OKLAHOMA GEOLOGY

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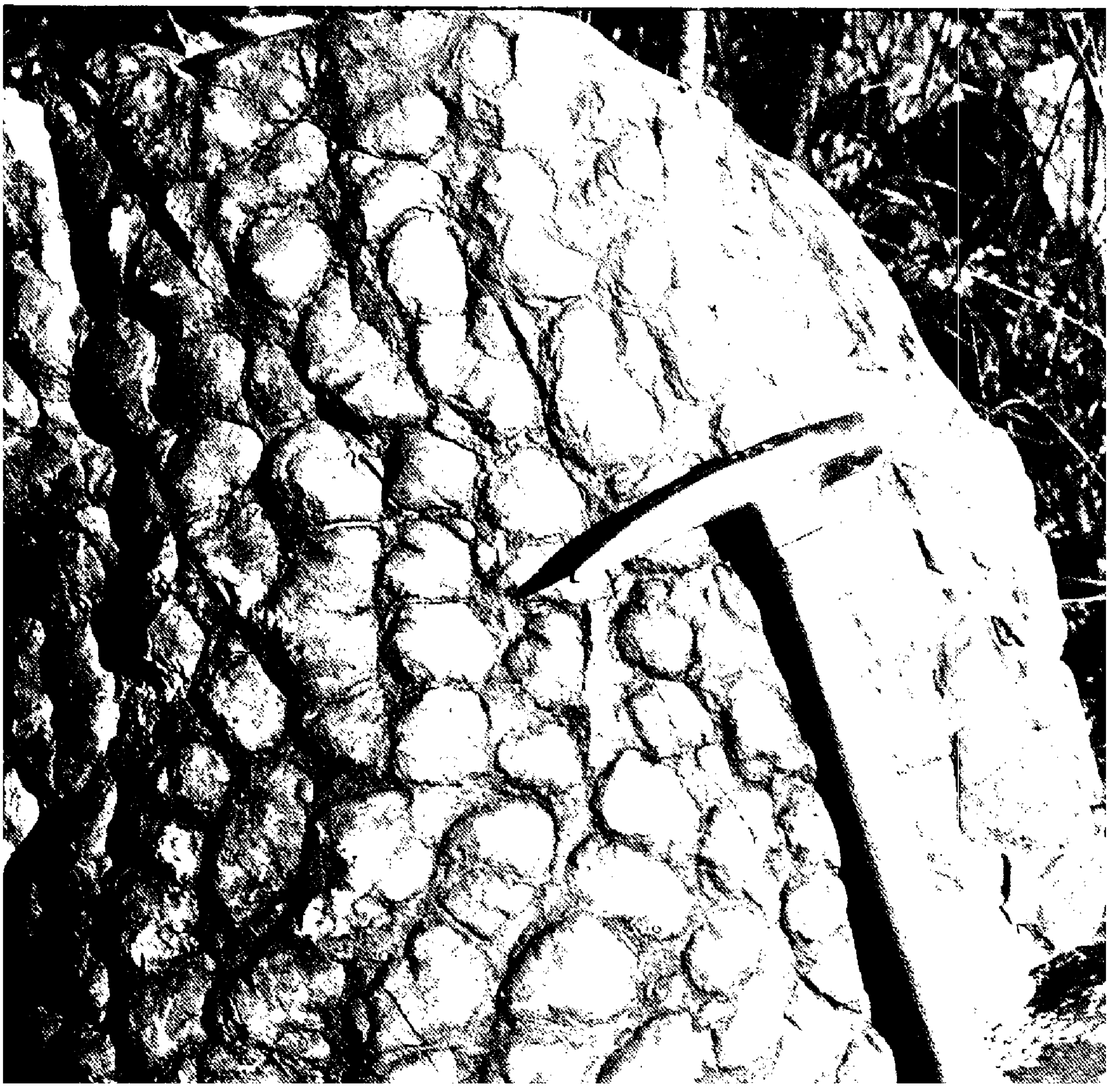

On the cover—

Load Casts from the Ouachita Mountains

Pictured are load casts on the bottom of a sandstone turbidite bed from the lower Atoka Formation (Pennsylvanian) in the frontal Ouachita Mountains of southeast Oklahoma. The original porosity of mud is much higher than that of sand. Therefore, a layer of sand rapidly deposited on a layer of mud forces excess pore fluids from the underlying mud leading to liquefaction of the sediments. The mud flows upward into flame shapes, and the sand sags, forming concave-up depressions. The extent of deformation is dependent on the shear strength of the sediment, which is in turn a function of grain cohesion, degree of packing, and pore-fluid pressure.

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OKLAHOMA GEOLOGY NOTES

C O N T E N T S

PRESIDENT HERBERT CLARK HOOVER AND THE PAWHUSKA LIMESTONE

Robert O. Fay[1]

Biography

Herbert Clark Hoover was born August 10, 1874, at West Branch, Cedar County, Iowa. One of three children born to Quaker parents Jesse Clark Hoover and wife Hulda Randall (Minthorn) Hoover, Herbert had an older brother, Theodore, and a younger sister, May (Fig. 1). His father, a blacksmith, died in 1880 when Herbert was six years old. After his mother died in 1884, the three children were taken into care by Quaker uncles and aunts.

In the summer of 1881, Herbert—or Bert, as he was known by his immediate family—was taken to Pawhuska, Osage Nation, Indian Territory (now Osage County, Oklahoma) by his mother's sister, Agnes (Minthorn) Miles. She was the wife of Major Laban J. Miles, the Osage and Kaw Indian agent appointed in 1878 by President Rutherford B. Hayes. Originally from West Branch, Iowa, Major Miles was the son of Benjamin Miles, who earlier had been assigned to teach school at Pawhuska.

Figure 1. Herbert Hoover (right) with his brother and sister, Salem, Oregon, about 1888.

Bert was described as a rosy-cheeked, cheery-looking little boy, in knee trousers and gray coat, with only a small hand satchel for his belongings. His Aunt Agnes, later a primary source for Hoover's biography, took him on the train from West Branch, Iowa, to Coffeyville, Kansas. From there they had to travel the 65 miles to Pawhuska by buckboard drawn by two mules. Bert stayed there about nine months. He enjoyed roaming the

[1]Oklahoma Geological Survey.

hills with his two cousins, Harriet and Theodore Miles, and their Indian friends. He had a pony to ride and mixed well with the Indian children, learning some of the Osage language and how to survive out of doors. He collected rocks and fossils in the surrounding area, which piqued his interest in geology, and he liked being out of doors. He used soft stone to write on the fence, like a blackboard. He visited a nearby hole in the side of a hill, called Panther Cave. He liked to read books and took an interest in Indian names such as Chief Pahu Ska (literally "white hair"), for whom Pawhuska was named. Benjamin Miles was mostly responsible for naming the town after the Chief.

In 1881, Pawhuska consisted of three stores, a blacksmith shop, a small stone hotel, a school for Indian children, the Indian Agency building, a two-story stone residence for the Indian agent and his family, and a few log and frame buildings occupied by traders.

When Bert had to return to Iowa in the spring of 1882, he wanted to take his "treasure"—his pile of rocks and fossils—with him. His hand satchel was so heavy it "bumped" down the agency steps, and he had to drag it to the buckboard. Uncle Laban made him leave most of the stones, substituting some clothes instead. Bert said, "Oh please, just let me take them. I'll leave my clothes. I'll leave anything, just so I can take them with me." He took a few specimens in his pockets, but had to leave the bulk behind, never to be seen again. From that time forward, Bert was interested in geology.

Cared for by his uncle, Allen Hoover, after his mother's death, Bert attended grammar school at a Quaker academy at Oskaloosa, Iowa. In 1886, Bert was sent to Newberg, Oregon, to live with another uncle, Dr. John Minthorn, head of a Quaker school. He stayed there until about 1889. A friend of Bert's father visited the family and talked to Bert about mining, giving Bert his initial interest in mining geology.

About 1889, Dr. Minthorn moved to Salem, Oregon, to open a real estate business connected with the Oregon Land Co., which included processing mining claims. He brought Bert along to work in that business.

In 1891, Bert moved to Portland, Oregon, and continued in real estate and mining leases, trying to educate himself in mining geology. A newspaper announced that a representative of Leland Stanford University would be in Portland that summer to give entrance examinations. Bert failed the exams, but the representative, Dr. Joseph Swan, a Quaker, offered to coach him, and Bert took the exams again. Herbert Hoover was admitted to Stanford University in August 1891, the year the university opened, and was one of the first students in geology.

At Stanford, located at Palo Alto, California, Herbert lived in a dormitory and took odd jobs to work his way through college, including taking in laundry. He worked as an assistant registrar and accepted a job as secretary to the head geologist, John Casper Branner, who was also the director of the Arkansas Geological Survey. In 1892, Dr. Branner found summer work for Herbert at the Arkansas Geological Survey where he assisted in compiling a topographic and geologic map of Arkansas. While on his way to this job, Herbert visited his Uncle Laban and Aunt Agnes in Pawhuska. He remained a few days and studied the government limestone quarries west of town to determine if a kiln could be erected and lime produced for building purposes. In the summers of 1893 and 1894, Herbert worked under Dr. Waldemar Lindgren studying mining areas of the Sierra Nevada Mountains of California for the U.S. Geological Survey, especially helping to complete the geology of the Lake Tahoe sheet.

After graduation in May 1895, Herbert worked for several months in a mine at Nevada City, California, west of Lake Tahoe, as a day laborer with a pick and shovel. Soon tiring of this, in 1896 Herbert sought more-professional employment in San Francisco with Louis Janin, an internationally known mining engineer considered to be one of the best on the West Coast. Mr. Janin had no work for Herbert as a geologist but hired him as a typist. Herbert could not type but accepted the job, rented a typewriter, and learned how to hunt and peck for four days, showing up for work the next week.

While typing a report for a client on the mine he had just worked in, Herbert began correcting information contrary to his own findings; Herbert proved to be right. After that, Mr. Janin decided to send Herbert to work as a geologist on a defunct mine; Herbert found ore, and the mine was reopened. Herbert's beginning salary was $50 a month, but after doing geology, it was raised to $250 a month. He was then sent into the field to examine mines in California, Arizona, New Mexico, Colorado, Utah, and Nevada.

In 1897, Mr. Janin was asked by a London firm to recommend a manager for a gold mine in the Cooleardie District of Western Australia. They wanted someone about 30 years old with experience and would pay $7,500 a year. Mr. Janin asked Herbert to apply for the job in London, but Herbert was only 23 years old and was turned down. The next day one of the directors talked to Herbert personally, decided that he was mature for his age, and asked the board to reconsider. Herbert was sent to Australia on a trial basis and was so successful that by 1899 he was admitted as a junior partner with the firm (Fig. 2). Herbert was then sent to China to direct their mining operations, especially coal mining, becoming director-general of the Chinese mines. His salary was doubled to $15,000 a year and, at age 25, he was one of the highest paid mining engineers in the world.

In February 1899, Herbert was married at Monterey, California, to Miss Lou Henry, daughter of a banker. Miss Henry was born in Iowa, and the family came to Monterey because of her mother's health. Miss Henry met Herbert at Stanford University where she also studied geology under Dr. Branner, entering as a freshman in 1895 when Herbert was a senior. She went to China with Herbert, and upon returning, the couple made their home in Palo Alto. They had two children before 1907, Herbert, Jr., and Alan. Both

Figure 2. Herbert Hoover, Perth, Western Australia, in 1898.

boys attended Stanford. Their uncle, Theodore, became dean of engineering, and Dr. John Branner became president of the university.

From 1901 to 1914, Herbert traveled over much of the world examining mines in Russia, Italy, Burma, and other countries. During World War I he worked for the Belgium Relief Agency; after the war he involved himself in politics. By 1905, at age 30, Herbert had accumulated $1,000,000. During his term in office, from 1929 to 1933, he was the wealthiest President of the United States. The family no longer called him Bert or Herbert, but referred to him as "President Hoover." He died in 1964 at age 90. See Irwin (1928), Rucker (1928), and Hartley (1929).

The Pawhuska Limestone

In the summer of 1892, while on his way to work for the Arkansas Geological Survey as an assistant under John F. Newsom, Herbert Hoover visited his Uncle Laban and Aunt Agnes Miles at Pawhuska for a few days. Major Miles wanted to produce lime for cement for building purposes at the Indian Agency and asked Hoover to investigate the limestone possibilities for a lime kiln near Pawhuska. Hoover did this, collecting samples and fossils, writing a report, and taking the fossils back to Stanford University with him. Hoover's report was never published. Stanford paleontologist Dr. James Perrin Smith identified the fossils and prepared two reports several years later.

In the first report, Smith (1894, p. 199–200) established the name Pawhuski Limestone, based upon Hoover's report:

> **The Pawhuski Limestone.** In the eastern part of Indian Territory are found large deposits of coal in the Upper Coal Measures, but further west, the same horizon is represented by marine limestone. In 1892, Mr. H. C. Hoover, of the Geological Survey of Arkansas, found at the government lime kiln, three miles northwest of Pawhuska, Oklahoma Territory, Osage Agency, a bed of massive limestone about 100 feet thick, lying horizontally on heavily bedded sandstones. The limestone is fossiliferous, but the sandstones are not. The fossils collected were placed at my disposal, and on examination, they proved to be: *Spirifer cameratus*, Morton; *Athyris subtilita*, Hall sp.; *Productus semireticulatus*, Martin sp.; *Productus nebrascensis*, Owen; *Productus longispinus*, Sowerby; *Streptorhynchus crassus*, Meek and Hayden. These are plainly of Upper Carboniferous age. The limestones cap the hills in that region, and spread over a great area, but fossils were collected at this place only.

In the second report, Smith (1896, p. 230, 234) used the same quotation, spelling the heading "The Pawhuski Limestone." On p. 234 of his report is a correlation table showing the bed to be Pennsylvanian in age. There was no measured section and no exact location, except for the mention of the government lime kiln, which apparently was established between 1892 and 1894.

In 1928 and 1929, Charles Newton Gould, first state geologist of Oklahoma, wrote letters to Smith and others trying to find out more details. In a letter dated December 1928, Smith wrote: "I identified the fossils for him [Hoover], on his return to Stanford; and later, in Arkansas Geological Survey reports, used the name [Pawhuska] inadvertently, fixing it; for Hoover's report was never published; it [the report] is still in manuscript form in the hands of Prof. T. J. Hoover at Stanford. Major Miles is still living now, at Wichita, Kansas." In December 1928, Gould wrote to

Theodore J. Hoover, Herbert's brother and dean of engineering at Stanford, but apparently received no reply and did not receive a copy of Herbert Hoover's original manuscript.

In January 1929, Gould prepared a news release intent upon building a monument to Hoover at Pawhuska, to be dedicated on March 4, 1929, the date Hoover was to be sworn in as President of the United States. In the news release Gould mentioned that the lime kiln can still be seen three miles west of Pawhuska and one mile east of the Timbered Hills. Apparently Gould's news release was never published, because the monument was not erected (Gould, 1959, p. 222–223). The first page of the news release reads as follows:

> **Norman, January (Special).**—One of the first monuments to be built in America in honor of Herbert Hoover, president-elect of the United States, will be dedicated near Pawhuska, Oklahoma, on March 4, 1929, at the time when Hoover takes the oath of office and becomes president of this country. The monument, which is being sponsored by a number of organizations at Pawhuska and in other parts of the state, will be built to commemorate the fact that in 1892, Herbert Hoover, then a young student of geology, first described and named the ledge of rock known by geologists throughout the country as the Pawhuska limestone. Dr. Charles N. Gould, director of the Oklahoma Geological Survey at Norman, who assembled the facts concerning Hoover's work at Pawhuska, stated that the present plan is to construct the monument of Pawhuska limestone, and include in it blocks of stone from Hoover's birthplace at West Branch, Iowa, from his present home at Palo Alto, California, and a slab of granite from the Wichita Mountains on which the inscriptions will be engraved. Miss Ruth Johnston, of Pawhuska, a member of the Business and Professional Womens Club of that city which is sponsoring the movement, is chairman of the committee in charge of arranging for the building of the monument, with the Chamber of Commerce and other civic organizations at Pawhuska co-operating with the project. Major Laban Miles, uncle of Herbert, now 85 years of age and whom Hoover was visiting at the time he discovered and named the Pawhuska limestone, is very much interested in the project and helping in every way he can. Mr. Charles Maguire, who was a teacher in the Indian School under Major Miles, remembers when Herbert Hoover visited his uncle as a small boy, and is helping to locate the spot where the monument is to be erected. Will Clark, county engineer of Osage County, and practically everyone in Pawhuska is interested in seeing the monument built. The State Board of Affairs has become interested in the project and has ordered a granite slab to be set into the structure, with the following words engraved on it, "Herbert Hoover here named the Pawhuska limestone, 1892." The monument will be ten feet high, and constructed in the shape of a pyramid, which is the symbol for engineers the world over.

Gould (1959, p. 223) said: "I suggested erecting a monument to President Herbert Hoover . . . But I did not get anywhere. No one would take the initiative. Later I learned that certain local politicians had instituted a whispering campaign to the effect that Gould was trying to boost a Republican, and so the idea of a monument . . . did not materialize."

Noah Fields Drake (1897), in his doctoral dissertation on the geology of northern Indian Territory, included a restudy of the Pawhuska limestone, giving a thickness of 10 feet and correctly spelling the name Pawhuska. Drake, also a student of Dr. Branner at Stanford University, was doing field work in 1896. Drake did not mention the government quarry, but did give several reconnaissance measured sections in the Pawhuska area, mentioning Smith's work (Drake, 1897, p. 386–387):

Dr. J. P. Smith called the limestone bed that outcrops from two to three miles west of Pawhuska, the Pawhuska limestone. A section of the strata in the vicinity of Pawhuska is about as follows:

		Feet
1.	Blue and red clays	at top
2.	Pawhuska limestone	10
3.	Clay shale	50
4.	Sandstone	50
5.	Clay shale	150
6.	Sandstones	at base

This limestone outcrop forms a little escarpment facing east and running north about two miles west of Pawhuska, while the first sandstone bed below the limestone caps the buttes and escarpments around the village.

In 1900, Gould made a trip through the northern Indian Territory, but did not measure the Pawhuska Limestone. In his publication of 1901 (p. 190) he stated: "From near Pawhuska to Winfield, Kansas, our route lay across the Flint Hills. Massive ledges of limestone with flinty concretions, alternating with beds of calcareous shale, composed practically all the rock seen. The Flint Hills have been too often described to require more than a passing mention in this place." Gould did not mention the government quarry, nor any specific locality for the type Pawhuska Limestone, nor did he mention anything about Smith or Drake.

In June 1901, George Irving Adams of the U.S. Geological Survey traced the Pawhuska Limestone northward into Kansas, correlating it with his Elk Falls Limestone. Adams (1901, p. 384–385) mentioned the government quarry and did not give a measured section. He introduced a new concept for the Pawhuska, stating that there were three limestone beds in the Osage Nation, but only two in Kansas, departing from the original concept of one limestone in the government quarry:

In June, a trip was made through the Osage Nation into Oklahoma. The previous geological work which had been done in this locality by Drake and by Gould consisted of sections across the rocks and did not permit accurate correlations. The formation which was selected to be traced is the limestone described in the writer's field notes as the Elk Falls (Kans. Geol. Surv., vol. iii). It occurs about 700 feet below the base of the Permian as determined by Prosser. It was chosen because, from its thickness and its relation to the adjacent formations, it was believed that it would be found persistent for a considerable distance southwestward. The line of its outcrop was followed from near Hewins, Kansas, and it was found to pass just west of Pawhuska, where it is the equivalent of the Pawhuska limestone, named by J. P. Smith, and mentioned in the sections by Drake and Gould. In southern Kansas, there are two heavy ledges of limestone separated by shales. In the Osage Nation, although it has not been previously so noted, there are three, all of which are persistent as far as the Arkansas River, although considerably thinner southward. The line of outcrop crosses the Arkansas River at Blackburn and continues to Ingalls, where it is the same as the limestones mentioned by Gould in his section made east of that place. Southwest of Ingalls the limestone becomes thinner. Its strike will carry it across the Cimarron River near Perkins.

In 1903, Adams and others (p. 64) defined Adams's previous correlations, but did not give a measured section, did not mention the government quarry, and were uncertain of his correlations, introducing Kansas terminology for the first time:

> **Pawhuska limestone.** Locality and thickness.—This formation was named by J. P. Smith, who determined some fossils from it and referred it to the Upper Coal Measures. On the authority of Mr. H. C. Hoover, who collected the fossils, the formation is reported to be 100 feet thick and to consist of massive limestone, which is found outcropping 3 miles northwest of Pawhuska. In Drake's section the greatest thickness given for a bed identified as Pawhuska limestone is 10 feet. The line of outcrop of this formation was not mapped by Drake. Correlation.—The Lecompton, Deer Creek, and Hartford limestone formations are shown in the mapping by Bennett [1896] to be the equivalent of the limestones which were reported by Haworth [1898] from Adams's field notes as the Upper and Lower Elk Falls. A more careful study has shown that what was called the Upper Elk Falls is the equivalent of the Deer Creek and Hartford. In the reconnaissance made in the Osage Nation by Adams (1901), the limestones which had been denominated the Elk Falls were traversed and found to be the equivalent of the Pawhuska, which had been named previously by Smith. In the report of this reconnaissance it is stated that the Pawhuska consists of three distinct members. It is possible that they are the equivalents of the Lecompton, Deer Creek, and Hartford formations, although there is little certainty in such correlation, the intervening distance being so great.

Everett Carpenter (1911) wrote a bachelor of arts thesis on the Pawhuska Quadrangle based upon studies made in 1909 while working under Carl D. Smith of the U.S. Geological Survey. The first topographic map of this area was published in 1909 (U.S. Geological Survey). The government quarry west of Pawhuska was not shown on the map. Carpenter did not give a measured section, did not have a geologic map, and defined the Pawhuska to be different from previous definitions, extending the top higher than the Hartford limestone (1911, p. 12–13):

> **Pawhuska formation.**—Above the Elgin is a series of limestones and shales to which the name Pawhuska is applied. It was first used by Smith (1894) who described it as consisting of 100 feet of limestone. Adams [and others] (1903) on the Carboniferous rocks of Oklahoma, retained the name in that treatise. The name is now well fixed in the literature. This series does not consist of persistent strata. Near the Kansas line it is essentially a limestone formation, but to the southward it looses its calcareous nature and becomes mainly sandstone and shale. None of the limestones which are present at the north side of the quadrangle extend very far toward the south. They gradually pinch out and new ones come in higher in the section. The lower part of the Pawhuska formation is the equivalent of the Lecompton, Deer Creek and Hartford formations of Haworth and Bennett (1908). The Pawhuska as defined in this paper extends higher than those mentioned.

(Carpenter, 1911, p. 13–14):

> **Buckcreek formation.**—Above the Pawhuska is a series of shales, limestones, and sandstones to which the name Buckcreek formation is applied. The base of the formation is formed by two relatively thick sandstones separated by only a few feet of sediments. These make a prominent and easily recognizable scarp which can be traced entirely across the quadrangle. A section made along the headwaters of Buck Creek is as follows:

Sandstone	60 feet
Shale and thin limestones	90 feet
Sandy shale	30 feet
Shale	70 feet

Luther Crocker Snider (1911, p. 225) stated that the Pawhuska Formation is 165 feet thick, citing Everett Carpenter as source.

In 1916, Kenneth Conrad Heald, working for the U.S. Geological Survey on the northwest part of the Pawhuska Quadrangle and using the unpublished notes of Carl D. Smith, restudied the Pawhuska Limestone, mostly north of the type area. His work (Heald, 1918a) included a generalized section of the Pawhuska Limestone (p. 61) and a discussion and more-detailed measured section (p. 66–68), giving a thickness of 130–180 feet with the Lecompton Limestone near the base and a red lime at the top, extending the upper boundary higher than that of Adams and others (1903). Heald did not mention the government quarry and did not give a measured section there. His generalized section (1918a, fig. 22, p. 61), beginning about 150 feet above the top of his Pawhuska and extending downward to the Elgin Sandstone, is:

	Thickness in feet	*(Probable equivalent)*
Cryptozoon-bearing limestone	2–6	(Wakarusa)
Sandstone, limestone, and shale	14–28	
Limestone	2–5	(Bird Creek)
Shale	23	
Yellow limestone	2	
Unconformity through overlying 4 beds		
Sandstone, limestone, and shale	15+	
Limestone in two beds	3	(Turkey Run)
Sandstone and shale, some limestone lentils	80+	
Pawhuska limestone:		
Limestone, "red lime"	2–5	(Pearsonia)
Shale and thin limestone	15–18	
Gray limestone	5–10	
Shale and thin limestone	15–20	
Limestone	5–10	
Shale and thin limestone	25–30	
Limestone	2	
Shale	5	
Limestone	2	
Shale	15	
Limestone	1	
Shale	10	
Lecompton limestone member	6–14	
Shale and thin sandstone	20–35	
Elgin sandstone:		
Sandstone, some limestone lentils, and shale	125–135	

Heald's (1918a) discussion of the Pawhuska Limestone is as follows:

> The Pawhuska limestone as here defined (see fig. 22) is made up of a series of limestone beds separated by shale with some associated lenses of sandstone, the whole

resting on the Elgin sandstone, and in places attaining a thickness of approximately 130 to 180 feet. Except in the highest and lowest beds, the appearance of the outcrops and the physical character of the several limestones are very similar, so that it is usually impossible to say at what horizon in the succession any particular outcrop belongs, unless its position with respect to the highest or lowest bed in the series can be determined. Usually any limestone occurring in this interval has been called "Pawhuska limestone," but the limestone exposed at the town of Pawhuska is believed to occur in the middle of the succession. The formation as here delimited was called in the field the "red lime" because in some places it has a conspicuous outcrop of a rust-red color. Outcrops similar in color were observed in the *Cryptozoon*-bearing limestone and in the Lecompton limestone member, near the base (see fig. 22), so this color is not in itself a reliable criterion upon which to base the identification of the "red lime." However, the prominent rust-red color is present in comparatively few places, and elsewhere the colors of the weathered and fresh surfaces are distinct from those of the underlying limestones. The most frequently observed color of the weathered surface of the "red lime" is a distinctive brownish gray; that of the fresh surface a blue gray with a reddish tinge. The greatest observed thickness of this bed was 7 feet, but the maximum thickness may be considerably greater, as the base of the bed is in most places concealed. In fact, as a rule, the bed does not appear as a ledge, but instead as a line of disconnected fragments of float. The rock is very hard and brittle and splits with a sharp, clean fracture under a heavy blow. The bedding is massive, and fragments of float may be of considerable size and are characteristically of irregular form. The distribution of fossils in this bed is far from uniform. At one point the rock may be full of invertebrate remains; at another there may be scarcely a trace of life. Above the "red lime" (the topmost bed of the Pawhuska limestone) is a series of sandstones. About 20 feet below it are the light gray limestone beds that make up the greater part of the thickness of the Pawhuska limestone. This 20-foot interval is in places entirely occupied by shale, but much more commonly it also contains sandstone which is indistinguishable in color and texture from that overlying the "red lime." A very thin limestone, so full of fossil *Fusulina* as to resemble a layer of dirty-yellowish rice, is also present in places, and is extremely helpful as a horizon marker. Below the sandstone and shale just described, there is a succession of limestones and shales with lenses of sandstone. The limestones are prominent, and by their resistance to erosion have produced terraced hill slopes on which each terrace is rimmed by a line of gray limestone float. The thickness of the beds varies from place to place, and it does not seem probable that any single bed is continuous throughout the region. The limestones are light gray on both weathered and fresh surfaces, hard, and tough. They are abundantly fossiliferous in some places, but show almost no trace of fossils in others. The bedding is massive. The light-gray surface is blotched with cinnamon-brown, and in the blotches, fossils, particularly *Fusulina*, appears to be more abundant than elsewhere in the beds. The lowest limestone in the Pawhuska formation is characterized by many large corals (*Campophyllum torquium*) which are very abundant in this bed at many localities, and which were not noticed in any of the other beds. This limestone is the Lecompton of Kansas. The shales between the limestones are so covered by soil and vegetation that their character is difficult to determine. With one exception, they appear to be greenish-gray and are more or less sandy. The exception is the bed which immediately overlies the Lecompton limestone, and which therefore presumably corresponds to the Tecumseh shale of Kansas. This shale is red on both weathered and fresh surfaces, and the color is evident in many localities in spite of the cover of soil and grass. No fossils were observed in this shale, except in one locality where it contained many beautifully preserved specimens of *Campophyllum torquium*. The following is a complete section of the Pawhuska limestone:

Section of Pawhuska limestone near the center of sec. 31, T. 29 N., R. 9E.:

	Thickness in feet
Limestone, reddish brown on both weathered and fresh surfaces, extremely hard, fossiliferous	10
Shale, gray; has some thin beds of gray sandstone	15
Limestone, light gray on both weathered and fresh surfaces, massive, fossiliferous; weathers rough	6+
Concealed	11
Thin limestone	1+
Concealed	6
Limestone. Lower part of exposure has light-gray weathered surface with cinnamon-brown blotches and some hematite-red markings; fossiliferous (*Fusulina* and crinoid stems). Top bed has dirty-gray weathered surface and dark-gray to brownish-blue fresh surface	10+
Concealed	21
Limestone, light gray with cinnamon-brown blotches on weathered surface, fossiliferous (*Fusulina*, crinoid stems, etc.)	2+
Concealed	17
Limestone, impure	1
Shale, red at top, concealed at base	11
Limestone, Lecompton member, light gray on weathered and fresh surfaces, massive, fossiliferous (corals)	6+
Shale, red, with lenticle of white thin-bedded sandstone	22

Elgin sandstone (reddish brown, fine grained, massive).

It is important to note that the only formal name used by Heald in the entire sequence was the name Lecompton limestone, including the beds 150 feet above the Pawhuska.

In 1917 and 1918, Heald continued his studies of Osage County assisted by many others, including Charles Franklin Bowen, Kirtley Fletcher Mather, and Dean Eddy Winchester. They studied individual townships and published the results in U.S. Geological Survey Bulletin 686 in 26 parts, the Pawhuska being treated mainly in parts C, E, F, M, Q, and R (Bowen, 1918; Heald, 1918a–c; Heald and Mather, 1918a,b; Winchester, 1918). They recognized that the true Pawhuska limestone was the same as the Deer Creek limestone of Kansas, but continued to use the broader definition for the Pawhuska, following Heald's previous definition of 1916–1918. They introduced five new names of limestones: Bird Creek, Turkey Run, Little Hominy, Plummer, and Okay, the latter three being included in their Pawhuska, with the Little Hominy being below the "red lime" and above the Deer Creek, the Plummer below the Deer Creek and above the Lecompton, and the Okay below the Lecompton and above the Elgin Sandstone. They correlated the Little Hominy with the Howard or Topeka Limestone of Kansas. Heald and Mather (1918a, p. 149–170) studied T. 25 N., R. 8 E., but did not mention the government quarry and did not give a section in that quarry area, although they recognized that the original Pawhuska Limestone is what they correlated as Deer Creek Limestone in this township. A generalized section is shown for the middle part of the township (Heald and Mather, 1918a, fig. 26, p. 150; Fig. 3 herein), with a thickness of about 140

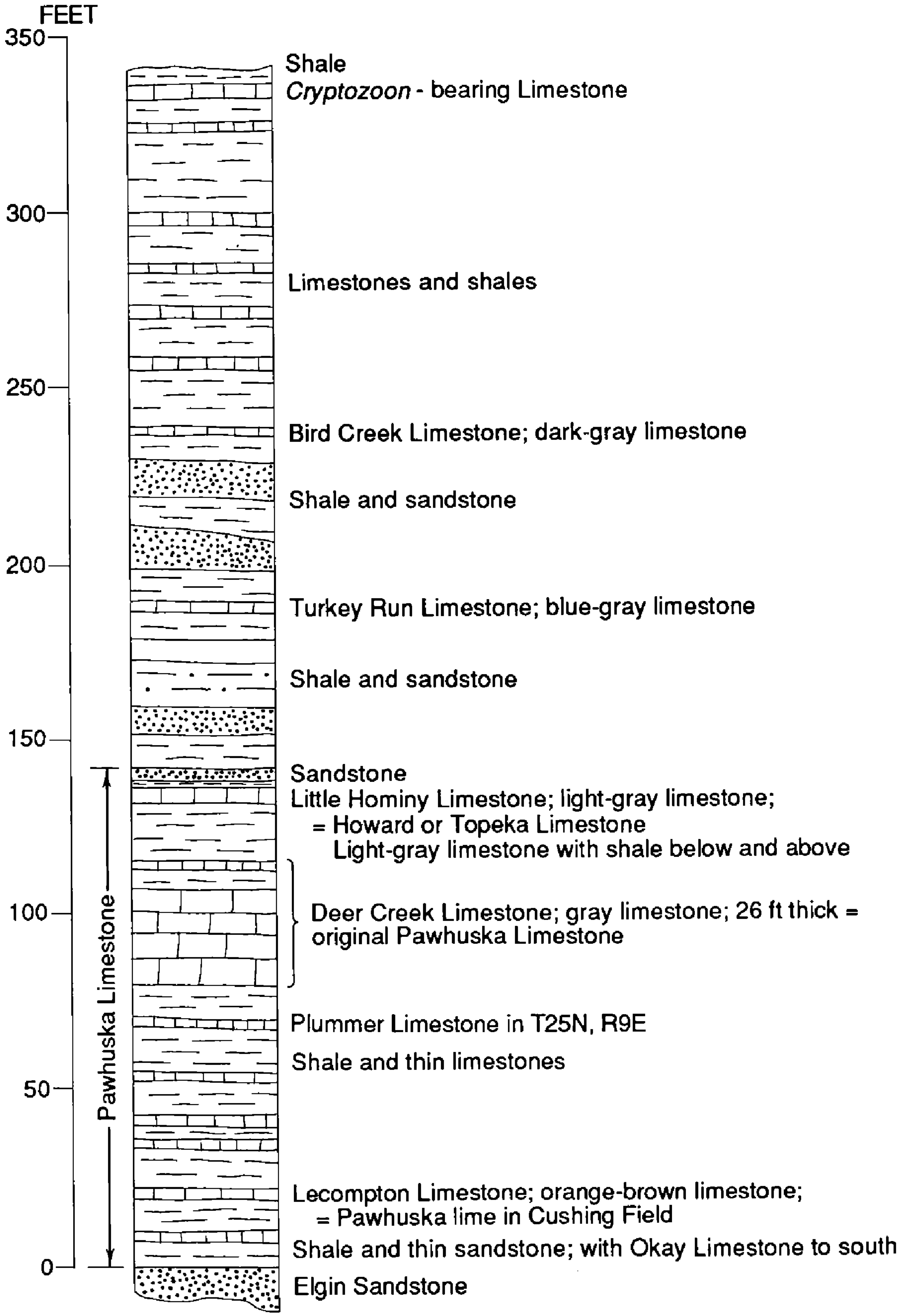


Figure 3. Measured section west of Pawhuska, by Heald and Mather (1918a).

feet for their Pawhuska. Snider (1920, p. 83) and Gould (1925, p. 78) followed Heald's work.

Beckwith (1928, p. 19–21) summarized much of the previous knowledge of the Pawhuska Limestone, recognizing the type area to be west of Pawhuska, and that the Deer Creek Limestone, as correlated by Heald and others, is the original Pawhuska Limestone. Beckwith correlated the "red lime" at the top with the Howard Limestone of Kansas, differing from Heald, who correlated the Little Hominy Limestone with the Howard Limestone. Beckwith did not mention the government quarry and did not present a measured section at that quarry.

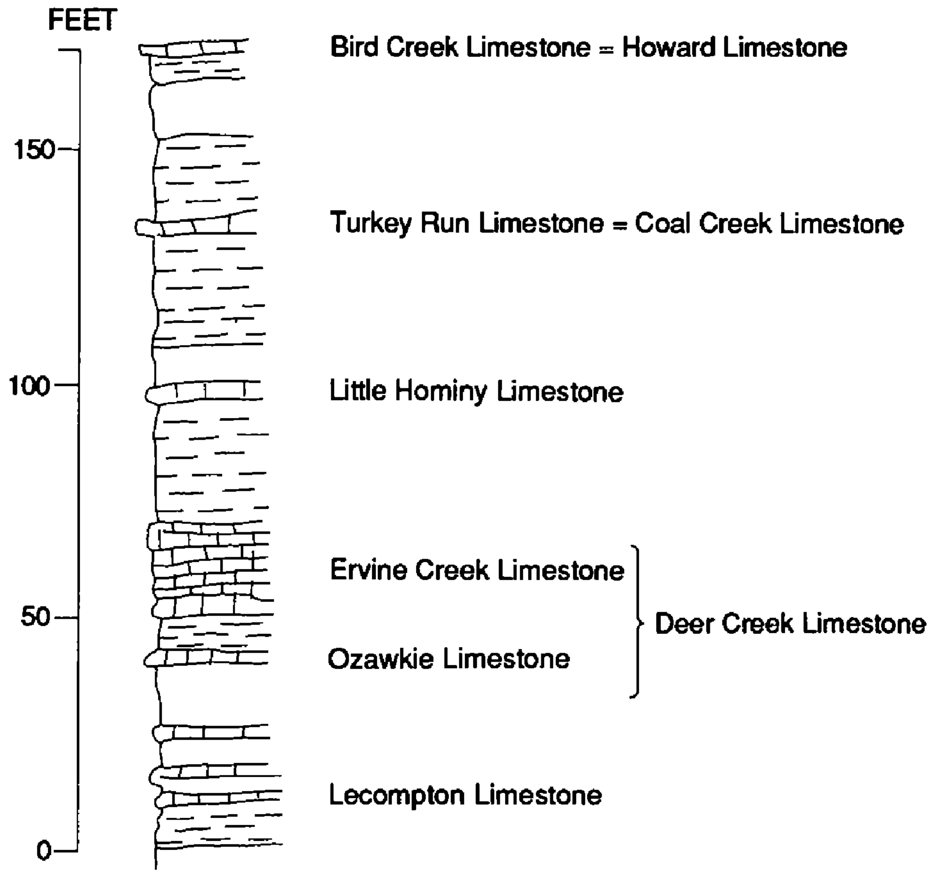
Moore and others (1937, p. 67, 75) showed correlated sections into the area west of Pawhuska, making a Stop 34 at the type Pawhuska Limestone in what appears to be sec. 2, T. 25 N., R. 8 E., or possibly sec. 11. No mention is made of the government quarry, but a measured section is given at the quarry. The description at Stop 34 is as follows:

> **Deer Creek limestone.** This is the type locality of the original Pawhuska limestone (J. P. Smith, 1892 [1894], who mentions work in this area by Herbert C. Hoover). Application of the term Pawhuska was extended by K. C. Heald to include all of the Shawnee beds above the Elgin sandstone. The Deer Creek at this place contains abundant fusulinids. Note occurrence of the dense, blue Rock Bluff limestone member, separated by black shale from the main quarry ledge, which is in the Ervine Creek limestone member. The accompanying sections of the Pawhuska group by A. N. Murray show the succession of beds and their correlation as studied by him. See graphic sections accompanying Stop 38 for measured section by R. C. Moore at this place, 3 miles west of Pawhuska.

The mileage is given as 3.7 miles west of railroad crossing in Pawhuska, on U.S. Highway 60, but the measured section is given incorrectly as sec. 6 instead of sec. 2, T. 25 N., R. 8 E. No mention is made of the Plummer Limestone. The section on the left is after Murray (in Moore and others, 1937, fig. 22, p. 67), and the section on the right is after Moore and others (1937, fig. 25, p. 75; Fig. 4 herein).

In March 1940, Mr. C. L. Ellis of the Osage Indian Agency at Pawhuska sent in a limestone sample from the quarry operated by Osage County in the SE¼ sec. 2, T. 25 N., R. 8 E. (Sheet No. 0321 of Oklahoma Geological Survey Laboratory Sample No. 8249, analysis by S. G. English, March 26, 1940). This was the first time that the Pawhuska quarry was located in detail.

Patrick Joseph Shannon (1954) completed his thesis on the geology of the Pawhuska area, giving locations of two quarries west of Pawhuska: one in the SE¼SW¼SE¼ sec. 2, T. 25 N., R. 8 E., and the other in the NE¼NE¼NE¼ sec. 11, T. 25 N., R. 8 E. His Pawhuska Formation extended from the base of the Lecompton Limestone to the top of the Turkey Run Limestone, being about 155 feet thick in T. 25 N. He recognized that the type Pawhuska Limestone of Smith (1894) is now the Ervine Creek Limestone Member of the Deer Creek Limestone, and that the underlying Plummer Limestone probably correlates with the upper Lecompton Limestone and was not included in the original type Pawhuska Limestone. He mapped and discussed each unit of the Pawhuska. His general section from the Wakarusa Limestone to the top of the Elgin Sandstone in T. 25 N. is shown in Figure 5.



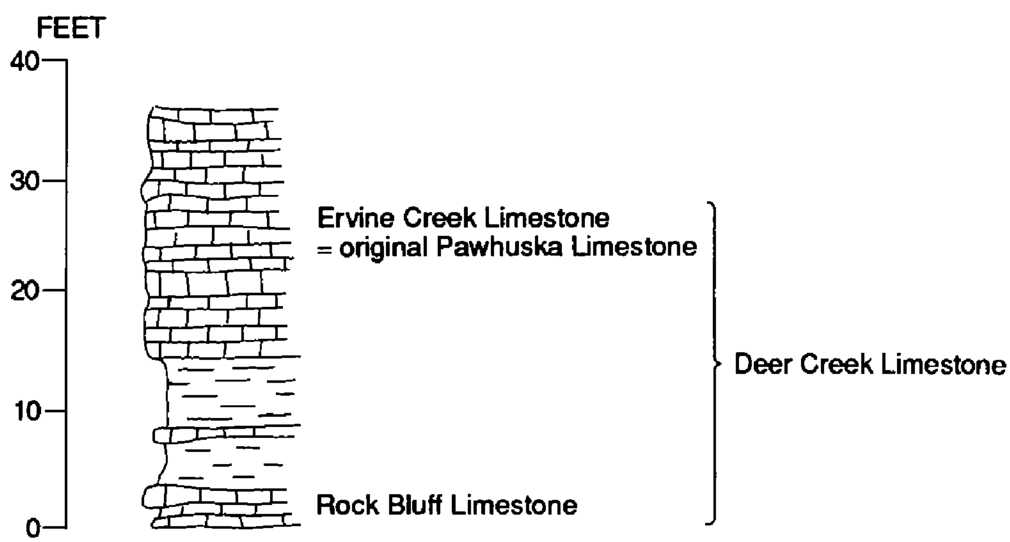


Figure 4. Measured section west of Pawhuska, by Moore and others (1937) and Murray in Moore and others (1937).

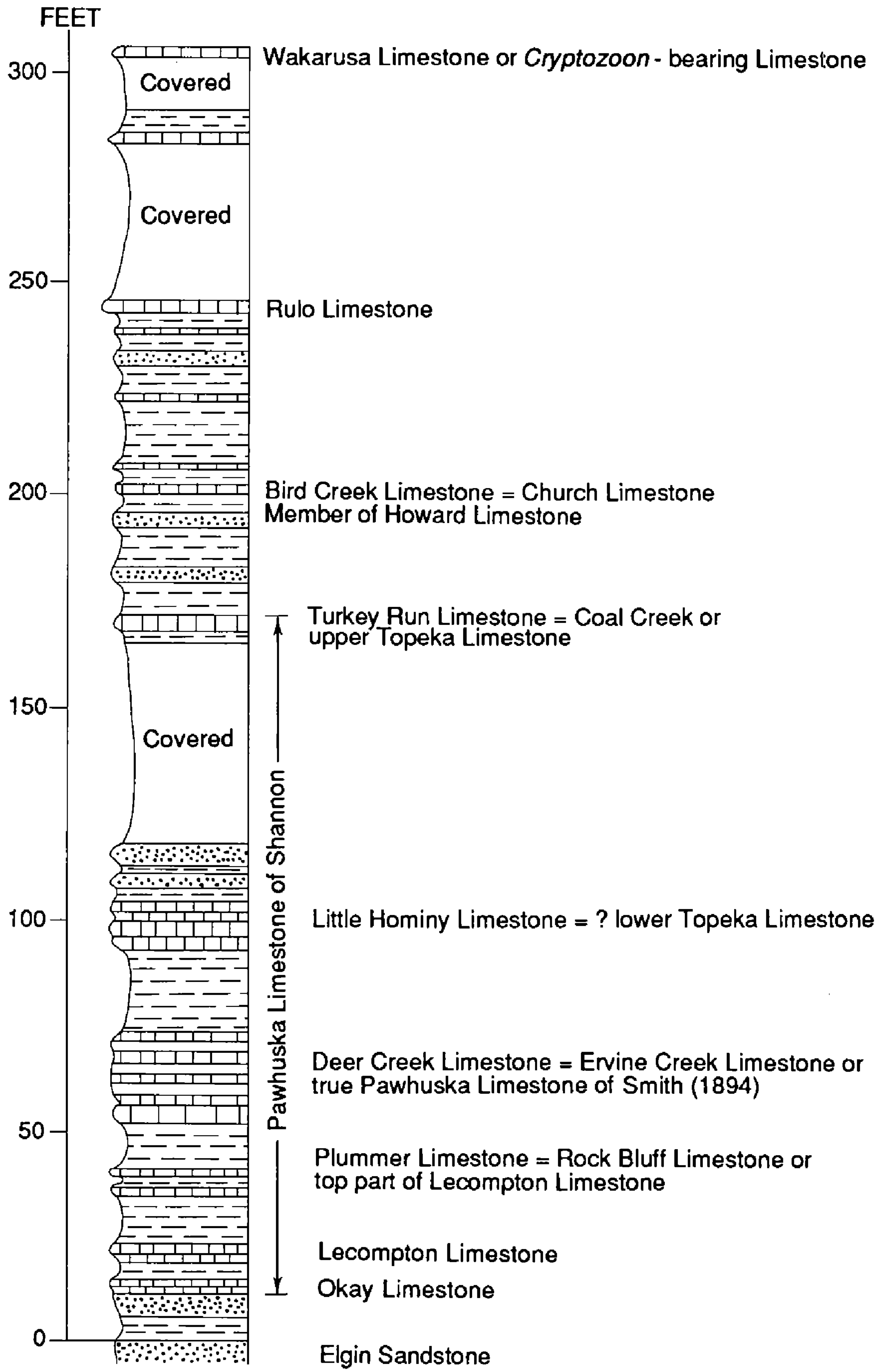


Figure 5. Measured section west of Pawhuska, by Shannon (1954).

As previously mentioned, Shannon (1954, p. 37) located two abandoned quarries west of Pawhuska, on the east side of the ravine leading to Lake Pawhuska: one being north of U.S. Highway 60, west of the airport, in SE¼ sec. 2, T. 25 N., R. 8 E., and a larger quarry south of the highway in NE¼ sec. 11, T. 25 N., R. 8 E. His descriptions of the rocks in these quarries are as follows (p. 90–91):

Measured section in abandoned quarry in NE¼ sec. 11, T. 25 N., R. 8 E.

	Thickness in feet
Deer Creek Limestone:	
Limestone, thin-bedded, light gray, dense, brittle, grading to conglomerate at top. Contains brown, softer fusulinid-bearing layers	8.0
Limestone, brownish-gray, fine-grained, dense, fossiliferous. Occasional channels cutting through bed, filled with fusulinids and fragments of other fossils in black, shaly matrix. Even-bedded	4.0
Limestone, thin, irregular bedding, light brownish gray, fine-grained, dense. Most fossiliferous layer in member. Some layers are almost solid fusulinids, also brachiopods, corals, and others	2.5
Limestone, light gray, fine-grained, dense, brittle, fossiliferous, fusulinid. Topped by bituminous, light brown layers	1.0
Limestone, massive bed, dark gray, medium-grained, dense, few fossils. Main escarpment-former in member	4.0
Total	19.5

Measured section in abandoned quarry in SE¼ sec. 2, T. 25 N., R. 8 E.

Deer Creek Limestone:	
Limestone, not described	14.5
Covered interval	11.5
Shale, black, fissile, fossiferous. Abundant corals, clams, gastropods, cephalopods. Numerous small, dark blue concretions	4.7
Plummer Limestone:	
Limestone, gray, fine-grained, dense, massive bed cut by vertical joints. Fossiliferous, traces show on surface. Weathers brown to orange. Very difficult to break	0.8
Lecompton Limestone:	
Shale, buff, nodular	1.2
Limestone, brown, coarse-grained, soft. Topped by layer of fusulinids. Doubtful position. Not measured.	

Shannon (1954, p. 39–40) mentioned that the quarries are good fossil collecting localities, having found cryptozoons, *Triticites* sp., the coral *Aulopora prosseri* Beede, the brachiopods *Composita subtilita* (Hall), *Dictyoclostus americanus* (Dunbar and Condra), *Linoproductus prattenianus* (Norwood and Pratten), *Neospirifer dunbari* King, and the cephalopod *Mooreoceras tuba* (Girty), from the Deer Creek Limestone. Shannon did not state which quarry was the type locality for Hoover's Pawhuska limestone, and it is possible that both quarries were opened about the same time. His map of this area is shown in Figure 6.

The Bluestem Lake Quadrangle map (U.S. Geological Survey, 1973), covering the area west of Pawhuska, shows a major quarry in the NW¼NW¼NW¼ sec. 12, T. 25 N., R. 8 E., with possible extension in the NE¼NE¼NE¼ sec. 11, T. 25 N., R. 8 E., and a depression and several lakes in the SE¼ sec. 2, T. 25 N., R. 8 E.

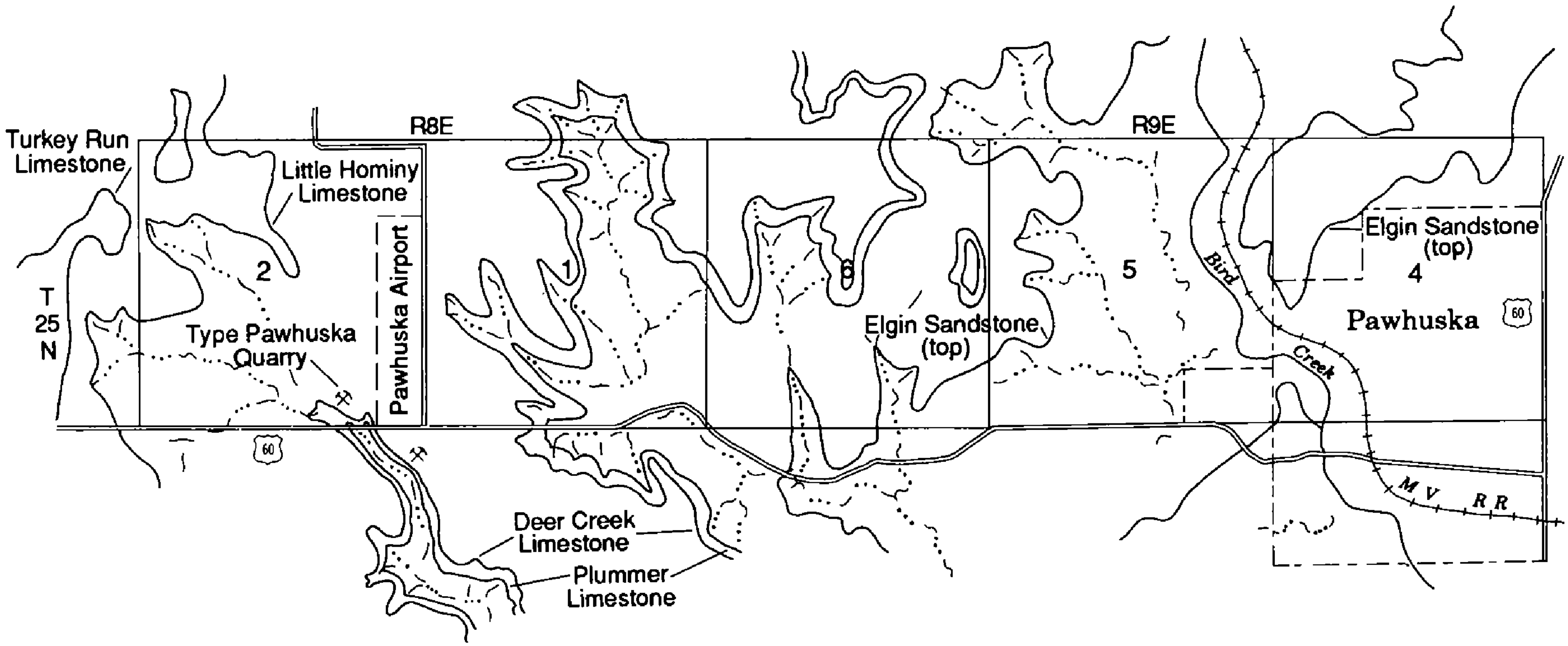


Figure 6. Geologic map of Pawhuska area and region west, by Shannon (1954).

Bellis and Rowland (1976, p. 34) measured a section in the Sedan Limestone Co. or Blake Stone Co. quarry in secs. 11 and 12, T. 25 N., R. 8 E., showing 23 feet of limestone on top of 4 feet of dolomite, termed Deer Creek–Lecompton limestone, the majority of the rock being algal mudstone. They showed a picture of the abandoned portion of the quarry (p. 37) and mentioned that the limestone portion was more than 95% $CaCO_3$, marginal for chemical-grade stone. They did not discuss the previous history of the quarry owners.

In conclusion, the type Pawhuska Limestone of Hoover (unpublished manuscript, 1892) was probably the rock exposed in the quarry in sec. 2, T. 25 N., R. 8 E., possibly in part of sec. 11, T. 25 N., R. 8 E., about 15–27 feet thick, correlated with the Ervine Creek Limestone of Kansas. Much additional work is needed in Kansas and Oklahoma concerning correct correlations of the Pawhuska and equivalent units.

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SPECIAL PUBLICATION 90-2. *Lithostratigraphy and Core-Drilling, Upper Atoka Formation through Lower Senora Formation (Pennsylvanian), Northeastern Oklahoma Shelf Area,* by LeRoy A. Hemish. 54 pages. Price $8.

Excerpts from author's text:

New knowledge of the strata between the upper part of the Atoka Formation and the lower part of the Senora Formation has resulted from a core-drilling project completed by the Oklahoma Geological Survey during 1988. Ten core-holes, ranging in depth from 150 ft to 441 ft, were drilled in the northeastern Oklahoma shelf, in an area extending from southern Muskogee County on the south to northern Craig County on the north.

A cross section, incorporating logs of the 10 core-holes, shows that seven coal beds observed in the northern shelf area can be correlated with coals named either in the southern shelf area or the Arkoma basin. The coal beds are all in the McAlester and Savanna Formations; from oldest to youngest, they are the Keefton, McAlester (Stigler), Upper McAlester (Stigler rider), Tamaha, Keota, Spaniard, and Sam Creek coals. None of these coal beds is known to have economic importance in the shelf area.

Several problems in stratigraphic nomenclature have developed among the states of Kansas, Missouri, and Oklahoma as the result of a subsurface study in Kansas; the problems apparently originated primarily from earlier miscorrelation of the Bluejacket Sandstone.

The primary purposes of the project were (1) to gather information concerning the geologic characteristics of the coal beds and associated strata in the stratigraphic interval from the Atoka Formation to the lower part of the Senora Formation; (2) to trace named lithostratigraphic units from their type areas in the shelf area from the Arkoma basin on the south to the Kansas state line on the north; (3) to correlate several previously unidentified coal beds in the Atoka–Senora interval; (4) to establish reliable thickness data for several formations in an area where south-to-north thinning, although known to occur, had not been well measured; (5) to establish depths to the post-Mississippian erosion surface, where rig capability permitted; and (6) to provide cores for public use from a stratigraphic interval which is poorly known owing to a paucity of good surface exposures.

Presentation of the logs of the 10 core-holes drilled by the OGS in 1988 for this project is intended to supplement an earlier report of core-drilling by OGS in the northeastern Oklahoma coal belt. Logs of 85 core-holes drilled during 1983–86 were presented in that report [OGS Special Publication 88-2].

SPECIAL PUBLICATION 90-4. *Bibliography and Index of Oklahoma Geology, 1981–84,* compiled by Elizabeth A. Ham. 93 pages. Price: $4.

The bibliography contains 1,180 entries that include journal articles, books and book chapters, theses and dissertations, maps, abstracts, and open-file reports on

Oklahoma geology. Most of the items listed were issued in 1981 through 1984, although a few entries have been retrieved from previous years.

The entries are indexed in detail under such categories as localities covered, geologic time periods, geologic provinces, and subdisciplines such as structural geology, geophysics, hydrology, stratigraphy, sedimentology, paleontology, and environmental geology.

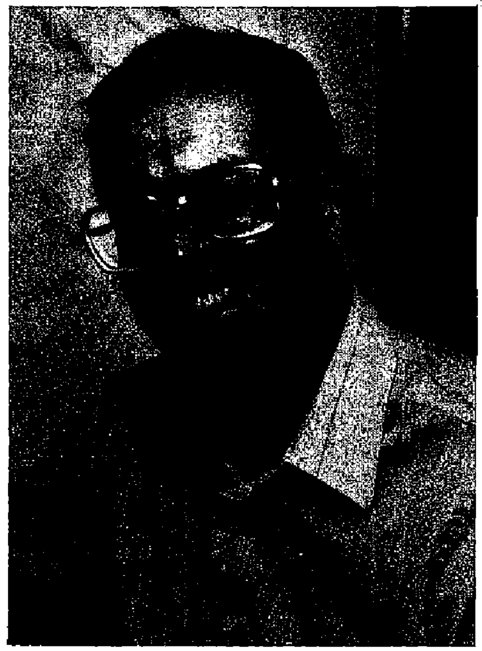
Since 1955 a bibliography has been issued by the Survey for those seeking information on the geology of Oklahoma and Oklahoma's earth resources. Previous versions have appeared in *Oklahoma Geology Notes*. The 1980 bibliography was published separately as OGS Special Publication 82-2. Listings covering the period 1955 through 1979 were combined in a two-volume set released as SP 81-5.

GEOLOGIC MAPS OF THE PANOLA, WILBURTON, AND RED OAK QUADRANGLES, LATIMER COUNTY, OKLAHOMA, by LeRoy A. Hemish, Neil H. Suneson, and Charles A. Ferguson. Scale 1:24,000. Ozalid copies. Price: $6 each.

The Ouachita COGEOMAP Project is a joint effort of the U.S. Geological Survey, Oklahoma Geological Survey, and Arkansas Geological Commission to prepare a series of new geologic maps of the Ouachita Mountains in Oklahoma and Arkansas. The project includes review and compilation of existing information and maps on the Ouachita Mountains, and new geologic mapping at a scale of 1:24,000 (7.5′ topographic base). The purpose of the mapping is threefold: The new maps should provide a basis for (1) resource exploration and development, (2) land-use planning such as highway construction, and (3) university field trips and future theses.

Based on existing geologic maps and resource interest and potential, the Oklahoma Geological Survey elected to focus its mapping effort on a west-to-east strip of 7.5′ quadrangles starting immediately southeast of Hartshorne, Oklahoma, and ending at the Arkansas state line. The mapping effort was designed to begin where the excellent geologic map by Hendricks and others (1947) ended, and to include all the area within the quadrangles south of the Choctaw fault. Later, it was decided to map those parts of the Arkoma basin affected by Ouachita tectonics and included in quadrangles that contain the Choctaw fault. Mapping began in 1986 and is continuing. The first three maps (Higgins, Damon, and Baker Mountain) were released in 1989. The Panola, Wilburton, and Red Oak Quadrangles are now available as black-and-white, author-prepared ozalids, comprising geologic map, cross sections, description and correlation of units, and list of wells.

SP 90-2, SP 90-4, and COGEOMAP geologic quadrangle maps of the Ouachita Mountains can be purchased over the counter or by mail from the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031. Add 10% to the cost of publication(s) for mail orders, with a minimum of 50¢ per order.



M. Charles Gilbert

GILBERT APPOINTED HEAD OF OU SCHOOL OF GEOLOGY AND GEOPHYSICS

M. Charles Gilbert, a native of Lawton who received two degrees in geology from the University of Oklahoma, has been appointed the new director of the OU School of Geology and Geophysics.

Gilbert comes to OU from Texas A&M University, where he has been a professor of petrology since 1983, serving two of those years as head of the department of geology. Prior to that, he was on the faculty of the Virginia Polytechnic Institute and State University for 15 years, including five years as chairman of the department of geological sciences. He also spent three of the seven years at Texas A&M as a geoscientist with the Office of Basic Energy Sciences, U.S. Department of Energy, and has been a frequent visiting geologist at the Oklahoma Geological Survey.

"We're very pleased to have someone with the scientific background and administrative experience that Gilbert has," said James F. Kimpel, dean of the College of Geosciences. "The faculty, alumni and search committee were unanimous in identifying Gilbert as the ideal candidate for the job. He will be teaching, doing research and leading the school in a time of expansion."

The School of Geology and Geophysics is one of three academic programs that make up the College of Geosciences and form the core of OU's $47 million Energy Center. The school has long been a prominent player in the training of exploration geogists for the energy industry, and recently has achieved national and international prominence for its geochemical research programs.

Gilbert received his bachelor's degree in 1958 and his master's degree in 1961 from OU, where he was a member of Phi Beta Kappa and Omicron Delta Kappa honor societies. He then earned his doctoral degree at the University of California at Los Angeles. He did postdoctoral work in experimental mineralogy and petrology in the Geophysical Laboratory at the Carnegie Institute of Washington.

One of Gilbert's areas of research has been the geology and petrology of the Wichita Mountains Igneous Province in Oklahoma, for which he has edited two OGS guidebooks on the subject, Guidebook 21—*Geology of the Eastern Wichita Mountains, Southwestern Oklahoma*, and Guidebook 23—*Petrology of the Cambrian Wichita Mountains Igneous Suite*. Gilbert's other research interests include magmatism and process of continental rifting, stability relations of pyroxenes and amphiboles, the interaction of sulfides with amphiboles and mica in ore deposits and in metamorphic terranes, and selected problems in Virginia geology.

He has published extensively and, since 1982, has been a consulting geology editor for McGraw-Hill Yearbooks of Science and Technology. Gilbert is a Fellow of the Mineralogical Society of America and of the Geological Society of America, and a member of the Mineralogical Society of Great Britain, the American Geophysical Union, American Association of Petroleum Geologists, and Sigma Xi.

OKLAHOMA CITY GEOLOGICAL SOCIETY ANNOUNCES NEW OFFICERS

Officers of the Oklahoma City Geological Society for the 1990–91 term are:

President: Kathy Gentry, Consultant
President Elect: Steve D. Bridges, Consultant
Past President: William S. Boyd, Latigo Oil and Gas, Inc.
Vice President: Thomas E. Davis, Viersen and Cockran
Treasurer: Dan Kennedy, Consultant
Secretary: Mark D. Orgren, Southwest Energy Production Co.
Library Director: Stewart Kirk, Triump Investments, Inc.
Shale Shaker Editor: Robin Buckner Price, Dwight's Energy Data, Inc.
Social Chairman: Karen Bellis Axtmann, First Seismic Corp.
Public Relations: Michael W. Schmidt, Oklahoma Corporation Commission
AAPG Delegate: Kathy Lippert, Southwest Energy Production Co.

Major Geohydrologic Units in and Adjacent to the Ozark Plateaus Province, Missouri, Arkansas, Kansas, and Oklahoma; Ozark Aquifer

The Ozark Aquifer, which crops out throughout a large area of the Ozark Plateaus Province, is defined and the geologic units that comprise the aquifer are identified. J. L. Imes prepared this USGS hydrologic investigations atlas at a scale of 1:750,000 (1 in. =~12 mi). Latitude about 35° to about 39°, longitude about 90° to about 96°. Three color sheets measure 34 × 41 in. each. Maps showing the altitude of the top of the aquifer and thickness of the aquifer are presented. A map of the predevelopment potentiometric surface of the aquifer shows water levels are controlled by topography in the extensive outcrop area, but the aquifer is confined in the western part of the province.

Order HA 0711-E from: U.S. Geological Survey, Map Distribution, Federal Center, Box 25286, Denver, CO 80225. The price is $7.20. (A $1 postage and handling charge is applicable on orders of less than $10.)

Major Geohydrologic Units in and Adjacent to the Ozark Plateaus Province, Missouri, Arkansas, Kansas, and Oklahoma; Western Interior Plains Confining System

The geologic units that comprise the confining system adjacent to the Ozark Plateaus Province are identified. J. L. Imes prepared this hydrologic investigations atlas at a scale of 1:750,000 (1 in. = ~12 mi). Latitude 34°30′ to about 39°, longitude 89° to about 96°. Three color sheets measure 41 × 35 in. each. Maps showing the altitude of the top and thickness of the confining system are presented. Ground water can flow laterally in more-permeable layers within the confining system. The predevelopment potentiometric surface of the near-surface weathered layer of the confining system near the province is controlled by topography.

Order HA 0711-H from: U.S. Geological Survey, Map Distribution, Federal Center, Box 25286, Denver, CO 80225. The price is $10.80.

Water Resources Data—Oklahoma, Water Year 1987

Records on surface water in Oklahoma are contained in this 324-page report by L. D. Hauth, D. M. Walters, T. E. Coffey, and D. K. White. Specifically, it includes (1) discharge records for 123 streamflow-gaging stations and five partial-record or miscellaneous streamflow stations, (2) state and content records for 30 lakes and reservoirs, and (3) water-quality records for 38 streamflow-gaging stations and three lakes.

Order USGS Water-Data Report OK-87-1 from: U.S. Geological Survey, Water Resources Division, 215 Dean A. McGee Ave., Room 621, Oklahoma City, OK 73102; phone (405) 231-4256. A limited number of copies are available free of charge.

Annual Yield and Selected Hydrologic Data for the Arkansas River Basin Compact, Arkansas–Oklahoma, 1988 Water Year

M. A. Moore, T. E. Lamb, and L. D. Hauth wrote this 36-page USGS open-file report.

Order OF 89-0054 from: U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225; phone (303) 236-7476. The price is $4 for microfiche and $6 for a paper copy; add 25% to the price for foreign shipment.

Flow Characteristics for Selected Streams in the Great Plains Subregion of the Central Midwest Regional Aquifer System and Selected Adjacent Areas; Kansas and Nebraska, and Parts of Colorado, Iowa, Missouri, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming

In this USGS hydrologic investigations atlas, E. R. Hedman and G. B. Engel provide flow-duration and low-flow frequency data for continuous-record streamflow- and spring-gaging stations. Values of mean annual precipitation (1951–80) and values of mean annual runoff also are presented. The ranges are from 12 to 52 in. for precipitation and from 0.02 to 25 in. for runoff. Three sheets. Lat 34° to about 43°30′, long 94°30′ to 105°. Scale 1:1,000,000 (1 in. = ~16 mi). Sheet 1 is 41 × 49 in.; sheet 2 is 40 × 58 in.; sheet 3 is 41 × 49 in. (all in color).

Order HA 0708 from: U.S. Geological Survey, Map Distribution, Federal Center, Box 25286, Denver, CO 80225. The price is $8.40; add 25% to the price for shipment outside North America. (A $1 postage and handling charge is applicable on orders of less than $10.)

UPCOMING MEETINGS

American Institute of Professional Geologists, Annual Meeting, October 9–12, 1990, Long Beach, California. Information: Stephen Testa, 6695 E. Pacific Coast Highway, Long Beach, CA 90803; (213) 430-6500.

Petroleum Hydrocarbons Conference, October 31–November 2, 1990, Houston, Texas. Information: National Water Well Association, 6375 Riverside Dr., Dublin, OH 43017; (614) 761-1711.

Water Resources, Annual Meeting, November 4–9, 1990, Denver, Colorado. Information: Kenneth Reid, American Water Resources Association, 5410 Grosvenor Lane, Suite 220, Bethesda, MD 20814-2192; (301) 493-8600.

American Geophysical Union, Fall Meeting, December 3–7, 1990, San Francisco, California. Information: AGU, 2000 Florida Ave., N.W., Washington, DC 20009; (202) 462-6900.

OKLAHOMA ABSTRACTS

The Oklahoma Geological Survey thanks the Geological Society of America and the authors for permission to reprint the following abstracts of interest to Oklahoma geologists.

Fusulinid, Conodont and Brachiopod Biostratigraphy of the Morrowan and Atokan Series, Ardmore Basin, Oklahoma

PATRICK K. SUTHERLAND, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019; and ROBERT C. GRAYSON, JR., Dept. of Geology, Baylor University, Waco, TX 76703

New analyses have been made of the distributions of fusulinids, conodonts and brachiopods in the Morrowan and Atokan intervals in the Ardmore basin, southern Oklahoma. These make possible a more refined understanding of boundary placement and intrabasinal stratigraphic relationships. Relatively continuous deposition is recorded in the southern part of the Ardmore basin by the stratigraphic succession that includes the Jolliff, Shale A, Otterville and Shale B members of the Golf Course Formation and the Bostwick, Shale C and Lester members of the Lake Murray Formation.

The above listed faunal groups suggest that the Morrowan–Atokan boundary is located either at the base of the Bostwick or slightly lower, within Shale A. The Atokan–Desmoinesian boundary is not at the base of the Lester, as previously suggested, but rather occurs in the middle-upper part of Shale C.

Reprinted as published in the Geological Society of America *Abstracts with Programs, 1990,* v. 22, no. 1, p. 33.

The Distribution of the Brachiopods *Wellerella* and *Enteletes* in the Lower Permian Wreford Megacyclothem (Nebraska, Kansas, and Oklahoma)

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The Lower Permian Wreford Megacyclothem consists of two partial but typical mid-continent cyclothems. It has been extensively collected for brachiopods, of which two genera, *Wellerella* and *Enteletes*, are being studied at present. Their identification to species is difficult because of the crushed nature of the specimens, but geographic, stratigraphic, and lithologic distribution summaries are possible.

Wellerella is limited both geographically and stratigraphically. It is found in many Wreford localities throughout most of Kansas, but not in the southernmost exposures in Kansas and northern Oklahoma. Stratigraphically it is limited to 5 of 22 horizons, occurring especially in the upper Speiser Shale and the lower Threemile limestone. Rock types containing *Wellerella* are normal marine calcareous shale and cherty limestone, and normal marine but shallower-water brachiopod-molluscan limestone.

Enteletes is somewhat more abundant than *Wellerella*. Geographically, it occurs throughout the Wreford outcrop belt in southern Nebraska and Kansas. It is more common in the lower cyclothem than in the upper one, and is found mostly in the lithologies that represent normal marine environments: calcareous shale, cherty limestone, and chalky limestone. A few *Enteletes* also occur in brachiopod-molluscan and molluscan limestones.

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Conodont Stratigraphy of the Woodford Shale (Late Devonian–Mississippian), Arbuckle Mountains, South-Central Oklahoma

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The Woodford Shale consists of predominantly black blocky to fissile shale, regionally cherty and pyritic. Outcrop thickness is approximately 80 m, however, subsurface thicknesses over 200 m have been reported from the Anadarko Basin. The Woodford lies unconformably over the Hunton Group (Silurian–Lower Devonian) throughout the Arbuckle region. It is overlain by the Sycamore Formation (Meramecian) in the southern outcrop belt, and by the "pre-Welden Shale" (Late Kinderhookian), Welden Limestone (Osagean), or Lower Caney Shale (Meramecian) to the north and east.

In the northern Arbuckles (Lawrence uplift) the basal Woodford consists of glauconitic sand, phosphate nodules and limestone pebbles in a green-brown shale matrix. The green shale yields Frasnian conodonts. Black shales lie directly above the basal conglomerate. The lower one to two meters of shale contains numerous conodont molds. Within the basal 20 cm of shale *Ancryodella lobata, Palmatolepis hassi, Pa.* cf. *proversa*, and *Pa. subrecta* occur. The Frasnian–Famennian boundary is located within 1.3 m of the base, indicated by the extinction of *Ancryodella* and appearance of *Pa. subperlobata. Palmatolepis regularis, Pa. minuta minuta, Pa. tenuopunctata,* and *Pa. quadrantinodosalobata* 4.0 m above the base indicate the Upper *crepida* Zone (lower Famennian). Isolated specimens found through the middle of the Woodford include *Pa. perlobata* ssp., *Pa. quadrantinodosa* ssp., and *Pa. glabra* ssp., indicating a middle Famennian age.

Phosphatic shales in the upper 20 m of the Woodford yield a diverse fauna of long ranging species, which includes *Palmatolepis gracilis expansa, Pa. gr. gracilis, Pa. gr. sigmoidalis, Branmehla inornatas, B. disparilis, Bispathodus stabilis, Fun-*

gulodus sp., and *Pseudopolygnathus marburgensis trigonicus,* indicative of the *expansa* to Lower/Middle *praesulcata* Zones. In the Lawrence uplift the Devonian–Carboniferous boundary is disconformable, indicated by the absence of *Siphonodella praesulcata* and species of *Protognathodus* before the first occurrence of *S. sulcata.* The *sulcata,* Lower *duplicata,* and Upper *duplicata* zones are recognized in the upper 1.0 m of the Woodford. The *sandbergi,* Lower *crenulata* and *isosticha*–Upper *crenulata* zones are recognized in the green-brown shales of the overlying "pre-Welden Shale."

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Problems Involving Conodont Biostratigraphy of Midcontinent Sections Presumed to be Complete at the Mississippian–Pennsylvanian Boundary

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The interpretation of the Mississippian–Pennsylvanian boundary as a significant regional unconformity in the southern midcontinent has been challenged during the past decade by reports of continuous deposition in the southern Illinois Basin, western Arkoma Basin, Oklahoma and the Llano region, central Texas. These supposedly continuous sections fall within shale intervals that represent either dark gray, somewhat deeper, marine sequences (Oklahoma and Texas), or near-shore delta or barrier-bay deposition (Illinois).

All three localities yield different conodont assemblages across the boundary sequence. In Illinois, an *Adetognathus unicornis*–*Cavusgnathus naviculus* assemblage characterizes the type Grove Church Shale (Chesterian) and *A. unicornis* extends into the presumed Wayside Shale (Pennsylvanian), where it is succeeded by *Idiognathoids sinuatus.* At Canyon Creek, southern Oklahoma, *A. unicornis* and *C. naviculus* are succeeded by *Declinognathodus noduliferus* in the Rhoda Creek Shale. In the eastern Llano region, Texas, *Gnathodus bilineatus,* without any other typical high Chesterian forms, is succeeded by *D. noduliferus.* Ecologic arguments have been invoked for these differences in conodont occurrences at the boundary, yet in the type Morrowan region, where there is an obvious unconformity at the Mississippian–Pennsylvanian boundary, an *A. unicornis* assemblage (Imo Shale) is succeeded by *Rhachistognathus primus,* followed by *D. noduliferus* (Hale Formation). The *D. noduliferus* assemblage is overlain by that of *I. sinuatus.* Thus, we regard the Llano and Illinois Basin successions as unlikely candidates for continuous deposition. The case for Canyon Creek may have merit, but it requires further study and description.

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Palaeogeographic Significance of Middle Ordovician Ostracodes from Oklahoma, U.S.A.

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During the Ordovician the continents of Laurentia, Baltoscandia, and Avalonia apparently moved together as the intervening lapetus Ocean was consumed. The Middle Ordovician Simpson Group (Whiterockian–Mohawkian) of the Arbuckle Mountains, Oklahoma, contains a prolific and diverse ostracode fauna spanning a time range critical to dating the closure of this ocean. Hitherto the ocean was considered a major faunal barrier to shelf benthic fauna without a planktonic larval stage well into the Silurian.

Taxonomic reappraisal of the Simpson ostracode faunas, and comparison with Middle Ordovician ostracodes from Scandinavia, the Baltic States and Britain, shows that strong faunal links (at least at the generic level) existed between Laurentia, Baltoscandia, and Avalonia by the late Whiterockian.

Biofacies analysis of the faunas shows that faunal links existed between more offshore benthic ostracodes, and presumed nektonic ostracodes first. Along with a host of other geological data the breakdown of ostracode provinciality indicates that the continents fringing the ocean were in relatively close geographical proximity by the Mohawkian.

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The Southern Oklahoma Aulacogen Basin: Its Implications for Middle Ordovician Ostracode Biofacies

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Sediments of the middle Ordovician Simpson Group (Whiterockian–early Mohawkian) of the Arbuckle Mountains, southern Oklahoma, USA, were deposited in the Southern Oklahoma Aulacogen basin and on the adjacent cratonal platform. Sedimentary facies display distinct lateral changes across this basin from nearshore environments on the shelf to deeper water environments below normal wave base in the Aulacogen centre.

The Simpson Group contains one of the most prolific and diverse ostracode faunas known from the North American continent and provides an ideal faunal database from which to examine possible bathymetrically defined ostracode biofacies down a clearly defined palaeoslope. Preliminary studies on the fauna have already identified marked differences between nearshore, prolific but low diversity leperditiid dominated ostracode faunas, and more offshore, high diversity palaeocope rich ostracode faunas.

Continuing taxomonic revision and biostratigraphic studies will clearly define and accurately assess the ranges of the Simpson Group ostracodes. This, combined with the well documented sedimentary evidence from the Simpson Group, will allow a thorough examination of the range of environments occupied by ostracodes during the Ordovician. Ultimately comparisons of revised North American ostracode taxa with recently revised European middle Ordovician taxa will enhance understanding of trans-Iapetus ostracode faunal links and middle Ordovician palaeogeography.

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Remediation and Solidification of Acid Sludge, Stroud, Oklahoma

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Sulfuric acid was used for cleaning crude oil to produce lub oil by many older refineries. Residue from the process was an oily acid sludge comprised of sediment, dirt, water, and sulfuric acid. This sludge was commonly disposed in holding lagoons on refinery property. Because of low pH, less than 1, material is hazardous waste. Closure of such oily sludge lagoons at a refinery near Stroud, Oklahoma, was accomplished by solidification and oil crystallization with high calcium oxide cement kiln dust. Sludge was dug from the ponds, then mixed with kiln dust for drying and oil crystallization. A Bomag mixer was used to premix material at the rate of about 1,000 cubic yards per hour. After mixing, the solidified material was compacted in a double-lined landfill. Daily tests were performed for dry density, unconfined compressive strength and pH. When material was improperly mixed, slope failure occurred which cost the project approximately $100,000 to correct. Total solidified sludge and soil buried was approximately 370,000 cubic yards. Final closure was completed in 1989 after three years of work effort. Project cost was approximately 11 million dollars.

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Geological Assessment of Radon Potential in Oklahoma

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The Oklahoma Geological Survey in cooperation with the Oklahoma State Department of Health evaluated and rated near-surface geologic conditions in Oklahoma for radon potential. Uranium was used as a mappable indicator for radon. The principal Oklahoma uranium occurrences are associated with (1) granite and sediments derived from the erosion of granitic rocks, (2) dark, organic-rich shale, (3) phosphatic black shale, and (4) coal beds.

Analytical data, airborne radiometric surveys, and uranium occurrence were the principal factors used to evaluate the bedrock formations for radon potential. Five radon-potential categories were developed: generally very low, generally low, locally low to moderate, locally moderate, and locally moderate to high. The modifiers generally and locally are used because the rating for a given area may not be uniformly distributed.

Twenty-six areas in the State were outlined, numbered, and assigned a radon potential category. Areas underlain by formations with uranium contents that equal or are less than the crustal average (2.5 ppm) are rated generally very low or generally low. Approximately 75% of the State is included in these two categories.

This study is a reconnaissance-level investigation based on existing geologic literature. The information, report and map are intended to serve as a guide for detailed future investigations. The map scale, limited analytical data, time constraints, and lateral lithologic variations in rock units precluded a site-by-site analysis.

Climate, rock/soil permeability, groundwater saturation and movement, and building construction and usage strongly affect indoor-radon levels. The low-moderate-high radon potential rating scheme only compares the distribution of uranium-bearing rocks from one outlined area to another.

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Seismicity and Neotectonics Along the Southern Midcontinent–Texas Craton Transect

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The Southern Midcontinent–Texas Craton Transect is a 700-km-long line that extends from the Kansas–Oklahoma border (37°N, 98°W) through point 34°N, 99°W to the Llano uplift in south-central Texas (31°N, 99°W). The transect lies west of and subparallel to the Nemaha uplift and crosses the Anadarko basin, Wichita–Amarillo uplift, Hollis–Hardeman basin, and the Red River uplift. The southern part of the transect is west of and parallel to the Bend arch.

More than 250 locatable earthquakes have occurred in a 200-km-wide zone that is centered on the transect. A majority of the known earthquakes (95%) occur along the Oklahoma part of the transect. Almost all the Oklahoma earthquakes have shallow focal depths (5 km) and define areas that are more seismically active. Over half of the earthquakes are associated with two seismic trends. One trend is located in north-central Oklahoma. A 40-km-wide and 145-km-long earthquake zone extends from El Reno (Canadian County) toward Perry (Noble County). Most of the earthquakes within this zone have occurred in the vicinity of the El Reno–Mustang area—the site of numerous earthquakes since 1908. A second seismic trend occurs in a 135-km-long by 40-km-wide zone along the eastern margin of the Anadarko basin. Over 90% of the earthquakes within this zone have taken place since 1977.

Recent investigations document Holocene movement on part of the Meers fault. The Meers fault is part of the Wichita frontal fault system that forms the boundary between the Amarillo–Wichita uplift and the Anadarko basin. No historical or recent earthquake activity is known to have occurred along this segment of the fault system. A few earthquakes have occurred along the Wichita frontal fault system and in the shelf and deep parts of the Anadarko basin.

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Southern Midcontinent–Texas Transect, Lineament Analysis

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The lineament analysis of the transect integrates four principal data sets: field work, published maps, conventional air photo analysis and remote sensing technology. The latter involves surveys of selected areas using Landsat TM data tapes, analysing false-color composite images of TM bands 2, 3 and 4 at a scale of approximately 1:70,000. Multitemporal data have been used to provide both contrasting sun angles and seasonal botanical variations. The areas selected for particular emphasis are: (a) the Llano uplift, (b) the Fort Worth basin, (c) the Hardeman basin, (d) the Wichita uplift/Slick Hills area, (e) the northern flank of the Anadarko basin, (f) the Nemaha ridge.

Completed work in the Wichita/Anadarko area suggests a generally complementary comparison of remotely sensed studies and conventionally aquired data. In general four principal overlapping modes are distinguishable from Landsat data: (i) 135–315 >(ii) 050–230 >(iii) 000–180 >(iv) 090–270. Timing on the various modes is difficult to assess as all modes cut the Permian (youngest rocks in the area) and attest to the overall simplicity of post Cambrian stress systems. Nevertheless it is possible to partially discriminate timing of the various modes. Thus, in general Lower Paleozoic strata are more densely fractured than Permian and less so than the basement. Some fractures are truncated by the two principal unconformities in the area (sub Permian and sub Upper Cambrian). An example of the complexity of timing relationships is provided by the Blue Creek Canyon area where some elements of a prominent north-south fracture trend within the basement of the Wichita uplift are clearly truncated by the overlying Lower Paleozoic unconformity, whereas in the same area fractures with a similar trend cut not just the Lower Paleozoic section but also the Permian. The dominant structural feature in the Anadarko–Wichita area is the Southern Oklahoma aulacogen which trends 120–300. The two dominant fracture modes in the area (135–315 and 050–230) are not orthogonal to this trend. The divergence may be explicable in terms of a stress system which has induced a long lasting pattern of left lateral oblique (transpressive) strain across the aulacogen. The available data are in agreement with independent calculations of strain ellipse patterns obtained from fold and shear belt orientations in the area.

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Crustal Shortening of the Wichita Uplift: Implications for the Southern Midcontinent–Texas Craton Transect

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The northern margin of the Wichita uplift is separated from the adjoining Anadarko basin by reverse faults that dip to the south or southwest. Chang and others (1989) interpreted data for a recent large-aperture seismic experiment to show that these faults are linked to a crustal detachment horizon at approximately 30 km depth. The identification of a zone of mechanical decoupling between the brittle upper crust and ductile lower crust places constraints on attempts to unravel the kinematic history of the uplift.

The Frontal fault zone that marks the structural transition from uplift to basin is made up of basement (upper crust) fault blocks which have undergone rotation and translation on brittle faults. Two assumptions are made concerning Carboniferous deformation of the upper crust: (1) the basement surface was a subplanar, subhorizontal datum prior to uplift; (2) brittle faults separated an interlocking mosaic of basement fault blocks during the uplift. The faults bounding these basement blocks must have geometries that produce the relative rotations of the basement surface recognized from subsurface mapping.

The construction and restoration of crustal-scale cross-sections across the northern margin of the uplift is used to investigate both the geometry of the faults and fault blocks in the Frontal fault zone, and the character of deformation at mid-crustal depths. The northeastward tilt of the basment surface in the southeastern part of the Frontal fault zone indicates a steepening of the principal uplift-bounding fault in the upper crust. The presence of a crustal detachment horizon at 30 km infers that the fault must dip less steeply with increasing depth. This suggests that the major uplift-bounding fault may have a flat-ramp-flat type of geometry.

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Geochemical and Petrographic Analyses of Phosphate Nodules of the Woodford Shale (Upper Devonian–Lower Mississippian)

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Black shales and associated phosphate nodules of the Woodford Shale formation (Upper Devonian–Lower Mississippian) in the Arbuckle and Ouachita Mountains of southern Oklahoma were deposited peripheral to the carbonate shelf adjacent to the North American craton. A deep water environment is inferred from geochemical and petrographic analyses of the shales, cherts, and nodules.

Interbedded shales and cherts have an abundance of siliceous organisms and lack terrestrial detritus and shallow-water fauna. Depletion of Ce in the Woodford shales relative to average shale compositions suggests the influence of deep oceanic water. Carbon isotope composition of shales, cherts, and phosphate nodules for $\delta^{13}C$ range from -27.5 to $-30.2‰$.

Phosphate nodules which occur in the top of the formation are early-diagenetic features that formed in the upper few centimeters of organic-rich sediment in a poorly oxygenated subaqueous environment. They are composed of carbonate-fluorapatite occurring as either primary marine apatite (structureless collophane) or various diagenetic morphologies of apatite (globular, botryoidal, or crystalline apatite). A hierarchy of apatite morphologies is indicative of stages of diagenesis. Apatite crystallites typically associated with silicified nodules represent the most advanced stage of phosphate diagenesis prior to sediment lithification.

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Hydrogeology of a Fine-Grained Alluvial Aquifer

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Detailed studies of a fine-grained alluvial aquifer in north-central Oklahoma have been conducted for more than five years. The field site contains 43 monitoring wells, 8 suction lysimeters, 5 neutron probe access tubes, and a variety of instruments used to measure water-level fluctuations, precipitation, temperature, and barometric pressure.

Infiltration is about one inch per hour, but the effect that the recharge produces on the water table and the chemical quality of ground water is controlled, in large part, by the preceeding soil-moisture content. Water movement through both the unsaturated and saturated zone is by preferred paths and piston flow, the former allowing a high velocity.

Aquifer tests illustrate that the hydraulic conductivity is several orders of magnitude greater than laboratory determinations and visual inspection would suggest.

During dry periods the water table declines about .1 foot per day. The decline is largely the result of transpiration, which does not entirely cease during winter. A major shift in the hydraulic gradient occurs when the water table declines below about 7.5 feet below the surface.

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