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Preliminary Report on Conodonts of the Meramecian Stage (Upper Mississippian) from the Subsurface of Western Kansas

By Thomas L. Thompson and Edwin D. Goebel

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PREFACE

Conodonts are microscopic toothlike and platelike structures belonging to an extinct, unknown group of marine animals which probably were bilaterally symmetrical, soft bodied, and free swimming. These fossil structures range from a fraction of a millimeter to about three millimeters in length. They are composed chiefly of calcium phosphate, are either amber or grayish black in color, and are translucent to opaque. Conodonts, known to range from the Lower Ordovician into the Upper Triassic, have a world-wide distribution and have been found to be a useful tool to the stratigraphic paleontologist, despite the fact that there has been little unanimity on the zoological affinity of the animal that bore the conodonts, or on the function that was performed by these structures (Hass, 1962). Conodonts are good index fossils because they are durable, abundant, distinctive, and widespread in their geographic distribution yet restricted in their stratigraphic ranges. Because they are minute, conodonts are well suited for subsurface investigation. They provide a relatively dependable means of correlating different lithologies of biostratigraphic equivalents.

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ABSTRACT

A preliminary report is made of the success of a pilot study of recovery of conodonts from well cores of subsurface Meramecian rocks of western Kansas, and on their use as stratigraphic indicators. Comparison with the standard section in the upper Mississippi Valley through the use of conodonts as a tool of correlation seems to be feasible and tends to substantiate the lithologic divisions used by Lee (1940) and Clair (1948).

Résumé: On a fait un rapport préliminaire du succès d'une étude pilote sur la récupération de conodontes des noyaux de sondages des roches du Meramecian souterrains de Kansas ouest, et sur leur emploi comme indicateurs stratigraphiques. La comparaison à la section étalon dans la Mississippi Valley supérieure par l'emploi de conodontes comme moyen de corrélation semble être faisible et tend à confirmer les divisions lithologiques employées par Lee (1940) et Clair (1948).

Resumen: Este es un informe preliminar de el éxito de un estudio piloto sobre la recuperación de conodontos de los sondeos de pozos de rocas subterráneas de edad del Meramecian en la parte occidental de Kansas, y de su uso como indicadores estratigráficos. La comparación con la sección clásica en el Mississippi Valley superior parece ser factible y tiende a verificar las divisiones litológicas usadas por Lee (1940) y Clair (1948) a través de el uso de los conodontos como instrumentos de correlación.

Auszug: Es wird ein vorläufiger Bericht über den Erfolg eines Erststudiums gegeben, das sich mit der Erlangung von Conodonten aus Bohrkernen von unterirdischen Meramecian Gesteinen West-Kansas und mit ihrem Gebrauch als stratigraphische Indikatoren befasste. Ein Vergleich mit der Standard-Schichtenfolge im oberen Mississippi Valley durch den Gebrauch von Conodonten als Korrelations-Handhabe scheint durchführbar zu sein und untermauert im allgemeinen die lithologischen Einteilungen, die von Lee (1940) und Clair (1948) gebraucht worden sind.

INTRODUCTION

The Mississippian sequence of rocks in western Kansas is confined to the subsurface (Fig. 1). In ascending order, Kinderhookian, Osagian, Meramecian, and Chesteran rocks are present (Fig. 2). Chesteran rocks are confined to the deeper parts of the Hugoton Embayment and unconformably overlie Meramecian rocks. Elsewhere in western Kansas, the Meramecian rocks are overlain unconformably by Pennsylvanian rocks.

The known thickness of the Meramecian rocks ranges from a featheredge on the flank of the Central Kansas Uplift to more than 850 feet in the center of the Hugoton Embayment. Presently, subdivision of the Meramecian rocks in western Kansas is based wholly on lithologic characteristics, some of which have been found useful elsewhere in Kansas. Establishment of Mississippian carbonate rock equivalents in western Kansas by electric log characteristics has been found to be generally unreliable. Stratigraphic equivalency has been demonstrated by means of unique insoluble residues from Mississippian rocks in Kansas.

Most Mississippian megafossils recovered from well cores consist of fragments of large shells and an occasional small shell large enough to allow tentative generic identification. Megafossils have been found to be abundant in certain parts of the Meramecian rocks of western Kansas, but because many Mississippian genera have long ranges, a list of genera would have slight value as evidence for age determination (Girty, 1940). For this reason, researchers recently have looked toward microfossils as a feasible tool for subdivision of the Mississippian rock section, especially the standard surface sections of Mississippian rocks.

The present usage of conodonts as guide fossils within the type area of the Chesteran Stage in the upper Mississippi Valley demonstrates the practicality of these forms as tools of correlation. The delineation of biostratigraphic zones and correlations based on conodonts from the Devonian-Lower Mississippian rocks have also been demonstrated for the upper Mississippi Valley standard section (Collinson and others, 1962). Because the usefulness of conodonts as guide fossils has been demonstrated in the type Mississippian section, a pilot study was established at the Kansas Geological Survey to determine if rock cores, previously correlated primarily on the basis of lithologic features and assigned to the Meramecian Stage in western Kansas, contained sufficient conodonts to make age determination possible (Thompson, 1962). Information on some cores from which megafossils had been previously identified (Girty, 1940), supplemented by that on cores recovered subsequently by the petroleum indus-

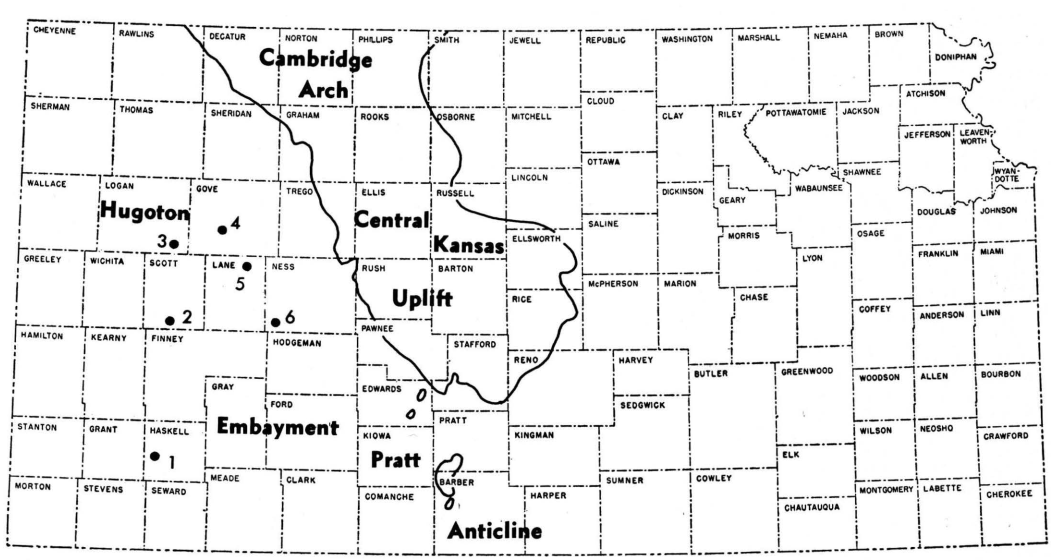

FIGURE 1.—Index map showing subsurface distribution of Mississippian rocks in western Kansas, major structural elements (Merriam and Goebel, 1959), and locations of wells used in this study. Mississippian rocks absent in enclosed areas.

try in western Kansas, was utilized.

Although a small number of cores was available for study and a restricted research period was imposed upon the pilot study, a sufficient recovery of conodont genera was realized to make a preliminary report of findings feasible at this time. Workers involved in mineral exploration and attempting subdivision of the Meramecian rocks in western Kansas should find immediate value in the preliminary results.

Previous Studies

Rocks of the Meramecian Stage appear in surface exposures in Kentucky, Illinois, Iowa, eastern Missouri, and southwestern Missouri. The formations in the type area include, in ascending order, the Warsaw, Salem, St. Louis, and Ste. Genevieve Limestones. The nearest complete Meramecian outcrop to western Kansas is in Ste. Genevieve County, southeastern Missouri, approximately 600 miles from the study area. The outcrop area was thoroughly studied by Weller and St. Clair (1928).

The Meramecian formations of southeastern Missouri have been traced into western Missouri by the Missouri Geological Survey. Through lithologic comparison of samples and residues from wells in western Missouri and eastern Kansas, Lee (1940) established the usage of the standard Meramecian formational names in Kansas. Clair (1948) described the equivalent formations in western Kansas. Maher and Collins (1949) reported the lithology of the Meramecian rocks in a series of cross sections across the Hugoton Embayment in parts of Colorado, Kansas, and Oklahoma. Lee (1953), on the basis of additional sample determinations, redescribed some Meramecian sections in southwestern Kansas. Girty (1940) identified megafossils of Mississippian age from some well cores in western Kansas.

Collinson and others (1962) defined conodont assemblage zones for the Upper Devonian and Mississippian units of the upper Mississippi Valley. Their report summarizes earlier studies within the Midcontinent region. Three earlier studies include Meramecian conodonts: Branson and Mehl (1941b) described the forms found in the "Keokuk Formation"—their collecting locality was later demonstrated to be of Warsaw age (Charles Collinson, Illinois Geological Survey, personal communication); Rexroad and Collinson studied the faunas of the St. Louis Limestone and of the Valmeyeran Series of Illinois (both manuscripts unpublished at the time of writing).

Mississippian formations not present within the standard section but from which Meramecian conodont faunas have been described include: the Carboniferous Limestone of Scotland (Hinde, 1900; Clarke, 1960); the Barnett Shale of Texas (Roundy, 1926; Hass, 1953; Elias, 1956, 1959); the Stanley Shale of Oklahoma (Hass, 1950, 1956; Elias, 1956, 1959); the Pella beds of

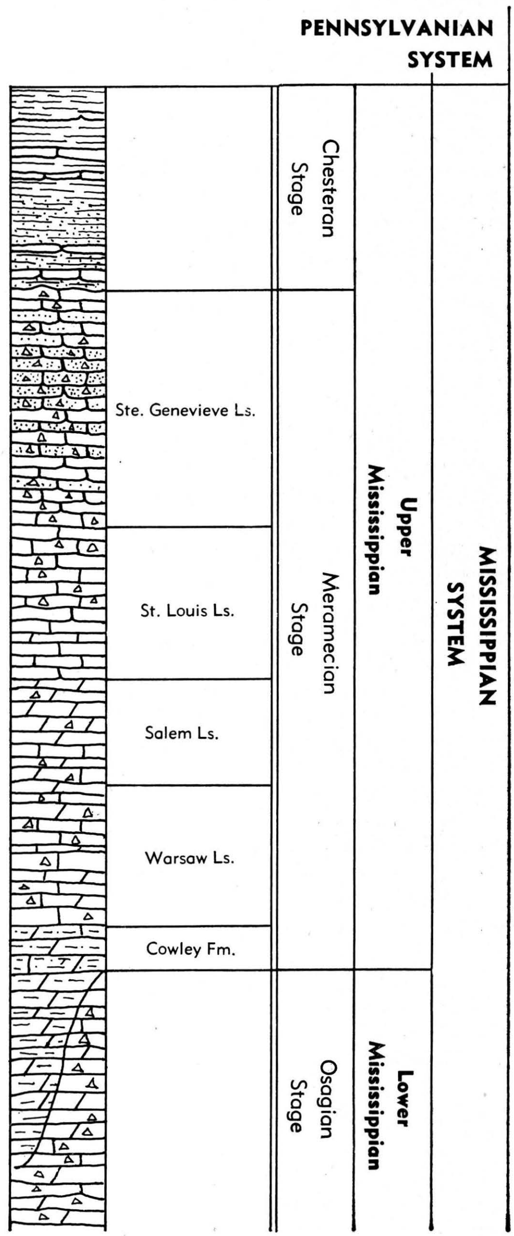

FIGURE 2.—Generalized section of Meramecian rocks in western Kansas (Jewett, 1959).

Iowa (Youngquist and Miller, 1949); and the subsurface Mississippian rocks in northeastern Mississippi (Hass, 1954).

Methods of Study

The validity of the results of any study often is limited by the researchers' procedures. Therefore, a brief review of methodology is included to assist evaluation of results.

Six cores from rotary drilled wells which penetrated the Meramecian section in the Hugoton Embayment in western Kansas were selected for study because of their completeness and their widespread distribution over the embayment. All six cores were necessary to represent the Meramecian section. The stratigraphic sequence represented was determined by evaluation of core descriptions and allied well-log data on file at the Kansas Geological Survey. The composite section is considered representative of the Meramecian section in the area studied.

From each core 200-gram samples were selected at approximately 1-foot intervals. Selection of samples was not influenced by any lithologic change. The amount of material available was controlled by the diameter of the cores, which ranged from 3 to 4 inches. Because cores are not replaceable, no more than one quadrant of each piece of core was available for use in this study, thus limiting the size of samples processed.

The samples were crushed in an electric-powered jaw crusher, then placed in beakers containing 10 percent glacial acetic acid. Shale was broken down by boiling and soaking with various detergents and deflocculants. The resulting residues were screened between 18- and 100-mesh sieves; the part retained on the 100-mesh sieve contained the conodont specimens.

Few samples were completely dissolved on the first acid immersion, necessitating the addition of fresh acid. Repeated acid treatment caused some etching of conodonts in early recovery attempts. To avoid destruction of specimens, the sample was sieved and the part retained on the 100-mesh screen, containing the conodont specimens, was separated from the partly digested material on the 18-mesh screen. The material retained on the 18-mesh screen was placed in fresh acid.

A total of 455 samples was processed in this study. From the residues of large volume the conodonts were concentrated by gravity separation in tetrabromethane; from residues of lesser volume the specimens were picked directly, through the use of a microscope. Specimens of conodonts picked from the residues were grouped first by sample and well, regrouped by genus and species, and finally grouped by stratigraphic position.

Location and Description of Cores

Lithologic core descriptions and horizons from which conodont specimens were collected are given in Table 1. Core data include names of wells, legal descriptions, and tops of Mississippian formations. The locations of the wells are shown graphically in Figure 1.

The wells chosen for study represent a sequence of Meramecian rocks ranging from an almost complete section from the center of the Kansas part of the Hugoton Embayment to a section containing only the lowermost Meramecian formations, situated near the truncated edge of the Mississippian rocks as they presently outline the Central Kansas Uplift.

In addition to the six cores described in this study, two cores (the No. 1 Thornbrough, sec. 16, T. 21 S., R. 35 W., and the No. 2-A Fralick, sec. 14, T. 27 S., R. 20 W.) were sampled and found to contain no identifiable conodonts.

The residue from the dominantly carbonate sequence of rocks in the No. 1 Thornbrough from 4,866 to 4,893 feet was characterized by a large percentage of rounded, frosted sand grains. One unidentifiable conodont fragment was found. The section studied from the No. 2-A Fralick core (4,805 to 4,843 feet) comprised alternating bands of maroon and green dolomite. Four reworked, unidentifiable conodont fragments were recovered from 48 samples processed.

Drilling samples, chosen for their cleanliness and apparent freedom from contamination, were processed from the No. 1 Watkins well (sec. 20, T. 32 S., R. 21 W.). A total of 115 samples was processed from a 565-foot sequence containing dominantly carbonate Meramecian rocks (complete section) which included silty dolomite and silty limestone in the lower part. Six reworked unidentifiable conodont fragments were found. The lack of recovered material could be accounted for by the small volumes of samples available (averaging 25 grams) or by the very fine size of the fragments. Other possible reasons for failure to recover specimens include: they were never present; they were destroyed or not recovered through procedural failures.

Acknowledgments

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of the Illinois Geological Survey for his interest and personal assistance in the study. Others who gave constructive criticisms on parts of this report include Wendell Johns, J. M. Jewett, William Furnish, and Brian Glenister.

Repository

All material recovered in this study has been retained by the Kansas Geological Survey.

STRATIGRAPHIC DESCRIPTION

The sequence of formations of the Meramecian Stage in western Kansas, in ascending order the Warsaw, Salem, St. Louis, and Ste. Genevieve Limestones, is a dominantly carbonate lithologic section. The partial or complete removal of the upper Meramecian formations by post-Mississippian erosion renders lithologic comparisons difficult. In some cases, even thorough lithologic comparisons cannot produce positive formational identification. This problem is compounded as the eastern, truncated edge of the eroded Mississippian rocks in the Hugoton Embayment is approached (against the Central Kansas Uplift). The known thickness of the Meramecian rocks ranges from a featheredge on the western flank of the Central Kansas Uplift to more than 867 feet in the center of the Hugoton Embayment. There has been removal by erosion of the Ste. Genevieve, St. Louis, and part of the Salem (Spergen) Limestones to the north and east. Onlap of the rocks toward the west, north, and east probably resulted in the lack of deposition of the Warsaw Limestone in the northern part of the embayment and the Warsaw, Salem, and most of the St. Louis strata in the southwestern part (Maher and Collins, 1949).

Moore and others (1951) noted that the Meramecian rocks lie disconformably on deeply eroded Osagian rocks in southern Kansas. A rapid increase in the percentage of chert in samples recovered from drilling wells is often cited as indicating the top of Osagian rocks. The thickness of the weathered Osagian chert, which averages 100 feet, has been advanced as the principal evidence of erosion at the close of Osagian time. The Osagian chert is coarse, white, opaque, blocky, generally deeply weathered, and tripolitic, thereby differing from the overlying dark, opaque, mottled fossiliferous chert of the Warsaw.

The lower half of the Warsaw Limestone at outcrops in southeastern Missouri is composed of blue to gray-black calcareous shale containing argillaceous limestone lenses, and the upper half is composed of fine-grained, argillaceous, cherty, dolomitic limestone. In western Kansas unique microfossiliferous Warsaw chert was noted by several early researchers. Clair (1948) noted that in some areas of western Kansas the Warsaw is shaly, and he observed mostly gray, mottled, opaque, and very microfossiliferous chert, in which most of the fossils were difficult to discern because they were nearly the color of the matrix. Disseminated grains of glauconite in both dolomite and chert is given as another diagnostic characteristic of the Warsaw Limestone. The top of the Warsaw was placed by Clair (1948) at the top of a somewhat persistent glauconite zone.

Maher and Collins (1949) felt separation of the Warsaw from the overlying Salem (Spergen) Limestone was not possible at the time of their investigation. A shoreward facies (north and west) and a basinward facies (southeast in the embayment) of the Salem-Warsaw Limestones were delineated by them. Lee (1953) also observed the similarities of lithologies of the Warsaw and Salem rocks in that they both comprise limestone interbedded with dolomite in sucrose beds in which fossil fragments are embedded in a dolomite matrix. Lee also noted that crowded masses of broken microfossils and spicules (sponge?) characterize the Warsaw chert. The chert is, for the most part, in greater relative abundance than in the Salem Limestone. Clair (1948) noted that the dolomite and dolomitic limestone of the Warsaw tend to be darker than limestone in the overlying Salem (Spergen) and range through shades of gray and brown.

Lee (1940, 1953) felt that the Cowley Formation is discernible next below the Warsaw Limestone, although the contact is often vague. As defined by Lee, the Cowley Formation extends across southern Kansas. The Cowley Formation is characterized by silty and siliceous dolomite and limestone and dolomitic siltstone. In some areas, large quantities of medium- and dark-gray, opaque, microfossiliferous chert are present. A glauconite zone at the base of the Warsaw Limestone distinguishes it from the Cowley Formation. The glauconite at the base of the Warsaw Limestone is characteristically light green in color and of earthy texture, and it occurs as void fillings in the limestone and dolomite, especially in the molds of fossils and in the centers of crinoid joints. A glauconite zone, when present, at the base of the Cowley consists mostly of dark-green clastic grains in silty and siliceous dolomite.

The Warsaw Limestone as defined by Lee (1940) ranges up to 250 feet in thickness in the

TABLE 1.—Core descriptions of intervals sampled from six wells used in study. Measurements in feet below surface. An asterisk indicates horizon in which conodont specimens were found; species listed in parentheses.

1. No. 1 EUBANK, HELMERICK & PAYNE OIL CO., NW NW NW SEC. 28, T. 28 S., R. 34 W., HASKELL COUNTY

Chesteran 5341 (top Mississippian rock)

5435-5443	Sandstone, fine grained, brown, silty

Ste. Genevieve Limestone 5444

*5446-5448	Limestone, shaly (*Cavusgnathus* sp., *Spathognathodus* sp.)
5448-5449	Shale, green, greasy, calcareous
5449-5461	Limestone, coarsely crystalline, brown

2. No. 1-A MARK, ATLANTIC OIL CO., C SE SE SEC. 28, T. 20 S., R. 33 W., SCOTT COUNTY

St. Louis Limestone 4756 (top Mississippian rock)

4756-4760	Limestone, white, large round sand grains included
*4760-4769	Limestone, lithographic, brown *(Apatognathus geminus)*
4769-4786	Limestone, medium crystalline, gray
*4798-4800	Same as above *(Neoprioniodus loxus)*
4800-4811	Limestone, oolitic, brown, some is lithographic
*4811-4812	Limestone, medium crystalline, brown (*Cavusgnathus* sp.)
4816-4817	Limestone, impure, argillaceous, large lumps of calcite embedded in dark material
*4826-4828	Limestone, oolitic, large round white oolites show concentric structure (*Taphrognathus* sp.)
4828-4836	Limestone, oolitic, arenaceous
4836-4840	Limestone, nonoolitic, brown, finely crystalline, some chert
4845-4846	Same as above
4846-4850	Limestone, brown, oolitic
*4850-4862	Limestone, lithographic, brown, embedded blue or black chert (*Cavusgnathus* sp.)
4875-4876	Limestone, with detrital material including large round sand grains
4880-4881	Limestone, medium crystalline, some detrital material
4885-4889	Limestone, lithographic, brown
4894-4898	Same as above
4898-4901	Limestone, lithographic, with much detrital conglomerate
4901-4902	Limestone, medium crystalline, brown, much blue and dark-gray chert
*4939-4948	Limestone, medium crystalline, brown, oolitic, stylolites (*Hindeodella* sp., *Neoprioniodus loxus*)

Salem Limestone 4960 (from scout data)

4960-4961	Limestone, brown, argillaceous, much foreign material; bryozoans, crinoids, oolites
4964-4974	Limestone, fragmental, fossiliferous; crinoids and bryozoans especially numerous; oolites present but not plentiful
4980-4981	Limestone, argillaceous; numerous bryozoans and crinoids
4981-4983	Dolomite, finely crystalline, gray
4983-4988	Limestone, medium crystalline, brown
4990-4991	Dolomite, granular, white, with small blue chert nodules
5012-5030	Limestone, brown, with crinoid fragments and oolites
*5030-5036	Limestone, brown, pure oolite rock (*Synprioniodina* sp.)
5036-5041	Limestone, conglomeratic, with crinoid fragments and oolites

Warsaw Limestone 5050

5050-5055	Limestone, finely crystalline, white or buff
*5055-5065	Limestone, brown, pure oolite rock *(Gnathodus texanus)*

3. No. 1 WATCHORN, ALMA OIL CO., C SW NE SEC. 13, T. 15 S., R. 33 W., LOGAN COUNTY

Ste. Genevieve Limestone 4460 (top Mississippian rock)

4460-4464	Shale, wavy bedded, black to gray, silty, conglomeratic, pieces of siltstone included
*4479-4489	Limestone, finely crystalline, dense, lower 6 inches microcrystalline *(Cavusgnathus unicornis)*

St. Louis Limestone 4488 (from scout data)

*4489-4499	Limestone, finely crystalline, dense, shale partings numerous, more shaly in lower 4 feet *(Neoprioniodus scitulus)*
*4576-4589	Limestone, finely crystalline, arenaceous (reworked *Gnathodus texanus* and *Taphrognathus varians*)

Salem Limestone 4612

*4628-4646 Limestone, fossil cast, porous, finely granular to coarsely crystalline, tan to buff, gray opaque to subopaque chert *(Taphrognathus varians)*

4. No. 1 Hocker-Smith, Argo Oil Co., NW NW NW sec. 19, T. 14 S., R. 29 W., Gove County

Pennsylvanian rock

*4346-4360 Limestone, finely crystalline, dolomitic, shaly, conglomeratic at base *(Cavusgnathus unicornis, Gondolella, Hibbardella, Hindeodella, Idiognathodus, Ligonodina, Metalonchodina, Ozarkodina, Streptognathodus, Synprioniodina)*

*4360-4378 Quasibreccia; large lumps of limestone included in wavy-banded shale *(Hindeodella, Ozarkodina, Streptognathodus)*

St. Louis Limestone 4368 (top Mississippian rock)

*4378-4397 Limestone, finely to medium crystalline, gray buff to tan, fossiliferous, dull to subvitreous, subopaque chert, pseudo-oolitic in part; quasibrecciated (*Cavusgnathus unicornis, C.* sp., *Hindeodella* sp., *Synprioniodina* sp., *Taphrognathus* sp.)

5. No. 1 Nimocks, Trigg et al, C NW NE sec. 16, T. 16 S., R. 28 W., Lane County

Salem Limestone 4485 (top Mississippian rock)

*4488-4491 Limestone, coarsely crystalline, buff, lower 1 foot microcrystalline and gray green *(Ligonodina levis)*

4494-4498 Limestone, coarsely crystalline, buff

4499-4500 Limestone, microcrystalline, gray green

*4510-4511 Same as above *(Taphrognathus varians)*

*4512-4513 Limestone, coarsely crystalline, buff (*Synprioniodina* sp.)

4516-4517 Same as above

4517-4518 Shale, green gray, calcareous, arenaceous

4518-4519 Limestone, coarsely crystalline, arenaceous

6. No. 1 Collins, Mid-Continent Petroleum Corp., NW NW NW sec. 24, T. 20 S., R. 26 W., Ness County

4452-4457 Siltstone, arenaceous, dense, gray in irregular dark bands and patches, minor iron stains in lower part

4460-4462 Siltstone, arenaceous, shaly, gray; white sandstone bands; thin- and wavy-bedded, mottled gray-greenish shaly bands with inclusions of small chunks of angular limestone

4463-4464 Limestone, dense, gray, stylolitic, and limestone, coarsely crystalline, gray brown, minor iron stains, vertical and horizontal fractures

4464-4465 Shale, silty, green, grading to dense gray limestone; limestone grades from dense lithographic at top to finely crystalline in lower part; lithographic part yellow to red brown with some waxy greenish shale intercalated; crystalline part gray brown and stylolitic

*4465-4471 Limestone, massive, medium crystalline, light gray, stylolitic (vertical and horizontal); waxy green irregularly banded (injected?) silty shale with limestone inclusions at base (*Ozarkodina* sp., *Spathognathodus* sp., and *Synprioniodina* sp.)

*4472-4477 Quasibreccia; limestone, coarse to medium crystalline, light gray, with injected irregular-banded green silty shale (*Synprioniodina* sp.)

Warsaw Limestone 4478

*4478-4480 Limestone, massive, dense to finely crystalline, light gray, no stylolites or banding; silty green shale with chunks of bluish-gray chert inclusions in lower 6 inches; large gray to pink chert nodule at 4480 (*Gnathodus texanus, Taphrognathus varians*)

*4483-4488 Limestone, massive, finely crystalline, gray brown, dense, stylolitic; vertical fractures *(Gnathodus texanus, Ligonodina levis, Taphrognathus varians)*

*4489-4495 Limestone chunks, finely crystalline, gray brown; waxy-green carbonaceous injected shale *(Gnathodus texanus, Taphrognathus varians)*

4496-4498 Limestone, massive, medium to coarsely crystalline, upper part reddish brown grading to light gray downward, lower half stylolitic

4499-4509 Siltstone, dense, gray, mottled; contains chert fragments, green shale fragments, and large percentage of black carbonaceous inclusions; density increases downward

4516-4528 Siltstone, dense, dark gray, wavy banded; contains unsorted fragments of gray to buff limestone, pyrite, cream chert, and black plant debris

4528-4537 Limestone, highly porous, light gray; composed almost entirely of fenestrate bryozoans

*4538-4549 Limestone or dolomitic limestone, medium crystalline, light gray, dense, irregular black streaks, very fine grained; some bryozoans (*Synprioniodina* sp.)

*4549-4555 Limestone, granular, dark gray, fossiliferous *(Neoprioniodus scitulus)* deepest part of the embayment. The Cowley Formation exceeds 200 feet in thickness in some localities in southwestern Kansas.

The lithology of the Salem Limestone is fairly consistent from the outcrop area in southeastern Missouri into the subsurface of western Kansas. It is a gray to buff, coarsely crystalline, fossiliferous limestone. The Salem Limestone of western Kansas consists dominantly of granular and semigranular limestone intercalated with sucrose dolomite and dolomitic limestone beds. Chert similar to that in the underlying Warsaw Limestone is observed to be in less proportion in the Salem. Free specimens of *Endothyra* (a foraminifer), not observed in the Warsaw, occur occasionally in cuttings from the Salem Limestone. Lee (1953) observed no oolites in cuttings he examined, although oolites are reported at the outcrop in southeastern Missouri. A distinctive chert often found in the Salem of the eastern and central Kansas subsurface is found sparingly in samples from wells in southwestern Kansas. It is a salmon-pink or flesh-pink, semiopaque, dark chert. The Salem Limestone is often difficult to distinguish from the overlying oolitic facies of the St. Louis Limestone. Moore and others (1951) reported an average of 100 feet of Salem Limestone in southwestern Kansas.

The St. Louis Limestone is represented by a great variety of lithologies, both in the outcrop area and in the subsurface. The facies include: oolitic coarsely crystalline limestone, lithographic limestone, oolitic finely arenaceous limestone, and dense dolomite. The chert content is also variable.

The St. Louis Limestone is distinguishable from the overlying and underlying formations in the subsurface if it is composed of lithographic limestone or dense dolomite. However, the oolitic coarsely crystalline limestone of southwestern Kansas is similar in lithology to the underlying Salem Limestone, and the oolitic arenaceous limestone cannot easily be distinguished from the lithology of the Ste. Genevieve Limestone. If one of these two St. Louis Limestone oolitic facies is present, as is common in the subsurface in western Kansas, the upper or lower St. Louis boundary is difficult to identify.

The St. Louis Limestone conformably overlies the Salem Limestone. It is overlain unconformably by the Ste. Genevieve Limestone in the central part of the embayment (Maher and Collins, 1949). Lee (1953) felt that the absence of silty limestone differentiated the St. Louis Limestone from the overlying Ste. Genevieve Limestone, and that the finely oolitic nature of some of the upper limestone beds was obscured in the dense matrix. The St. Louis is distinguished from the underlying Salem Limestone on the basis of first appearance of sucrose dolomite or dolomitic limestone. The St. Louis Limestone ranges from a few feet to about 200 feet in thickness in the deeper parts of the Hugoton Embayment.

In the outcrop area in Ste. Genevieve County, Missouri, the Ste. Genevieve Limestone is a gray, dense limestone, sparsely oolitic and arenaceous, and locally shaly. Sandstone lenses are present toward the top. In western Kansas, the Ste. Genevieve Limestone is a white to buff, finely oolitic, finely arenaceous, dense limestone, essentially like that at the southeastern Missouri outcrops except for the absence of shale. The oolites are mainly fine grained, but some medium- and coarse-grained oolites occur in silty limestone in the lower part of the formation. The formation averages 200 feet in thickness in the embayment.

Strata of the Ste. Genevieve Limestone lie disconformably below Chesteran rocks but seemingly are conformable on the St. Louis Limestone except in the central part of the basin. Clair (1948) observed that the oolites of the Ste. Genevieve Limestone in western Kansas were elliptical rather than round and always darker than the surrounding matrix, thus differing from the round, light-colored, fine St. Louis oolites. This difference in oolitic beds is often not discernible. Beds of Ste. Genevieve cannot be positively identified if they overlie the finely oolitic limestone of the St. Louis.

The Chesteran rocks consist of a sequence of granular and semigranular, sublithographic, and silty limestone, calcareous shale, and marl formations interstratified with fossiliferous dark-gray and black shale, very dark gray shale, and, toward the base, variegated shale, yellow shale, maroon shale, silty calcareous shale, and brown sandstone (Lee, 1953).

THE CONODONT FAUNA

The total of 217 conodont specimens found in the six well cores from western Kansas comprises 83 specimens from 423 samples of the Meramecian Stage and 134 specimens from 32 samples of rock now identified as Desmoinesian (Pennsylvanian) in age. The average yield of Meramecian limestone was two specimens for each 200 grams of sample (seven to ten specimens per kilogram). The 83 Meramecian specimens represent eight species of six genera and several indeterminant forms and fragments of five genera. Ten genera are represented in the 134 Desmoinesian specimens.

The Meramecian conodont species and the numbers of individuals recovered in this study are:

Apatognathus geminus (Hinde, 1900) (1)
Cavusgnathus unicornis Youngquist and Miller, 1949 (2)
Cavusgnathus sp. (4)
Gnathodus texanus Roundy, 1926 (24)
Hindeodella sp. (2)
Ligonodina levis Branson and Mehl, 1941 (2)
Neoprioniodus loxus Rexroad, 1957 (2)
Neoprioniodus scitulus (Branson and Mehl, 1941) (2)
Ozarkodina sp. (1)
Spathognathodus sp. (3)
Synprioniodina sp. (6)
Taphrognathus varians Branson and Mehl, 1941 (16)
Taphrognathus sp. (2)

The identifiable conodont species recovered in this study and the occurrences described by other authors are given in the following list.

Apatognathus geminus (Hinde): The lower Carboniferous of Scotland (Hinde, 1900; Clarke, 1960), the St. Louis Formation in the Illinois Basin (Rexroad and Collinson, 1963).

Cavusgnathus unicornis Youngquist and Miller: The Pella beds of Iowa (Youngquist and Miller, 1949), the Chesteran Stage of southwestern Illinois (Rexroad, 1957), the Glen Dean Formation of the Illinois Basin (Rexroad, 1958) and Kentucky and equivalent formations of Virginia and West Virginia (Rexroad and Clarke, 1960), the Kincaid Formation in Illinois (Rexroad and Burton, 1961), the Paoli and equivalent formations in the Illinois Basin (Rexroad and Liebe, 1962), and the Carboniferous in the Adrar-Tanezrouft (Sahara) region (Lys and Serre, 1957).

Gnathodus texanus Roundy: The Barnett Shale of Texas (Roundy, 1926; Hass, 1953; Elias, 1956), the lower Stanley Shale of Arkansas (Hass, 1950) and Oklahoma (Hass, 1956), the lower Caney Shale of Oklahoma (Branson and Mehl, 1941a; Elias, 1956), unnamed subsurface black shale in northeastern Mississippi (Hass, 1954), and the Paoli and equivalent formations in the Illinois Basin (Rexroad and Liebe, 1962).

Ligonodina levis Branson and Mehl: The "Keokuk Formation" of Iowa and Missouri—now believed to be of Warsaw age (Branson and Mehl, 1941b), the Unterkarbons of Europe (Bischoff, 1957), the Chesteran Stage of southwestern Illinois (Rexroad, 1957), the Glen Dean Formation in the Illinois Basin (Rexroad, 1958) and Kentucky and equivalent formations in Virginia and West Virginia (Rexroad and Clarke, 1960), the Kincaid Formation of Illinois (Rexroad and Burton, 1961), and the Paoli and equivalent formations in the Illinois Basin (Rexroad and Liebe, 1962).

Neoprioniodus loxus Rexroad: The Chesteran Stage of southwestern Illinois (Rexroad, 1957), the Glen Dean Formation of the Illinois Basin (Rexroad, 1958) and Kentucky and equivalent formations in Virginia and West Virginia (Rexroad and Clarke, 1960), the Kincaid Formation of Illinois (Rexroad and Burton, 1961), and the Paoli and equivalent formations in the Illinois Basin (Rexroad and Liebe, 1962).

Neoprioniodus scitulus (Branson and Mehl): The Caney Shale of Oklahoma (Branson and Mehl, 1941a; Elias, 1956, 1959), the Kincaid Formation of Illinois (Cooper, 1947; Rexroad and Burton, 1961), the Chesteran Stage of southwestern Illinois (Rexroad, 1957), the Glen Dean Formation of the Illinois Basin (Rexroad, 1958) and Kentucky and equivalent formations in Virginia and West Virginia (Rexroad and Clarke, 1960), and the Paoli and equivalent formations in the Illinois Basin (Rexroad and Liebe, 1962).

Taphrognathus varians Branson and Mehl: The "Keokuk Formation" of Iowa and Missouri—now believed to be of Warsaw age—(Branson and Mehl, 1941b) and the Valmeyeran Series of the Illinois Basin (Rexroad and Collinson, unpublished manuscript*).

Taphrognathus sp.: The "Keokuk Formation" of Iowa and Missouri (*T. varians* in Branson and Mehl, 1941b, pl. 6, fig. 34 only; this specimen believed by the present authors to represent a St. Louis stratigraphic leak in Warsaw strata), and the St. Louis Formation of the Illinois Basin (Rexroad and Collinson, 1963).

The most abundant Meramecian species are *Gnathodus texanus* and *Taphrognathus varians,* which together make up over half the total fauna. The genera *Cavusgnathus* and *Apatognathus* are represented by much smaller populations but are stratigraphically important to the fauna. Species of the genera *Ligonodina, Neoprioniodus, Spathognathodus, Synprioniodina, Ozarkodina,* and *Hindeodella* are present, the

* Manuscript entitled "Conodonts of the Valmeyeran Series in the Illinois Basin," by C. B. Rexroad and C. W. Collinson, was consulted by the present authors; publication date unknown.

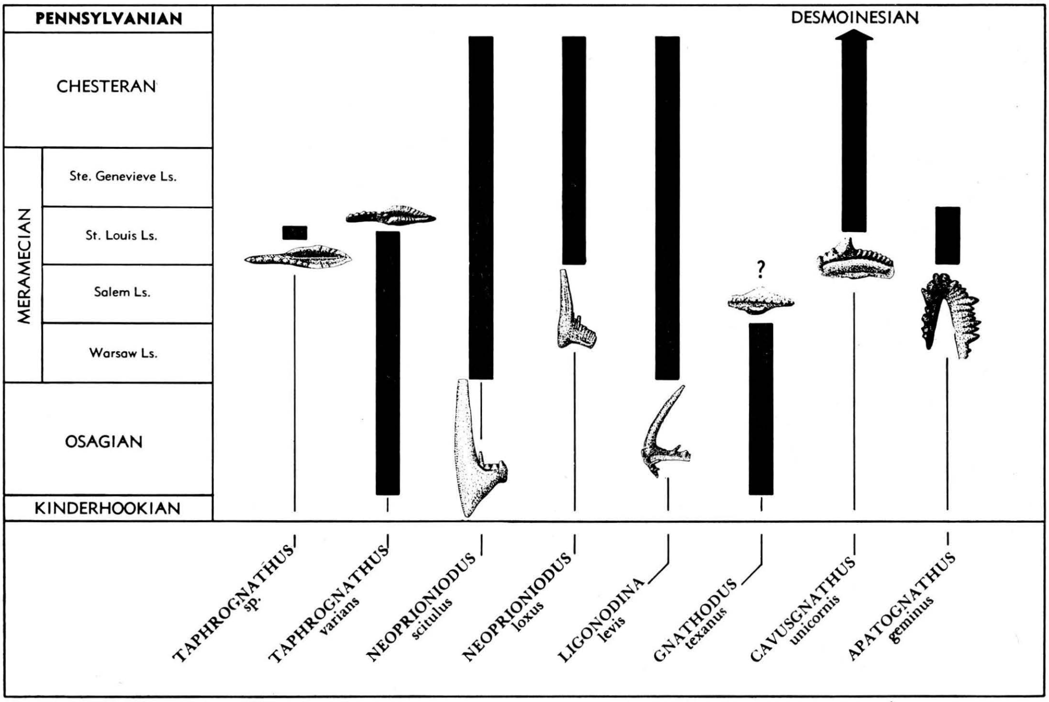

FIGURE 3.—Stratigraphic range chart of conodont species from Meramecian Stage in western Kansas.

latter four represented by fragmental specimens only.

Stratigraphic Implications of Fauna

The most important conodont genera to the stratigraphy of the Meramecian Stage in western Kansas are *Cavusgnathus, Gnathodus,* and *Taphrognathus* (Fig. 3). Of these three genera, *Taphrognathus* is the most important stratigraphic indicator, ranging from the Keokuk Limestone (Osagian Stage) to the St. Louis Limestone. During St. Louis time, *Taphrognathus* evolved into *Cavusgnathus* (Rexroad, 1959), the latter replacing *Taphrognathus* in stratigraphic importance from late St. Louis time at least through Chesteran time. *T.* sp. is the transitional form for *Taphrognathus* to *Cavusgnathus,* and it is restricted to the St. Louis Limestone. (For illustration see Branson and Mehl, 1941b, pl. 6, fig. 34.) *G. texanus* ranges from the Keokuk Limestone through the Warsaw Limestone; the upper limit of the range possibly approximates the Warsaw-Salem formational boundary.

Apatognathus geminus appears to be restricted to the St. Louis Limestone, and it represents the youngest known species of the genus.

None of the other forms found is stratigraphically important in this study, but the occurrences are included in the belief that future studies may increase their value as stratigraphic indicators.

Identification of Meramecian Formations by Fauna

Formations of the Meramecian Stage in western Kansas appear to be distinguishable by their conodont fauna. The following discussion lists these formations and their characteristic conodont faunas based upon preliminary observations.

The Warsaw Limestone is generally characterized by the presence of *Gnathodus texanus* and abundant specimens of *Taphrognathus varians.* The abundance of the latter possibly distinguishes the Warsaw conodont fauna from that of the Osagian Stage; *T. varians* is much less abundant in the Osagian Stage.

The Salem Limestone appears to be characterized by the presence of abundant specimens of *Taphrognathus varians* and the seeming absence of *Gnathodus texanus, T.* sp., *Apatognathus geminus,* and species of *Cavusgnathus.*

The St. Louis Limestone is characterized by the presence of *Taphrognathus* sp., *T. varians,* *Apatognathus geminus,* and species of *Cavusgnathus.*

The Ste. Genevieve Limestone is characterized by the presence of species of *Cavusgnathus* and the absence of species of *Taphrognathus* and possibly *Apatognathus.* Presently, this unit must be distinguished from Chesteran strata by lithologic criteria; the conodont fauna is insufficiently known for positive identification.

Correlation of Cores by Fauna

The stratigraphic sequence in western Kansas described as Meramecian in age appears to be correlatable with the type Meramecian section on the basis of conodonts. Table 2 depicts the stratigraphic distribution of the conodont species described in this study, showing distribution by formation and by well. Except for the No. 1 Collins and No. 1 Hocker-Smith wells (wells 4 and 6), the lithologic correlation (based on scout information, sample logs, and core descriptions) of the wells studied was in good agreement with correlation by the conodont fauna.

One of the two identifiable conodonts (Table 2) found in the No. 1 Eubank core (well 1), the cavusgnathid indicates an equivalence to the St. Louis Limestone or higher section, and the Ste. Genevieve lithologic correlation appears reasonable.

Eight identifiable conodont specimens were found in the No. 1-A Mark core (well 2). One specimen of *Gnathodus texanus* was found in the Warsaw Limestone. No identifiable species were found in the Salem Limestone. Six conodont specimens, including the cavusgnathids, *Taphrognathus* sp., and *Apatognathus geminus,* identified the St. Louis Limestone and corroborated the lithologic correlation.

Fifteen identifiable conodont specimens were found in the No. 1 Watchorn core (well 3). The Salem Limestone yielded only three specimens of *Taphrognathus varians;* the St. Louis Limestone contained eight specimens, including four reworked *Gnathodus texanus* and three reworked *T. varians;* the Ste. Genevieve Limestone yielded one specimen of *Cavusgnathus unicornis.* The Salem-St. Louis boundary interpreted by lithologic comparison is supported by the conodont fauna, but the St. Louis-Ste. Genevieve boundary cannot be defined by the present conodont collection.

Four identifiable conodont specimens from the No. 1 Nimocks core (well 5) indicate a possible Salem age. The lack of *Gnathodus texanus* and cavusgnathids and the presence of *Taphrognathus varians* facilitate the acceptance of this correlation.

The recovery of specimens from the No. 1 Hocker-Smith core (well 4) presented special problems. Scout data list the top of the Mississippian rocks (Warsaw Limestone) in this well at 4,339 feet and the top of the Osagian rocks at 4,344 feet depth. The drillers log indicates the interval between 4,161 and 4,397 feet had been cored. On the basis of the scout-top pick of the Mississippian rocks in the well, the cores were prepared in the standard way and residues were collected. The interval from 4,378 to 4,397, a finely crystalline limestone that is dolomitic, conglomeratic, and shaly at the base, contained specimens of the conodont genera *Gondolella, Hibbardella, Hindeodella, Idiognathodus, Ligo-*

Table 2.—Stratigraphic distribution of conodont species found in Meramecian rocks in western Kansas. Occurrence is indicated by X; parentheses indicate reworked specimens. Well locations indicated on Table 1.

Formation	Warsaw Limestone		Salem Limestone			St. Louis Limestone			Ste. Genevieve Limestone		Pennsylvanian rocks
Well	2	6	2	3	5	2	3	4	1	3	4
Apatognathus geminus	—	—	—	—	—	X	—	—	—	—	—
Cavusgnathus unicornis	—	—	—	—	—	—	—	X	—	X	X
C. sp.	—	—	—	—	—	X	—	X	X	—	—
Gnathodus texanus	X	X	—	—	—	—	(X)	—	—	—	—
Hindeodella sp.	—	—	—	—	—	X	—	X	—	—	X
Ligonodina levis	—	X	—	—	X	—	—	—	—	—	—
Neoprioniodus loxus	—	—	—	—	—	—	X	—	—	—	—
N. scitulus	—	X	—	—	—	—	X	—	—	—	—
Ozarkodina sp.	—	X	—	—	—	—	—	—	—	—	X
Spathognathodus sp.	—	X	—	—	—	—	—	—	X	—	—
Synprioniodina sp.	—	X	X	—	X	—	—	X	—	—	—
Taphrognathus varians	—	X	—	X	X	—	(X)	—	—	—	—
T. sp.	—	—	—	—	—	X	—	X	—	—	—

nodina, Metalonchodina, Ozarkodina, Streptognathodus, Synprioniodina, and one specimen of *Cavusgnathus unicornis. Gondolella, Idiognathodus,* and *Metalonchodina* are known only from Pennsylvanian strata. Only one species of *Streptognathodus* (*S. unicornis* Rexroad and Burton) has been described from rocks older than Pennsylvanian. The specimens recovered from this cored interval indicated a probable Pennsylvanian age. Ellison (1941) attested the presence of cavusgnathids in the Pennsylvanian. Conodont specimens recovered from 4,346 to 4,360 feet, in a limestone, included three conodont species, *C. unicornis, C.* sp., and *Taphrognathus* sp. (the transitional form), which indicate a St. Louis age. It would appear from the recovery of guide fossils that this core was inverted when boxed. On the basis of this assumption, in Table 1 the inverted footages have been corrected and the rocks of Pennsylvanian age restored to correct stratigraphic position. None of the specimens recovered from the No. 1 Hocker-Smith core appears to have been reworked, although there are several conglomeratic and quasibrecciated beds.

Quasibrecciation, a term proposed by Fowler and Robbie (1961), refers to "brecciated-like limestone" in which dove-tailed fragments of limestone set in a groundmass of either mudstone or siltstone like pieces of a jig-saw puzzle. The mudstone or siltstone seems to have been deposited around the limestone fragments. Little transportation is involved but evidence of current action is present in the groundmass.

The lithology of the St. Louis (4368-4397 feet) in the Hocker-Smith core is mostly fine- to medium-grained, buff, crystalline limestone in fragments separated by films and fillings of green, sandy, calcareous, shaly groundmass material. Many stylolites were observed. The shaly material appears to show some flow structure.

The lithology of parts of the No. 1 Collins core (well 6) is similar to the St. Louis lithology found in the No. 1 Hocker-Smith core in that it includes large fragments of finely crystalline limestone with interspersed green silty clayey shale.

Data assembled from sample logs of other wells in the vicinity of the No. 1 Collins well indicate the presence of some Salem Limestone overlying Warsaw Limestone. No Salem was identified in the core. Correlation using conodonts places the top of the Warsaw at a depth of 4,468 feet. From sample logs the top of the Warsaw is picked on a lithologic basis at 4,527 feet. The depth of 4,527 feet is a level in the core at which fenestrate bryozoans are the dominant constituent of the core. The lack of agreement between the lithologic pick and the conodont specimens collected from the No. 1 Collins well led to several reexaminations of the core and careful redescription. It was observed that no conodonts were recovered from the shaly, clayey, sandy sections of this well. Conodont specimens recovered were apparently from the carbonate chunks of rock. In the section from 4,480 to 4,495 feet, the most significant guide fossil to the Warsaw Limestone, *Gnathodus texanus,* was found in abundance.

CONCLUSIONS

Four conodont species seem to be useful as probable stratigraphic indicators of Meramecian rocks in western Kansas. They are: *Gnathodus texanus* (Osagian through Warsaw), *Taphrognathus varians* (Osagian through St. Louis), *T.* sp. (St. Louis), and *Apatognathus geminus* (St. Louis). The genus *Cavusgnathus* is important to the upper part of the Meramecian section, after its first appearance in mid-St. Louis time. The other forms of conodonts recovered in this study seem not to be stratigraphically important to the Meramecian conodont fauna.

The conodont fauna from the Meramecian Stage of the Mississippian rocks of western Kansas has been observed to compare favorably with that of the standard section in the upper Mississippi Valley, studied by Rexroad and Collinson (unpublished manuscript). The number of specimens found was small, reflecting in this area the low average yield of conodont specimens from limestone compared to the yield from shale, as has been noted by Rexroad (1957).

From the Meramecian Stage in western Kansas were recovered 83 specimens of conodonts representing eight species (from six genera) and several indeterminate forms and fragments (from five genera). Although the number of specimens recovered was small, the yield was believed to be sufficient to warrant a preliminary report on the usefulness, as a tool for correlation, of conodonts recovered from cores of the dominantly carbonate Meramecian section of Mississippian rocks in western Kansas. Obviously, additional study is needed to validate the usefulness of conodonts as guide fossils, both stratigraphically and geographically, in other sections of Meramecian rocks in the Midcontinent region. Undoubtedly, additional investigation is also needed in evaluation of conodonts from other sections of Mississippian rocks in the Midcontinent region.

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Part 1. **The December 25, 1961, Earthquakes in Northwestern Missouri and Northeastern Kansas,** by Louis F. Dellwig and Lee C. Gerhard, p. 1-12, fig. 1-3, March 31, 1962.

Part 2. **Progress Report of the Kansas Basement Rocks Committee and Additional Precambrian Wells,** by Virgil B. Cole and Daniel F. Merriam, p. 1-11, fig. 1-3, April 15, 1962.

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Part 4. Neogene **(Plio-Pleistocene) Fresh-Water Ostracodes from the Central High Plains,** by Edwin D. Gutentag and Richard H. Benson, p. 1-60, fig. 1-15, pl. 1-2, June 30, 1962.

Part 5. **Some Bryozoans from the Beil Limestone Member of the Lecompton Limestone (Virgilian) of Kansas,** by Ronald D. Perkins, T. G. Perry, and Donald E. Hattin, p. 1-25, fig. 1, pl. 1-5, November 15, 1962.

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Part 1. **Preliminary Report on Conodonts of the Meramecian Stage (Upper Mississippian) from the Subsurface of Western Kansas,** by Thomas L. Thompson and Edwin D. Goebel, p. 1-16, fig. 1-3, August 1963.