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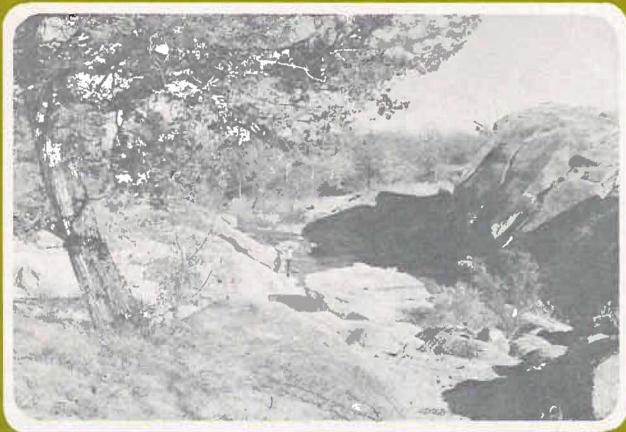

OKLAHOMA GEOLOGY NOTES

VOLUME 29 NUMBER 6 DECEMBER 1969

Cover Picture

Devil's Den in the Arbuckle Mountains

Devil's Den, 4 miles north-northwest of Tishomingo in the E½ sec. 20, T. 3 S., R. 6 E., Johnston County, is a small recreational area in the Arbuckle Mountains where Tishomingo Granite has been deeply incised into a highly rugged landscape. Pennington Creek has eroded the Cretaceous sands and gravels that once blanketed the area and has cut down 50 to 75 feet into granite. The privately owned park provides picnic tables, fireplaces, water, and wood and is open to visitors for a small fee from May 15 to September 15.

The Tishomingo Granite is a coarse-grained porphyry. Subhedral phenocrysts of pink microcline 0.5 to 2.0 inches long make up 35 to 50 percent of the rock and are embedded in a matrix of quartz, plagioclase (An_{12}), and biotite. The Tishomingo Granite is clearly Precambrian; it has been isotopically dated at 1,350 million years from zircon crystals collected at Ten Acre Rock, 5 miles northwest of Devil's Den.

—Kenneth S. Johnson

(Cover photograph courtesy of the Oklahoma Industrial Development and Park Department)

Springs in the Ozark Region, Northeastern Oklahoma*

Roy H. Bingham†

INTRODUCTION

Springs are a large potential source of good quality water in northeastern Oklahoma. Discharge measurements during September and October 1968 show that 26 of the largest springs were flowing about 21 mgd (million gallons per day), an amount sufficient to furnish domestic supplies to a population of about 200,000. Data on the springs were collected during a reconnaissance of the water resources in the Tulsa quadrangle, made by the U. S. Geological Survey in cooperation with the Oklahoma Geological Survey. The quadrangle area and the Ozark Region, where numerous springs are located, are shown in figure 1. Locations of springs tested are shown in table I.

The existence and location of springs in this region depend upon the position of the water table, the topography of the area, and the lithology and structure of the geologic formations. The only geologic features described here are those that are necessary to provide an understanding of the physical framework through which ground water moves.

GEOLOGIC SETTING

The generalized geology of the area (fig. 2) was taken from the geologic map of Oklahoma (Miser, 1954). In this area, part of the Ozark uplift, formations exposed at the surface consist primarily of Mississippian age chert, limestone, and shale. Alluvium and terrace deposits were omitted from the map because they have little relation to springs in the area.

Strata that are essential to the existence of springs include, in ascending order, the Chattanooga Shale (Devonian and Mississippian), the St. Joe Limestone Member of the Boone Formation (Mississippian),‡ and the Reeds Spring and Keokuk Formations (Mississippian), all described by Huffman (1958, p. 38-47). In the northern part of the area, the strata generally dip gently toward the northwest, and in the southern part, they generally dip toward the south and southwest. The area is traversed by a series of northeast-southwest-trending faults, but the relation of the faults to the location of springs is not known.

The springs are more numerous where deep valleys and steep hillsides have been formed by erosion. The Chattanooga Shale crops out in some of the deep valleys and is widely distributed in the

* Publication authorized by the Director, U. S. Geological Survey.

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‡ The Boone Formation is not recognized by the Oklahoma Geological Survey as a formal part of the Oklahoma stratigraphic column and is designated as the "Boone" Formation.

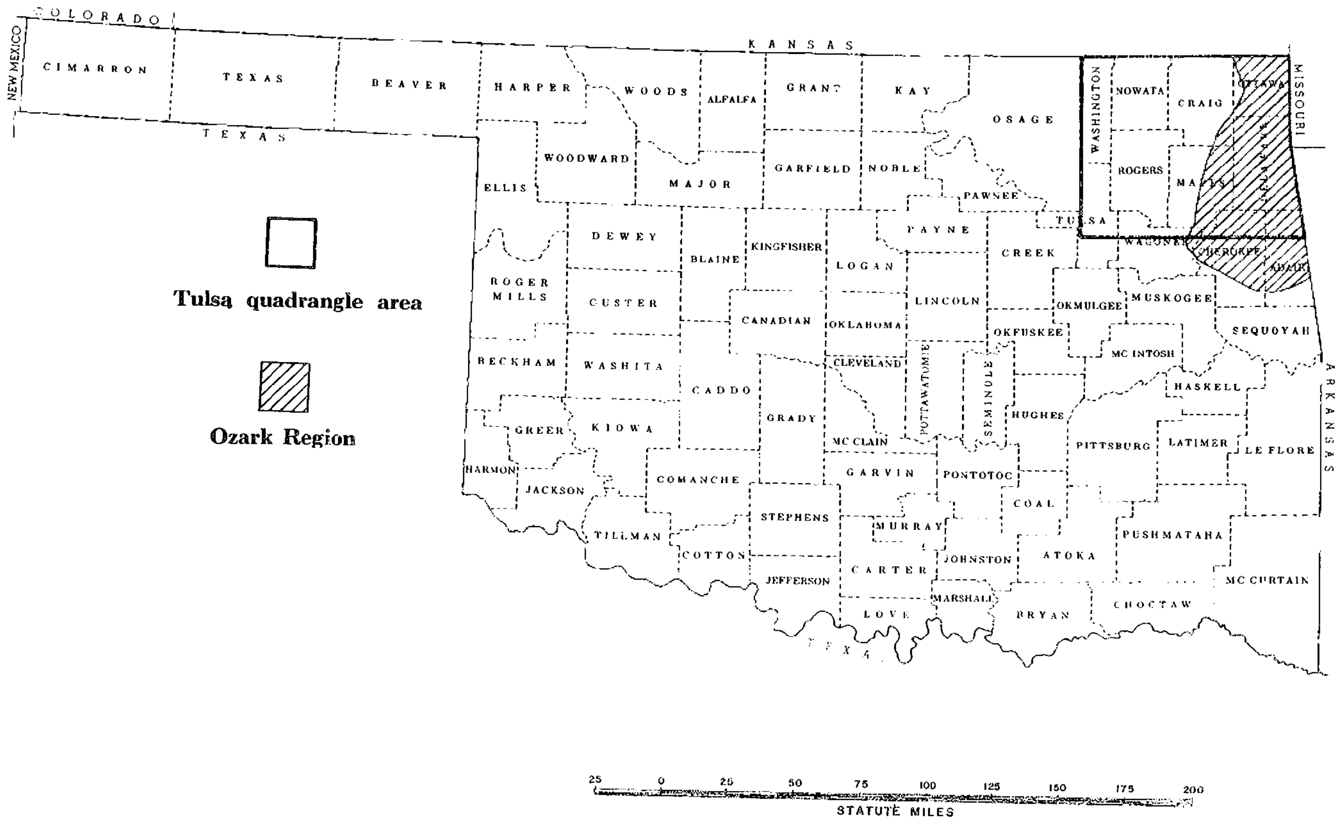


Figure 1. Map showing Tulsa quadrangle area and the Ozark Region.

TABLE I.—LOCATIONS OF SELECTED SPRINGS

SPRING NUMBER	T-N	R-E	SECTION	
		Adair County		
1	16	24	16	SE¼NE¼SW¼
2	18	24	23	NW¼SE¼NW¼
3	19	25	28	NE¼NW¼SW¼
		Cherokee County		
4	18	20	22	NW¼SW¼NW¼
5	19	21	20	SW¼NE¼SW¼
6	19	21	32	SE¼SE¼NE¼
		Delaware County		
7	20	23	33	SW¼SW¼SE¼
8	20	24	21	NE¼SE¼NE¼
9	20	25	15	SE¼SW¼NE¼
10	20	25	32	NW¼NE¼NW¼
11	21	24	34	NW¼NE¼NE¼
12	22	23	13	NW¼NE¼NE¼
13	22	24	6	NE¼NE¼SW¼
14	22	24	22	SW¼SW¼SE¼
15	23	22	20	SE¼NE¼NE¼
16	24	25	22	NE¼NE¼SW¼
		Mayes County		
17	20	20	23	NE¼NE¼SW¼
18	20	20	34	NW¼SE¼SE¼
19	20	21	20	SE¼SE¼SW¼
20	21	21	12	NE¼SE¼SE¼
21	21	21	22	NE¼SW¼SW¼
22	22	21	15	SW¼NE¼SW¼
		Ottawa County		
23	25	24	2	SE¼NW¼NE¼
24	27	25	7	SW¼NE¼NW¼
25	27	25	29	SE¼SE¼SE¼
26	27	25	29	SE¼SE¼SE¼
27	27	25	30	SE¼SW¼SE¼
28	28	24	15	NE¼SW¼SE¼
29	29	24	25	SW¼NW¼NW¼

subsurface throughout the area. The shale is insoluble and generally impermeable and serves as a barrier to the downward percolation of ground water.

The St. Joe consists of limestone and limy shale. Few springs flow from this formation because the limy shale is a deterent to the movement of water.

The Reeds Spring Formation consists of about equal amounts of thin, alternating layers of dense, fine-grained limestone and dark-gray to blue-gray chert. The chert layers are resistant to weathering, but, because of brittleness, the chert is subject to fracturing during structural movements. These fractures are the main passageways through which water from precipitation moves downward to the ground-water reservoir. The flushing and surging action of the moving water dissolves and abrades some of the limestone between the layers of chert, forming

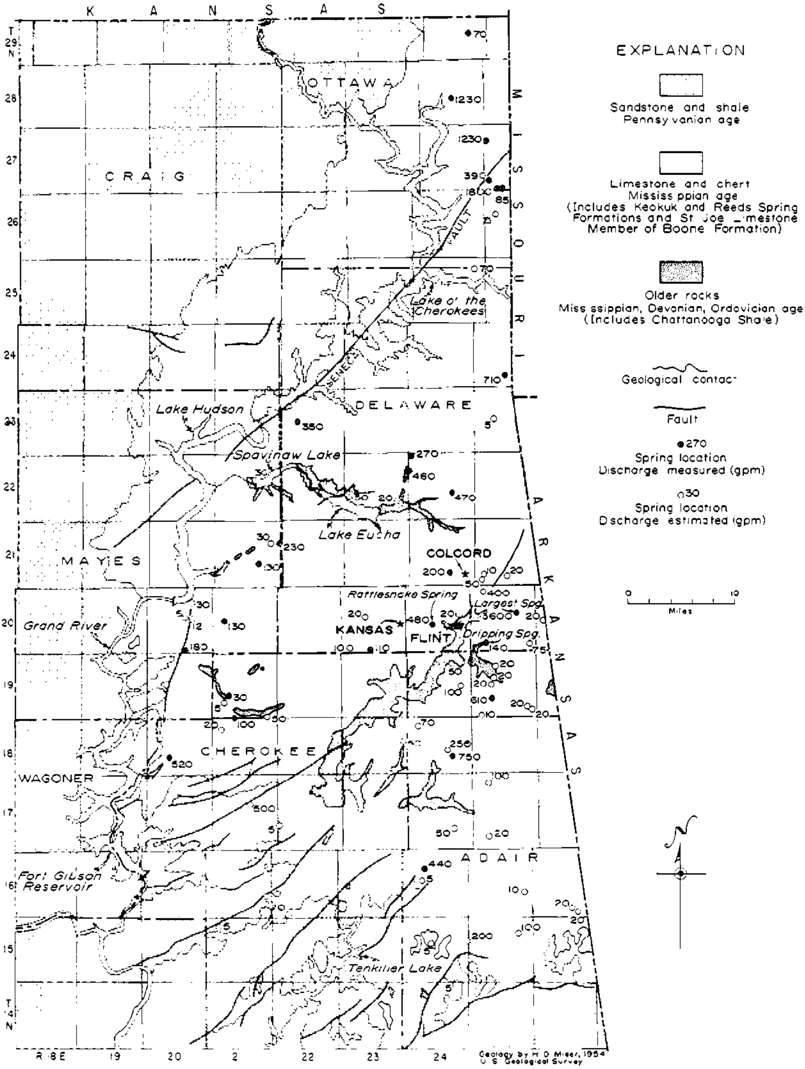


Figure 2. Map showing generalized geology, location, and discharge of springs in northeastern Oklahoma.

a network of water-filled cavities along bedding planes of the bedrock. Most of the springs in northeastern Oklahoma flow directly from bedding-plane cavities in the Reeds Spring Formation (fig. 3).

The Keokuk Formation, which crops out in 50 percent or more of the Ozark uplift in Oklahoma, consists of massive, mottled, fossiliferous chert locally interbedded with irregular masses of dense limestone. The

Figure 3. Photograph of Dripping Spring near Flint, Oklahoma, in Delaware County. The spring flows from openings in the Reeds Spring Formation.

formation is highly fractured and is the source of residuum that blankets the bedrock formations in the Ozark Region.

GROUND-WATER MOVEMENT

During the principal recharge period, from November to April, the cherty residuum acts much like a sponge, absorbing part of each rainfall and transmitting the water downward to the water table or to the top of the bedrock (fig. 4). Because of the bedrock's low permeability, the water flows laterally along the bedrock-residuum contact until it eventually enters joints, bedding planes, fractures, and other openings. These openings have been enlarged by solution and abrasion, forming extensive underground cavity systems in the Keokuk and Reeds Spring Formations. The water is stored temporarily in these cavity systems because little, if any, of the water penetrates the underlying, relatively impermeable Chattanooga Shale. The stored water drains slowly from the bedrock and sustains the flow of springs and perennial streams. During dry periods when there is little or no surface runoff, most of the stream flow is provided by discharge from ground water.

Little water from precipitation recharges the ground-water reservoir during the dry summer months because most of the precipitation is lost to evaporation or is transpired by active plant growth. The relationships between precipitation, spring flow, and water levels in wells are shown in figure 5. Changes in water level and spring flow indicate seasonal variations in the rate of recharge to the ground-

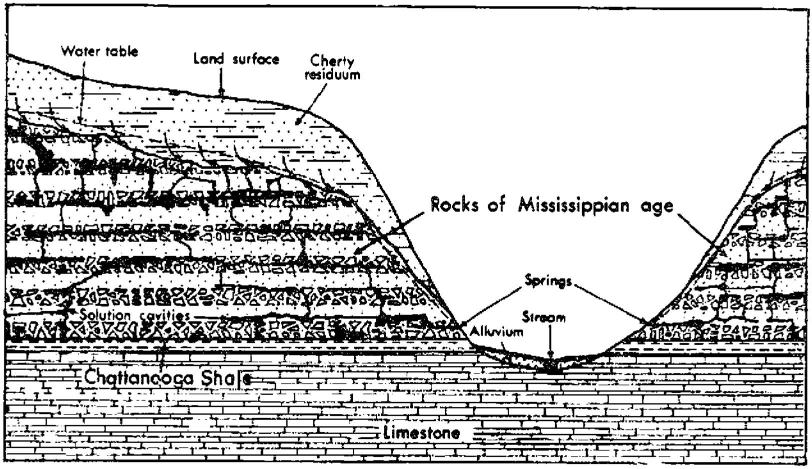


Figure 4. Schematic section illustrating the occurrence and movement of ground water in northeastern Oklahoma.

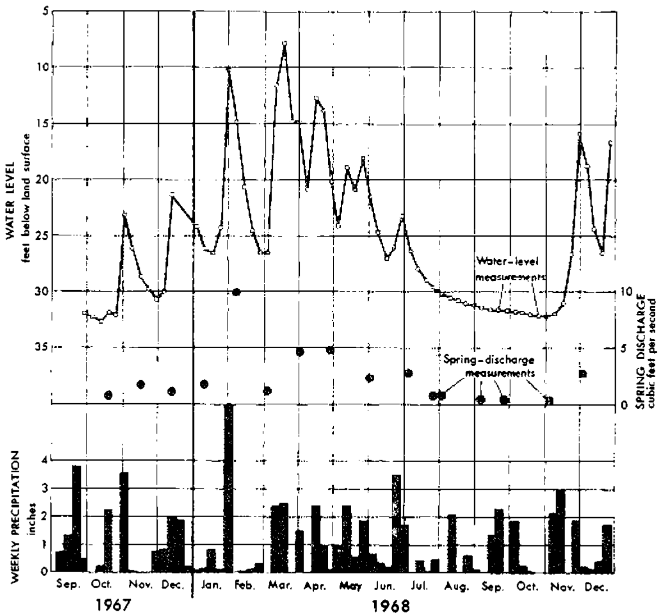
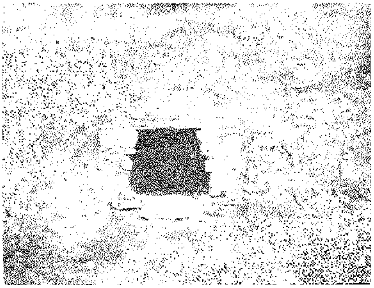


Figure 5. Graphs showing precipitation and water-level fluctuations at Kansas and discharge measurements of a spring near Colcord.

water reservoir. The sustained flow of the springs during dry periods depends upon the storage capacity of the formation and on the interconnection of solution cavities in the rock through which the water moves.

A change in the route of water movement, such as the change that occurred at Rattlesnake Spring (8, table I), may cause a spring to cease flowing continuously. Rattlesnake Spring is located in the roadside park on State Highway 33, east of Kansas, Oklahoma, in Delaware County. Figure 6a shows the dry cavity that is located on the north side of the park roadway. Water flows from this cavity for short periods during heavy rainfall in the winter and early spring, although a few years ago the spring flowed continuously. Figure 6b shows the new outlet of Rattlesnake Spring on the south side of the park roadway opposite the dry cavity. The flushing, surging action of the flowing water formed additional openings in the bedrock, allowing the ground water to percolate downward to a level below the dry cavity and thereby forming the new spring outlet. The land surface at the new spring site is 2 or 3 feet lower than the land surface at the dry cavity. Water flows continuously through vertical fractures in the bedrock at the new spring site.



a.

b.

Figure 6. Photographs of Rattlesnake Spring.
a. Dry cavity that has ceased to flow continuously.
b. New spring outlet.

DISCHARGE OF SPRINGS

The amount of water discharged from springs fluctuates in response to changes in ground-water storage. Long-term records are required to determine the average discharge and range in discharge of springs, but such spring records are not available for the Ozark Region in Oklahoma. However, discharge measurements were made at monthly intervals for about 1 year at four selected springs (11, 13, 16, 27 in table I). Figure 5 is a graph of monthly discharge measurements at a spring near Colcord (11, table I), and discharge fluctuations shown in the graph are similar to fluctuations of other springs in the area. The rate of spring flow is highest during the spring recharge period, declines during the summer, and is generally lowest in the fall.

Flow at one spring (1, table I) in Adair County was measured in June 1964, and, during September and October 1968, measurement of flow was made at 25 selected springs in the area (fig. 2 and table II). The largest spring (9, table I) was flowing 3,600 gpm (gallons per minute) from bedding-plane openings in the Reeds Spring Formation (fig. 7). The total flow of all the selected springs was about 21 mgd, and the estimated flow of other springs shown on figure 2 was about 4 mgd. The combined measured and estimated flow of 25 mgd is probably a small fraction of the total ground water discharged in the area because numerous small springs and seeps are not taken into account. Nevertheless, 25 mgd is sufficient to supply water for several industries or to furnish domestic water supplies to a population of about 200,000.

TABLE II.—DISCHARGE OF SELECTED SPRINGS IN NORTHEASTERN OKLAHOMA

SPRING NUMBER	DISCHARGE		DATE MEASURED‡
	CFS*	GPM†	
1	0.98	440	June 23
2	1.70	750	Oct. 8
3	1.36	610	Sept. 24
4	1.10	520	Oct. 7
5	0.07	30	Sept. 23
6	0.21	100	Oct. 7
7	0.25	110	Oct. 8
8	1.07	480	Sept. 24
9	8.02	3,600	Oct. 1
10	0.31	140	Oct. 2
11	0.45	200	Sept. 24§
12	1.03	460	Sept. 24
13	0.60	270	Oct. 8§
14	1.05	470	Sept. 24
15	0.78	350	Sept. 25
16	1.58	710	Sept. 26§
18	0.40	180	Sept. 23
19	0.29	130	Sept. 24
20	0.51	230	Sept. 24
21	0.30	135	Sept. 23
24	2.74	1,230	Sept. 26
25	4.01	1,800	Sept. 25
26	0.19	85	Sept. 25
27	0.87	390	Sept. 25§
28	2.74	1,230	Sept. 26
29	0.16	70	Sept. 26

* Cubic feet per second. One cfs equals approximately 450 gpm.

† Gallons per minute.

‡ All measurements were taken in 1968, except spring 1, which was taken in 1964.

§ Observation spring measured monthly.

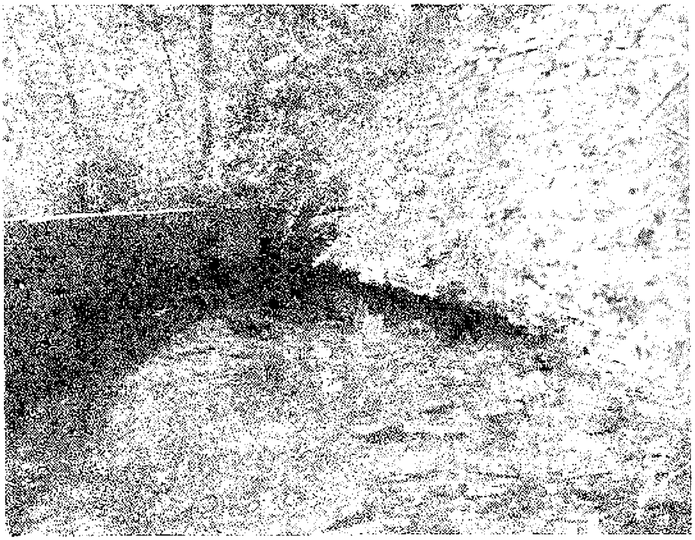


Figure 7. Photograph of largest spring in the area.

USE OF SPRINGS

The springs in northeastern Oklahoma are used mostly to supply water for livestock, although a few furnish domestic water supplies or are used for recreation purposes. Only a small part of the available spring flow is used for any purpose. Spring discharge, however, helps to maintain base flow of the perennial streams that supply water to surface reservoirs, towns, and industries in the area. Water flowing from springs is available for many uses because the water is at land surface, and the chemical quality of the water remains nearly constant.

CHEMICAL QUALITY OF THE WATER

Quality data indicate all spring water is of good quality and suitable for most uses. The dissolved solids concentrations of water samples collected from 23 of the springs ranged from 83 to 243 mg/l (milligrams per liter) (table III). Hardness ranged from 65 to 201 mg/l; the water is hard in less than half the springs sampled. Sulfate and chloride concentrations were far below the maximum recommended for drinking water.

All spring water in the area is probably of the same general quality because the springs flow from formations that contain similar soluble minerals. Although the chemical quality of the spring water is good, the bacterial quality should be examined before the water is used for human consumption. Contamination of ground water in bedrock is likely because solution cavities are generally open and therefore natural filtration of bacteria does not occur.

TABLE III—ANALYSES OF WATER SAMPLES FROM SELECTED SPRINGS IN NORTHEASTERN OKLAHOMA

(Data are in milligrams per liter, except temperature and pH)

Spring Number	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate* (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved Solids (Residue at 180°C)	Hardness as $CaCO_3$	Specific Conductance (Micromhos at 25°C)	pH	Temperature (°C)
2	28	1.8	2.2	1.1	86	1.0	4.5	2.0	94	78	164	7.8	16
3	22	0.8	3.4	1.0	62	1.0	6.2	4.9	83	58	136	7.6	15
4	30	1.0	2.8	1.6	98	0.5	5.6	1.9	107	80	182	7.7	16
6	41	0.0	3.4	1.3	122	1.0	4.2	4.0	125	102	213	8.1	15
7	43	0.5	7.0	0.6	128	2.2	13.0	1.3	140	110	248	7.8	15
8	28	0.2	3.9	1.1	80	0.9	9.4	1.3	102	72	166	7.8	16
9	37	0.5	3.9	1.5	110	1.4	6.6	2.6	114	94	203	8.1	19
10	32	0.5	4.0	1.0	96	1.5	4.0	10.0	107	82	186	7.9	16
11	24	2.1	3.2	1.1	76	1.3	5.1	7.2	89	68	153	7.8	17
13	60	0.5	4.5	1.0	176	1.5	8.6	9.9	188	152	320	8.3	16
14	50	0.0	3.6	1.6	146	3.7	6.6	4.2	147	126	252	8.0	18
15	46	1.0	2.7	1.5	144	5.8	3.9	13.0	161	120	247	8.0	16
16	54	3.4	30.0	3.0	160	1.8	49.0	4.2	243	148	451	7.9	17
17	64	2.4	3.9	1.5	198	1.1	4.6	6.2	188	170	330	7.8	17
18	39	0.0	2.7	1.6	118	5.2	3.2	1.4	116	98	207	7.9	19
19	50	1.4	2.5	0.6	156	1.4	2.8	0.1	140	130	255	8.2	16
20	49	0.5	2.4	1.4	144	5.3	3.4	1.8	145	124	248	8.0	18
22	37	1.4	3.2	1.4	116	0.6	6.0	0.0	114	98	211	8.0	19
23	61	1.4	3.3	1.2	178	5.6	7.8	2.9	180	158	313	8.1	19
25	43	0.5	4.2	1.0	116	1.8	7.4	13.0	150	110	239	7.8	15
27	40	0.5	3.7	1.7	108	6.5	6.2	16.0	143	102	225	8.2	17
28	56	1.4	3.9	1.2	178	6.8	4.1	3.9	167	146	298	8.3	16
29	67	5.4	3.5	1.2	218	15.0	2.8	2.9	214	190	364	8.3	22

*Includes carbonate (CO_3) and bicarbonate (HCO_3).

SUMMARY

Springs are a large potential source of ground water in the Ozark Region of northeastern Oklahoma where water of good chemical quality flows directly from openings in bedrock formations of Mississippian age. Openings in the bedrock provide passageways for movement of water from points of recharge to points of discharge. Additional discharge records are needed to determine the variability of spring flow in northeastern Oklahoma.

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Huffman, G. G., 1958, Geology of the flanks of the Ozark Uplift, northeastern Oklahoma: Okla. Geol. Survey, Bull. 77, 281 p.

Marcher, M. V., 1969, Reconnaissance of the water resources of the Fort Smith quadrangle, central-eastern Oklahoma: Okla. Geol. Survey, Hydrologic Atlas 1, scale 1:250,000.

Miser, H. D., 1954, Geologic map of Oklahoma: U. S. Geol. Survey and Okla. Geol. Survey, scale 1:500,000.

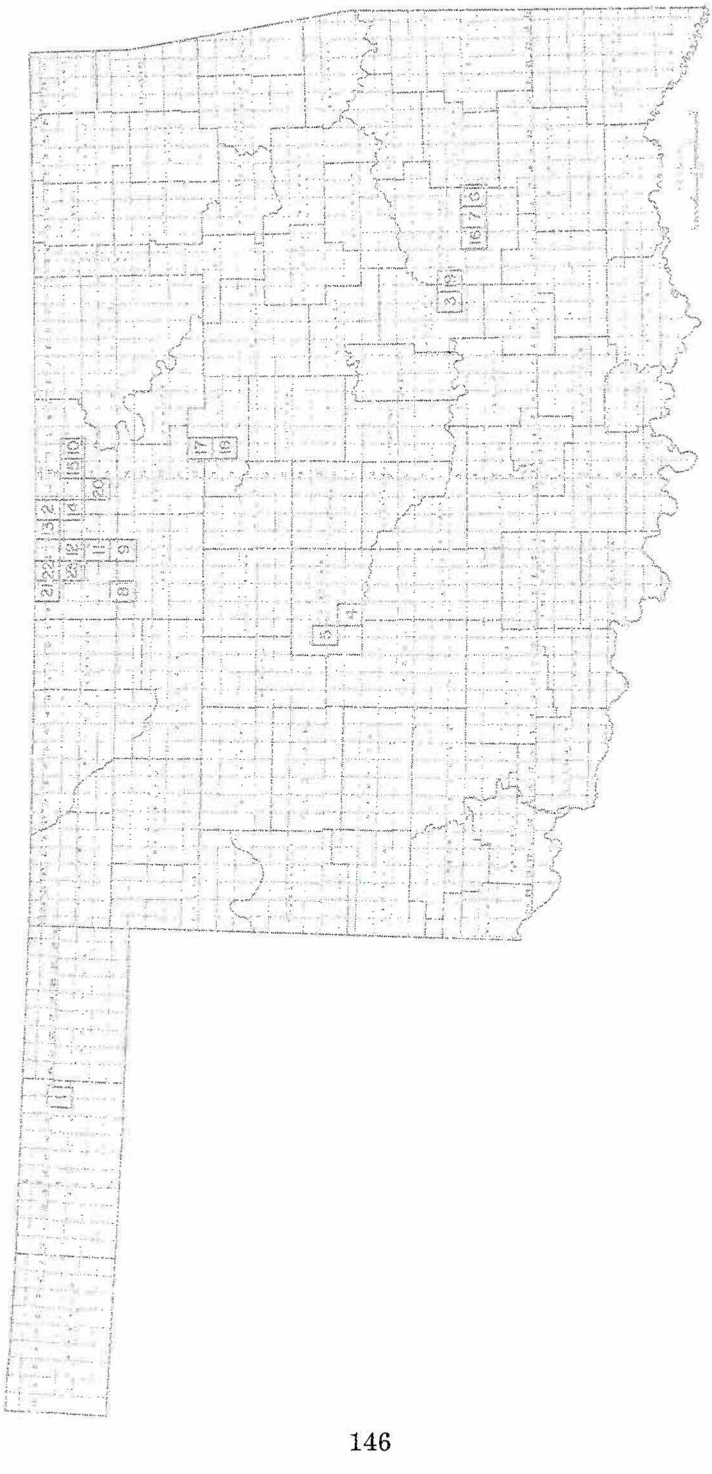
Reed, E. W., Schoff, S. L., and **Branson, C. C.**, 1955, Ground-water resources of Ottawa County, Oklahoma: Okla. Geol. Survey, Bull. 72, 203 p.

Earth Science Editors Travel to Houston

Houston, Texas, was the site of the Third Annual Conference of the Association of Earth Science Editors, and conference host was Western Geophysical Company of Houston, represented by Carl H. Savit, editor for the Society of Exploration Geophysics. Guest speakers for the conference were Professor A. Hacquaert and Dr. Anders Martinsson, president and past-president, respectively, of Editerra (European Association of Earth Science Editors).

Pre-conference activities included a tour of the NASA Manned Spacecraft Center, highlighted by a discussion of lunar materials brought back by the men of Apollo 11, a showing of noteworthy photographs of Earth's geologic features taken on various orbital missions, and a trip to NASA Mission Control Center.

Panel discussions on illustration preparation, new techniques in publication, and cooperative publishing made up the two-day schedule of talks, and a dinner on Thursday evening featured Professor Hacquaert's discussion of the similarities and need for closer ties between AESE and Editerra. During the business meeting on Friday, Dr. Martinsson presented his joint resolution with Dr. A. A. Meyerhoff, 1969 AESE chairman, calling for closer cooperation and exchange of ideas between their two organizations.



Recently Issued Topographic Maps

Twenty-three new quadrangles of Oklahoma topographic maps have been issued since April, and all are 7½-minute sheets. A total of 351 sheets is now available and 319 are in various stages of preparation.

In the April issue of the *Notes,* 16 new topographic quadrangles were listed, and since that time the following 7½-minute sheets have been published (numbers refer to map, opposite page; county names are in parenthesis):

1. Adams (Texas)
2. Blackwell NW (Grant, Kay)
3. Calvin E (Hughes)
4. Cogar NE (Canadian, Grady, Caddo)
5. Fort Reno SW (Canadian)
6. Hartshorne (Pittsburg, Latimer)
7. Hartshorne SW (Pittsburg)
8. Hillsdale (Garfield, Grant)
9. Hunter (Garfield, Grant)
10. Kildare (Kay)
11. Lamont NW (Grant)
12. Medford (Grant)
13. Medford NE (Grant)
14. Nardin (Kay, Grant)
15. Newkirk SW (Kay)
16. Savanna (Pittsburg)
17. Stillwater N (Payne)
18. Stillwater S (Payne)
19. Stuart (Hughes, Pittsburg)
20. Tonkawa (Kay)
21. Wakita (Grant)
22. Wakita NE (Grant)
23. Wakita SE (Grant)

—*Carl C. Branson*

Hydrologic Atlas of Fort Smith Quadrangle Available

In November the Oklahoma Geological Survey, in cooperation with the U. S. Geological Survey, released Hydrologic Atlas 1, *Reconnaissance of the Water Resources of the Fort Smith Quadrangle, East-Central Oklahoma,* by Melvin V. Marcher, as the first product of a 10-year investigation for the State of Oklahoma on water resources. HA-1, at a scale of 1:250,000, is made up of four sheets that show the geology, availability of ground water, chemical quality of ground water, and surface-water information of the area. Copies of HA-1 are available through the Oklahoma Geological Survey for $3.00.

HA-1 includes about 6,300 square miles in east-central Oklahoma and is the first of nine hydrologic atlases designed to provide reconnaissance appraisals of the State, exclusive of the Panhandle, where hydrologic knowledge is limited or is not readily available. In addition to the Fort Smith quadrangle, the Tulsa, Ardmore, McAlester, and Oklahoma City quadrangles are in various stages of preparation for presentation as Hydrologic Atlases 2-5, respectively.

Relatively little has been done in Oklahoma to expand the knowledge of her own water resources, while surrounding states have been developing large water programs of their own. As a step toward Oklahoma's water-resource development, the 10-year cooperative program was initiated and will include, in addition to an inventory of State water resources, maps showing the base of fresh water for the State and a detailed investigation of selected reservoirs in the State. Such information is vital to urban and industrial planners for the future economic development of Oklahoma and to regulatory agencies for valuable basic data.

Pilot Study for National Petroleum Data System Initiated

A national petroleum data system for oil and gas fields is the object of a pilot study contracted by the U. S. Department of Interior with The University of Oklahoma. Included in the study is an evaluation of the General Information Processing System (GIPSY), which has been in use at the Merrick Computing Center, The University of Oklahoma, since July 1968 as the primary system support in various projects (see article on page 6, February 1969, of the *Notes* for more information on GIPSY).

The project will focus initially on selected fields from states for which the best data are currently available. The process of selection, reduction, storage correlation, analysis, and interpretation of data from approximately 100 to 200 fields will then be integrated with a dissemination system.

The data-format part of the study is to provide a standardized means of recording essential reservoir information for data processing. At present, such standardization is almost nonexistent.

OKLAHOMA ABSTRACTS

GSA Annual Meetings, Atlantic City, New Jersey November 10-12, 1969

The following are abstracts of papers related to Oklahoma geology presented at the 1969 Annual Meetings of the Geological Society of America and Associated Societies; they are reproduced as printed from the program of the meetings. Permission of the authors and of Edwin B. Eckel, editor of the Geological Society of America, to reproduce these abstracts is gratefully acknowledged.

Oklahoma Geology Notes should not be given as the primary source in citations of or quotes from the abstracts. The correct citation is Geol. Soc. America and Assoc. Socs., 1969 Ann. Mtgs., Program, Pt. 7, P._____. Page numbers are given in brackets at the lower right of each abstract.

Coal-Balls: Their Origin, Nature, Geologic Significance and Distribution

CROSS, AUREAL T., Department of Geology, Michigan State University, East Lansing, Michigan 48823

Coal-balls are generally irregular, nodular masses of petrified peat preserved in local areas and at various levels in the original peat bed. Early mineralization caused a cessation of decay (which continued in the surrounding peat, throughout the coalification process) and protected the embedded and permineralized plant tissues from further compaction or loss of volume. Decay of the plants may have already proceeded, before mineralization, to a greater or lesser stage and varies according to plant organs and different species. Calcium carbonate is the principal primary mineral; magnesium carbonate and iron pyrite the most important secondary minerals. Silica may be primary or secondary.

The cause and source of mineralization vary but all deposits (which it has been possible to verify) appear to have a marine inundation of the peat bed resulting in accumulation of fossiliferous marine mud or limestone above the peat. This limestone may be bedded but more often is in local lenses, somewhat conforming to and above the area of coal-ball distribution. Coal-balls formed at or near the top of the peat bed often contain marine fossils, and some of these appear to contain allochthonous plant debris which may have been reworked from the peat below.

OKLAHOMA ABSTRACTS is intended to present abstracts of recent unpublished papers on Oklahoma geology. The editors are therefore interested in obtaining abstracts of formally presented or approved documents, such as dissertations, theses, and papers presented at professional meetings, that have not yet been published.

A significant unresolved question is the general absence of true coal-balls in coal beds later than Pennsylvanian. Two new localities, Whiteoak and Tulsa, in NE Oklahoma, contain good plant remains. Coal-ball-like "concretions" from Utah show extensively decayed apparently autochthonous plant debris. The age (Cherokee to Waubansee) and geographic distribution of North American coal-balls are presented on a new summary chart.

[42]

Application of the Generalized Information Processing System (GIPSY) to the Storage and Retrieval of Earth Sciences Literature

MOODY, D. W., and OLAF KAYS, U. S. Geological Survey, Washington, D. C. 20242

For the past 5 years the U. S. Geological Survey has used photocomposition techniques to prepare bibliographies and abstracts of earth science literature (e. g., *Bibliography of North American Geology*) for publication. The resulting machine readable data base of nearly 100,000 citations and abstracts is readily available for computerized information retrieval.

The Generalized Information Processing System (GIPSY), developed by the University of Oklahoma's Merrick Computing Center, provides a simple and flexible means of searching this data base. GIPSY enables the user to search for numbers, works, word stems, or phrases contained in variable field, variable length records. At present a GIPSY bibliographic record may contain up to 21 fields in order to accommodate document descriptions from a variety of sources. A record from the *Bibliography of North American Geology*, however, only uses fields for the document number, author(s), title, citation, type of illustrations, date, index terms, and abstract.

The retrieved records may be printed in a variety of predefined report formats, or they may be formatted at the time the search is executed. This feature allows direct use of the information by other text processing programs.

Limited experience with files ranging from a few thousand to more than 30,000 records (citations and abstracts) suggests that a search using 3 to 4 index terms is sufficient to satisfy most user requests with a high degree of recall. A permuted title index of the retrieved records enables the user to then quickly select those documents that are most relevant to his query.

[152-153]

Flysch Sub-Facies in Stanley-Jackfork Rocks, Ouachita Mountains, Arkansas

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Bedding characteristics, sedimentary structures, and lithologic associations indicate that the Stanley-Jackfork Formations are flysch deposits. Important lateral changes at points of delta influx, heads of turbidity flows, and parallel the base of marginal slopes allow easy differentiation from more distal turbidites. Delta front and prodeltaic rocks possess poor bedding and sorting, reflecting sedimentation chiefly from suspension and redistribution by weak tractional currents and slumping. Proximal turbidites (fluxoturbidites) include massive, scoured A/A sequences consisting only of Bouma's A division and sharp, even-bedded AE sequences with thin mudstone interbeds. Shallow channels and elongate scours are excellent top and bottom indicators in A/A sequences. Distal turbidites, consisting of sandy flysch and shaly flysch, more closely approach the sedimentary structures of a complete Bouma sequence. Laminated sandstones dominate sandy flysch which presumably is gradational between AE sequences and shaly flysch. Shales exceed sandstones and siltstones in the latter which were deposited more distant from the point source. The pelagic facies includes shales, mudstones, siliceous shales, and impure cherts, all commonly associated with distal turbidites. Disturbed and disrupted beds developed at the foot of a northern unstable slope, the resulting bedding dependent upon type of material involved, its state of consolidation, and the distance moved. This allochthonous material entered at right angles to basinal turbidites flowing westward down the trough axis. Highest sand-scale ratios parallel the axis of the trough while slope deposits contain higher pelitic contents which frequently are disturbed.

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The Johns Valley Boulders in the Late Paleozoic Ouachita Facies, A Product of Wildflysch Sedimentation

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Boulders in the Johns Valley Formation of the central Ouachita Mountain province are a product of wildflysch sedimentation in the late Paleozoic Ouachita geosyncline. Enclosed clasts occur in a variety of sedimentary deposits which include structureless and laminated paraconglomerates, orthoconglomerates, and exotic sandstone beds. Boulders range in age from late Cambrian through early Pennsylvanian, and were derived from a linear sourceland comprised predominantly of foreland carbonate strata, but one which also contained subordinate quantities of transitional and geosynclinal lithologies. Its paleogeographic location was immediately north of a hinge line flexure which separated the foreland and geosynclinal tectonic provinces. Structurally, the sourceland was manifested as a rising, fault-bounded geanticlinal ridge, which was the locus of an emergent archipelago; prominent islands of the archipelago functioned as major boulder dispersal centers.

Throughout Johns Valley deposition, steep and unstable marginal paleoslopes were maintained along the geanticlinal ridge by periodic tectonism and subaqueous erosional processes. Boulders derived from the ridge were dispersed into the Ouachita geosyncline by a combination of mass movement media which include mudflows, rock slides, rock falls, and turbidity currents. The prolific introduction of boulders into the Ouachita geosyncline during Johns Valley deposition resulted in the development of a wild-flysch subfacies indigenous to the northern margin of the trough, as contrasted with turbidite flysch facies of the trough interior.

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Appalachian-Ouachita Structural Salients and Clastic Wedges: Common Genesis?

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The Appalachian-Ouachita orogenic belt includes six regional arcuate structural salients and intervening recesses. The belt is widest in the salients, which are characterized by numerous narrow folds, internally deformed thrust sheets, and decollements. Frontal structures terminate laterally away from the salients. In the recesses the narrower, less complex deformed belt generally consists of few thrust faults and folds.

The stratigraphic section in each salient is dominated by one or more thick, semicircular wedges of clastic rocks. The clastic wedges thin and in part grade to carbonate facies not only across strike onto the craton but also along structural strike into the recesses.

Clastic wedges and structural salients are approximately concentric and coextensive; therefore, a common genesis is indicated (and a working hypothesis is suggested). Salients may have originated as rapidly subsiding geosynclinal basins, where thick clastic sediments accumulated in a variety of environments. Clastic sediments evidently were derived from adjacent, contemporaneous uplifts along the geosyncline margin. Orogenic climax resulted in compression of the marginal uplifts against the incompetent, thick, basinal clastic wedges which were cast into wide complexes of decollement structures. In contrast, recesses evidently subsided less rapidly and received thinner, partly shallow-water carbonate sequences. Tectonism, which generated the major basins and uplifts of the salients, occasioned contemporaneous individual structures in the recesses; and, there deformation culminated in relatively simple structures in competent rocks. Sedimentary facies indicate various, multiple times of deformation in different salients and recesses.

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CLAY MINERALS CONFERENCE, DALLAS-FT. WORTH, TEXAS OCTOBER 19-22, 1969

Swelling Characteristics of Hydroxy-Aluminum Interlayered Clays

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The hypothesis tested was that macroscopic swelling of montmorillonitic clays is reduced by the presence of interlayer materials. Fine and coarse clay fractions of Camargo and Panther Creek bentonite samples were artificially interlayered by reaction of $Al_2(SO_4)_3$ and NaOH in 0.5 percent suspensions of the clays. All four clay fractions reacted similiarly to artificial interlayering. At a high Al:clay ratio (16 meq Al/g clay), the cation-exchange capacity (CEC) was completely lost, surface area reduced to one-half its original value, and a basal spacing of approximately 13 A exhibited after K saturation and heating at 500°C. No macroscopic swelling occurred in samples so treated. At smaller concentrations of hydroxy-aluminum (8 and 2 meq Al/g clay), the clay properties were less drastically altered. Extraction of interlayered clays with Na citrate restored the original CEC, surface area, and basal spacings to the clays and resulted in slight enhancement of CEC and surface area of the coarse fractions. Nontreated clays were found to have a strong attractive force that prevented swelling; its effect was considerably greater in the coarse than in the fine-clay fractions. Treatment with hot Na citrate resulted in two- to seven-fold increases in swelling but only slight increases in CEC and surface area. Evidence presented supports the hypothesis that macroscopic swelling of montmorillonitic clays is greatly reduced by small amounts of interlayer material. Reduced swelling occurs even when other clay properties may be only slightly different from nontreated samples. Indications are that interlayer materials occur naturally in clays from bentonite deposits.

The University of Oklahoma

Experimental Determination of Partition Coefficients for Calcium, Strontium, and Barium in Aragonite Precipitated from Sea Water at Low Temperatures

EDWARD LEIGHMAN GAFFORD, JR., The University of Oklahoma, Ph.D. dissertation, 1969

The partition of calcium, strontium, and barium has been measured between sea water and precipitates of aragonite at low temperatures and atmospheric pressure. The distribution of calcium, strontium, and barium between the solution and precipitate approximates the Doerner-Hoskins relationship, thus surface equilibrium is maintained between solution and solid during the coprecipitation process. The partition of calcium and strontium between precipitates of aragonite and sea water approximates more closely the logarithmic distribution law than that of the calcium and barium distribution.

Aragonite was precipitated from sea water by the addition of dilute solutions of sodium carbonate. Barium was quantitatively separated by ion-exchange techniques, and both strontium and barium were analyzed by flame spectrophotometry.

The partition coefficient $K^{A}_{Sr^{++}}$ is 1.29± 0.04 at 25°C, 1.20± 0.03 at 35°C and decreases to 1.15± 0.02 at 45°C. The partition coefficient $K^{A}_{Ba^{++}}$ is 3.16 at 25°C, 2.78 at 35°C, and 2.71 at 45°C. The strontium content of the inorganically precipitated aragonites ranges from 9,200 to 10,200 ppm, and barium ranges from 96 to 113 ppm.

Many marine organic and inorganic aragonites contain amounts of strontium similar to those predicted from the distribution data. Recent marine non-skeletal aragonites that contain less strontium than those precipitated in the laboratory might be considered organic in origin.

The barium content of naturally occurring aragonites appears not to conform to the predicted values of determined partition coefficients. The low level of barium content in modern marine aragonites cannot, therefore, be interpreted by the results of distribution coefficient data.

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Marine Communities of a Portion of the Wewoka Formation (Pennsylvanian) in Hughes County, Oklahoma

WEST, RONALD ROBERT, The University of Oklahoma, Ph.D. dissertation, 1969

Nineteen fossil assemblages contained in a thin interval of the Middle Pennsylvanian Wewoka Formation in a small geographic area have been shown to represent mixed fossil assemblages as defined by J. A. Fagerstrom. The major contributors to these fossil assemblages are further shown to have lived, died, and been preserved at the collecting site (i. e. members of fossil communities). This has been accomplished through a consideration of size-frequency distributions, nature of preservation, mode of occurrence and orientation within the enclosing sediment, percentages of articulation, opposite valves, broken individuals, and, to some extent, dispersion of the fossils, population density, assemblage composition, and diversity. Application of Q-mode cluster analysis using the coefficient of association developed by L. R. Dice resulted in a consolidation of these remanent fossil populations into four residual fossil communities. These communities are named for the dominant metazoan genus that occurs in each one. Stratigraphically, from the lowest to the highest, these are: the *Glabrocingulum* community, Transitional community, *Cleiothyridina* community, and *Mesolobus* community.

The structure of each of the four communities was constructed on the basis of inferred feeding type and mode of life of the residual community members. These Wewoka communities appear to have been structured in the same manner as Recent marine benthic communities of similar substrates. Differences in the communities and their structures are not reflected in the substrate mineralogy and/or chemistry. Food eaten by Recent invertebrates that are morphologically similar and/or taxonomically related to the fossil organisms was used as the basis for constructing a generalized food web for these four Pennsylvanian benthic communities.

Various depositional environments were inferred for each of the lithologic units defined in this investigation. These are, in ascending order: backswamp marshy area to tidal flat, shore margins of a partly restricted bay or delta-front area, more open portions of a bay or prodelta area (more "normal" marine conditions), restricted bay (nearer shore area), with terrigenous detritus being added by a deltaic complex, and deltaic sand deposition (distributary system). Three of the communities are compatible with the second, third, and fourth environments. The Transitional community characterizes an environment intermediate between the second and third.

Examination of shale-claystone sequences above and below the one studied in detail suggests that there is a cyclicity of environments within the Wewoka. This is reflected by the contained fossil assemblages and subtle changes in the claystone lithologies. Additional investigations of these fossil assemblages will probably show that they represent benthic communities, which migrated in and out of the area depending on the physiochemical conditions. Fluctuations in the amount and type of terrigenous clastics carried into the area may be the primary key to the cyclicity of these communities.

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