ? *Tumulites varians.* An interesting feature of this zone is the presence of aulococerid coleoid cephalopods in both Arkansas and Utah (Flower and Gordon, 1959).

EUMORPHOCERAS BISULCATUM ZONE

Bisat (1924, p. 41, 48) cited the *E. bisulcatum* and *Nuculoceras nuculum* zones as typifying the upper part of the *Eumorphoceras* Zone in the north of England. In more recent years, *E. bisulcatum* has been recognized as the name-bearing species of the lowest subzone (E_2a) of the upper *Eumorphoceras* (E_2) Zone in northwest Europe (Ramsbottom, 1969).

Nuculoceras is unknown in the United States, but *Eumorphoceras bisulcatum,* described originally from the Caney Shale of Oklahoma, is distributed widely. In the United States this species is the name bearer for the zone that is generally equivalent to the upper *Eumorphoceras* (E_2) Zone of England (Gordon, 1964b, p. 74, 75). Gordon recognized three subzones in Arkansas, based on species he assigned to *Cravenoceras.* In a later paper (Gordon, 1970), these were treated as zones, and equivalent beds in the Chainman Shale in Utah and Nevada were divided into two zones. A separate terminology for the West and the midcontinent was regarded as necessary because the ammonoid faunas are somewhat different on either side of the Transcontinental arch.

In Arkansas this zone occurs in the Pitkin Limestone and in the overlying *Peyton Creek Beds* at the base of the Cane Hill Formation (Imo Shale of Gordon, 1964b). Gordon found ammonoids in only the middle and upper parts of the Pitkin, but recently some have been discovered in the lower part (Taylor, 1973). Those in the middle and upper parts of the Pitkin belong in the *Cravenoceras richardsonianum* Subzone (or Zone of Gordon, 1970, p. 819) and include *Cravenoceras* (*Richardsonites*), *richardsonianum, Eumorphoceras bisulcatum,* and *E. girtyi.* In the topmost shale member of the Pitkin, *Cravenoceras* (*Stenoglaphyrites*) *involutum* is locally abundant and characteristic of the *Cravenoceras involutum* Subzone (or Zone) of Gordon (1964b, p. 79; 1970, p. 819).

The largest and best preserved fauna within this zone comes from the *Peyton Creek Beds* and occupies approximately the lowermost 100 feet of the Cane Hill Formation. Species of the *Cravenoceras miseri* Subzone (or Zone) include *C. miseri, C. bransoni, C.* (*Richardsonites*) *mapesi, Fayettevillea friscoensis, Somoholites cadiconiformis, Syngastrioceras imprimis, Delepinoceras bressoni, Metadimorphoceras saundersi, Eumorphoceras richardsoni, E. imoense, Peytonoceras ornatum,* and *Anthracoceras paucilobum.* This fauna occurs also in the Rhoda Creek Formation of Oklahoma (McCaleb, and others, 1964; Gordon, 1964b; Saunders, 1966, 1971, 1973).

In the Great Basin, the two subzones (or zones) recognized are those of *Cravenoceras hesperium* below and *C. merriami* above. *C. hesperium* continues upward into the *C. merriami* Subzone but is subordinate to it in the upper subzone. The *C. hesperium* Subzone is present in the upper member of the Great Blue Limestone of Utah, the Chainman Shale of Utah and Nevada, the Diamond Peak Formation and *Indian Springs Formation* (Webster and Lane, 1967) of Nevada, and the Perdido Formation of California. The following species are known from it: *Cravenoceras hesperium, C. inyoense, C. nevadense, Fayettevillea* n. sp., *Delepinoceras californicum, Proshumardites* sp., *Arcanoceras macallisteri, Eumorphoceras paucinodum, E.* aff. *E. bisulcatum, Anthracoceras colubrellus,* and *Glyphiolobus humphreyi* (Miller and Furnish, 1940; Youngquist, 1949a, b; Gordon, 1964b). *Cravenoceras hesperium* has also been found in the Heath Shale of Montana (Easton, 1962, p. 102).

The *Cravenoceras merriami* Subzone (or Zone) occurs in the Manning Canyon Shale of Utah, Chainman Shale of Utah and Nevada, the Diamond Peak, *Indian Springs,* and Eleana Formations of Nevada, and the Rest Spring Shale of California. Its species include: *Richardsonites merriami, C. hesperium, Cravenoceratoides* cf. *C. nititoides, Syngastrioceras walkeri* (? *Somoholites cadiconiformis* fide Saunders, 1971), *Eumorphoceras bisulcatum, Dombarocanites masoni,* and other forms (Youngquist, 1949a, b; Gordon, 1964b, Webster and Lane, 1967).

The upper several hundred feet of Mississippian rocks in the Great Basin contains predominantly brachiopod faunas. Only a few scraps of goniatites have been found, most of which are not positively identifiable; they resemble, however, shells in the *C. merriami* Subzone, rather than those of missing European zones. The *Nuculoceras nuculum* (E_2c) Subzone of the upper *Eumorphoceras* (E_2) Zone and the entire *Homoceras* (H) Zone are not represented in the United States, but the presence locally of beds of that age is indicated by the occurrence of Zone 19 foraminifers.

CONODONT ZONATION

Mississippian conodont zonation in North America was summarized by Collinson, Rexroad, and Thompson (1970). Since 1970 additional information about the Devonian-Mississippian boundary and the conodont zones near the boundary has been published by Klapper (1971), and Sandberg, Streel, and Scott (1972). Dunn (1970a, b), Lane, Sanderson, and Verville (1972), and

Lane and Straka (1974) have contributed information about the Late Mississippian conodont zones and the Mississippian-Pennsylvanian boundary. Little new information about Meramec and Chester conodont zonation has been published. This summary is based primarily on the above mentioned papers supplemented by unpublished reports on collections referred for study. Figure 88 is modified from figure 7 of Sando, Mamet, and Dutro (1969), which provided a base for correlation with megafaunal and foraminiferal zones.

No worldwide conodont zonation has been accepted. Three regional zonations are used: (1) the earliest, a zonation for Germany, was proposed by Bischoff (1957) and modified by Voges (1959, 1960) and Meischner (1970), (2) a different zonation was proposed for North America, Mississippi Valley, by Collinson, Scott, and Rexroad (1962), and (3) a British zonation was proposed by Rhodes, Austin, and Druce (1969). The European zonations are applicable to the Mississippian in North America only in a general way. The German zonation in part has been applied in the Cordilleran region by Sandberg and Klapper (1967), but the Collinson, Scott, and Rexroad (1962) zonation has been more generally used in the United States. Thompson and Fellows (1969), however, have modified the zones in the Early Mississippian. The relationship of the various zonal schemes is shown in figure 2 and table 1 of Collinson, Rexroad, and Thompson (1970).

All the Mississippian zonations proposed are useful locally. There is evidence that the ranges of some species, especially species of *Gnathodus*, are different in North America and Europe. Some of the zones proposed are assemblage zones, some are acme or abundance zones, others are range zones, and still others are based on the presence of one species and the absence of another. The last is a questionable practice for intercontinental zonation when geographic and ecologic ranges of the species are not known. The zonation used in this summary (fig. 88) is more general than those used previously for local areas. It recognizes five assemblage zones: the *Siphonodella, Bactrognathus, Taphrognathus, Cavusgnathus,* and *Adetognathus unicornis* Zones. The *Siphonodella* Zone is also an abundance zone, the *Bactrognathus* Zone a range zone, and the *Taphrognathus, Cavusgnathus,* and *Adetognathus* Zones apparently represent an evolutionary lineage.

The Devonian-Carboniferous boundary in Europe and the Devonian-Mississippian boundary in North America have long been under discussion. The history of the problem in Europe was reviewed by Austin, Druce, Rhodes, and Williams (1970). The problem in the United States was reviewed by Collinson, Rexroad, and Thompson (1971) who recommended that the boundary in the standard section be drawn at or near the base of the Hannibal Shale, but that the base of the "Glen Park Limestone" be used. Sandberg, Streel, and Scott (1972, p. 183) reported that *Siphonodella sulcata* occurs in the base of the Hannibal and "Glen Park" Formations and they regard the two formations as facies equivalents. A Devonian-Mississippian boundary at the base of the Hannibal Shale is justified mainly by conodont zonation, but the boundary seems to agree with other evidence and is generally acceptable. This boundary is the base of the *Siphonodella sulcata* Zone of Sandberg, Streel, and Scott (1972) and includes the *Protognathodus kuehni–P. kockelli* Zone of Collinson, Rexroad, and Thompson (1971).

The base of the Mississippian, defined as the base of the Hannibal Shale in the Mississippi Valley section, probably corresponds to the base of the Carboniferous in Europe. There the base of the Lower Carboniferous is placed at the base of the *Gattendorfia* Zone (cephalopods) and this coincides with the base of the *Siphonodella sulcata* Zone. The presence of a similar sequence of conodont zones in the Late Devonian and Early Carboniferous in many parts of the world tends to confirm the opinion that the base of the Mississippian, as here designated, is the same horizon as the base of the Carboniferous. Detailed evidence for this correlation is given by Sandberg, Streel, and Scott (1972), and the correlation by conodont zonation is strengthened by spore zones in the Late Devonian.

MISSISSIPPIAN CONODONT ZONES

SIPHONODELLA ASSEMBLAGE ZONE

The *Siphonodella* Assemblage Zone is characterized by an abundance of the following genera: *Siphonodella, Polygnathus, Spathognathodus,* and *Pseudopolygnathus. Elictognathus* and *Dinodus* are present in many places. Of these, only *Elictognathus* and *Dinodus* are confined to the zone, and their ranges represent a shorter interval than the *Siphonodella* Zone. *Protognathodus* ranges from the Late Devonian into the Mississippian *Siphonodella* Zone, and *Gnathodus* appears in the zone and is common in the upper part of the zone. The lower boundary of the zone is placed at the first appearance of *Siphonodella sulcata* and the upper boundary is marked by the disappearance of abundant siphonodellas and, perhaps, their extinction. Several species of *Pseudopolygnathus, Polygnathus* and *Spathognathodus* die out at the top of the zone. *Siphonodella* is reported with *Scaliognathus* and *Dollymae* in Germany, but these specimens are thought to be reworked (Męischner, 1970, p. 1176). Matthews, Saddler, and Selwood (1972, p. 551) reported *Siphonodella* and *Dollymae* on the same slab of siliceous shale, from Devonshire, England. I have identified a single specimen of *Siphonodella* from a sample collected by W. J. Sando, 800 feet above the base of the Madison Limestone in Montana. This sample is Osage in age according to Sando. McCaleb and Wayhan (1969, p. 2100) list *Siphonodella crenulata*, identified by Klapper from zone A of McCaleb and Wayhan, which Sando (oral commun., 1973) regarded as Osage in age. All of these examples of late occurrence of *Siphonodella* may be due to reworking, but the upper limit of the range of *Siphonodella* is not yet established.

The *Siphonodella* Zone is divided into two subzones: the *Siphonodella sulcata* Subzone below and the *Siphonodella cooperi* Subzone above.

The *S. sulcata* Subzone is present in the lower and middle part of the Hannibal Shale in the Mississippi Valley. The base of the subzone is the first appearance of *S. sulcata* at the base of the Mississippian. The abundance peaks of *S. sulcata* and *Protognathodus kuehni* and *P. kockeli* are in the lower part of the subzone, and the abundance peak of *S. duplicata* occurs in the upper part, along with *S. sandbergi.*

The *S. cooperi* Subzone is present in the upper part of the Hannibal Shale and the Chouteau Limestone in the Mississippi Valley. It is characterized by an abundance of the advanced forms of *Siphonodella* and the appearance of *Gnathodus. Gnathodus punctatus* is common in the upper part of the subzone in southwestern Missouri and in the Cordilleran region, but this part of the subzone is absent in the Upper Mississippi Valley sections.

BACTROGNATHUS ASSEMBLAGE ZONE

The *Bactrognathus* Assemblage Zone occurs in the *Meppen* of Collinson, Rexroad, and Thompson (1971), Fern Glen, and Burlington Formations in the upper Mississippi Valley. The base is marked by the first appearance of *Bactrognathus* and the first abundance of *Pseudopolygnathus multistriatus* and *Gnathodus semiglaber.* Within the zone are the ranges of several distinctive genera, including *Scaliognathus, Doliognathus, Dollymae,* and *Staurognathus*. The upper boundary of the zone is marked by the disappearance of these distinctive genera and the appearance of *Taphrognathus varians* and an abundance of *Gnathodus texanus.* The youngest known species of *Polygnathus, P. mehli,* occurs in the upper part of this zone.

Several locally useful subzones in the Mississippi Valley are based on the overlapping of species of *Gnathodus, Polygnathus,* and *Pseudopolygnathus.*

In Germany, the approximately equivalent *Scaliognathus anchoralis* Zone overlaps the range of *Siphonodella* and includes the range of *Dollymae* and *Gnathodus punctatus,* according to Meischner (1970). This overlap of ranges is not present in Belgium, according to Austin and Groessens (1973) and Groessens (1971), who ascribe the German overlap of ranges to reworking.

TAPHROGNATHUS ASSEMBLAGE ZONE

The *Taphrognathus* Assemblage Zone includes the Keokuk, Warsaw, Salem, and lower part of the St. Louis Limestones in the Mississippi Valley. It is essentially the range zone of the species *T. varians*, and, while this species is common in the Warsaw to St. Louis interval, it is rare in the Keokuk Limestone. The total range of the species overlaps the assemblage zones used here. The base of the assemblage zone is marked by a few specimens of *T. varians* and more abundant specimens of *Gnathodus texanus*. The top of the zone is indicated by transitional forms between *Taphrognathus* and *Cavusgnathus* and the appearance of *Cavusgnathus unicornis, Spathognathodus scitulus,* and abundant specimens of *Apatognathus* species. *Spathognathodus coalescens* is abundant in the Warsaw Limestone.

CAVUSGNATHUS RANGE ZONE

The *Cavusgnathus* Range Zone extends from the base of the upper part of the St. Louis Limestone to the base of the *Grove Church Formation* in the top of the Chester Series in the Mississippi Valley. The base is indicated by the first abundance of *Cavusgnathus unicornis,* transitional forms from *Taphrognathus,* and abundance of *Apatognathus* and *Spathognathodus sicitulus.* A number of zones in this interval in the upper Mississippi Valley have been recognized by Collinson, Rexroad, and Thompson (1971), but these zones are not very distinct. Species of limited range are rare and most collections include only the abundant long-ranging species. A lower subzone of the Chester is suggested by the ranges of *Gnathodus texanus,* lower third of the Chester, and *G. bilineatus,* Glen Dean Limestone and below. This is limited in usefulness because of difficulties in the taxonomy of gnathodids and questions about total ranges of gnathodid species. *Cavusgnathus naviculus* is confined to the formations of late Chester age and together with the total range of the bar-type genus *Kladognathus,* defines a possible late Chester subzone.

ADETOGNATHUS UNICORNIS ASSEMBLAGE ZONE

The *Adetognathus unicornis* Assemblage Zone is confined to the latest formation of the Chester, the *Grove Church Formation,* in the upper Mississippi Valley; it also occurs in the Pitkin Limestone in Arkansas, the Helms Formation in west Texas, and in the *Indian Springs Formation* in Nevada. The base of the zone is marked by the first appearance of *Adetognathus*

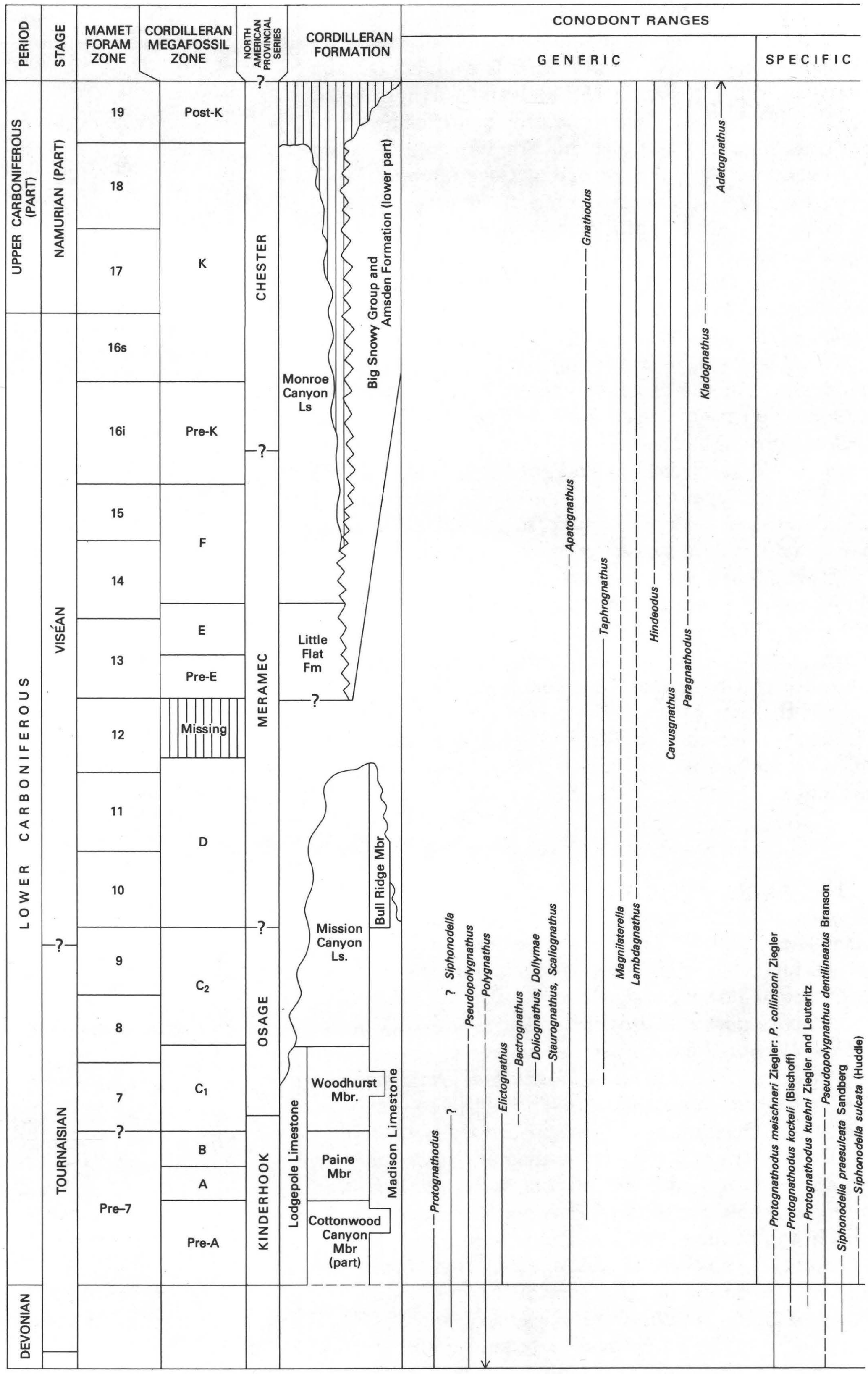
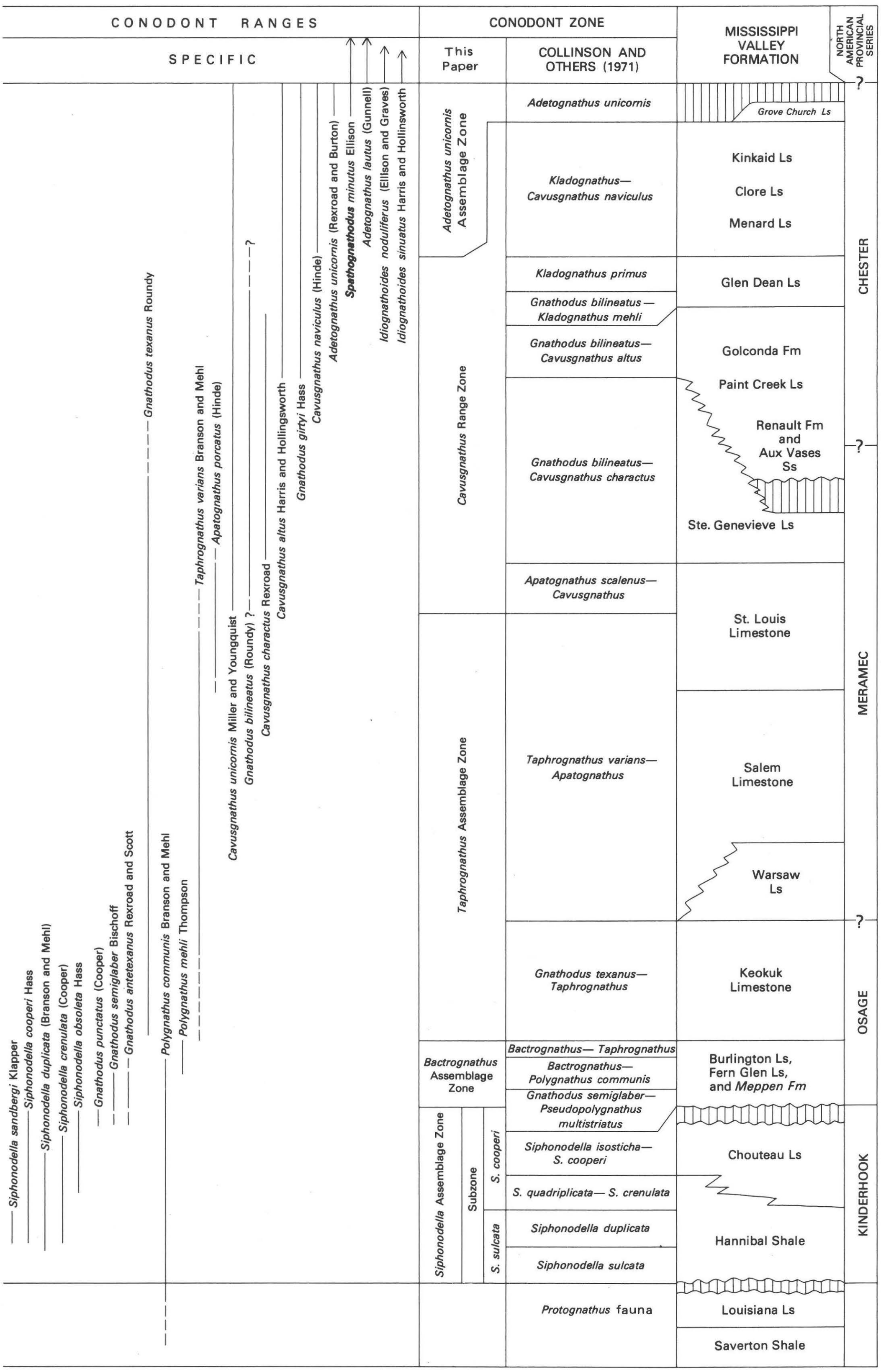


FIGURE 88. — Conodont zones and ranges. Base



modified from Sando, Mamet, and Dutro (1969, fig. 7).

unicornis (Rexroad and Burton) and *Spathognathodus minutus*. Both species continue upward into the Morrow Series of the Pennsylvanian.

The boundary between the Mississippian and the Pennsylvanian has presented problems partly because the type sections are separated by many miles. In Pennsylvania and West Virginia much of the section is nonmarine and, therefore, difficult to correlate with the nearly continuous marine sections in the Cordilleran region. The conodont faunas of the western Late Mississippian and Early Pennsylvanian sequence have been studied by Webster (1969), Dunn (1970a, b), Lane, Sanderson, and Verville (1972), and Lane and Straka (1974). These authors generally agree that on the basis of conodonts the base of the Pennsylvanian can be drawn at the first appearance of *Adetognathus lautus* —*A. gigantus, Rhachistognathus primus, Idiognathoides noduliferus, I. sulcatus,* and *Adetognathus spatus*. The appearance of the foraminifer genera *Millerella* and *Eostaffella* at approximately the same horizon tends to confirm the boundary based on conodonts.

RESIDUAL INCONSISTENCES IN CORRELATION

In this report we have used the small Foraminifera as a common denominator by means of which the charts, based on different phyla of fossils, can be compared one to the other. The zonal scheme of Mamet (Mamet and Skipp, 1971) as related to the type Mississippian sequence is shown on the three principal charts (figs, 85, 86, 88). This scheme was developed originally for the section in Belgium and, in part, has been correlated with the European goniatite zones. However, some controversy exists among workers in Belgium as to the correlation of the Dinantian rocks, even within a relatively limited region. So it is not surprising that certain difficulties have arisen in correlating the rocks of various regions of North America with those across the Atlantic Ocean by means of several different groups of animals. The heartening truth is that the discrepancies in correlation now involve relatively minor intervals of the geologic column.

One of our principal difficulties has been to ascertain the position of the Tournaisian-Viséan boundary in the American section. Mamet and Skipp (1971, p. 1141) equated it with the Osage-Meramec boundary. The ammonoids, however, suggest a correlation with a level within the Osage Series. Works on Belgian stratigraphy with regard to the ammonoids (Delepine, 1940, p. 8, 9; Conil, Mortlemans, and Pirlet, 1971, p. 17, 18) place high in the Tournaisian (zones Tn_3b, Tn_3c) the limestones that contain ammonoid faunas closely related to our *Protocanites lyoni* Zone. Correlation by conodonts suggests that the Tournaisian-Visean boundary should be placed approximately at the contact between the Burlington and Keokuk Limestones in the type Mississippian sequence. Paproth (1969), who employed both conodont and ammonoid zones in her correlation and also considered the foraminifers, placed the top of the Kinderhook high in the Tournaisian, but she found difficulty in correlating the Osage and its upper boundary.

The seeming discrepancies will be resolved as more comparative data, involving a wide variety of fossils, become available. The pursuit of biostratigraphy in the United States has reached the point where paleontologists, before making general statements about the time-stratigraphic classification, are more willing to look outward from their particular disciplines and to compare their results with those of their colleagues working on other fossil groups.

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Evaporite Deposits in Mississippian Rocks of the Eastern United States

By WALLACE DE WITT, JR., EDWARD G. SABLE, *and* GEORGE V. COHEE

PALEOTECTONIC INVESTIGATIONS OF THE MISSISSIPPIAN SYSTEM IN THE UNITED STATES, PART II: INTERPRETIVE SUMMARY AND SPECIAL FEATURES OF THE MISSISSIPPIAN SYSTEM

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1010–T

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EVAPORITES IN THE APPLACHIAN BASIN

By WALLACE DE WITT, JR.

Commercially exploited evaporites of Mississippian age occur only in the Maccrady Shale and Little Valley Limestone of the Saltville district in southwest Virginia, a 16- by 3-mile belt between Plasterco, Washington County, and Chatham Hill, Smyth County. The evaporite-bearing rocks lie along the trough of the Greendale syncline (pt. I, chap. C, fig. 3) which is locally overturned and recumbent in the vicinity of Saltville (fig. 89; Cooper, 1964, p. 94, fig. 8). Salt is found only in a 3-mile segment in the immediate vicinity of Saltville and Plasterco; whereas gypsum and anhydrite are more widespread (Cooper, 1966, p. 24). Excepting these deposits in the Greendale syncline, evaporites are sparsely distributed in the Mississippian rocks of the Appalachian basin. Traces of anhydrite and gypsum have been reported from the Little Valley and Hillsdale Limestones along the Allegheny Front (pt. I, chap. C, fig. 3) in southwest Virginia (Wilpolt and Marden, 1959, p. 595). Anhydrite was observed in drill cuttings from the Hillsdale part of the Greenbrier Limestone in south West Virginia (Martens, 1945), and small amounts of clear anhydrite occur locally in the St. Louis Limestone, the basal part of the well driller's ***Big lime***, in east Kentucky. Throughout most of the basin, however, the Mississippian rocks are largely devoid of evaporites.

Much of the following discussion of the Saltville district is from Cooper (1964, 1966), who has studied the area intensively for a number of years.

Salt and gypsum were found relatively early in the settlement of southwest Virginia, and by 1815 both commodities were being produced in the Saltville district. Saltville was one of the principal sources of salt for the Confederacy, and the district became increasingly important to the South as other sources of this vital commodity were lost during the closing phases of the Civil War. Since then, Saltville has been the site of a thriving chemical industry using salt from the Mississippian rocks and limestone from Ordovician strata contiguous to the Greendale syncline. Salt is dissolved from the Maccrady Shale and transported to the chemical plant in the form of brine.

In the Saltville district, anhydrite, gypsum, and salt occur mainly in the upper part of the Maccrady Shale, a part that has been informally designated the plastic shale member by Cooper (1966, p. 15), and, to a lesser extent, in the basal part of the overlying Little Valley Limestone. Thus, most of the salt lies within interval B,

FIGURE 89. — Index maps of localities and geologic features mentioned in text, Saltville area, Virginia.

although some is in the base of interval C. The entire Maccrady Shale, but particularly the evaporite-bearing member, thickens markedly into the axial part of the Greendale syncline. At Saltville, for example, in a lateral distance of 1 mile the Maccrady thickens from 350 feet on the flank of the syncline to more than 1,600 feet near the axis of the trough (Cooper, 1966, p. 16). Although some thickening of the soft strata undoubtedly resulted from the flowage of the relatively incompetent evaporites into the trough of the syncline during post-Mississippian folding, Cooper (1966, p. 22) has indicated that much of the thickening is the result of original deposition in a tectonically controlled, locally silled basin or trough. In Locust Cove, about 15 miles northeast of Saltville along the Greendale syncline (pt. I, chap. C, fig. 3), detailed mapping of the Maccrady by Eckroade (Cooper, 1964, p. 94) disclosed a normal fault that offset the upper evaporite-bearing member of the Maccrady. The member is more than three times as thick in the downthrown block as in the upthrown block. These data clearly indicate tectonic control of the growing Greendale syncline in the Saltville district at the time when the Maccrady evaporites were accumlating in a hypersaline environment.

Post-Mississippian folding and faulting played an important part in preserving the salt at Saltville and in the conversion of anhydrite to gypsum in other parts of the district. Cooper (1966, p. 27–28) has indicated that in the 3-mile segment of salt beds around Saltville impermeable lower Paleozoic rocks in the plate of the Saltville thrust lie on the upper limb of the overturned Greendale syncline in contact with the salt-bearing part of the Maccrady. The tight caprock prevented removal, by deeply circulating ground waters, of salt from the thick sequence of evaporites in the axial part of the trough. In this part of the district, salt and anydrite occur in abundance, and gypsum is present only in relatively small amounts in the subsurface. In contrast to the Saltville locality, north and south along the syncline where the trough is less tightly folded and permeable lower Paleozoic rocks overlie the Maccrady, gypsum is abundant, whereas anhydrite and salt are not. In these areas, according to Cooper (1966, p. 28), deep circulation of ground water has removed the salt from the sequence and has hydrated the anhydrite to gypsum. This hypothesis is a reasonable explanation for the relatively mutual exclusiveness of the main masses of salt and gypsum in the Saltville district.

From his regional study of the Maccrady and related rocks and a synthesis of the depositional history of the strata, Cooper (1966, p. 15, 32) has concluded that the Saltville evaporites accumulated in a small locally subsiding trough and that large amounts of evaporites will probably not be found in these beds at other localities in the folded Appalachian Mountains. To date, his conclusion has been substantiated by deep drilling both in the folded rocks of the Valley and Ridge province and in the flat-lying strata of the Appalachian Plateaus province (pt. I, chap. C, fig. 3).

EVAPORITES IN THE EASTERN INTERIOR BASIN

By Edward G. Sable

INTRODUCTION

Significant amounts of bedded gypsum and anhydrite, including exploited or potential commerical deposits, occur in the lower part of the St. Louis Limestone (mid-interval C) in the Eastern Interior basin—Illinois, Indiana, and Kentucky. Lesser amounts of these evaporites, as nodular masses, geode fillings, and veinlets, are also found in the St. Louis, Salem, and Harrodsburg Limestones, in some units of the Borden Group or Formation, and in the Fort Payne Formation (pl. 15). The bedded deposits discussed appear to represent recrystallized and at least in part altered products of primary inorganic precipitates; the minor occurrences are largely postlithification open-space fillings or replacements of carbonate rocks.

Evaporite occurrences in Illinois were described by Saxby and Lamar (1957), those in Indiana, by McGregor (1954), and those in Kentucky, by McGrain and Helton (1964). Petrology of the Indiana evaporite deposits was discussed by Bundy (1956). All data on bedded evaporite distribution and thickness are based on subsurface information. The map (fig. 90) shows areas of St. Louis evaporite-bearing beds and cumulative thicknesses of bedded evaporites.

DISTRIBUTION AND THICKNESS

Evaporite beds in the lower part of the St. Louis Limestone occur in a southeast-trending belt from west-central Illinois to south-central Kentucky. The St. Louis Limestone as a whole, less than 100 to more than 400 feet thick, consists dominantly of very fine grained dense limestone, the features of which indicate deposition in a low-energy marine environment. The lower part of the St. Louis, less than 20 to more than 200 feet thick (fig. 90), is referred to as the evaporite unit or evaporite-bearing zone. Thickness limits for this unit appear to be somewhat wider in Indiana than in Illinois and Kentucky (McGregor, 1954, p. 16–18; Saxby and Lamar, 1957, p. 7; McGrain and Helton, 1964, p. 9). In this unit, beds containing relatively high proportions of gypsum and (or) anhydrite are reported to be $<1–15$ feet thick in Illinois, $<1–20$ feet thick in Indiana, and

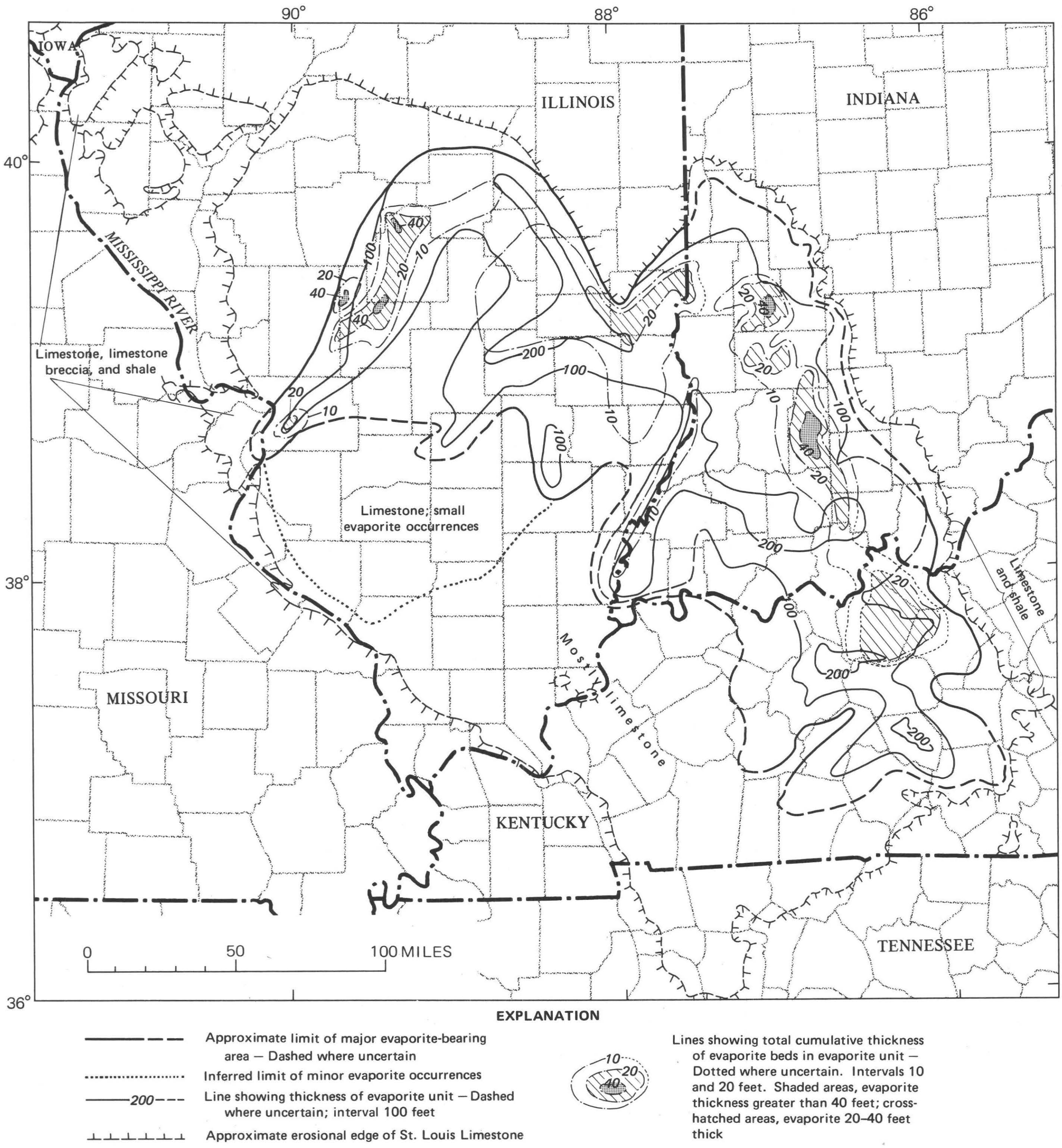

FIGURE 90. — Distribution of major evaporite occurrences in St. Louis Limestone in Eastern Interior basin. Modified from McGregor (1954), Saxby and Lamar (1957), and McGrain and Helton (1964).

<1–20 feet thick in Kentucky. They are interbedded with limestone, dolomitic limestone, dolomite, and minor mudstone. Although evaporite beds seem most widespread in the lower part of the evaporite unit, regional continuity of individual beds seems unlikely (Saxby and Lamar, 1957, p. 7, 13).

The areas of maximum cumulative evaporite bed thicknesses (more than 20 feet) — in central and eastern Illinois, west- and south-central Indiana, and west-central Kentucky — are shown in figure 90. These areas indicate nonuniform thickness distribution which corresponds only partly to total thickness trends of the evaporite unit and suggest localized accumulations near the margins of the Eastern Interior basin.

No St. Louis bedded evaporites have been observed in outcrop within the region. In the subsurface the evaporite unit thins eastward toward the Cincinnati arch–Kankakee arch trend and westward toward the Mississippi River valley (fig. 90). Along the eastern margins of outcrop, beds probably correlative with the evaporite unit are marine limestone, dolomite, and minor mudstone, including carbonaceous shale. Westward, along the Mississippi River valley, probable correlatives of the evaporite unit are limestone and gray mudstone and limestone conglomerates and breccias which may be extensive in the subsurface of western Illinois, Missouri, and Iowa. Southwestward, the evaporite unit appears to grade into a predominantly limestone section which contains minor evaporite occurrences in southwestern Illinois (Saxby and Lamar, 1957, p. 10) and clastic limestones in southwestern Indiana (Pinsak, 1957, p. 40). The northern limits of the evaporite unit in eastern Illinois lie along a post-Mississippian erosional edge; originally, the unit extended an unknown distance northward.

The absence of St. Louis bedded evaporite in presumably correlative rocks of outcrop belts and in subsurface areas adjoining evaporite occurrences has been explained as due to nondeposition of evaporites or their removal from original sites of deposition. In southern Illinois and extreme western Kentucky, absence of evaporite beds probably reflects an environment of normal salinity, open circulation, and depth of water not conducive to primary evaporite precipitation. In western and southwestern Illinois, the presence of limestone breccia beds in the lower part of the St. Louis Limestone may represent solution removal of evaporites previously deposited over large areas of Illinois, Iowa, and Missouri (Saxby and Lamar, 1957, p. 15; Collinson, 1965, p. 7). The breccias have also been attributed, by some authors, to wave action and regional deformation.

In the eastern outcrop belts of St. Louis Limestone in Indiana and west-central Kentucky, no breccia beds have been recognized in beds correlated with the evaporite unit. Older Mississippian strata of different lithologies, however, do contain locally abundant gypsum- and anhydrite-filled geodes and nodules of unknown origin. These occurrences may have resulted from solution of bedded evaporites by ground water, downward and lateral transportation, and redeposition in suitable host rock. Deposition of St. Louis bedded evaporites in these eastern areas, as in the western ones, may have been areally more extensive than the present distribution pattern shows.

FACTORS AFFECTING EVAPORITE DEPOSITION

The St. Louis evaporite deposits imply climatic factors of warmth and low rainfall and shallow hypersaline water conditions in which evaporation and restricted circulation were significant factors. Precipitation from supersaturated sea water is agreed to by all investigators. Whether anhydrite or gypsum or both minerals were precipitated as primary deposits in the St. Louis evaporite unit is not known. On the basis of experimentally derived stability conditions of the system $CaSO_4 \cdot H_2O$ and his own petrographic observations, Bundy (1956, p. 251) concluded that "gypsum may be the predominant or only form of calcium sulphate precipitated from sea water." Saxby and Lamar (1957, p. 4) favored anhydrite to be the original precipitate. Petrographic evidence indicates that secondary occurrences of gypsum are quantitatively significant, and anhydrite has also been recognized as a secondary mineral in the St. Louis evaporites (Bundy, 1956; Saxby and Lamar, 1957, p. 4).

The relative importance of tectonic and depositional features which may have affected the distribution and thickness of evaporite accumulation in the St. Louis is difficult to assess. Although structural features probably provided the major framework for evaporite deposition, irregular preexisting bottom topography and partial removal of evaporites by nearly contemporaneous submarine erosion may have been factors in the nonuniform distribution of the evaporite beds. The following discussion summarizes evidence bearing on the problem.

STRUCTURAL CONTROLS

Prior to evaporite deposition, the major controls for depositional thicknesses of interval B and early interval C sediments were tectonic. Three major structural features included (1) a relatively stable, slowly downsinking shelf in western Illinois and Missouri areas, (2) a rapidly subsiding, southwest-trending basinal trough across northwestern Indiana to beyond southern Illinois, and (3) an unstable shelf or platform along the Cincinnati arch–Kankakee arch trend. The rocks deposited by the end of Salem (early interval C) time indicate that shallow-water conditions existed over large areas, which suggests that major structural irregularities had been largely infilled except perhaps in the deeper parts of the trough in southern Illinois. Following deposition of Salem sediments, the evaporite unit and succeeding St. Louis strata accumulated. Total thicknesses of the St. Louis Limestone in Illinois (fig. 91) indicate elements which suggest that the gross

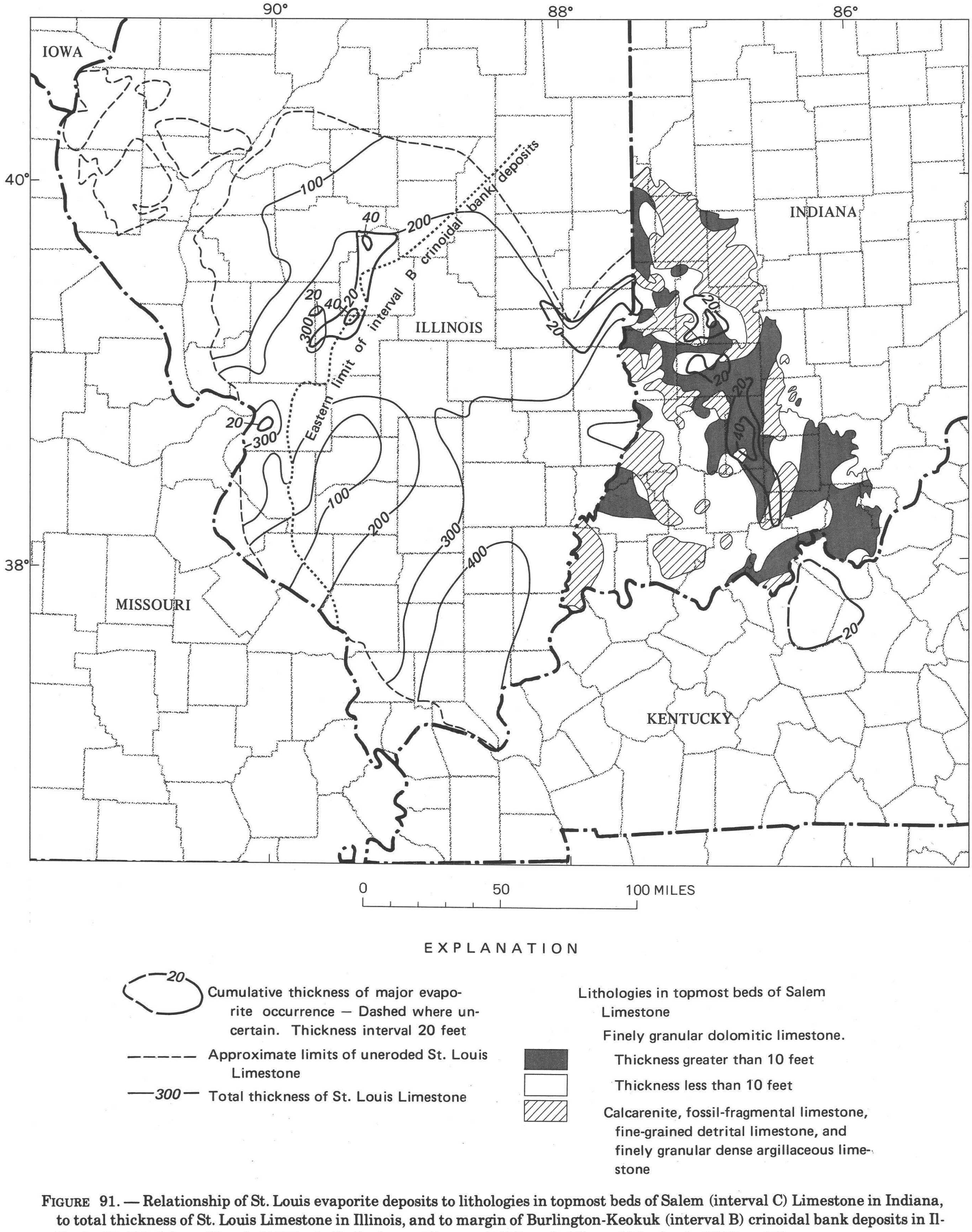

FIGURE 91. — Relationship of St. Louis evaporite deposits to lithologies in topmost beds of Salem (interval C) Limestone in Indiana, to total thickness of St. Louis Limestone in Illinois, and to margin of Burlington-Keokuk (interval B) crinoidal bank deposits in Illinois. Modified from Pinsak (1957, pl. 5), Saxby and Lamar (1957, p. 8, 10), and Lineback (1966, p. 12).

structural framework, although somewhat modified, continued into St. Louis time. Within this framework, evaporite beds accumulated on the wide shelf areas marginal to the basin where sediment infilling was essentially in balance with slow subsidence. Farther south, in the basin, more rapid subsidence may have exceeded sedimentation rates with resulting deeper water conditions, as suggested by the darker hues of St. Louis rocks there.

In Indiana and Kentucky, the belt of major evaporite occurrences (fig. 91) lies between the present La Salle anticlinal belt and the Cincinnati arch–Kankakee arch trend. McGregor (1954, p. 20) favored structural controls as important factors in deposition of the Indiana evaporites in which differential epeirogenic movement resulted in intrasilled basins between the La Salle anticlinal belt and the Cincinnati and Kankakee arches.

In central and west-central Illinois, major evaporite occurrences do not as clearly correspond to present linear structural trends as they do in Indiana and Kentucky. However, thinning of the total St. Louis section in western and southwestern Illinois (fig. 91) suggests northeast-trending positive elements which flanked the evaporite deposits. These elements appear to have generally corresponded to the present Mississippi River arch and to the Vandalia arch which was prominent during Late Devonian time.

NONSTRUCTURAL CONTROLS

Although the general framework for St. Louis evaporite deposition was probably due to tectonic causes, it is not clear whether the nonuniform distribution of evaporites resulted wholly from this factor or were also the results of preexisting nonstructural bottom topography. Nonstructural controls may have included depositional irregularities in the underlying Salem Limestone in Indiana and Kentucky and similar features inherited from interval B deposition in central and southwestern Illinois. Pinsak (1957, p. 20) suggested erosion, transportation, and redeposition of fine-grained components by storm waves and wave-generated currents as a further possible factor for the patchy distribution of evaporites and apparent intergradation of different lithologies.

The Salem Limestone includes a variety of carbonate rock types characterized by lateral discontinuity of individual units (Pinsak, 1957, p. 38–39). Reconstruction of the physical environment of Salem deposition in Indiana suggests a relatively flat sea floor with scattered positive depositional elements (Pinsak, 1957, p. 47). Irregular thicknesses of Salem occur in a belt along the main Indiana evaporite occurrences and are believed by Pinsak to have been influenced by locations of Silurian reefs. Comparison of Salem thicknesses (taken from Pinsak, 1957, pl. 3) with major St. Louis evaporite occurrences in Indiana indicates that irregular Salem thickness maximums lie marginal to or between areas of evaporite maximums. The distribution of lithologies at the top of the Salem, directly underlying the evaporite unit in Indiana (generalized from Pinsak, 1957, pl. 5), is shown in figure 91. The distribution of finely granular dolomitic limestone in the topmost Salem corresponds closely with evaporite thickness maximums and may indicate that hypersaline conditions were already operative during late Salem time. Adjacent to belts of dolomitic limestone, sporadic occurrences of calcarenites and detrital limestones roughly delimit areas of thick evaporites. These limestones may have acted as positive elements which provided circulation barriers to adjoining sites of evaporite deposition. Although such elements may have initially exercised environmental controls, it seems doubtful that they were topographically high enough to account for repeated evaporite deposition in sections 100–200 feet thick. Local tectonic controls like those suggested by McGregor seem to best explain prolonged St. Louis evaporite deposition in Indiana.

In central and southwestern Illinois, major evaporite occurrences correspond closely to the southeastern margin of the shelf on which interval B bank sediments (crinoidal limestones of Burlington-Keokuk) accumulated (fig. 91). Infilling of the basinal trough to the east by Borden deltaic sediments and overriding of the banks by detrital sediments (Warsaw) may have provided topographic irregularities conducive to evaporite deposition there.

SUMMARY

Deposition of the St. Louis evaporite unit represents a partial withdrawal and restriction of seas after the more widespread marine conditions during which earlier Mississippian sediments were deposited, and before the widespread transgressions of late St. Louis time. Climatic and tectonic conditions were probably major causal factors, but irregular infilling of the major basin during interval B and early interval C also may have had important effects in displacing marine waters and producing semi-isolated shoal areas conducive to evaporite deposition.

A model representing hypothetical conditions during evaporite unit deposition is shown in figure 92. Influx of marine waters is assumed to have been largely through the Cumberland saddle area, on the basis of suggestive evidence that this area afforded connections to the Appalachian basin seaway during early interval C time (Sable, pt. I, chap. E, p. 79) and on the basis of the reconstruction, by Swann (1963), of a dominant northwesterly marine current direction during late interval

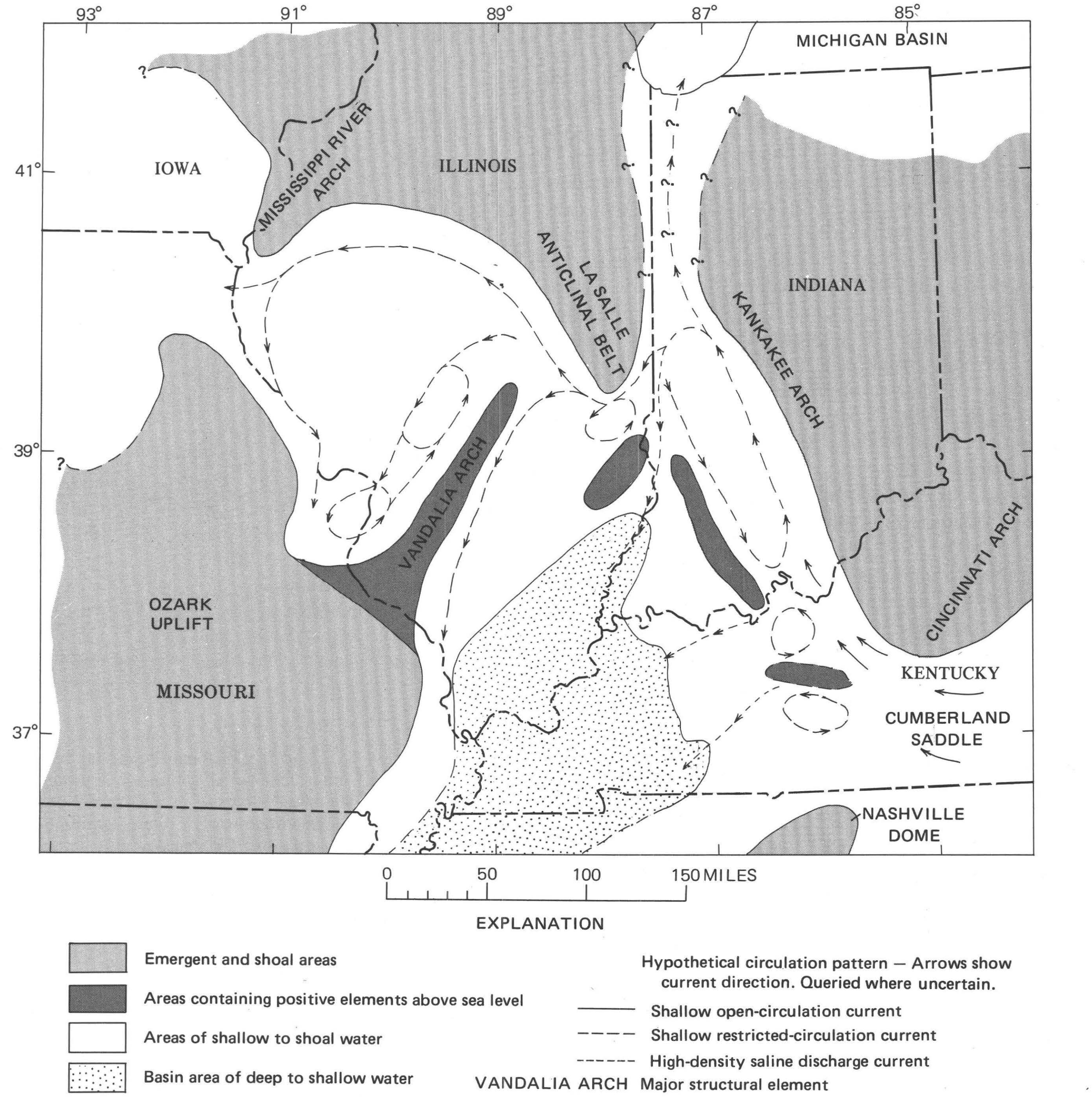

FIGURE 92.—Paleogeographic model of Eastern Interior basin showing hypothetical framework of St. Louis evaporite deposition.

C and interval D time. Surface waters may have flowed in a broad front from the main basin toward shelf areas, however, and possibly became increasingly more saline through progressive shelfward evaporation. Perhaps only slight topographic restrictions along the shallowest marginal parts of the shelf were necessary to afford environments conductive to evaporte precipitation in these areas.

EVAPORITES IN THE MICHIGAN BASIN

By GEORGE V. COHEE

The Mississippian evaporite deposits of the Michigan basin are primarily gypsum and anhydrite and are limited to the Michigan Formation of Late Mississippian age (interval C). During the time of deposition of the formation, the basin appears to have been isolated periodically from the open Mississippian seaway. In the isolated basin, both evaporation and the chemical precipitation of anhydrite took place. The gypsum was formed by hydration of the anhydrite. As many as eight beds of gypsum have been reported in the Michigan Formation in southwestern Michigan where the gypsum is mined. In the Central basin area (pt. I, chap. D, fig. 9), some drill holes show a dozen or more individual beds of anhydrite occurring at intervals throughout the 500 feet of greenish-gray shale, dolomite, and sandstone of the formation. Anhydrite and gypsum are present in the Michigan Formation throughout its extent in the basin. The depth to the Michigan Formation in the Central basin area is about 1,000 feet.

The aggregate thickness of the beds of gypsum in the areas where it has been mined varies from place to place, and in Kent County it ranges from less than 1 foot to as much as 38 feet (Grimsley, 1904). The aggregate thickness of the gypsum in the Iosco County area exceeds 40 feet, and in the Central basin area the aggregate thickness of gypsum and anhydrite attains a maximum of 100 feet (fig. 93). Gypsum may also occur in modules of various sizes. Beds of salt have not been reported in the Michigan Formation, but veinlets of salt have been reported in a few places in the formation.

The Michigan Formation thickens from less than 100 feet at its southern boundary beneath the glacial drift to about 500 feet in Missaukee County. The formation is exposed in Kent, Huron, and Iosco Counties, and gypsum has been mined from it at Grand Rapids, Kent County and is being quarried at Alabaster and National City, Iosco County. By the end of 1964, 50 million tons of gypsum had been mined in Michigan.

Because of the arid and evaporating conditions within the Michigan basin during late interval B and interval C time, the seawater at times became a highly concentrated solution of mineral salts. The connate waters enclosed within the porous sandstone deposited in the Central basin area are remarkably concentrated brines. The brine from the Marshall Sandstone (upper part of interval B) was used as a source of chlorine and bromine in 1880 by Hubert Dow, founder of the Dow Chemical Company, Midland County (Kelley, 1964). Since the first industrial use of the brine from the Marshall, it has provided many different compounds of calcium and magnesium in addition to those of chlorine and bromine. For many years the entire domestic output of primary metallic magnesium was obtained from the brines of the Marshall Sandstone by electrolysis of the magnesium chloride. The depth to the Marshall Sandstone in the Central basin area is about 1,300 feet.

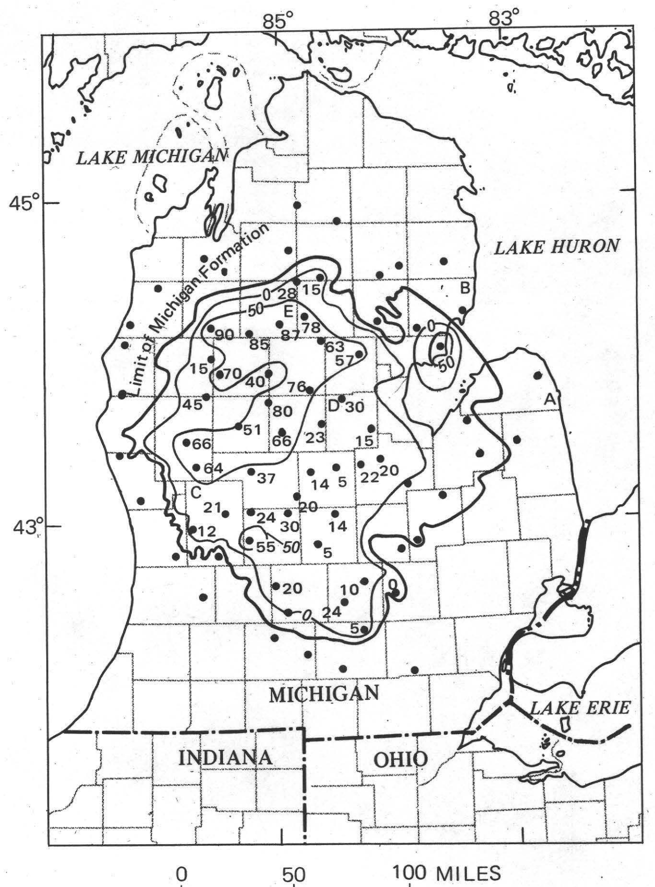

FIGURE 93. — Extent of the Michigan Formation and the distribution and thickness of contained gypsum and anhydrite in the lower peninsula of Michigan. Numbers show cumulative thickness in feet. Unnumbered localities are points with no gypsum and anhydrite. Counties mentioned in text: A, Huron; B, Iosco; C, Kent; D, Midland; E, Missaukee.

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Oil and Gas in Mississippian Rocks in part of Eastern United States

By WALLACE DE WITT, JR., GEORGE V. COHEE, *and* LAURA W. MCGREW

PALEOTECTONIC INVESTIGATIONS OF THE MISSISSIPPIAN SYSTEM IN THE UNITED STATES, PART II: INTERPRETIVE SUMMARY AND SPECIAL FEATURES OF THE MISSISSIPPIAN SYSTEM

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1010–U

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OIL AND GAS IN MISSISSIPPIAN ROCKS IN PART OF EASTERN UNITED STATES

By WALLACE DE WITT, JR., GEORGE V. COHEE, and LAURA W. MCGREW

PETROLEUM AND NATURAL GAS IN MISSISSIPPIAN ROCKS OF THE APPALACHIAN BASIN

By WALLACE DE WITT, JR., and LAURA W. MCGREW

INTRODUCTION

Rocks in each of the four intervals of the Mississippian System have produced oil and gas at various places in the Appalachian basin. Generally, gas and oil occur in close proximity in the western part of the basin; whereas gas is present mainly unassociated with oil in the central and east-central part of the basin. The Mississippian strata in the northern half of the basin, which accumulated largely in nearshore marine and subaerial delta-complex environments, are considerably more petroliferous than the rocks in the southern half of the basin which were deposited in a dominantly open-sea neritic environment (pl. 14). Commercial accumulations of oil and gas are confined mainly to the gently folded rocks of the Appalachian Plateaus province; whereas only a scattering of small gas pools and noncommercial accumulations of oil has been found in the more complexly folded and faulted Mississippian rocks of the Valley and Ridge province (fig. 94). Several factors appear to be responsible for the segregated occurrence of gas and oil in specific parts of the basin. The Mississippian strata in the Valley and Ridge province were deposited largely in a subaerial environment that precluded the development of widespread source beds for oil and gas. Also, the rocks of the Valley and Ridge province were subjected to greater heat and pressure during the folding of the region than were equivalent strata in the Appalachian Plateaus province to the west. The greater heat and pressure appears to have decreased the amount of oil present in these beds by converting the petroleum into highly mobile natural gas. Fractures and joints produced during folding shattered the seals on existing reservoir rocks and permitted the entrapped gas to escape. Uplift and erosion of the deformed strata in the Valley and Ridge province since the episode of folding have continued the process of unsealing possible reservoirs and have accelerated the rate at which these deformed strata lost entrapped gas.

HISTORICAL REVIEW

Although the States within the Appalachian basin include the birthplace of the oil industry, data are unavailable to determine even approximately the amount of oil and gas produced from the Mississippian rocks of the basin. Within 2 years after the drilling of the Drake well at Titusville, Pa., in 1859, oil was being produced from shallow wells in the Berea sand at several localities in northern Ohio (Orton, 1888, p. 328, 332). The most notable of these was the Mecca pool in north-central Trumbull County, where in addition to producing oil from the shallow Berea sand and the subjacent *2nd Berea* (Cussewago-*Murrysville*) *sand,* operators made one of the first efforts in the United States to drain oil from an oil sand by mining. Two shafts and a connecting galley were nearly completed before a flood of water overwhelmed the venture. Pumps were unable to stem the flow, and only a disappointingly small quantity of oil was recovered from the workings. The operation, like several more recent attempts to mine oil from the petroliferous sands in the Appalachian basin, was abandoned.

As drilling techniques and equipment improved during the second half of the 19th century, exploratory drilling spread from shallow pools along the north and west periphery of the basin downdip into the trough of the basin. Many oil and gas pools were found in the Mississippian rocks of eastern Kentucky, eastern Ohio, western Pennsylvania, and West Virginia. By 1920 much of the area underlain by Mississippian rocks in the northern part of the Appalachian Plateaus province had been tested by wildcat wells, and the areas contiguous to oil and gas pools had been intensively drilled.

Exploration for oil and gas in the Mississippian

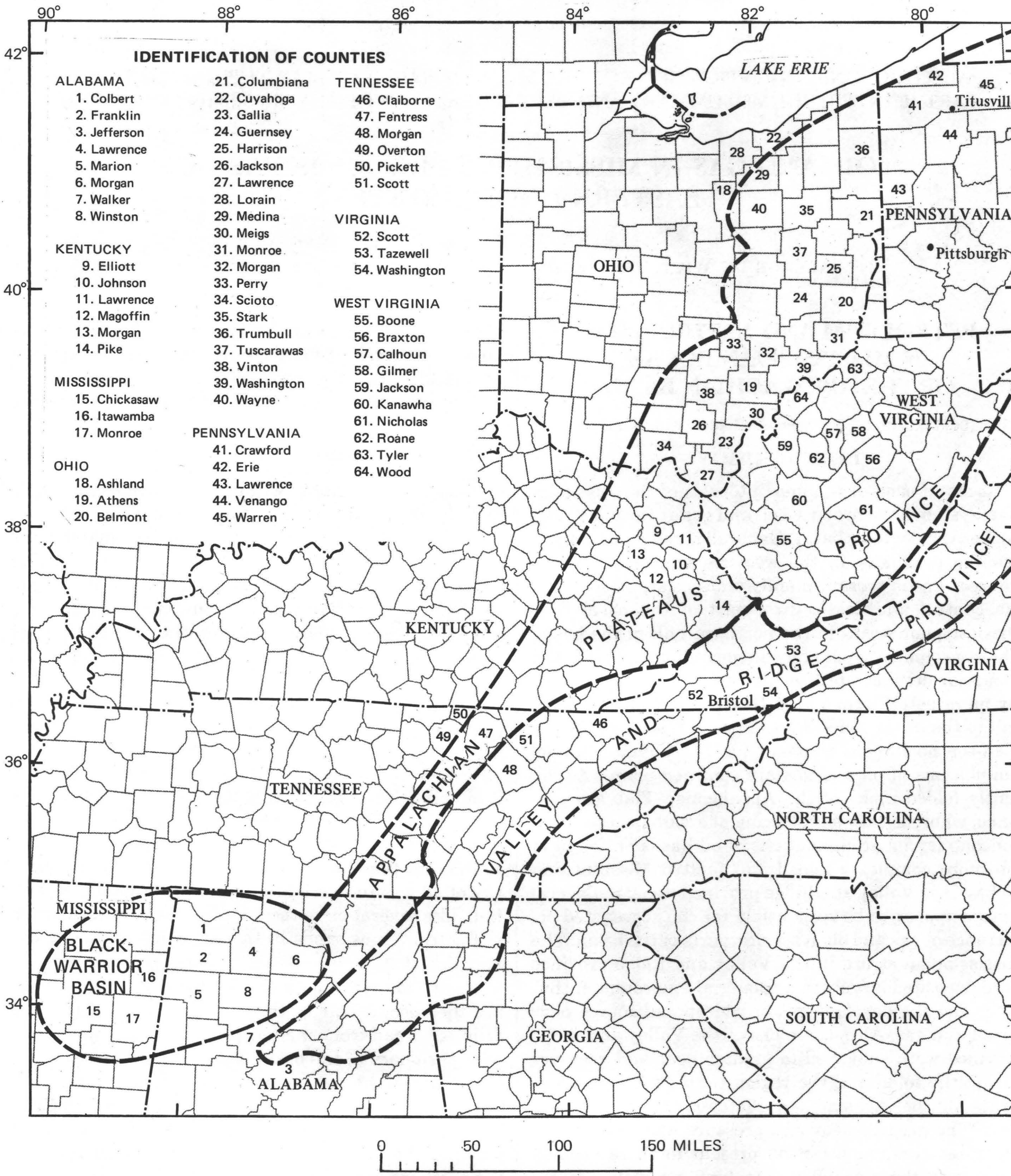

FIGURE 94. — Localities and areas in the Appalachian basin mentioned in the text.

strata of the Appalachian basin was far from a uniform process. Exploratory drilling increased greatly in times of plenty and stagnated during business recessions and panics. Each successful wildcat well induced a local flurry of excitement, and a potential boom hung on the results of the first few development wells in the prospective pool area. Because the infant oil industry evolved in the Appalachian basin long before the advent of the integrated major oil company, the industry was dominated by the independent operator and by the small drilling and producing company. Geologic thinking tended to be extremely provincial, and exploration advanced piecemeal in the several States that compose the basin. Integrated operations were largely unknown in the Appalachians during these years, and development of the petroleum industry was severely hampered at many times by a lack of adequate capital.

During the period 1910–40, drilling for oil and gas in the Mississippian rocks continued throughout much of the western part of the basin and scattered wildcat wells penetrated the Mississippian strata in the Valley and Ridge province to the east of the major producing areas. During this time secondary recovery of oil by gas injection was undertaken in several of the Mississippian oil sands (Rogers, 1951). Some of these projects were successful and recovered almost as much oil by gas injection as was originally produced by pumping. The depression of the early 1930's greatly curtailed exploratory drilling and field development. The low price of oil and gas brought an early abandonment of some oil or gas fields because the value of the well tubing and casing as "junk" pipe exceeded the market value of the producible oil or gas.

Increased demand for gas and oil during World War II and in the decade that followed led to a brief spurt of exploration and development activity. Newly introduced well-stimulation techniques, such as double shooting of low-permeability fine-grained reservoir rocks, acid treating of carbonate reservoir strata, and inducing fractures in petroliferous reservoir rocks by hydrafrac treatment (Brown, 1952), extended the life of many old oil pools, led to redrilling areas in which old wells had encountered noncommercial amounts of oil or gas within the Mississippian rocks, and added to the known reserves of oil and gas in the Appalachian basin. Secondary recovery of oil — mainly by the displacement of residual oil from partly depleted oil sands by water flooding — was successfully applied to several large pools of Mississippian age during the 1940's and 1950's. Some pools responded favorably to water flooding; among these were the Chatham-Lodi pool, Medina County, Ohio, and the Cabin Creek pool, Boone and Kanawha Counties, W. Va. (Terrell, 1945). Flooding was successful in the *Weir sands* in Johnson and Morgan Counties, Ky. In other pools of Mississippian age, efforts to water flood were less successful for several reasons.

The deepest drilling in the Mississippian rocks to date is in Tazewell County, Va., where gas is being produced from the *Berea sand* at depths slightly greater than a mile.

Mississippian rocks in the Appalachian basin have produced oil and gas for more than 100 years. Not all of the contained petroleum has been discovered, and about 50 percent of the in situ oil remains to be extracted. Some areas, particularly those underlain by oil- and gas-productive sands of older systems, have been extensively drilled, and the petroleum potential of the Mississippian rocks of these areas is relatively well known. Other areas remain to be more thoroughly tested by additional drilling.

The southern part of the Appalachian basin region has never been a major oil- and gas-producing area. Some of the first petroleum produced in the United States was discovered in Tennessee by pioneers drilling for brines to make salt, and some of these wells reportedly antedated the famous Drake well of 1859 in Pennsylvania which is considered to be the initial commercial discovery of petroleum (Floyd, 1965, p. 88). Semmes (1929, p. 2) stated that the first report of oil in Alabama was published in the Niles National Register in 1841 and that the oil was found during a dredging operation on the Tombigbee River. The Watson wells drilled in Lawrence County in 1865 represent the first actual prospecting for oil in Alabama, and the Goyer well completed in Lawrence County in 1891 reportedly produced 25 barrels of oil a day (Semmes, 1929, p. 2).

Between about 1912 and 1930 in the southern part of the Appalachian basin several small wells were discovered that produced oil and gas from Mississippian strata. The Glenmary area in Scott County, Tenn., was discovered in 1912 and still produces some oil and gas from fissured and fractured St. Louis Limestone (Nelson, 1924, p. 629; Floyd, 1965, p. 88). This accumulation is on a small faulted anticline (Lusk, 1927, p. 915). The Bone Camp field in Morgan County, Tenn., was developed in 1924 and still produces oil and gas from porous limestone in the middle part of the Fort Payne Formation. The Spring Creek field, abandoned by 1924, produced oil from the Fort Payne Formation in shallow wells less than 200 feet deep (Nelson, 1924, p. 628).

Early prospecting for oil and gas in Mississippi was confined mostly to the Gulf Coast area, but in 1926 gas was discovered in the Amory field, Monroe County, Miss., in the Black Warrior basin. This field produced about 1.5 billion ft^3 (cubic feet) of gas from the

Hartselle Sandstone prior to its abandonment in 1938 (Welch, 1959).

Exploration continued sporadically throughout the southern Appalachian basin during the 1930's and 1940's. By 1951 with the discovery of oil in oolitic limestone of Chester age in Deer Lodge field, Morgan County, Tenn., the State was producing more than 12,000 barrels of oil and nearly 130 MMft^3 (million cubic feet) of gas per year. Of this total, 90 percent of the oil and more than 90 percent of the gas was being produced in Scott and Morgan Counties from Mississippian limestones of Osage, Meramec, and Chester age (Milhous, 1952, p. 1075, 1078).

By the late 1960's, Tennessee production had dropped to less than 6,000 barrels of oil and less than 50 MMft^3 of gas per year (Van Den Berg and others, 1969, p. 1222).

The discovery of gas in sandstones of Chester age in the Hamilton field in Marion County, Ala., in 1950, and in the Muldon field in Monroe County, Miss., in 1951, stimulated exploration in the Black Warrior basin in Mississippi and Alabama. During the 1950's and early 1960's, 11 more gas fields were developed in that area — 1 in Alabama and 10 in Mississippi. Production in all 12 fields is from sandstones in interval D.

Asphaltic sandstone and limestone and oil seeps have been noted in numerous places in outcrops of Mississippian rocks on the northern flank of the Black Warrior basin, and numerous oil shows have been encountered in wells in intervals B, C, and D rocks, but commercial quantities of oil have not been found to date in the Black Warrior basin.

OIL AND GAS IN INTERVAL A

The *2nd Berea sand* of southeastern Ohio is a gas-productive sand of Bedford age (pl. 15, col. 10) that accumulated as an offshore barrier bar in the shallow Ohio Bay, which separated the Red Bedford delta to the west from the vast Pocono-Price delta complex to the east (Pepper and others, 1954, pls. 2, 13*B*). The bar, which is composed of coarse silt and very fine quartz sand, produced gas along an 85-mile linear trend from Morgan County to Gallia County in southeastern Ohio. The largest volume wells were found along the crest of the bar where the sand is more than 30 feet thick. Smaller volume gas wells were drilled to the west on the landward side of the bar where thinner and finer grained sand interfingers with lagoonal shale. Several small oil pools were found in the southern part of the area (Pepper and others, 1954, pl. 1), but until the advent of hydrafrac treatment most of the oil wells were marginal producers. Fracture treatment of the relatively fine sand stimulated both oil and gas wells in the *2nd Berea sand*, and the total amount of hydrocarbons recovered from this sand has been greatly augmented by hydrafrac treatment. Gas wells in the *2nd Berea sand* had initial yields ranging from 5,000 to 80,000 ft^3/d (cubic feet per day) and were increased to as much as 300,000 ft^3/d by shooting with nitroglycerin and to as much as 500,000 ft^3/d by hydrafrac treatment.

In northern Ohio the Euclid Siltstone Member of the Bedford Shale of Cuyahoga County (de Witt, 1951, p. 1356) shows the same stratigraphic relation to the main body of red shale as does the *2d Berea sand* of southeastern Ohio (Pepper and others, 1954, p. 54). Quarrymen reported that some parts of the Euclid contained so much crude oil that the stone was strongly discolored and unfit for sale as ornamental building stone (Bownocker, 1915, p. 70). These data suggest that at one time before erosion breached the seal on the Euclid, the member contained appreciable amounts of gas and oil similar to that of the *2d Berea sand.*

A sequence of sand-filled distributary channels as much as 150 feet thick lies along the main axis of the Red Bedford delta from Ashland County south to Athens County, Ohio, where the channels trend southeast and east toward the eastern shore of the delta (Pepper and others, 1954, pl. 1). The channel sands are partly of Bedford age and partly of Berea age. Locally, in Ashland and Wayne Counties, oil is present in the channel sands. Although the source of the petroleum may have been either the marine *Berea sand* adjacent to the channels or the overlying Sunbury Shale, the oil migrated into the porous and permeable channel sands and is produced in part from rocks of Bedford age. The wells are generally small, ranging from 1 to 10 bbl/d (barrels per day) initial yield, although some wells originally produced as much as 45 bbl/d. The serpentine configuration of the channel sands makes development drilling risky. However, drilling depths are shallow, the wells are generally long lived, and efforts at water flooding some of the channel sands have been moderately successful.

The fine to coarse, locally pebbly, ***Murrysville sand,*** the subsurface equivalent of the Cussewago Sandstone, (pl. 15, col. 5) underlies much of western Pennsylvania and adjacent northeastern Ohio (Pepper and others, 1954, pl. 1). The sand is a delta and prodelta blanket accumulation, which exceeds 120 feet in thickness near the dispersal center in central Pennsylvania and thins to a featheredge in northeastern Ohio. An equivalent sand, locally called the ***Gantz, Berea,*** or ***50-foot sand*** by well drillers, covers much of northeastern West Virginia. The ***Murrysville*** equivalent appears to have been deposited by distributaries emanating from the same source area as the ***Murrysville sand*** (Pepper and others, 1954, p. 59–61).

In northeastern Ohio, where only a few feet of silty gray shale generally separates the *Murrysville sand* from the younger *Berea sand*, drillers commonly call the *Murrysville "2nd Berea"* although the *Murrysville* is not a lithic correlative of the *2nd Berea sand* of southeastern Ohio. Throughout much of its extent in Pennsylvania and Ohio, the Murrysville is a gas sand that yields gas readily in large volume because of the high porosity and extensive lateral permeability of the sand. Wells with initial open flows of 2–25 MMft^3/day were not uncommon during the first drilling program to the *Murrysville* in western Pennsylvania. Gas, oil, and large volumes of saltwater are present in the *Murrysville sand* in northeastern Ohio and adjacent northwestern Pennsylvania. In the Homeworth pool, Columbiana County, Ohio, an impermeable zone as much as 6 feet thick separates the *Berea sand* from the older *Murrysville*. Commonly, wells to the *Berea* in this field were small producers ranging from 5 to 10 bbl/d. When these wells penetrated the *Murrysville sand* their production increased as much as 50 bbl/d, unless saltwater was found. If saltwater was present in the lower sand, it usually drowned the well. Many porous lenses in the *Murrysville sand* in this part of Ohio are charged with saltwater. For example, drillers refrained from drilling into the *Murrysville sand* in the Plum Run and adjacent pools in western Harrison County because of excessive amounts of saltwater in the sand.

Wells in the thick section of *Berea sand* in parts of Stark, Tuscarawas, and Guernsey Counties, Ohio (Pepper and others, 1954, pl. 1) encountered gas and saltwater in a coarse sand at the base of the sequence. Locally, the gas-productive sand was separated from the main mass of finer sand by a few feet of light-gray silty shale. Decreased pressure in the wells resulting from the production of gas from the basal sand was commonly sufficient to admit saltwater in quantities sufficient to flood out the gas and lead to early abandonment of the wells. Most probably, the saliniferous gas sand is a lens of *Murraysville* west of the main sheet sand as suggested by Pepper (Pepper and others, 1954, p. 72).

Oil and gas in the *Murrysville sand* accumulated in stratigraphic traps produced by differences in grain size of the sand and by selective cementation of parts of the sand body. Structure is of secondary importance to the entrapment of gas and oil. In western Pennsylvania gas has migrated to the crests of low-amplitude anticlinal folds. Elsewhere, the sinuous outlines of gas pools suggest that the gas was trapped in channel sands and that the accumulation is stratigraphic rather than structural.

Although the *Murrysville* equivalent in northeastern West Virginia is gas bearing, the sand is much less petroliferous than the *Murrysville* (Pepper and others, 1954, pl. 1). The sand is commonly thinner and finer than most of the *Murrysville* in Pennsylvania. Possibly because the *Murrysville* equivalent was deposited in an area of lower energy south of the main area of accumulation of the Cussewago-*Murrysville* delta, the sand is less well sorted and its content of finer grained components are higher than in the *Murrysville*. Both factors could produce a decrease in porosity and permeability of the *Murrysville* equivalent. The sand would be less receptive to infiltration by hydrocarbons and less gas productive than its counterpart to the north in Pennsylvania.

The Berea Sandstone — the *Berea sand* or *Berea grit* of the well drillers — has been one of the most important producers of gas and oil in the Mississippian rocks of the Appalachian basin during the last 100 years. Locally, in northern and central Ohio, the outcropping Berea Sandstone contains detectable amounts of oil. Oil seeps in northwestern Trumbull County (Prosser, 1912, p. 317) and in southeastern Lorain County (Orton, 1888, p. 332) aroused the interest of well drillers and led to the early discovery of small pools in the *Berea sand* at shallow depths.

The Berea is a fine to very fine quartz sand in northern Ohio and grades laterally into coarse quartz siltstone to the east and to the south (Foreman and Thomsen, 1940, p. 50; de Witt, 1951, p. 1358). The sand is coarsest in northern Ohio near the distributaries of the Berea delta where small pebbles are present locally within a channel sand facies (Pepper and others, 1954, p. 32). The Berea is also somewhat pebbly in central West Virginia near the mouths of several distributaries from the Gay-Fink and Cabin Creek deltas (Pepper and others, 1954, p. 76, 78). The depositional history of the Berea is relatively complex and involves detritus from two major source areas — one east of the Appalachian basin and the other to the north of the basin. The Berea accumulated partly subaerially on several deltas and partly as sheet sands in nearshore, shallow-shelf environments. The interaction of the several depositional enrivonments produced a complex pattern of reservoir rocks and related source beds.

Both oil and gas occur in stratigraphic traps which resulted from differences in the competency of the depositing currents, the degree to which the sands were reworked by marine currents, and selective postdepostional cementation of parts of the sand body. Structural modification of stratigraphic traps is relatively unimportant in the gently dipping strata in the western part of the basin but becomes relatively important in the central and east-central part of the basin. For example, oil and a small amount of gas is present in discrete pools in the channel sands of the Chatham-Lodi field, Medina County, Ohio. Structure does not appear to have affected the location of oil pools within the channel sands. In contrast, pools of oil and gas along the Gay-Fink trend in north-central West Virginia show the effect of structural movements upon accumulation of hydrocarbons. Gas pools occur where the trend crosses anticlinal axes, and oil pools lie in the troughs of adjacent synclines. Although the primary factor for the accumulation of gas or oil in the Gay-Fink trend is the presence of porous sand in the stream channel (Pepper and others, 1954, p. 75), gentle folding after deposition of the channel sand has influenced the ultimate location of individual oil or gas pools.

Oil and gas pools associated with delta deposits are significant features in the *Berea sand* of Ohio, Virginia, and West Virginia (Pepper and others, 1954, pls. 13E–H). Channel sands in the deltas have produced oil and gas in quantity. The irregular thickness, porosity, and permeability of the channel sands, resulting from variations in the competency of the depositing currents within the distributary systems, formed the irregular pattern of large- and small-volume wells present within a given pool. Commonly, in the channel sands, zones of well-sorted, coarser sand with scattered lenses of small pebbles are the best and most prolific reservoir rocks. These lenses of better sorted and more petroliferous sand occur in a sinuous randomly oriented pattern within the channel sands. Generally, the most productive wells are in small clusters in more or less connected bodies of thick sand that are embedded in a sheet of thinner, less porous and less productive sand. Configuration of sand bodies in the Chatham-Lodi field, Medina County, Ohio, suggests that some of the sand accumulated as point bars in a series of braided and meandering channels on the Berea delta in northern Ohio. The scattered arrangement of lenses of thick porous sand within the channel system makes development drilling more risky than drilling in the more extensive marine prodelta sheet sands that accumulated in the Ohio Bay seaward from the deltas.

Oil and gas pools in many parts of the Berea appear to be closely related to shoreline and nearshore beaches and bars in which extensive linear zones of better sorted porous sand are enveloped in a sheet of less porous and impermeable sandy strata. Pools of this sort commonly show a better grouping of the more productive wells, which are surrounded sequentially by a halo of less productive wells and a blanket of nonproductive sand — "tight and dry sand" in the parlance of the well drillers. Typical of pools associated with shoreline features that formed during stillstands of the Berea sea are the Liverpool pool in Jackson and Roane Counties, W. Va., Hemlock Grove pool in Meigs County and Corning pool in Perry County, Ohio, and the Ogden pool in Wood County, W. Va.

Some fairly extensive oil and gas fields in the Berea occur in extensive porous zones in a uniform blanket of sand that accumulated in a shallow-shelf marine environment. The producing sand is uniform throughout the pool area. These pools commonly contain many wells with about the same productive potential and show a uniform thickness of pay sand throughout. The Bessemer pool, Lawrence County, Pa., Plum Run and Scio pools, Harrison County, Ohio, and the Louisa pool, Lawrence County, Ky., are characteristic of the blanket-sand-type oil pool. Commonly, these pools contain a considerable amount of saltwater associated with the oil and gas.

In summary, oil and gas occur in the *Berea sand* mainly in stratigraphic traps which formed in subaerial, shoreline, and nearshore shallow-marine environments in different parts of an extensive sandy unit that covered much of the northern part of the Appalachian basin during middle Kinderhook time. Subsequent folding locally modified some of the accumulations, particularly in the central and east-central part of the basin. Production in the *Berea sand* ranged from small-volume near-surface wells with an initial yield of several barrels per day to deep wells in the central part of the basin with initial production of as much as 750 bbl/d of oil or 10 MMft^3 of gas (Heck, 1941, p. 812).

Small amounts of oil and gas were found in the Corry Sandstone (pl. 15, col. 8), a marine sheet sand that accumulated along the southwest side of the Knapp delta in Warren, Venango, Erie, and Crawford Counties, Pa. Two small pools, one oil and one gas, produced briefly from the fine-grained Corry in southern Venango County (Pepper and others, 1954, pl. 1).

In part of eastern Kentucky where large amounts of natural gas are present in the black shales of Late Devonian age and also in a part of southern Ohio centering in southern Meigs County, some gas has been obtained from the black Sunbury Shale. In both areas, gas was produced from the Sunbury when the shale was involved in well-stimulation operations that were being applied either to the *Berea sand* in Ohio or to the basal Mississippian and Upper Devonian section in eastern Kentucky. The amount of gas derived from the Sunbury (Hunter, 1935, p. 917) was insufficient to warrant exploiting the Sunbury as a potential gas producer, but the extra gas was a bonus to operators who were attempting to produce gas from the subjacent strata.

There are no known occurrences of oil or gas in interval A rocks in the southern part of the Appalachian basin, where the entire interval is represented by the thin Maury Formation.

OIL AND GAS IN INTERVAL B

Oil and gas are present in rocks of Osage age at many places in the Appalachian basin. In general, the strata in interval B are least petroliferous in the lower part of the sequence and become increasingly more productive in the coarser grained rocks in the upper part of the section, exclusive, of course, of the more strongly folded and faulted rocks in the Valley and Ridge province.

Gas and traces of oil have been found in a series of lenticular fine sands that lies at or near the lower boundary of the Osage strata in the northern and northwestern part of the basin. In western Pennsylvania, the patchy *2d gas sand*, whose base arbitrarily marks the base of interval B (pl. 15, col. 7), has produced gas in wells in the Pittsburgh area. In eastern Ohio near equivalent strata, which well drillers call *Welch Stray, Stray, Gable* (pl. 15, col. 10), or occasionally *Weir*, have produced small amounts of gas locally in parts of Belmont, Monroe, and Washington Counties. In some wells, drilling was terminated in the younger sand when it was gas productive on the mistaken belief of the drillers that the well had penetrated the older *Berea sand*.

The *Hamden gas sand* (Stout and others, 1935, p. 904) lies about 100 feet above the Berea (pl.15, col. 10) in Jackson and Vinton Counties and in adjoining counties in southern Ohio. The sand, which appears to be a part of the Vanceburg facies of the Cuyahoga Formation, yielded gas from a pool in the vicinity of Hamden, Vinton County, and from scattered wells to the south in Jackson, Lawrence, and Scioto Counties.

Gas and occasional traces of oil have been found in lenticular sands in the lower 30–70 feet of interval B in parts of western West Virginia and contiguous eastern Kentucky. Commonly, these gas-producing strata are fine-grained sandstone or sandy siltstone which yield gas slowly because of their fine grain and low permeability. Well drillers generally refer to these gas sands as the *2d Weir, Weir,* or *Squaw*. Sparse data indicate that the sands are near time equivalents but are not parts of a single discrete sheet sand.

A series of lenticular, laminar-bedded fine-grained silty sandstone as much as 100 feet thick occurs in the interval from 75 to 175 feet above the base of interval B in eastern Kentucky and western West Virginia. Beds of sandstone are commonly intercalated in a sequence of dark-gray to brownish-black shale. The sandy sequence is commonly called *Weir sand* by the drillers. The *Weir* has been most productive of oil and gas in Elliott, Johnson, Lawrence, Magoffin, and Morgan Counties, Ky. The sand has produced gas and some oil in West Virginia, but the *Weir* seems to become less productive eastward across the basin. Locally, the *Weir* responds well to water flooding and has produced a considerable amount of oil in secondary recovery operations in eastern Kentucky.

The *Weir sands* have a complex depositional history. The sands are subsurface equivalents of parts of the Borden Formation of central Kentucky and of parts of the Price Formation of western Virginia. The Borden Formation was deposited in an open-sea marine environment; whereas the Price rocks accumulated largely in a subaerial environment. The *Weir sands*, which lie intermediate between the Borden and the Price, were probably deposited in a nearshore relatively high-energy environment. Depending upon their position with respect to the Price shoreline, the *Weir sands* may have accumulated as prodelta sheet sands, bars, or beaches.

The thickest and one of the most extensive accumulations of petroliferous sandstone in the Mississippian rocks of the basin occupies the upper 100–250 feet of interval B. Well drillers long ago gave the name *Big Injun sand* to this thick sequence of fine- to coarse-grained, locally pebbly, quartz sandstone. The *Big Injun* contains the subsurface equivalents of several Osage age sandstones including the Burgoon Sandstone Member of the Pocono Formation of Pennsylvania, the Black Hand Sandstone Member of the Cuyahoga Formation and the sandstones of the Logan Formation of Ohio, the Rockwell Formation and Purslane Sandstone of western Maryland, and probably the Price Formation or Pocono Sandstone of northern Virginia and northeastern West Virginia. Because the *Big Injun* is composed of several overlapping sand bodies which were derived from different source areas and which accumulated in subaerial and marine environments, the depositional history is complex and not well understood. Although the *Big Injun* has been a prolific producer of gas and oil for about 75 years, its stratigraphy and sedimentation are much less well known than those of the *Berea sand*.

The main area of oil and gas accumulation in the *Big Injun* covers much of southwestern Pennsylvania, southeastern Ohio, northern West Virginia, exclusive of the eastern panhandle, and extends locally into southeastern Kentucky. The *Big Injun* is a thick sequence in which several gas- or oil-productive zones may be present in a single pool. Commonly, the producing zones are separated vertically by sequences of impermeable, nonporous strata. The *Big Injun* generally contains large amounts of saltwater as well as oil or gas. For example, during the development of the Sistersville oil field, Tyler County, W. Va., one of the first wells drilled, the Pole-Cat Run well, encountered saltwater in abundance and was temporarily abandoned. However, when wells in the vicinity produced some oil with the saltwater, the drillers began to pump the Pole-Cat. The well produced saltwater at the rate of 3,500 bbl/d for many weeks before oil began to appear in the water. After long pumping, the Pole-Cat well developed a steady production of 500–600 bbl/d of oil and a decreasing amount of water accompanying the oil

(Bownocker, 1903, p. 195). Lafferty (1941, p. 803) noted that in areas where the *Big Injun* contains much water, accumulations of oil and gas are governed by structural control, whereas in the absence of much water, structure has little effect upon the location of oil or gas pools.

Permeability and porosity show great variation in some parts of the *Big Injun*. Lenses of pebbles and pebbley sandstone deposited in beach, bar, or channel accumulations form productive zones with high rates of yield. Some of the largest volumes of oil or gas from the so-called shallow sands in the Appalachian basin were produced from the *Big Injun*. The Big Moses well, Tyler County, W. Va., had an estimated initial yield of 50 MMft^3/d (White, 1899, p. 358), and oil wells that produced as much as 2,400 bbl/d (Brownocker, 1903, p. 195) were reported from the *Big Injun sand* in the Sisterville pool.

Nonporous zones of sandstone or sandy shale separate the productive parts of the *Big Injun* at many places in the basin. The *Big Injun* is underlain at many places by a series of lenticular sand bodies 10–80 feet thick that may occur at the base of the *Big Injun* or may be separated by as much as 60 feet of sandy and shaly rock from the base of the *Big Injun*. These lenticular sands, which locally produce oil or gas, are generally called the *Squaw sand* by the well drillers because of the occurrence of the *Squaw* just below the *Big Injun* (Bownocker, 1903, p. 187). In contrast to the *Big Injun sand*, the *Squaw* is commonly free of large quantities of saltwater, and the occurence of gas or oil in the *Squaw* is unrelated to structure.

In southeastern Ohio, centering in Washington County, and in the contiguous part of West Virginia, a discrete gas- and oil-productive sand as much as 40 feet thick overlies the *Big Injun*. The younger sand, called the *Keener sand* by well drillers, is separated from the *Big Injun* by as much as 40 feet of silty or sandy gray shale and from the younger *Lime sand* of Meramec age and the *Mountain*, or *Big lime* of Chester age, by a lesser thickness of red or gray shaly strata (pl. 15, col. 10; Bownocker, 1903, p. 197, 204; Lafferty, 1941, p. 802; Stout and others, 1935, p. 903). Generally, the *Keener* is a very fine to medium-grained quartz sandstone that locally contains lenses of quartz pebbles. The extent and stratigraphic relations of the *Keener sand* are difficult to determine because south and southeast of the Ohio River in north-central West Virginia drillers also apply the name *Keener* to the uppermost productive zone in the *Big Injun sand* (pl. 15, col. 17) or to a younger sand body in the Loyalhanna facies of the Greenbrier Limestone (McCord and Eckard, 1963, p. 4–9; Rittenhouse, 1949, p. 1707; Schrider and Wasson, 1966, p. 9). The relatively porous and permeable *Keener sand* has been an important oil sand in southeastern Ohio where many wells had initial production of 60–100 bbl/d (Bownocker, 1903), and some wells exceeded 500 bbl/d (Condit, 1916, p. 242). The *Keener* has also produced gas in Ohio and West Virginia.

A red siltstone and sandstone facies of the Maccrady Formation, which the drillers call the *Red Injun sand* (Lafferty, 1941, p. 802), is locally gas productive in Pike County, Ky., and in adjacent western West Virginia. The volume of gas found in the *Red Injun sand* is generally small in comparison to the amount in the older *Big Injun sand*.

The Fort Payne Formation, which makes up interval B throughout most of the southern part of the Appalachian basin, produces or has produced oil and gas from several wells and fields in north-central Tennessee. The Bone Camp field, developed in 1924 in Morgan County, Tenn., produces oil and gas from a depth of 1,400 feet from the middle part of the Fort Payne Formation and accumulation is due to porosity conditions in the limestone and a structural terrace (Floyd, 1965, p. 88). The Spring Creek field in Overton County produced oil for a few years in the early 1920's from crevices in the Fort Payne Formation in wells less than 200 feet in depth (Lusk, 1927, p. 914). In 1961 gas production from the Fort Payne Formation was discovered in an old gas well in Scott County (Milhous, 1962, p. 813). In 1960 five wells in Fentress and Pickett Counties were producing oil from the "lower Mississippian," presumably interval B (Milhous, 1961, p. 767).

Shows of oil have been reported in the Fort Payne Formation in Chickasaw County, Miss., and Franklin County, Ala. (Welch, 1959), but no production from interval B rocks has been reported from these States.

OIL AND GAS IN INTERVAL C

In contrast to the general absence of oil and gas in commercial quantities in the Mississippian rocks of the Valley and Ridge province, gas was produced from sands in the basal part of the Little Valley Limestone (pl. 15, col. 24) in the Early Grove anticline, a small fold in the Greendale syncline of Scott and Washington Counties, southwestern Virginia (Averitt, 1941, p. 19). Wells with initial fields of as much as 1.5 MMft^3/d were encountered, and for a brief time gas from the Early Grove field was supplied to Bristol, Tenn.–Va. The supply of gas has been exhausted, and recent attempts to find more gas in the area have not been successful.

The *Big lime* of the well drillers — the sequence of calcareous strata of Meramec and Chester age that makes up the Greenbrier Group of West Virginia and adjacent eastern Kentucky, the Maxville Limestone of Ohio, the Loyalhanna Limestone and *Wymps Gap Limestone Member* of the Mauch Chunk Formation of southwestern Pennsylvania and adjacent Maryland — has produced oil and gas at many places in the central part of the Appalachian basin. Oil and gas are trapped in zones of oolite and fossil-fragmental limestone, dolomitized oolite, dolomitized nonoolitic limestone, and in beds and layers of quartz sandstone in the carbonate sequence.

Probably, the most extensive and prolifically productive oil and gas zones in interval C, the Meramec part of the *Big lime*, lie in the basal part of the subsurface equivalent of the Hillsdale Limestone (pl. 15, col. 20) in southern West Virginia and adjacent southeastern Kentucky. These zones are commonly present in the basal 50 feet of the *Big lime*. Gas and oil occur in a sequence of porous lenses of oolitic dolomitized sandy limestone which accumulated as offshore bars and channel sands on a subdued topography that had been cut into the red rocks of the Maccrady Formation (Youse, 1964, p. 474). These zones of oolitic sand formed and accumulated as the Meramec sea spread north and west across the recently exposed western flank of the Appalachian basin. Youse (1964, p. 475) indicated that dolomitization of the porous zones took place concurrently with or shortly after the oolitic material was deposited. Dolomization of these carbonate sands increased the porosity and permeability of the zones and added to the volume of pore space available to accumulating oil and gas. Gas wells with initial production of as much as 20 $MMft^3/d$ have been drilled in the basal porous zones of the *Big lime* in extreme southwestern Virginia and adjacent Kentucky (Youse, 1964, p. 465). Rittenhouse (1949, p. 1713) showed that zones of quartz sand and clastic carbonate rock occur at many other places within the *Big lime* sequence above the basal porous zones. However, the younger zones of clastic strata are considerably less petroliferous than the basal zone of southern West Virginia.

In part of north-central West Virginia, centering in Calhoun County, the basal 20–80 feet of the Greenbrier sequence consists of sandy dolomite and dolomite-cemented quartz sand. The well drillers commonly include these calcareous sandy rocks in the *Big Injun sand*, although petrographic studies by Martens (1954) and by Flowers (1956, p. 11) clearly show that the calcareous rocks are a part of the Loyalhanna Limestone of Meramec age. This sandy facies of the *Big lime* has produced oil and gas in a number of pools in north-central West Virginia. Although some wells have yielded much gas, they have not produced as much as the wells in the basal zone of the *Big lime* in southwestern West Virginia.

In parts of Monroe and Washington Counties, Ohio, the basal part of the drillers' *Mountain lime* or *Big lime* contains lenses of carbonate-cemented medium-grained quartz sandstone as much as 15 feet thick. Locally, these beds, which the drillers call the *Lime sand*, have produced gas, oil, and saltwater. Condit (1916, p. 242) reported that most of the oil wells had initial production below 25 bbl/d, but exceptionally large wells with initial production in excess of 500 bbl/d have been found in the *Big lime sand* in southern Belmont and northern Monroe Counties.

In the southern part of the Appalachian basin, oil and gas have been produced from rocks of interval C in the Glenmary field in Scott County, Tenn. There, oil and gas accumulation is in the fissured and fractured St. Louis Limestone (Floyd, 1965, p. 88; Nelson, 1924, p. 629) and the *Ste. Genevieve Limestone* (Milhous, 1961, p. 767, 768). In 1959, oil was discovered in an oolitic zone of the Warsaw Limestone in a well drilled through the Pine Mountain overthurst block in Claiborne County, Tenn., but the well was temporarily abandoned within a few months (Milhous, 1960a, p. 715; 1960b, p. 93). Oil and gas from the *Ste. Genevieve* is reported in several small scattered wells in Scott and Morgan Counties, Tenn.

The Tuscumbia Limestone, although it has not been productive to date, has given promising shows of oil in Franklin, Walker, Jefferson, Winston, and Marion Counties, Ala., and in Itawamba County, Miss., and is considered to be a potential producing horizon under favorable structural and permeability conditions (Semmes, 1929, p. 59; Welch, 1959).

OIL AND GAS IN INTERVAL D

By and large, the Chester age strata, the rocks in interval D, are the least petroliferous of the four Mississippian intervals in the Appalachian basin. Some oil and gas is present in porous zones of oolite and fragmented-fossil sandstone in the upper part of the *Big lime* in western Virginia, southwestern West Virginia, and adjacent southeastern Kentucky. However, the amount of petroleum and gas is much less than is present in the Meramec part of the *Big lime* in the same general area. Youse (1964, p. 470) showed that as the zones of oolite decreased in number and thickness in the upper part of the *Big lime*, the amount of finely crystalline to subcrystalline limestone increased in proportion. He suggested that the decrease in clastic content of the upper part of the *Big lime* resulted from deposition in an environment of decreasing energy. The absence of extensive reservoir rocks in the upper part of the *Big lime* precludes the presence of large reserves of oil or gas in this part of the sequence (Youse, 1964, p. 474).

Throughout much of West Virginia and adjacent eastern Kentucky, the upper beds of limestone in the

Big lime intertongue with noncarbonate clastic rocks in the basal part of the Pennington or Mauch Chunk Formations in a 20- to 80-foot thickness in which discrete beds of limestone are intercalated with layers of shale, siltstone, and sandstone. Commonly, the drillers refer to one or more of the massive beds of limestone as the *Little lime* and the intercalated shale as the *Pencil Cave* (Flowers, 1956, p. 5–6). Locally, some of the sandstone in the transitional sequence contains oil or gas. The drillers' *Blue Monday sand*, so-called because of the hardness of the finer part of the sand body, of Braxton, Calhoun, Gilmer, and Nicholas Counties, W. Va., is typical of the sands found near or at the top of the *Big lime–Little lime* sequence (Flowers, 1956, p. 4; Lafferty, 1941, p. 799).

The Pennington Formation or Group of central and southern West Virginia and adjacent parts of Kentucky, Tennessee, and Virginia contains many lenticular sandstone bodies, several of which produced gas or oil. Some of the sandstone are extensive sheets that appear to have accumulated as prodelta marine sands; whereas others are markedly lenticular and probably accumulated as bars, beaches, and channel sands associated with the distributaries of the Mauch Chunk–Pennington delta complex. Gas and saltwater are present in quantity in the southern part of the area. In extreme southwestern West Virginia and the adjacent plateau area of Virginia, the *Ravenscliff sand,* the subsurface equivalent of the Princeton Sandstone, and the *middle Maxton sand,* the subsurface equivalent of the Stony Gap Sandstone (Wilpolt and Marden, 1959, p. 600–601), are the main gas sands of the Pennington sequence. Wells with initial production in excess of 2 $MMft^3/d$ have been obtained in these sandstones in southern West Virginia.

To the north, in central and northern West Virginia and east-central Kentucky, drillers encounter several highly lenticular gas-productive sandstones associated with the red beds of the Pennington or Mauch Chunk part of the Chester sequence. These sandstones have been called *Bradley, Maxton* (Lafferty 1941, p. 799), and occasionally *Salt sand* by the well drillers. Closely spaced drilling in many parts of the area clearly demonstrated that these Chester sands are extremely lenticular, and their apparent continuity in parts of West Virginia and Kentucky is more than the result of correlation implied by the drillers' terminology than the physical extent of discrete sand bodies. The permeability and porosity of some of these sands are locally high, and wells with initial production in excess of 1 $MMft^3/d$ are not uncommon from these sands. Generally, the life of such wells is brief and is terminated suddenly by a flood of saltwater. The presence of large amounts of saltwater in the late Chester sandstones as well as in the younger basal Pennsylvanian sandstones led the drillers to apply the name *Salt sand* to many of the lenticular bodies in the sequence above the *Big lime* in the northern half of the Appalachian basin. Commonly, the *Salt sands* lie in the basal part of the Pennsylvanian sequence; however, in places in northern West Virginia and contiguous Kentucky drillers have applied the name to sands of Mississippian age in the upper part of the Mauch Chunk–Pennington sequence (Lafferty, 1941, p. 797–798).

Two limestone horizons in interval D produce oil and gas in fields in north-central Tennessee (Milhous, 1960b, p. 93). These are the Glen Dean Limestone (Bangor Limestone of this report) and the *Gasper Formation* (*Girkin Formation* or upper part of the *Monteagle Limestone* of this report).

Numerous oil seeps have been found in the Hartselle Sandstone in Morgan, Lawrence, Franklin, and Colbert Counties, Ala., and the *Bethel Sandstone* (Tanyard Branch Member of the Pride Mountain Formation of this report) and the oolitic limestone and shale of the *Gasper Formation* show local asphalt impregnation in northern Alabama (Semmes, 1929, p. 52). The Hartselle Sandstone and several sandstone lenses in the Floyd Shale had shows of oil in many of the wells drilled in the Black Warrior basin (Welch, 1959), but there has been no oil production from fields in that area.

The Black Warrior basin fields produce gas from four sandstones in interval D. These are the *Carter* and *Sanders sands* in the upper part and the *Evans* and *Lewis sands* in the lower part of the Floyd Shale (Welch, 1959).

PETROLEUM AND NATURAL GAS IN MISSISSIPPIAN ROCKS OF THE MICHIGAN BASIN

By George V. Cohee

Oil and gas production from rocks of Mississippian age (pl. 14) in the Michigan basin has been from the Berea Sandstone of interval A and the Ravenna Dolomite, the Berea time equivalent on the western side of the Southern Peninsula. The most important production has been from the lenticular sandstones in the basal part of the Michigan Formation of interval C. These lenticular sandstone bodies, which occur in the Central basin area, are contemporaneous with part of the upper part of the Marshall Sandstone to the south. (See pt. I, chap. D and pl. 15, cols. 50–52.)

After the discovery of the Drake well in Pennsylvania in 1859 and the drilling for oil near Petrolia,

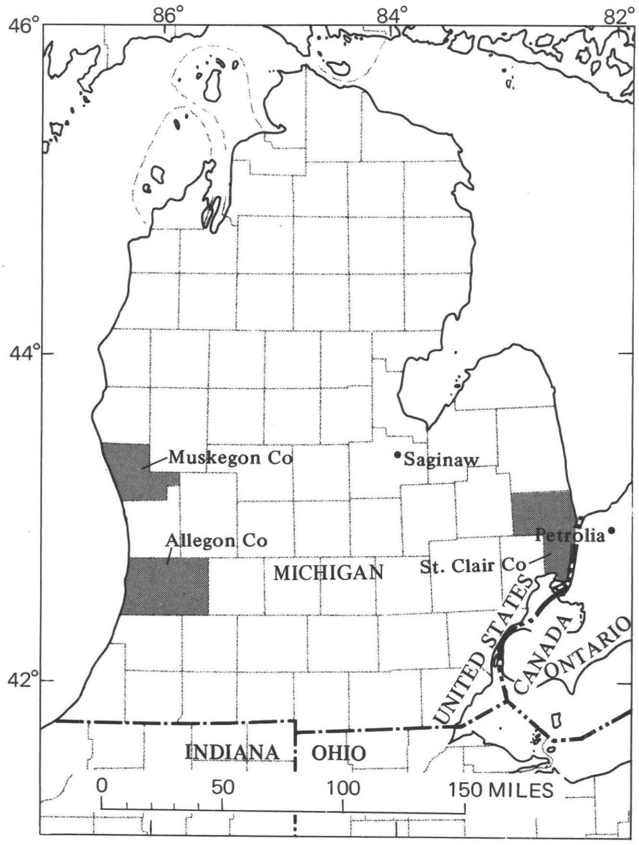

FIGURE 95.—Counties in Michigan from which oil and natural gas have been produced from Devonian rocks.

Ontario, interest in the exploration for oil spread to eastern Michigan. In 1886, the Port Huron field in St. Clair County was discovered with production from the Dundee Limestone of Devonian age (fig. 95). Oil was found in Devonian rocks in Allegan County, western Michigan, in the early years of the present century. The first Mississippian oil production was found in the Saginaw field, Saginaw County, in 1925 (fig. 96).

Although oil production from the Saginaw field was small, it helped to maintain the exploratory interest in oil in Michigan. In 1928, the discovery of the Muskegon field, Muskegon County, in western Michigan, and the Mt. Pleasant field, Midland County, in the central part of the Michigan basin, demonstrated the potential oil and gas possibilities of the basin. The first commercial natural gas production in Michigan was from the Traverse Group of Devonian age in the Muskegon field, Muskegon County (Newcombe, 1933, p. 136).

BEREA SANDSTONE

The first commercial production of oil from the Berea Sandstone was in 1925 at Saginaw, Mich. The wells were at depths ranging from 1,800 to 1,860 feet and produced as much as 40 bbl/d, depending upon location on the Saginaw anticline and the amount of porosity of the sandstone.

Oil has been produced from the Berea Sandstone in the Saginaw, Birch Run, and Fremont fields in Saginaw County, the Kawkawlin field in Bay County, the Larkin field in Midland County, and the Deep River and Clayton fields in Arenac County (fig. 96). In these fields the accumulation of oil was in the less porous uppermost sandstone beds of the Berea, and saltwater was found in the friable porous sandstone beneath. Although commercial oil and gas production has been on anticlines and domes, shows of oil in the Berea were found in a few wells which were apparently structurally low.

The producing zone is generally 13–16 feet thick, and the initial production of all the Berea wells drilled to date ranged from 5 to 185 bbl/d of oil and from 1 to 16 $MMft^3/d$ of gas. The cumulative oil production from the Berea has amounted to 2,272,550 barrels through 1967.

Gas wells of considerable size were completed in the Berea in the Clayton, Deep River, and North Adams fields, Arenac County. The cumulative gas production from the Berea through 1967 has been 10,317,880,000 cubic feet.

THE "BEREA" OF WESTERN MICHIGAN

Although the Berea Sandstone does not extend into the western part of the Southern Peninsula, the name has been used for certain beds contemporaneous with the Berea of eastern Michigan. The western boundary of the Berea Sandstone extends through Alpena and Oscoda Counties to the north, Isabella and Gratiot Counties in the central part of the basin, and Jackson and Lenawee Counties to the south (fig. 95).

In western Michigan from Ottawa, Kent, and Barry Counties on the south, to Manistee and Wexford Counties on the north, dolomite or dolomitic limestone occurs in the top of the Ellsworth Shale. This dolomite bed, which may be sandy or silty in places, has been called "Berea" by some workers (for example, Hale, 1941). Commercial gas production was obtained from the so-called "Berea" Dolomite in the Ravenna and Cedar Creek gas fields in Muskegon County and the Coopersville, South Talmadge, and Walker fields in Ottawa and Kent Counties. Shows of oil and gas were reported elsewhere in western Michigan in wells penetrating the so-called "Berea."

MICHIGAN "STRAY" SANDSTONE

The Clare (McKay) field, Clare County, in the Central basin, was the first field in which natural gas

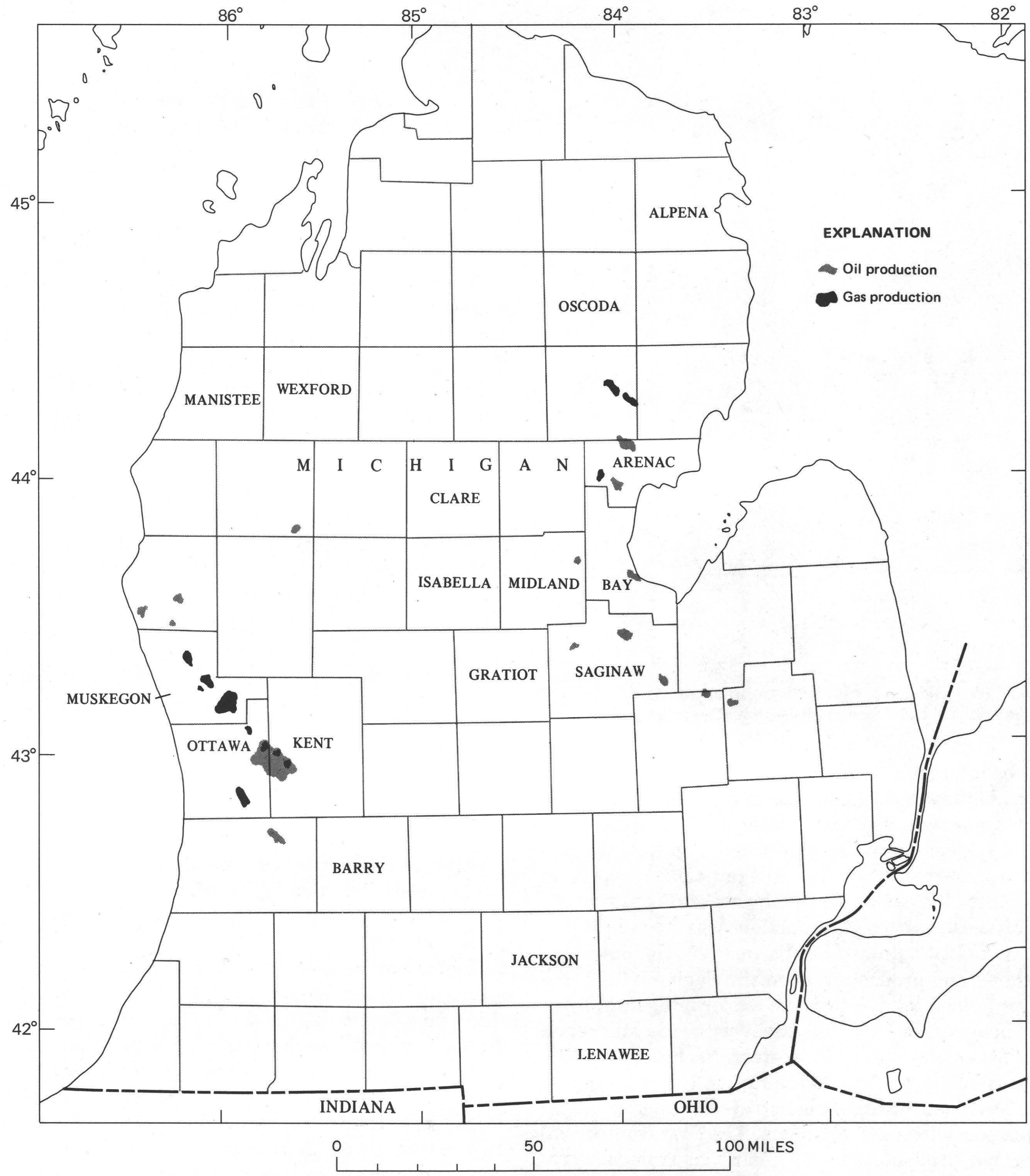

FIGURE 96. — Areas from which oil and natural gas have been produced from the Berea Sandstone and its equivalents, of interval A, in the Michigan basin.

was produced from Mississippian rocks in commercial quantities.

Production was from a sandstone near the base of the Michigan Formation (interval C). The sandstone, which has commonly been called the *Michigan "Stray" sandstone*, proved to be one of the most important gas-producing formations in Michigan (fig. 97). In some areas in the Central basin, a sandstone lens above the *"Stray" sandstone* has been called the *"Stray, Stray" sandstone*. The *"Stray" sandstone* has been found over

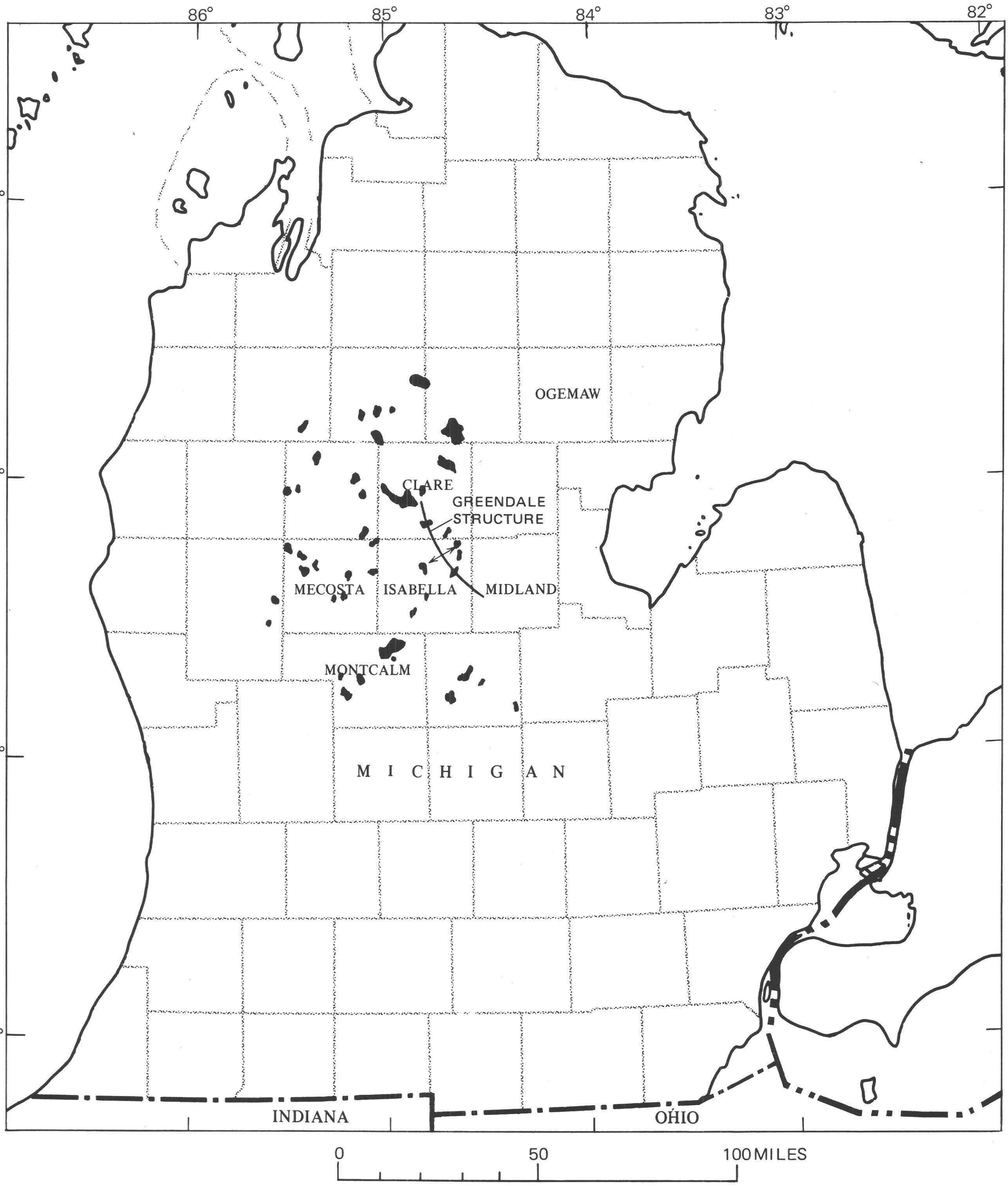

FIGURE 97. — Areas (black) from which natural gas has been produced from the ***Michigan "Stray" sandstone*** (interval C) in the Michigan basin.

an area of about 20,000 square miles in the Michigan basin (Vary and others, 1968), but the local distribution is erratic. The sandstone is productive of natural gas on anticlinal structures trending northwestwardly, such as the Greendale structure which extends from Midland County to Clare County (fig. 97). The sandstone may be missing in wells drilled off structure.

Subsurface studies have shown that while the lower part of the Michigan Formation was being deposited in the northern half of the Central basin, the Napoleon

Sandstone Member of the Marshall Formation was being deposited in the southern half of the basin (Cohee and others, 1951). Hard (1938) stated that gas-bearing *"Stray" sandstone* of the Clare, Vernon, and Leaton fields, in Clare and Isabella Counties, grades into the top of the Napoleon Sandstone Member southwest of the Greendale structure as the intervening layers thin and disappear. Monnett (1948) concluded that there is sufficient evidence to justify the general acceptance of the gradational relationship and interfingering of the Marshall and Michigan Formations. It appears that the lower part of the Michigan Formation and the upper part of the Marshall Sandstone were deposited in deltaic and littoral environments of deposition. The lower part of the Michigan in the northern part of the Central basin is the offshore phase in late Marshall time, and the Napoleon Sandstone Member of the Marshall Sandstone in the southern part of the area represented the nearshore deposit. During Marshall time, a large amount of sand was transported into the sea, from the Wisconsin highlands to the west and from the Canadian Shield to the northeast. In places, the sand extended northward into the offshore zone and formed the *Michigan "Stray"* lenticular masses of sandstone. The minerals occurring in minor amounts in the Marshall of western Michigan differ from those in eastern Michigan (McGregor, 1954).

The *Michigan "Stray" sandstone*, which has been important in gas production in the State, is of special importance now for the underground storage of natural gas. At least 12 of the depleted *Michigan "Stray"* fields have been developed as gas storage reservoirs. The Six Lakes field in Mecosta and Montcalm Counties, one of the largest *Michigan "Stray"* fields, produced 51.3 billion cubic feet of gas and now provides a working storage capacity of 43.1 billion cubic feet between a base well head pressure of 325 lb/in^2 (pounds per square inch) and a top well head pressure of 685 lb/in^2 (Vary and others, 1968).

OTHER OCCURRENCES IN MISSISSIPPIAN ROCKS

Showings of natural gas and some oil have been found in the sandstones in the lower and upper parts of the Coldwater Shale (interval B) in different parts of the State, but there has been little commercial production. The name *"Richmondville"* has been applied to some sandstone lenses in the Coldwater that have had showings of gas. Some gas production was obtained from the *"Weir sand"* in the Coldwater in the Logan gas field, Ogemaw County.

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Barite in Rocks of Mississippian Age

By DONALD A. BROBST

PALEOTECTONIC INVESTIGATIONS OF THE MISSISSIPPIAN SYSTEM IN THE UNITED STATES, PART II: INTERPRETIVE SUMMARY AND SPECIAL FEATURES OF THE MISSISSIPPIAN SYSTEM

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BARITE IN ROCKS OF MISSISSIPPIAN AGE

By DONALD A. BROBST

INTRODUCTION

Barite, the sulfate of barium used chiefly as a weighting agent in drilling mud, occurs in three major types of commerical deposits — bedded, vein and cavity filling, and residual (Brobst, 1958), all of which are associated with sedimentary rocks of Mississippian age, especially in the midcontinent region, in Arkansas, Illinois, Kentucky, Missouri, and Tennessee (fig. 98).

ARKANSAS

The bedded deposits of Arkansas have been of national commercial significance and have produced more than 8 million tons of barite from 1940 to 1974, according to data from the "Minerals Yearbook," the annual volume of the U.S. Bureau of Mines. The Arkansas production record is second in the United States only to that of Missouri whose 10 million tons of barite mined since 1850 have come chiefly from residual deposits associated with Cambrian and Ordovician rocks in the Washington County district (Brobst and Wagner, 1967, p. 100). The deposits of barite in Mississippian rocks in the other States mentioned above have been of considerably less economic significance.

Deposits of bedded barite occur in the Stanley Shale, generally within 200 feet of the contact with the underlying Arkansas Novaculite on the south flank of the Ouachita Mountains, chiefly in Hot Spring, Montgomery, and Polk Counties, Ark. The individual beds of barite are a few inches to several feet thick and are intercalated with beds of black shale, generally siliceous, siltstone, and sandstone. The barite beds are gray to black, contain as much as 90 percent barium sulfate, and give off a distinct fetid odor when struck by a hammer. Many of these deposits have been described by Scull (1958), Jones (1948), and McElwaine (1946a, b).

The largest of these deposits occurs in the Chamberlain Creek syncline near Magnet Cove, Hot Spring County, where the ore zone is about 60 feet thick, 3,200 feet long, and as much as 1,800 feet wide (Scull, 1958, p. 61). The ore body is truncated on the west by the alkali-rich igneous rocks of the intrusive complex at Magnet Cove of Late Cretaceous age. These igneous rocks are considered by some as the source of the barium-rich hydrothermal solutions that selectively replaced various beds in the Stanley Shale.

The many bedded barite deposits in Montgomery and Polk Counties, western Arkansas, are geologically similar to the deposit in Chamberlain Creek syncline near Magnet Cove, except for the lack of closely associated intrusive igneous rocks. A hydrothermal origin for these deposits seems less acceptable than for the deposit near Magnet Cove. It seems possible that some bedded barite could form during the time of sedimentation of the associated sequence of rocks or as a result of diagenetic processes. Shawe, Poole, and Brobst (1969) have described deposits of sedimentary origin in siliceous Paleozoic rocks in Nye County, Nev. The possibility that barite-rich rocks may form a sedimentary facies was discussed further by Brobst (1973, p. 80–81), and it opens attractive suggestions for prospecting for new deposits of bedded barite in many sedimentary basins, including those with Mississippian rocks.

As an aid to prospecting in rocks and soils, a relatively simple, rapid, and inexpensive turbidimetric chemical method was developed to determine barium in concentrations from 500 to 10,000 ppm (parts per million) and applied in Arkansas by Brobst and Ward (1965). From the studies with the turbidimetric test, the barium content of the Stanley Shale in 1,930 samples collected away from known barite deposits in an area of 950 square miles was less than 500 ppm (Brobst and Ward, 1965, p. 1027). The rock halos of increasing barium content around barite deposits were rarely more than 150 feet in stratigraphic thickness above and below the ore zone (Brobst and Ward, 1965, p. 1028). Similar prospecting could now be done easily by X-ray fluorescence and emission spectrographic methods.

FIGURE 98. — Geographic and political localities and areas mentioned in text.

MISSOURI

In the central district of Missouri, chiefly in Cole, Cooper, Miller, Moniteau, and Morgan Counties, some barite deposits are associated with the Mississippian Burlington Limestone, although most of the several hundred known deposits are associated with rocks of Ordovician age. The most important deposits of this region, described as circle deposits by Mather (1946, p. 45–47), are bell, flask, or cone shaped in vertical section with the apex up, and approximately circular in plan. According to Mather (1947, p. 98–99), they probably formed by the enlargement of solution channels through caving of large volumes of roof and wall rocks. The caving extended upward until the roof attained the character of a stable arch, thus producing the cone- or bell-shaped enclosure filled with broken rock. The solution of the debris continued during the formation of the structure. Barite, calcite, and some associated galena, sphalerite, and chalcopyrite were deposited after the structure was stabilized. Barite cemented the rock fragments, and by strengthening the structure, probably prevented further solution of the walls and rock debris. The remaining open spaces were then filled with a red tallowlike clay deposited during erosion of the overlying ground.

Most of the circle deposits are small, the largest being about 200–250 feet in diameter. One deposit was worked to a depth of 125 feet, but the depths of most are unknown because mining operations generally ceased before reaching the bottom. The grade of the ore varied greatly, and no general figures can be given. The weathering of many of these deposits resulted in the formation of some commercially valuable residual barite deposits.

The small, scattered barite deposits of the central district of Missouri can at best support only small mining operations under present economic conditions. The aggregate tonnage of barite in these deposits, however, constitutes a resource that may be large but exploitable only under more favorable economic conditions. (Brobst and Wagner, 1967, p. 106).

TENNESSEE

Barite occurs as disseminated coarse fragments and in very thin, discontinuous stringers in residual clay derived from the nearly flat-lying Warsaw Limestone in the Pall Mall district, at the eastern edge of the Highland Rim, about 10 miles north of Jamestown, Fentress County, Tenn. (Rankin and others, 1938, p. 2–3). The district has yielded perhaps 50,000 tons of barite since 1934 from workings restricted to a single bed 10–30 feet thick that is underlain by a sticky green clay derived from a shaly limestone. The barite generally is overlain by several feet of barren cherty residual clay.

Rankin and his coworkers (1938, p. 3) believed that the barite was concentrated from disseminated fragments in the limestone and that it may not have had a deep-seated source because no vein or breccia deposits have been seen in the unweathered limestones. The barite-bearing bed has been exposed to weathering over a large area along the eastern edge of the Highland Rim, and the green clay and the Warsaw cherts could be used as guides to the discovery of other ore bodies. More recently, Maher (1970, p. 28) suggested that the St. Louis Limestone in Tennessee should also be prospected for barite deposits similar to those in the Pall Mall district.

ILLINOIS AND KENTUCKY

In southern Illinois and western Kentucky, sedimentary rocks of Mississippian age are host rocks for vein and bedded replacement deposits containing fluorspar, sphalerite, galena, and barite. The district has yielded about one-half of the total U.S. production of fluorspar, but only a very small part of the total barite production because the barite, though abundant, is erratically distributed through the deposits. The geology and economics of this mining district have been described by Bradbury (1959) and Bradbury, Finger, and Major (1968) who cited recent literature on the district.

Bradbury, Finger, and Major (1968, p. 12–13) described the relation of the deposits to the kind of host rock. The strong, competent Ste. Genevieve and St. Louis Limestones are the most favorable hosts for vein deposits that are associated with faults and other fractures in the rocks. Openings as much as 30 feet wide were mineralized. The bedded replacement deposits occur chiefly at three levels in the 190-foot sequence of rocks between the base of the Bethel Sandstone downward to the top of the Fredonia Limestone Member of the Ste. Genevieve Limestone (fig. 99). These limestone units were more easily replaced because they probably contained more carbonate, were more porous, and were more fractured than other beds. The Renault Formation in the Cave-in-Rock area, Hardin County, Ill., was reported by Bradbury, Finger, and Major (1968, p. 12) to contain substantial amounts of fluorspar. The bedded replacement bodies are elongate and are 4–15 feet thick, 50–300 feet wide, and 200 to more than 10,000 feet long.

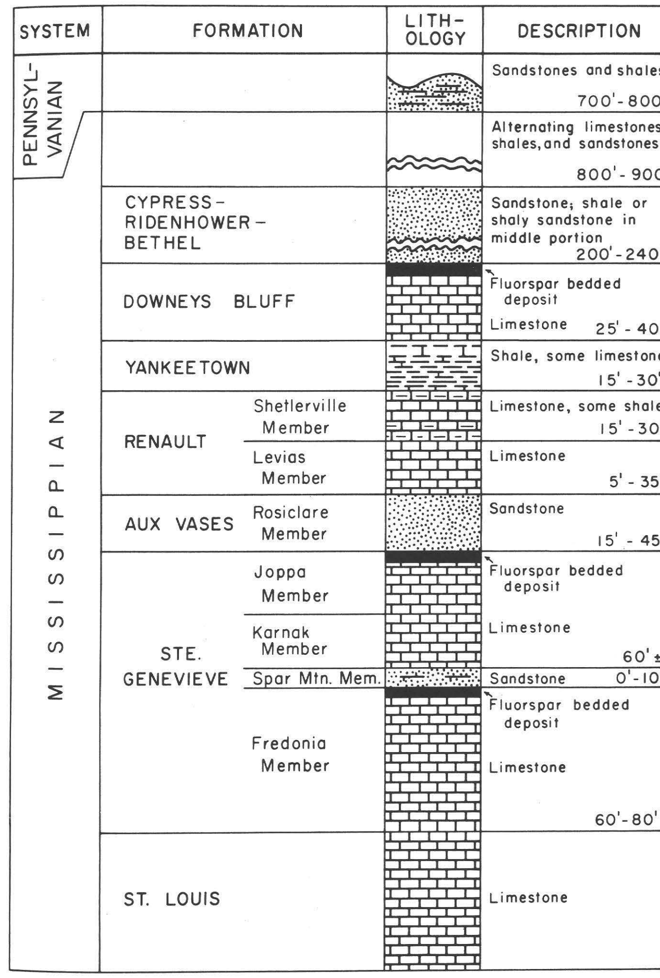

FIGURE 99.—Principal fluorspar-bearing portion of stratigraphic column of the southeastern Illinois fluorspar district. Black bands represent horizons most favorable for the occurrence of bedded deposits. The most productive parts of veins generally occur below the Rosiclare Member. The thickness of beds is given in feet. Reprinted from Bradbury, Finger, and Major (1968, p. 13).

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Index to Localities and Sources

By KATHARINE L. VARNES, *Coordinator*

PALEOTECTONIC INVESTIGATIONS OF THE MISSISSIPPIAN SYSTEM IN THE UNITED STATES, PART II: INTERPRETIVE SUMMARY AND SPECIAL FEATURES OF THE MISSISSIPPIAN SYSTEM

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INDEX TO LOCALITIES AND SOURCES (PL. 1)

By KATHARINE L. VARNES, Coordinator

EXPLANATION AND ABBREVIATIONS

The localities used in the preparation of the chapters of part I are listed here; the numbered localities are shown on plate 1. An independent series of index numbers has been assigned to each State; not all numbers for any one State have been used for the published maps. Complete bibliographic data are listed in the section entitled "References" at the end of each chapter in part I. An asterisk (*) denotes that the source of data is in the files of an individual or organization and, therefore, is not listed in a bibliography. Data references for a few localities were given in confidence and are so listed.

Citations of sources of data used in compilation of the maps fall into six categories:

1. Published data and theses. Shown as: author's name; year of publication (or completion of thesis); page, plate, figure, or stratigraphic section number or name. Location: section, township, and range, if available.
2. Unpublished reports. Shown as: asterisk, author's name, affiliation, and date. Location: section, township, and range,
3. Unpublished measured sections from the files of individuals or organizations. Shown as: asterisk, measurer, name of organization or individual owner; date (if known). Location: section, township, and range, or specific locality.
4. Unpublished well logs. Shown as: name of company drilling; well number; farm name. Location: coordinate location, specific locality, or county (in Texas). Asterisk, name of person and (or) organization that prepared log; year samples were examined (if known).
5. Written and oral communications. Shown as: asterisk, name, affiliation, date, form (oral or written). Location: section, township, and range, or specific locality.
6. Confidential sources. Shown as: well name, location, and confid., or only as confid.

Note.—In the absence of a standard land let in Kentucky and Tennessee many control points in these States are located by the Carter coordinate system.

The abbreviations used in the index of localities and sources include the following:

Agr.	Agriculture
AmStrat.	American Stratigraphic Company
ASLS	Abilene Sample Log Service
Assoc.	Associated, Association
AT and SF	Atchinson, Topeka and Santa Fe Railroad
Bros.	Brothers
Bur.	Bureau
Cen.	Central
cen.	center
Chem.	Chemical
Co.	Company
col., cols.	column, columns
Comm.	Commission
commun.	Communication
confid.	Confidential
Const.	Construction
Corp.	Corporation
Dept.	Department
Devel.	Development
Dist.	District
Div.	Division
Drlg.	Drilling
DSL	Denver Sample Log
E.	east
Est.	Estate
Explor.	Exploration
fig.	figure
Found.	Foundation
gen.	general
Geo-Log	Geological Sample Log Company
Geol.	Geologic(al), geologist(s)
Govt.	Government
GS	Geological Services, Inc.
Inc.	Incorporated
Ins.	Insurance
KSLS	Kansas Sample Log Service
Lab.	Laboratory
Libr.	Library
loc.	locality

Ltd.	Limited
MCGS	Mid-Continent Geological Services
MCGS (AmStrat)	AmStrat log now owned by Mid-Continent Geological Services
MCGS (DSL)	Denver Sample Log now owned by Mid-Continent Geological Services
MCGS (Ellison)	Ellison sample log now owned by Mid-Continent Geological Services
Mfg.	Manufacturing
Min.	Mining, Mineral
Missouri DGSWR	Missouri Division of Geological Survey and Water Resources
Mtn., Mtns.	Mountain, Mountains
Mus.	Museum
NM BMMR	New Mexico Bureau of Mines and Mineral Resources
N.	north
Nat.	Natural
Natl.	National
NE.	northeast
NPRR	Northern Pacific Railroad
NTSLS	North Texas Sample Log Service
NW.	Northwest
NWGS	Northwest Geological Service
Oklahoma Geol. Surv. (Shell)	Shell Oil Company log in files of Oklahoma Geological Survey
p.	page
PAPC	Pan American Petroleum Corporation
PBSL	Permian Basin Sample Log
Pet.	Petroleum
PI	Petroleum Information
PL	Paleontological Laboratory
pl.	plate
prep.	preparation
Prod.	Producing, Production
quad.	quadrangle
Res.	Resources
Ref.	Refining
rept.	report
RR	Railroad
S.	south
SE.	southeast
sec., secs.	section, sections
Serv.	Service
Soc.	Society
Strat.	Stratigraphic
Surv.	Survey
SW.	southwest
Synd.	Syndicate
TPSLS	Texas Panhandle Sample Log Service
Tr.	Trustee
Trans.	Transmission
TVA	Tennessee Valley Authority
Twp.	Township
Univ.	University
unpub.	unpublished
UPRR	Union Pacific Railroad
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
W.	west
WCTSLS	West Central Texas Sample Log Service
W. & K.	Ware and Kapner Sample Log Service

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    Welch, 1958. 15–4S–12W.
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    Harris, Peace, and Harris, 1963, pl. 3. 4S–11W.
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58. Gulf 1 Smith; 19–15S–53W. *AmStrat.
59. Kinney-Coastal-Ohio 1 Rockwell; 18–1S–45W. *AmStrat.
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61. Livermore 1 Green; 8–2S–43W. *AmStrat.
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63. Lion 1 Thim; 23–2S–50W. *AmStrat.
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191. Mid-Colorado 1 Mower; 14–14S–95W. *Confid.
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193. Amerada 1 Asbury Creek; 14–9S–101W. *AmStrat.
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29. J. O. Davis 1 Byland; 10–10N–3E. *Illinois State Geol. Surv., 1946.
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37. Central Illinois Light C–17, 29–27N–2W. *Illinois State Geol. Surv.
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110. O. W. Hogsett 2 Nelson; 7–22N–9E. *Illinois State Geol. Surv., 1963.
112. L. H. Leyh 1 Turpin and Miller; 5–21N–11W. *Illinois State Geol. Surv., 1950.
113. Illinois Power C–9; 31–21N–10E. *Illinois State Geol. Surv.
114. E. A. Hays 1 Richmond; 23–21N–7E. *Illinois State Geol. Surv., 1949.
115. Union Hill Gas Storage 19–M; 13–21N–6E. *Illinois State Geol. Surv., 1959.
116. Paul W. McElyea 1 Houser; 22–21N–5E. *Illinois State Geol. Surv., 1963.
117. Lester R. Stensel 1 E. D. Swartz; 30–21N–4E. *Illinois State Geol. Surv., 1960.
118. Stanley W. Kluzek 1 Cora Pfeifer; 29–21N–1W. *Illinois State Geol. Surv., 1961.
119. Keith Railway Equipment 1 C. R. Wilson; 19–21N–5W. *Illinois State Geol. Surv., 1946.
120. Northern Ordnance 1 F. B. Greuel; 7–3N–1W. *Illinois State Geol. Surv., 1944.
121. Northern Ordnance 1 Alber Yaap; 1–3N–2W. *Illinois State Geol. Surv., 1941.
122. M. Siegel 1 F. Hite; 15–3N–3W. *Illinois State Geol. Surv., 1940.
123. G. E. Brainerd 1 Agnes Foster; 21–3N–4W. *Illinois State Geol. Surv., 1940.
124. Cities Serv. 1 Foley; 3–3N–5W. *Illinois State Geol. Surv., 1957.
125. Plymouth Well Co. 1 Bowen City test; 22–3N–6W. *Illinois State Geol. Surv., 1947.
126. Herndon Drlg. 1 M. D. Laffey; 17–3N–7W. *Illinois State Geol. Surv., 1944.
127. Lee O. Werner 1 Putnam; 13–3N–9W. *Illinois State Geol. Surv., 1955.
128. Ohio 1 Theo Dougherty; 34–2N–7W. *Illinois State Geol. Surv., 1929.

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129. H. F. Robison 1 E. A. Rainey; 13–2N–4W. *Illinois State Geol. Surv., 1955.
130. J. R. Covington 1 R. Richardson; 36–2N–3W. *Illinois State Geol. Surv., 1960.
131. W. C. McBride 1 L. Loring; 15–2N–2W. *Illinois State Geol. Surv., 1952.
132. O. D. Arnold and others 1 Quinn; 27–2N–1W. *Illinois State Geol. Surv.
133. Niagara Oil 1 Friend; 21–20N–8W. *Illinois State Geol. Surv., 1960.
134. Bay 1 Grace M. Lake; 11–20N–2W. *Illinois State Geol. Surv., 1940.
135. Don Durr 1 Dinsmore; 27–20N–2E. *Illinois State Geol. Surv., 1962.
136. R. E. Sutton 1 Art Lubbers; 27–20N–3E. *Illinois State Geol. Surv., 1963.
137. Little Wabash Drlg. 1 Kenneth Headlee; 14–20N–7E. *Illinois State Geol. Surv., 1956.
138. Barber and Sievers 1 Lindsay; 20–20N–8E. *Illinois State Geol. Surv.
139. Robert Hurst 1 Bussard; 11–20N–13W. *Illinois State Geol. Surv., 1953.
140. James R. Dollahan 1 Kelley; 21–20N–11W. *Illinois State Geol. Surv., 1959.
141. George Howard and others 1 (?) Cox; 1–19N–13W. *Illinois State Geol. Surv.
142. Union Hill Gas Storage 1 J. G. Pfeffer; 22–19N–7E. *Illinois State Geol. Surv., 1960.
143. Theo Meyers 1 Valentine; 12–19N–6E. *Illinois State Geol. Surv., 1959.
144. Omar Kersey 1 (?) De Land city well; 9–19N–5E. *Illinois State Geol. Surv.
     McDowell and Murvin 1 Schwartz; 18–19N–5E. *Illinois State Geol. Surv., 1950.
145. W. F. Simms and T. Parkin 1 N. Pence; 8–19N–3E. *Illinois State Geol. Surv.
146. Elmer E. Allspach 1 Park; 7–19N–3W. *Illinois State Geol. Surv., 1950.
147. Cantine and Haley 1 William Johnson; 24–19N–5W. *Illinois State Geol. Surv., 1960.
148. Shawnee 1 Carl Schmidt; 23–19N–7W. *Illinois State Geol. Surv., 1960.
149. Jacob L. Pinkston 1 William Kramer; 9–19N–10W. *Illinois State Geol. Surv., 1950.
150. M. M. Speckler 1 Herron; 13–1N–1W. *Illinois State Geol. Surv., 1960.
151. Schwartz and others 1 Aber; 25–1N–2W. *Illinois State Geol. Surv.
152. Kirk Drlg. 1 Schone; 7–1N–4W. *Illinois State Geol. Surv., 1960.
153. Golden Oil Assoc. 2 Hecox; 21–1N–5W. *Illinois State Geol. Surv., 1932.
154. Guy Nations 1 Dinkladge; 33–1N–6W. *Illinois State Geol. Surv., 1944.
155. Cities Serv. 1 G. A. Rischar. 20–1N–7W. *Illinois State Geol. Surv.
156. Walmar Oil 1 Bradford; 2–1N–9W. *Illinois State Geol. Surv.
157. Ohio 1 (?) S. A. Hubbard; 16–1S–9W. *Illinois State Geol. Surv., 1929.
158. Concord Drlg. 1 Jefferson; 10–1S–5W. *Illinois State Geol. Surv., 1957.

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159. E. E. Goad 1 Worth; 32–1S–3W. *Illinois State Geol. Surv., 1957.
160. Clyde O. Williams 1 Doris Logsdon; 29–1S–2W. *Illinois State Geol. Surv., 1957.
161. V. S. & S. Drlg. 1 Lambert Bros.; 6–18N–10W. *Illinois State Geol. Surv., 1960.
162. Herman Herring 1 Starr and Broughton; 22–18N–3W. *Illinois State Geol. Surv., 1950.
163. James O. McCue 1 Christison; 1–18N–1W. *Illinois State Geol. Surv., 1960.
164. Tuley and Carter 1 Brighton; 4–18N–4E. *Illinois State Geol. Surv., 1949.
165. E. V. Richardson 1 E. B. Kelley; 12–18N–6E. *Illinois State Geol. Surv., 1958.
166. Charles Bates 1 Cole; 36–18N–8E. *Illinois State Geol. Surv., 1955.
167. A. M. Meyers 1 D. A. Silver; 11–18N–9E. *Illinois State Geol. Surv.
168. A. M. Meyers and others 1 N. Forman; 13–18N–14W. *Illinois State Geol. Surv., 1938.
169. F. E. Richards well; 20–17N–11W. *Illinois State Geol. Surv.
170. Allen P. Lucht 1 Everett Miller; 12–17N–13W. *Illinois State Geol. Surv., 1957.
172. Arnett Drlg. 1 H. Struck; 18–17N–11E. *Illinois State Geol. Surv., 1956.
173. S. D. Tate 1 Grace L. Raymond; 4–17N–10E. *Illinois State Geol. Surv., 1955.
174. Douglas Oil and Gas 1 Bozdeck; 33–17N–9E. *Illinois State Geol. Surv., 1913.
175. J. E. Carlson 1 Sebens; 24–17N–6E. *Illinois State Geol. Surv., 1963.
176. Jay-Vee Devel. 1 Woodward; 17–17N–5E. *Illinois State Geol. Surv., 1959.
177. Eureka Oil 1 William Rhodes; 28–17N–3E. *Illinois State Geol. Surv., 1940.
178. M. H. Richardson 1 Troutman; 29–17N–2E. *Illinois State Geol. Surv., 1957.
179. E. J. Cunningham 1 M. N. Hamilton; 25–17N–3W. *Illinois State Geol. Surv., 1957.
180. Earnest Zink 1 Epling; 8–17N–7W. *Illinois State Geol. Surv., 1956.
182. Cass Community Oil 1 James Maslin; 2–17N–10W. *Illinois State Geol. Surv.
183. Cass Oil Enterprises 1 Albert Meier; 17–17N–11W. *Illinois State Geol. Surv., 1961.
184. Charles Eager 1 W. L. Davis; 8–2S–4W. *Illinois State Geol. Surv., 1959.
185. O. A. Reed 1 Bertha Phillips; 19–2S–6W. *Illinois State Geol. Surv., 1960.
186. Clarence Shachtsick 1 John Reichert; 12–2S–8W. *Illinois State Geol. Surv., 1941.
187. Arnold Beach 1 Mason; 7–3S–6W. *Illinois State Geol. Surv., 1956.
188. B & O Oil Producers 1 Seybold; 9–3S–4W. *Illinois State Geol. Surv., 1957.
190. Charles Measley 1 Nichols; 12–3S–2W. *Illinois State Geol. Surv., 1954.
191. Buck and Bock 1 Melvin Knack; 29–16N–12W. *Illinois State Geol. Surv., 1961.
192. M. W. Brown 1 A. E. Crum; 1–16N–11W. *Illinois State Geol. Surv., 1940.
193. J. F. Horn Oil 1 William Beilschmidt; 25–16N–9W. *Illinois State Geol. Surv.

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194. V. S. & S. Drlg. 1 Emma Martin and others; 5–16N–7W. *Illinois State Geol. Surv.
195. S. D. Jarvis and others 1 Veech; 11–16N–3E. *Illinois State Geol. Surv., 1941.
196. Natl. Assoc. Pet. 1 Howard Reed; 6–16N–5E. *Illinois State Geol. Surv., 1954.
197. Natl. Assoc. Pet. 1 Clara B. Matthews; 15–16N–6E. *Illinois State Geol. Surv., 1954.
198. Panhandle Eastern Pipe Line 1 Phillips; 35–16N–7E. *Illinois State Geol. Surv., 1957.
199. Ohio 1 Williams; 13–16N–8E. *Illinois State Geol. Surv., 1930.
200. John Carlson 1 Travis; 19–16N–9E. *Illinois State Geol. Surv., 1956.
201. Ohio 1 Lewis Shaw; 36–16N–8E. *Illinois State Geol. Surv., 1944.
202. C. H. Lewis 1 (?) Wagoner; 25–16N–10E. *Illinois State Geol. Surv.
203. T. J. Pate 1 H. C. Hathaway; 32–16N–13W. *Illinois State Geol. Surv., 1949.
204. J. Ruston 1 Greenwalt; 30–16N–11W. *Illinois State Geol. Surv., 1952.
205. F. J. Casey and others 1 (?) Gwinn; 30–15N–11E. *Illinois State Geol. Surv.
206. Huego Oil 1 Willard Van Auken; 20–15N–10E. *Illinois State Geol. Surv., 1944.
207. Bill Montgomery 1 Williams; 14–15N–9E. *Illinois State Geol. Surv., 1957.
208. Sohio 1 M. Schable; 15–15N–6E. *Illinois State Geol. Surv., 1949.
209. Decatur Oil and Gas 1 L. W. Cook; 21–15N–2E. *Illinois State Geol. Surv.
210. Sun 1 Joseph F. Damery; 5–15N–1E. *Illinois State Geol. Surv., 1955.
211. Parshall-Graham 1 Yockey; 36–15N–2W. *Illinois State Geol. Surv.
212. Millar and others 1 G. W. Sample; 11–15N–3W. *Illinois State Geol. Surv.
213. Collins Bros. 1 Bennet Bros.; 9–15N–4W. *Illinois State Geol. Surv., 1955.
214. A. M. Brians 1 M. M. Thornton; 24–15N–7W. *Illinois State Geol. Surv., 1957.
215. E. G. Brown 1 W. Bellatti; 16–15N–8W. *Illinois State Geol. Surv.
216. Collingwood, 1933, p. 44. 2–15N–13W. R. R. Long 1 (?) S. H. Simpson; 26–15N–12W. *Illinois State Geol. Surv.
217. Collingwood, 1933, p. 43. 24–15N–14W.
218. Herndon Drlg. 1 Byron A. Campbell; 15–4S–5W. *Illinois State Geol. Surv., 1944.

218a. Koenig and others, 1961, p. 72.

219. J. O. Gill and C. E. Kindred 1 Tittsworth; 13–5S–6W. *Illinois State Geol. Surv., 1944.
220. Panhandle Eastern Pipe Line 21–1 Mumford; 21–5S–4W. *Illinois State Geol. Surv.
221. Super Oil Co. 1 R. E. and Clay Rush; 19–5S–2W. *Illinois State Geol. Surv., 1936.
222. John I. Wood 1 Homer Wood; 9–14N–9W. *Illinois State Geol. Surv, 1961.
223. V. R. Gallagher 3 Stout Heirs; 15–14N–5W. *Illinois State Geol. Surv., 1961.
224. Collins Bros. 1 Lela Gorden; 21–14N–1E. *Illinois State Geol. Surv., 1955.
225. P. Fulk 1 D. C. Miller; 11–14N–4E. *Illinois State Geol. Surv., 1956.

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225a. W. L. Topf 1 T. D. Basler; 26–14N–9E. *Illinois State Geol. Surv.

226. Mabee and others 1 Oakland Bank; 31–14N–14W. *Illinois State Geol. Surv.

227. James H. Barton 1 Jerry Englum; 6–14N–12W. *Illinois State Geol. Surv., 1949.

228. M. Luther Livengood and C. S. Cookney 3 R. and M. Stoneburner; 3–13N–13W. *Illinois State Geol. Surv.

229. Fulk 1 Cockran; 23–13N–9E. *Illinois State Geol. Surv., 1946.

230. Carter Oil 1 Daily-Hopper; 14–13N–7E. *Illinois State Geol. Surv., 1956.

231. Texas 1 Frederick-Wabash Unit; 36–13N–5E. *Illinois State Geol. Surv., 1957.

232. M. H. Richardson 1 Zeller; 5–13N–4E. *Illinois State Geol. Surv., 1962.

233. Illican Oil 1 Carr; 12–13N–2E. *Illinois State Geol. Surv., 1940.

234. Louis Nonneman 1 Montgomery; 19–13N–1W. *Illinois State Geol. Surv., 1957.

Walter H. Koelbel 1 Meyers; 19–13N–1W. *Illinois State Geol. Surv., 1951.

235. Natl. Assoc. Pet. 1 Peabody Coal Co.; 32–13N–3W. *Illinois State Geol. Surv.

236. Gulf 1 H. Dambacher Comm.; 15–13N–5W. *Illinois State Geol. Surv., 1955.

237. Panhandle Eastern Pipe Line 1 Doolin; 16–13N–8W. *Illinois State Geol. Surv., 1955.

238. C. T. Hunt 2 E. F. Cuddy; 2–13N–10W. *Illinois State Geol. Surv.

239. A. L. Bedell 1 E. C. Adams; 27–13N–13W. *Illinois State Geol. Surv., 1954.

240. Koenig and others, 1961, p. 67.

241. Erie Drlg. 1 Allison; 11–7S–3W. *Illinois State Geol. Surv., 1941.

242. Beatrice Creamery 1 Chicago Cold Storage Warehouse Co.; 26–12N–13W. *Illinois State Geol. Surv., 1944.

243. S. B. Geiger 1 (?) C. and A. RR; 13–12N–12W. Collingwood, 1933, p. 50.

244. James Castle 1 Glenn Butcher; 17–12N–9W. *Illinois State Geol. Surv., 1949.

245. Paul F. Bergschneider 1 Lester A. Miller; 26–12N–6W. *Illinois State Geol. Surv., 1955.

246. Cities Serv. 1 M. T. Nolan; 10–12N–4W. *Illinois State Geol. Surv., 1956.

246a. Ring and Kinsell 1 McDonald; 7–12N–2W. *Illinois State Geol. Surv., 1956.

Roger Bros. and others 1 Johnson; 27–12N–2W. *Illinois State Geol. Surv., 1937.

247. Skiles Oil 1 H. Schmidt; 10–12N–1W. *Illinois State Geol. Surv., 1956.

Earl Landon 1 Neal; 10–12N–1W. *Illinois State Geol. Surv., 1949.

248. McDaniel and Workman 1 Clark; 21–12N–2E. *Illinois State Geol. Surv., 1953.

R. E. J. McFarland 1 Cozalet; 6–12N–2E. *Illinois State Geol. Surv., 1946.

249. Producers Oil and Devel. 1 Boys Estate; 27–12N–3E. *Illinois State Geol. Surv., 1962.

Atkins and Hale 1 Runkel; 32–12N–3E. *Illinois State Geol. Surv.

251. Carter 1 J. H. Seaman; 35–12N–7E. *Illinois State Geol. Surv., 1954.

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252. Carlson 1 Goodman; 19–12N–10E. *Illinois State Geol. Surv., 1954.

253. Natl. Assoc. Pet. 1 Harlan S. Cockcroft and others; 1–12N–11W. *Illinois State Geol. Surv., 1949.

254. H. R. Snavely 1 S. M. Scholfield; 6–11N–11W. *Illinois State Geol. Surv., 1940.

255. Allen and Sherrit 2 Harper; 5–11N–14W. *Illinois State Geol. Surv., 1940.

256. Kingwood 1 Tomberlin; 21–11N–10E. *Illinois State Geol. Surv.

257. Seaboard and Wiggins 1 Miller; 32–11N–2E. *Illinois State Geol. Surv.

257a. J. L. Crawford 1 C. S. Miller; 13–11N–2W. *Illinois State Geol. Surv., 1951.

Werner 1 Townsend; 5–11N–1W. *Illinois State Geol. Surv., 1950.

258. Dickenson 2 Jones; 36–11N–5W. *Illinois State Geol. Surv., 1953.

259. Adams and Lagers 1 Amos Bristow; 7–11N–7W. *Illinois State Geol. Surv., 1943.

260. Hettick Oil Devel. Assoc. 1 C. P. Starkweather; 36–11N–9W. *Illinois State Geol. Surv., 1943.

261. Kewanee 1 Eula; 32–11N–11W. *Illinois State Geol. Surv., 1960.

262. K. Murray 1 Potts Heirs; 17–11N–12W. *Illinois State Geol. Surv., 1935.

263. Koenig and others, 1961, p. 64.

264. Koenig and others, 1961, p. 61.

266. Carrolton city well; 22–10N–12W. *Illinois State Geol. Surv.

267. B. W. Quick 1 Charles W. Meng; 9–10N–10W. *Illinois State Geol. Surv., 1951.

268. Calvert 1 O. McLin; 20–10N–7W. *Illinois State Geol. Surv.

269. Texas 1 Springfield Marine Bank; 32–10N–3W. *Illinois State Geol. Surv., 1944.

Jack Brown 1 Cecil Lipe; 28–10N–3W. *Illinois State Geol. Surv., 1940.

270. Harmony Oil 1 W. H. Osborne; 11–10N–1W. *Illinois State Geol. Surv., 1950.

271. Partlow and Cochenour 1 Davis; 8–10N–4E. *Illinois State Geol. Surv., 1958.

Rose and Durbin 1 C. Flenner; 9–10N–4E. *Illinois State Geol. Surv.

272. English and others 1 McLory; 14–10N–6E. *Illinois State Geol. Surv.

273. Natl. Assoc. Pet. 1 Allie M. Handley; 26–10N–7E. *Illinois State Geol. Surv., 1947.

274. John Gambill 1 A. Lacy; 24–10N–10E. *Illinois State Geol. Surv., 1956.

275. Magnolia 1 Ella Mae Young; 19–10N–13W. *Illinois State Geol. Surv., 1962.

F. D. Strickler 1 Minnie Jackson; 19–10N–13W. *Illinois State Geol. Surv., 1939.

276. Pierson and Yeager 1 E. Robinson; 17–10N–11W. *Illinois State Geol. Surv.

277. Arkansas Fuel 1 Alexander; 4–9N–12W. *Illinois State Geol. Surv.

278. J. E. Thompson 1 Clarence Briggs; 15–9N–14W. *Illinois State Geol. Surv., 1947.

279. Union Prod. Pet. 1 Cox; 29–9N–9E. *Illinois State Geol. Surv., 1954.

280. Natl. Assoc. Pet. 3 Krogman; 31–9N–7E. *Illinois State Geol. Surv., 1946.

G. J. McDevitt 1 A. Dust; 33–8N–6E. *Illinois State Geol. Surv.

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281. Skelly 1 W. O. Chesterman; 7–9N–3E. *Illinois State Geol. Surv.
282. Northern Ordnance 1 Mary O'Conner; 28–9N–1E. *Illinois State Geol. Surv., 1943.
283. Don Frazier (Hoover) 1 Earl Battles; 10–9N–2W. *Illinois State Geol. Surv., 1944.
284. A. M. Lacey 1 Luddeks; 28–9N–4W. *Illinois State Geol. Surv., 1942.
    Collingwood, 1933, pl. 1.
285. G. A. Fuller and J. H. Turner 1 Dr. H. R. Chamness; 4–9N–6W. *Illinois State Geol. Surv., 1944.
286. Calvert Drlg. 1 Mile Wheeler; 27–9N–7W. *Illinois State Geol. Surv., 1957.
287. George E. Brainerd 1 Carlinville Natl. Bank; 35–9N–8W. *Illinois State Geol. Surv., 1943.
288. Hughes 1 J. Kallall; 22–8N–12W. *Illinois State Geol. Surv.
289. E. M. Gould and Son 1 Grover Pierce; 27–8N–10W. *Illinois State Geol. Surv.
290. Spence Bros. 1 Spence Bros.; 13–8N–9W. *Illinois State Geol. Surv., 1943.
291. California 1 Otto E. Lay; 34–8N–5W. *Illinois State Geol. Surv., 1963.
    Siegel and Schlosberg (Casseday) 1 Niemann; 29–8N–5W. *Illinois State Geol. Surv., 1938.
292. Superior 1 Flake Bost; 22–8N–2W. *Illinois State Geol. Surv., 1952.
293. Humble 1 Weaber-Horn Unit; 28–8N–3E. *Illinois State Geol. Surv., 1961.
294. Pure 1 W. J. Dammerman; 33–8N–5E. *Illinois State Geol. Surv.
295. Huffman and others 1 King; 20–8N–10E. *Illinois State Geol. Surv.
296. Hastings and others 1 Athey; 18–8N–12W. *Illinois State Geol. Surv.
297. Carl Robinson and others 1 O. Walters; 19–7N–12W. *Illinois State Geol. Surv., 1949.
298. Denver Producers and Refiners 1 H. Dennis; 14–7N–14W. *Illinois State Geol. Surv., 1940.
299. Keystone 1 O. R. Ball; 9–7N–9E. *Illinois State Geol. Surv., 1949.
300. Henry and Pearson 1 Miller; 26–7N–7E. *Illinois State Geol. Surv.
301. William H. Brown 1 Radliff; 24–7N–1E. *Illinois State Geol. Surv.
    W. A. Baldridge 2 Browning; 30–7N–2E. *Illinois State Geol. Surv.
302. M. H. Richardson 1 Mary J. Sills; 23–7N–3W. *Illinois State Geol. Surv., 1948.
303. L. L. Benoist 1 Fred Krummel; 12–7N–4W. *Illinois State Geol. Surv., 1948.
304. Madison Coal Corp. Mine 5 well 15; 35–8N–6W. *Illinois State Geol. Surv., 1934.
    R. A. Sloan 1 Consolidation Coal Co. (Henry Reuther); 20–7N–6W. *Illinois State Geol. Surv.
305. A. W. Gerson 1 Knight; 32–7N–11W. *Illinois State Geol. Surv.
306. J. T. Elmore and Co. 1 Bell; 33–7N–12W. *Illinois State Geol. Surv., 1932.
307. E. W. Franke 1 (?) W. H. Simon (Seven Oaks); 8–12S–2W. *Illinois State Geol. Surv.
308. Calhoun Drlg. 1 (?) Fred Jacobs; 21– 13S–2W. *Illinois State Geol. Surv., 1954.

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309. H. H. Ferguson well 1; 8–6N–12W. *Illinois State Geol. Surv., 1932.
310. Collingwood, 1933, p. 19–22.
312. Madison County Oil and Gas 1 Heine; 21–6N–8W. *Illinois State Geol. Surv., 1946.
313. Mason and Sohio 1 Mohme; 14–6N–5W. *Illinois State Geol. Surv., 1947.
314. Joseph Kesl, Jr. 1 Robert C. Marti and others; 27–6N–4W. *Illinois State Geol. Surv., 1948.
315. Anderson and Associates 1 J. Morris; 16–6N–3W. *Illinois State Geol. Surv.
316. A. T. Whitehead 1 C. Poland; 26–6N–2W. *Illinois State Geol. Surv.
317. Benedum-Trees 1 Van Zant (Moore); 24–6N–1W. *Illinois State Geol. Surv.
    Kingwood 1 L. Dayton; 14–6N–1W. *Illinois State Geol. Surv.
318. Texas 1 William Smail; 25–6N–2E. *Illinois State Geol. Surv., 1962.
    F. E. Turner 1 R. W. Winters; 24–6N–2E. *Illinois State Geol. Surv.
    Claude Neon Lights 1 Charles Poland; 31–6N–2E. *Illinois State Geol. Surv.
319. Herndon Drlg. 1 (?) Kossl; 12–6N–4E. *Illinois State Geol. Surv., 1960.
320. Kingwood 1 McWhorter; 15–6N–6E. *Illinois State Geol. Surv.
321. Freeman Lomelino 1 Xavier Ochs; 27–6N–10E. *Illinois State Geol. Surv., 1949.
321. H. H. Weinert 1 M. Bergbower Comm.; 16–6N–10E. *Illinois State Geol. Surv., 1947.
322. United Oil Producers (Zahniser) 1 Jones; 12–6N–13W. *Illinois State Geol. Surv., 1929.
323. Mahutska 1 Chalmer Seaney; 6–6N–11W. *Illinois State Geol. Surv.
    Natl. Assoc. Pet. 1 Stifle; 6–6N–11W. *Illinois State Geol. Surv.
324. Bell Bros. 1 W. R. Wampler; 27–5N–11W. *Illinois State Geol. Surv., 1944.
325. Rush and Meredith 1 Mushrush (Wagner); 20–5N–13W. *Illinois State Geol. Surv., 1942.
    Bell Bros. 1 G. Kersey; 1–5N–13W. *Illinois State Geol. Surv.
326. Pure 1 M. P. Redman; 16–5N–10E. *Illinois State Geol. Surv., 1940.
    Pure 1A E. E. Kropp; 31–5N–10E. *Illinois State Geol. Surv., 1940.
327. Phillips 1 J. R. Murvin; 22–5N–7E. *Illinois State Geol. Surv., 1944.
328. Natl. Cooperative Ref. Assoc, 1 R. Vangelson "A"; 15–5N–5E. *Illinois State Geol. Surv., 1960.
    Paul Doran 1 C. J. Peyton; 21–5N–5E. *Illinois State Geol. Surv., 1948.
329. E. V. Richardson 1 Amelia M. Williams; 35–5N–4W. *Illinois State Geol. Surv., 1955.
330. J. William Everhart 1 Kaufman; 2–5N–6W. *Illinois State Geol. Surv., 1955.
331. T. C. Havelka 1 T. C. Havelka; 24–5N–8W. *Illinois State Geol. Surv., 1933.
332. Maggos and Kost 1 Lindberg Park; 8–5N–9W. *Illinois State Geol. Surv., 1938.
333. Madison Coal Corp. mine well 6; 26–4N–8W. *Illinois State Geol. Surv.

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Mode, Bruce, and Lacy 1 Keneipp Heirs; 19–1S–12W. *Illinois State Geol. Surv., 1941 and 1943.
387. Ryan Oil 1 Schaefer Heirs; 7–2S–13W. *Illinois State Geol. Surv., 1946.
388. Superior (Fox and Fox) 1 Camilla Green; 19–2S–11E. Murray, 1954.
389. Leach Bros. 1 Jos. Ellen; 3–2S–10E. *Illinois State Geol. Surv.
390. New Penn (Nation Oil) 1 Xanders; 7–2S–9E. *Illinois State Geol. Surv.
391. B. H. Keck and others 1 Young; 29–2S–7E. *Illinois State Geol. Surv.
Rockhill 7–A Twist; 33–2S–7E. *Illinois State Geol. Surv.
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435. Paul Mosbach 1 Burr Oak Coal Corp.; 23–7S–2E. *Illinois State Geol. Surv.
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273. C. E. Weddel E. Barnard; 35–13N–1E. *Indiana Geol. Surv.
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298. Yakey and Deitch 1 P. and C. Blair; 16–11N–8W. *Indiana Geol. Surv.
299. Smith 1 Gibault Home for Boys; 15–11N–9W. *Indiana Geol. Surv.
300. Carter 1 A. Harden and others; 16–10N–10W. *Indiana Geol. Surv.
301. Cline 1 K. Payne and Carter 1 B. Payne; 20–10N–8W. *Indiana Geol. Surv.
302. Reagan 1 B. and H. Reagan; 19–10N–6W. *Indiana Geol. Surv.
303. Sun 1 G. Chambers; 23–10N–5W. *Indiana Geol. Surv.
Pure 1 (?) G. McDaniel; 29–10N–5W. *Indiana Geol. Surv.
304. Indiana Gas and Water 1 C. Champlin; 10–10N–1W. *Indiana Geol. Surv.
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314. Gulf 1 T. Fiscus; 16–9N–5W. *Indiana Geol. Surv.
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315. Siepman Oil 1 M. Strahla; 10–9N–7W. *Indiana Geol. Surv.
316. Texas Gas Explor. 1 C. Wheat; 19–9N–8W. *Indiana Geol. Surv., 1957.
317. Jarvis 1 F. Lane; 8–9N–9W. *Indiana Geol. Surv.
318. Siosi-Pardoe 1 B. Cushman; 18–8N–10W. *Indiana Geol. Surv.
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72. Larson Well 1 Frank Smith; 1–84N–26W. *Iowa Geol. Surv., 1960.
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82. Thorpe Well 1 Harry Hackfort; 20–83N–34W. *Iowa Geol. Surv., 1939.
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84. Thorpe Well 1 town of Soldier; 19–83N–42W. *Iowa Geol. Surv., 1962.
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102. Thorpe Well 1 town of Altoona; 13–79N–23W. *Iowa Geol. Surv., 1949.
103. F. S. McCutchoen 1 Reed Ice Cream Co.; 33–79N–24W. *Iowa Geol. Surv., 1947.
104. Thorpe Well 1 town of Waukee; 33–79N–26W. *Iowa Geol. Surv., 1959.
105. Northern Nat. Gas 5 Walker; 10–79N–29W. *Iowa Geol. Surv., 1953.

IOWA — Continued

106. Harlan Drlg. 2 town of Harlan; 18–79N–38W. *Iowa Geol. Surv., 1957.
107. Thorpe Well 1 town of Menlo; 27–78N–31W. *Iowa Geol. Surv., 1948.
108. Hunt 1 McConnell; 11–78N–30W. *Iowa Geol. Surv., 1946.
109. Hunt 1 Macklin; 17–78N–28W. *Iowa Geol. Surv., 1946.
110. Varner Well 1 General Mills; 28–78N–23W. *Iowa Geol. Surv., 1960.
111. Kaldenberg 1 Sulley Co-op Creamery; 8–78N–17W. *Iowa Geol. Surv.
112. Thorpe Well 4 town of Montezuma; 6–78N–14W. *Iowa Geol. Surv., 1946.
113. Latta 1 Chester Kauffman; 11–77N–6W. *Iowa Geol. Surv., 1958.
114. Doyle 1 Chester Miller; 18–77N–8W. *Iowa Geol. Surv., 1955.
115. Well 6 town of North English; 12–77N–11W. *Iowa Geol. Surv., 1945.
116. Hunt 1 Lovell; 23–77N–33W. *Iowa Geol. Surv., 1948.
117. Atlantic Coal Min. 1 prospect; 6–76N–36W. *Iowa Geol. Surv., 1941.
118. Well 1 town of Indianola; 36–76N–24W. *Iowa Geol. Surv., 1955.
119. Thorpe Well 1 town of What Cheer; 10–76N–13W. *Iowa Geol. Surv., 1959.
120. Sleigher 1 Baker; 21–76N–12W. *Iowa Geol. Surv., 1956.
121. Thorpe Well 1 town of Keota; 25–76N–10W. *Iowa Geol. Surv., 1960.
122. Hoeg and Ames 1 town of West Chester; 31–76N–8W. *Iowa Geol. Surv., 1958.
123. Jennings 1 Urban Backhorst; 6–76N–7W. *Iowa Geol. Surv., 1956.
124. Latta 1 Schaeffer Bros.; 4–76N–6W. *Iowa Geol. Surv., 1959.
125. Latta 1 Rath Packing Co. 18–75N–4W. *Iowa Geol. Surv., 1960.
126. Jennings 1 Cotter School; 18–75N–5W. *Iowa Geol. Surv., 1949.
127. Jennings 1 Homer Jones; 2–75N–6W. *Iowa Geol. Surv., 1953.
128. Edwards 1 Robert Wiley; 17–75N–7W. *Iowa Geol. Surv., 1946.
129. Doyle 1 Dorothy Brinning; 31–75N–9W. *Iowa Geol. Surv., 1959.
130. Pence 1 John Bombel; 18–75N–10W. *Iowa Geol. Surv., 1960.
131. Bruine Kool 1 Van Zee Quarry; 34–75N–14W. *Iowa Geol. Surv., 1961.
132. F. S. McCutcheon 1 Lake Keomah State Park; 24–75N–15W. *Iowa Geol. Surv., 1940.
133. Bruine Kool 1 Arnold Van Zee; 5–75N–18W. *Iowa Geol. Surv.
134. Hoeg and Ames 1 town of St. Charles; 23–75N–26W. *Iowa Geol. Surv., 1956.
135. Layne Bowler 1 town of Greenfield; 7–75N–31W. *Iowa Geol. Surv., 1930.
136. Northern Nat. Gas 1 Test; 11–75N–39W. *Iowa Geol. Surv., 1945.
137. Thorpe Well 1 town of Oakland; 12–75N–40W. *Iowa Geol. Surv., 1939.
138. Thorpe Well 1 School for the Deaf; 8–74N–43W. *Iowa Geol. Surv., 1939.

IOWA — Continued

139. Layne-Western 1 Hedrick; 36–74N–13W. *Iowa Geol. Surv., 1945.
140. McNabb 1 Dr. Anson Hayes; 3–74N–12W. *Iowa Geol. Surv., 1958.
141. Layne-Western 1 town of Richland; 27–74N–10W. *Iowa Geol. Surv., 1952.
142. Pence 1 C. C. Lowe; 26–74N–8W. *Iowa Geol. Surv., 1958.
143. Jennings 1 Ruth Davis; 28–74N–7W. *Iowa Geol. Surv., 1958.
144. Hoeg and Ames 1 town of Crawfordsville; 15–74N–6W. *Iowa Geol. Surv., 1955.
145. Jennings 1 George Van Allen; 33–74N–5W. *Iowa Geol. Surv., 1956.
146. Jennings 1 Dave Hull; 32–74N–4W. *Iowa Geol. Surv., 1946.
147. Jennings 1 E. L. Naylor; 17–73N–3W. *Iowa Geol. Surv., 1946.
148. Jennings 1 Harney Anderson; 36–73N–4W. *Iowa Geol. Surv., 1951.
149. Jennings 2 Fred Holt; 21–73N–6W. *Iowa Geol. Surv., 1958.
150. Van Winkle 1 Harry Clark; 20–73N–7W. *Iowa Geol. Surv., 1946.
151. Jennings 1 Gypsum test; 33–73N–13W. *Iowa Geol. Surv., 1958.
152. Bell and others 1 Kenworthy; 2–73N–36W. *Iowa Geol. Surv., 1950.
153. Frank Oakin 1 Henry Paul; 15–73N–40W. *Iowa Geol. Surv., 1948.
154. Council Bluffs Explor. Trust 1 Thieschafer; 6–73N–43W. *Iowa Geol. Surv., 1950.
155. Ohio 1 Peterson; 5–72N–38W. *Iowa Geol. Surv., 1941.
156. Layne-Western 1 town of Albia; 9–72N–17W. *Iowa Geol. Surv., 1956.
157. Layne-Western 8 Morrell; 30–72N–13W. *Iowa Geol. Surv., 1943.
158. Varner 1 town of Fairfield; 24–72N–10W. *Iowa Geol. Surv., 1957.
159. Jennings 1 Marshall Lines; 23–72N–5W. *Iowa Geol. Surv., 1956.
160. Dietsch 1 Anderson; 8–72N–2W. *Iowa Geol. Surv., 1947.
161. Jones 1 Amel Gerling; 34–71N–2W. *Iowa Geol. Surv., 1951.
162. Jennings 1 Joe Wall Jasper; 1–71N–4W. *Iowa Geol. Surv., 1955.
163. Thorpe Well 1 town of New London; 26–71N–5W. *Iowa Geol. Surv., 1939.
164. Varner 1 Mental Health Institute; 15–71N–6W. *Iowa Geol. Surv., 1955.
165. Jennings 1 Mabel Collins; 10–71N–7W. *Iowa Geol. Surv., 1954.
166. Layne-Western 1 Michigan-Wisconsin Pipeline; 36–71N–10W. *Iowa Geol. Surv., 1951.
167. Thorpe Well 1 Cardinal Community School; 9–71N–12W. *Iowa Geol. Surv., 1960.
168. Layne-Western 1 town of Russell; 6–71N–20W. *Iowa Geol. Surv., 1956.
169. Phillips 1 Creston; 31–71N–30W. *Iowa Geol. Surv., 1939.
170. Monchrief 1 Hayes; 29–71N–41W. *Iowa Geol. Surv., 1960.
171. Johnson 1 R. D. Lucus; 28–70N–43W. *Iowa Geol. Surv., 1941.
172. Thorpe Well 1 town of Lenox; 8–70N–32W. *Iowa Geol. Surv., 1940.
173. Sunbery Well 1 town of Garden Grove; 33–70N–24W. *Iowa Geol. Surv., 1958.

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174. Van Winkle 1 town of Stockport; 19–70N–8W. *Iowa Geol. Surv., 1948.
175. Jennings 1 town of Salem; 24–70N–7W. *Iowa Geol. Surv., 1959.
176. Varner 1 Danville State Park; 25–70N–5W. *Iowa Geol. Surv., 1940.
177. Jennings 1 Fred Wagner; 2–70N–4W. *Iowa Geol. Surv., 1952.
178. Jones 1 Cal Fischer; 24–70N–3W. *Iowa Geol. Surv., 1952.
179. Jennings 1 J. J. Pfeifer; 17–69N–2W. *Iowa Geol. Surv., 1954.
180. Gray 4 I O P; 1–69N–4W. *Iowa Geol. Surv., 1941.
181. Jennings 1 G. E. Wheeler; 34–69N–5W. *Iowa Geol. Surv., 1950.
182. Schlicher 1 Stephen Wall Japper; 3–69N–6W. *Iowa Geol. Surv., 1959.
183. Jennings 1 William Hennings; 21–69N–7W. *Iowa Geol. Surv., 1954.
184. Jennings 2 town of Keosaqua; 36–69N–10W. *Iowa Geol. Surv., 1954.
185. Thorpe Well 1 Appanoose County Home; 32–69N–18W. *Iowa Geol. Surv., 1955.
186. Thorpe Well 1 town of Leon; 33–69N–25W. *Iowa Geol. Surv., 1949.
187. Ohio 1 Wisnam; 23–68N–41W. *Iowa Geol. Surv., 1941.
188. Iowa Devel. 1 Wilson; 25–68N–37W. *Iowa Geol. Surv., 1940.
189. Pryor and Lockhart 1 Marr Est. 32–68N–33W. *Iowa Geol. Surv., 1941.
190. L. B. Jackson 1 Jackson; 7–68N–26W. *Iowa Geol. Surv., 1952.
191. Schlicher 1 Midwest Packing Co.; 7–68N–8W. *Iowa Geol. Surv., 1937.
192. Schlicher 1 Tresa Wellman; 11–68N–6W. *Iowa Geol. Surv., 1954.
193. Jennings 1 Bob Consbrock; 9–68N–4W. *Iowa Geol. Surv., 1956.
194. Well 1 Kermit Sweeny; 5–68N–3W. *Iowa Geol. Surv., 1946.
195. Thorpe Well 1 town of Lineville; 20–67N–23W. *Iowa Geol. Surv., 1954.
196. Thorpe Well 1 town of Lamoni; 3–67N–27W. *Iowa Geol. Surv.
197. Stanolind 1 W. P. Turner; 8–67N–29W. *Iowa Geol. Surv., 1944.
198. Schlicher 1 King's Daughters; 11–66N–5W. *Iowa Geol. Surv., 1952.
199. Vermillion 1 Wertz; 10–65N–5W. *Iowa Geol. Surv., 1949.

KANSAS

1. Valley 1 Mann; 21–1S–19E. *Kansas Geol. Surv.
4. Kiska Oil 1 Kraus; 36–1S–7E. *Schlumberger, KSLS.
5. Davon Oil 1 Schaeffer; 20–1S–6E. *Schlumberger, Kansas Geol. Surv.
6. Gulf 1 Baker; 1–1S–2E. *Schlumberger.
7. Natl. Assoc. Pet. 1 Roe; 19–1S–7W. *Schlumberger.
8. Musgrove Pet. 1 Jackson; 21–1S–16W. *Schlumberger.
9. Empire Drlg. 1 Atens; 6–1S–22W. *Schlumberger, KSLS.
10. Great Lakes Carbon 1 Minshall; 35–1S–23W. *Schlumberger, KSLS.
11. D. G. Hansen 1 Thompson; 28–1S–24W. *Welex, KSLS.
12. Gulf 1 Butler; 16–1S–25W. *Schlumberger.
13. Helmerich and Payne 1 Sauvage; 3–1S–27W. *Schlumberger.

KANSAS — Continued

14. Great Basins Pet. 1 Commercial Bank of Nelson; 23–1S–28W. *Schlumberger.
16. Westheimer-Neustadt 1 Glasco; 10–1S–38W. *Schlumberger, KSLS.
17. Ben F. Brack 2 Judy; 35–1S–39W. *Schlumberger, KSLS.
18. Ohio 1 Rose; 35–1S–40W. *Schlumberger, KSLS.
19. Deep Rock Oil 1 Clark; 23–1S–42W. *Schlumberger, KSLS.
20. Phillips 1 Wilkins; 16–2S–37W. *Schlumberger, KSLS.
21. Miami Pet. 1A Brumm; 7–2S–36W. *Schlumberger, KSLS.
22. Westheimer-Neustadt and Shear 1 Cahoj; 13–2S–36W. *Schlumberger, KSLS.
23. K. and E. Drlg. and Bradley Bros. 1 Focke; 16–2S–34W. *Schlumberger, Kansas Geol. Surv.
24. Murfin Drlg. 1B Niemuth; 1–2S–32W. *Schlumberger, KSLS.
25. Musgrove Pet. 1 Mines; 11–2S–30W. *Schlumberger, KSLS.
26. E. K. Carey Drlg. 1 Monaghan; 15–2S–27W. *Schlumberger, KSLS.
27. Strain and Hall 1 Odle; 14–2S–26W. *Schlumberger, KSLS.
28. Empire Drlg. 1 Brooks; 19–2S–22W. *Schlumberger, KSLS.
29. Texas 1 Baynes; 8–2S–19W. *Schlumberger, KSLS.
30. Anschutz Drlg. 1 Cannon; 17–2S–17W. *Schlumberger, KSLS.
31. Charles A. Lasky 1A Habiger; 34–2S–11W. *Schlumberger, KSLS.
32. Texas 1 Murdock; 16–2S–13E. *Schlumberger.
33. Ohio 1 Lamparter; 3–2S–14E. *Schlumberger.
35. Carter 1 Huffles; 25–3S–13E. *Schlumberger.
36. Five Nations Drlg. 1 Seematter; 24–3S–8E. *Schlumberger, KSLS.
37. Rex and Morris Drlg. 1 Kohlmeyer; 9–3S–3E. *Schlumberger, KSLS.
38. James H. Snowden 1 Lull; 5–3S–11W. *Schlumberger, KSLS.
39. Russell Cobb, Jr., 1 Jacobs; 16–3S–20W. *Schlumberger, KSLS.
40. Great Lakes Carbon 1 Muir; 12–3S–23W. *Schlumberger, KSLS.
41. Harry Gore 1 Hershiser; 34–3S–23W. *Schlumberger.
42. Anderson-Prichard 1 Brooks; 17–3S–25W. *Schlumberger, KSLS.
43. Phillips and Westgate Greenland Oil 1 Vernon; 32–3S–28W. *Lane Wells.
44. Anderson-Prichard 1 Nitsch; 3–3S–29W. *Schlumberger, KSLS.
45. M. J. Lebsack 1 Unger; 3–3S–30W. *Welex, KSLS.
46. J. O. Farmer 1 Fikan; 11–3S–33W. *Schlumberger, KSLS.
47. Service Drlg. 1 Beeson; 8–3S–38W. *Schlumberger, KSLS.
48. Falcon-Seaboard Drlg. 1 Zweygardt; 1–3S–41W. *Schlumberger, KSLS.
49. R. G. Lawton 1 Rueb; 13–3S–42W. *Schlumberger, KSLS.
50. Atomic Drlg. and Serv. 1 Mundhenke; 18–4S–39W. *Welex, KSLS.
52. Jackson, Shear, and Parker 1 Bowles; 24–4S–34W. *Welex.
53. Jackson, Shear, and Parker 1 Ruda; 14–4S–33W. *Welex, KSLS.
54. Sinclair 1 Bremer; 28–4S–28W. *Schlumberger.
55. Texas 1 Keenan; 25–4S–27W. *Schlumberger, KSLS.
56. Harry Gore 1 Nauer; 27–4S–26W. *Schlumberger, KSLS.
57. Trans-Era Pet. 1 Troube; 20–4S–22W. *Schlumberger, KSLS.
58. R. W. Shields 1 Smith; 27–4S–21W. *Schlumberger, KSLS.

KANSAS — Continued

59. Natl. Cooperative Ref. Assoc. 1 Becker; 29–4S–20W. *Schlumberger, KSLS.
60. Stanolind 1 Brennecke; 2–4S–19W. *Schlumberger.
61. Carter 1 Jackson; 20–4S–18W. *Schlumberger.
62. Flynn Oil 1 Willis; 8–4S–16W. *Schlumberger.
63. Kewanee 1 Carlson; 25–4S–1E. *Schlumberger.
64. George Johnston 1 Brown; 21–4S–7E. *Schlumberger, KSLS.
65. Shawver-Armour 1 Sedlacek; 31–4S–8E. *Welex.
66. Carter 4 Explor.; 24–4S–16E. *Schlumberger, KSLS.
67. Woods Oil and Gas 1 Whaley; 34–4S–13E. *Schlumberger.
68. Kaiser-Francis Oil and Gas 1 Atwater; 14–5S–15E. *Schlumberger, KSLS.
69. Ohio 1 Kratochvil; 30–5S–7E. *Schlumberger, KSLS.
71. Kewanee 1 Sherman; 13–5S–3E. *Schlumberger.
72. Kewanee 1 Strawberry; 2–5S–1E. *Schlumberger.
75. Carter 5 Explor.; 5–5S–10W. *Schlumberger, KSLS.
76. Helmerich and Payne 1 Meyer; 10–5S–11W. *Kansas Geol. Surv.
77. Cities Serv. 1 Higby; 29–5S–18W. *Schlumberger, KSLS.
78. Cities Serv. 1 Sullivan; 26–5S–23W. *Schlumberger, KSLS.
79. Harry Gore 1 Sheetz; 5–5S–25W. *Schlumberger, KSLS.
80. Herndon Drlg. 1 Bader; 20–5S–26W. *Schlumberger, KSLS.
81. Continental 1 Gillespie; 34–5S–27W. *Schlumberger.
82. E. K. Carey Drlg. 1 Wachendorfer; 35–5S–29W. *Schlumberger, KSLS.
83. Derby Oil 1 Skiles; 17–5S–30W. *Schlumberger, KSLS.
84. Jackson, Shear, and Parker 1 Grover; 32–5S–33W. *Schlumberger, KSLS.
85. J. S. Carter 1 Henry; 27–5S–34W. *Welex, KSLS.
86. Petroleum 1 Falconer; 6–5S–36W. *Schlumberger, KSLS.
87. Jackson, Shear, and Parker 1 Eggers; 23–5S–37W. *Schlumberger, KSLS.
88. J. O. Farmer 1 Neitzel; 3–5S–39W. *Welex, KSLS.
89. Texas 1 Walz; 3–5S–42W. *Schlumberger, KSLS.
90. R. G. Lawton 1 Bair; 20–6S–41W. *Schlumberger, KSLS.
91. Shell 1 Harden; 24–6S–40W. *Schlumberger, KSLS.
92. Miami Pet. 1A Ackerman; 30–6S–37W. *Schlumberger, KSLS.
93. Derby Oil 1 Nickel; 16–6S–35W. *Schlumberger, KSLS.
94. Texas 1 Dougherty; 23–6S–33W. *Schlumberger.
95. Jackson, Shear, and Parker 1 Foster; 14–6S–32W. *Schlumberger, KSLS.
96. Natl. Cooperative Ref. Assoc. 1 Hardesty; 20–6S–26W. *Schlumberger, KSLS.
97. Wood River Oil and Ref. 1 Oliver; 24–6S–23W. *Schlumberger, KSLS.
98. Natl. Assoc. Pet. 1 Probst; 18–6S–19W. *Schlumberger, KSLS.
99. Sinclair-Prairie 1 Frye; 25–6S–17W. *Schlumberger.
100. Anderson-Prichard 1 Delaney; 29–6S–15W. *Schlumberger, KSLS.
101. Shawver-Armour 1 Daniels; 32–6S–5W. *Schlumberger, KSLS.
102. Shawver-Armour 1 O'Dette; 5–6S–4W. *Schlumberger, KSLS.
103. Shawver-Armour 1 Blosser; 8–6S–3W. *Schlumberger, KSLS.
104. Stanolind 1 Campbell; 26–6S–2W. *Schlumberger, KSLS.
105. Shawver-Armour 1 Budenbender; 10–6S–8E. *Schlumberger.
106. Cities Serv. 1 O'Connor; 21–6S–9E. *Schlumberger, KSLS.
107. Mendenhall Drlg. 1 Johnson; 35–6S–13E. *KSLS.

KANSAS — Continued

108. Kaiser-Francis Oil and Gas 1 Biggart; 20–6S–14E. *Welex, KSLS.
110. Carter 1 Graham; 27–7S–13E. *Schlumberger, KSLS.
111. Robert H. Kirk 1 Kelly; 25–7S–10E. *Schlumberger.
112. Shawver-Armour 1 Stelter; 4–7S–8E. *Schlumberger, KSLS.
113. Vickers Pet. 1 Lutz; 10–7S–7E. *Schlumberger, KSLS.
115. Shawver-Armour 1 Hall; 18–7S–3W. *Schlumberger, KSLS.
116. Texas Pacific Coal and Oil 1 Gasper; 31–7S–10W. *Schlumberger, KSLS.
117. Anderson-Prichard 1 Stephenson; 32–7S–15W. *Schlumberger, KSLS.
118. Harry Koplin 1 Tatman; 23–7S–18W. *Schlumberger, KSLS.
119. Keating Drlg. 1 Ridgley; 6–7S–21W. *Lane Wells, KSLS.
120. Davis and Childs Motor 1 Scott; 7–7S–22W. *Schlumberger.
121. Empire Drlg. 1 Goddard; 21–7S–24W. *Schlumberger, KSLS.
124. J. S. Carter 1 Foster; 6–7S–31W. *Schlumberger, KSLS.
125. Miami Pet. 1 Stewart; 28–7S–33W. *Schlumberger, KSLS.
126. Colorado Oil and Gas 1 Hills; 22–7S–34W. *Schlumberger, KSLS.
127. Natl. Cooperative Ref. Assoc. 1 Wright; 34–7S–36W. *Schlumberger, KSLS.
128. Miami Pet. 1 Bear; 18–7S–37W. *Schlumberger, KSLS.
129. Texas 1 McArthur; 18–8S–36W. *Schlumberger, KSLS, Kansas Geol. Surv.
130. Texas 1 Federal Land Bank; 7–8S–35W. *Schlumberger, KSLS, Kansas Geol. Surv.
131. Derby Oil 1 Schielke; 17–8S–34W. *Schlumberger, KSLS.
133. Ashland Oil and Ref. 1 Misner; 33–8S–32W. *Schlumberger, KSLS.
134. Anschutz Drlg. 1 Dally; 10–8S–30W. *Schlumberger, KSLS.
135. Don Pratt 1 Cooper; 25–8S–29W. *Schlumberger, KSLS.
136. Cities Serv. 1B James; 7–8S–28W. *Schlumberger, KSLS.
137. Union of California 1 Pratt; 23–8S–26W. *Schlumberger, Kansas Geol. Surv.
138. Sohio 1 Brault; 20–8S–21W. *Schlumberger, Kansas Geol. Surv.
139. Shell 9 Krug; 19–8S–17W. *Schlumberger.
140. Cities Serv. 1 Post; 3–8S–16W. *Schlumberger.
141. Carter 1 Neuschwanger; 15–8S–14W. *Schlumberger.
142. Olson Drlg. 1 Palen; 26–8S–10W. *Schlumberger, Kansas Geol. Surv.
143. Northern Ordnance 1 Burr; 35–8S–9W. *Schlumberger, Kansas Geol. Surv.
144. Cities Serv. 1 Blake; 8–8S–4W. *Schlumberger, Kansas Geol. Surv.
145. Rupp-Ferguson Oil 1 Larson; 21–8S–2W. *Halliburton, KSLS.
146. E. H. Adair and others 1 Stoffer; 1–8S–7E. *Schlumberger.
149. Brunson-Spines 1 Fevurley; 25–8S–20E. *Welex, KSLS.
151. Caddo Oil 1 Ebel; 32–9S–10E. *Schlumberger.
152. Derby Oil 1 Gaston; 33–9S–4E. *Schlumberger, KSLS.
153. Westgate-Greenland Oil 1 Foote; 29–9S–1W. *Schlumberger.
155. Northern Ordnance 1 Vandament; 3–9S–13W. *Schlumberger, Kansas Geol. Surv.
156. Anderson-Prichard 1 Beisner; 5–9S–15W. *Schlumberger, KSLS.
157. Phillips 2 Nettie; 34–9S–17W. *Halliburton.
158. Continental 11 Trexler; 15–9S–21W. *Schlumberger.
160. Trans-Era Pet. 1 Bell; 13–9S–28W. *Schlumberger, KSLS.
161. Gulf 1 Manhart; 28–9S–29W. *Schlumberger, KSLS.

KANSAS — Continued

162. Empire Drlg. 1 Moellering; 28–9S–30W. *Schlumberger, KSLS.
163. Phillips 1A Keller; 19–9S–32W. *Schlumberger, KSLS.
164. Van-Grisso Oil 1 Touslee; 11–9S–35W. *Schlumberger, KSLS.
165. Musgrove Pet. 1 Van Donge; 31–9S–38W. *Schlumberger, KSLS.
166. Van-Grisso Oil 1 Golden; 24–10S–42W. *Schlumberger, KSLS.
167. Sinclair-Prairie 1 Mercer; 28–10S–40W. *Schlumberger, KSLS.
168. Sinclair 1 Cogswell; 20–10S–38W. *Schlumberger, KSLS.
169. Excelsior Oil and Falcon-Seaboard Drlg. 1 Marshall; 17–10S–36W. *Schlumberger, KSLS.
170. H. K. Riddle 1 Albers; 26–10S–32W. *Schlumberger, KSLS.
173. B and R Drlg. 1 Von Lintel; 2–10S–26W. *Schlumberger.
174. Empire Drlg. 1 Knoll; 16–10S–25W. *Schlumberger, KSLS.
175. Harry Gore 1 Stites; 1–10S–23W. *Halliburton, KSLS.
176. Sinclair 4 Baldwin; 5–10S–20W. *Schlumberger.
177. Birmingham-Barlett Drlg. 1 Marcotte; 18–10S–19W. *Schlumberger.
178. Champlin Oil and Ref. 1 Brungardt; 35–10S–17W. *Schlumberger, KSLS.
179. Anderson-Prichard 1A Ruggles; 23–10S–15W. *Schlumberger, KSLS.
180. Harbar Oil and Gas 1 Rasmussen; 29–10S–9W. *Schlumberger, Kansas Geol. Surv.
181. Graham Devel. Synd. 1 Rathbun; 35–10S–7W. *Halliburton, KSLS.
182. Westgate-Greenland Oil 1 Schlotz; 22–10S–2W. *Schlumberger, Kansas Geol. Surv.
183. Kewanee 1 Clay; 27–10S–3E. *Schlumberger, KSLS.
189. Anderson Drlg. 1 Gramse; 4–11S–18E. *Kansas Geol. Surv.
191. Ramsey Pet. 1 Kaul; 2–11S–11E. *Kansas Geol. Surv.
192. Carter 1 Hankammer; 27–11S–10E. *Schlumberger, Kansas Geol. Surv.
193. Cities Serv. 2 Yaege; 25–11S–8E. *Schlumberger, KSLS.
194. Pure 1 Landon; 25–11S–7E. *Schlumberger, KSLS.
195. Olin Oil and Gas 1 Duenney; 36–11S–6E. *Schlumberger, KSLS.
196. Rupp-Ferguson Oil 1 Metz; 33–11S–7W. *Halliburton, KSLS.
197. Carter 8 Explor. 21–11S–8W. *Halliburton, Kansas Geol. Surv.
198. Northern Ordnance 1 Beverly; 11–11S–14W. *Schlumberger.
199. Lario Oil and Gas 1 Cress; 13–11S–17W. *Schlumberger.
200. Midstates Oil 6B Wasinger; 21–11S–18W. *Lane Wells.
201. Herndon Drlg. 1 Davis; 24–11S–20W. *Schlumberger, KSLS.
202. Peel-Hardman Oil 1 Osborn; 7–11S–21W. *Schlumberger, KSLS.
203. Natl. Cooperative Ref. Assoc. 1 Brown; 13–11S–25W. *Halliburton, KSLS.
206. Texas 1 Smith; 30–11S–36W. *Schlumberger, KSLS.
207. Toto Gas 1 Stover; 7–12S–40W. *Schlumberger, KSLS.
208. Texas 1 Federal Farm and Mortgage; 17–12S–30W. *Schlumberger, Kansas Geol. Surv.
209. Newmont and GMR 1 Lamoreaux; 8–12S–29W. *Schlumberger, KSLS.
210. Wick Pet. 1 Neiden; 16–12S–23W. *Schlumberger, KSLS.
211. Murfin Drlg. 1 Bahl; 32–12S–19W. *Schlumberger, KSLS.
212. Stearns Drlg. 1 Fink; 8–12S–14W. *Schlumberger, KSLS.

KANSAS — Continued

213. Northern Ordnance 1 Colliver; 29–12S–12W. *Schlumberger, Kansas Geol. Surv.
214. Auto Ordnance 1 Gelker; 20–12S–2W. *Schlumberger, Kansas Geol. Surv.
215. Stanolind 1 Duggan; 12–12S–1W. *Schlumberger, Kansas Geol. Surv.
216. Stanolind 1 Equitable Life; 17–12S–1E. *Schlumberger, Kansas Geol. Surv.
217. Kriswell Drlg. 1 Kuntz; 13–12S–2E. *Schlumberger.
218. Olin Oil and Gas 1 Ritter; 5–12S–5E. *Schlumberger, KSLS.
219. Carter 1 Meseke; 29–12S–9E. *Schlumberger.
220. Empire Oil and Ref. 1 Schwalm; 19–12S–11E. *Kansas Geol. Surv.
221. Jenkins and Scott 1 Hayden; 8–12S–14E. *Kansas Geol. Surv.
223. Al Smith and others 1 Smith; 28–12S–19E. *Kansas Geol. Surv.
224. Kaiser-Francis Oil and Gas 1 McKnight; 17–13S–12E. *Schlumberger, KSLS.
225. Carter 1 G. H. Davis; 33–13S–10E. *Schlumberger, KSLS.
226. Woods Oil and Gas 1 Munzer; 13–13S–9E. *Schlumberger, KSLS.
227. F. G. Holl 1 McArthur; 6–13S–8E. *Welex, KSLS.
228. Glickman Oil 1 Mynatt; 8–13S–1W. *Welex, KSLS.
229. Glickman Oil 1 Royal; 24–13S–2W. *Welex, KSLS.
230. Rupp-Ferguson Oil 1 Craig; 20–13S–3W. *Halliburton, KSLS.
231. Kewanee 1 Rahmeier; 8–13S–9W. *Schlumberger, KSLS.
232. Brack Oil 1 Letsch; 15–13S–12W. *Schlumberger.
233. A. F. Schmidt 1 McKune; 17–13S–15W. *Lane Wells, KSLS.
234. Carl Todd Drlg. 1 Kuhn; 24–13S–17W. *Schlumberger, KSLS.
235. Davis Bros. Oil 1 Mermis; 10–13S–19W. *Schlumberger, KSLS.
236. Jones, Shelburne, and Farmer 1 Moon; 32–13S–21W. *Schlumberger, KSLS.
237. Deep Rock Oil 1 Nicholson; 29–13S–22W. *Schlumberger, KSLS.
238. Phillips 1 Folkers; 31–13S–23W. *Schlumberger, Kansas Geol. Surv.
239. Cities Serv. 1 Victory Life; 36–13S–30W. *Halliburton, KSLS.
240. J. S. Carter 1 Ross; 36–13S–34W. *Schlumberger, KSLS.
241. Target Drlg. 1 Fankhauser; 31–13S–39W. *Welex, KSLS.
242. Skelly 1 Sexson; 19–13S–42W. *Schlumberger, KSLS.
243. Natl. Cooperative Ref. Assoc. 1B Goodrich; 9–14S–42W. *Schlumberger, KSLS.
244. Continental 1 Christy; 34–14S–32W. *Schlumberger, KSLS.
246. Cities Serv. 1 Coberly; 15–14S–29W. *Schlumberger, KSLS.
248. Leben Drlg. 1 Rohr; 19–14S–18W. *Schlumberger, KSLS.
249. Lewis Drlg. 1 Penny; 31–14S–17W. *Schlumberger, KSLS.
250. Bay 1 Anschutz; 12–14S–12W. *Schlumberger, KSLS.
251. Frankfort Oil 1 Kuck; 8–14S–10W. *Schlumberger.
252. Texas 1 Hockman; 31–14S–9W. *Schlumberger, KSLS.
253. Atlantic 1 Hoeffner; 2–14S–2W. *Schlumberger, KSLS.
254. Cities Serv. 1 Lockhart; 19–14S–11E. *Schlumberger, KSLS.
256. Woods Oil and Gas 1 Oberle; 14–14S–15E. *Schlumberger, KSLS.
257. Universal Oil 1 Harrington; 12–14S–22E. *Kansas Geol. Surv.
259. Schermerhorn Oil 1 Johanning; 17–15S–19E. *Schlumberger, KSLS.

KANSAS — Continued

260. Waco Oil 1 Volgast; 17–15S–18E. *Schlumberger, KSLS.
261. Carter 1 Woodbury; 11–15S–10E. *Schlumberger, KSLS.
262. Champlin Oil and Ref. 1 Schruben; 5–15–9E. *Schlumberger, KSLS.
263. Carter 1 Lindgren; 18–15S–8E. *Schlumberger, KSLS.
264. Gold Oil 1 Nelson; 6–15S–7E. *Schlumberger, Kansas Geol. Surv.
265. Phil Han Oil 1 Bailey; 17–15S–1W. *Halliburton.
266. Northern Ordnance 1 Warner; 10–15S–3W. *Schlumberger, Kansas Geol. Surv.
267. Rupp-Ferguson Oil 1 Farrington; 15–15S–6W. *Halliburton, KSLS.
269. Bennett and Roberts 1 Berrick; 13–15S–13W. *Schlumberger, KSLS.
270. Texas 1 Dumler; 26–15S–15W. *Schlumberger, KSLS.
271. Don Pratt 1 North; 21–15S–20W. *Halliburton, KSLS.
272. Deep Rock Oil 1A Moore; 1–15S–21W. *Schlumberger, KSLS.
274. Ben F. Brack Oil 1 Stutz-Bradley; 1–15S–26W. *Halliburton, KSLS.
275. Petroleum 1 Garvey; 11–15S–27W. *Schlumberger, KSLS.
276. Hugoton Prod. 1 Dirks; 28–16S–33W. *KSLS.
277. Virginia Drlg. 1 Harper; 26–16S–30W. *Schlumberger, KSLS.
280. Palmer Oil 1 Ryan; 23–16S–21W. *Halliburton, KSLS.
281. Solar Oil 1 Schmidt; 28–16S–19W. *Schlumberger, KSLS.
282. Sohio 1 Schneider; 9–16S–18W. *Schlumberger.
283. M. B. Armer 1 Taylor; 14–16S–16W. *Schlumberger, KSLS.
284. Helmerich and Payne 1 Davis; 32–16S–14W. *Halliburton.
285. Texas 1 Urbanek; 15–16S–10W. *Schlumberger, KSLS.
286. Phillips 1 Rathbun; 31–16S–8W. *Halliburton, KSLS.
287. Republic Nat. Gas 1 Hawkinson; 25–16S–5W. *Schlumberger, KSLS.
288. Vickers Pet. 1 Bozart; 3–16S–1E. *Schlumberger, Kansas Geol. Surv.
289. Augusta Oil 1 Hoffman; 25–16S–4E. *KSLS.
290. Lincoln Oil 1 Breckbill; 24–16S–5E. *Schlumberger, KSLS.
291. E. H. Adair 1 Lindquist; 35–16S–6E. *Welex, KSLS.
293. White and Ellis Drlg. 1 Miller; 1–16S–12E. *Schlumberger, KSLS.
294. Messman-Rinehart 1 Woodward; 23–16S–16E. *Schlumberger, KSLS.
295. Lance Hill and others 1 Bowman; 17–16S–18E. *Welex, KSLS.
296. McDonald 1 Lee; 16–16S–23E. *Kansas Geol. Surv.
297. Shell 1 Hagins; 13–17S–11E. *Schlumberger, KSLS.
298. Cities Serv. 1 Cobb; 6–17S–10E. *Schlumberger, KSLS.
299. Natural Gas and Oil 1 Alexander; 4–17S–8E. *Schlumberger, KSLS.
300. Westgate-Greenland Oil 1 Myers; 23–17S–7E. *Schlumberger.
301. Rex and Morris Drlg. 1 Pankratz; 21–17S–3E. *Schlumberger, KSLS.
302. Phillips 1 Holcomb; 28–17S–1W. *Halliburton.
304. Auto Ordnance 1 Melander; 9–17S–3W. *Schlumberger.
305. Texas 1 Dahlsten; 21–17S–4W. *Schlumberger, KSLS.
306. Anschutz Drlg. 1 Kratzer; 14–17S–8W. *Schlumberger.
307. John Hawley 1 Schreiber; 33–17S–15W. *Schlumberger, KSLS.
308. Morrison Drlg. 1 Eichel; 23–17S–17W. *Lane Wells, KSLS.
309. Texas 1 Laughlin; 35–17S–19W. *Schlumberger, KSLS.
313. Musgrove Pet. 1 Nelson; 16–17S–37W. *Schlumberger, KSLS.

KANSAS — Continued

314. United Prod. 1 Hiebert; 5–17S–42W. *Schlumberger, KSLS.
315. Amerada 1 Grube; 24–18S–32W. *Schlumberger, KSLS.
316. Trans-Era Pet. 1 Antenan; 9–18S–23W. *Schlumberger, KSLS.
317. Panhandle Eastern Pipe Line 1–21 Grose; 21–18S–22W. *Schlumberger, KSLS.
318. Imperial Oil of Kansas 1 Seuser; 5–18S–17W. *Schlumberger.
319. D. R. Lauck Oil 1 Trester; 33–18S–14W. *Lane Wells, KSLS.
320. Beardmore Drlg. 1 Straub; 20–18S–11W. *Schlumberger, KSLS.
321. Eldorado Ref. 1 Wohlford; 31–18S–8W. *Halliburton, KSLS.
322. Time Pet. 1 Berggren; 27–18S–3W. *Welex, KSLS.
324. William Gruenerwald 1 Guthrie; 11–18S–8E. *Welex, KSLS.
325. Huber, Anderson, and Haworth 1 Ball; 23–18S–10E. *Schlumberger.
326. Cities Serv. 1 Mounkes; 27–18S–13E. *Schlumberger, KSLS.
327. Cities Serv. 1 Baldwin; 11–19S–10E. *Schlumberger, KSLS.
328. Stanolind 1 Kline; 10–19S–7E. *Schlumberger, KSLS.
329. Anderson-Prichard 1 Church; 24–19S–5E. *Schlumberger, KSLS.
330. Anderson-Prichard 1 Jost; 22–19S–2E. *Schlumberger, KSLS.
331. Roland Jones and others 1 Schroeder; 35–19S–1E. *KSLS. Texas 1 Weinbrunner; 34–19S–1E. *Schlumberger.
332. Rex and Morris Drlg. 1 Reikowsky; 34–19S–1W. *Schlumberger, KSLS.
333. Skelly 1 Conway; 30–19S–4W. *Schlumberger, KSLS.
334. L. B. Jackson 1 Ramage; 16–19S–6W. *Schlumberger, KSLS.
335. Flynn Oil 1 Gray; 17–19S–8W. *Schlumberger, KSLS.
336. D. R. Lauck 1 Johnson; 6–19S–11W. *KSLS.
337. Lohmann and Johnson Drlg. 1 Button; 13–19S–13W. *Schlumberger.
338. Tatlock Oil 1 Rudiger; 30–19S–14W. *Schlumberger, KSLS.
339. Tatlock Oil 1 Peterson; 36–19S–16W. *Schlumberger, KSLS.
340. Skelly 1 Pechaneco; 2–19S–17W. *Schlumberger, KSLS.
341. Musgrove Pet. 1 Shiney; 12–19S–19W. *Schlumberger, KSLS.
342. Wolf Creek Oil 1 Thalheim; 1–19S–20W. *Schlumberger.
343. Badger Drlg. 1 De Wold; 18–19S–21W. *Halliburton, KSLS.
344. Hilton Drlg. 1 Schaben; 9–19S–24W. *Halliburton, KSLS.
345. Gulf and Pan American 1 Lewis; 33–19S–27W. *Welex, KSLS.
346. Phillips 1 Kees 3–19S–30W. *Schlumberger, Kansas Geol. Surv.
347. Stanolind 1 Turpin; 16–19S–31W. *Schlumberger, Kansas Geol. Surv.
348. Cities Serv. 1 Murphy; 16–20S–28W. *Schlumberger, KSLS.
349. Sun 1 Prose; 13–20S–27W. *Schlumberger, KSLS.
350. Sun 1 Ficken; 31–20S–23W. *Schlumberger, KSLS.
351. Leben Drlg. 1A Buckbee; 3–20S–22W. *Halliburton, KSLS.
352. Cities Serv. 1 Rissee; 14–20S–20W. *Schlumberger, KSLS.
353. Morrison Drlg. 1 Harper; 4–20S–18W. *Lane Wells, KSLS.
354. Texas 1 Russell; 7–20S–16W. *Schlumberger, KSLS.
355. Victor Drlg. 1 DeWerff; 32–20S–12W. *Schlumberger, KSLS.
356. Petroleum 1C Malone; 25–20S–10W. *Atlas Corp., KSLS.
359. Texas 1 Schmidt; 31–20S–3E. *Schlumberger, Kansas Geol. Surv.
360. Amerada 1 Lostutter; 1–20S–7E. *Schlumberger.

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361. Morrison Drlg. 1 Norton; 36–20S–8E. *Lane Wells, KSLS.
362. Shell 1 Johnson; 15–20S–11E. *Schlumberger, KSLS.
363. Brundred Oil 1 Louk Disposal; 2–21S–19E. *Kansas Geol. Surv.
364. C. J. Cramm and others 1 Allen; 13–21S–15E. *Kansas Geol. Surv.
365. Stanolind 1 Butler; 1–21S–13E. *Schlumberger, KSLS.
366. J. W. McKnab 1 Babbinger; 23–21S–10E. *Schlumberger.
367. Aurora Gasoline 1 Voth; 17–21S–1E. *Schlumberger, KSLS.
368. Gulf 1 Bell; 34–21S–16W. *Schlumberger.
369. Welch and Olsson Drlg. 1 Bryant; 11–21S–20W. *Schlumberger, KSLS.
370. Colorado Oil and Gas 1 Antrim; 18–21S–22W. *Schlumberger, KSLS.
371. H and H Drlg. 1 Goebel; 14–21S–24W. *Schlumberger, KSLS.
372. Metropolitan Pet. Assoc. and others 1 O'Brien; 18–21S–25W. *Schlumberger, KSLS.
373. Shell 1 Case; 7–21S–30W. *Schlumberger, Kansas Geol. Surv.
375. United Prod. 1 Staerkel; 14–22S–41W. *Schlumberger, KSLS.
376. Stanolind 1 Patterson; 23–22S–38W. *Schlumberger, Kansas Geol. Surv.
377. Shell 1 Baumann; 4–22S–29W. *Schlumberger, KSLS.
378. W. J. Coppinger and others 1 Schmitt; 23–22S–25W. *Schlumberger, KSLS.
380. Atlantic 1 Mooney; 20–22S–21W. *Schlumberger, KSLS.
381. Superior 1 Norris; 9–22S–20W. *Schlumberger, Kansas Geol. Surv.
382. Gulf 1 Wells; 27–22S–19W. *Schlumberger, KSLS.
383. Musgrove Pet. 1 Schartz; 20–22S–16W. *Schlumberger, KSLS.
384. Phillips 1 Bordewick; 1–22S–14W. *Schlumberger.
385. Transit Corp. and Lion Oil 1 Krankenburg; 19–22S–12W. *Halliburton, KSLS.
386. Atlantic 1 Sankey; 22–22S–10W. *Schlumberger, KSLS.
387. Atlantic 1 Beitler; 27–22S–8W. *Schlumberger, KSLS.
388. Beardmore Drlg. 1 Rice; 5–22S–5W. *Schlumberger, KSLS.
391. E. H. Adair 1 Wallace; 6–22S–3E. *Schlumberger, KSLS.
394. W. E. Ellis and others 3 Barngrover; 7–23S–15E. *Schlumberger.
395. J. A. Sutton and others 1 Nickel; 27–23S–2E. *Schlumberger, KSLS.
396. Jocelyn and Varn Oil 1 Linn; 27–23S–2W. *Schlumberger, KSLS.
397. Union Texas Nat. Gas 1 Hill; 27–23S–4W. *Schlumberger, KSLS.
398. Atlantic 1 Short; 14–23S–8W. *Schlumberger, KSLS.
399. K. and E. Drlg. 1 Belden; 20–23S–10W. *Schlumberger.
400. Westgate-Greenland Oil 1 Copeland; 2–23S–14W. *Schlumberger, KSLS.
401. M. B. Armer 1 Garvin; 30–23S–15W. *Schlumberger, KSLS.
403. Atlantic 1 Hall; 36–23S–22W. *Schlumberger, KSLS.
404. Champlin Oil and Ref. 4 Garden City; 18–23S–34W. *Schlumberger, KSLS.
405. Continental 1 Northup; 16–24S–23W. *Schlumberger, KSLS.
407. Twin Oil 1 Bogerd; 10–24S–18W. *Schlumberger, KSLS.
408. Nat. Cooperative Ref. Assoc. 1 Lovette; 17–24S–17W. *Schlumberger, KSLS.
409. Gulf 1 Saterlee; 31–24S–14W. *Schlumberger, KSLS.
410. Stanolind 1 Hartnett; 23–24S–11W. *USGS.

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Stanolind 6 Ferris; 23–24S–11W. *Lane Wells.
411. Manhart, Millison, and Beebe 1 Hinshaw; 17–24S–9W. *Halliburton, KSLS.
412. Stearns Drlg. 1 Milburn; 24–24S–8W. *Lane Wells, USGS.
413. Leben Drlg. 1 Webster; 15–24S–2W. *Schlumberger, KSLS.
416. Phillips 1S Cartwright; 1–24S–9E. *Halliburton.
417. Ale Oil 1 Sallyards; 27–25S–9E. *Schlumberger.
418. Cities Serv. 1S Pierpont; 33–25S–5E. *Schlumberger.
420. E. H. Adair and others 1 Childers; 14–25S–1W. *KSLS.
421. Atlantic 1 Univ., 6–25S–2W. *Schlumberger.
422. Westgate-Greenland Oil 1 Popp; 7–25S–4W. *Kansas Geol. Surv.
423. J. M. Huber 1 Haines; 5–25S–5W. *Schlumberger, Kansas Geol. Surv.
425. Midstates Oil 1 Westfahl; 16–25S–8W. *Schlumberger, KSLS.
426. Skiles Oil 1 Wright; 17–25S–9W. *Schlumberger, KSLS.
429. Isern Bros. 1 Haynes; 22–25S–15W. *Welex, KSLS.
430. Cities Serv. 1 Wokaty; 25–25S–17W. *Schlumberger, KSLS.
431. A. G. Hill Oil 1 Miller; 17–25S–19W. *Schlumberger, KSLS.
433. Bay 1C Buhrle; 4–26S–41W. *Schlumberger, KSLS.
434. Continental 1 Klaysteuber; 29–26S–31W. *Schlumberger, KSLS.
435. Colorado Oil and Gas 1 Nau; 25–26S–23W. *Schlumberger, KSLS.
436. Natural Gas and Oil 1 Craft; 15–26S–19W. *Schlumberger, KSLS.
437. Natl. Assoc. Pet. 1A Madden; 13–26S–18W. *Schlumberger, KSLS.
438. Phillips 1A Newsom; 13–26S–17W. *Schlumberger, KSLS.
439. Aurora Gasoline 1 Schultz; 21–26S–16W. *Halliburton, KSLS.
441. D. R. Lauck Oil 1 Schrack; 15–26S–13W. *Schlumberger, KSLS.
442. Bennett and Roberts 1 Hayes; 21–26S–10W. *Halliburton, KSLS.
443. Aylward Drlg. 1 Hay; 25–26S–8W. *Schlumberger, KSLS.
444. Morris Mizel 1 Knoblauch; 26–26S–5W. *Schlumberger, KSLS.
445. Champlin Oil and Ref. 1 Peltzer; 15–26S–3W. *Schlumberger, KSLS.
446. Barbara Oil 1 Simon; 20–26S–2W. *Schlumberger, KSLS.
447. British-American 1 Petrie; 36–26S–1W. *Schlumberger.
448. Kewanee 4A Schramm; 34–26S–1E. *Schlumberger.
449. Cities Serv. 1 Thacker; 27–26S–3E. *Schlumberger, KSLS.
451. Delta Oil 1 Eck; 16–27S–13E. *Elgin Corp., KSLS.
452. Delta Oil 1 Oakes; 30–27S–12E. *Elgin Corp., KSLS.
453. Kewanee Oil 1 Worley; 2–27S–9E. *Schlumberger, KSLS.
455. Morris Sitrin and others 1B Bates; 10–27S–4E. *Lane Wells.
456. Producers and Refiners 1 Turner; 30–27S–2E. *USGS.
457. Derby Oil 1 Derby; 4–27S–1E. *Schlumberger, KSLS.
458. Drillers Prod. 1 Martin; 22–27S–2W. *Welex, KSLS.
459. Rupp-Ferguson Oil 1 Scheer; 22–27S–3W. *Schlumberger, KSLS.
460. Bankoff Oil 1 Rosenhagen; 21–27S–4W. *Schlumberger, KSLS.
461. S and S Drlg. 1 Wimer; 25–27S–6W. *Welex, KSLS.
463. Gulf 1 Calista-State; 35–27S–9W. *Schlumberger, KSLS.
464. Skelly 1A Miles; 30–27S–10W. *Schlumberger.
465. Natl. Cooperative Ref. Assoc. 1 Montgomery; 1–27S–12W. *Schlumberger, KSLS.
466. Rooney and Siegfried 1 Ward; 12–27S–15W. *Welex, KSLS.

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467. M. B. Armer and others 1 Reeder; 22–27S–16W. *Halliburton, KSLS.
468. Gulf 1 Rice; 30–27S–18W. *Schlumberger, KSLS.
469. Sinclair-Prairie 1 Young; 34–27S–21W. *Lane Wells, KSLS.
471. United Prod. 1 Lane; 25–27S–41W. *Schlumberger, KSLS.
472. J. M. Huber 1 Weirauch; 23–28S–31W. *Schlumberger.
473. Champlin Oil and Ref. 1 Becker; 34–28S–29W. *Schlumberger, KSLS.
474. Skelly 1 Slocum; 2–28S–27W. *Schlumberger, Kansas Geol. Surv.
476. D. R. Lauck 1 Seyfert; 14–28S–15W. *Welex, KSLS.
477. Sinclair 1 Smith; 17–28S–13W. *Schlumberger, KSLS.
479. Brimingham and Bartlett Drlg. 1 Ralston; 6–28S–4E. *Schlumberger, KSLS.
481. Hamilton and Dunn Drlg. 1 Doggett; 10–29S–11E. *Elgin Corp., KSLS.
482. Rex and Morris 1 Mann; 6–29S–4E. *Lane Wells.
483. Stickle Drlg. 1 Farber; 32–29S–2E. *Schlumberger, KSLS.
484. Texas 1 Parsons; 30–29S–2W. *Schlumberger, KSLS.
485. Texas 1 Casner; 33–29S–4W. *Schlumberger, KSLS.
486. Anschutz Drlg. 1 Liddeke; 27–29S–5W. *Halliburton., KSLS.
487. W. E. Green 1 Brand; 16–29S–7W. *Schlumberger, KSLS.
489. Herndon Drlg. 1 Blair; 3–29S–12W. *Schlumberger, KSLS.
490. Natural Gas and Oil 1 Larrison; 26–29S–13W. *Schlumberger, KSLS.
491. Falcon-Seaboard Drlg. 1 McColm; 18–29S–21W. *Schlumberger, KSLS.
492. Texas 1 Andrews; 17–29S–23W. *Schlumberger, Kansas Geol. Surv.
493. Continental 1 Wade; 3–29S–28W. *Schlumberger, KSLS.
494. Superior 1 Wade; 30–29S–41W. *Schlumberger, KSLS.
496. Pan American 1 Watkins; 20–30S–32W. *Schlumberger, KSLS.
497. Shell 1 Statton; 12–30S–25W. *Schlumberger, KSLS.
498. Big X Drlg. 1 Taylor; 21–30S–23W. *Schlumberger, KSLS.
499. Gulf 1 Moberly; 31–30S–17W. *Schlumberger, KSLS.
500. Natl. Cooperative Ref. Assoc. and Murfin Drlg. 1 Weede; 6–30S–14W. *Schlumberger, KSLS.
503. Aurora Gasoline and Natl. Cooperative Ref. Assoc. 1 Locke; 12–30S–7W. *Welex, KSLS.
504. Sun 1 Fruend; 23–30S–3W. *Schlumberger, KSLS.
505. Sun 1 Matthews; 5–30S–1W. *Schlumberger, KSLS.
506. Champlin Oil and Ref. 1 Bevis; 13–30S–3E. *Schlumberger, KSLS.
507. K. and E. Drlg. 1 Nelson; 6–31S–13E. *Schlumberger, KSLS.
508. W. L. Hartman 1 Crowley; 3–31S–6E. *Schlumberger, KSLS.
509. Shell 8 Taton; 36–31S–2E. *Schlumberger, Lane Wells.
510. J. P. Gaty and others 1 Lawless; 14–31S–1E. *Schlumberger, KSLS.
511. Franco-Central Oil 1 Bonjour; 13–31S–1W. *Schlumberger, KSLS.
512. Producers Pipe and Supply 1 Renn; 14–31S–2W. *Welex, KSLS.
514. Aladdin Pet. 1 Johns; 34–31S–4W. *Halliburton, KSLS.
515. Gene Goff 1 Moritz; 30–31S–5W. *Schlumberger, KSLS.
517. Carter 1 Antrim; 25–31S–9W. *Schlumberger, KSLS.
518. Champlin Oil and Ref. 1 Nurse; 23–31S–13W. *Schlumberger, KSLS.
522. Gulf 1 Lorimer; 36–31S–20W. *Schlumberger, Kansas Geol. Surv.
523. Texas 1 Moore; 25–31S–22W. *Schlumberger, KSLS.
524. Gulf 1 Abell Ranch; 21–31S–23W. *Schlumberger, KSLS.

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525. Stanolind 1 Bear; 17–32S–40W. *Schlumberger.
526. Stanolind 1 Rickers; 27–32S–29W. *Schlumberger, Kansas Geol. Surv.
527. Northern Nat. Gas 1 Collingwood; 8–32S–27W. *Schlumberger, KSLS.
528. Sinclair-Prairie 1 Central Life; 23–32S–24W. *Schlumberger, KSLS.
529. Olson Oil 1 Morton; 24–32S–19W. *Schlumberger, KSLS.
530. Parker Pet. 1 Cary; 30–32S–17W. *Halliburton, KSLS.
531. Rupp-Ferguson Oil 1 Schuette; 9–32S–16W. *Halliburton, KSLS.
532. Orville H. Parker 1 Duncan; 34–32S–12W. *Halliburton, KSLS.
533. Helmerich and Payne 1 Winters; 16–32S–10W. *Schlumberger, Kansas Geol. Surv.
534. Beardmore Drlg. 1 Allen; 22–32S–9W. *Schlumberger, KSLS.
536. Sohio 1 Ayers; 16–32S–5W. *Schlumberger, KSLS.
537. Champlin Oil and Ref. 1 Lauterbach; 21–32S–2W. *Schlumberger, KSLS.
539. Aladdin Pet. 1 Beckenholdt; 13–32S–9E. *Schlumberger, KSLS.
540. Aladdin Pet. 1 Floyd Ranch; 31–32S–11E. *Schlumberger.
541. Frankfort Oil 1 Carter; 23–32S–14E. *Schlumberger.
542. W. E. Schwartz 5A Burton; 27–33S–12E. *Schlumberger.
543. Stickle Drlg. 1 Bolay; 34–33S–1W. *Schlumberger, Kansas Geol. Surv.
544. Herndon Drlg. 1 Schmidt; 30–33S–2W. *Schlumberger, KSLS.
545. E. H. Adair 1 Shobe; 29–33S–4W. *Schlumberger, KSLS.
546. Gulf 1 Rife; 31–33S–6W. *Schlumberger, KSLS.
549. Beardmore Drlg. 1 Bevans; 35–33S–12W. *Schlumberger, KSLS.
550. Lion 1 De Geer; 2–33S–15W. *Schlumberger.
551. J. M. Huber 1 Einsel; 11–33S–17W. *Schlumberger, KSLS.
552. Panhandle Devel. 1A Wheatley; 23–33S–31W. *Schlumberger, KSLS.
553. Colorado Oil and Gas 1 Central Life; 34–34S–42W. *Schlumberger, KSLS.
556. Sunray Oil 1 Harper; 21–34S–21W. *Schlumberger, KSLS.
557. J. M. Huber and Columbian Fuel 1 Lemon-Barbee; 7–34S–19W. *Schlumberger, KSLS.
558. Shell 1 Miller; 24–34S–18W. *Schlumberger, KSLS.
559. Chicago Corp. 1B Davis Ranch; 9–34S–15W. *Schlumberger, KSLS.
560. Superior 1 Ott; 6–34S–13W. *Schlumberger, KSLS.
561. Sinclair 1 Good; 35–34S–12W. *Schlumberger, KSLS.
563. William Gruenerwald 1 Hibbard; 23–34S–9W. *Schlumberger, KSLS.
564. J. M. Huber 1 Cather; 16–34S–7W. *Schlumberger, KSLS.
565. J. M. Huber 1 Misak; 21–34S–5W. *Schlumberger, Kansas Geol. Surv.
566. Gypsy Oil 1 Douglas; 23–34S–2W. *Kansas Geol. Surv.
568. Texas 1 White; 7–34S–2E. *Schlumberger, KSLS.
569. Texas 1 Booten; 21–34S–3E. *Schlumberger.
570. Salina Drlg. 1 Metz; 34–34S–5E. *Schlumberger.
571. Frankfort Oil 1 Graham; 33–34S–10E. *Schlumberger.
572. Frankfort Oil 1 Wheeler; 4–34S–15E. *Schlumberger.
573. Frankfort Oil 1 Merdith; 15–34S–17E. *Schlumberger.
574. Jayhawk Ordnance Works water well; 4–34S–25E. Abernathy, 1943, p. 77–112.
576. Dave Morgan 1 Oldham; 16–35S–4E. *Schlumberger.

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577. A. Gutowsky and others 1 Trimper; 11–35S–3E. *Schlumberger.
579. Pure 1 Meyer; 4–35S–6W. *KSLS.
580. Aurora Gasoline 1 Zellers; 10–35S–8W. *Halliburton, KSLS.
581. Chicago 1 Davis Ranch; 11–35S–15W. *Schlumberger, KSLS.
582. Eason Oil 1 O'Connell; 10–35S–17W. *Schlumberger, KSLS.
583. Veeder Supply and Devel. 1 Schumaker; 11–35S–13E. *Schlumberger, KSLS.
585. Musgrove Pet. 1 Plummer; 23–12S–35W. *Schlumberger, KSLS.
586. Flynn Oil 1 Pierce; 4–14S–38W. *Halliburton.
587. Anadarko Prod. 1 Honeywell; 7–16S–37W. *Schlumberger, KSLS.
588. Dozier Oil 1 Shearmire; 21–18S–34W. *KSLS.
589. Caulkins Oil 1 Brunswig; 6–18S–39W. *Schlumberger, KSLS.
590. Atlantic 1 McHugh; 23–21S–34W. *Schlumberger, Kansas Geol. Surv.
591. Stanolind 1 Judd; 15–21S–38W. *Schlumberger, Kansas Geol. Surv.
593. Kingwood Oil 1 Rose; 22–25S–25W. *KSLS.
594. Mobil 1 State Tract 12; 1–25S–33W. *Schlumberger.
595. W. B. Osborn 1 Johnson; 18–25S–36W. *Schlumberger, KSLS.
596. Texas 1 Seal; 9–24S–27W. *Schlumberger, Kansas Geol. Surv.
597. Phillips and Natl. Cooperative Ref. Assoc. 1A Jury; 20–26S–29W. *Schlumberger, KSLS.
599. Helmerich and Payne 17 Jones; 9–27S–34W. *Schlumberger, KSLS.
600. Shell 1–26 Fowler; 26–27S–37W. *Schlumberger, KSLS.
602. Deep Rock 1 Weatherbee; 17–29S–26W. *Schlumberger.
603. Pan American 1 Kelman; 20–29S–32W. *Schlumberger, KSLS.
604. Pan American 1 Goertzen Gas Unit, 5–29S–38W. *Schlumberger, KSLS.
605. Pan American 1 Appleton; 26–39S–29W. *Schlumberger, KSLS.
606. Cities Serv. 1C Blair; 29–30S–33W. *Welex, KSLS.
607. Hugoton Prod. 2–36 Jarvis; 36–30S–38W. *Schlumberger, KSLS.
608. Magnolia 1 Garten; 17–31S–31W. *Schlumberger.
609. Shell 1 Lahey; 21–31S–34W. *Schlumberger, KSLS.
610. Mobil 1 Cutter; 1–31S–35W. *Schlumberger, KSLS.
611. Hugoton Prod. 1 Spikes; 16–31S–38W. *Schlumberger, KSLS.
612. Pan American 1 Perkins Gas Unit; 28–31S–40W. *Schlumberger, KSLS.
614. Sinclair 1 Lemert; 21–32S–33W. *Schlumberger, KSLS.
615. Northern Nat. Gas 1A Stout; 9–32S–36W. *Schlumberger, KSLS.
616. Panhandle Eastern Pipe Line 1 Shafer; 25–32S–39W. *Schlumberger, KSLS.
617. Anadarko Prod. 1 Davies; 36–33S–32W. *Schlumberger, KSLS.
618. Panhandle Eastern Pipe Line 2 Shuck; 20–33S–34W. *Schlumberger, KSLS.
620. Skelly 1 Gabbert; 25–34S–24W. *Schlumberger, KSLS.
621. Hamilton Bros. 1 Baughman; 16–34S–34W. *Welex, KSLS.
622. J. M. Huber 1A Wallace; 13–35S–32W. *Schlumberger.
623. Stanolind 1 Feathers; 15–35S–33W. *Schlumberger, KSLS.
624. Republic Nat. Gas 1 Hanke; 6–35S–36W. *Schlumberger,

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718. Cities Serv. B-1 Greenwood; 14–33S–42W. *Schlumberger, KSLS.
719. Sun 1 Gates Ranch; 18–34S–16W. *Schlumberger, KSLS.
720. Mobil 1 Cunningham Est.; 13–34S–37W. *Schlumberger, KSLS.
721. Sunray, Sinclair, and Sun 1 Brodie; 32–32S–23W. *KSLS.

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23. 1 W. M. Berton; V–76. *Kentucky Geol. Surv.
24. Piney Oil and Gas 1 G. W. Gilbert; 23 or 24–V–78. *Kentucky Geol. Surv.
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64. C. J. Simpson 1 Michael Helminger; 20–13N–13E. *Michigan Geol. Surv., 1961.
65. William M. Joy and J. Oliver Black 1 John Tomczyk; 35–10N–16E. *Michigan Geol. Surv., 1953.
66. Melvin F. Lanphar 1 Max and Helen Graybiel; 32–8N–13E. *Michigan Geol. Surv., 1962.
67. Brown City and Peck 1 Thumb Oil and Gas Devel. Trust; 15–9N–12E. *Michigan Geol. Surv., 1938.
68. A. L. Williams 1 G. Totten; 11–9N–7E. *Michigan Geol. Surv., 1942.
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71. Edward J. Van Core 1 Edward Fleagle; 15–8N–2W. *Michigan Geol. Surv., 1940.
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73. Freeman Oil 1 Fred Loomis; 17–8N–5W. *Michigan Geol. Surv., 1942.
74. J. V. Wicklund 1 E. Z. Cutler; 10–8N–8W. *Michigan Geol. Surv., 1935.
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78. G. W. Strake 1 Winnie Van Koevering; 30–5N–13W. *Michigan Geol. Surv., 1959.
79. Producers Committee 1 George Riddering; 30–7N–12W. *Michigan Geol. Surv., 1942.
80. Muskegon Devel. 1 E. W. Ruehs; 30–5N–10W. *Michigan Geol. Surv., 1939.
81. Boston Oil and Gas 1 E. and E. Marshall; 16–6N–8W. *Michigan Geol. Surv., 1937.
82. McClure Oil 1 Greta M. McClellan; 3–4N–8W. *Michigan Geol. Surv., 1961.
83. C. P. MacDonald, Tr., 1 Louis Koeppen; 19–6N–3W. *Michigan Geol. Surv., 1939.
84. Hilmur Oil 1 Cicarlon; 28–4N–3E. *Michigan Geol. Surv., 1930.
85. E. C. Barlow 1 E. C. Barlow; 4–5N–4E. *Michigan Geol. Surv., 1941.
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88. Sunray Mid-Continent Oil 1 H. G. Richardson; 18–6W–12E. *Michigan Geol. Surv., 1960.
89. Carter 1 Ignacy Skonieczny; 15–5N–16E. *Michigan Geol. Surv., 1955.
90. Panhandle Eastern Pipe Line 1–31 Kaser; 31–4N–14E. *Michigan Geol. Surv., 1961.
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93. Arthur F. Etienne 1 J. J. Eisner; 7–2N–4E. *Michigan Geol. Surv., 1942.
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98. Wolverine Nat. Gas 1 Otis Reynolds; 25–1N–8W. *Michigan Geol. Surv., 1940.
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100. Norman L. Stevens 1 R. A. and L. M. Starback; 29–1N–15W. *Michigan Geol. Surv., 1950.
101. Whitehill and Drury 1 Ament and Webster; 35–2S–16W. *Michigan Geol. Surv., 1938.
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107. McClure Oil 1 Gumper; 19–4S–1W. *Michigan Geol. Surv., 1955.
108. John Neyer and Ray Miller 1 Dixon; 31–1S–1E. *Michigan Geol. Surv., 1960.
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110. William B. Darke 1 Lindsley; 32–4S–5E. *Michigan Geol. Surv., 1956.
111. Chesapeake and Ohio RR 1 Fee; 23–1S–8E. *Michigan Geol. Surv., 1958.
112. Bernhardt Oil and Gas 1 Frank Kain; 30–7S–6E. *Michigan Geol. Surv., 1958.
113. Neptune Oil and Gas 1 Raymond Est.; 3–9S–3E. *Michigan Geol. Surv., 1961.
114. R. G. Lawton 1 Donald Drewyor; 25–6S–2E. *Michigan Geol. Surv., 1962.
115. McClure Oil 1 Varga; 1–5S–1W. *Michigan Geol. Surv., 1955.
116. McClure Oil and Good and Good Drlg. 1 Glenn W. Plum; 35–7S–1W. *Michigan Geol. Surv., 1961.
117. W. J. Morris 1 Boyd A. Zeiter; 24–8S–4W. *Michigan Geol. Surv., 1952.
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119. McClure Oil 1 Ames; 7–6S–4W. *Michigan Geol. Surv., 1960.
120. McClure Oil 1 Van Schoick and others; 2–5S–7W. *Michigan Geol. Surv., 1957.
121. Carter 1 O. Pierce, D. K. Fowler and K. Fowler; 10–7S–7W. *Michigan Geol. Surv., 1960.
122. B. G. Hilliard and John E. Ferguson 1 E. High Krupp; 17–5S–9W. *Michigan Geol. Surv., 1960.
123. Tom McDaniel 1 John T. Ruchoft; 10–7S–12W. *Michigan Geol. Surv., 1940.

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124. F. W. Kahlet 1 Carlisle Hartsell; 26–5S–14W. *Michigan Geol. Surv., 1962.
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2. Adams Oil & Gas 1 Lewellen; 9–10S–1W. *Schlumberger, 1939.
3. G. C. Grasty 1 Kentucky Lumber, 7–10S–10E. *Welch, 1959, col. 10.
4. Walter E. Sistrunk 1 O. H. Evans; 16–11S–9E. *Welch, 1959, col. 9.
5. Walter E. Sistrunk 1 Gilmore-Puckett Lumber; 10–11S–8E. *Welch, 1959, col. 8.
6. J. F. Michael 1 Temple-Harmon Unit; 8–11S–7E. *Welch, 1959, col. 7.
7. K. A. Ellison 1 W. H. Neely; 28–11S–5E. *Schlumberger, 1953.
8. L. E. Salmon 1 Rex Patterson; 12–11S–1E. *Schlumberger, 1953.
9. Honolulu Oil 2 D. R. Davis; 27–12S–1E. *Schlumberger, 1954.
10. Justiss Mears A–1 J. W. Clarke; 19–12S–2E. *Schlumberger, 1952.
11. Union Prod. 1 Dinsmore; 28–12S–3E. *Welch, 1959, col. 3.
12. Vaughey & Vaughey 1 U.S.A.; 9–12S–4E. *Welch, 1959, col. 4.
13. Carter 1 T. O. Abernathy; 29–12S–5E. *Welch, 1959, col. 5.
14. Pure 1 E. L. Murphree; 28–12S–6E. *Welch, 1959, col. 6.
15. J. R. McLean & A. G. Hill 1 Brasfield-Boyd Unit; 31–13S–17W. *Schlumberger, 1959.
16. Magnolia Pet. 1 Bertha Pierce; 22–13S–7E. *Schlumberger, 1954.
17. Pan American Prod. 1 LeeRoy Murphree; 30–13S–6E. *Schlumberger, 1956.
18. Shell 1 J. E. McCain and others Unit; 8–13S–5E. *Schlumberger, 1960.
19. Carter 1 Fowler-Langly Unit; 22–13S–2E. *Welch, 1959, col. 2.
20. Seaboard 1 J. L. Williams; 35–13S–1E. *Welch, 1959, col. 1.
21. Phillips Pet. 1 Crawford "C"; 33–14S–2E. * Schlumberger, 1957.
22. Carter 1 Minnie S. Pulliam; 24–14S–4E. *Schlumberger, 1953.
23. Carter 1 Clem Baskin Heirs; 19–14S–5E. *Schlumberger, 1953.
24. Shell & Feazel 1 Mrs. Lee Harrington; 25–14S–6E. *Schlumberger, 1952.
25. J. R. McLean & A. G. Hill 1 R. A. Murphree; 17–14S–7E. *Schlumberger, 1959.
26. Shell 1 Dalrymple; 1–14S–19W. *Schlumberger, 1957.
27. Vaughey & Vaughey 1 Monroe Board of Supervisors; 16–14S–17W. *Schlumberger, 1954.
28. Atlantic Ref. 1 Margaret Myers; 31–15S–18W. *Schlumberger, 1954.
29. Union Prod. 1 Nancy Watson; 31–15S–7E. *Schlumberger, 1952.
30. Union Prod. 1 Neal; 21–15S–6E. *Schlumberger, 1952.
31. Union Prod. (formerly Marshall R. Young) 1 J. N. Henderson; 22–15S–4E. *Schlumberger, 1953.

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32. Shell 1 Jarrett and others; 25–16S–5E. *Schlumberger, 1958.
33. Atlantic Ref. 1 R. G. Dunning; 12–19N–16E. *Schlumberger, 1947.
34. McAlester Fuel A–1 W. P. Sudduth; 6–19N–15E. *Schlumberger, 1958.
35. Pure 1 H. W. Henry; 15–12N–15E. *Lane Wells, 1962.
36. O. W. Williams 1 Bon Adams; 33–8S–9E. *S. W. Welch, unpub. sample and E-log study.
37. L. E. Salmon 1 Wilson Est.; 29–9S–3E. *S. W. Welch, unpub. sample and E-log study, 1954.
38. William H. Pine–Eula Little; 24–10S–7E, 1956. *S. W. Welch, unpub. sample and E-log study, 1956.
39. Hass, 1956, p. 37. Tishomingo County. 2S–11E.
339. Holman and Russell 1 E. K. Thomas; 18–24N–7W. Flawn and others, 1961, p. 358, Beikman and Drakoulis, 1958a, p. 14.
340. Phillips 1 Knowlton and Perthshire; 2–24N–7W. Caplan, 1954, pl. 5. Flawn and others, 1961, p. 350. Beikman and Drakoulis, 1958a, p. 14.

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1. Revere Consolidated School well 3; 28–66N–7W. *Missouri DGSWR.
2. Birney Gosser well; 34–67N–16W. *Missouri DGSWR, 1956.
3. Cities Serv. 1 Cambel; 2–66N–38W. *Missouri DGSWR, 1961.
4. Greene, 1945, p. 37, 12–66N–39W.
5. Brunson-Spines 1 Pierce; 32–65N–41W. *Missouri DGSWR, 1961.
6. Fee 2 W. F. Rankin; 11–65N–40W. *Missouri DGSWR.
7. William Gruenwald and Associates 1 Watkins; 32–65N–-39W. *Missouri DGSWR, 1960.
8. Palensky and others 1; O. O. Wallace; 10–65N–36W. *Missouri DGSWR, 1946.
9. Greene, 1945, p. 147, 1–65N–31W.
   Grant City Oil and Gas 2 Alex Porter; 12–65N–31W. *Missouri DGSWR.
10. George Moore 1 Noel Moss; 30–65N–24W. *Missouri DGSWR.
11. Dan McLaughlin 1 Harvey Johnson; 13–65N–21W. *Missouri DGSWR.
12. R. W. Clovis–C. F. Dittman and others 1 J. W. Huston; 26–65N–19W. *Missouri DGSWR.
13. Grohskopf and others, 1939, p. 125–126. 28–65N–16W. G. Medlin and G. Mickle 1 Cassidy; 28–65N–16W. *Missouri DGSWR, 1962.
14. Morrow and Rogers 1 Mrs. J. O. Seamster; 6–65N–13W. *Missouri DGSWR.
15. A. L. Luther 1 Luther; 13–65N–12W. *Missouri DGSWR, 1959.
16. William Strickler 2 Medill; 15–65N–8W. *Missouri DGSWR, 1951.
   Richardson Well Drlg. 1(?) W. H. Ayers; 23–65N–9W. *Missouri DGSWR, 1962.
17. Black and Black Oil 1 William Scalf; 4–65N–7W. *Missouri DGSWR.
18. St. Joe Lead 1 St. Francisville; 5–65N–8W. *Missouri DGSWR.
19. Schlicher Well Drillers 1(?) Lester Kirchner; 26–64N–7W. *Missouri DGSWR, 1954.
20. Midland Oil 1 A. J. Ammons; 10–64N–10W. *Missouri DGSWR.

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21. Cities Serv. 1 James; 13–64N–13W. *Missouri DGSWR, 1962.
22. Cities Serv. 1 Cragg; 21–64N–14W. *Missouri DGSWR.
23. J. W. Eddington 1 Johnson-Capps; 31–64N–15W. *Missouri DGSWR.
24. Morrow and Rodgers 1 J. A. Cooley; 33–64N–17W. *Missouri DGSWR.
24a. Cities Serv. 1 (core hole 6) Fechtling; 1–64N–17W. *Missouri DGSWR, 1962.
25. R. H. Van Hoose 1 W. J. Watson; 26–64N–21W. *Missouri DGSWR.
26. McQueen and Greene, 1938, p. 162–163, 5–64N–26W.
27. Palensky and others 1 J. M. Slagle and Son; 13–64N–33W. *Missouri DGSWR, 1947.
28. Grunerwald 1 Weedin; 33–64N–40W. *Missouri DGSWR, 1959.
29. J. E. Palensky and Son 1 Christian; 16–63N–41W. *Missouri DGSWR, 1958.
30. Roger F. Williams 1 Seymour; 16–63N–40W. *Missouri DGSWR, 1961.
31. Stanolind 1 W. A. McDonald; 30–63N–34W. *Missouri DGSWR, 1944.
32. McQueen and Greene, 1938, p. 159–160, 9–63N–28W.
33. J. W. Eddington 1 and 2 H. W. Clark; 8–63N–14W. *Missouri DGSWR.
34. Mayson Oil 1 McGonigle; 20–63N–13W. *Missouri DGSWR.
35. Grohskopf and others, 1939, pl. 1. 26–63N–12W.
36. Cities Serv. 1 (core hole No. 3) Corbin; 24–63N–11W. *Missouri DGSWR, 1962.
37. Richmond Well Drlg. 1(?) Williamston School; 28–63N–8W. *Missouri DGSWR, 1961.
38. Grohskopf and others, 1939, p. 64–65, 14–62N–6W.
39. Richmond Well Drlg. 1(?)McReynolds; 27–62N–9W. *Missouri DGSWR, 1961.
   Platte Oil 1 Everett Hayden; 29–62N–9W. *Missouri DGSWR.
40. L. O. Hill 1 Schemmp; 21–62N–10W. *Missouri DGSWR, 1962.
   H. A. Black 1 E. Schemmp; 21–62N–10W. *Missouri DGSWR.
41. Kenneth Hagerly well 1; 30–62N–11W. *Missouri DGSWR, 1948.
42. Inland Oil and Gas B W. H. Nooning; 3–62N–13W. *Co. record, 1908.
43. Cities Serv. 1 (core hole 4c) Draper; 13–62N–14W. *Missouri DGSWR.
44. Ward McGinnis 1 G. W. Laughlin; 18–62N–15W. *Missouri DGSWR.
45. H. V. Elwell and others 1 Taylor; 12–62N–21W. *Missouri DGSWR.
46. Greene, 1945, p. 94–99. 3–62N–26W.
47. Greene, 1945, p. 115–119. 30–62N–38W.
48. Thorsen and Pebley 1 Roy Grant; 23–62N–40W. *Missouri DGSWR.
49. Greene, 1945, p. 108–114, 1–61N–38W.
50. Percy F. Garey 1 Patterson; 11–61N–37W. *Missouri DGSWR, 1956, 1959.
51. H. L. and L. Devel. Co. 1(?) Malinda Lackey; 8–61N–15W. *Missouri DGSWR.
52. Johnson Oil 1 Harold Early; 16–61N–12W. *Missouri DGSWR.
   Reinke and Oberthein 1 Frank Campbell; 18–61N–12W. *Missouri DGSWR.

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53. Frank A. Schaffer well 1; 11–61N–11W. *Missouri DGSWR, 1955.
54. W. H. Thomas well 2; 31–61N–5W. *Co. record, 1888.
55. Richmond Well Drlg. 1 Kenneth Toliver; 7–60N–7W. *Missouri DGSWR.
56. Cities Serv. 1 Scoggin; 26–60N–10W. *Missouri DGSWR, 1961.
57. A. V. Steelman 1 H. C. Palmer; 15–60N–11W. *Missouri DGSWR.
58. Greene, 1945, p. 17–23, 28–60N–35W.
59. Greene, 1945, p. 104–107, 32–60N–37W.
60. Garey and others 1 Windle; 13–59N–39W. *Missouri DGSWR, 1961.
61. McQueene and Greene, 1938, p. 169–176. 4–59N–38W.
62. McQueen and Greene, 1938, p. 105–107. 8–59N–35W.
63. Greene, 1945, p. 87–94. 18–59N–32W.
64. McQueen and Greene, 1938, p. 151–153. 5–59N–27W.
65. Ethel Consolidated School Dist. well 1; 30–59N–16W. *Missouri DGSWR, 1954.
66. Grohskopf and others, 1939, p. 104–105. 10–59N–14W.
67. Art Kassner and others 1 R. G. Thrasher; 16–59N–10W. *Missouri DGSWR, 1961.
68. Ed Wright 1 Enoch Turner; 27–59N–9W. *Missouri DGSWR.
69. Cities Serv. 1 Fichtner; 21–59N–8W. *Missouri DGSWR.
70. Fabius River Devel. 1 Charles Tate; 22–59N–6W. *Missouri DGSWR, 1938.
71. Grohskopf and others, 1939, p. 112–113. 36–58N–6W.
72. Illinois Oil 1 Filling Station at Shelbyville; 20–58N–10W. *Missouri DGSWR.
73. Grohskopf and others, 1939, p. 87–88. 28–58N–23W.
74. Walter Chenault and others 1 Glen Dice; 2–58N–30W. *Missouri DGSWR, 1952.
75. Greene, 1945, p. 81–87. 30–58N–31W.
76. Ohio 1 A. J. Schneider; 18–58N–33W. *Missouri DGSWR.
78. Greene, 1945, p. 39–45, 24–57N–35W.
79. Grohskopf and others, 1939, p. 120–124. 21–57N–34W.
    F. O. McCain 1 Frank Bermond; 26–58N–34W. *Missouri DGSWR.
80. McQueen and Greene, 1938, p. 149, 23–57N–32W.
81. Greene, 1945, p. 69. 11–57N–31W.
82. E. L. Thorne and Lee E. Williams 1 O'Neal; 10–57N–26W. *Missouri DGSWR.
83. Grohskopf and others, 1939, p. 84–85. 2–57N–24W.
84. Marceline Gas Oil and Devel. (G. W. Early and others) 1 S. Landreth; 30–57N–18W. *Missouri DGSWR, 1933.
85. McGee, 1888, p. 326–333. 22–57N–14W.
86. General Field Serv. 1 Luke Smoot; 20–57N–8W. *Missouri DGSWR, 1962.
87. Koenig and others, 1961, p. 45. 28–57N–4W.
88. Koenig and others, 1961, p. 40. 11–56N–4W.
89. D. C. Chickadonz and J. P. Donnell and others 1 Turner; 3–56N–8W. *Missouri DGSWR, 1950.
90. General Field Serv. 1 Welch Greenwell; 4–56N–10W. *Missouri DGSWR.
91. R. Y. Powell 1 College Mound oil test; 28–56N–15W. *Co. record, 1907.
93. Greene, 1945, p. 122–126. 15–56N–23W.
94. Fell and others 1 Harper-Whitaker; 28–56N–30W. *Missouri DGSWR, 1952.
95. Fell and others 1 Arthur Deaver; 34–56N–31W. *Missouri DGSWR.
96. McQueen and Greene, 1938, p. 117–120. 32–56N–35W.

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97. Ohio 1 Poston (Meek); 29–55N–35W. *Missouri DGSWR, 1941.
98. Carter 1 McQueen; 2–55N–34W. *Missouri DGSWR.
99. Greene, 1945, p. 64–69. 18–55N–31W.
100. Todd and Luehring 1 J. H. Benson; 30–55N–29W. *Missouri DGSWR.
101. McQueen and Greene, 1938, p. 130–131. 4–55N–26W.
102. Missouri Blue Hill Oil 1 William O'Roark; 21–55N–24W. *Missouri DGSWR.
102a. E. W. Littrell well; 33–55N–20W. *Missouri DGSWR.
103. Prairie Hill School well; 32–55N–16W. *Missouri DGSWR, 1950.
104. Boy Scout Thunder Bird Camp well 2; 23–55N–13W. *Missouri DGSWR, 1959.
106. E. D. Coleman well; 13–55N–9W. *Missouri DGSWR, 1941.
     Northwestern Mutual Life Ins. 1 Levings; 17–55N–9W. *Missouri DGSWR, 1941.
107. R. E. Sydenstricker 1(?) Elliot Key; 36–55N–8W. *Missouri DGSWR, 1955.
108. Lloyd Longenman well; 34–55N–7W. *Missouri DGSWR, 1953.
109. Fred E. Hollingsworth and C. R. Bailey 1 E. O. Laird; 34–55N–5W. *Missouri DGSWR, 1955.
110. Atlas Portland Cement 1 Jones; 28–55N–4W. *Missouri DGSWR, 1963.
111. Koenig and others, 1961, p. 36. 12–55N–3W.
112. Koenig and others, 1961, p. 33. 20–54N–1W.
113. Koenig and others, 1961, p. 37–38. 27–54N–2W.
114. Koenig and others, 1961, p. 19. 13–54N–5W.
115. Mac Frys well; 28–54N–7W. *Missouri DGSWR.
116. Hohn Drlg. 1(?) City of Madison; 14–54N–12W. *Missouri DGSWR, 1960.
117. Huntsville Sinclair Min. 1 Fee; 32–54N–14W. *Missouri DGSWR.
118. Collinson and McHenry 1 Kirk; 15–53N–36W. *Missouri DGSWR, 1963.
119. Greene, 1945, p. 140–145, 16–53N–34W.
120. J. H. Turner & Berry Bros. 1 B. H. Rule; 20–53N–33W. Greene, 1945, p. 134–140.
121. Eastern Drlg. Co. 1 D. W. Williams. 28–53N–32W. Greene, 1945, p. 60–64.
122. McQueen and Greene, 1938, p. 199. 29–53N–28W.
     Greene, 1945, p. 146–147. 8–53N–28W.
123. Campbell and others 1 L. I. Rust; 21–53N–26W. *Missouri DGSWR.
124. Frank Buttram 1 Vance Bros.; 35–53N–18W. *Missouri DGSWR.
125. Layne-Western 1(?) American Telephone and Telegraph; 19–53N–10W. *Missouri DGSWR.
126. Fee 1 Jesse L. Wilson; 27–53N–9W. *Missouri DGSWR.
127. Vandalia Drlg. 2 Melvin; 34–53N–7W. *Missouri DGSWR, 1956.
128. Vandalia Drlg. 1(?) Mrs. Georgie Bryant; 22–53N–5W. *Missouri DGSWR, 1952.
129. Moore, 1928, p. 72. 53N–1E.
130. Frank Davidson well; 26–52N–1W. *Missouri DGSWR, 1941.
131. John T. Bradley well; 4–52N–4W. *Missouri DGSWR, 1963.
132. Charles Stack 1(?) Vandalia Reorganized School Dist. 2; 7–52N–5W. *Missouri DGSWR.
133. Thorp Well 1(?) City of Farbee; 21–52N–6W. *Missouri DGSWR, 1962.

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134. J. T. Watts (?) R–3 School Dist.; 16–52N–9W. *Missouri DGSWR, 1963.
135. K. E. Wallace 1(?) City of Clark; 23–52N–13W. *Missouri DGSWR.
136. C. R. Gallemore 1 Buckler; 22–52N–14W. *Missouri DGSWR.
137. Fee 1 James Pyle; 14–52N–16W. *Missouri DGSWR.
138. Fee 1 Harry Tickmeyer; 16–52N–17W. *Missouri DGSWR, 1938.
139. J. L. Gordon well; 20–52N–19W. *Missouri DGSWR, 1948.
140. R. E. Garnett well; 26–52N–20W. *Missouri DGSWR, 1947.
141. R. E. Lightfoot well; 5–52N–21W. *Missouri DGSWR.
142. MacVicar, Rood, and Marion 1 Carlos Bricken; 8–52N–22W. *Missouri DGSWR, 1948.
143. Greene, 1945, p. 145. 14–52N–26W.
144. McQueen and Greene, 1938, p. 138–140. 1–52N–30W.
145. Greene, 1945, p. 56–60. 36–52N–32W.
146. McQueen and Green, 1938, p. 189–190. 29–52N–34W.
147. Reed and Fell 1 Fred Klamm; 19–51N–33W. *Missouri DGSWR, 1945.
148. August W. Luehmann well; 32–51N–26W. *Missouri DGSWR, 1955.
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228. Pan American 1 Navajo B; 10–31N–19W. *AmStrat.
229. Humble 1–C Navajo; 8–31N–18W. *AmStrat.
230. Honolulu 1 Navajo; 6–31N–17W. *AmStrat.
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234. Continental 1 Unit; 13–30N–21W. *AmStrat.
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243. Shell 113–17 Carson Unit; 17–25N–11W. *AmStrat.
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288. A. G. Hill 1 Federal A; 27–9N–19E. *R. B. Johnson, USGS.
289. General Crude 1; 21–10N–23E. *R. B. Johnson, USGS.
290. General Crude 1–1 State; 2–8N–23E. *PBSL.
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292. Sid Katz 1 Mabel Field; 12–1N–22E. *PBSL.
293. Woolworth Hawkins 1 Myrick; 17–2N–25E. *PBSL.
294. Pure 1 Federal Pure; 31–3N–28E. *PBSL.
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6. James H. Snowden 1 M. A. Morrison; 34–130N–103W. *AmStrat.
8. General Atlas 1 Ketterling; 15–131N–73W. *AmStrat.
9. Ohio 1 Standing Rock Sioux Tribal; 29–131N–80W. *AmStrat.
10. T and O Oil 1 Ohlhauser; 132N–78W. *AmStrat.
13. Roeser and Pendleton 1 Weber; 35–133N–76W. *AmStrat.
14. Youngblood and Youngblood 1 Kelstrom; 26–133N–83W. *AmStrat.
15. Mobil F–22–30–P Cruise; 30–134N–75W. *AmStrat.
16. Socony-Vacuum F–14–24 Jacobs; 24–134N–96W. *AmStrat.
18. Calvert 1 Craig; 25–136N–71W. *AmStrat.
19. Hunt Trust Est. and others 1 Fuller; 6–136N–73W. *AmStrat.
22. Caroline Hunt Trust 1 Nicholson; 32–137N–77W. *AmStrat.
23. Amerada 1 Louis Koppinger; 20–137N–95W. *AmStrat.
26. Calvert Explor. 1 Wanzek; 12–139N–67W. *AmStrat.
28. Caroline Hunt 1 Schlabach-State; 36–139N–76W. *AmStrat.
29. Deep Rock 1 H. Johnson "A"; 30–139N–86W. *AmStrat.
30. Pan American 1 Raymond Vetter; 27–139N–90W. *AmStrat.
31. Hunt 1 Kudrna; 20–139N–97W. *AmStrat.
32. Amerada 1 Dan Cheadle; 9–139N–100W. *DSL Serv.
33. Continental-Pure 1 Dronen; 9–140N–75W. *AmStrat.
35. Hunt 1 Paul Tyberg; 23–140N–79W. *AmStrat.
37. Sinclair 1 Joseph Muecke; 29–140N–94W. *AmStrat.
38. Blackwood and Nichols 1 Gilman no. 1; 15–140N–105W. NWGS no. 231.
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40. Magnolia 1 State "A"; 36–141N–73W. *AmStrat.
41. Youngblood and Youngblood 1 Wachter; 3–141N–81W. *AmStrat.
42. Socony-Vacuum F–42–6–F; Dvorak 6–141N–94W. *NWGS 269.
44. General Atlas 1 Peplinski; 21–142N–63W. *NWGS.

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49. Carter 1 State; 16–143N–71W. *AmStrat.
50. Amerada 1 Marie Selle; 27–143N–92W. *AmStrat.
52. Shell NPRR 41x–5–1 Federal; 5–143N–101W. *AmStrat.
54. Caroline Hunt 1 Board of Univ. and School Lands; 36–144N–75W. *AmStrat.
55. Hunt 1 Anton Novy; 14–144N–77W. *AmStrat.
56. Williston Oil and Gas Co. 1 Boeckel and others; 10–144N–88W. *Billings Geol. Serv.
58. Shell NP 32–16–1 State; 16–145N–101W. *AmStrat.
59. T. M. Evans 1 F. L. Bailey; 26–145N–62W. *AmStrat.
60. Evans Prod. 1 Chris Erickson; 24–145N–64W. *Billings Geol. Serv.
62. Cardinal 1 Graves Federal Land Bank; 23–146N–66W. *AmStrat.
65. Continental 1 Lueth; 27–146N–73W. *AmStrat.
67. Caroline Hunt Trust 1 Bauer; 19–146N–76W. *AmStrat.
68. Herman Hanson Oil, Synd. 1 N. D. Hanson; 2–146N–81W. *AmStrat.
70. Stewart 1 Jack Dvirnak; 20–146N–96W. *AmStrat.
72. C. Hunt Trust Est. 1 Norris Thormadsgard; 31–147N–71W. *AmStrat.
73. C. Hunt Trust Est. 1 J. R. Matz; 1–147N–75W. *AmStrat.
74. Mayfair Minerals 1 Edward Lockwood; 5–147N–93W. *AmStrat.
75. Wetch-Zachmeier-Disney 1 Ceblaskey; 9–148N–62W. *AmStrat.
78. Amerada 1 U.S.A. Reed; 18–148N–95W. *AmStrat.
80. Gulf-Sun 1 Bennie Pierre Federal; 28–148N–104W. *AmStrat.
83. Mobil F–22–22–1 Bird Bear and others; 22–149N–91W. *AmStrat.
87. Calvert Explor. 1 State; 16–150N–67W. *AmStrat.
88. Hunt Trust 1 Obed Larson; 32–150N–70W. *AmStrat.
89. Stanolind 1 McLean County; 28–150N–80W. *AmStrat.
91. Gulf 1 L. Bird's Bill; 30–150N–94W. *AmStrat.
98. Texas 1 Koeser–NCT–1; 35–151N–97W. *AmStrat.
101. W. H. Hunt 1 Neumann; 33–152N–82W. *AmStrat.
103. Stanolind 1 Louis Drags Wolf; 28–152N–94W. *AmStrat.
107. Phillips-Gulf-Skelly 1 Hoehn; 13–152N–102W. *AmStrat.
114. Stanolind 1 Walter Waswick; 2–153N–85W. *AmStrat.
119. Carter 1 Allyn Mac Diarmid; 16–154N–65W. *AmStrat.
120. Natl. Bulk Carrier–Smith and Summers 1 Stadum; 31–154N–70W. *AmStrat.
122. Calvert Drlg. 1 Wright; 14–154N–78W. *AmStrat.
123. California 1 Kamp; 3–154N–96W. *AmStrat.
124. Texas 1 Donahue; 23–154N–100W. *NWGS.
128. W. H. Hunt 1 W. and D. Dunham; 24–155N–90W. *NWGS.
132. Lion (Monsanto) 1 Ed; 26–156N–77W. *AmStrat.
134. Quintana 1 Chris Linnertz; 33–156N–83W. *AmStrat.
137. Champlin Ref. 1 Tank; 7–156N–96W. *AmStrat.
139. Charles Rhodes 1 R. R. Gibbons; 17–157N–65W. *AmStrat.
140. Shell 1 Gifford Marchus; 23–157N–70W. *AmStrat.
142. Harrison 1 J. H. Anderson and others; 21–157N–85W. *NWGS.
143. W. H. Hunt 1 L. C. Anderson; 25–157N–89W. *AmStrat.
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151. Ajax 1 Bell; 28–158N–72W. *AmStrat.
152. California 1 Martha Thompson; 7–158N–81W. *AmStrat.
153. Amerada 3 Clifford-Hanson; 18–158N–94W. *AmStrat.
158. Midwest Explor. 1 Union Life Ins.; 24–160N–67W. *AmStrat.
160. Lion 1 Nelson; 22–160N–72W. *AmStrat.
162. California 1 Blanche Thompson; 31–160N–81W. *AmStrat.
164. Pure 1 Gunderson (OWDD); 11–160N–98W. *AmStrat.
165. Los Nietos Union 1 Ellis; 12–161N–60W. *AmStrat.
169. Cardinal 1 Joseph Andrieux; 2–161N–74W. *AmStrat.
170. California 4 Bert Henry; 6–161N–79W. *AmStrat.
172. Calvert 1 Oscar Johnson; 13–161N–85W. *AmStrat.
173. Sun 1 William Wayne; 20–162N–69W. *AmStrat.
175. Lion 1 Wallace; 14–162N–76W. *AmStrat.
177. Dakamont Explor. 1 Jacobson; 6–162N–96W. *AmStrat.
178. Kerr-McGee and Argo 1 Johnson Est.; 34–162N–101W. *AmStrat.
181. Lion 1 Nodak; 36–163N–73W. *AmStrat.
182. Lion (Monsanto) Tomahawk 1 Pilloud; 7–163N–74W. *AmStrat.
183. Calvert and others 1 L. T. Hanson; 30–163N–78W. *AmStrat.
184. Carter 1 D. Moore; 7–163N–102W. *AmStrat.
186. Pan American 1 Huber; 15–145N–91W. *AmStrat.
188. Wright and Pollard 1 Guscette; 20–142N–61W. *Billings Geol. Serv.
190. Powers Lake 1 G. A. Vincent, Wild; 21–159N–57W. *NWGS.
191. Hunt 1 Peter Lenertz; 17–153N–77W. *Billings Geol. Serv.
192. Frazier-Conroy Drlg. 1 Sarah-Dunbar; 13–146N–63W. *Billings Geol. Serv.
194. Champlin Ref. 1 Elmer Heim; 12–133N–65W. *Billings Geol. Serv.
195. S. D. Johnson 1 John Rath, Jr.; 30–137N–67W. *Billings Geol. Serv.
196. Hunt 1 Shoemaker; 3–157N–78W. *Billings Geol. Serv.
197. Caroline Hunt 1 Soder Investment; 31–142N–76W. *Schlumberger.
198. Western Nat. Gas 1 Truax-Traer; 13–132N–102W. *Lane Radioactivity Log Wells.
199. Phillips 1 Phillips-Carter Dakota; 29–136N–81E. *Schlumberger.
200. Rhodes-Langenfeld 1 Frank Murphy; 18–163N–65W. *Schlumberger.
201. Union Oil of California 1 Arne Saari; 35–161N–68W. *Schlumberger.

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35. C. B. Smith and Son 2 E. D. Mackall; Columbiana 15′ quad. *Ohio Geol. Surv.
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42. Ward and Co. 2 Douglas Gates. New Matamoras 15′ quad. *Ohio Geol. Surv.
43. Pawnee 5 Summit County Poor Farm. Kent 15′ quad. *Ohio Geol. Surv.
44. Ohio 1 O. and E. Hines. Urichsville 15′ quad. *Ohio Geol. Surv.
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47. Belmont Quad. Drlg. 1 Charles Zimmer. Cambridge 15′ quad. *Ohio Geol. Surv.
48. Tri-State 1 E. O. Bond. Cumberland 15′ quad. *Ohio Geol. Surv.
49. Ohio Fuel Gas 1 E. H. Derry. Conesville 15′ quad. *Ohio Geol. Surv.
50. Clyde M. Foraker 1 Charles W. Dearth. McConnelsville 15′ quad. *Ohio Geol. Surv.
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52. Sinclair-Prairie 1 W. T. Longworth. Keno 15′ quad. *Ohio Geol. Surv.
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54. Ohio Fuel Gas 1 J. H. Glynn. West Salem 15′ quad. *Ohio Geol. Surv.
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64. Carl Curtis 1 J. C. Larimer. Logan 15′ quad. *Ohio Geol. Surv.
65. Ohio Fuel Gas 1 Eugene F. Reasoner. Zaleski 15′ quad. *Ohio Geol. Surv.
66. Townsend Watkins Oil 2 James Queen. Wilkesville 15′ quad. *Ohio Geol. Surv.
67. H. K. Porter 1 Orvil Jones. Bidwell 15′ quad. *Ohio Geol. Surv.
68. Bertha M. Burnett well 1. Athalia 15′ quad. *Ohio Geol. Surv.
69. Ironton Portland Cement 1 Fee. Ironton 15′ quad. *Ohio Geol. Surv.
70. Trenton Gas 2 Joseph Hamer. Oak Hill 15′ quad. *Ohio Geol. Surv.
71. Ohio Fuel Gas 2–5125 Belle M. Buckley. Oak Hill 15′ quad. *Ohio Geol. Surv.
72. Pittsburg Gas 1 W. A. Jackson, Jackson 15′ quad. *Ohio Geol. Surv.
73. F. P. Hurst 1 McKeal. Jackson 15′ quad. *Ohio Geol. Surv.
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2. Union Oil of California 1 Hoffman; 30–29N–19W. *MCGS (DSL).
3. Champlin Ref. 1 Diamund; 17–29N–17W. *MCGS (DSL).
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13. Bay Pet. and Josaling Pet. 1 Hoover; 14–29N–3W. *MCGS (DSL).
14. Pure 1 Lutz; 14–29N–2W. *MCGS.
15. Boren 1 Oklahoma School Lands; 33–29N–1W. *MCGS.
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37. Continental 1 Maltbie; 8–28N–9W. *MCGS (AmStrat).
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39. Thornton, 1958, p. 62.
40. Allied Materials 1 Morrow; 32–28N–16W. *MCGS.
41. Gulf 1 Zimmerman; 12–28N–18W. *MCGS (DSL).
42. Calvert Drlg. 1 Dodson; 9–28N–20W. *MCGS.
43. Ohio 1 Yank; 27–28N–21W. *MCGS (DSL).
44. Sinclair 1 Holcomb; 7–28N–22W. *MCGS.
45. Deep Rock 1 Lamunyon; 21–28N–24W. *W. L. Adkison, USGS.
46. Hoffman, 1964, p. 9, sec. 25. *MCGS.
47. Hamilton Bros. 1–32 Bennett; 32–27N–21W. *MCGS.
48. McDermott 1 Morrow; 19–27N–16W. *MCGS (AmStrat).

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49. Thornton, 1958, p. 63.
50. Mabee 1 Brown; 29–27N–8W. *MCGS (DSL).
51. Thornton, 1958, p. 47, no. 7.
52. Thornton, 1958, p. 56.
53. Thornton, 1958, p. 51, no. 11.
54. Davis and Wharton 1 Bohan; 21–27N–4W. *MCGS (AmStrat).
55. Duncan 1 Durland; 5–27N–3W. *MCGS (DSL).
56. Texas 1 Tolle Heirs; 5–27N–2W. *MCGS (DSL).
57. Texas 1 Shepherd; 24–27N–2W. *MCGS (DSL).
58. Manahan 1 Bowman; 35–27N–1E. *MCGS (DSL).
59. Rhoades, 1968, p. 61–62.
60. Rhoades, 1968, p. 66–67.
61. Rhoades, 1968, p. 62–63.
62. Rhoades, 1968, p. 67. 5–27N–10E.
63. Kitchen, 1963, p. 49.
64. Kitchen, 1963, p. 64.
65. Kitchen, 1963, p. 78.
66. Strong, 1961, p. 203.
67. Thrall 1 Davis; 13–27N–23E. *Oklahoma Geol. Surv. (Shell).
68. Strong, 1961, p. 205.
69. Strong, 1961, p. 157.
70. Kitchen, 1963, p. 87.
71. Rhoades, 1968, p. 55–56.
72. Rhoades, 1968, p. 51–53.
73. Olson 1 Osage; 23–26N–4E. *Oklahoma Geol. Surv. (Shell).
74. Marshall and others 1 Hermes; 6–26N–4E. *Oklahoma Geol. Surv. (Shell).
75. T. M. Evans and others 1 Esch; 35–26N–1W. *MCGS (DSL).
76. Aberdeen Pet. 1 Burke; 27–26N–2W. *MCGS (DSL).
77. Helmerich and Payne 1 Bolger; 36–26N–4W. *MCGS (DSL).
78. Thornton, 1958, p. 52, no. 12.
79. Eason 1 Hudson; 14–26N–6W. *MCGS (DSL).
80. Thornton, 1958, p. 46, no. 6.
81. Phillips 1 Sandra; 8–26N–15W. *MCGS (AmStrat).
82. Deep Rock 1 Phillips; 4–26N–17W. *MCGS (DSL).
82. Deep Rock 1 Phillips; 4–26N–17W. *MCGS (DSL).
83. Sunray Mid-Continent 1 Klinger; 12–25N–26W. *MCGS.
84. Hoffman, 1964, p. 8, sec. 23. *MCGS.
85. Gulf 1 Shade; 31–25N–14W. *MCGS.
86. Thornton, 1958, p. 64, no. 23.
87. Thornton, 1958, p. 45, no. 5.
88. Samedon 1 Wilson; 4–25N–7W. *MCGS.
89. Cummings-McIntyre 1 Combs; 6–25N–5W. *MCGS (DSL).
90. Thornton, 1958, p. 55.
91. Thornton, 1958, p. 53, no. 13.
92. McCaughey 1 Park and others; 25–25N–4W. *MCGS (DSL).
93. Weimer and Fitzhugh 1 Proctor; 9–25N–3W. *MCGS (AmStrat).
94. Calvert Drlg. 1 Herbig; 15–25N–2W. *MCGS (AmStrat).
95. Wico Oil 1 Scott; 8–25N–1W. *MCGS.
96. Sinclair 1 Cromer; 9–25N–1E. *MCGS (DSL).
97. Sinclair 1 Buffalo; 30–25N–8E. *Oklahoma Geol. Surv. (Shell).
98. Glenn, 1963, p. 46. 6–25N–11E.
99. Glenn, 1963, p. 47. 25–25N–11E.
100. Glenn, 1963, p. 66. 7–25N–13E.
101. Glenn, 1963, p. 67. 7–25N–14E.
102. Glenn, 1963, p. 67. 4–25N–16E.
103. Strong, 1961, p. 161.
104. Strong, 1961, p. 163.
105. Glenn, 1963, p. 70. 12–24N–15E.

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106. Glenn, 1963, p. 74. 31–24N–13E.
107. Glenn, 1963, p. 73. 25–24N–11E.
108. Glenn, 1963, p. 48. 8–24N–11E.
109. Texas 1 Eberwine; 22–24N–6E. *Oklahoma Geol. Surv. (Shell).
110. Texas 1 Thompson; 8–24N–4E. *MCGS (DSL).
111. Gulf and others 1 Hon; 34–24N–1E. *Oklahoma Geol. Surv. (Shell).
112. McDuffie, 1962, p. 17. 23–24N–2W.
113. McDuffie, 1962, p. 17. 22–24N–3W.
114. McDuffie, 1962, p. 16. 1–24N–5W.
115. Sunray Mid-Continent 1 Hermansky; 32–24N–5W. *MCGS.
116. McDuffie, 1962, p. 16. 5–24N–6W.
117. McDuffie, 1962, p. 16. 28–24N–7W.
118. McDuffie, 1962, p. 16. 7–24N–8W.
119. Adkison and Sheldon, 1963, p. 30.
120. Gulf and others 1 Bentley; 21–24N–12W. *MCGS.
121. Thornton, 1958, p. 66.
122. Texoma Prod. 1 Bur. of Land Management; 22–24N–16W. *MCGS.
123. Hottinger-Zavoico 1 State; 32–24N–17W. *MCGS (AmStrat).
124. Hoffman, 1964, p. 8, sec. 4. *MCGS.
125. Sun 1 Cooper Unit "E". *MCGS.
Hoffman, 1964, p. 16.
126. Hoffman, 1964, p. 9, sec. 24.
Sinclair 1 Berry. *MCGS (DSL).
127. Hoffman, 1964, p. 12, sec. 3.
128. Parker 1 Hensley; 21–23N–18W. *MCGS.
129. Blackwell Zins 1 McBride; 7–23N–14W. *MCGS.
130. Thornton, 1958, p. 42.
131. Amerada 1 Rexroat; 14–23N–11W. *MCGS.
132. Adkison and Sheldon, 1963, p. 36.
133. McDuffie, 1962, p. 20. 16–23N–7W.
134. McDuffie, 1962, p. 19. 23–23N–6W.
135. McDuffie, 1962, p. 17. 5–23N–4W.
136. Deep Rock 1 Dunn; 15–23N–3W. *MCGS (DSL).
137. McDuffie, 1962, p. 17. 24–23N–2W.
138. Stanolind 1 Henke; 25–23N–1W. *Oklahoma Geol. Surv. (Shell).
139. Glenn, 1963, p. 52. 28–23N–11E.
140. Glenn, 1963, p. 75. 18–23N–12E.
141. Glenn, 1963, p. 63–64.
142. Strong, 1961, p. 165.
143. Strong, 1961, p. 169.
144. Strong, 1961, p. 172.
145. Glenn, 1963, p. 76. 25–22N–14E.
146. Glenn, 1963, p. 64–65.
147. Glenn, 1963, p. 55. 33–22N–11E.
148. Guffey and Gillispie 1; 9–22N–10E. *Oklahoma Geol. Surv. (Shell).
149. Martin 1 Gilbert; 24–22N–2E. *Oklahoma Geol. Surv. (Shell).
150. Morgan 1 Wentz; 12–22N–1E. *Oklahoma Geol. Surv. (Shell).
151. Deep Rock A–1 Miller; 26–22N–1W. *MCGS (DSL).
152. McDuffie, 1962, p. 17. 19–22N–1W.
153. McDuffie, 1962, p. 19. 28–22N–4W.
154. McDuffie, 1962, p. 19. 17–22N–5W.
155. Frankfort 1 Dulick; 32–22N–6W.
Hoffman, 1964, p. 7. *MCGS.
156. Adkison and Sheldon, 1963, p. 38.
157. Thornton, 1958, p. 40.

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158. Woodward 1 Walker; 34–22N–13W. *MCGS (AmStrat).
159. Pan American 1 Noble Unit "C".
Hoffman, 1964, p. 7, *MCGS.
160. Thornton, 1958, p. 37.
161. Pan American 1 Harris; 12–22N–16W. *MCGS.
162. Signal 1 Bradshaw; 27–22N–17W. *MCGS (DSL).
163. Union of California 1 Sherman; 13–22N–20W. *MCGS.
164. Gulf 1 Wichert; 14–21N–13W. *MCGS.
165. Gulf 1 Turner; 2–21N–7W. *B. R. Haley, USGS.
166. McDuffie, 1962, p. 19. 17–21N–7W.
167. McDuffie, 1962, p. 18. 34–21N–6W.
168. McDuffie, 1962, p. 18. 21–21N–4W.
169. Halliburton 1 Luckenbaugh; 19–21N–3W. *MCGS (AmStrat).
170. McDuffie, 1962, p. 19. 12–21N–3W.
171. Fleet and Richardson 1 Wagner; 25–21N–2W. *MCGS (DSL).
172. F. L. Bishop and Lynn Drlg. 1 Cress; 4–21N–1E. *MCGS (AmStrat).
173. Boyle 1 Ritthalter; 29–21N–2E. *MCGS (DSL).
174. Harper-Turner 1 Stokes; 32–21N–4E. *MCGS (DSL).
175. Hyde, 1957, p. 50.
176. Krueger, 1957, p. 90. 17–21N–10E.
176a. Sun 1 Perryman; 21–3N–22W. *Ware and Kapner.
177. Krueger, 1957, p. 91. 29–21N–11E.
178. Krueger, 1957, p. 94. 6–21N–10E.
179. Krueger, 1957, p. 95. 2–21N–15E.
180. Strong, 1961, p. 194.
181. Strong, 1961, p. 182.
182. Strong, 1961, p. 177.
183. Krueger, 1957, p. 87. 28–20N–14E.
184. Krueger, 1957, p. 86. 31–20N–13E.
185. Krueger, 1957, p. 84. 1–20N–11E.
186. Krueger, 1957, p. 82. 9–20N–10E.
187. Hyde, 1957, p. 49.
188. Hyde, 1957, p. 50.
189. McDuffie, 1962, p. 18. 19–20N–1W.
190. McDuffie, 1962, p. 18. 1–20N–3W.
191. Olson Oil 1 Caudle; 27–20N–3W. *MCGS (DSL).
192. Delaney 1 Cline; 22–20N–4W. *MCGS (AmStrat).
193. McDuffie, 1962, p. 18. 2–20N–5W.
194. Hoffman, 1964, p. 7, sec. 14. *MCGS.
195. Hunt and Altus 1 Munkers; 16–20N–9W. *MCGS (DSL).
196. White Eagle 1 Westfahl; 16–20N–10W. *MCGS.
197. Hoffman, 1964, p. 13, sec. 8. *MCGS (DSL).
198. Hoffman, 1964, p. 13, sec. 7. *MCGS.
199. Hoffman, 1964, p. 7, sec. 19. *MCGS (DSL).
200. Magnolia 1A Borden; 22–20N–20W. *MCGS (AmStrat).
201. Rowland, 1962, p. 18–19.
202. Rowland, 1962, p. 19–20.
203. King Stevenson 1 Kirkham; 14–19N–14W. *MCGS.
204. Rowland, 1962, p. 21. 19–9N–11W.
205. Adkison and Sheldon, 1963, p. 54.
206. Rowland, 1962, p. 21. 26–19N–9W.
207. Calvert Drlg. 1 Binkley; 6–19N–8W. *MCGS.
208. Rowland, 1962, p. 23. 11–19N–7W.
209. Barbre 1 Faqua; 21–19N–5W. *MCGS (DSL).
210. Schermerhorn 1 Bridal; 5–19N–4W. *MCGS (DSL).
211. Rowland, 1962, p. 25. 11–19N–2W.
212. Rowland, 1962, p. 23. 35–19N–2W.
213. Breco 1 Wilcox.
Rowland, 1962, p. 23. 25–19N–1W.
214. Wilcox 1 Brown; 12–19N–1E. *MCGS (DSL).

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215. Warren Bradshaw and others 1 Walkere; 12–19N–2E. *MCGS (DSL).
216. Heinzelmann, 1957, p. 53.
217. Hyde, 1957, p. 51. 5–19N–5E.
219. Hyde, 1957, p. 51. 33–19N–8E.
220. Hyde, 1957, p. 48.
221. Hyde, 1957, p. 52.
222. Krueger, 1957, p. 76. 19–19N–11E.
223. Krueger, 1957, p. 77. 26–19N–11E.
224. Krueger, 1957, p. 78. 18–19N–12E.
225. Krueger, 1957, p. 79. 23–19N–13E.
226. Krueger, 1957, p. 80. 10–19N–14E.
227. Strong, 1961, p. 180.
228. Strong, 1961, p. 200.
229. Darnell, 1958.
230. Krueger, 1957, p. 73. 23–18N–15E.
231. Krueger, 1957, p. 71. 11–18N–13E.
232. Krueger, 1957, p. 68. 9–18N–12E.
233. Graybol 1 Walke; 1–18N–10E. *Louise Jordan, Oklahoma Geol. Surv.
234. Krueger, 1957, p. 64. 32–18N–10E.
235. Hyde, 1957, p. 46.
236. Heinzelmann, 1957. p. 56.
237. Rowland, 1962, p. 25. 24–18N–1W.
238. Zephyr Pet. 1 Cravens; 17–18N–2W. *MCGS (DSL).
239. Rowland, 1962, p. 22–23. 17–18N–3W.
240. Danciger 1 Knecht; 21–18N–4W. *Oklahoma Geol. Surv. (Shell).
241. Rowland, 1962, p. 22. 23–18N–5W.
242. Rowland, 1962, p. 22. 30–18N–7W.
243. Rowland, 1962, p. 21–22.
244. Adkison and Sheldon, 1963, p. 64.
245. Hoffman, 1964, p. 17. *MCGS.
246. Rowland, 1962, p. 20–21.
247. Hoffman, 1964, p. 7, sec. 13. *MCGS.
248. Rowland, 1962, p. 22. 1–17N–7W.
249. Rowland, 1962, p. 24–25.
250. Kirkpatrick Oil 1 Brow; 20–17N–3W. *MCGS.
251. Rowland, 1962, p. 25. 7–17N–2W.
252. Mohawk Drlg. 1 Washington; 25–17N–1W. *MCGS.
253. British-American 1 Gibson; 8–17N–2E. *Oklahoma Geol. Surv. (Shell).
254. Heinzelmann, 1957, p. 60.
255. Heinzelmann, 1957, p. 66.
256. Hyde, 1957, p. 45.
257. Krueger, 1957, p. 47. 22–17N–11E.
258. Krueger, 1957, p. 52. 33–17N–12E.
259. Krueger, 1957, p. 56. 27–17N–13E.
260. Krueger, 1957, p. 56. 19–17N–15E.
261. Darnell, 1957, p. 47.
262. Darnell, 1957, p. 44.
263. Darnell, 1957, p. 41.
264. Darnell, 1957, p. 75.
265. Darnell, 1957, p. 73.
266. Darnell, 1957, p. 49.
267. Wood Oil 1 Miller; 32–16N–14E. *Louise Jordan, Oklahoma Geol. Surv., 1962.
268. Mid-Continent 1 Beets; 1–16N–1OE. *Louise Jordan, Oklahoma Geol. Surv., 1955.
269. Hyde, 1957, p. 44. 33–16N–9E.
270. Trigg 1 Jennings; 18–16N–8E. *Oklahoma Geol. Surv. (Shell).
271. Flynn 1 Johnson; 1–16N–5E. *Oklahoma Geol. Surv. (Shell).

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272. Heinzelmann, 1957, p. 71.
273. Lewis 1 Thomas; 31–16N–3E. *MCGS (DSL).
274. Herndon 1 Griffith; 17–16N–2E. *MCGS (DSL).
275. O'Rourke-Baker 1 Cassidy; 20–16N–1W. *MCGS (DSL).
276. Oil Capitol 1 Katschor; 18–16N–2W. *MCGS.
277. Rowland, 1962, p. 25. 7–16N–3W.
278. Harper-Turner 1 Zatchyo; 17–16N–4W. *MCGS (AmStrat).
279. Rowland, 1962, p. 25. 28–16N–5W.
280. Rowland, 1962, p. 24. 15–16N–6W.
281. Magnolia 1 Miller; 22–15N–16W. *MCGS.
282. Mobil 1 Dobbins; 9–15N–15W. *MCGS.
283. Rowland, 1962, p. 23. 14–15N–8W.
284. MacMillan-Blackwood, Nichols 1 Krout; 14–15N–4W. *MCGS (DSL).
285. Long and Unger 1 Bohanan; 34–15N–3W. *MCGS (AmStrat).
286. Davidor and Davidor 1 Harned; 4–15N–2W. *MCGS (DSL).
287. Zypher and Alpha 1 Filbury; 26–15N–2W. *MCGS (DSL).
288. Harper-Turnee and others 1 Sharum; 7–15N–1W. *MCGS (DSL).
289. Mizel Bros. 1 Stewart; 20–15N–1E. *MCGS (DSL).
290. Heinzelmann, 1957, p. 75.
291. Sherry 1 Childers; 2–15N–7E. *Oklahoma Geol. Surv. (Shell).
292. Silurian 1 Ireland; 25–15N–9E. *Oklahoma Geol. Surv. (Shell).
293. Bryan 1–A Davis; 21–15N–11E. *Oklahoma Geol. Surv. (Shell).
294. Lambert 1–A Darby; 29–15N–14E. *Oklahoma Geol. Surv. (Shell).
295. Huffman, 1958, p. 173.
296. Matlock 1 Ramsey; 19–15N–26E. *Oklahoma Geol. Surv. (Shell).
297. Huffman, 1958, p. 160.
298. Texaco 19 Fee NTC 2; 11–14N–11E. *Louise Jordan, Oklahoma Geol. Surv., 1961.
299. Vierson 1 Kimball; 13–14N–10E. *Oklahoma Geol. Surv. (Shell).
300. Smith 1 Tiger; 25–14N–9E. *Oklahoma Geol. Surv. (Shell).
301. Shamblin and others 1 Lumm; 8–14N–8E. *Oklahoma Geol. Surv. (Shell).
302. Mid-Continent 1 Bear; 3–14N–7E. *Oklahoma Geol. Surv. (Shell).
303. Heinzelmann, 1957, p. 96.
304. Heinzelmann, 1957, p. 91.
305. Heinzelmann, 1957, p. 80.
306. Heinzelmann, 1957, p. 86.
307. Heinzelmann, 1957, p. 81.
308. Eason 1 Hough; 21–14N–1E. *MCGS (DSL).
309. Ellzey, 1961, p. 14. 22–14N–5W.
310. Sinclair 1 Treece; 24–14N–6W. *MCGS.
311. Hoffman, 1964, p. 7, sec. 17. *MCGS.
312. Ellzey, 1961, p. 14. 22–13N–7W.
313. Ellzey, 1961, p. 14. 2–13N–6W.
314. Pan America 1 Kay Bee Investment; 23–13N–5W. *MCGS.
315. Manahan 1 Zawisza; 34–13N–2E. *MCGS. (DSL).
316. Stanolind and others 1 Strader; 8–13N–3E. *Oklahoma Geol. Surv. (Shell).
317. Fullerton 1 State; 36–13N–3E. *MCGS. (DSL).
318. Clark and Marshall Nye 1 Richardson; 23–13N–4E. *MCGS (DSL).
319. Berry and Johnson 1 Schooland; 16–13N–5E. *Oklahoma Geol. Surv. (Shell).

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320. Amerada 1 Long; 12–13N–6E. *Oklahoma Geol. Surv. (Shell).
321. Mid-Continent 1 Stokes; 20–13N–8E. *Oklahoma Geol. Surv. (Shell).
322. Sinclair-Prairie 1 Davis; 9–13N–10E. *Oklahoma Geol. Surv. (Shell).
323. Kennedy and others 1 Dugger; 10–13N–11E. *Oklahoma Geol. Surv. (Shell).
324. Welch and Logan 10 Chully; 14–13N–12E. *Louise Jordan, Oklahoma Geol. Surv., 1962.
325. Colton-Phillips 1 Wheeler; 20–13N–13E. *Oklahoma Geol. Surv. (Shell).
326. Gled Oil 1–A Fox; 22–13N–14E. *Oklahoma Geol. Surv. (Shell).
327. Manhart, Millison, and Beebe 1 Philbrook; 6–13N–15E. *Oklahoma Geol. Surv. (Shell).
328. U.S.S.R.A.M. 1 Marshall; 23–13N–19E. *Oklahoma Geol. Surv. (Shell).
329. Wilson 1–24 Govt.; 24–13N–21E. *S. E. Frezon, USGS.
330. Huffman, 1958, p. 124.
331. Harris 1 Cheek; 19–12N–25E. *MCGS.
332. Lohman-Johnson 2 Cook; 8–12N–24E. *R. J. Lantz, USGS.
333. Thompson 1 Ruby; 30–12N–22E. *Oklahoma Geol. Surv. (Shell).
334. Oklahoma Oil 1–A Wolfe; 35–12N–17E. *Oklahoma Geol. Surv. (Shell).
335. Scruggs 1 Laning; 19–12N–15E. *Oklahoma Geol. Surv. (Shell).
336. Hamon and Cox 19 Reynolds; 26–12N–13E. *Louise Jordan, Oklahoma Geol. Surv., 1962.
337. Colton-Phillips 1–A Wilson; 10–12N–12E. *Oklahoma Geol. Surv. (Shell).
338. Carter and others 1 Yarhola; 9–12N–11E. *Oklahoma Geol. Surv. (Shell).
339. Tulsa Oil and Gas 1 Palmer; 3–12N–9E. *Oklahoma Geol. Surv. (Shell).
340. Monahan 1 Replogle; 15–12N–8E. *MCGS (DSL).
341. Alma Oil 1 Martin; 4–12N–7E. *Oklahoma Geol. Surv. (Shell).
342. Ramsey 1 Parks; 22–12N–6E. *Oklahoma Geol. Surv. (Shell).
343. Gulf 1 Henthorne; 1–12N–4E. *MCGS (DSL).
344. Mid-Continent 1 Fowler; 33–12N–4E. *Oklahoma Geol. Surv. (Shell).
345. Carlock 1 Kirschner; 15–12N–5W. *MCGS (DSL).
346. Ellzey, 1961, p. 14. 14–12N–7W.
347. Cities Serv. 1 Porter "B"; 5–12N–8W. *MCGS.
348. Ellzey, 1961, p. 11. 12–11N–11W.
349. Woodward 1 Sterrett; 9–11N–5W. *MCGS.
350. Stanolind 1 Hood; 9–11N–2E. *MCGS (DSL).
351. Deep Rock and others 1 Rose; 26–11N–2E. *Oklahoma Geol. Surv. (Shell).
352. Sun 1 Allenbaugh; 18–11N–4E. *MCGS (DSL).
353. Mid-Continent 1 Ne-Thah-Pea-Se; 24–11N–4E. *Oklahoma Geol. Surv. (Shell).
354. Summit Drlg. 1 Good; 4–11N–5E. *Oklahoma Geol. Surv. (Shell).
355. Vierson 1 Meyers; 1–11N–6E. *Oklahoma Geol. Surv. (Shell).
356. Woodson 1 Gilliland; 24–11N–7E. *Oklahoma Geol. Surv. (Shell).
357. Seran 3 Seran; 2–11N–8E. *Oklahoma Geol. Surv. (Shell).

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358. Replogle 1 Lehmer; 3–11N–9E. *Oklahoma Geol. Surv. (Shell).
359. Merrick 1 Cook; 29–11N–10E. *Oklahoma Geol. Surv. (Shell).
360. Phillips 1 Wood; 31–11N–13E. *Oklahoma Geol. Surv. (Shell).
361. Wigdon 2 Koch; 15–11N–15E. *Oklahoma Geol. Surv. (Shell).
362. Tidewater Oil 1 Sizemore-Winkle; 25–11N–17E. *MCGS.
363. Frezon, 1962, pl. 1. 31–11N–19E.
364. Harris 1 Standifer; 5–11N–20E. *MCGS.
365. Frezon, 1962, pl. 1. 5–11N–23E.
366. Frezon, 1962, pl. 1. 23–11N–25E.
367. Frezon, 1962, pl. 1. 3–10N–21E.
368. Frezon, 1962, pl. 1. 18–10N–18E.
369. Frezon, 1962, pl. 1. 30–10N–16E.
370. Phillips 1 Blankenship; 33–10N–13E. *Oklahoma Geol. Surv. (Shell).
371. Commercial Oil 1 Jones; 13–10N–10E. *Oklahoma Geol. Surv. (Shell).
372. Burke-Greis 1 Rhae; 14–10N–9E. *Oklahoma Geol. Surv. (Shell).
373. Chapman-McFarland 4 Deatherage; 1–10N–8E. *Oklahoma Geol. Surv. (Shell).
374. Stanolind-Amerada 1 Buck; 11–10N–7E. *Oklahoma Geol. Surv. (Shell).
375. Pace 1 Marine; 18–10N–6E. *Oklahoma Geol. Surv. (Shell).
376. Atlantic and others 1 Schooland; 36–10N–4E. *Oklahoma Geol. Surv. (Shell).
377. Stanolind 2 Goodman; 5–10N–4E. *Oklahoma Geol. Surv. (Shell).
378. Hall-Jordan 1 Whitehead; 36–10N–3E. *Oklahoma Geol. Surv. (Shell).
379. Stanolind 1 Miller; 21–10N–3W. *MCGS.
380. Olson Drlg. 1 Theimer; 6–10N–5W. *MCGS (DLS).
381. Adkison and Sheldon, 1963, p. 105.
382. Jordan and others, 1962.
383. Weidman, 1932, p. 63.
384. Weidman, 1932, p. 67.
385. Reed, Schoff, and Branson, 1955, p. 148.
386. Howell, Holloway, and Howell 1 Anadarko Basin; 4–9N–12W. *Ellzey, 1961, p. 11.
387. Humble 1 Harris; 7–9N–5W. *MCGS.
388. Petroleum 1 Crowder; 14–9N–3W. *MCGS.
389. Smith Bros. 1 Dawson; 6–9N–3E. *Oklahoma Geol. Surv. (Shell).
390. Amerada 1 Grounds; 22–9N–5E. *Oklahoma Geol. Surv. (Shell).
391. Justin Oil 1 Rhea; 12–9N–6E. *Oklahoma Geol. Surv. (Shell).
392. Stanolind 1 Aldridge; 22–9N–8E. *Oklahoma Geol. Surv. (Shell).
393. Potco 1 Morrison; 13–9N–10E. *Oklahoma Geol. Surv. (Shell).
394. Frezon, 1962, pl. 1. 12–9N–13E.
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TENNESSEE — Continued

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88. Milhous, 1959, p. 117–119. 11–15S–3E.
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205. Milhous, 1959, p. 153–154. 16–A–56E.
206. Milhous, 1959, p. 165–166, 12–A–55E.
207. Milhous, 1959, p. 413, 1–A–54E.
208. Milhous, 1959, p. 416, 25–B–53E.
209. Milhous, 1959, p. 407–408. 25–B–52E.
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211. Milhous, 1959, p. 55, 24–A–45E.
212. Klepser, 1937, pl. 3. Overton, Clay, and Jackson Counties.
213. Hiers, 1950, p. 11–43.
214. Butts, 1919, p. 14.
215. Butts, 1919, p. 19.
216. Butts, 1919, p. 14.
217. *P. R. Vail, Tennessee Div. Geol., 1955, secs. 34, 35. Fentress County.
218. Milhous, 1959, p. 167–168, 17–1S–55E.
219. Milhous, 1959, p. 495–496, 5–1S–60E.
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224. *P. R. Vail, Tennessee Div. Geol., 1955, sample study 383, 10–3S–60E.
225. Milhous, 1959, p. 452–453, 23–2S–59E.
226. Forest Oil 3 Rugby Land Co.; 14–2S–58E. Milhous, 1959, p. 125.
227. Norwood P. Johnson 1 Gernt; 16–2S–57E. Milhous, 1959, p. 126.
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229. Milhous, 1959, p. 137–138. 2–2S–54E.
230. Adams and others, 1926, pl. 49, p. 162. Overton County. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 60., 2S–51E.
231. Butts, 1919, p. 14.
232. Klepser, 1937, pl. 3. SW. Overton, SE. Jackson Counties.

TENNESSEE — Continued

233. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 52. Overton County.
234. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 37. Fentress County.
235. Travis Smith and others 1 Beatty and Harris; 17–3S–55E. Milhous, 1959, p. 149–150. *P. R. Vail, Tennessee Div. Geol., 1955, sample study 331.
236. Milhous, 1959, p. 323–324. 16–3S–57E.
237. Payne and others 1 Sam Galloway; 14–3S–58E. Milhous 1959, p. 316.
U.S. Oil 1 O. K. Hammond; 14–3S–58E. *P. R. Vail, Tennessee Div. Geol., 1955(?), sample study 690.
238. Milhous, 1959, p. 345–347. 15–3S–59E.
239. Milhous, 1959, p. 450–451. 25–3S–60E.
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241. McCallum, 1958. 3S–64E.
242. Philley, 1961. 3S–72E.
243. Byerly, 1957. 5S–65E.
244. Nelson Oil and Gas 1 Boos; 4–5S–64E. *P. R. Vail Tennessee Div. Geol., 1955(?), sample study 997.
245. *Milhous, 1959, p. 317–320. 8–4S–58E.
246. Nelson, 1925, p. 37. Putnam County.
247. Klepser, 1937, pl. 3. Putnam County.
248. Klepser, 1937, pl. 3. Smith and Putnam Counties.
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250. Macel and others 1 S. G. Sutton; 1–7S–54E. *P. R. Vail, Tennessee Div. Geol., 1955(?), sample study 648.
251. Stearns, 1954, p. 12. Peavine Mtn., Cumberland County.
252. Milhous, 1959, p. 320–321. 4–5S–58E.
253. Elder 1956. 7S–62E.
254. Harding, 1957. 8S–59E.
255. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 44. Also R. G. Stearns, 1954, p. 13. Cumberland County.
256. Shell 1 Peterson; 2–8S–56E. Milhous, 1959, p. 80. *P. R. Vail Tennessee Div. Geol., 1955(?), sample study 1011.
257. Rackow, Zimmerlee and Co. 1 Forbes; 18–7S–54E. Milhous, 1959, p. 66.
258. Kingwood 1 Harrison; 12–8S–53E. Milhous, 1959, p. 77–79. *P. R. Vail, Tennessee Div. Geol., 1955(?), sample study 343.
259. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 39. W. of Bon Air, White County.
260. Tennessee Oil and Gas 1 J. T. Keithly; 9–8S–49E. Milhous, 1959, p. 589.
261. Adams and others, 1926, pl. 49, p. 162. 7S–49E.
262. Peterson, 1962, p. 12, sec. 76. 6S–49E.
263. Peterson, 1962, p. 12, sec. 78. Hass, 1956, p. 29, well 74. 6S–48E.
264. Klepser, 1937, pl. 3. De Kalb and White Counties.
265. Klepser, 1937, pl. 3. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 57. De Kalb and White Counties.
266. Klepser, 1937, pl. 3. White, De Kalb, and Warren Counties.
267. Peterson, 1962, pl. 12. 8,9S–48,49E.
268. Keith, 1895. 11S–68E.
269. Hayes, 1894, 9S–58E.
270. Martin, 1941.
271. Milhous, 1959, p. 10–11. 22–9S–52E.
272. Peterson, 1962, p. 12, sec. 57(B). 10S–50E.
273. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 40. Spencer, Van Buren County.
274. Milhous, 1959, p. 560–561. 2–10S–48E.

TENNESSEE — Continued

275. Consolidated Drlg. 1 H. I. Dotson; 25–10S–46E. *Milhous, 1959, p. 567.
R. S. Lord 1 Frank S. McGee; 17–10S–46E. Milhous, 1959, p. 569.
276. Dome Oil and Gas 1 Gilliam Smith; 12–10S–45E. Milhous, 1959, p. 566.
277. Klepser, 1937, pl. 3. Cannon and Coffee Counties.
278. Peterson, 1962, p. 11, sec. 75.
279. Milhous, 1959, p. 569–571. 8–11S–46E.
280. Bean, 1942. Bledsoe County.
281. Bean, 1942. Rhea County.
282. Priddy, 1936. Rhea County.
283. Gilbert, 1957. 13S–54E.
284. Peterson, 1962, p. 12, sec. 5. 12S–53E.
285. Milhous, 1959, p. 561–562. 5–12S–49E.
286. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 42. Warren County.
287. Consolidated Drlg. 1 Howard Cope; 6–12S–46E. Milhous, 1959, p. 566.
288. Jervian 1 Gordon McCorkle; 18–11S–45E. Milhous, 1959, p. 574.
289. Klepser, 1937, pl. 3. Coffee and Moore Counties.
290. Tennessee Oil and Gas 3 C. E. Price; 13S–41E. Milhous, 1959, p. 64.
291. Peterson, 1962, p. 11, sec. 80. 14S–44E.
292. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 15. Grundy County.
293. Sequatchie Gas 1 Sewanee Iron and Fuel Co.; 17–14S–46E. Milhous, 1959, p. 178.
294. Beatty and Harris 1 Travis Smith; 15–14S–48E. *P. R. Vail, Tennessee Div. Geol., 1955(?), sample study 434.
295. Hayes, 1894.
296. Peterson, 1962, p. 11. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 7. 15–45E.
297. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 1. Marion County.
298. Klepser, 1937, pl. 3. Franklin, Moore, and Lincoln Counties.
299. *M. N. A. Peterson, Tennessee Div. Geol., 1955(?), secs. 73 and 74. 18S–41E.
300. Peterson, 1962, p. 11, sec. 58. 17S–42E.
301. Adams and others, 1926, pl. 49, sec. 17.
302. Adams and others, 1926, pl. 49, sec. 16; Nelson, 1925, p. 28; Peterson, 1962, p. 11. Sherwood, Franklin County.
303. *Peterson and Barnes, Tennessee Div. Geol., 1955(?), secs. 62 and 65.
304. *Peterson and Barnes, Tennessee Div. Geol., 1955(?), sec. 64.
305. Frink, 1946, p. 588. Also Conant and Swanson, 1961, pl. 7, well 222.
306. Hass, 1956, p. 36, well 226. *P. R. Vail, Tennessee Div. Geol., 1955, sec. 12.
307. Hayes, 1894. Hass, 1954, p. 36, well 228.
308. Swingle, 1959, p. 104. 17S–55E.
309. Hass, 1956, p. 28, well 54.
310. Hass, 1956, p. 13, well 9S.
311. Hass, 1956, p. 30, well 89.
312. Hass, 1956, p. 14, well 100.
313. Hass, 1956, p. 31, well 107.
314. Hass, 1956, p. 35, well 220.
315. Hass, 1956, p. 31, well 126a.
316. Hass, 1956, p. 35–36, well 225.

TEXAS

ANDREWS

559. Forest 1 Lineberry; Andrews. *PBSL.
560. Magnolia 1 Peay; Andrews. *PBSL.
561. Stanolind 1 Univ. of Texas "BN"; Andrews. *PBSL.
562. Continental 1 Univ. "6–17"; Andrews. *PBSL.
563. Phillips 1 Texas Univ. "TT"; Andrews. *PBSL.
564. Texas 1 Texas "AX"; Andrews. *PBSL.
565. Skelly 1 Means; Andrews. *PBSL.
566. Texas 1 Texas-Mabee; Andrews. *PBSL.
567. Placid and Gulf 1 Thornberry; Andrews. *PBSL.
568. Shell–Cities Serv. 8 King; Andrews. *PBSL.
569. Stanolind 1 Midland Farms "AE"; Andrews. *PBSL.
570. Anderson-Prichard 1 Fasken "H–2"; Andrews. *PBSL.
571. Stanolind 1 Cowden; Andrews. *PBSL.
572. Plymouth, Helmerick, and Payne 1–28 Fasken; Andrews. *PBSL.

ARCHER

240. Kadane and Sons 1 W. J. Frey "E"; Archer. *NTSLS.
241. Texas 1 J. B. Ferguson; Archer. *NTSLS.
242. Petrex 1–A49 Petrex; Archer. *NTSLS.
243. Bay 1 W. M. McGreagor; Archer. *NTSLS.
244. White Eagle 1 Sebring; Archer. *NTSLS.
245. Austral 1–B Parkey Ranch; Archer. *NTSLS.
246. Sztykgold 1 Peyson; Archer. *NTSLS.
247. Deep Rock 1 L. T. Key; Archer. *NTSLS.
248. Tennessee Gas Trans. 1 E. E. Treet; Archer. *NTSLS.
249. Perkins and Cullum 1–D Titken; Archer. *NTSLS.
250. Feldman 1 Tuberville; Archer. *NTSLS.
251. Burns 1 F. Brezina; Archer. *NTSLS.

ARMSTRONG

53. Standard of Texas A–1 A. L. Palm; Armstrong. *TPSLS, 1952.
54. Placid 1 Matheson; Armstrong. *TPSLS.
55. Stanolind 1 Corbin; Armstrong. *TPSLS, 1952.
56. Hassie Hunt Trust 1 M. Helms; Armstrong. *TPSLS, 1952.
57. Burdell 1 McGehee; Armstrong. *TPSLS, 1954.
58. H. L. Hunt 4 Ritchie; Armstrong. *TPSLS, 1952.
59. Hassie Hunt 1 J. A. Cattle Co.; Armstrong. *TPSLS.
60. Hunt 8 Ritchie; Armstrong. *TPSLS.

BAILEY

117. Lion 1 Birdwell; Bailey. *TPSLS.
118. Phillips 1 Stephens "A"; Bailey. *PBSL.
119. Shell 1 Nichols; Bailey. *TPSLS.

BANDERA

1036. General Crude 1 S. H. Anderson; Bandera. Flawn and others, 1961, p. 211. *WCTSLS.
1037. Rossman (Stan-Ross) 1 Goodenough; Bandera. Flawn and others, 1961, p. 213.
1038. H. L. McBride 1 Fee; Bandera. Flawn and others, 1961, p. 211–212.
1039. Plateau (Peerless) Oil 1 R. D. Garrison; Bandera. Flawn and others, 1961, p. 212–213.
1040. Humble 1 Thompson; Bandera. Flawn and others, 1961, p. 211.

BAYLOR

228. Pure 1 W. T. Waggoner "B"; Baylor. *NTSLS.
229. Pure D–1 W. T. Waggoner; Baylor. *NTSLS.
230. Pure 1–BB W. T. Waggoner; Baylor. *NTSLS.

TEXAS — Continued

BAYLOR — Continued

231. Humble 4–S Waggoner Est.; Baylor. *NTSLS.
232. Texas 1A Waggoner; Baylor. *NTSLS.
233. Harper and Turner 1 Arledge; Baylor. *NTSLS.
234. Deep Rock 1 A. F. Wirz; Baylor. *NTSLS.
235. Lynn B–1 C. Cowan; Baylor. *NTSLS.
236. Continental 1 J. H. Thomas; Baylor. *NTSLS.
237. Burk Royalty 1 Fayette County School Land "A"; Baylor. *NTSLS.
238. Robinson-Puckett 1 L. L. Stout; Baylor. *NTSLS.
239. Rycade 1 J. H. Jenkins; Baylor. *NTSLS.

BELL

871. A. B. Johnson 1 F. C. Howard; Bell. Flawn and others, 1961, p. 218.
872. Rio Grande Oil 1 D. W. Hair; Bell. Flawn and others, 1961, p. 220.
873. U. S. Army 1 McCloskey Hospital; Bell. Flawn and others, 1961, p. 221–222.
874. Dunham 1 J. E. Hunt; Bell. *WCTSLS.
875. Shell 1 C. E. Massie; Bell. *WCTSLS.
876. Shamrock and Casey 1 Sudie Baugh; Bell. Flawn and others, 1961, p. 220.
877. J. B. Hartman 1 B. F. Warrick; Bell. Flawn and others, 1961, p. 217.

BEXAR

1041. Mid-Tex Prod. 1 C. G. Walker; Bexar. Flawn and others, 1961, p. 226.
1042. Hickok and Reynolds 1 Ewert; Bexar. Flawn and others, 1961, p. 225. *WCTSLS.
1043. Gas Ridge Synd. (Clark Oil) 1 Pepper; Bexar. Flawn and others, 1961, p. 224.

BLANCO

975. Plummer, 1950, p. 23; Blanco. Battle Branch.
976. Cloud and Barnes, 1946, p. 308–317; Blanco. Johnson City area.
977. Johnson (R. A. Rodson and others) 1 Glasscock; Blanco. Flawn and others, 1961, p. 229.
978. R. K. Blumberg 1 Wagner; Blanco. Flawn and others, 1961, p. 228.
979. E. L. Nixon 2 Hohenberger; Blanco. Flawn and others, 1961, p. 230.
980. Theodore Hicks 1 Albert Specht; Blanco. Flawn and others, 1961, p. 228.

BORDEN

464. Phillips 1 Dennis "A"; Borden. *PL.
465. Sinclair 1 Sterling Williams; Borden. *PL.
466. Double U Oil 1 Spinnler "A"; Borden. *PBSL.
467. Helmerich and Payne 1 Dorward; Borden. *PBSL.
468. Amerada 1 J. R. Canning; Borden. *PBSL.
469. Shell 1 Clayton and Johnson; Borden. * PBSL.
470. Standard of Texas 1 T. L. Griffin "6"; Borden. * PL.

BOSQUE

765. Closuit 1 "Fee"; Bosque. *WCTSLS.
766. H. C. Plumley 1 Lynch; Bosque. *WCTSLS.
767. McKinzie 1 Fee; Bosque. *WCTSLS.
768. American Republics 1 F. T. Shaffer; Bosque. *WCTSLS.
769. Buie and others 1 A. M. Anderson; Bosque. *WCTSLS.

TEXAS — Continued

BOSQUE — Continued

770. Southland and others 1 R. T. Greenwade; Bosque. *WCTSLS.
771. American Liberty 1 Reichert; Bosque. *WCTSLS.

BOWIE

319. A. M. Sutton 1 J. G. Newkirk; Bowie. Flawn and others, 1961, p. 233.
320. J. K. Wadley 1 Bently Johnson; Bowie. Flawn and others, 1961, p. 233.

BREWSTER

1148. Floyd C. Dodson and others 1 Texas American Synd.; Brewster. *PL, 1959.
1149. Pure 1 Massie West; Brewster. *PL, 1956.
1150. E. B. Clark Drlg. and others 1 Catto-Gage; Brewster. *PL, 1963.
1151. King, 1937, p. 56–65; Brewster.
1152. Sun 1 Nellie Mae McElroy; Brewster. *PL, 1956.

BRISCOE

93. Hassie Hunt and Standard of Texas 1 W. D. Owens; Briscoe. *TPSLS, 1952.
94. H. L. Hunt 9 Ritchie; Briscoe. *TPSLS, 1952.
95. Hunt 2 Ritchie; Briscoe. *TPSLS.
96. Amarillo Oil 1 Bryant Edwards "B"; Briscoe. * TPSLS, 1958.
97. H. L. Hunt 3 Ritchie; Briscoe. * TPSLS, 1952.
98. Gulf 1 Rodgers "D"; Briscoe. *TPSLS, 1956.
99. Humble 1 Howard Ranch; Briscoe. *TPSLS, 1959.
100. H. L. Hunt 10 Ritchie; Briscoe. *TPSLS, 1952.
101. Midstates 1 Hickok and Reynolds Royalty Co.; Briscoe. *TPSLS, 1951.
102. Amerada 1 J. C. Hamilton; Briscoe. *TPSLS, 1951.

BROWN

734. Lyda Johnson 1 G. C. Gass; Brown. *WCTSLS.
735. Lone Star 1 R. W. Smith; Brown. *WCTSLS.
736. Edgell 1 W. S. Richmond; Brown. *WCTSLS.
737. Empire Gas and Fuel 1 Fuller; Brown. Abilene Geol. Soc., 1949.
738. Lone Star 1 J. Shannon Heirs; Brown. *WCTSLS.
739. J. M. Johnson 1 Billy Barr; Brown. *WCTSLS.

BURNET

935. E. A. Dunham and Hensman Drlg. 1 W. F. Day; Burnet. Flawn and others, 1961, p. 238. *WCTSLS.
936. Twin Cities Oil and Gas 1 Taylor; Burnet. Flawn and others, 1961, p. 239.
937. Plummer, 1950, p. 34; Burnet. Doublehorn Creek.
   Plummer, 1950, p. 22; Burnet. South of bridge at Marble Falls.
   Plummer, 1950, p. 22; Burnet. 5 mi. southeast of Marble Falls.
   Cloud, Barnes, and Hass, 1957, p. 815; Burnet. Burnham Branch.
938. Al Belanger 1 Nella T. Evans; Burnet. Flawn and others, 1961, p. 238.
939. Cloud, Barnes, and Hass, 1957, p. 815; Burnet. Houy Ranch.

CALLAHAN

624. Star 1–B H. W. Ross; Callahan. *ASLS.
625. Fain-McGaha 1 R. D. Williams; Callahan. *ASLS.
626. King 1 L. C. Ray; Callahan. *ASLS.

TEXAS — Continued
CALLAHAN — Continued

627. Star 1 Ella Tyler; Callahan. *ASLS.
628. Producers Devel. 1–B Eisenhower; Callahan. *ASLS.
629. Scott and others 1 G. A. Chrane; Callahan. *ASLS.
630. Humble 1 L. J. McFarlane; Callahan. *ASLS.
631. Oil Well Drlg. 1 A. Hickman; Callahan. *ASLS.
632. Sunray 1 Aspin; Callahan. *ASLS.
633. Bay 1 F. A. Windham; Callahan. *ASLS.
634. Standard Oil Kansas 1 R. L. Murphy; Callahan. *ASLS.
635. Anzac 1 F. Cutbirth; Callahan. *ASLS.
636. Groebl 1 Gary; Callahan. *ASLS.

CARSON

42. Cabot Carbon 50 Ware; Carson. *TPSLS.
43. Skelly 1 Skelly-Schafer; Carson. *TPSLS.
44. Pure 1 Read; Carson. *TPSLS.

CASTRO

83. Pan American 1 M. L. Robbins; Castro. *TPSLS.
84. Sun 1 Herring; Castro. *TPSLS.
85. Anderson-Pritchard 1 McDaniel; Castro. *TPSLS.
86. Sun 1 Haberor; Castro. *TPSLS.

CHILDRESS

109. Totten, 1956, p. 1956, fig. 6.
110. Texas 1 P. B. Smith; Childress. *TPSLS, 1953.
111. Maguine 1 Smith L and C Co.; Childress. *TPSLS.
112. Murphy 1 Clark; Childress. *TPSLS.
113. Texas 1 F and M Trust; Childress. *TPSLS.
114. Placid Oil 1 K. M. Waters; Childress. *NTSLS, 1948(?).
115. Sinclair 1 W. Mullins; Childress. *TPSLS, 1951.
116. Texas 1 S. B. W. Hughes; Childress. *TPSLS, 1951.

CLAY

252. Ohio 1 P. P. Langford; Clay. *NTSLS.
253. Shaw 1 J. P. Boddy; Clay. *NTSLS.
254. Ada 1 T. Douthitt; Clay. *NTSLS.
255. Wood and others 1 C. T. Mattox; Clay. *NTSLS.
256. Bridwell 1 T. Watson; Clay. *NTSLS.
257. E. A. Smith 1 J. W. Moser; Clay. *NTSLS.
258. Stephens Pet. 1 B. Edwards; Clay. *NTSLS.
259. Johnson and Acme Die and Machine 1 F. Wines; Clay. *NTSLS.
260. Gulf 1–A Fields; Clay. *NTSLS.
261. Vaughan 1–A Hapgood; Clay. *NTSLS.
262. S. D. Johnson 1 E. Childs; Clay. *NTSLS.

COCHRAN

193. Texas 1 Thompson; Cochran. *PBSL.
194. Humble 1 Masten; Cochran. *PBSL.
195. Rowan 1 Grimes; Cochran. *PBSL.
196. Stanolind 1 Reed "D"; Cochran. *PBSL.
197. Delta 1 Starnes; Cochran. *PBSL.
198. Stanolind 1 Reed "C"; Cochran. *PBSL.
199. Texas 2 Mallet L and C; Cochran. *PBSL.

COKE

707. Sun 1 F. F. Jameson; Coke. *ASLS.
708. Humble 1 J. W. Arledge; Coke. *WCTSLS.
709. Randle 1 S. M. King Est.; Coke. *ASLS.
710. Mar-Tex 1 Gee; Coke. *ASLS.
711. Harper and Huffman 1 A. S. Eubanks; Coke. *PBSL.
712. Norsworthy 1 Mims; Coke. *PBSL.

TEXAS — Continued
COKE — Continued

713. Amerada 1 March Ranch; Coke. *ASLS.
714. LaGlora and Dykes 1 M. G. Reed; Coke. *PBSL.

COLEMAN

721. Waggoner 1 Wethered; Coleman. *ASLS.
722. Tex Harvey 1 E. W. Webb; Coleman. *ASLS.
723. B. F. Phillips, Jr., 1 A. A. Purcell; Coleman. *ASLS.
724. Westates 1 R. Jameson; Coleman. *ASLS.
725. Burt and others 1 G. E. Kemp; Coleman. *ASLS.
726. Wildcats 1 V. M. Close; Coleman. *ASLS.
727. Naylor 1 M. L. Stone; Coleman. *ASLS.
728. Starnes 1 and Brannon-Murry 7 Sealy Smith; Coleman. Abilene Geol. Soc., 1949.
729. Hubbard 1 T. E. Campbell; Coleman. *ASLS.
730. Mid-Continent 1–A M. Horne; Coleman. *ASLS.
731. Anzac 24, 19, 13 Overall; Coleman. Abilene Geol. Soc., 1949.
732. Eastland Oil and others 1 J. T. Padgett; Coleman. *ASLS.
733. Durbin and others 1 C. H. Weiss; Coleman. *ASLS.

COLLIN

441. Hill and Hill 1 L. Carruth; Collin. *NTSLS.
442. Deep Rock 1 W. M. Sherley; Collin. Flawn and others, 1961, p. 241–242. *NTSLS.
443. Humble 1 Miller; Collin. *NTSLS.
444. Crocker 1 J. Murray; Collin. *NTSLS.

COLLINGSWORTH

73. Herbert Oil 1 Coleman-Hess; Collingsworth. *TPSLS, 1956.
74. Superior 1 Brown; Collingsworth. *TPSLS.
75. Tatum, Bennett, and Depauw 1 A. F. Wischkaemper, Jr.; Collingsworth. *TPSLS, 1953.
76. Lubbock Machine and Supply 1 Alexander; Collingsworth. *TPSLS.
77. Union Prod. 1 B. Glenn; Collingsworth. *NTSLS, 1947.
78. Humble 1 Scruggs; Collingsworth. *TPSLS, 1950.

COMAL

1032. Roland Blumberg 1 D. C. Knibbe; Comal. Flawn and others, 1961, p. 243.

COMANCHE

740. Continental 1 N. L. Box; Comanche. *WCTSLS.
741. Bankline 2 Callaway; Comanche. *WCTSLS.
742. Sohio 1 B. Frasier; Comanche. *WCTSLS.
743. Sohio 1 M. Tate; Comanche. *WCTSLS.
744. Coats and Foster 1 C. A. Scott; Comanche. *WCTSLS.
745. Wood 1 P. D. Patton; Comanche. *WCTSLS.
746. Texas 1 O. B. Brinson; Comanche. *WCTSLS.
747. Bryant 2 E. D. Ward; Comanche. *WCTSLS.
748. O. L. Johnson 1 T. L. Hutchinson; Comanche. *WCTSLS.
749. H. O. Newman 1 T. J. Kelly, Jr.; Comanche. *WCTSLS.
750. Murray and White 1 W. S. Lawrence; Comanche. *WCTSLS.
751. Humble 1 J. A. Mercer; Comanche. *WCTSLS.
752. Humble 1 E. R. Hayes; Comanche. *WCTSLS.
753. Humble 1 Foreman; Comanche. *WCTSLS.

CONCHO

847. Allison-Prestridge 1 D. A. Sims; Concho. *WCTSLS.
848. Brown and Stone 1 H. L. Mosley; Concho. *WCTSLS.
849. Progress 1 M. Sansom; Concho. *WCTSLS.
850. Skelly 1 McCulloch; Concho. *WCTSLS.
851. Strake 1 Smith Land and Cattle Co.; Concho. *ASLS.

TEXAS — Continued
CONCHO — Continued

852. Texas 1 A. Rainwater; Concho. *WCTSLS.
853. Guy Mabee Drlg. 1 A. H. Denis; Concho. *PBSL.
854. Dobbs and Bradshaw 1 J. W. Welty; Concho. *WCTSLS.
855. Plymouth 2 A. N. Miller; Concho. *PBSL.

COOKE

275. Humble 1 V. Castle; Cooke. *NTSLS.
276. Northern Pump 1 F. B. Mitchell; Cooke. *NTSLS.
277. Sun 1 D. L. Monroe; Cooke. *NTSLS.
278. Seitz 1 R. A. Richie; Cooke. *NTSLS.
279. Kimbell 1 A. L. Williams; Cooke. *NTSLS.
280. Taylor and others 1 C. Pendleton; Cooke. *NTSLS.
281. Continental 1 C. G. Whaley; Cooke. *NTSLS.
282. Scott 1 L. C. Brittain; Cooke. *NTSLS.
283. Lake 1 Pace Bros.; Cooke. *NTSLS.
284. Dillard 1 A. Ware; Cooke. *NTSLS.
285. Continental 1 H. M. Berry; Cooke. *NTSLS.
286. Howell and Holloway 1 D. Hudspeth; Cooke. *NTSLS.
287. Broday Drlg. 1 Scott and Potter; Cooke. *NTSLS.

CORYELL

786. Amerada 1 N. F. Tate; Coryell. *WCTSLS.
787. Keystone Texas 1 J. S. Clark; Coryell. Flawn and others, 1961, p. 247.
788. General Crude 1 E. Day; Coryell. *WCTSLS.
789. Gehrig 1 W. B. Duncan; Coryell. *WCTSLS.
790. Buckeye–Mid Texas 1 Strickland Ranch; Coryell. *WCTSLS.
791. New York Synd. 1 C. Gotcher; Coryell. Flawn and others, 1961, p. 247.

COTTLE

146. Deep Rock 1 Portwood; Cottle. *TPSLS.
147. Humble J–1 Matador; Cottle. *TPSLS.
148. Jones and Stasney 1 Wilie; Cottle. *TPSLS.
149. Seaboard-Shamrock 1 Tapper; Cottle. *TPSLS.
150. Totten, 1956, p. 1956, fig. 5.
151. General Crude 1 Swenson "B"; Cottle. *TPSLS.
152. General Crude 33–1 Swenson "C"; Cottle. *TPSLS.
153. General Crude 29–1 Swenson "C"; Cottle. *TPSLS.
154. Gulf 1 Shamberger; Cottle. *TPSLS.
155. Sun 1 Hughes; Cottle. *TPSLS.

CRANE

802. Sinclair-Prairie 1 McKnight; Crane. *PBSL.
803. Gulf 1 Waddell; Crane. *PBSL.
804. Atlantic 1 Univ.; Crane. *PBSL.
805. Atlantic 1 Everett-Glass; Crane. *PBSL.
806. Gulf 1 State "E"; Crane. *PBSL.
807. Atlantic 1–A Univ.; Crane. *PBSL.
808. Humble 1 Cowden; Crane. *PBSL.
809. Humble 5 Cowden; Crane. *PBSL.

CROCKETT

879. Texas Pacific Coal and Oil 1 Univ. "G"; Crockett. *PBSL; PL, 1957.
880. Shell 1–5 Univ.; Crockett. *PBSL.
881. Pan American 1 Univ. "DL", Crockett. *PBSL; PL, 1959.
882. Texas 12 State of Texas "CY"; Crockett. *PBSL.
883. Continental 1 C. T. Harris "E"; Crockett. *PBSL; PL, 1956.
884. Monterey Oil 23–40 Harris; Crockett. *PBSL; PL, 1960.
885. Duquesne Oil 2 Shannon Est.; Crockett. *PBSL; *PL, 1957.

TEXAS — Continued
CROCKETT — Continued

886. Texas Gulf Prod. 1 Univ. "Q"; Crockett. *PBSL; PL, 1955.
887. Sinclair 1 Univ.-Crockett "154"; Crockett. *GS; PL, 1960.
888. Gulf 1 Shannon Hospital "A"; Crockett. *GS; *PL, 1961.
889. Magnolia 1 Shannon Hospital; Crockett. *PBSL; PL, 1957.
890. Chamber and Kennedy 1 Hugh Andrews; Crockett. *PBSL.
891. LaGorce Oil and Garlitz and Howell 1 Jack and Nettie Holt; Crockett. *PBSL.
892. Ohio 2 Halff and Bivens; Crockett. *PL, 1956.
893. Forest Oil 1 J. S. Todd; Crockett. *PBSL.
894. Sun 1 Univ.; Crockett. *GS; PL, 1961.
895. Continental 1 Univ. "31–36"; Crockett. *PBSL.
896. Cities Serv. 1 Bean "B"; Crockett. *GS; PL, 1961.
897. Sinclair 1 M. S. Jones; Crockett. *PBSL.
898. Sinclair 1 Frank J. Friend; Crockett. *PBSL.
899. Texas 1 V. L. Pierce; Crockett. *PBSL.
900. Continental 1 D. A. Friend; Crockett. *PBSL.
901. Honolulu 1 Lou Adams; Crockett. *GS; PL, 1961.
902. Sun 1–X Myrtle Mitchell; Crockett. *PBSL.

CROSBY

211. Humble 1 Irvin; Crosby. *PBSL.
212. Natl. Assoc. 1 Abel; Crosby. *PBSL.
213. Ohio 2 Morgan; Crosby. *PBSL.
214. Texas Gulf Prod. 1 Hinson; Crosby. *PBSL.

CULBERSON

1068. Continental 1 E. E. Pokorny; Culberson. *PL, 1959.
1069. TXL Oil 1–C Culberson Fee; Culberson. *PL, 1961.
1070. Magnolia 1 Homer Cowden "A"; Culberson. *PL, 1961.
1071. Socony Mobile 1 State-Barrett; Culberson. *PL, 1960.
1072. TXL Oil 1 Culberson-Fee "BT"; Culberson. *PL, 1961.
1073. Sinclair 1 State; Culberson. *PL, 1962.
1074. King, 1965, p. 43. Culberson.
1075. Gulf 1 M. A. Grisham; Culberson. *PBSL.
1076. TXL Oil 1 Harry Goode; Culberson. *PL, 1960.
1077. Tidewater 1 Delaware Basin Properties, Inc.; Culberson. *PL, 1961.
1078. Sinclair 1 K. P. Looney; Culberson. *PL, 1961.
1079. Burford and Sams 1 J. B. Foster; Culberson, *PL, 1962.
1080. Canter, Hamm, and O'Brien 1 J. B. Foster; Culberson. *PL, 1961.
1081. Sunray Mid-Continent and Sinclair 1 J. B. Foster; Culberson. *PL, 1962.
1082. Cosden Pet. 1 C. R. Cockrell; Culberson. *PBSL.

DALLAM

1. Pure 1 Federal Land Bank; Dallam. *TPSLS.
2. Pure 1 Sneed; Dallam. *TPSLS.
3. Humble 1 Sheldon; Dallam. *TPSLS.
4. Humble 1 Belo; Dallam. *TPSLS.

DALLAS

556. Magnolia 1 Trigg Est.; Dallas. *WCTSLS.
557. City of Dallas 45 (water well); Dallas. Flawn and others, 1961, p. 248.
558. Lacey and Guiberson 1 Meyers (Moyer?); Dallas. Flawn and others, 1961, p. 248.

DAWSON

459. Amerada 1 Adcock; Dawson. *PBSL.
460. Seaboard 1 Barrow; Dawson. *PBSL.
461. Magnolia 1 Eiland; Dawson. *PBSL.

TEXAS — Continued

DAWSON — Continued

462. Seaboard 6–A Robison; Dawson. *PBSL.
463. Magnolia 1 Foster; Dawson. *PBSL.

DEAF SMITH

48. Frankfort 1 Coffee; Deaf Smith. *TPSLS.
49. Frankfort 1 Allison-Hayes; Deaf Smith. *TPSLS.
50. Humble 1 Reinauer; Deaf Smith. *TPSLS.
51. Honolulu 1 Ponder; Deaf Smith. *TPSLS.

DENTON

429. Hunt 1 Jones; Denton. *NTSLS.
430. Maguire 1 E. R. Wade; Denton. *NTSLS.
431. Howell-Holloway 1 B. Lewter; Denton. *NTSLS.
432. Burk Royalty (Northern Ordnance) 1 D. W. Light, Jr., and others; Denton. *NTSLS.
433. Texas 1 A. Trietsch; Denton. *NTSLS.
434. Stemmons 1 J. B. Thomas; Denton. *NTSLS.
435. Hall and Glasco 1 Carroll; Denton. *NTSLS.
436. Texas 1 W. T. Evers; Denton. *NTSLS.
437. Holliman Drlg. and J. R. McLean 1 C. K. Justus; Denton. *NTSLS.
438. Carter 1 Allen; Denton. *NTSLS.
439. Carter-Gifford 1 M. A. Knox; Denton. *NTSLS.
440. Trentman, Jr., and others 1 R. M. King; Denton. *NTSLS.

DICKENS

215. Natl. Assoc. Pet. 1 Blackwell; Dickens. *PBSL.
216. Union 1 Elliott; Dickens. *PBSL.

DONLEY

61. Magnolia 1 Lewis; Donley. *TPSLS.
62. Humble 1 Roach; Donley. *TPSLS, 1954.
63. Doswell and others 1 McMurtry; Donley. *TPSLS, 1950.
64. Underwood and Corsica 1 Carpenter; Donley. *TPSLS.
65. Underwood and Corsica 1 Carpenter; Donley. *TPSLS, 1954.
66. Alan Drlg. 1 Sharrett Meyers; Donley. *TPSLS, 1952.
67. Shamrock 1 Adair; Donley. *TPSLS.
68. General Crude 1 Keystone; Donley. *TPSLS.
69. H. L. Hunt 5 Ritchie; Donley. *TPSLS, 1952.
70. Lewis and Welch 1 L-R. G. Ranch; Donley. *TPSLS.
71. General Crude 1–30 Keystone; Donley. *TPSLS.
72. Stanolind 1 Broome; Donley. *TPSLS.

EASTLAND

637. Lone Star 1–E G. P. Mitcham; Eastland. *WCTSLS.
638. Skelly 1 A. L. Thomas; Eastland. *ASLS.
639. British-American 1 J. W. Courtney; Eastland. *WCTSLS.
640. T–P Coal and Oil 30 J. E. Butler; Eastland. *WCTSLS.
641. Deep Rock 1 J. J. Hawkins; Eastland. *WCTSLS.
642. Senate 1 Speegle; Eastland. *ASLS.
643. Signal 1 C. U. Connellee; Eastland. *WCTSLS.
644. Globe-Shive Drlg. 1 L. Leiske; Eastland. *WCTSLS.
645. Murphy 1 R. M. Day; Eastland. *WCTSLS.
646. Algord 1 O. P. Wheeler; Eastland. *ASLS.
647. Star 1 M. E. Flippen; Eastland. *ASLS.

ECTOR

674. Forest 1 TXL "L"; Ector. *PBSL.
675. Blackwood and Nichols 1–5 Neatherly; Ector. *PBSL.
676. Phillips 1–A–E TXL; Ector. *PBSL.
677. Humble 1 Vest; Ector. *PBSL.
678. Phillips 1 Stockton; Ector. *PBSL.

TEXAS — Continued

ECTOR — Continued

679. Stanolind and Cities Serv. 2–D Cowden; Ector. *PBSL.
680. Cities Prod. 1 Cowden "Q"; Ector. *PBSL.
681. Humble 1 York "B"; Ector. *PBSL.
682. Bagley 1 Cowden; Ector. *PBSL.

EDWARDS

1002. Taylor Oil and Gas (Delhi-Taylor) 1 Holman; Edwards. *WCTSLS.
1003. Sinclair 1 W. L. Miers; Edwards. *PBSL; PL, 1960; WCTSLS.
1004. Jack Woodward and Dan Auld 1 Hal and Charlie Peterson; Edwards. *PBSL; PL, 1960.
1005. Humble 1 J. L. Greer; Edwards. *PBSL; PL, 1961.
1006. Lewis Mabee 1 Wheat-Bradford; Edwards. *WCTSLS.
1007. Dan Auld and others 1 Rigsby; Edwards. *PL, 1960.
1008. Spencer Chem. (Cascade Pet.) 1 Earwood; Edwards. *WCTSLS.
1009. Texas 1 J. E. Phillips; Edwards. *WCTSLS.
1010. Shell 1 J. H. Brown; Edwards. *WCTSLS; PL, 1960.
1011. J. Dalglish and others 1 Peterson; Edwards. *PBSL; PL, 1960.
1012. H. M. Naylor Oil 1 Lloyd Mitchell; Edwards. *WCTSLS.
1013. Plateau Oil 1 Hatch; Edwards. *WCTSLS.
1014. Shell 1 Elsie I. Honeycutt; Edwards. *PBSL.
Shell 1 Honeycutt; Edwards. Flawn and others, 1961, p. 251.
1015. Slagter Prod. 1 Whittenburg; Edwards. *PBSL; WCTSLS.
1016. Humble 1 Collins; Edwards. Flawn and others, 1961, p. 250. *PBSL; WCTSLS.
1017. Hunt 1 Allison; Edwards. Flawn and others, 1961, p. 250–251. *WCTSLS.
1018. Val Verde Ventures 1 J. H. Harding; Edwards. *PBSL; PL, 1961.
1019. Gulf 1 Anderson-Dunham; Edwards. *PL, 1962.
1020. Phillips 1 Carson "A"; Edwards. Flawn and others, 1961, p. 251.

EL PASO

1056. Harbour, 1972.
1057. King and others, 1945. Hueco Mtns.

ELLIS

668. Lesco (Lasco?) 1 Lesage; Ellis. Flawn and others, 1961, p. 252.
669. Triangle 1 Hale; Ellis. Flawn and others, 1961, p. 253.
670. J. B. Stoddard 1 W. E. Smith; Ellis. Flawn and others, 1961, p. 253.

ERATH

648. Sun 1 Fambrough; Erath. *WCTSLS.
649. Cities Serv. 1 Parkey "D"; Erath. *NTSLS.
650. Texaco 1 Claude Irons; Erath. *NTSLS.
651. J. B. Collier, Jr., 1 Diamond C Ranch; Erath. *WCTSLS.
652. McCarthy 1 W. C. Hedrick; Erath. *WCTSLS.
653. Fitzgerald 1 Wilcoxson; Erath. *WCTSLS.
654. Lewis Mahan 1–A Noah Grimes; Erath. *WCTSLS.
655. Lubbock Machine 1 N. E. Whitefield; Erath. *WCTSLS.
656. Burks and others 1 Lackey; Erath. *WCTSLS.
657. Finley-Hamilton 1 Medford; Erath. *WCTSLS.
658. American Liberty 1 D. A. Fellers; Erath. *WCTSLS.

FALLS

878. Humble 1 Pucek; Falls. Flawn and others, 1961, p. 254.

TEXAS — Continued

HAMILTON — Continued

759. Amerada 1 S. R. Campbell; Hamilton. *WCTSLS.
760. Lone Star Gas 1 E. L. Riewe; Hamilton. *WCTSLS.
761. E. C. Johnston 1 H. Costen; Hamilton. *WCTSLS.
762. Phillips 1–A Townson; Hamilton. *WCTSLS.
763. American Mfg. 1 T. W. Winters; Hamilton. *WCTSLS.
764. Skelly 1 E. Price; Hamilton. *WCTSLS.

HANSFORD

9. Phillips 2 Hitch "E"; Hansford. *TPSLS.
10. Humble 1 S. P. and K. K. Jackson; Hansford. *TPSLS.
11. Texas 1 Blakemore; Hansford. *TPSLS.
12. K and H Operating 1 Cator; Hansford. *TPSLS.
13. Gulf 1 Collard; Hansford. *TPSLS.

HARDEMAN

156. Reynolds, Kirk, and Neeb 1 W. F. Williams; Hardeman. *NTSLS.
157. Magnolia 1 S. E. Malone; Hardeman. *NTSLS.
158. Pan American 1 Bestwall Gypsum; Hardeman. *NTSLS.
159. Sun 1 S. H. Sorenson; Hardeman. *NTSLS.
160. Shell 1 K. G. Davis; Hardeman. *NTSLS.
161. Maxwell 1 Emerson-Huie-Cox; Hardeman. *NTSLS.
162. Addison Warner 1 Belew; Hardeman. *NTSLS.
163. Pure 1 J. Williams; Hardeman. *NTSLS.
164. Gulf 1 Dodson and others; Hardeman. *NTSLS.

HARTLEY

19. Standard of Texas 1–26 Walker; Hartley. *TPSLS.
20. British-American 1 Houghton; Hartley. *TPSLS.
21. Athens 1 Houghton; Hartley. *TPSLS.
    Bridwell 1 Houghton; Hartley. *TPSLS.
22. Kerr-McGee 1 Berneta; Hartley. *TPSLS.

HASKELL

378. Geochemical Surveys and Intex 1 M. Cornelius; Haskell. *ASLS.
379. Phillips 1 R. W. Herren; Haskell. *NTSLS.
380. Humphrey 1 J. M. Collins; Haskell. *ASLS.
381. Roark, Hooker, and Hill 1 C. B. Long; Haskell. *ASLS.
382. Pan American 1 J. R. Coody; Haskell. *NTSLS.
383. Mid-Continent 1 M. Waldrop; Haskell. *NTSLS.

HAYS

981. Shell 1 Harwell; Hays. Flawn and others, 1961, p. 271–272.
982. Mann 1 Reeder; Hays. Flawn and others, 1961, p. 271.

HEMPHILL

34. Magnolia 1 Feldman; Hemphill. *TPSLS, 1957.

HILL

772. Humphrey 1 J. E. Osborne; Hill. *WCTSLS.
773. Hunt 1 E. W. Wright; Hill. *WCTSLS.
774. Hill-Texas (B. H. Harrison and others) 1 C. Weatherby; Hill. Flawn and others, 1961, p. 273.
775. Hillsboro City 3 (Market Square well); Hill. Flawn and others, 1961, p. 273.
776. Phillips 1–A Posey; Hill. *WCTSLS.
777. A. P. Merritt 1 Henry Nors; Hill. Flawn and others, 1961, p. 274.
778. Humble 1 M. Holderman; Hill. Flawn and others, 1961, p. 273.

TEXAS — Continued

HOCKLEY

200. Big Chief 1 De Loache; Hockley. *PBSL.
201. Stanolind 1 Bowman–OWOD; Hockley. *PBSL.
202. Sohio 1 Ellwood; Hockley. *PBSL.
203. Honolulu-Signal 1 Ellwood; Hockley. *PBSL.
204. Honolulu 1 Lockett "A"; Hockley. *PBSL.

HOOD

659. Signal 1 Dennis Jones; Hood. *WCTSLS.
660. Sunray 1 H. B. Little; Hood. *WCTSLS.
661. Sunray 1 J. R. Black; Hood. *WCTSLS.
662. Davidson 1 G. V. Matthews; Hood. *NTSLS.
663. Mid-Continent 1 Squaw Creek Cattle Co.; Hood. *WCTSLS.
664. DeSoto 1 B. W. Wann; Hood. *WCTSLS.

HOWARD

581. Texas Pacific Coal and Oil 1 Spencer; Howard. *PBSL.
582. Stanolind 1 Anderson; Howard. *PBSL.
583. Harper and Huffman 1 Oldham; Howard. *PBSL.
584. Southern Minerals and Forest 1 Guthrie "A"; Howard. *PBSL.
585. Stanolind 1 Barber "A"; Howard. *PBSL.
586. Cosden 1 Crawford; Howard. *PBSL.
587. Stanolind 1 TXL "D"; Howard. *PBSL.
588. Stanolind 1 Gaskins; Howard. *PBSL.

HUDSPETH

1058. Magnolia 1 State of Texas 39881; Hudspeth. *R. F. Meyer, 1963.
1059. General Crude 1 Merrill and Voyles; Hudspeth. *PL, 1960.
1060. King, King, and Knight, 1945.
1061. Western States Oil, Lockhart, Roseborough, and Benton 1 Gardner and Mosely; Hudspeth. Albritton and Smith, 1965.
1062. Gulf 1–J Burner-State "B"; Hudspeth. *PL, 1963.
1063. J. P. Hurndall and R. A. Gray 1 J. S. Pierce; Hudspeth. *PBSL.
1064. King, 1949; Hudspeth.
1065. *P. B. King and J. B. Knight, USGS; Hudspeth. McAdoo sec.
1066. *P. B. King and J. B. Knight, USGS; Hudspeth. Circle Ranch sec.
1067. *P. B. King, USGS; Hudspeth. Sierra Diablo notes, Bass Canyon sec.

HUNT

445. Humble 1 E. M. Anderson; Hunt. Flawn and others, 1961, p. 276.
446. Humble 1 Rutherford; Hunt. Flawn and others, 1961, p. 276.

HUTCHINSON

25. Huber 2 C. H. Jasper; Hutchinson. *TPSLS.
26. Pan American 1 Allen; Hutchinson. *TPSLS.
27. Sinclair 1 Theis; Hutchinson. *TPSLS.
28. Holmes 1 Quinn "C"; Hutchinson. *TPSLS.

IRION

831. M. J. and M. M. C. 1–A Sugg; Irion. *PBSL.
832. Amerada 1 Van Keuren; Irion. *PBSL.
833. McAlester 1–70 Sugg; Irion. *PBSL.
834. Wilshire 1 Phillips-Bean; Irion. *PBSL.
835. Morgan-Aikman 1 Mayer; Irion. *PBSL.
836. Hunt 1–M Noelke; Irion. *PBSL.

TEXAS — Continued

LAMB — Continued

123. Texas 1 Chisholm; Lamb. *TPSLS.
124. Texas 1 Union Compress Warehouse Co.; Lamb. *TPSLS.
125. Seaboard 1 Jackson; Lamb. *TPSLS.
126. San Juan 1 Jones; Lamb. *TPSLS.
127. Humble 1 Jackson; Lamb. *TPSLS.

LAMPASAS

869. Robertson and McKissick 1 Smith; Lampasas. *WCTSLS.
870. Plummer, F. B., 1950, p. 34; loc. 141—T—11 Lampasas. 4.4 miles west of Lampasas.
    Plummer, F. B., 1950, p. 22; 500 feet SW of Esperyville church, Burnet.
    Cloud and Barnes, 1946, p. 349; Pillar Bluff area, Burnet.

LIMESTONE

796. Texas 1 Keeling; Limestone. Flawn and others, 1961, p. 289.
797. Farrell Drlg. 1 J. R. Gillam; Limestone. Flawn and others, 1961, p. 289.

LIPSCOMB

18. Gulf 1 Porter "A"; Lipscomb. *TPSLS.

LLANO

934. Cloud and Barnes, 1946, p. 257—287; Llano. Moore Hollow and Warren Springs areas.

LUBBOCK

205. Humble 1 Farris; Lubbock. *PBSL.
206. Phillips 1 Karry; Lubbock. *PBSL.
207. Humble 1 Parr; Lubbock. *PBSL.
208. Bankline, Wilshire, and Basin 1 Elliott; Lubbock. *PBSL.
209. Amerada 1 Stribling; Lubbock. *PBSL.
210. Livermore and Sanders 1 Lindsey; Lubbock. *PBSL.

LYNN

340. Honolulu 1 King; Lynn. *PBSL.
341. Sunray 1 Sunray-Sohio-Ernst; Lynn. *PBSL.
342. Shell 1 Coleman and others; Lynn. *PBSL, PL, 1960.
343. Humble 1 J. Q. Cox; Lynn. *PBSL.
344. Barnsdall 1 Williams; Lynn. *PBSL.
345. Dan and Jack Auld 1 Thomas; Lynn. *PBSL.
346. Humble 1 Thomas; Lynn. *PBSL.
347. Cities Serv. 1 Gregory; Lynn. *PBSL.

MCCULLOCH

856. Cashin 1 Smith Est.; McCulloch. *WCTSLS.
857. McMillen and Rominger 1 Jordt (Randal); McCulloch. *WCTSLS.
858. Clark and others 1 J. B. Lively; McCulloch. *WCTSLS.
859. Amerada 1 G. Riley; McCulloch. *PBSL.
860. Weatherford (Northwest Oil) 1 P. S. Pumphrey; McCulloch. *WCTSLS.
861. Easterwood 1 K. and W. C. Johnson; McCulloch. *WCTSLS.
862. F. B. Plummer, 1950, pl. 6, sec. 4. McCulloch. White Ranch.
863. Plummer, F. B., 1950, p. 33, fig. 11; McCulloch. About 3 miles NE. of Brady.

MCLENNAN

792. F. J. Ossenbeck 1 Charles Bezdek; McLennan. Flawn and others, 1961, p. 293.
793. Waco Oil and Ref. 1 G. H. Harrington; McLennan. Flawn and others, 1961, p. 294.

TEXAS — Continued

MCLENNAN — Continued

794. Falcow 1 H. Mattlage; McLennan. *WCTSLS.
795. Daniel Oil 1 E. W. Estes; McLennan. Flawn and others, 1961, p. 290.

MARTIN

573. Stanolind 1 Mabee; Martin. *PBSL.
574. Spartan, Lohman, Gardiner 1 Wolcott; Martin. *PBSL.
575. Texas 1—X Texas; Martin. *PBSL.
576. Stanolind 1 Flyat; Martin. *PBSL.
577. Phillips 1 Schardauer "C"; Martin. *PBSL.
578. Gallery and Hurt 1 Powell; Martin. *PBSL.
579. Gulf 1—E Glass "B"; Martin. *PBSL.
580. Tidewater 1 Dickinson; Martin. *PBSL.

MASON

932. Plummer, 1950, p. 22; Mason. Leon Creek.
933. Cloud and Barnes, 1946, p. 154, 160—161; Mason.
    Plummer, 1950, p. 37; Mason.
    Plummer, 1950, p. 22; Mason. Llano River.
    Plummer, 1950, p. 22, 24; Mason. Honey Creek.

MAVERICK

1054. Humble 1 Bandera CSL; Maverick. Flawn and others, 1961, p. 290.

MEDINA

1050. Roxana Pet. 1 Rothe; Medina. Flawn and others, 1961, p. 296.
1051. Switzer and others (also O'Dell, Haught, and Bond) 1 Martin Zerr; Medina. Flawn and others, 1961, p. 296—297.
1052. John I. Moore 1 Alfred J. Wurzbach; Medina. Flawn and others, 1961, p. 295—296.
1053. Humble 1 E. E. Wilson; Medina. Flawn and others, 1961, p. 295.

MENARD

926. Wayne Allison 1 Fritz Volkmann; Menard. *PBSL; PL, 1960.
927. General Crude 1—1 Joe Wilhelm; Menard. *WCTSLS.
928. Honolulu 1 B. K. Neel; Menard. *PL, 1959.
929. Honolulu 1 George Kothmann; Menard. *PBSL; PL, 1959.
930. Tucker Drlg. 1 L. F. Callan; Menard. *PBSL.
931. Deep Rock 1 W. P. Bevens; Menard. *PBSL.

MIDLAND

683. Magnolia 1 Nobles; Midland. *PBSL.
684. Texas 1 Scharbauer; Midland. *PBSL.
685. Cities Prod. 1 Parks; Midland. *PBSL.
686. Warren 1 Sanders; Midland. *PBSL.
687. General American 1 Peek; Midland. *PBSL.
688. Plymouth 1—38 Midkiff; Midland. *PBSL.

MILLS

781. Pure 1 W. A. Triplitt; Mills. *WCTSLS.
782. Trigger Mtn. 1 J. F. Burdett; Mills. *WCTSLS.
783. Miller and others 1 George Nieman; Mills. *WCTSLS.
784. Fisher-Stoker 1 Leonard; Mills. *WCTSLS.
785. Deep Well 1 Segelquist Bros.; Mills. *WCTSLS.

MITCHELL

589. Standard Oil of Texas 1 B. F. Dunn and others; Mitchell. *PBSL.
590. Superior 2 Jim Plaster; Mitchell. *PBSL.
591. Standard Oil of Texas 1 J. Dell Barber and others; Mitchell. *PBSL.

TEXAS — Continued
MITCHELL — Continued

592. Humble 1 A. C. Pratt; Mitchell. *PBSL.
593. Great Western 1 C. W. Baumann; Mitchell. *PBSL.
594. Magnolia 22 Foster; Mitchell. *PBSL.
595. Humble 1 W. P. Cooper; Mitchell. *PBSL.
596. Hurlbut and others 1 B. L. Wolfjen; Mitchell. *PBSL.
597. Continental 1 I. L. Ellwood; Mitchell. *PBSL.
598. Sun 2 Elwood Est.; Mitchell. *PBSL.
599. Amerada 1 J. F. McCabe; Mitchell. *PBSL.

MONTAGUE

263. Standard Oil of Texas and Reno 1 Cato Heirs; Montague. *NTSLS.
264. Seitz 1 Johnson-LaForce Unit; Montague. *NTSLS.
265. Ambassador 1 W. R. Hodges; Montague. *NTSLS.
266. Stephens Pet. 1 Chandler; Montague. *NTSLS.
267. Magnolia 1 Carminati; Montague. *NTSLS.
268. Grace 1 J. K. Seibold and others; Montague. *NTSLS.
269. Texas 1 P. E. Boedecker; Montague; *NTSLS.
270. Continental 1 J. B. Williams; Montague. *NTSLS.
271. Continental 1 J. T. Garrett; Montague. *NTSLS.
272. Mid-Continent 1 L. Orrell; Montague. *NTSLS.
273. McGuire 1 Whitehead; Montague. *NTSLS.
274. Omohundro 1 Shoemaker; Montague. *NTSLS.

MOORE

23. Texas 1 Lacy Meek; Moore. *TPSLS, 1957.
24. Skelly 16 Armstrong; Moore. *TPSLS.

MOTLEY

135. Lion 1 Shoenail; Motley. *TPSLS, 1953.
136. Amerada 1 Birnie; Motley. *TPSLS, 1951.
137. Humble 1 Matador "H"; Motley. *TPSLS, 1950.
138. Humble 1–K Matador; Motley. *TPSLS, 1953.
139. General Crude 5–1 Swenson; Floyd. *TPSLS.
140. Humble 2–D Matador; Motley. *TPSLS, 1958.
141. Pan American 1 Brandon; Motley. *TPSLS, 1957.
142. Pan American 1 Brandon; Motley. *TPSLS.
143. General Crude 43–1 Swenson "E"; Motley. *TPSLS.
144. Humble 1–B Matador; Motley. *TPSLS, 1951.
145. Skelly 1 Windham; Motley. *TPSLS.

NAVARRO

779. Hunt 1 Hamilton; Navarro. *Confid.
780. Falcon Drlg. 1 J. C. Keitt; Navarro. Flawn and others, 1961, p. 298.

NOLAN

600. Cities Serv. 1–B B. Etheridge; Nolan. *ASLS.
601. Humphrey and Sons 1 Chitwood; Nolan. *ASLS.
602. Ohio 1 City of Sweetwater; Nolan. *PBSL.
603. Skelly 1 Bradberry; Nolan. *ASLS.
604. Union and Sun 1 P. Starnes "B"; Nolan. *PBSL.
605. Deep Rock 1–A Georgia Tech; Nolan. *PBSL.
606. Norsworthy 1 N. M. Brooks; Nolan. *PBSL.
607. Lytle 1 W. A. Elliott; Nolan. *ASLS.
608. Wilshire and British-American 24–182 R. L. Spires; Nolan. *PBSL.
609. Seaboard Delaware 1 B. Hanks; Nolan. *ASLS.
610. Sun 1 E. Parramore; Nolan. *PBSL.
611. Brennand 1 M. S. Cook; Nolan. *ASLS.
612. Norsworthy 1 R. H. Jordan; Nolan. *ASLS.

TEXAS — Continued

OCHILTREE

14. Welch 1 Brillhart; Ochiltree. *TPSLS.
15. Gulf 1 Stump; Ochiltree. *TPSLS.
16. Texas 1 Daniel "A"; Ochiltree. *TPSLS.
17. Gulf 1 Womble; Ochiltree. *TPSLS.

OLDHAM

35. Superior 1–312 Matador L. and C. Co.; Oldham. *TPSLS.
36. Shell 1–58 Alamosa; Oldham. *TPSLS.
37. Stanolind 1 Herring; Oldham. *TPSLS.
38. Superior 4 Matador; Oldham. *TPSLS.
39. Humble 1 Binford; Oldham. *TPSLS.

PALO PINTO

531. Ambassador 1 Johns; Palo Pinto. *WCTSLS.
532. Trans-Gulf 1 Stanolind-McClure; Palo Pinto. *WCTSLS.
533. Skelly 1 W. J. Rhodes; Palo Pinto. *WCTSLS.
534. Hoblitzelle and others 1 Hudspeth; Palo Pinto. *WCTSLS.
535. Woods Trucking 1 R. Hittson, Sr.; Palo Pinto. *WCTSLS.
536. Kadane and Sons 1 L. C. Taylor; Palo Pinto. *WCTSLS.
537. Signal 1 L. B. Carpenter; Palo Pinto. *WCTSLS.
538. Pan American 1 C. B. Long; Palo Pinto. *WCTSLS.

PARKER

539. Continental 1 C. P. Johnson; Parker. *WCTSLS.
540. B. J. Taylor 1 H. D. Durham; Parker. *WCTSLS.
541. B. J. Taylor 1 W. C. Linehan; Parker. *WCTSLS.
542. Kadane and Sons 1 R. T. Land; Parker. *WCTSLS.
543. Crader 1 O. V. Sneed; Parker. *WCTSLS.
544. Humble 1 C. H. Tompkins and others; Parker. *WCTSLS.
545. Rowan and others 1 J. E. Carter; Parker. *WCTSLS.
546. Cities Serv. 1 Glenn; Parker. *WCTSLS.
547. Humble 1 J. H. Doss; Parker. *WCTSLS.
548. Owings 1 T. B. Saunders; Parker. *WCTSLS.
549. Sunray 1 B. F. Fletcher; Parker. *WCTSLS.
550. Devonian 1 R. Buck; Parker. *WCTSLS.
551. Kadane and Sons 1 Winston; Parker. *NTSLS.

PARMER

79. U.S. Smelting 1 Osborn "A"; Parmer. *TPSLS.
80. Gulf 1–A Keliehor; Parmer. *TPSLS.
81. Stanolind 1 Jarrell; Parmer. *TPSLS.
82. Sunray 1 Kimbrough; Parmer. *TPSLS.

PECOS

1094. Atlantic 1 Harold L. Lowry; Pecos. *PL, 1959.
1095. Mississippi River Fuel 1–A J. C. Trees Est.; Pecos. *PL, 1963.
1096. Hiawatha 1 J. C. Trees Est.; Pecos. *PL, 1949.
1097. Richardson and Bass 1 Texas Cotton Industries; Pecos. *PBSL. William A. and Edward R. Hudson 1 Charles F. Hart; Pecos. *PBSL.
1098. Jergins Oil 1 H. J. Eaton; Pecos. *PBSL.
1099. Socony Mobil 1–B Effie Potts Sibley; Pecos. *PL, 1963.
1100. Continental 1 E. E. Bonebrake; Pecos. *PL, 1959.
1101. Midwest Oil 1 J. P. O'Neill; Pecos. *PBSL.
1102. N. G. Penrose and McDaniel and Beecherl 1 Cordova Union; Pecos. *PBSL.
1103. Humble 1 O. L. Barnes State "B"; Pecos. *PBSL.
1104. Brown and Thorp Drlg. and La Gloria 1 A. A. Sullivan "F"; Pecos. *PBSL.
1105. Atlantic 1 O. C. Kelly; Pecos. *PL, 1960.
1106. Atlantic 1 Lucas-State; Pecos. *PL, 1961.
1107. Humble 1 W. C. Tyrell Trust "E"; Pecos. *PL, 1961.

TEXAS — Continued

PECOS — Continued

1108. Santiago Oil and Gas 1 Hinyard Land and Cattle Co.; Pecos. *PL, 1959.
1109. G. B. Putnam and others 1 McDonald and State; Pecos. *PL, 1955.
1110. Humble 1 Univ. "AG"; Pecos. *PL, 1956.
Pan American 1–DP Univ.; Pecos. *PL, 1960.
1111. Forest Oil 1 Pecos River Bed; Pecos. *PL, 1962.
1112. Bell Pet. 34–1 Plymouth-Univ.; Pecos. *PL, 1960.
1113. Felmont Oil 1 White and Baker; Pecos. *PL, 1959.
1114. North Central Oil and others 1 Lowery and Wilson; Pecos. *PL, 1960.
Forest Oil 1 White and Baker "Block 2"; Pecos. *PL, 1956.
1115. Tidewater 1 White and Baker "B"; Pecos. *PL, 1957.
1116. British-American 1 White and Baker; Pecos. *PL, 1957.
1117. Gulf 231 I. G. Yates; Pecos. *PL, 1959.
1118. Sinclair 1 Popham Land and Cattle Co.; Pecos. *PL, 1962.
1119. Humble 1 L. W. Stone; Pecos. *PL, 1959.
1120. TXL Oil 1 Pecos Fee; Pecos. *PL, 1962.
1121. Gulf 1 State "LM"; Pecos. *PL, 1962.
1122. W. D. Comer 1–B J. L. Nutt; Pecos. *PL, 1961.
1123. Hassie Hunt Trust 2 H. A. Wimberly; Pecos. *PL, 1961.
Southern Minerals and General Crude 1–A Jasper County School Land; Pecos. *PL, 1961.
1124. Southern Minerals and General Crude 2–A Jasper CSL; Pecos. *PL, 1961.
Southern Minerals, and others 4–A Jasper CSL; Pecos. *PL, 1962.
1125. Tidewater 1 Mary McKenzie Carter; Pecos. *PL, 1961.
1126. Tidewater 1 White and Baker Ranch "A"; Pecos. *PL, 1957.
Tidewater 1 White and Baker Ranch; Pecos. *PL, 1956.
Helmerich and Payne (Cardinal Div.) 9–C White and Baker; Pecos. *PL, 1956.
1127. Trice Prod. 1 Frank A. Perry; Pecos. *PL, 1961.
Standard Oil of Texas 1 Frank A. Perry "24"; Pecos. *PL, 1957.
1128. Cities Serv. and others 1 Priest; Pecos. *PL, 1957.
Humble 1 Roy Priest; Pecos. *PL, 1962.
Standard Oil of Texas 1 Frank A. Perry "30"; Pecos. *PL, 1956.
1129. Standard Oil of Texas 5–24 Claude Owens "2"; Pecos. *PL, 1961.
1130. Pan American (was Rowan Drlg. and others) 1 Douglas Oil Co.; Pecos. *PL, 1960.
1131. Standard Oil of Texas 1 Hellon Hokit "1"; Pecos. *PL, 1956.
1132. Hunt 47 Elsinore Royalty Co.; Pecos. *PL, 1955.
1133. Hunt and Gulf 48 Elsinore Royalty Co.; Pecos. *PL, 1956.
1134. Hunt 51 Elsinore Royalty Co.; Pecos. *PL, 1958.
1135. George S. Hammonds 1 J. W. Robbins; Pecos. *PL, 1956.
1136. Gulf 1 Jerusha Robbins and others; Pecos. *PL, 1956.
1137. Standard Oil of Texas 1 Fred P. Montgomery; Pecos. *PL, 1959.
1138. Humble 1 Carolyn H. Harral; Pecos. *PL, 1961.
1139. Standard of Texas and others 3, 5, 7, and 14 Charles C. Canon and others; Pecos. *PL; 1956, 1957.
1140. Phillips 1 Ada Price; Pecos. *PL, 1962.
1141. Neville G. Penrose 1 Rashap; Pecos. *PL, 1961.
1142. Humble 1 Charles C. Canon; Pecos. *PL, 1960.
1143. Continental 1 Mrs. Kennie Noelke; Pecos. *PL, 1956.
1144. Humble 1 William M. Edwards; Pecos. *PL, 1957.

POTTER

40. Sinclair 9 Bevins; Potter. *TPSLS.
41. Whittenburg 1 Whittenburg-Masterson; Potter. *TPSLS.

TEXAS — Continued

PRESIDIO

1145. Gulf 1 H. J. Hubbard; Presidio. *PL, 1961.
1146. Pure 1 J. F. Lane; Presido. *PL, 1961.
1147. Flawn and others, 1961, p. 61.

RANDALL

52. Frankfort 1 White; Randall. *TPSLS.

REAGAN

821. Amerada 1 Mitchell; Reagan. *PBSL.
822. Livermore and Smith 1 Hughes; Reagan. *PBSL.
823. Humble 1 Sawyer; Reagan. *PBSL.
824. Gulf 1 Hughes; Reagan. *PBSL.
825. Humble 1 Malone; Reagan. *PBSL.
826. Humble 1–E Sawyer; Reagan. *PBSL.
827. Union 2 Scott; Reagan. *PBSL.
828. Phillips 1 Univ. "ZZ"; Reagan. *PBSL.
829. Hunt and Moore 1–E Univ. "A"; Reagan. *PBSL.
830. Atlantic 1 Univ. "4B"; Reagan. *PBSL.

REAL

1033. Tucker Drlg. 1 C. M. Brown Est.; Real. *WCTSLS.
1034. John I. Moore and Dan Auld 1 Claude Haby; Real. *PBSL.
1035. Stanolind 1 Knippa; Real. Flawn and others, 1961, p. 299.

RED RIVER

312. Welch 1 R. Williams; Red River. Flawn and others, 1961, p. 303.
313. Bentley, Shephard, and Stephens 1 Southern Pine Lumber Co.; Red River. Flawn and others, 1961, p. 300.
314. Concord 1 Dillahunty; Red River. Flawn and others, 1961, p. 300–301.
315. Texas Trading 1 Southern Pine Lumber Co.; Red River. Flawn and others, 1961, p. 302.
316. Byars 1 Chapman; Red River. Flawn and others, 1961, p. 300.
317. Magnolia 1 Henry; Red River. Flawn and others, 1961, p. 302.
318. Texas 1 H. O. Solomon; Red River. Flawn and others, 1961, p. 302–303.

REEVES

1083. Continental 1 Charlotte Montgomery; Reeves. *PL, 1960.
1084. El Paso Nat. Gas 1 Hoefs; Reeves. *PL, 1962.
1085. El Paso Nat. Gas 1 Guy Caldwell; Reeves. *PL, 1962.
1086. Sun 1 Terrell Unit; Reeves. *PL, 1963.
1087. TXL Oil 1–K–T Reeves Fee; Reeves. *PL, 1960.
1088. Gulf 2 R. Cleveland and others; Reeves. *PL, 1961.
1089. Miami Operating 1 Balmorhea Ranches, Inc.; Reeves. *PL, 1956.

ROBERTS

29. Stanolind 1 Lips; Roberts. *TPSLS.
30. Cities Serv. 1 Theis; Roberts. *TPSLS.
31. Gulf 1 Haggard; Roberts. *TPSLS.
32. Phillips 1 Carruth; Roberts. *TPSLS.
33. Phillips 2 Gay Est.; Roberts. *TPSLS.

RUNNELS

715. Humble 1 J. A. Broadstreet; Runnels. *ASLS.
716. F. K. Johnson 1 C. B. Spill; Runnels. *ASLS.
717. Standard Oil of Texas 1 Lilly Est.; Runnels. *ASLS.
718. Hickok and Reynolds 1 R. G. Erwin; Runnels. *ASLS.
719. Pan American 1 J. W. Barr; Runnels. *ASLS.
720. Superior 1 McDowell; Runnels. *ASLS.

TEXAS — Continued

SAN SABA

864. Newman 1 M. L. Weldon; San Saba. *WCTSLS.
865. Three Widows 1 Minnie Ballard; San Saba. *WCTSLS.
866. Norman and others 1 Gibbons; San Saba. *WCTSLS.
867. F. B. Plummer 1950, pl. 6, sec. 5, p. 22; Gibons Ranch. San Saba.
868. W. H. Hass, 1953, p. 73; 1959, p. 371; San Saba. 2.4 mi. SE. of courthouse of San Saba.

SCHLEICHER

903. R. W. Fair 1 Univ. "53"; Schleicher. *PBSL.
904. Humble 1 R. L. Henderson and wife; Schleicher. *PBSL.
905. Stanolind 1 R. S. Williams; Schleicher. *PBSL.
906. Robert W. Berry and others 1 A. B. Thomerson and others; Schleicher. *PBSL; PL, 1954.
907. Alvin C. Hope 1 Upton and Upton; Schleicher. *PBSL; PL, 1957.
908. Fryer and Hanson Drlg. 1 D. E. DeLong; Schleicher. *PBSL.
909. Sinclair-Prairie 1 Mary F. McClatchy; Schleicher. *PBSL.
910. Ashland 1 Brown; Schleicher. *PBSL.
911. Humble 1 D. M. Boyd; Schleicher. *GS; PL, 1961.
912. Texas Crude Oil and B. L. McFarland 1–8 N. Daughdrill; Schleicher. *PBSL.
913. Texas Crude Oil 1–15 T. C. Meador; Schleicher. *PBSL.
914. Ohio 1 A. L. Baugh and others; Schleicher. *PBSL.
915. Humble 1 D. M. Boyd; Schleicher. *GS; PL, 1961.
916. Skelly 1 J. T. Jackson; Schleicher. *PBSL.
917. C. E. Marsh II and others 1 Willoughby; Schleicher, *PBSL.
918. C. E. Marsh II 1 Davis; Schleicher. *PBSL.
919. Atlantic 1 W. B. Roberts; Schleicher. *PBSL.
920. Sorrels Oil 1 Mary Tisdale and others; Schleicher. *PBSL.
921. Cooper Gas 5–A–32 and 1–D–39 Bert Page; Schleicher. Ellison, 1957, p. 249.
922. TXL Oil 1 Mrs. C. R. Judkins; Schleicher. *GS; PL, 1961.
923. Humble 1 Sol Mayer "B"; Schleicher. *PBSL; PL. 1959.
924. F. A. Callery 1 S. E. Jones; Schleicher. *PBSL.
925. Magnolia 1 Mary Ball; Schleicher. *PBSL. PL, 1960.

SCURRY

471. Drlg. and Explor. 1–A Jones Bros.; Scurry. *PBSL.
472. Pan American 1 B. A. Moore; Scurry. *PBSL.
473. Texaco 249 P.L. Fuller NCT–1; Scurry. *PBSL.
474. Ohio 1–C J. W. Neal Est.; Scurry. *PBSL.
475. Louisiana Land and Explor. 1 E. C. Howell; Scurry. *PBSL.
476. Slick-Moorman 1 W. Sturgeon; Scurry. *PBSL.
477. Norsworthy 1 D. D. Feldman and others; Scurry. *PBSL.
478. Cities Serv. 1 Burney; Scurry. *PBSL.
479. Burdell 1 W. Brown; Scurry. *PBSL.
480. Amerada 1 J. Beck; Scurry. *PBSL.

SHACKELFORD

506. Texas Pacific Coal and Oil 1 P. S. Fincher; Shackelford. *ASLS.
507. Big West Drlg. (14–B) 1 J. H. Nail; Shackelford. *ASLS.
508. Deep Rock 1 Dawson and Conway; Shackelford. *ASLS.
509. Humble 1 Diller Est.; Shackelford. *ASLS.
510. West Central Drlg. 17–B J. M. Alexander; Shackelford. *ASLS.
511. Roeser and Pendleton 1 J. P. Morris Est.; Shackelford. *ASLS.
512. Mitchell 1 T. C. Partney; Shackelford. *ASLS.
513. McElroy Ranch 1 J. H. Sedwick; Shackelford. *ASLS.

TEXAS — Continued

SHACKELFORD — Continued

514. Phillips 1 Roark; Shackelford. *ASLS.
515. Danciger and Intex 1 Edwards Heirs; Shackelford. *ASLS.
516. Dean Bros. 1 J. P. Strickland; Shackelford. *ASLS.
517. Humble 1 H. O. West; Shackelford. *ASLS.
518. Starr 1 J. D. Windham; Shackelford. *ASLS.
519. King and others 1 C. B. Snyder; Shackelford. *ASLS.

SHERMAN

5. Phillips 1 Brady "E"; Sherman. *TPSLS.
6. Phillips 1 Virginia; Sherman, *TPSLS.
7. Phillips 1 Kathryn "B"; Sherman. *TPSLS.
8. I.T.I.O. (Cities Serv.) 1 S. J. Calvirid; Sherman. *TPSLS, 1955.

SOMERVELL

1174. M. E. Davis 1 T. H. Cousins; Somervell. *WCTSLS.

STEPHENS

520. Star 1 Walker Est.; Stephens. *WCTSLS.
521. Stephens and General Crude 1 B. Burgess; Stephens. *WCTSLS.
522. Tennessee Gas and Oil 1 S. P. Robertson; Stephens. *WCTSLS.
523. Oxford Drlg. 1 McMahon-Doss; Stephens. *ASLS.
524. McElroy Ranch 2 J. Barker and others; Stephens. *WCTSLS.
525. T–P Coal and Oil 1 C. L. Trammell; Stephens. *WCTSLS.
526. T–P Coal and Oil 1 S. L. Harris; Stephens. *WCTSLS.
527. American Mfg. 2 R. M. Rogers; Stephens. Abilene Geol. Soc., 1949.
528. Hunt 2 Hamilton; Stephens. *ASLS.
529. Jarrell and others 1 L. E. Turner; Stephens. *WCTSLS.
530. J. M. Gillans 1 Copeland; Stephens. Abilene Geol. Soc., 1949.

STERLING

697. Progress and Ray Albaugh 1 N. C. Parramore; Sterling. *PBSL.
698. Plymouth 1 F. W. Williams (Frost); Sterling. *PBSL.
699. Sunray Mid-Continent 1 G. H. McEntire; Sterling. *PBSL.
700. Humble 1 W. L. Foster, Jr., and others; Sterling. *PBSL.
701. Hunt 1 C. J. Copeland; Sterling. *PBSL.
702. Humble 1 R. T. Foster "B"; Sterling. *PBSL.
703. Texas 1–B W. L. Foster NCT–1; Sterling. *PBSL.
704. Wayne Babb 1 H. B. Bailey; Sterling. *PBSL.
705. Ultra 1 E. F. Atkinson; Sterling. *PBSL.
706. Humble 1 L. C. Harris and others; Sterling. *PBSL.

STONEWALL

365. Continental 1 Springer; Stonewall. *ASLS.
366. Cities Serv. 1–B Ward; Stonewall. *ASLS.
367. British-American 1 B. E. Tatum and others; Stonewall. *ASLS.
368. Woodley and Kirby 1 Godfrey; Stonewall. *ASLS.
369. Champlin Ref. 1 C. H. Boyd; Stonewall. *PBSL.
370. Medders-Roberts 1 Boyd; Stonewall. *ASLS.
371. Kadane and Sons 1 Peacock; Stonewall. *ASLS.
372. Moss and others 1–A Pumphrey; Stonewall. *ASLS.
373. Honolulu 1 S. Baugh; Stonewall. *PBSL.
374. Continental 1 Flowers; Stonewall. *ASLS.
375. G. Goff and others 1 Beulah Branch and others; Stonewall. *ASLS.
376. General Crude 1 J. W. Kennedy; Stonewall. *ASLS.
377. Rowan 1 W. Z. Rutherford; Stonewall. *ASLS.

TEXAS — Continued

SUTTON

948. Continental and others 1 Sol Mayer; Sutton. *PBSL.
949. C. L. Norsworthy, Jr., and Lone Star Prod. 1 R. M. Thompson; Sutton. Lisman, 1957, p. 57. *PBSL.
950. Texaco 1–C Allison NCT–I; Sutton. *PBSL; PL, 1960. Bluebonnet Oil and Gas 1 H. Walker Est.; Sutton. *PBSL.
951. T. A. Kirk and H. L. Neeb 1 B. B. Dunbar; Sutton. *PL, 1962.
952. Placid Oil 1 E. S. Mayer; Sutton. *PBSL.
953. C. L. Norsworthy, Jr., 1 Barton Heirs; Sutton. *PBSL.
954. C. L. Norsworthy, Jr., 1 R. A. Halbert; Sutton. *PBSL.
955. Amerada 1 Dilla Rode; Sutton. *GS; PL, 1961.
956. Ada Oil 1 Rip Ward; Sutton. *PBSL.
957. C. L. Norsworthy, Jr., 1 Sam Allison; Sutton. *PBSL.
958. Ada Oil 1 John D. Fields; Sutton. *PBSL.
959. C. L. Norsworthy, Jr., 1 E. E. Sawyer; Sutton. *PBSL.
960. Shell 1 Aldwell; Sutton. *PBSL.
961. C. L. Norsworthy, Jr., 1 M. S. Clarkson; Sutton. *PBSL.
962. Monterey Oil 1 Anderson; Sutton. *GS; PL, 1960.
963. C. L. Norsworthy, Jr., 1 Mrs. Harold Friess; Sutton. *PBSL.
964. Tucker Drlg. 1 Holman Est.; Sutton. *PBSL, PL, 1960.
965. Humble 1 D. J. Harrison; Sutton. *PBSL, PL, 1960.
966. H. L. Hunt 1 Bundy; Sutton. *WCTSLS.

SWISHER

87. Frankfort 1 Bradford; Swisher. *TPSLS.
88. Standard of Texas 1 Johnson; Swisher. *TPSLS, 1952.
89. H. L. Hunt 1 J. A. Bivens; Swisher. *TPSLS, 1952.
90. Humble 1 Nanny; Swisher. *PBSL.
91. L. B. Newman 1 M. A. Patton; Swisher. *TPSLS, 1956.
92. Frankfort Oil 1 Sweatt; Swisher. *TPSLS, 1958.

TARRANT

552. Carter 1 T. R. Hinton; Tarrant. *NTSLS.
553. Andrade III 1 R. B. Sharpless; Tarrant. *NTSLS.
554. Sullivan and others 1 L. and W. C. Putnam; Tarrant. *WCTSLS.
555. Rowan and others 1 B. L. Marcum; Tarrant. *WCTSLS.

TAYLOR

613. Roark, Hooker, and Roark 1 J. C. Hamner; Taylor. *ASLS.
614. Hovgard 2 H. H. and M. T. Ramsey; Taylor. *ASLS.
615. Sojourner 1 H. McCoy; Taylor. *ASLS.
616. West Central Drlg. 1 J. W. Seymore; Taylor. *ASLS.
617. Lester and Duffield and others 1 G. C. Stewart; Taylor. *ASLS.
618. Katz and Venable 1 L. Fletcher; Taylor. *ASLS.
619. Cherry and others 1 D. H. Christian; Taylor. *ASLS.
620. Delta 1 Marshall; Taylor. *ASLS.
621. Robinson-Puckett 1 A. B. Pfluger; Taylor. *ASLS.
622. Robinson-Puckett 1 E. T. Calvert; Taylor. *ASLS.
623. Little and Crawford 1 A. P. Head; Taylor. *ASLS.

TERRELL

1153. Shell and Humble 1 J. E. Smith; Terrell. *PL, 1959.
1154. Gulf 1 H. B. Allison; Terrell. *PL, 1959.
1155. Pan American 1 Ethel Corder; Terrell. *PL, 1959.
1156. Texas Crude and Superior 1–22 Allison; Terrell. *PL 1961.
1157. Humble 1 Annie Spencer; Terrell. *PL 1960.
1158. Sinclair 1 Alma H. Poulter; Terrell. *PL, 1960.
1159. Magnolia and Western Nat. Gas 1 Brown and Bassett; Terrell. Flawn and others, 1961.

TEXAS — Continued

TERRY

329. Honolulu 1 Covington; Terry. *PBSL.
330. Texas 1 Cowan; Terry. *PBSL.
331. Honolulu 19 Ellington "B"; Terry. *PBSL.
332. Humble 1 J. D. Beasley; Terry. *GS; PL, 1961.
333. Seaboard 1 Hinsun; Terry. *PBSL.
334. Texas 1 Spradling; Terry. *PBSL.
335. Anderson-Prichard 1 Oil Devel.; Terry. *PBSL.
336. Williamson, Roden, and TPC and C 1–A Colins; Terry. *PBSL.
337. Anderson-Prichard 1 Rich; Terry. *PBSL.
338. Amerada 1 Willard; Terry. *PBSL.
339. Tide Water Oil 1 Nystel; Terry. *PBSL.

THROCKMORTON

384. Warren 1 H. Allen; Throckmorton. *NTSLS.
385. Deep Rock 1 T. W. Forman; Throckmorton. *NTSLS.
386. Cities Serv. 1–41 Swenson; Throckmorton. *NTSLS.
387. Cities Serv. 1–170 Swenson; Throckmorton. *NTSLS.
388. K. J. Rich 1 Boyd; Throckmorton. *NTSLS.
389. Sky-Hi 1 P. G. Speth and others; Throckmorton. *NTSLS.
390. Texon and others 1 G. R. Davis; Throckmorton. *NTSLS.
391. Deep Rock 1 N. Wright; Throckmorton. *NTSLS.
392. Cities Serv. 1 Matthews Ranch; Throckmorton. *NTSLS.
393. Pan American 2 W. R. Matthews; Throckmorton. *NTSLS.
394. Hanlon-Boyle 1 K. Beaty and others; Throckmorton. *NTSLS.

TOM GREEN

837. Fletcher 1 E. C. Sugg; Tom Green. *PBSL.
838. Ohio 1–A J. W. Turner and others; Tom Green. *PBSL.
839. Lookabough 1 J. Y. Rust Est.; Tom Green. *ASLS.
840. Standard Oil of Texas 1 B. W. Moore and others; Tom Green. *PBSL.
841. Honolulu and Wahlemaier 1 C. R. Norsworthy; Tom Green. *PBSL.
842. H. B. Poff 1 L. V. Baden; Tom Green. *ASLS.
843. American Republics 1 E. E. Foster; Tom Green. *PBSL.
844. American Republics 1 A. C. Hennig and others; Tom Green. *PBSL.
845. Norsworthy 1–X J. W. Duff; Tom Green. *PBSL.
846. Republic Nat. Gas 1 J. W. Johnson; Tom Green. *PBSL.

TRAVIS

489. Midcoast (B. R. Floyd) 1 E. A. Jones; Travis. Flawn and others, 1961, p. 315.

489a. P. S. Griffiths and others 1 (2?) Evans; Travis. Flawn and others, 1961, p. 314.

UPTON

810. Sinclair 1 Davis; Upton. *PBSL.
811. Seaboard 1 Meiners; Upton. *PBSL.
812. Wilshire 1 McElroy; Upton. *PBSL.
813. Pure 1 Hanks "A"; Upton. *PBSL.
814. Humble 1 Pembrook; Upton. *PBSL.
815. Texas Pacific Coal and Oil 1 Egoff; Upton. *PBSL.
816. Richardson and Bass 1 Neal; Upton. *PBSL.
817. Ohio 1 Cox "A"; Upton. *PBSL.
818. Monsanto 1 Koy; Upton. *PBSL.
819. Phillips 1 Univ. "H"; Upton; *PBSL.
820. Vickers 1 Univ. of Texas; Upton. *PBSL.

TEXAS — Continued

UVALDE

1047. Bernard Einstoss 1 Roswell Wardlaw; Uvalde. Flawn and others, 1961, p. 317.
1048. Universal 1 Mtn. Eagle Ranch; Uvalde. Flawn and others, 1961, p. 319. *WCTSLS.
1049. Humble 1 R. L. Anderson; Uvalde. Flawn and others, 1961, p. 317. *WCTSLS.

VAL VERDE

983. Magnolia 1 L. M. Morrison; Val Verde. Flawn and others, 1961, p. 326. *PBSL; PL, 1956.
984. Pure 1 T. L. Drisdale; Val Verde. *PBSL; PL, 1957.
985. R. J. Caraway 1 Guida Rose; Val Verde. Flawn and others, 1961, p. 319. *PBSL.
R. J. Caraway 1 Whitehead; Val Verde. Flawn and others, 1961, p. 320.
986. Humble 1 Mills Min. Trust; Val Verde. Flawn and others, 1961, p. 323. *PBSL; PL, 1957.
987. Stanolind 1 Wayne W. West; Val Verde. Flawn and others, 1961, p. 330. *PBSL.
988. Phillips 1 B. E. Wilson; Val Verde. Flawn and others, 1961, p. 320. *PBSL; PL, 1961.
989. Western Nat. Gas 1 Bassett; Val Verde. Flawn and others, 1961, p. 331.
990. Killam 1 Everett; Val Verde. Flawn and others, 1961, p. 326.
991. Killam 1 Babb; Val Verde. Flawn and others, 1961, p. 326.
992. Sinclair 1 J. H. Herd; Val Verde. *GS; PL, 1961.
993. Phillips 1–A Guinn; Val Verde. Flawn and others, 1961, p. 328. *PBSL; PL, 1957.
994. Shell and Gulf 1–X Robert J. Cauthorn, Jr.; Val Verde. *PL, 1962.
995. Humble 1 Emma Wardlaw; Val Verde. Flawn and others, 1961, p. 323. *PBSL; PL, 1959.
996. C. A. Maurer 1 John W. Ingram; Val Verde. Flawn and others, 1961, p. 327.
997. Douglas Oil 1 J. E. Sellers (Sellars); Val Verde. Flawn and others, 1961, p. 320–321.
998. Fenslund (Fensland) Oil 1 Abb Rose; Val Verde. Flawn and others, 1961, p. 322.
999. Petrocel 1 Waldrop; Val Verde. Flawn and others, 1961, p. 328.
1000. D. Henry Werblow and Assoc. 1 Maude S. Newton; Val Verde. Flawn and others, 1961, p. 331. *PBSL.
1001. S. F. Hurlbut 1 Bluff Creek Ranch; Val Verde. Flawn and others, 1961, p. 324. * PBSL.

WARD

798. Socony Mobil 1 George Sealy "56"; Ward. *PL, 1959.
799. Gulf 1 Sealy Smith Found.; Ward. *PBSL.
800. Phillips 1–B Texas Univ.; Ward. *PBSL.
801. Gulf 44 W. A. Estes; Ward. *PL, 1959.

WICHITA

184. Hunter Bros. 1 B. Lee; Wichita; *NTSLS.
185. Taubert and Sneed 1 A. Powell; Wichita. *NTSLS.
186. Wood "A"–8 E. D. Heiserman; Wichita. *NTSLS.
187. Morrison 1 Krohn; Wichita. *NTSLS.
188. Akin and Dimock 1 Beulah May; Wichita. *NTSLS.
189. Continental and Phillips 1 R. L. Jackson; Wichita *NTSLS.
190. Continental 1 Hausler Bros.; Wichita. *NTSLS.
191. Goldsmith and others 1 R. L. Kempner; Wichita. *NTSLS.

TEXAS — Continued
WICHITA — Continued

192. Continental 1 S. Cunningham; Wichita. *NTSLS.

WILBARGER

168. Sunray Mid-Continent 2 C. F. Mock; Wilbarger *NTSLS.
169. Medders 1 C. H. Higgins; Wilbarger. *NTSLS.
170. Grace 1 H. Colley; Wilbarger. *NTSLS.
171. Dillard 1 E. D. Hollar; Wilbarger. *NTSLS.
172. Amerada 1 Alexander; Wilbarger. *NTSLS.
173. Dillard (Rycade) 1 B. Bond; Wilbarger. *NTSLS.
174. Blackwood-Nichols 1 C. Ayers; Wilbarger. *NTSLS.
175. Grace and Ford 1 R. B. Arnold; Wilbarger. *NTSLS.
176. Phillips 1–SW32 Milham Unit; Wilbarger. *NTSLS.
177. Cities Serv. 1 Lawson-Waggoner "AL" ; Wilbarger. *NTSLS.
178. Socony Mobil 1 Waggoner Est., Block "A"; Wilbarger. *NTSLS.
179. Cities Serv. 19–S Gussman-Waggoner "N"; Wilbarger. *NTSLS.
180. Continental 1 Waggoner "39"; Wilbarger. *NTSLS.
181. Continental 1 W. T. Waggoner "52"; Wilbarger. *NTSLS.
182. Woodson 1 J. B. Johnson; Wilbarger. *NTSLS.
183. Star A–1 Waggoner; Wilbarger. *NTSLS.

WILLIAMSON

940. Shell (and Sinclair) 1 Purcell; Williamson. Flawn and others, 1961, p. 337–338. *WCTSLS.
941. Hewitt and Dougherty 1 Pearson; Williamson. Flawn and others, 1961, p. 335.
942. W. E. Green (Reeves) 1 Lehman; Williamson. Flawn and others, 1961, p. 334.
943. S. L. Carpenter 1 S. J. Seward; Williamson. Flawn and others, 1961, p. 332–333.
944. Carr (Hewitt and Dougherty) 1 Maggie Mather; Williamson. Flawn and others, 1961, p. 333.
945. Sol Kopel 1 Ragsdale (Sauer); Williamson. Flawn and others, 1961, p. 335–336.
946. R. C. Miller and R. V. Mayfield 1 Miller (Fee); Williamson. Flawn and others, 1961, p. 336.
947. Palm Valley Oil (Round Rock Oil ?) 1 Walsh; Williamson. Flawn and others, 1961, p. 336.

WINKLER

671. Shell 1 Univ. "17–A": Winkler. *PBSL; PL, 1956.
672. Skelly 167 S. M. Halley: Winkler. *PBSL; PL, 1960.
673. Superior 1–D Sealy-Smith; Winkler. *PL, 1962.

WISE

419. Cities Serv. 1 E. B. Monk; Wise. *NTSLS.
420. Miles Prod. and C. M. and M. 1 Florida and others; Wise. *NTSLS.
421. Cities Serv. 1 B. O. Manning; Wise. *NTSLS.
422. C. M. and M.–Trio Drlg. 1 N. Kirk; Wise. *NTSLS.
423. Mid-Continent and Howell 1 G. S. Kaker; Wise. *NTSLS.
424. Cities Serv. E. T. McKissick; Wise. *NTSLS.
425. Champlin 1 Stanfield; Wise. *NTSLS.
426. Christie, Mitchell, and Mitchell 1 D. W. Newsome; Wise. *NTSLS.
427. Signal and others 1 J. Daly; Wise. *NTSLS.
428. Lone Star 1 R. A. Hudson; Wise. *NTSLS.

TEXAS — Continued

YOAKUM

321. Continental 1 Rodgers; Yoakum. *PBSL.
322. Stanolind 1 Argo Oil; Yoakum. *PBSL.
323. General American 1 Richmond; Yoakum. *PBSL.
324. Fullerton 1 Wolters; Yoakum. *PBSL.
Star Oil 1 Taylor Heirs "A"; Yoakum. *PBSL.
325. Fulton 1 Keller; Yoakum. *PBSL.
326. Texas 1 Fitzgerald; Yoakum. *PBSL.
327. Murchison and Fikes 1 Keely; Yoakum. *PBSL.
328. Anderson-Prichard 1 Hanks; Yoakum. *PBSL.

YOUNG

395. Pollard 1 Bloodworth "A"; Young. *NTSLS.
396. Pure 1 J. K. Jeffery; Young. *NTSLS.
397. Texaco 1 F. V. Hinson; Young. *NTSLS.
398. Wood and Cox 1–C. H. Shanafelt; Young. *NTSLS.
399. Netex 1 G. A. Welch; Young. *NTSLS.
400. Humble 1 Daws and others "B"; Young. *NTSLS.
401. Anderson 1 N. D. Stovall "E"; Young. *NTSLS.
402. Texas 1 I. McPherson; Young. *NTSLS.
403. Superior 1 A. C. Deats and others; Young. *NTSLS.
404. Texas 1 T. G. Price; Young. *NTSLS.
405. Gulf 1 Norton Property "E"; Young. *NTSLS.
406. Ratliff 1 N. D. Stovall; Young. *NTSLS.

UTAH

1. Huddle and McCann, 1947. 12–1N–9W.
2. Huddle, Mapel, and McCann, 1951. 29–2N–7W.
3. Kinney and Rominger, 1947. 7–2N–1E.
4. Strickland, 1956. 11, 14–2N–18E.
6. Kinney, 1951. 30, 31–1S–24 E.
7. Tidewater-Mohawk 58–7 Pine Ridge; 7–3S–20E. *AmStrat.
8. Gulf 1 Ute Federal; 12–4S–22E. *AmStrat.
9. Thomas, McCann, and Raman, 1945, chart 16. 16–4S–24E.
10. Phillips 1 Watson B; 34–9S–25E. *AmStrat.
11. Carter 1 Minton State; 32–14S–20E. *AmStrat.
12. Phillips 1 Two-Waters; 22–14S–25E. *AmStrat.
13. Turnbow, 1961, p. 76. 26–15S–10E.
14. Equity 1 Mounds; 33–15S–12E. *AmStrat.
15. Texaco 1 Fence Canyon Unit; 36–15S–22E. *AmStrat.
16. Sinclair 1 Govt.—San Arroyo; 26–16S–25E. *AmStrat.
17. Frontier-Stanolind 1 Crittenden; 12–17S–25E. *AmStrat.
18. El Paso Nat. Gas 1 Pack Saddle; 12–18S–12E. *AmStrat.
19. Parker and Roberts, 1963, p. 48. 29–19S–12E.
20. Continental Union, Mtn. Fuel 1 Unit; 23–20S–21E. *AmStrat.
21. Hansen and Bell, 1949, p. 140–141.
22. Equity 1 Govt.; 28–22S–15E. *AmStrat.
23. Standard of California 2 Unit; 27–23S–11E. *AmStrat.
24. Parker and Roberts, 1963, p. 48. 15–23S–17E.
25. General Pet. 45–5–G San Rafael River area; 5–24S–15E. *AmStrat.
26. Delhi 1 Russell; 34–25S–12E. *AmStrat.
27. Turnbow, 1961, p. 76. 18–26S–7E.
29. Parker and Roberts, 1963, p. 48. 29–26S–20E.
30. Phillips 1 Schick; 16–27S–16E. *AmStrat.
31. Parker and Roberts, 1963. 11–28S–4E.
32. Stanolind 1 Caineville Unit; 29–28S–8E. *AmStrat.
33. Pure 1 Teasdale-USA; 8–30S–6E. *AmStrat.
34. Mitchell, 1961, p. 178. 10–30S–24E.
35. Midwest 1 Hughes; 30–34S–19E. *AmStrat.
37. Parker and Roberts, 1963, p. 48. 20–35S–26E.
38. California 1 Unit; 12–36S–1E. *AmStrat.

UTAH — Continued

39. California 1 Unit; 18–36S–10E. *AmStrat.
40. Parker and Roberts, 1963, p. 49. 33–37S–15E.
42. Parker and Roberts, 1963, p. 49. 15–39S–18E.
43. Carter 1 Bluff Bench Unit; 29–39S–22E. *AmStrat.
45. Parker and Roberts, 1963. 4–39S–24E.
47. Knight and Baars, 1957, p. 2280. 5–40S–26E.
49. Carter 1 White Mesa; 1–42S–24E. *AmStrat.
50. Ohio 1 Navajo; 10–43S–21E. *AmStrat.
51. Tidewater 1 Unit; 34–42S–2W. *AmStrat.
52. Pacific Nat. Gas–Southern Union 1–27 Range Creek; 27–17S–16E. *AmStrat.
53. Skelly 1 Emery Unit; 34–22S–5E. *AmStrat.
54. Phillips 2 Onion Creek; 13–24S–23E. *AmStrat.
55. La Rue 1 Govt.; 15–27S–22E. *AmStrat.
56. Tennessee Gas 1–A USA–Sorrell Butte; 33–29S–12E. *AmStrat.
57. Humble 1 Rustler dome; 4–29S–20E. *AmStrat.
58. Texas Pacific Coal and Oil 1 Govt. A; 33–32S–15E. *AmStrat.
59. Phillips 2 Escalante anticline; 29–32S–3E. *AmStrat.
60. Hunt 1 Circle Cliffs; 24–34S–7E. *AmStrat.
61. Byrd Oil 1 Govt.; 5–40S–5E. *AmStrat.
62. Shelby 1–A Nokai dome; 27–40S–12E. *AmStrat.
64. Superior 1 Kanab Creek Unit; 16–42S–7W. *AmStrat.
101. Blue, 1960, p. 31–35.
102. Olson, 1960, p. 115–130, 131–138, 326–339.
Stokes, 1963.
103. Peace, 1956, p. 20–24.
104. Peace, 1956, p. 30–31.
105. Baker, 1959, p. 30–32.
106. Paddock, 1957, p. 48–57, 87.
107. Anderson, 1957, p. 62.
Anderson, 1960, p. 114–115.
108. Anderson, 1957, p. 62–69.
Anderson, 1960, p. 114–115.
109. Stokes, 1963.
110. Stokes, 1963.
Doelling, 1964, p. 172–205.
111. Rigby, 1958, p. 38–49.
112. Teichert, 1959, p. 38–48.
113. Schaeffer, 1960, p. 78–88.
114. Sadlick, 1965, p. 42, 150–154.
Schaeffer, 1960, p. 78–88.
115. Nolan, 1935, p. 24–35.
Morris and Lovering, 1961, p. 81–114, pl. 4.
116. Nolan, 1935, p. 24–35.
Morris and Lovering, 1961, p. 81–114, pl. 4.
117. Gilluly, 1932, p. 22–34.
Bissell, 1959a, p. 37–58.
118. Morris, 1964, p. L4, pl. 1.
119. Tooker and Roberts, 1961 p. 20–25.
120. Young, 1955, p. 28–34, 69–79.
121. Cohenour, 1959, p. 87–93, 168–177.
122. Staatz and Carr, 1964, p. 65–70, pl. 1.
123. Groff, 1959, p. 70–85.
*H. T. Morris, USGS, 1966, written commun.
Approx. 9, 10, 11, 12S–4W, 5W.
124. Doelling, 1964, p. 172–205.
126. Crittenden, 1965a.
*M. D. Crittenden, Jr., USGS, 1960, written commun. Approx. 2S–2E.
127. Crittenden, 1965b.
Calkins and Butler, 1943, p. 20–28.

WEST VIRGINIA — Continued

14. Wilpolt and Marden, 1959, pl. 28; Martens, 1945, p. 732. NW. Mullins 15′ quad.
15. Martens, 1945, p. 497. NE. Flattop 15′ quad.
16. Martens, 1945, p. 55. North-central Peytonia 15′ quad.
17. Martens, 1945, p. 80. East-central Madison 15′ quad.
18. Martens, 1945, p. 88. East-central Peytonia 15′ quad.
19. Martens, 1945, p. 95. NE. Logan 15′ quad.
20. Martens, 1945, p. 114. SW. Gassaway 15′ quad.
21. Martens, 1945, p. 131. North-central Sutton 15′ quad.
22. Martens, 1945, p. 128. SE. Burnsville 15′ quad.
23. Martens, 1945, p. 133. West-central Steubenville 15′ quad.
24. Martens, 1945, p. 141. SE. Guyandot 15′ quad.
25. Martens, 1945, p. 150. West-central Arnoldsburg 15′ quad.
26. Martens, 1945, p. 156. NE. Arnoldsburg 15′ quad.
27. Martens, 1945, p. 177. NE. Otter 15′ quad.
28. Martens, 1945, p. 187. South-central Otter 15′ quad.
29. Martens, 1945, p. 205. West-central Centerpoint 15′ quad.
30. Bayles and others, 1956. SE. Marietta 15′ quad.
31. Martens, 1945, p. 212. East-central Holbrook 15′ quad.
32. Martens, 1945, p. 213. East-central part of West Union 15′ quad.
33. Martens, 1945, p. 217. NW. Fayetteville 15′ quad.
34. Martens, 1945, p. 225. Central Glenville 15′ quad.
35. Martens, 1945, p. 249. South-central Wellsville 15′ quad.
36. Martens, 1945, p. 257. West-central Clarksburg 15′ quad.
37. Martens, 1945, p. 264. East-central Weston 15′ quad.
38. Martens, 1945, p. 278. North-central Ripley 15′ quad.
39. Martens, 1945, p. 302. Central Ripley 15′ quad.
40. Martens, 1945, p. 306. NE. Winfield 15′ quad.
41. Martens, 1945, p. 319. South-central Kenna 15′ quad.
42. Martens, 1945, p. 326. NW. Montgomery 15′ quad.
43. Martens, 1945, p. 335. NE. Charleston 15′ quad.
44. Martens, 1945, p. 346. SE. Charleston 15′ quad.
45. Martens, 1945, p. 360. NW. Charleston 15′ quad.
46. Martens, 1945, p. 371. Central St. Albans 15′ quad.
47. Martens, 1945, p. 374. NE. Burnsville 15′ quad.
48. Martens, 1945, p. 379. West-central Vadis 15′ quad.
49. Martens, 1945, p. 385. SW. St. Albans 15′ quad.
50. Martens. 1945, p. 388. West-central Midkiff 15′ quad.
51. Martens. 1945. p. 392. North-central Logan 15′ quad.
52. Martens, 1945, p. 420. North-central New Martinsville 15′ quad.
53. Martens, 1945, p. 428. North-central Littleton 15′ quad.
54. Martens, 1945, p. 433. South-central Ravenswood 15′ quad.
55. Martens, 1945, p. 438. Central Naugatuck 15′ quad.
56. Martens, 1945, p. 442. Central Blacksville 15′ quad.
57. Martens, 1945. p. 455. West-central Morgantown 15′ quad.
58. Martens, 1945, p. 456. South-central Clay 15′ quad.
59. Martens, 1945, p. 458. East-central Marietta 15′ quad.
60. Martens, 1945, p. 465. Central St. Marys 15′ quad.
61. Martens, 1945, p. 477. SE. Morgantown 15′ quad.
62. Martens, 1945, p. 481. East-central Milton 15′ quad.
63. Martens, 1945, p. 484. SE. Winfield 15′ quad.
64. Martens, 1945, p. 489. SW. Eccles 15′ quad.
65. Martens, 1945, p. 503. South-central Meadow Creek 15′ quad.
66. Martens, 1945, p. 507. NE. Mullins 15′ quad.
67. Martens, 1945, p. 517. SW. part of West Union 15′ quad.
68. McCord and Eckard, 1963, p. 5–13.
69. Martens, 1945, p. 543. South-central Walton 15′ quad.
70. Martens, 1945, p. 551. West-central Fairmont 15′ quad.
71. Martens, 1945, p. 567. South-central New Martinsville 15′ quad.

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72. Martens, 1945, p. 569. SE. Crawford 15′ quad.
73. Martens, 1945, p. 571. West-central Sago 15′ quad.
74. Martens, 1945, p. 575. East-central Crawford 15′ quad.
75. Martens, 1945, p. 580. SE. Ceredo 15′ quad.
76. Martens, 1945, p. 584. SE. Louisa 15′ quad.
77. Martens, 1945, p. 597. NE. Wayne 15′ quad.
78. Martens, 1945, p. 613. North-central Naugatuck 15′ quad.
79. Martens, 1945, p. 617. Central Hacker Valley 15′ quad.
80. Martens, 1945, p. 643. SE. Littleton 15′ quad.
81. Martens, 1945, p. 660. SE. Elizabeth 15′ quad.
82. Martens, 1945, p. 665. NW. Elizabeth 15′ quad.
83. Martens, 1945, p. 669. NW. Belleville 15′ quad.
84. Martens, 1945, p. 671. East-central Belleville 15′ quad.
85. Martens, 1945, p. 689. West-central Marietta 15′ quad.
86. Martens, 1945, p. 700. South-central Pineville 15′ quad.
87. Martens, 1939, p. 82. West-central Morgantown 15′ quad.
88. Martens, 1939, p. 91. SW. Belleville 15′ quad.
89. Martens, 1939, p. 111. SW. Phillipi 15′ quad.
90. Tucker, 1936, p. 293. SE. Wheeling 15′ quad.
91. Tucker, 1936, p. 304. Central Point Pleasant 15′ quad.
92. Tucker, 1936, p. 298. Central Glenwood 15′ quad.
93. Tucker, 1936, p. 405. SE. Ripley 15′ quad.
94. Tucker, 1936, p. 27. South-central Paytonia 15′ quad.
95. Tucker, 1936, p. 107. North-central Clay 15′ quad.
96. Tucker, 1936, p. 490. Central Cowan 15′ quad.
97. Tucker, 1936, p. 357. West-central Richwood 15′ quad.
98. Tucker, 1936, p. 118. NW. Beckley 15′ quad.
99. Hennen and Reger, 1914. Baltimore and Ohio RR between Anderson and Rowlesburg.
100. White, 1924. Potomac River gorge east of Piedmont, W. Va.
101. Grimsley, 1916. Sleepy Creek coal field, Handcock 15′ quad.
102. Grimsley, 1916, p. 140. Rockwell Run, Paw Paw 15′ quad.
103. Tilton and others, 1927, p. 97–101. Hampshire County, Wardensville 15′ quad.
104. Tilton and others, Prouty, 1927, p. 333. Hardy County, Moorefield 15′ quad.
105. Reger, 1923, p. 111. Limestone Mtn., Parsons 15′ quad.
106. Reger, 1931, p. 187. 6½ miles E. of Elkins, Horton 15′ quad.
107. Reger, 1931, p. 155. 6 miles SW. of Elkins, Elkins 15′ quad.
108. Reger, 1931, p. 144. Arvondale Junction: NE. Hacker Valley 15′ quad.
109. Reger, 1931, p. 165. 8 miles NW. of Durbin, Durbin 15′ quad.
110. Reger, 1931, p. 168. 3 miles NW. of Durbin, Durbin 15′ quad.
111. Reger, 1931, p. 170. SE. Pickens 15′ quad.
112. Reger, 1931, p. 176. NE. Mingo 15′ quad.
113. Tilton and others, 1927, p. 178. At Onego, Onego 15′ quad.
114. Tilton and others, 1927, p. 182. Central Fort Seybert 15′ quad.
115. Price, 1929, p. 93. South-central Mingo and north-central Marlinton 15′ quads.
116. Price, 1929, p. 112. East-central Lobelia 15′ quad.
117. Price and others, 1939, p. 180; Wells, 1950. SW. to SE. Lobelia 15′ quad.
118. Price and others, 1939, p. 202. South-central White Sulphur Springs 15′ quad.
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120. Reger, 1926, p. 239. SE. Meadow Creek 15′ quad.
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