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**OKLAHOMA GEOLOGY**

# NOTES



## *Cover Picture*

### PHOTOMICROGRAPH OF HEAVY MINERALS FROM THE SENORA FORMATION WITHIN THE ARKOMA BASIN

The Senora Formation is the youngest member of the Cabaniss Group, which is middle Desmoinesian in age. It crops out from Coal and Hughes Counties north-northeasterly to Craig County, with the outcrop pattern narrowing toward the north. In the Arkoma Basin the formation is primarily made up of a sandstone lower unit that is interbedded with shales and an upper unit that is primarily shale.

The cover illustration is a photomicrograph of a heavy-mineral slide, taken at a magnification of  $\times 25$ , showing two euhedral zircon grains, one displaying inclusions, and several subhedral and anhedral (rounded) grains of zircon. Adjacent to the clear euhedral zircon grain is a weathered zircon grain; the other grains are either individual leucoxene grains or leucoxene-coated grains of indeterminate type. Also shown are several quartz grains that were trapped within the heavies during separation from the light minerals. The heavy minerals are from a sandstone sample collected 1,000 feet east of the northwest corner, sec. 36, T. 6 N., R. 10 E., Hughes County, Oklahoma.

The nonopaque, heavy-mineral suite from the Senora Formation in Hughes and Pittsburg Counties is predominantly an ultrastable assemblage of zircon, tourmaline, rutile, and anatase, with minor amounts of staurolite and garnet. The postulated source of the Senora material is the sedimentary strata within the Ouachita Mountain area.

—*David Harold Hawk*

# THE MINERAL INDUSTRY OF OKLAHOMA IN 1969\* (Preliminary)

AREL B. McMAHAN †

Value of Oklahoma mineral production in 1969 exceeded \$1 billion for the third consecutive year, according to estimates by the Bartlesville Office of Mineral Resources of the Bureau of Mines, U. S. Department of the Interior. Production of mineral fuels (petroleum, natural gas, natural-gas liquids, helium, and coal) accounted for 94.6 percent of the total value.

## MINERAL FUELS

Value of total mineral-fuels output increased by about 8 percent according to preliminary data. Individually, coal-output value increased 32.8 percent, natural-gas liquids 22 percent, natural gas 11.7 percent, crude petroleum 5.4 percent, and helium 3.3 percent. Increased coal output resulted from development in three areas: Howe Coal Company mine, Le Flore County; Peabody Coal Company mine, Craig County; and Kerr-McGee Corporation, Choctaw mine, Haskell County. Gain in production of natural gas was reflected in the increased number of producing wells; producing wells at the end of September totaled 8,406 compared with 8,059 at the end of 1968.

Increased petroleum output resulted from a strong demand for Oklahoma crude. The daily production allowable for the State's wells was set at 90 percent of the basic depth-acreage formula for January and February by the Oklahoma Corporation Commission. The allowable was raised to 100 percent for March and remained unchanged through December. Preliminary data indicated an increase in producing wells through the first nine months.

## NONMETALS

Value of nonmetallic mineral production increased 5.6 percent. Gains were recorded in output of stone, clays, cement, and lime; preliminary data indicated a decline in production of sand and gravel and tripoli. The decline in output of sand and gravel was due to decreased building contracts.

## METALS

Value of metals production dropped about 29 percent. Several zinc mines were shut down because of flooding in the Picher field in the Tri-State district as a result of cessation of pumping in the field in November 1968. The decline in zinc- and lead-output value was offset somewhat by increased output value of copper and silver.

\*This U. S. Bureau of Mines Mineral Industry Surveys report was prepared December 9, 1969.

†Mineral Specialist, U. S. Bureau of Mines, Bartlesville Office of Mineral Resources, Bartlesville, Oklahoma.

TABLE I.—MINERAL PRODUCTION IN OKLAHOMA<sup>1</sup>

MINERAL	1968		1969 (PRELIMINARY)	
	QUANTITY	VALUE (THOU- SANDS)	QUANTITY	VALUE (THOU- SANDS)
Clays <sup>2</sup> (thousand short tons)	726	\$ 967	799	\$ 1,064
Coal (bituminous) (thousand short tons)	1,089	6,401	1,330 <sup>2</sup>	8,500 <sup>2</sup>
Gypsum (thousand short tons)	931	2,565	939	2,575
Helium, Grade A (thousand cubic feet)	308,600	8,700	320,700	8,987
Lead (recoverable content of ores, etc.) (short tons)	2,387	631	<sup>4</sup>	<sup>4</sup>
Natural gas (million cubic feet)	1,390,884	197,506	1,510,810	220,578
Natural-gas liquids:				
Natural gasoline and cycle products (thousand 42-gallon barrels)	13,905	38,829	14,800	41,590
LP gases (thousand 42-gallon barrels)	25,497	39,520	27,400	53,980
Petroleum (crude) (thousand 42-gallon barrels)	223,623	668,202	225,050	704,407
Salt (thousand short tons)	7	44	9	50
Sand and gravel (thousand short tons)	5,041	6,288	4,784	5,829
Stone (thousand short tons)	17,290	21,950	17,676	22,888
Zinc (recoverable content of ores, etc.) (short tons)	6,921	1,869	<sup>4</sup>	<sup>4</sup>
Value of items that cannot be disclosed:				
bentonite, cement, copper, lime, silver, tripoli, volcanic ash, and value indicated by footnote 4	----	23,360	----	26,884
Total	----	\$1,016,832	----	\$1,097,332

<sup>1</sup> Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

<sup>2</sup> Excludes bentonite; included with "Value of items that cannot be disclosed."

<sup>3</sup> Based primarily on railroad car loadings.

<sup>4</sup> Included with "Value of items that cannot be disclosed."

# TRACE-ELEMENT ANALYSES OF THE ADA SHALES AND SANDSTONES, SEMINOLE AND PONTOTOC COUNTIES, OKLAHOMA

ASSAD IRANPANAH\*

A semiquantitative emission spectrographic analysis of 28 selected samples from Ada shales and sandstones was performed to investigate the geochemistry of the Ada Formation (Pennsylvanian), and the results show that some elements are enriched in particular groups of rocks. Boron, copper, nickel, and chromium are more abundant in the shale units. No apparent difference in the zirconium or thorium concentrations exists between sandstone and shale units. Calcium and magnesium have approximately equal concentrations in the sandstones and shales, except for those that lack carbonate cement or carbonate rock fragments. Data obtained from the trace-element analyses of the sandstones seem to be meaningless because of their wide variability in proportion of grains and matrix materials and in the relative amount of clay minerals, carbonates (both as cement and allochems), and organic materials (asphaltic sandstone). The results may be improved by separation of the clay content from the sandstones and by making separate analyses of the trace elements.

*Discussion of Results.*—The Ada Formation is a Paleozoic terrigenous rock unit that crops out in east-central Oklahoma (fig. 1) and consists of interbedded sandstone and shale with one conglomerate unit at the base (fig. 2).

A study was undertaken to determine the geologic history of this formation because it contains evidence of late Paleozoic orogeny in the Arbuckle Mountain area (Iranpanah, 1966). Petrographic studies of the shale and sandstone members, shape-index analysis of the conglomerate member, and examination of various textural properties provided some criteria useful for environmental interpretation. However, most of these clastic features studied in hand specimen or under the petrographic microscope are related primarily to the source area and mechanical processes of sedimentation.

A trace-element study was made to provide some information on the geochemistry of the Ada Formation. The elements investigated for the interpretation of the environment were boron, titanium, thorium, manganese, nickel, chromium, copper, vanadium, zirconium, calcium, and magnesium. The concentration of elements such as strontium, gallium, lithium, rubidium, fluorine, and sulfur, which are characteristic elements used for the interpretation of marine versus nonmarine environments, were not measured because of technical difficulties.

The abundance of boron in marine sediments has been used by many workers for environmental interpretation. Landergren (1945) suggested that boron can be used as an indicator of paleosalinity. Boron would seem to be a better element for environmental determina-

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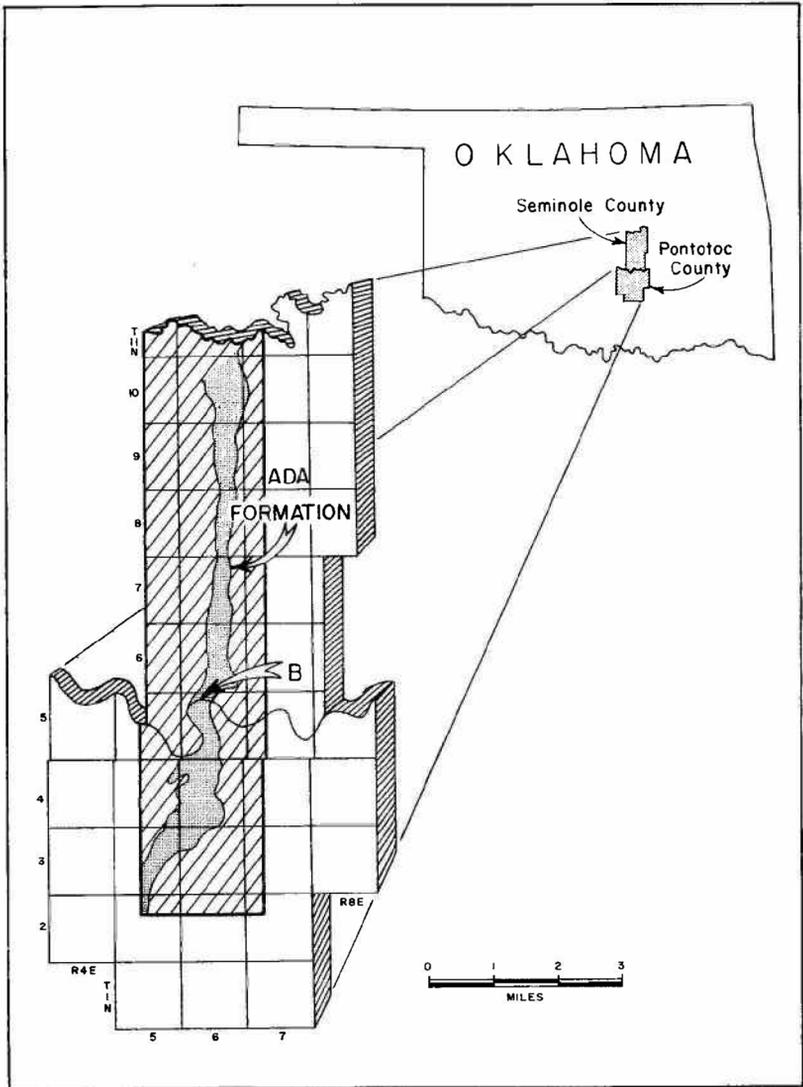


Figure 1. Index map showing generalized outcrop of the Ada Formation in Pontotoc and Seminole Counties, Oklahoma.

tion than sulfur and fluorine because it occurs in the sediments in a relatively insoluble form, but fluorine and sulfur are both more susceptible to post-depositional removal. The probable form of combination of boron in the clay-mineral structure has been shown by Degens, Williams, and Keith (1957, 1958) and indicates that boron is fixed in the octahedral layers of the clay structure in such a way that it can

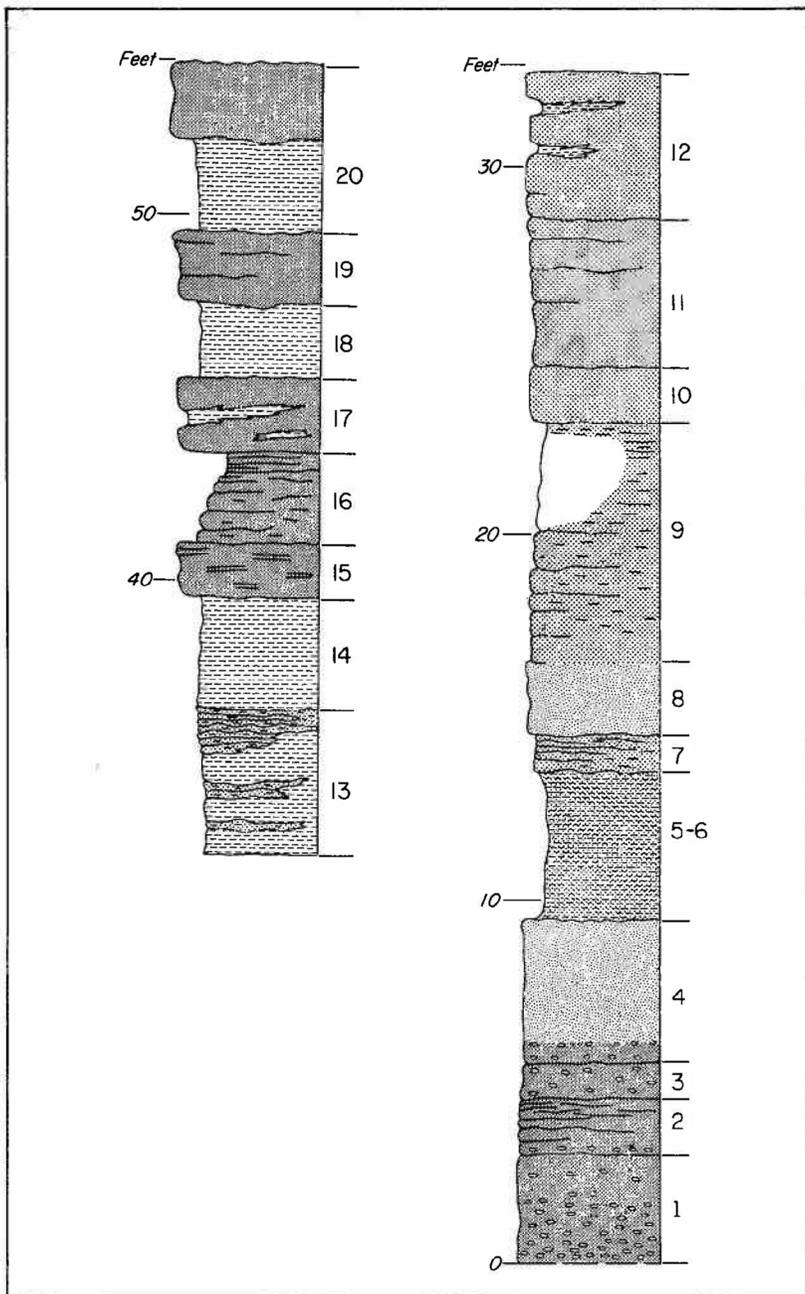


Figure 2. Stratigraphic section B of Ada Formation, sec. 4, T. 5 N., R. 6 E.

be removed only by treatment of the clay with moderate to strong acids. Boron is, in part, in a similarly insoluble form in modern marine muds (Goldberg and Arrhenius, 1958). Degens, Williams, and Keith (1958) have also suggested that boron may occur in tourmaline formed by reaction between ocean water and clay minerals.

The boron content in the Ada Formation ranges from a value of about 1 ppm in the sandstones, to as much as 75 ppm in shale units. In general, the boron content increases in the shale units northward from an average of about 20 ppm to 38 ppm in an irregular manner. The maximum boron content was found to be 75 ppm, which is present in the uppermost shale unit.

Comparison of the boron content within the Ada shale units shows that boron increases to the top of the formation in a single section (fig. 2) as does the illite content. Frederickson and Reynolds (1960) suggested that in clay minerals boron is preferentially associated with illite. Thus the boron content appears to be proportional to the illite content of the shale.

Boron in the sediments of the Ada Formation may have been transported into the environment of deposition, after alteration of primary source rocks, in the structure of illitic clays or as hydrolyzates or oxides.

The clay-size fraction derived as detritus from the source area should be closely related to the environmental conditions of the primary basin and/or to the composition of the bedrock, soil, and climate of the source area. Some modification, such as adsorption, recrystallization, and the other chemical reactions, may also take place in order for the sediments to attain an equilibrium with the new environment. Determination of the degree to which the sediments have approached equilibrium with the new environment and a quantitative evaluation of how much of the clay fraction was derived from the source area and/or deposited authigenically is difficult. Therefore the application of trace-element analyses in reworked sediments, such as the Ada Formation, must be made with extreme caution.

The results of this investigation show that the amount of boron decreases as the particle size decreases. The carbonate fraction of the shale units also decreases by decreasing the size fraction; however, I found no relationship between the two. According to Sahama (1945), boron might be precipitated in the sea as relatively insoluble calcium and magnesium borates. However, Landergren (1945) suggested that boron in the sediments occurs in a relatively soluble form.

The data would suggest that boron is concentrated in minerals of the coarser size fractions. This apparent contradiction of boron being associated with illite and also concentrated in the coarser size fractions is explained by the presence of rock fragments with high illite contents. Thus the boron would seem to be derived from the same area.

The results of the analyses of the thorium content were found to be unsatisfactory as they show surprisingly little deviation from one sample to another.

The calcium and magnesium contents for most samples are more than 1,000 ppm, except for those that lack carbonate cement (table I).

TABLE I.—TRACE-ELEMENT ANALYSES OF ADA SEDIMENTS  
CONCENTRATION OF ELEMENTS (PPM)

SAMPLE NO.	SIZE (MICRONS)	B	Ti	Mn	Cu	V	Ni	Cr	Zr	Th	Ca	Mg
A-1	Bulk	ND	200	50	<1	25			ND	500	1000	500
A-4	Bulk	ND	80	75	<1	25			ND	400	>1000	300
B-6	Bulk	10	200	ND	<1	25	1	10-25	50	200	200	1000
B-7	Bulk	5	75	ND	1	10	ND	10-25	ND	400	75	300
B-10	Bulk	ND	50	ND	<1	<10			ND	300	100	50
B-13	Bulk	10	350	50	1	75	5	50	100	400	1000	>1000
B-13	1/2-1/4	<10	100	ND	1	10	<5	ND	ND	ND	300	1000
B-14	Bulk	20	400	75	300	50	40	50	150	300	>1000	>1000
B-14	1/8-1/100	<10	100	ND	75	25	<5	<25	ND	400	300	1000
B-16	Bulk	10	300	50	50	50	1	<50	200	400	1000	>1000
B-16	8-16	<10	200	50	1	10	5	ND	ND	400	>1000	>1000
B-18a	Bulk	20	400	75	50	75	10	<50	150	400	>1000	>1000
B-18b	Bulk	75	350	75	50	50	10	<50	200	350	>1000	>1000
B-18	1/8-1/100	10	75	ND	50	25	5	25	ND	300	200	1000
C-1	Bulk	ND	250	75	50				75	300	>1000	>1000
C-1b	Bulk	ND	150	100	1				100	400	>1000	>1000
C-4	Bulk	1	100							350	>1000	>1000
C-10	Bulk	1	100							550	>1000	>1000
D-6	Bulk	1	75							500	>1000	>1000
D-7	Bulk	1	50							350	>1000	>1000
D-22	Bulk	1	75							300	>1000	>1000
D-23	Bulk	1	200							350	>1000	>1000
E-4a	Bulk	50	1000	75	10	200	50	50	300	550	1000	>1000
E-4b	Bulk	25	300	100	1	100	40	1	350	600	800	>1000
F-5	Bulk	ND	75							300	1000	>1000
F-7	Bulk	10	400							400	1000	1000
F-8 <sub>a</sub>	Bulk	ND	75							500	>1000	500
G-8	Bulk	ND	300							550	300	500

The nickel content was found to be a maximum of 1 ppm in the sandstones and 40 ppm in the shales. Nickel commonly is more predominant in a marine environment than in fresh water. During weathering, nickel remains largely in the solid products of disintegration and is deposited with the hydrolyzate sediments (Rankama and Sahama, 1950).

Copper was found to be present in an amount of 1 ppm in the sandstones, but 1 to 300 ppm in the shale units. The abundance of copper in the lower shale unit is compatible with the presence of a rather sharp endothermic peak at about 350°C in the DTA patterns. This peak is believed to belong to a sulfide compound, probably chalcopyrite.

The remainder of the semiquantitative data listed in table I shows no definite pattern of variation in concentration of the trace elements.

*Conclusions.*—Comparison of the boron content within the Ada shale units shows that boron increases to the top of the formation in a single section (measured section B, fig. 1) as does the illite content. Frederickson and Reynolds (1960) suggested that in clay minerals boron is preferentially associated with illite. Therefore, the conclusion is that boron in the Ada sediments was transported into the environment of deposition from alteration of the primary source rocks in the structure of illitic clays. Thus the boron content is a useless geochemical indicator of the environment of deposition for the Ada Formation. The remaining trace elements provide little definitive information for the interpretation of the environment of deposition.

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## Mineral Map of Oklahoma

GM-15, *Mineral Map of Oklahoma* (exclusive of oil and gas fields), by Kenneth S. Johnson, will be released by the Oklahoma Geological Survey in February and represents a complete revision and updating of an earlier map issued in 1955. The new map shows the distribution of the State's mineral resources and the locations and names of companies mining and using these resources. Published at a scale of 1:750,000 (1 inch = 12 miles), the map is available for \$1.00 from the Survey, The University of Oklahoma, Norman, Oklahoma 73069.

Annual mineral production in Oklahoma is valued at more than \$1 billion, nearly 5 percent that of the entire United States, and the State is the fourth leading producer in the nation. Names of operating companies are shown on the new mineral map beside the location of the company mine, pit, quarry, or plant. Included among new mining operations in the State are the Kerr-McGee and Howe Coal Company coal mines in eastern Oklahoma and Eagle-Picher's copper mine in the southwest.

Distinctive color-keyed symbols show active strip mines or quarries, active underground mines, plants separated from their quarries, inactive pits, quarries, and mines, and isolated mineral deposits or prospects. These symbols distinguish nonmetallic deposits and mines, metallic deposits and mines, and deposits and mines in asphalt and coal. Outlined separately on the map are large areas underlain by the following major resources: coal, dolomite, glass sand, granite, gypsum, lead and zinc, limestone, and salt.

Although Oklahoma is well known as an oil state, its nonpetroleum mineral resources represent a vast reserve of future wealth. The State ranks third among the states in production of helium, second in tripoli, and fifth in gypsum. A brief paragraph on each of the State's non-petroleum mineral resources discusses the purity, reserves, distribution, and economic uses of the material. To aid in further studies, a list of 54 publications containing the best available information on geology, distribution, and economic development of each mineral resource in Oklahoma is also included.

The new Oklahoma mineral map represents an important tool in the preliminary evaluation of mineral resources in the State and should be of great interest to potential mineral producers, highway and construction industries, educators and students of earth science and economic geography, and mineral collectors throughout the State.

### New Theses Added to O. U. Geology Library

The following master's thesis and doctoral dissertation have been added to The University of Oklahoma Geology Library recently:

#### **Master of Science Thesis**

*Geology and petrology of selected tectonic dolomite areas in the*

*Arbuckle Group, Arbuckle Mountains, south-central Oklahoma*, by Kenneth A. Sargent.

#### Doctoral Dissertation

*Stratigraphic, structural, and geomorphological factors controlling oil accumulation in Upper Cambrian strata of central Ohio*, by Edward Dawson Dolly.

## OKLAHOMA ABSTRACTS

### THE UNIVERSITY OF IOWA

#### Basal Maquoketa Phosphatic Beds

SAMUEL H. BROMBERGER. The University of Iowa, Ph.D. dissertation, 1968

A study of phosphatic horizons in the lower portion of the Maquoketa Formation of Iowa and of strata believed to be equivalent to the Maquoketa in nearby states was undertaken with the goal of formulating a comprehensive hypothesis of origin for these rocks. Samples were collected from exposures and cores over an area that included the states of Iowa, Wisconsin, Illinois, Indiana, Missouri, and Oklahoma. Exposures of the contact between the Maquoketa and subjacent carbonates are relatively scarce in this area.

Maquoketa rocks are separated from subjacent carbonate rocks by an unconformity of regional extent. Only in very few places (e. g., near Kentland, Indiana) are underlying rocks visibly truncated by Maquoketa strata. In other exposures and cores, the pre-Maquoketa unconformity may be marked by a karstlike surface. In most cases, however, indirect evidence must be relied upon to support the presence of an unconformity.

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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.

Limestones and dolomites that underlie Maquoketa and equivalent rocks may contain particulate phosphatic debris or apatite as replacement of carbonate. A phosphatic crust, believed to have been formed by direct chemical precipitation of apatite, may occur on the surface of the carbonates.

Maquoketa phosphatic horizons are predominantly phosphate- and pyrite-bearing carbonates. Several types of phosphatic particles are recognized within these beds. Phosphatic oolites and pisolites seem to have been formed by direct chemical precipitation. There is no evidence to indicate that they were once carbonate. Phosphatic pebbles and phosphatic shells of organisms belonging to groups known to secrete carbonate shells are thought to be the product of apatite replacement. Some of the pebbles and shells are incompletely replaced, thus attesting to their original carbonate composition, though some of the pebbles could have been derived by reworking of the precipitated apatite crust. Small phosphatic clasts with no internal structure are also present. Some of the phosphatic debris in Maquoketa rocks was originally phosphatic (i. e., conodonts and inarticulate brachiopods).

There is generally one phosphatic horizon at the base of the Maquoketa, but there may be additional horizons higher in the formation. These are discontinuous geographically and occur without predictable periodicity in the section. The stratigraphically higher phosphatic horizons are believed to be the product of reworking of lower horizons by waves and currents.

The mineralogy of apatites is reviewed. The Maquoketa apatite is thought to be carbonate fluorapatite (francolite) on the basis of a comparison of its lattice dimensions with published data. Recent investigations suggest that carbonate is part of the crystal lattice in francolite.

The most immediate origin of the famous "depauperate fauna" found in the lower part of the Maquoketa Formation would seem to be transportation of fossils, as has been suggested by Tasch (1953). However, knowledge of the ultimate origin of this fossil assemblage will have to await restudy of the fossils by taxonomists.

(Reprinted from Dissertation Abstracts,  
Pt. B, vol. 29, no. 6, p. 2084-B)

## WASHINGTON UNIVERSITY

### Tectonic Genesis of the Ozark Uplift

TIKRITY, SAMMI SHERIF, Washington University, Ph.D. dissertation, 1968

Based on geological and geophysical study of the eastern half of the Ozark Uplift and the surrounding regions, three major Paleozoic tectonic elements of the Ozark Uplift are recognized. These are here

called the St. Francois dome, the Ozark arch, and the Decaturville dome. The central part of each of the three tectonic elements is underlain by granitic Precambrian basement. These granitic basements were structurally higher than the felsitic, metamorphic, and more basic basements of the surrounding regions in Precambrian time. Thus, the Paleozoic tectonic elements reflect their Precambrian ancestors.

Each of the three elements has had a different Paleozoic tectonic history. The St. Francois dome was uplifted initially in early Pennsylvanian time when it attained more than 80 percent of its total 13,000 feet of structural relief. The other two features were uplifted in late Early Ordovician and in late Middle Devonian, when they attained about 60 percent of their present 11,000 feet of structural relief. These two features were rejuvenated during the early Pennsylvanian period of deformation.

The sedimentary environment of the epeiric seas changed drastically after each of these three tectonic episodes and was characterized by the deposition of clastic sediments.

Post-Pennsylvanian uplifts make up less than 18 percent of the total accumulative differential movement of the Ozark Uplift, and the area has not been penneplained since it emerged from the last Pennsylvanian sea.

The Ozark arch has not been active, at least since the late Cretaceous time, while the St. Francois dome was active in Late Tertiary and in Recent geologic time. This trend is probably continuous into present time and may explain the seismicity of the area.

The basement faulting was the primary factor in the delineation of the tectonic and structural pattern of the sedimentary features of the area. The lighter blocks of the Earth's crust, predominantly granite, were moving upward in stages, relative to the heavier blocks, through geologic time. The tectonic forces that moved these blocks differentially were vertical, contrary to the traditionally accepted interpretation of tangential and/or compressional forces.

The faults of the area are steeply dipping. These faults are either normal or high-angle reverse type, whereas strike-slip and thrust faults are unknown in the area. Folds are present, but these are fault-controlled asymmetrical anticlines that have no equivalent synclines.

(Reprinted from Dissertation Abstracts,  
Pt. B, vol. 29, no. 12, p. 4717-B)

## THE UNIVERSITY OF WISCONSIN

### Origin of Isolated Sandstone Masses in Shales of Late Paleozoic Flysch, Ouachita Mountains, Southeastern Oklahoma

BLACK, BRUCE ALLEN, The University of Wisconsin, Ph.D. dissertation, 1969

This thesis deals with the mode of occurrence, distribution, description, and genesis of sandstone masses that occur partially or entirely isolated in shales of an Upper Mississippian-Lower Pennsylvanian flysch succession in the Ouachita Mountains of southeastern Oklahoma.

Methods of study utilized in this investigation include field observations of mode of occurrence, local and areal distribution, nature and relationship of enclosing shale, type and variety of megascopic surface features, and variations in size. In addition, approximately 250 specimens were collected for detailed laboratory studies, including shape analysis, examination of external surface features, X-radiography of 210 specimens to determine nature and variety of internal sedimentary and deformational structures, and examination of 15 thin sections to check for microscopic brecciation and mineralization of small-scale faults.

Information derived from these field and laboratory studies permits recognition of five types of isolated sandstone masses, namely, detached load-casts, isolated load-pockets, ball-and-pillow structure, slide blocks, and sandstone masses produced by submarine plastic mass flow downslope.

Distinction between these five types of isolated sandstone masses is not always obvious, particularly in hand specimen, but sufficient information can commonly be obtained from field relationships and various features of the masses themselves to permit recognition of each type in most situations. None of the characteristics described in this thesis is unique to any single type, and it is doubtful, therefore, that a set of rigid criteria can be established for differentiating one type from another in some situations, particularly where poor exposures, superimposed structural complexities, and/or mixed occurrences exist.

It is quite possible, as well as highly probable, that some of the isolated sandstone types may pass through a series of stages, starting as one kind and ending up as another, depending on whether the deformation process is arrested at some intermediate stage or goes to completion. The isolated sandstone masses, therefore, may be visualized as comprising a spectrum of soft sediment deformation that on one extreme involves very local vertical adjustments between a freshly deposited sand layer and an underlying water-saturated mud, whereas on the other extreme lateral displacements dominate the deformation process, possibly to the extent that a turbidity current results if the liquid limit of the mass is exceeded.

It is concluded that all five types of isolated sandstone masses are products of soft sediment deformation. Deformation of some types was initiated and culminated before deposition of the sand ceased, but, in other types, deformation was initiated sometime after deposition ceased, although it had culminated before deposition of the covering layer or before burial to any great depth. Included in the latter category are isolated load-pockets and ball-and-pillow structures, both of which collectively constitute the most abundant and widespread types in the Stanley-Jackfork-Johns Valley-Atoka flysch sequence. Sandstone masses produced by plastic mass flow downslope are the most abun-

dant and characteristic of the Johns Valley Formation in exposures in the Winding Stair Range and in the north limb of the Lynn Mountain syncline west of U. S. Highway 271.

Mode of occurrence, local and areal distribution, distinguishing characteristics, morphology, and nature of deformation as revealed by field relationships and X-radiography preclude a concretionary origin or genesis by folding and faulting in conjunction with the Ouachita orogeny, although the effects of the latter have been superimposed on some sandstone masses now occurring in fault zones.

(Reprinted from Dissertation Abstracts,  
Pt. B, vol. 30, no. 4, p. 1750-B)

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