Sinkholes and Related Geologic Features in Kansas

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ABSTRACT

Sinkholes and related features such as caves, natural bridges, and other solution features are numerous in Kansas both on the surface and in the subsurface. Two major types of sinks are recognized, solution-subsidence and solution-collapse, and are classified as simple, complex, or coalescing. Stratigraphically these structures are present in rocks ranging in age from Cambro-Ordovician to Recent. In general, it was found that the geographic distribution of sinks is stratigraphically controlled in the eastern part of the state and structurally controlled in the west. Individual sinks on the surface, as well as subsurface areas of karst development, are described.

INTRODUCTION

Since 1879 when Mudge published the first description of a sinkhole in Kansas, there has been considerable interest in these and related features, and much has been published about them. These publications deal with a variety of aspects of surface and subsurface sinks, such as physical description, origin, classification, age, and relation to structure. Sinkholes are numerous on the surface throughout the state and locally form an important element of the physiography. They have received some publicity because of their spectacular nature of occurrence. Also, in

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recent years with increased data available from wells drilled in search for oil, gas, and water, it has been possible to reconstruct buried karst topographic surfaces and locate subsurface sinks.

One of the better known sinkholes in Kansas is the "Meade Salt Sink." This feature, located in Meade County, has been mentioned in many reports and described in detail by numerous authors. It received considerable publicity at the time of its formation, when it developed across an often-used cattle trail and wagon road. The sinkhole was filled with salt water, and at one time apparatus was set up on the rim to recover salt from the brine (Cowgill, 1885).

Other well known solution-subsidence and collapse features in the state are Big Basin and Little Basin with associated St. Jacob's Well in Clark County. They are natural scenic spots because they are in Permian redbeds in the region known as the "Gyp Hills." Also in the same area in nearby Barber County is Natural Bridge, which has become a favorite picnic place and has attained the unofficial status of a park.

Known sinks occur in beds as old as Cambro-Ordovician (Arbuckle group) and affect practically the entire overlying geologic column, including Recent deposits. Early in 1956 a drilling rig slumped into a newly formed hole, possibly a sink, 40 feet wide and 20 feet deep, a short distance northeast of Iuka, Pratt County, Kansas (The Kansas City Times, March 2, 1956). If this is a sinkhole, it probably is the most recent which has developed in the state.

Distribution and configuration of these features have economic implications, especially in the location of petroleum. It seems that subsurface sinks in oil-producing areas commonly are barren of petroleum. (Ver Wiebe, 1947; Glover, 1953). In the neighboring state of Missouri, surface sinks have been found to contain such economic products as fire clay and pyrite (Lee, 1913; Keller, Westcott, and Bledsoe, 1953). However, as yet these materials have not been found in Kansas sinks. In the Tri-State zinc and lead district, it has been recognized that location of ore is, at least in part, controlled by solution features in Mississippian strata (Smith and Siebenthal, 1904). Location of these structures could be of importance in an exploration program seeking future reserves of these minerals.

Sinks, where numerous on the surface, affect local ground-water conditions. General recognition of an area of sinks, solution features, and slumped blocks also is important in structural geologic mapping either on the surface or in the subsurface. Many other economically valuable data may be derived from study of these features.
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GENERAL FEATURES

Terminology

The word rim is used to indicate ground surface immediately surrounding the sinkhole on which commonly is developed a series of cracks. Lip refers to the intersection of rim and wall of the sink. As rock surrounding the sink is eroded, the lip progressively moves away from the center of the cavity displacing the rim. Lip may be hard to define because no sharp break occurs if the rim area slopes toward the sinkhole and the wall of the sink is gentle. In this case, distinguishing the wall from the floor also may be difficult. Wall is the side of the sink and may be gentle, steep, vertical, or overhanging. The floor is the bottom of the sink. It may be irregular if composed of collapsed broken material from the cavern roof, or smooth if material was let down slowly and continuity of the original surface was maintained, providing the original surface was smooth. Oftentimes the floor is obscured by water. The filling is material deposited in the sinkhole. A cavern, or cavity, is a void formed either by solution of rock or by other means. When the roof of the cavern gives way and overlying rocks collapse or subside into the void, a sinkhole is formed.

Physical Characteristics

Physical characteristics include such things as size, shape, depth, area, volume of rock involved, and number of sinks per unit area. Sinkholes range from a few feet to several thousand feet in diameter. Several large ones in Logan County have diameters of more than one-half mile (Carlton R. Johnson, personal communication). Normally, individual sinks have diameters measured in tens or hundreds of feet, but the Ashland-Englewood basin is locally more than 12 miles wide.

Shapes may be circular, subcircular, oval, elliptical, and irregular. Depth of sinkholes ranges from a few feet to more than 200 feet. Geologic literature provides few data on area of a single sink. However, area involved ranges probably from less than one acre to more than 3,000. The Ashland-Englewood basin, for example, covers many square miles and is the largest solution feature in Kansas.

Only two estimates are available on volume of rock involved in collapsed sinks. Amount of material affected in the Potwin sink was given as 500,000 cubic feet (Gordon, 1938), and 1½ million cubic feet was quoted for the Smoky Basin cave-in (Moore, 1926).
Hay (1896) counted 42 sinks in a square mile. However, because this is the only figure found in the literature, it is not known whether it is low, average, or high.

**Classification**

Sinks are difficult to classify, because of their diverse nature, and it is hard to reduce the numerous variations to fit a simple usable classification. However, such a classification has been proposed by Frye and Schoff (1942) to apply to Kansas sinks. They propose a tripart division: simple, complex, and coalescing.

1. **Simple**—Simple sinks have one period of subsidence. Deposits filling the sinkholes are conformable, but dip toward the center of the sink.

2. **Complex**—Complex sinks have several periods of subsidence. Later subsidences affect only parts of the previous one or ones, and as a result, many diverse dips and local unconformities characterize sediments deposited in the hole.

3. **Coalescing**—Coalescing sinks are the result of two or more sinks which have formed close together and have been joined when their rims either collapsed or were worn away by erosion. The result is a series of connected sinks, and as might be expected, the outline is irregular. An example of this type is the Ashland-Englewood basin in Clark County.

In addition, there are two major types of sinks (Thornbury, 1954, p. 321): (1) *solution-subsidence sinks*, those developed by slow downward solution with no physical disturbance of the rock being let down, and (2) *collapsed sinks*, those developed by collapse of rock above a previously formed underground void. Both types occur in Kansas, but the collapsed kind attract more public attention because they are more spectacular in forming.

**Stratigraphic Distribution**

Sinks in Kansas occur in beds ranging in age from Ordovician to Recent. Figure 1 is a generalized columnar section of Kansas rocks. As rocks older than Mississippian do not crop out in the state, all sinks occurring in pre-Mississippian rocks are present in the subsurface only.

Distribution of the different rock systems roughly parallels precipitation belts. It happens that outcrops of Mississippian and Pennsylvanian beds occur in the area of greatest rainfall. Farther west, Permian strata crop out in an area of less rainfall than that of Pennsylvanian rocks; Cretaceous beds are exposed in a belt of moderate precipitation; and Tertiary rocks in an area of least rainfall. Much of
western Kansas receives between 10 and 20 inches of moisture a year and is classed as semiarid.

Because of differences in bedrock across the region, form and type of sinks differ. Loosely consolidated Tertiary sediments, thick uniform
Cretaceous strata, Permian redbeds, thin alternating beds mainly of limestone and shale of the Permo-Pennsylvanian, and massive, cherty limestone of Mississippian age all react differently to formative processes of sink development. The most soluble beds in the geologic section are salt, gypsum, chalk, and limestone.

Limestone is present in quantity in Mississippian, Pennsylvanian, Permian, and Cretaceous Systems. The Mississippian surface is a site of pronounced sink development, and in certain areas this surface is in an advanced stage of karst development. Many sinks and related features have been described in the area of Mississippian outcrop in extreme southeastern Kansas (Pierce and Courtier, 1937). In the Pennsylvanian, several formations, Oread limestone, Stanton limestone, and Wyandotte limestone, for example, are noted for having sinks and related solutional features. There are undoubtedly other Pennsylvanian stratigraphic units in which sinks have formed but have not been reported. The lower part of the Permian section, which in many respects is like Pennsylvanian beds, contains many limestones in which sinks form. Some are the Cresswell, Fort Riley, Florence, and Red Eagle. The Fort Riley seemingly is most susceptible to sinkhole formation. Limestone in the Cretaceous occurs in the Greenhorn and Niobrara formations. Chalk is restricted to the Cretaceous, but is present over much of the western one-third of the state. Caliche, an impure form of calcium carbonate, is present in the Tertiary Ogallala formation and younger deposits.

Salt deposits are present in the Wellington and other Permian formations in Kansas, and because of the solubility of salt it is important. Salt underlies much of south-central, central, and western Kansas. Gypsum also is a major rock type in the middle and upper parts of the Permian in Kansas. Gypsum is widespread both geographically and stratigraphically, attaining moderate thickness at several stratigraphic positions. The most important Permian gypsum is probably in the Blaine formation.

Geographic Distribution

Sinkholes have been reported from 26 of the 105 counties in the state. Sinks were described from about one-third of the more than 50 counties in which the geology has been worked in detail. More spectacular ones in other counties, although not mapped, have received attention and have been discussed in geologic literature (Fig. 2).

Geographic distribution of many sinks is controlled by outcrop pattern of different stratigraphic units, for example, a series of sinks is developed along the outcrop of the Fort Riley limestone through Cowley,
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Butler, Chase, Morris, and Wabaunsee Counties. Because the outcrop of different units crosses the state from north to south as bands, distribution of sinks in eastern Kansas coincides with this pattern.

Pierce and Courtier (1937) found that recent sinks on the Mississippian surface in southeastern Kansas are controlled to a certain extent by location of buried "fossil" sinks. Seemingly these areas of old sinks are more susceptible to recurrent development.

In McPherson, Harvey, and Sedgwick Counties distribution of a set of sinks corresponds to the eastern limit of the Permian Wellington salt (Williams and Lohman, 1949).

A reeflike bed of limestone in the Red Eagle formation of Permian age locally controls sink development in northern Lyon County (Howard G. O'Connor, personal communication).

Fent (1950) found that sinkholes were especially numerous where late Pleistocene deposits overlie deeper early Pleistocene channels.

Factors involved in sink distribution discussed above have been stratigraphic; another important consideration is structure. In western Kansas, were soluble beds are deeply buried, structural control seemingly is the dominant factor.

There are numerous examples of sinks controlled by faulting. In Logan County, Carlton R. Johnson (personal communication) states that probably all larger sinks are controlled by an intricate pattern of normal faults in the Niobrara formation—something like a horst and graben effect. Smith (1940) believes that the Coolidge sink in Hamilton
County occurs along a line of post-Ogallala faulting. In Wallace County Elias (1931) gives several examples of linear trends of sinks, which he regards as arranged along faults. Sinks in the Stanton County area near Bear Creek probably began to form at the time of folding and faulting of the Syracuse anticline, and the process is still continuing (McLaughlin, 1946). Faulting has played a major role, especially in Meade County, in sink development, according to Frye (1950). Surface water has been allowed access to deeply buried soluble rock of the Permian via fault planes. Without this water circulation, it is doubtful that cavities could have been formed with subsequent subsidence and formation of sinks. For example, the "Meade Salt Sink" appears to be associated with a fault, because it is located a short distance east of the Crooked Creek fault. Insufficient information is available to make any other comparisons, but correlation of structure and sinks is obvious.

A generality can be given, then, for geographic distribution of sinks in the state. For the most part, in eastern Kansas sink distribution is controlled by stratigraphic considerations and in western Kansas by structural factors. This generalization, however, may prove invalid with additional information; and as should be expected, many exceptions are possible.

**Origin**

A distinction should be made between depressions and sinkholes. Sinkholes are formed either by solution-subsidence or solution-collapse, whereas High Plains depressions, on the other hand, may be formed by compaction, silt infiltration, or animal action as well as solutional processes. In other words, sinkholes are depressions, but not all depressions are sinkholes. Frye (1950) has given an excellent summary on origin of Great Plains depressions in which he includes a discussion of sinkholes. According to him there are six causes of these depressions: (1) deep-seated solution, (2) solution of carbonate rocks, (3) eolian action, (4) differential silt infiltration, (5) animal action, and (6) faulting. Only deep-seated solution, solution of carbonate rocks, and faulting are factors involved in sinkhole development; other causes concern development of the High Plains depressions which are not true sinkholes.

Deep-seated solution features cited by Frye (1950) are in the Meade-Clark County area in the southwestern part of the state. Specific examples are the "Meade Salt Sink", Big Basin, Little Basin, Jones Ranch sink, and Ashland-Englewood basin. In this area, surface water has gained access to and dissolved cavities in deeply buried Permian salt and gypsum
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Subsequent collapse of the roofs of these cavities has produced sinks.

Examples in western Kansas of solution of carbonate rocks are the Coolidge sink and Smoky Basin cave-in. Chalk solution aided by water circulation along fault planes is believed by Frye to result in sinkhole formation.

Fault control is important, according to Frye, especially in Meade County. Several other examples of sinks controlled by faulting have previously been mentioned.

Three conditions are necessary for formation of sinks: (1) soluble beds, (2) water, and (3) time. Other factors also to be considered are: type of rock, thickness of soluble beds, depth of burial of soluble beds, amount of rainfall and its distribution, and available ground water. All these factors determine configuration and distribution of sinks. Depending on circumstances, the result will be solution-subsidence or solution-collapse structures.

**SURFACE SINKS**

**Description of Individual Sinks**

*Ashland-Englewood Basin (Ashland Basin)*

The Ashland basin in southern Clark County, southwestern Kansas, forms a large topographic depression. It is a coalescing sink (Frye, 1942). The depression probably was caused by solution of Permian salt and gypsum, which occur less than 1,000 feet below the surface (Frye, 1950; Jewett, 1951; Smith, 1940).

This large sink is as much as 12 miles wide and 500 feet below the general level of the High Plains (Schoewe, 1949). The wall is Permian red beds capped by late Tertiary Ogallala. The basin is dissected and drained by Cimarron River. As much as 100 feet of late Pleistocene fill has been deposited in the depression. Frye (1950) dates subsidence as mid-Pleistocene to late-Pleistocene and believes that solution is directly related to faults that formed in Pleistocene time in the area.

*Big Basin and Little Basin*

Two sinks in western Clark County are well known; the larger, Big Basin, is located just west of the smaller Little Basin, which contains within its boundaries a picturesque and smaller sink known as St. Jacob's Well (Fig. 3a, 3b).

Big Basin is situated in sec. 24 and 25, T. 32 S., R. 25 W. The sink is subcircular and approximately one mile in diameter. The floor is
Figure 3a. Big Basin, Clark County (Ada Swineford, 1951).
Figure 3b. Little Basin and St. Jacob’s Well, Clark County (1955).
Figure 3c. Natural Bridge, Barber County (1955).

relatively flat and 125 to 150 feet below the rim. Small depressions, or sags, often retaining water, occur on the floor of the basin. The wall
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of the sink is still essentially vertical although slightly dissected. Permian, Cretaceous, and Tertiary rocks crop out in the wall on the rim above the basin. Its formation probably occurred from several hundred to a few thousand years ago (Smith, 1940).

Little Basin is about one-third mile east of Big Basin. The floor is 35 feet below the rim level. Although Little Basin is shallower than Big Basin, the two sinks are believed to be the same age. St. Jacob’s Well, a relatively recent sink, is on the floor of Little Basin. Because water is retained in this smaller sink, a moist condition forms an “oasis” in the semiarid country.

Both Big and Little Basins are believed to be due to solution of the underlying soluble Permian beds.

Cherokee County Sinks

Sinkholes are observable where rocks of Mississippian age crop out in some areas of southeastern Kansas. Sinks have developed in the thick and soluble limestone of the Mississippian in post-Cherokee time as well as recently. Howe (1954) reports that Pennsylvanian strata are commonly faulted in older sinks because collapse of caverns in the Mississippian limestone occurred after consolidation of overlying sediments. Some faults have a throw of as much as 6 feet. Pyrite and marcasite are common along fault planes.

Nine recent sinks were described by Pierce and Courtier (1937). “Fossil” sinks dated as post-lower Cherokee are exposed in four of the recent sinks.

Two of the recent sinks subsided about 1905. One is located in the SW1/4 sec. 34, T. 32 S., R. 25 E.; the other is in the NW1/4 sec. 28, T. 33 S., R. 25 E. Both sinks are elliptical, 75 to 125 feet across and 30 or more feet deep. Their walls are nearly vertical.

Two more sinks are in the W1/2 sec. 34, T. 32 S., R. 25 E. The earlier sink was formed in 1911. A few years prior to 1911 a sag, about 14 feet in diameter, appeared in a corn field, but no water was retained in the depression. In 1911, a larger hole suddenly appeared in the area of the former sag. The wall was vertical and extended down 72 feet; water was present in the bottom. In 1933, the north rim sank approximately 20 feet. The second sink in sec. 34 formed in 1922 and was a shallow depression about 10 feet in diameter.

Two other shallow sinks, about 10 feet in diameter, are located in the NE1/4 sec. 9, T. 32 S., R. 25 E. One formed about 1921 and the other in 1929.
Another sink in the NE$\frac{1}{4}$ sec. 34, T. 32 S., R. 25 E. was reported to have formed in 1911 or 1912. It was filled prior to 1937, and no further data on it are available.

In 1924, cracks appeared in the soil in the El$\frac{1}{2}$ sec. 9, T. 32 S., R. 25 E. The area of soil cracks subsided in 1929 to form a vertical-walled, elliptical sinkhole, 75 to 125 feet across and 30 feet deep.

All known sinks in Cherokee County are attributed to solution of underlying Mississippian limestone.

**Coolidge Sink**

On December 18, 1926, a hole suddenly appeared in the ground 15 miles south of Coolidge, Hamilton County (NE$\frac{1}{4}$ sec. 22, T. 25 S., R. 43 W.). On July 1, 1930, the sinkhole was reported to be about 60 feet in diameter and 40 feet deep (Bass, 1931). It was circular with a steep and undercut wall; the floor sloped at a low angle toward the center of the depression. Three sets of crevices encircled the structure.

By August 8, 1930, the sinkhole had enlarged to a diameter of 104 feet and increased in depth to 68 feet (Bass, 1931). The material in which the sinkhole was formed was homogeneous silt; no stratified rock could be seen in the hole. The depression had increased in size to 150 by 200 feet in 1941 and had elongated from its original circular shape, engulfing a nearby county road. It also had filled with water to within 15 feet of the rim (McLaughlin, 1943).

Smith reported that in 1940 water filled the hole within 10 feet of the surface and that the wall had slumped so that no overhang was visible.

Bass attributed the sink to solution and formation of a cavern with subsequent collapse of the roof. He reported that bedrock dips at 5° towards the sink, indicating that the entire area of recent subsidence may be part of a larger and older sink. Landes (1931) studied the area and determined that Graneros shale was exposed below the rim. From this, Landes decided the original cavern must have been formed in either salt or gypsum in the Permian section. Smith found that this sink is but one of a linear series and suggests they occur along a post-Ogallala fault.

"**Meade Salt Sink**"

Sudden sinking of a circular area 150 to 200 feet across took place sometime between the 3rd and 18th of March, 1879, in Meade County, 1½ miles southeast of Meade. The sink is on the east side of Crooked
Creek, just east of the Crooked Creek fault. The Great Salt Well, as it was called at the time of formation, engulfed a portion of the "Jones

Figure 4a. Hamilton County sink, Hamilton County (Ada Swineford, 1951).
Figure 4b. Hamilton County sink, Hamilton County (Ada Swineford, 1951).
and Plummer Trail", an often-used wagon road and cattle trail (Cragin, 1884). Mudge (1879) states that by the 18th of March it was 60 feet deep and had a circumference of 610 feet; it was nearly circular with a perpendicular wall. Saline water filled the hole within 17 feet of the land surface. Depth of water ranged from 15 to 27 feet at the edge to 42 feet at the center. Water finally rose to within 14 feet of the ground surface.

Concentric sod cracks formed on the rim around the sinkhole. They were 5 to 15 feet deep and 1 to 10 inches wide. The most distant cracks were 126 feet from the hole.

From the saline water Mudge (1879) states 1 bushel of salt was recovered for every 43 gallons of water, about a 7 percent concentration. At one time salt was produced commercially from the well.

At present, the sink is filling with sediment. Water now in the sink is not saline. In the last few years the sinkhole has been completely dry (Walter H. Schoewe, personal communication).

Mudge (1879) thought a cavern had been formed in the Dakota formation, softer material being washed out by subterranean water, causing subsequent caving. Johnson (1901), Smith (1940), and Frye (1942) suggest that the cavern formed in underlying Permian salt beds and that overlying rocks collapsed.

Frye (1942) points out that the shallowest soluble rock is in Permian red beds several hundred feet below the present water table. He believes that Pliocene faulting provided necessary openings for water to have access to soluble beds in the Permian and therefore controlled development of solution caverns. Period of sink formation thus has been limited to post-Pliocene time.

**Mitchell County Sink**

An unusual type of sink developed in Mitchell County in 1927. Subsidence of a trench in loess, 200 feet long, 75 feet wide, and 18 feet deep, necessitated moving a farm house. Landes (1932) reports that flat discoidal pebbles of the Fort Hays limestone (member of the Niobrara formation, Cretaceous) derived from nearby outcrops are found in loess at the level of the trench floor. He believes that solution of limestone pebbles formed a small cave in the loess. Erosion by circulating ground water enlarged the cave. The result was a collapse of the overlying loess and formation of a sinkhole.

A second collapsed cave 40 feet long was formed in 1931 at right angles to the main trench.
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Jones Ranch Sink

The Jones Ranch sink, 8 miles southeast of Meade, forms a large topographical depression in Meade County (T. 32 and 33 S., R. 27 W.). The sink is subcircular, three miles in diameter, and controls a centripetal drainage pattern. It is dissected and partly filled with sediments. Exposed beds of rock dip slightly into the sink. Its origin is attributed to solution and collapse (Smith, 1940; Frye, 1942; Jewett, 1951). Frye and Leonard (1952) have dated the fill as early Wisconsinan from contained molluscan fauna. They point out that such isolated features are dated either by fossils or by intersection of lines of dissection.

Old Maid's Pool

This sinkhole in Wallace County (sec. 30, T. 12 S., R. 40 W.) is northwest of Sharon Springs (Fig. 5a). Moore (1926a) describes it as 80 feet in maximum depth and three-eighths mile in diameter. A small lake 300 feet wide is in the bottom. The hole is circular, and the wall is moderately dissected. Pierre shale is exposed on the south side of the basin (Elias, 1931).

Potwin Sink

A recent sink which occurred suddenly near Potwin has been described by Gordon (1938). The hole, located in the SE1/4 sec. 24, T. 24 S., R. 3 E., Butler County, was formed on the afternoon of September 22, 1937. It was 90 feet by 150 feet, elongated in an east-west direction, and about 45 feet deep. Clear green water filled the hole within 15 feet of the rim.

The wall of the sink, which consisted of unstratified loam, was perpendicular. It was estimated that approximately 500,000 cubic feet of material was involved in the subsidence.

The rim was estimated to be about 35 feet below base of the Herington limestone. Winfield limestone, had it been present, would have been near the level of the rim and Towanda limestone would have been a few feet below the bottom of the sinkhole. Gordon believed that solution had taken place in the Fort Riley limestone about 75 feet below base of the sinkhole and that sudden collapse of the cavern roof resulted in the sinkhole.

Two older partly filled sinks are found in the vicinity of the Potwin sink.

Smoky Basin Cave-in

A sudden subsidence which took place near Smoky Hill River about 5 miles east of Sharon Springs on March 9, 1926, attracted nationwide...
attention (Fig. 5c). The sink (sec. 33 and 34, T. 13 S., R. 39 W., Wallace County) had a diameter of about 50 feet. By March 11 it had
increased in size to about 125 by 250 feet giving it an irregular elliptical shape (Moore, 1926a). On April 13 dimensions had increased to 150
by 290 feet, and still later to about 250 feet north-south by 350 feet east-west. The wall was vertical down to water level 165 to 170 feet below

Figure 7a. Floor of small sink in Douglas County (1956).
Figure 7b. Sinkhole, Douglas County (1956).
the lip. Water was 50 feet deep in the center of the hole. Moore (1926) estimated total depth of the sink as 300 to 350 feet and material involved as approximately 1½ million cubic feet. Pierre shale is exposed in the
Wall of the sinkhole, and the Niobrara formation is exposed a short distance east of the area.

Moore (1926) suggested that because of size and large amount of material involved, the sink was due to roof collapse into a cavity of considerable size in the upper part of the Niobrara chalk. Chalk was dissolved by eastward-moving ground water, which entered the formation at the outcrop farther west.

Russell (1929) discarded the idea by Moore of solution of the Niobrara and postulated instead that the sink was the indirect result of structural deformation. He thought there was too much shale in the Niobrara to be dissolved for cavern formation and also found no evidence that the formation carried water. Clue to the origin of the sink, he believes, lies in the structure of the region because in nearby counties there are many faults, which were formed during pre-Ogallala and post-Ogallala deformation. He believes cavities, strong enough to resist pressures for a long time, occurred along faults, ultimately collapsing as did the Smoky Basin cave-in. Many previously formed sinkholes probably have been obliterated by erosion and deposition so that only recent ones are evident. Russell reports a fault having a throw of 50 feet in the north wall of the cave-in.

Elias (1930) is of the opinion that the theory of collapse or subsidence along fault voids is unsound. He suggests that the fault may have aided indirectly in the cave-in by permitting surface water to descend underground and gain access to underlying chalk, causing subsequent solution in the Niobrara formation.

**Flint Hills Sinks**

Hay (1896) describes numerous sinks on upland areas of the Flint Hills in the Fort Riley Military Reservation, Riley County. Although not large, deep, nor spectacular, they are described here because they are representative of the common upland type in Kansas.

Sinks range in diameter from 30 to 50 feet and in depth from 8 to 10 feet. All are roughly circular or oval in shape. Hay counted as many as 42 individual sinks in one square mile. Most individual sinks do not retain water. One of the larger sinks in the area contains five smaller ones in its floor.

Upland sinks on the Fort Riley Reservation have been formed by solution and subsidence of the Fort Riley limestone, which lies near the surface in the region. The Fort Riley is readily soluble and exhibits well defined jointing.
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Figure 9. Two sinks in Wabaunsee County (H. G. O'Connor, 1955).

Similar sinks have been reported in Wabaunsee County (Fig. 9) by Savage (1881) and in Morris County by William R. Atkinson (personal communication), Hay (1896), and Schoewe (1949). Small, circular, shallow sinks due to solution of the Fort Riley limestone also occur in Cowley County (Bass, 1929) and Butler County (Fath, 1921).

SUBSURFACE SINKS

Some "fossil" sinks have been preserved in the rock record and occur in the subsurface. Inasmuch as we can examine the subsurface record accurately only by well logs, it is evident that our present knowledge of subsurface sinks is limited to areas that have been sufficiently drilled to permit accurate and detailed study of the "hidden" geology.

Erosion of overlying strata exposes subsurface karst areas that formed in the past. In the southeastern corner of the state, sinks that formed in Mississippian rocks during late Mississippian and early Pennsylvanian time, and were buried until recently, are now seen on the surface.

Sinks in the subsurface have been described in both central and eastern Kansas, but none are known to have been reported in the far western part of the state.

Central Kansas

Buried hills and sinks have been recognized from subsurface data in several areas of the Midcontinent region. One area that has been studied in detail and excellently described by Walters (1946) includes
Oil occurs in sedimentary strata surrounding and covering six buried Precambrian hills. Buried sinks adjacent to the hills were formed in the Cambro-Ordovician Arbuckle dolomite preceding deposition of Pennsylvanian sediments. Age of sink formation is early Pennsylvanian. During this time Precambrian hills were topographically higher than Cambro-Ordovician rocks, which dip slightly away from the hills. The entire area was above sea-level and was subjected to weathering and erosion. Solution features that developed on the exposed Cambro-Ordovician dolomite include solution valleys as well as sinks and resulted in a youthful karst plain.

Each of six hills was completely surrounded by solution valleys 20 to 80 feet deep. Each of the valleys surrounding the low hills had no known surface and outlet and consequently was a moat-type feature. It is interesting to note that the wider and broader part of the asymmetrical valley formed on the most gentle slope of the hill, and that the widest valley is around the largest hill and the narrowest valley surrounds the smallest hill.

Sinkholes are found on the plain surrounding the low hills. They are scattered and abundant but have limited areal extent. Many wells in the area were drilled on a 10-acre spacing; therefore some of the sinks are known to occupy less than 20 acres. Sinkholes are 10 to 60 feet deep. Valley sinks, believed by Walters to have been formed by closely spaced coalesced sinkholes, also were found on the plain along with individual sinks. Walters calls attention to the fact that valleys surrounding the hills indicate that these features are solutional, whereas the same physiographic criteria indicate that sinks are due to solution but do not prove their origin. Evidence that sinkholes and valleys are true solution features is the occurrence of untransported residual weathered products of the dolomite in the lowest part of the depression.

Untransported weathering products, which Walters calls residuum, are formed from less soluble constituents of the Cambro-Ordovician dolomite. Residuum material includes chert fragments, clay, sand, silt, quartz crystals, and shale; the same insoluble residues are obtained in the laboratory by dissolving the Cambro-Ordovician dolomite core samples.

Gordin reports one well in the Bemis pool of Ellis County that penetrated a sinkhole in the Arbuckle group. This well struck the Arbuckle 270 feet lower than did nearby wells. Another well in the
same pool encountered weathered chert derived from Mississippian rocks in a cavern in the Arbuckle.

In the Silica pool of Barton County, a well-developed karst topography is reported by Ver Wiebe (1941). In this pool there are 36 known depressions in the Arbuckle, each filled with detrital material of early Pennsylvanian age. Probably the deepest sink was penetrated by the Lario No. 2 Zohorsky "A" well, which encountered 163 feet of conglomerate.

Within the area of the Trapp pool, Russell and Barton Counties, there are at least 12 known subsurface depressions. They are believed to be ancient sinkholes in the Arbuckle. Depressions are a few feet to 168 feet deep.

Sinks in the Arbuckle rocks, filled with Simpson sediments, have been described by Redman (1947) in the Ryan oil field Rush and Pawnee Counties, which is on the southwestern flank of the Central Kansas uplift. These remnants of Simpson shale, which are about 20 miles from the paleo-outcrop, have been preserved in sinks by reason of their position. Solution of the Arbuckle to form sinks took place prior to removal of Simpson shale, probably in pre-Pennsylvanian or early Pennsylvanian time.

**Eastern Kansas**

Sinkholes of probable Simpson age occur in the subsurface of Johnson, Miami, Coffey, Linn, and Woodson Counties (Merriam and Atkinson, 1956). Sinks were formed in limestone and dolomite of the Arbuckle group and contain abnormally thick deposits of Simpson age, chiefly St. Peter sandstone. Chert conglomerate and green shale are present in the bottom of six described sinkholes. Green shale, composed mainly of an illitic clay and quartz, is interpreted as a residual weathering product which formed either in sinkholes or in the near vicinity and washed into the depressions. Although exact age determination is difficult to make, it is believed that these Simpson filled sinkholes formed in pre-Simpson time and were filled during deposition of Simpson sediments (Merriam and Atkinson, 1956).

Smith and Anders (1951) describe a sink in Mississippian rocks in the Davis Ranch oil pool in Wabaunsee County. An abnormal thickness of 420 feet of Cherokee sediments is interpreted as fill in a sinkhole on the Mississippian surface.

Rich (1930) and Shenkel (1955) also mention a sinkhole on the Mississippian surface in Dickinson County that is visible in surface Per-
mian beds. Another subsurface sink, in Morris County, also is mappable in surface rocks. Lee (1940) mentions a sink on the buried Mississippian surface in Sumner County.

With increased drilling for oil and gas in the state, other buried sinkholes will undoubtedly be revealed. In general, the Arbuckle and Mississippian surfaces seemingly are more susceptible to sink formation than many other subsurface rocks.

**AGE OF SINKS**

Age of known Kansas sinks ranges from Ordovician to Recent. Several periods in geologic history seem to have been more favorable for sink formation than others, and several of these time intervals should be mentioned.

The first is pre-Simpson—post-Ar buckle time, when the low relief surface of the Arbuckle was exposed to prolonged weathering and erosion. It was during this interval that sink formation took place in eastern Kansas, especially on the flanks of the rising Chautauqua arch. Other areas, as on the Central Kansas uplift, must have been subjected to the same processes, but most of the evidence was destroyed by later erosion.

The next period especially favorable to formation of sinks was in early Pennsylvanian time. The surface rock in large areas of Kansas which had low relief, was at that time thick Mississippian limestone. Before complete inundation by Pennsylvanian seas, the region was effectively weathered and eroded and an extensive karst topography developed on this Mississippian surface. On the Central Kansas uplift, Arbuckle rocks were again exposed to erosion processes after removal of overlying beds. It was at this time that a well-developed karst topography was formed on the Arbuckle surface locally on the Central Kansas uplift as described by Redman (1947), Walters (1946), and Ver Wiebe (1941, 1947).

The next period of comparatively rapid sink development, which is well recorded, began in the Pliocene and is still in process. This kind of sink development occurring at the present differs somewhat from that in pre-Simpson—post-Ar buckle time and early Pennsylvanian time. Numerous and varied rock types are exposed on the surface, and thus conditions are not favorable for extensive development of karst topography. Sinks are abundant locally, however.

**RELATED FEATURES**

Commonly associated with sink development in Kansas are caves, natural bridges, underground drainages, and soil cracks. These related
features are more prominent in the western part of the state. For the most part, they are minor and do not form a major part of the physiography. They, like sinks, are restricted geographically and stratigraphically to areas and rock formations susceptible to solutional processes.

Because Kansas has no extensive limestone plateaus, as do Indiana and Kentucky, well developed karst topography and karst-related features are not present.

Lee and Payne (1944) describe an interesting occurrence of cave deposits in Mississippian rocks found in the subsurface of the McLouth gas and oil field, in Jefferson and Leavenworth Counties. Pennsylvanian deposits occur in the caves, which were found at depths of as much as 150 feet below the top of the Mississippian. No sinkholes were found to be associated with the caves.

Davis (1955) describes in detail three small caves in the Stanton limestone formation (Pennsylvanian) in Wilson and Montgomery Counties.

Caves, presumably in the Fort Riley limestone (Permian), have been mentioned by Savage (1891) as occurring in Wabaunsee County. Stalactites and stalagmites occur in the caves. William R. Atkinson (personal communication) relates the occurrence of caves in the Fort Riley limestone in southwestern Morris County. Caves in this part of the geologic section are usually low and narrow but long. The well known Butler County cave in the Fort Riley limestone should also be mentioned (John M. Jewett, personal communication).

Solution of the Blaine gypsum (Permian) has resulted in formation of many small sinks, caves, and natural bridges in Barber and Comanche Counties. Caves in this area and adjoining portion of Oklahoma are commonly called "The Bat Caves". These caverns have been described in detail by Twente (1955). Grimsley and Bailey (1899) describe a gypsum cave on Cave Creek, four miles west of Evansville, known as Big Gypsum cave. A stream entered from the west of the 100-foot cave and left by an east opening.

The largest and best known natural bridge in Kansas spans Bear Creek 7 miles south of Sun City in Barber County (Fig. 3c). The bridge was 12 feet above the small stream, and the 55-foot span was 35 feet wide in May, 1934 (Jewett, 1935). Many other small natural bridges occur in this part of the state, but are not as well known as Sun City Natural Bridge. They also have formed by solution of Permian gypsum.
Absence of surface drainage courses may indicate subterranean water courses in soluble rocks. In the Bird City area in Cheyenne County, there is an absence of drainage channels. In western Kansas, White Woman Creek offers an excellent example of subsurface water drainage. The stream enters the state in Greeley County and flows east across Wichita County into western Scott County, where the surface water course disappears. No re-entry to the surface is known. The point at which the stream disappears is a short distance west of the Modoc basin.

McLaughlin (1946) mentions the area of the Bear Creek depression, where Bear Creek crosses the northwestern corner of Grant County. In places, drainage consists of a series of sinkholes and short intermittent streams, indicating underground water channels.

In southern Kearny County, surface expression of the Bear Creek drainage ends abruptly. Many other small streams, especially in Wichita, Scott, Kearny, Finney, Grant, and Haskell Counties, flow for a short distance on the surface and then disappear underground.

Soil cracks commonly are found in a concentric pattern on the rim encircling sinkholes. Their formation is due to subsidence of surface deposits into the sinkhole causing separation and readjustment of material on the surrounding rim.

An interesting man-made subsidence of considerable size occurred in Hutchinson in 1924. Removal of salt by five solution wells underlying the city resulted in slight settlement of some buildings in the business district (Young, 1927).

**SUMMARY**

It is difficult to concisely summarize or to make any definite statements concerning many varied aspects of sinks or related features. It is possible to make some generalizations, however.

In terms of geologic time, sinkholes, as physiographic features, exist for relatively short periods. Only if sinks are buried will they be preserved, and then in many cases, it may be difficult to recognize them. Surface sinks may be recognized by topographic expression, structure, and physical characteristics; subsurface sinks may be revealed by abnormally thick sediments different from normal stratigraphic succession of beds and by structure.

Several conditions such as soluble beds, adequate rainfall, adequate ground-water movement, and time are necessary for sink formation. Different combinations of these factors produce different results and determine whether solution-subsidence or collapsed features are formed.
In general, it would seem that simple sinks are the most common in Kansas. Simple and complex sinks are present in most of the state, whereas the coalescing ones are found only in the western part.

Generally speaking, sinks in eastern Kansas are smaller than those in the western part of the state. Sinks in the state range from a few feet to several thousand feet in diameter. Shapes vary, but most are circular or elliptical. In cross section, they are cone or funnel shaped. Sinks range in depth from a few feet to several hundred feet. Again generalizing, it seems the shallower ones are in the eastern part of the state and the deeper ones in the western part. The area involved in a single sink ranges from less than an acre to several thousand acres or even many square miles as in the case of large coalescing sinks. As many as 42 sinks a square mile have been recorded in Kansas.

Sinks occur in beds ranging in age from Cambro-Ordovician to Recent. Salt, gypsum, chalk, and limestone are the rock types most generally affected by solutional processes.

Geographic distribution of sinks is controlled by both stratigraphy and structure. For the most part, in eastern Kansas sink distribution is controlled by stratigraphic factors and in the western part of the state by structural elements.

Origin of sinks is by solutional processes. High Plains depressions that are formed by eolian action, compaction, and animal action are not to be confused with true sinks formed by solution.

Age of sinks ranges from Ordovician to Recent. Three periods of rather intensive sink development are preserved in the geologic record. One was in post-Arbuckle-pre-Simpson time, the second in post-Mississippian-pre-Pennsylvanian time, and the third from Pliocene time to the present day. Sinks, undoubtedly, formed in many other periods of history, but have not been adequately preserved in the record in Kansas.

Related features, commonly associated with sink development, include caves, natural bridges, and underground drainages. These surface features are more pronounced in the western part of the state.
SELECTED ANNOTATED BIBLIOGRAPHY


Mentions typical karst topography on Mississippian surface which is dotted with sinkholes.


Southeastern Kansas above sea at end of Mississippian; topography mature and probably not much different from present Ozark topography; probably modified by effects of solution; Cherokee beds have subsided into solution caverns on Mississippian limestone; sinks common in district southeast of Pittsburg.


Very shallow circular basins or filled sinks, up to 30 feet in diameter on uplands floored by Fort Riley limestone.


Describes in detail a circular sinkhole 100 feet wide, 40–50 feet deep. Formed by solution of the Greenhorn limestone and collapse of the roof on December 18, 1929.


Mentions buffalo wallows and formation of sinks on upland areas during the Quaternary.


Mentions sinkholes developed in the Cresswell limestone SW1/4 sec. 6, T. 9 S., R. 6 E.


Mentions collapse of Mississippian limestone and slumping of overlying Pennsylvanian Cherokee beds into openings. Resistivity may be used to indicate favorable areas but not as a guide for lead and zinc ore.


Contour map on base of Tertiary show depressions that might be due to solution and removal of salt with consequent slumping of overlying beds.


Describes in generalities a circular sink 150–300 feet in diameter, about 100 feet deep with salt water in Ford (?) County, which is probably the "Meade Salt Sink."


Mentions "Meade Salt Sink" which formed across the "Jones and Plummer Trail."
Sinkholes and Related Features in Kansas

Describes many caves and natural bridges in connection with the solution of gypsum in the Cave Creek formation.


Mentions "Meade Salt Sink" contained about 41/2 percent salt and formed in 1878.

Attributes large circular pits to buffalo wallows and describes their formation.

Describes in some detail three small caves in Wilson and Montgomery Counties occurring in the Pennsylvanian Stanton formation.

Discusses the origin of the Smoky Basin cave-in in light of previously suggested theories. Cavity formed in Cretaceous Niobrara formation with subsequent collapse of the roof. Fault exposed in wall of cave-in indirect cause of subsidence by allowing surface water to penetrate down to soluble chalk through fissures developed in connection with faulting.

Discusses theories on the origin of sinks and depressions in western Kansas. Describes cave-ins in T. 12 S., R. 39 W.; T. 12 S., R. 38 W.; the Old Maid's pool; Devil's hole; and others.

Mentions the occurrence of sinks in the Permian Fort Riley formation in Butler County.

Mentions saucer-shaped depressions of the High Plains and the basins formed by the solution of salt and gypsum in underlying Permian rocks.

Says uplands of the Flint Hills are pitted with sinkholes.

Small depressions, called sinkholes, a few hundred feet in diameter and 10–20 feet deep, especially numerous where late Pleistocene deposits overlie deeper early Pleistocene channels. Some described as being formed by compaction, other by solution and collapse of salt, gypsum, and limestone beds in the Cretaceous and Permian. In the central Kansas region probably due to compaction of unconsolidated material.
Describes soil cracks near Jewell City that were up to 7 feet deep and 3 feet wide.

Discusses in detail origin of the Meade artesian basin during Tertiary, Pleistocene, and Recent time and associated solution and collapsed structures. Describes the "Meade Salt Sink."

Development of sinks in Meade County climax during the Pleistocene. Formed by the solution of Permian red beds several hundred feet below the surface. This was possible after the area had been faulted to allow surface water passageways underground. Describes the "Meade Salt Sink" which formed in March, 1879; Jones Ranch sink; Ashland and Englewood basins (Clark County); and the Meade basin.

Depressions in Thomas County not due to solution-subsidence, but probably differential compaction.

Faults important in development of sinks in Meade basin. Sinks formed by solution of Permian salt and gypsum; mentions "Meade Salt Sink."

In Clark and adjoining counties there is an unusual type of Wisconsin alluvium filling some sinks. As features were isolated during deposition, dating of these beds depends on contained fossils and intersection of lines of dissection.

"Meade Salt Sink" and many undrained depressions mentioned in road log.

Sinks adjacent to Meade basin in Meade and Clark Counties occur along faults, many filled with Pleistocene sediments; sinks formed by solution and collapse of Permian salt and gypsum.

Presents a classification of sinks as (1) simple (one subsidence), (2) complex (several subsidences), and (3) coalescing (sinks formed close together and rims collapsed or worn down by erosion). Discusses origin of some southwestern Kansas sinks.


Solution pans, grooves, and slots developed on Cretaceous sandstone in central Kansas are described; also various theories of origin are discussed.


Possible to locate sinks in Ordovician Arbuckle beds on the Central Kansas uplift with seismograph. Reflection from lower Kansas City accurately reveals structure on top of eroded Arbuckle because of "draping" effect over sinks caused by compaction of sink fill. Important as oil not located in sinks but on highs.


Describes sink near Potwin, Kansas in Butler County which formed on the afternoon of September 22, 1937; 90 by 150 feet, sides perpendicular, 40 feet deep, volume of soil missing about 500,000 cubic feet. Several other sinks in the same section; mentions two areas in Ellis County of subsurface sinks.


Mentions several solution features caused by leaching of gypsum; gives natural bridges, underground water courses, and caves as examples.


Description of Meade artesian basin and fault; mentions "Meade Salt Sink," Big Basin, and St. Jacob's Well.


In generalities mentions sinkholes in southwestern Kansas.


Discussed origin of sinkholes (swales or lagoons) by natural settling. Development of arroyos next step after formation of swales.


Mentions many shallow enclosed basins on the "table lands." Describes a series of broad cracks in Sherman County that were formed in May, 1894.


In sec. 9, T. 14 S., R. 7 E. sinkholes are numerous (42 in one square mile). Some nearly 50 by 35 feet and 10 feet deep. Sinkholes in Morris County on Kansas-Neosho watershed and others in sec. 30, T. 14 S., R. 7 E.

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Lowermost Pennsylvanian beds deposited on surface of low relief and caverns collapsed in underlying Mississippian rocks after consolidation of Pennsylvanian sediments; strata in sinks commonly faulted.

Several natural bridges, which were produced by solution of gypsum beds of Permian age, are associated with sinks and underground water channels.

Contains information on the Ashland-Englewood (Ashland), Jones Ranch, and Meade basins.

Large depressions in sec. 2, T. 12 S., R. 37 W.; sec. 6, T. 12 S., R. 36 W.; sec. 6, T. 11 S., R. 36 W.; sec. 12, T. 13 S., R. 33 W.; and sec. 15, T. 13 S., R. 35 W. Good example in sec. 29, T. 12 S., R. 37 W. Discusses origin of depressions and discards the idea of buffalo wallows, compaction, and origin of solution cavities in the Niobrara formation (Cretaceous). Depressions probably are related to the structure of the region; also mentions other small upland depressions.

Discusses in detail the Cox basin, Englewood basin, Big Basin, St. Jacob's Well, "Meade Salt Sink," Scott and Meade basins, Cheyenne bottoms, Odee basin, and Ashland basin. Discusses at length his theory on the formation of basins by ground settlement and solution and collapse.

Mentions sinkholes in the Fort Riley limestone northeast of Haverhill, Kansas.

Stop 6 at a sinkhole described by Pierce and Courtier (1937).

Mentions Big Basin, St. Jacob's Well, and Natural Bridge in Clark and Barber Counties.

Discusses the origin of the Missouri fire clays.

Solution of salt forms caves, the roofs of which collapse forming sinkholes; and suggests Big Basin, Little Basin (Clark County) may have been formed this way. Not enough salt in the Whitehorse for the solution of this formation to form caverns to collapse. Many slump structures in Barber County probably caused by solution of gypsum.

Original cavern probably in pre-Dakota (Cretaceous) strata, may be Permian salt but more probably Permian gypsum. Graneros shale is exposed on rim of sinkhole, not Carlile as mentioned by Bass (1931).


Mentions Coolidge sink, Big Basin, and Natural Bridge as being formed by dissolution of soluble rock by ground water and falling in of cavern roof.


Postulates that the small, highly faulted areas in these counties are due to rocks sinking into large caverns dissolved in deeper soluble rocks such as the Fort Hays limestone (Cretaceous).


Undrained depressions with diameters from a few feet to a mile are common feature of uplands; serve as catchment basins in recharging ground water.


Describes sinks near Rolla, Missouri and the economic products associated with them.

LEE, WALLACE, and others. (1946) Structural development of the Forrest City basin of Missouri, Kansas, Iowa, and Nebraska: U. S. Geol. Survey Oil and Gas. Investi., Prelim. map 48 (esp. sheet 1).

Two wells have abnormally thick sections of St. Peter standstone (Ordovician) and is interpreted as being sink fill in Arbuckle rocks.
LEE, WALLACE, LEATHEROCK, CONSTANCE, and BOTINELLY, THEODORE. (1948) The stratigraphy and structural development of the Salina basin in Kansas: Kansas Geol. Survey Bull. 74, p. 1–155 (esp. p. 34, 122). Mentions the Kasper No. 1 James well in Johnson County having an abnormal thickness of St. Peter.

LEE, WALLACE, and PAYNE, THOMAS G. (1944) McLouth gas and oil field, Jefferson and Leavenworth Counties, Kansas: Kansas Geol. Survey Bull. 53, p. 1–193 (esp. p. 42–46). Describes Pennsylvanian sediments which were deposited in caves in Mississippian limestone; found to depths of 150 feet below top of the Mississippian; one well encountered a pre-Pennsylvanian sink (Tidal No. 1 McCutchen, sec. 33, T. 34 S., R. 2 E.).


MOORE, RAYMOND C. (1926) Note on subsidence near Sharon Springs, Wallace County, Kansas: Kansas Geol. Survey Bull. 11, p. 95–96. On March 9, 1926 in sec. 33 and 34, T. 13 S., R. 39 W. (Wallace County), a sink formed 250 by 350 feet and about 50 to 170 feet deep; wall vertical; volume of sediment involved about 1 1/2 million cubic feet. Pierre shale in wall; due to formation of cavity in upper part of Niobrara followed by collapse of roof. (1926a) The subsidence near Sharon Springs, Kansas: Science, vol. 64, no. 1649, p. 130–131. Also mentions Old Maid’s pool, northwest of Sharon Springs as 80 feet deep, 3/8 mile in diameter.


Sinkholes and Related Features in Kansas


PIERCE, W. G., and COURTIER, W. H. (1937) Geology and coal resources of the southeastern Kansas coal field: Kansas Geol. Survey Bull. 24, p. 1–122 (esp. p. 58–60). Describes nine recent sinks in Cherokee County formed since 1905. Pennsylvanian Cherokee is in sinks developed on the Mississippian limestone surface. “Fossil” sinks in which the beds are faulted are exposed in four of the recent sinks. Recent sinks are on higher parts of the Mississippian lime and are associated with the Miami trough or the Joplin anticline.


———. (1953a) Geology and ground-water resources of Sherman County, Kansas: Kansas Geol. Survey Bull. 105, p. 1–130 (esp. p. 14, 28–30). Larger depressions probably formed by compaction as too big for buffalo wallows and soluble beds too deep under Cretaceous and Tertiary cover; shallow ones could be buffalo wallows.


RICH, JOHN L. (1930) Circular structural depressions in central Kansas: Geol. Soc. America Bull., vol. 41, p. 315–320. Describes two sinks, one in detail in Dickinson and Morris Counties. The one in sec. 28, T. 16 S., R. 4 E. has depth of 95 feet on the surface Permian Herington limestone, regular outline, slightly elevated rim, 2 to 3 miles in diameter. The other is in sec. 20, T. 15 S., R. 5 E.

RUSSELL, WILLIAM L. (1929) Local subsidence in western Kansas: Am. Assoc. Petroleum Geologists Bull., vol 13, no. 6, p. 605–609. Describes the Smoky Basin cave-in; Old Maid’s pool; sinks in Sherman County and others. Suggests origin by cavities formed during deformation along fault planes. Strata of cavities resisted pressure for long time and later caved-in. Maintains it’s impossible to have voids form in Niobrara (Cretaceous) chalk as formation is mainly shale and there is no evidence for contained ground water in the formation.
Mentions sinks in Wabaunsee, Douglas, and Barton Counties. Surface depressions in Wabaunsee County 40–80 feet in diameter and occur on high prairie surface.

Mentions or describes sinks in Morris County, also Cheyenne Bottoms, Lake Inman, and associated sinks in McPherson County, Big Basin, Little Basin, and St. Jacob’s Well, Englewood-Ashland basin, Scott basin, Sharon Springs sink, Old Maid’s pool, and others; also discusses origin.

Shows a subsurface sink on the Mississippian surface in sec. 21 and 28, T. 16 S., R. 4 E.

On highway U. S. 24, 17.7 miles northwest of Manhattan is large sink in Cresswell limestone member; several others across road. Also mentions many undrained depressions in road log.

Mentions or describes Hamilton County sink, “Meade Salt Sink,” Big Basin, St. Jacob’s Well, Jones Ranch sink, Ashland basin, Finney basin, and others.

Discusses a pre-Pennsylvanian subsurface sinkhole in Wabaunsee County. An abnormal thickness of Cherokee, supposedly fill, in a sink on the Mississippian surface; occurs in the Carter No. 1 “C” Davis well (SW 1/4 sec. 28, T. 13 S., R. 10 E.).

Discusses the karst development on the Mississippian surface in southeastern Kansas.

Gives evidence for solubility of gypsum and relates to it physiographic features. Mentions Big Basin, gypsum caves, Natural Bridge, etc.

Solution of salt by ground water on a large scale would produce settling of overlying beds and cause a change in the surface topography.

General reference on sinkholes.

Describes in detail many caves in Barber and Comanche Counties which are formed in the Permian Blaine gypsum formation.
Sinkholes and Related Features in Kansas


Discusses karst topography on the Arbuckle (Ordovician) surface in the Silica and Trapp oil fields on the Central Kansas uplift. Thirty-six depressions up to 163 feet deep and filled with detrital material are known in the Silica field.


Briefly discusses the buried karst topography on the Ordovician Arbuckle surface in central Kansas.


Mentions solution-subsidence for sinks in the Meade basin.


Swales or sinks on upland surface in Scott County; one with water in it located in SW1/4 sec. 26, T. 18 S., R. 32 W.


Discusses in detail history, formation, etc. of the buried karst topography on the Arbuckle (Ordovician) surface in Barton County. Solution features include sinks, valley sinks, and solution valleys. Sinks are 10–60 feet deep, about 20 acres in size and filled with Pennsylvanian sediments.


Discusses several recent sinks. Suggests origin caused by removal of salt by solution from the Permian Wellington. A line of sinks in McPherson, Harvey, and Sedgwick Counties coincides with the eastern margin of the salt beds.


Subsidence in Hutchinson due to removal of salt by solution from wells; cavities in salt beds caused subsidence of overburden. The adjustment was over a period of about one month.