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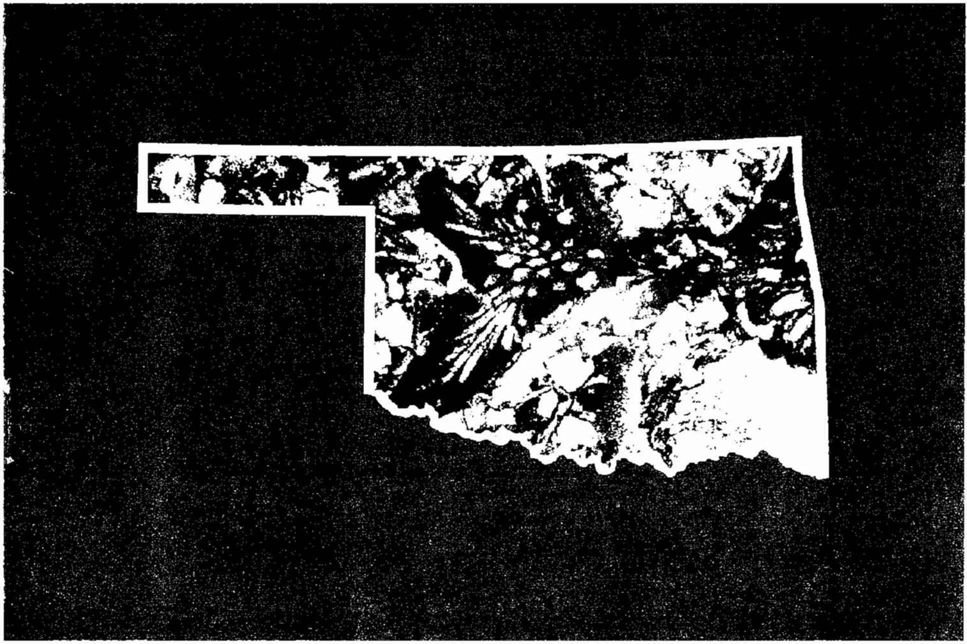
OKLAHOMA GEOLOGY NOTES



VOLUME 26 NUMBER 6 JUNE 1966

Cover Picture

LOWER MISSISSIPPIAN BIOHERM

The cover picture is a photomicrograph (x12) of a thin section from one of the biohermal developments within the St. Joe Limestone of northeastern Oklahoma. The bioherm is on the north side of Salina Creek, sec. 8, T. 21 N., R. 22 E., near Kenwood, Delaware County.

The St. Joe, thickening abruptly from 25 feet to 125 feet, forms a steep bluff with moderately dipping flank beds. This section, from a bed above the core area, is a crinoidal, bryozoan calcarenite and exhibits a bryozoan which is the organism forming the core network of the bioherms.

These bioherms are developed within the St. Joe Limestone in northeastern Oklahoma, southwestern Missouri, and northwestern Arkansas. They are described by A. R. Troell in the Journal of Sedimentary Petrology (vol. 32, no. 4, 1962) and by M. E. Anglin in the Shale Shaker (vol. 16, no. 7, 1966).

— *T. L. Rowland*

Statistics of Oklahoma's Petroleum Industry, 1965

Louise Jordan

In 1965, the greatest concentration of wildcat activity in Oklahoma was along the north flank of the Anadarko basin in Garfield, Kingfisher, Alfalfa, and Major Counties where the principal objective is production from fractured Mississippian limestone. Interest was revived in deeper and older formations, particularly the Hunton, with the discovery of gas in East Arnett in Ellis County by the Pan American 1 Boyd Unit (C SW¼ SE¼ sec. 32, T. 20 N., R. 23 W.). This previously abandoned dry hole, deepened from 10,964 to 15,000 feet, was perforated at 13,426 to 13,429 feet in the uppermost part of the Hunton carbonates. Gas flowed at a rate of 9,500,000 cubic feet per day through a ¾-inch choke. This production is probably related to structural control rather than to the truncated edge of the Hunton, which is being developed farther to the north on the shelf. Nearest previously discovered Hunton production is 45 miles north in the Selman field in Harper County. One well about 30 miles north at East Fort Supply found some gas production in the Hunton in 1962.

Two new areas of gas production (West Durham and Northeast Crawford) were found in Virgilian rocks in northern Roger Mills County. The axis of the Anadarko basin at the surface crosses the southern part of the county, and no well has penetrated rocks older than Springer even though depths of 16,000 and 19,000 feet have been reached in the northern and southern parts of the county, respectively. First gas production in the county was discovered in 1961 at West Reydon field in Morrow sandstones (Jordan, 1962), and first oil production in 1964 in Tonkawa sandstones in sec. 21, T. 17 N., R. 25 W., now included in the Bishop field.

In the Arkoma basin area, the gas-productive area continues to increase in size, with discoveries at West Cedar and Peno in Le Flore County, and at McAlester, Southwest McAlester, and South Quinton in Pittsburg County. Two wildcats in Haskell County were successfully completed, but these have already been included in the expanded Kinta field. Production is from Morrowan and Atokan sandstones. In the southern part of the Wilburton field, the Shell 1-4 Williams-Mabry well (sec. 4, T. 4 N., R. 18 E.) discovered gas which flowed at a rate of 2 million cubic feet per day from the Spiro at 2,947 feet in an upthrown block along the Choctaw fault. Normal depth to the Spiro in the Wilburton pool is 11,000 feet.

Well data have been compiled and published annually by various organizations. The *Oil and Gas Journal* has been for many years the primary source used by the U. S. Bureau of Mines for data on exploratory, development, and total wells drilled in the United States. *World Oil* has compiled similar data in its annual forecast-review issues. The International Oil Scouts Association publishes a comprehensive report annually on development and exploration in the oil industry. The Committee on Statistics of Exploratory Drilling of the American Association of Petroleum Geologists has compiled and published in the *Bulletin* data on exploratory drilling since 1937. Normally the data in these publications do not agree.

In late 1965, after the Federal Government had completed its investigation into energy resources of the United States and had pointed out to the petroleum industry that the statistics were not complete and left much to be desired, the AAPG's former Committee on Statistics of Exploratory Drilling (CSED) was expanded to report on all wells and was renamed the Committee of Statistics of Drilling (CSD). The collection and publication of the data are to be a joint venture between the AAPG and the *Oil and Gas Journal.* Under the new program every well drilled in the United States is reviewed by a CSD member, who is a geologist. This will be the first total well count in which a geologist's judgment and knowledge of drilling conditions in his area will be reflected in the data collected. The data gathered will fill the information gap spotted by the Federal Government. In all probability the total number of wells drilled in Oklahoma, as well as in other states, will take a jump in 1966 because many new sources of unreported drilling information have already been discovered. The official statistics will be published monthly by the *Oil and Gas Journal.*

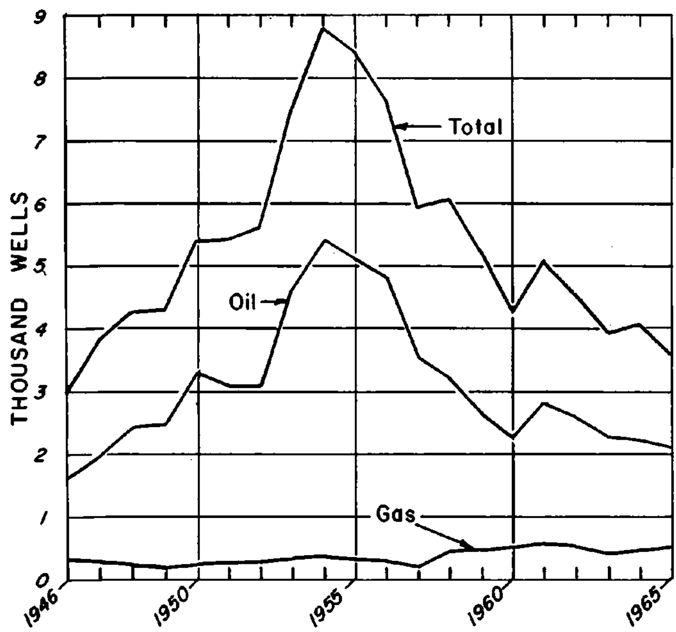


Figure 1. Graph showing total wells drilled, oil wells completed, and gas wells completed in Oklahoma, 1946-1965. Source: Oil and Gas Journal.

TABLE I.—DRILLING ACTIVITY IN OKLAHOMA, 1965

	1965					1964	1966
	CRUDE	GAS	DRY	SERVICE	TOTAL	TOTAL	FORECAST
All wells							
Number of completions	2,183	549	1,277	481	4,490	4,516	4,786
Footage	9,745,377	3,557,078	5,734,222	910,806	19,947,483	18,465,093	21,398,000
Average footage	4,464	6,479	4,490	1,894	4,443	4,089	
Exploration wells							
Number of completions	56	43	319		418	484	529
Percentage of completions	13.4	10.3	76.3		100		
Footage	386,981	326,679	1,757,081		2,470,741	2,887,968	
Average footage	6,910	7,597	5,508		5,911	5,967	
Development wells							
Number of completions	2,127	506	958	481	4,072	4,032	4,257
Footage	9,358,396	3,230,399	3,977,141	910,806	17,476,742	15,577,125	

Source: Oil and Gas Journal, annual forecast and review issue, vol. 65, no. 5, January 31, 1966.

Table I summarizes drilling activity in Oklahoma in 1965. Total wells drilled and number of oil wells completed in 1965 continue the decline from a major peak established in 1954 and a minor rise in 1961 (fig. 1). The number of gas wells completed has remained fairly constant since 1957, averaging about 500 a year.

Table II summarizes hydrocarbon production for 1965 and shows the data of the previous year for comparison. The figures on cumulative production (1891-year) differ in the base used in previous years. Totals by the American Petroleum Institute and the U. S. Bureau of Mines omit production for the years 1905 and 1906 because it was combined with that of Kansas. Arnold and Kemnitzer (1931) made estimates for Oklahoma of 8,264,000 and 18,091,000 barrels for these two years, and it seems more reasonable to include these figures in the cumulative total.

Table III gives the marketed production and value of petroleum, natural gas, natural gasoline, and liquefied petroleum gas from 1956 through 1965 and the cumulative totals. The table is repeated this year because the value of crude petroleum and volume of natural gas through 1954 were incorrectly reported last year in *Oklahoma Geology Notes* (vol. 25, p. 157).

Estimated reserves of crude oil and liquid hydrocarbons in Okla-

TABLE II.—HYDROCARBON PRODUCTION IN OKLAHOMA, 1964-1965

	END OF 1964	END OF 1965
Crude oil and lease condensate		
Total annual production (1,000 bbls)[1]	202,524	200,750
Value ($1,000)[1]	587,320	582,175
Cumulative production, 1891-year (1,000 bbls)	9,052,534[4]	9,253,284
Daily production (bbls)[3]	556,000	560,300
Total number of producing wells[4]	83,068	84,152
Daily average per well (bbls)[3]	6.7	6.7
Oil wells on artificial lift (estimated)[2]	76,602	76,200
Natural gas		
Total annual marketed production (MMCF)[1]	1,323,390	1,385,400
Value ($1,000)[1]	166,747	175,950
Total number of gas and gas-condensate wells[2]	6,813	7,100
Natural-gas liquids		
Total annual marketed production (1,000 gals)[1]	1,434,857	1,464,200
Value ($1,000)[1]	62,066	63,420

[1] Item for 1964 is U. S. Bureau of Mines final figure. Item for 1965 is U. S. Bureau of Mines preliminary figure.

[2] World Oil, annual forecast and review issue, vol. 162, no. 3, February 15, 1966.

[3] Oil and Gas Journal, annual forecast and review issue, vol. 65, no. 5, January 31, 1966.

[4] Figure differs from that shown in 1964 statistical report (Okla. Geology Notes, vol. 25, p. 156) primarily because it is based upon Oklahoma Geological Survey compilation. See footnote on table III.

Table III.—Cumulative (through 1955) and Yearly (1956-1965) Marketed Production and Value of Petroleum, Natural Gas, Natural Gasoline, and Liquefied Petroleum Gas in Oklahoma[1]

Year	Crude Petroleum		Natural Gas		Natural Gasoline and Cycle Products		Liquefied Petroleum Gas	
	Volume (1,000 bbls)	Value ($1,000)	Volume (MMCF)	Value ($1,000)	Volume (1,000 gals)	Value ($1,000)	Volume (1,000 gals)	Value ($1,000)
Through 1955	7,230,010	11,443,269	12,977,332	1,378,370	14,420,482	890,729	3,673,364	120,097
1956	215,862	600,096	678,603	54,288	489,963	26,543	579,101	23,427
1957	214,661	650,423	719,794	59,743	460,644	25,329	587,140	21,824
1958	200,699	594,069	696,504	70,347	440,798	26,029	657,114	25,822
1959	198,090	578,423	811,508	81,151	448,353	29,443	675,869	27,070
1960	192,913	563,306	824,266	98,088	531,995	33,074	762,258	32,409
1961	193,081	561,866	892,697	108,016	521,237	33,358	817,082	30,141
1962	202,732	591,977	1,060,717	135,772	552,795	35,764	838,903	25,223
1963	201,962	587,709	1,233,883	160,405	555,467	35,131	810,894	28,981
1964	202,524	587,320	1,323,390	166,747	554,053	34,011	880,804	28,055
1965[2]	200,750	582,175	1,385,400	175,950	560,400	33,620	903,800	29,800
	9,253,284	$17,340,633	22,604,094	$2,488,877	19,536,187	$1,203,031	11,186,329	$392,849

[1] Figures from: Minerals Yearbooks of the U. S. Bureau of Mines. Totals for crude petroleum differ from those compiled by the U. S. Bureau of Mines and the American Petroleum Institute principally because of the exclusion from U. S. B. M. and A. P. I. compilations of an estimated production of 26,355,000 barrels for the years 1905-1906. The cumulative figures for the value of crude petroleum and volume of natural gas through 1954 were incorrectly reported last year in Oklahoma Geology Notes, vol. 25, p. 157.

[2] Preliminary figures for 1965.

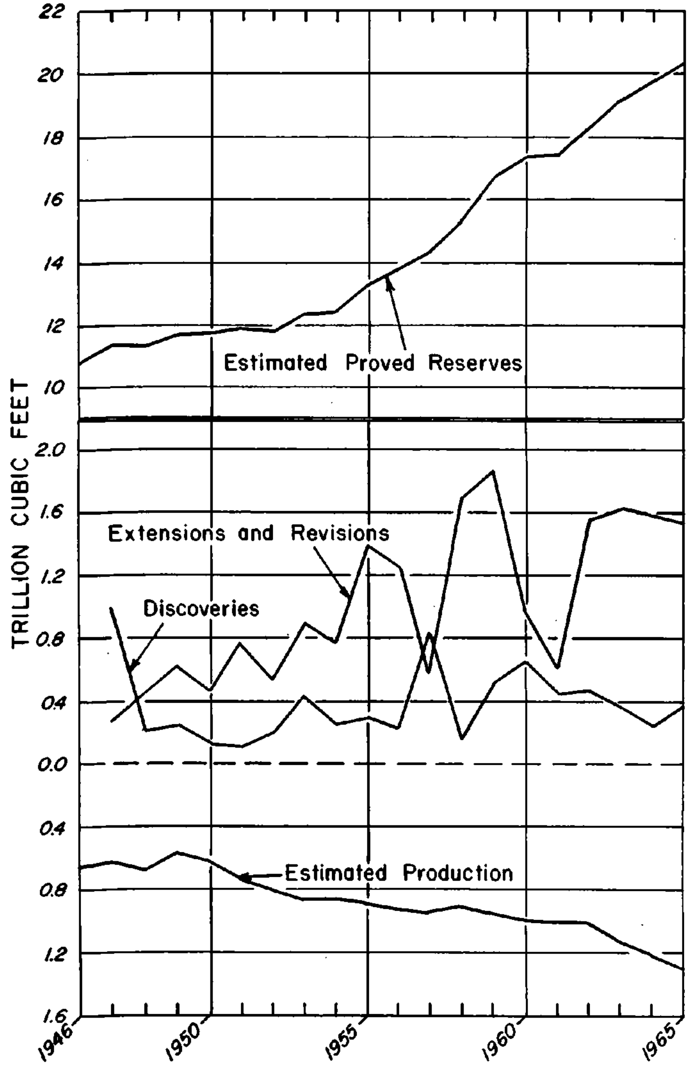


Figure 2. Graph showing statistics on estimated proved reserves of total liquid hydrocarbons in Oklahoma, 1946-1965. Estimated production is plotted in reverse direction (increasing downward) to indicate subtraction from reserves. Source: American Petroleum Institute, annual reports.

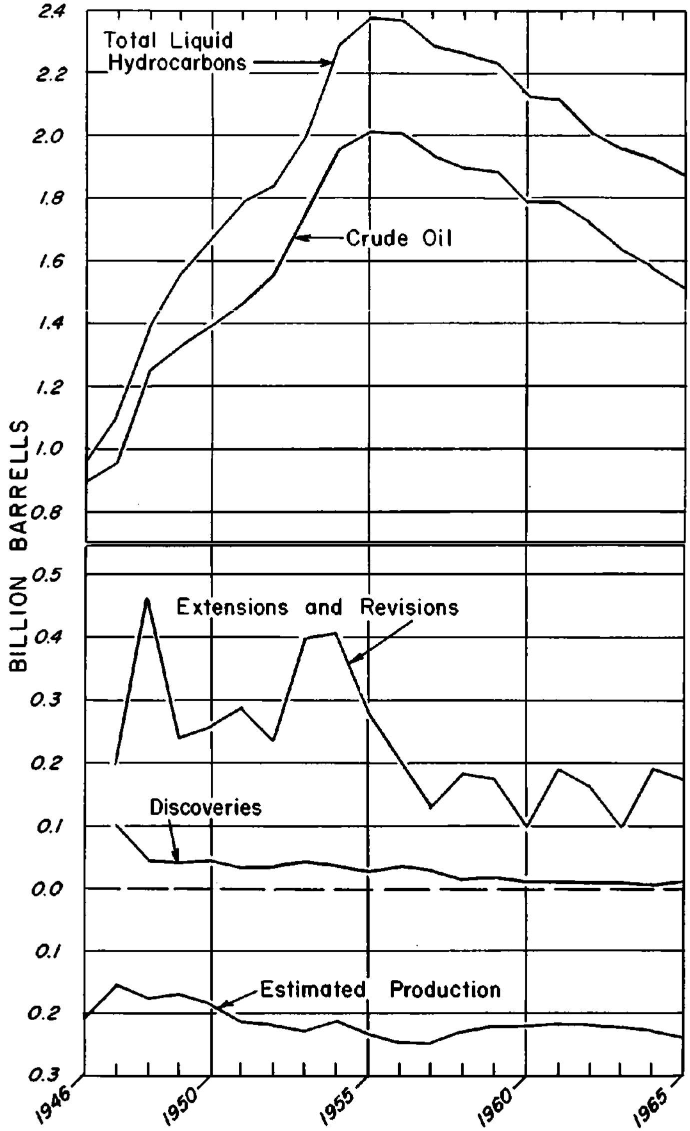


Figure 3. Graph showing statistics on estimated proved reserves of natural gas in Oklahoma, 1946-1965. Estimated production is plotted in reverse direction (increasing downward) to indicate substraction from reserves. Source: American Gas Association, annual reports.

homa continue to decline from the peak established in 1955. Figure 2 is a graph of the statistics on estimated proved reserves of crude oil and liquid hydrocarbons which have been annually compiled since 1946 by the American Petroleum Institute. Reserves from discoveries, which seldom are defined or fully developed during the year of discovery, have declined since 1947. Extensions of existing reservoirs normally provide important new reserve additions each year. Development drilling continues to generate reserve extensions and revisions of earlier years. Discoveries of the giant fields, Golden Trend in 1945, Elk City in 1947, and of new and deeper zones and in-fill drilling in Sho-Vel-Tum (Velma, Sholom Alechem, and Tatums) and perhaps the unitization of West Edmond in 1947, account for the peak of the extensions-revisions curve in 1948 and for the continued increase in estimated reserves of crude oil through 1952. A second peak of the extensions-revisions curve in 1953-1954 (fig. 2) appears to be related to the pronounced increase in the number of oil wells completed during these years as shown on figure 1.

Oklahoma ranks third (after Texas and Louisiana) in estimated proved reserves of natural gas among the states. Since 1954 these reserves have increased at a higher rate than in previous years (fig. 3). Since 1957 the number of gas wells completed have averaged around 500, and reserves have increased from 14 trillion to more than 20 trillion cubic feet. However, annual production during this period has increased from 0.94 trillion to 1.30 trillion cubic feet. In the curve showing reserves added because of discoveries, peaks in 1953, 1957, and 1960 are followed within a year or two by peaks on the extensions-revisions curve. The peak in 1955-1956 is probably related to reserves found during development drilling in Beaver County, that in 1958-1959 to those found in Harper County and along the northern shelf of the Anadarko basin, and the sustained high in 1962-1965 by development drilling in the Arkoma basin as well as in the Anadarko.

In order that estimated proved reserves in Oklahoma may continue to increase, new discoveries of considerable reserves will have to be made. For the United States as a whole, the reserve/production ratio hit a new low, declining from 18.4 in 1964 to 17.6 in 1965. The gas-reserves gain was primarily the result of a proportionately greater concentration of development efforts in existing fields and was not related to exploration for new fields. The gas-reserves gain in 1965 for Oklahoma was 600,179,000 cubic feet, or less than half of the 1,303,649,000 cubic feet of net production. Construction in progress of additional pipelines to the Arkoma basin and Anardako basin areas will result in substantial increase in natural-gas production in 1966.

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Petrology of Lester Limestone (Desmoinesian), Carter and Love Counties, Oklahoma*

W. R. Cronoble[1] and Dwight E. Waddell[2]

INTRODUCTION

The Lester Member of the Dornick Hills Formation (fig. 1) is composed of a lower limestone unit (approximately 4.5 feet thick) that is separated from an upper limestone sequence (10 to 15 feet thick) by a relatively thick shale unit ranging in thickness from 90 to 150 feet. For convenience in discussing petrological aspects of the Lester limestones, the terms "upper Lester" and "lower Lester" are employed for the limestones above and below the shale, respectively. Figure 2 shows the locations of five Lester stratigraphic sections sampled in the Ardmore area, Oklahoma.

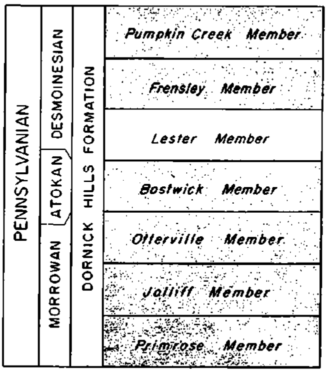

Figure 1. Subdivisions of the Dornick Hills Formation (Pennsylvanian) in the vicinity of Ardmore, Oklahoma.

The name Lester was proposed by Tomlinson (1929, p. 32) for a ledge of oölite grainstone in NE¼ NE¼ NE¼ sec. 13, T. 4 S., R. 1 E., Carter County, Oklahoma (fig. 2, stratigraphic section 1). The Atokan age of the Lester Member has not been contested. However, both the upper and the lower Lester are probably early Desmoinesian in age (fig. 1) because they contain the Desmoinesian fusulinids *Fusulina insolita* and *Fusulina mutabilis*.

Carbonate samples from the five stratigraphic locations were examined in thin section with the use of standard binocular and petrographic microscopes. The stratigraphic position of each sample is indicated in figure 3. Each carbonate thin section was analyzed with the use of the Folk (1959) techniques and concepts. Percentages of individual skeletal elements were estimated from each thin section. Although generic identification of skeletal elements is normally impossible because of the random cut of skeletal fragments, it is possible to identify such fragments as to phylum, and, commonly, as to class. Table I is a list of the estimated percentages of the different skeletal elements. Abrasion and fragmentation of skeletal elements were also

* Paper presented at the Ninth Geological Symposium, Norman, Oklahoma, March 1, 1966.

[1] Balcron Oil Company, Billings, Montana.
[2] Shell Oil Company, Midland, Texas.

observed. Insoluble-residue analyses were obtained for carbonate samples (table II). Limestone types, biologic assemblages, abrasion and fragmentation of skeletal material, and insoluble residues are discussed separately, and subsequently integrated to ascertain the environmental conditions under which the Lester limestones were deposited.

The "t-test," as discussed by Folk (1961, p. 57), was used to determine if variations in percentages of insoluble material and relative abundances of skeletal elements were significant or perhaps were due to chance sampling. In all cases, the variations in insoluble and skeletal content are real and significant. In most cases, the "t-tests" indicate less than one chance in one thousand that the variations are not real.

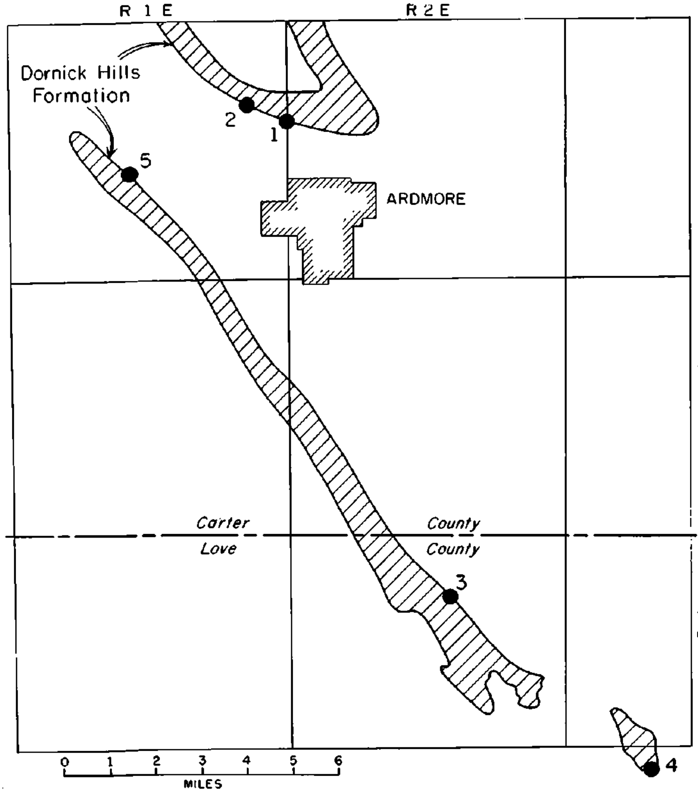

Figure 2. Outcrop map of the Dornick Hills Formation in the vicinity of Ardmore, Oklahoma, showing locations of stratigraphic sections of the Lester Member used in this study. Stratigraphic section 1 is the type section of the Lester Member.

Figures A, B, and C of plate I are illustrations of rock types collected from stratigraphic sections 1 and 2 (figs. 2, 3). These thin sections are characterized by an abundance of oölites, sparry calcite cement, and large (longer than 1 mm) bryozoan fragments (both fenestrate bryozoan, as in figs. A, B of pl. I, and encrusting bryozoan, as in fig. C). Minor percentages of pelecypods, gastropods, brachiopods, arthropods, and crinoids (throughout this paper, crinoid designation encompasses all echinodermal material observed in thin sections) are also incorporated into these rocks (table I). The estimated percentages of allochems occurring in the thin sections are given in table II. Oölites occur in all of the upper Lester samples. However, oölites are much more abundant in samples from stratigraphic sections 1 and 2, where the range is from 30 to 55 percent of total sample as compared to 1 to 15 percent at other localities. Percentages of skeletal material are lower in the oölite-rich rocks. Skeletal fragments in figures A-C of plate I are relatively large compared to fragments occurring in other photomicrographs. Most of the rocks collected from stratigraphic sections 1 and 2 are classified as slightly sandy bryozoan oösparites (to be included in the rock name, individual skeletal groups must constitute 10 percent or more of the rock).

The upper Lester rocks shown in figures D and E of plate I, collected from stratigraphic sections 3 and 5, are similar in rock type and are classified as sandy bryozoan-crinoidal-brachiopodal biosparrudite (terminology of Folk, 1959). This rock type dominates the sequence at localities 3 and 5. The percentage of oölites increases from the base to the top of the measured sections at these two localities. At locality 5 the increase is from 10 percent to 15 percent, and at locality 3 it is from a trace to 3 percent.

Considerably more quartz sand grains are associated with upper Lester samples from stratigraphic sections 3 and 5 (table II) than with samples from the more oölitic rocks of stratigraphic sections 1 and 2 and rocks from stratigraphic section 4. Skeletal elements in rocks collected from stratigraphic sections 3 and 5 show a higher degree of abrasion and of fragmentation in particular than do those occurring in samples from locations 1, 2, and 4.

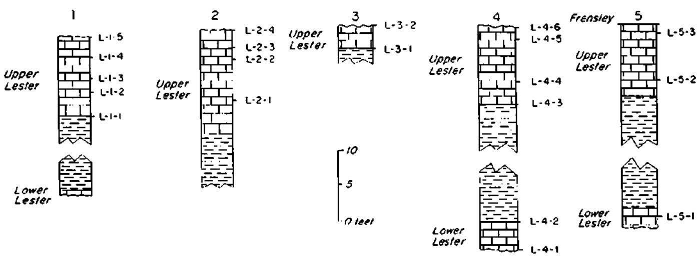

Figure 3. Columnar sections of the upper and lower Lester units showing stratigraphic positions from which samples were taken.

Figures F (lower Lester) and G (upper Lester) of plate I illustrate basic rock types collected from stratigraphic section 4. The rock type at stratigraphic section 4 is classified as *Osagia*-crinoidal-brachiopodal-bryozoan biomicrosparrudite (microspar results from recrystallization of micrite; Folk, 1959). The occurrence of microspar in these samples is probably due to the process of grain growth as discussed by Bathurst (1958, p. 28-30). Micrite was the probable original matrix; because of grain growth, the diameters of crystals (originally 1 to 4 microns) average 5 to 15 microns.

Excellent examples of the growth form *Osagia* sp. Twenhofel (intergrowth of probable blue-green algae and the foraminifer, *Nubecularia* sp.; Johnson, 1946, p. 1102-1103) occur in all samples collected from stratigraphic section 4. Bryozoan, crinoid, and brachio-

TABLE I.—PERCENTAGE AND TYPE* OF SKELETAL MATERIAL IN THE LESTER MEMBER

Sample Number	Bz	Cr	Pe	Ga	Ar	Od	Fr	Al	Os	Br
				upper Lester						
L-1-1	10	3	5		3	tr		tr		8
L-1-3	5	1	5	2	1	1		1	1	10
L-1-4	10	5	5	2		1	1		tr	5
L-1-5	7	2	8	3		1	1	tr	2	1
L-2-1	14	5	5	tr	tr			tr	2	4
L-2-2	18	5	3	2		tr		tr	tr	1
L-2-3	15	4	5	5					tr	1
L-2-4	20	4	3	3					2	3
L-3-1	30	20	1			2	1		3	10
L-3-2	20	20	2			3			tr	3
L-4-3	15	20	2		tr	1			10	5
L-4-4	15	25	1					1	10	10
L-4-5	20	20	1	tr		1	2		10	10
L-4-6	15	20	1				1		10	5
L-5-2	15	20	1		2	2	1		1	10
L-5-3	10	20	2	1		1	tr			10
				lower Lester						
L-4-1	10	25	2		tr	2			20	10
L-4-2	5	20	1			2			30	10
L-5-1	20	25	2	1		1			1	10
				Frensley Member † (locality L-5)						
		5	5				5			

* **Bz** = bryozoans; **Cr** = crinoids (includes all echinodermal fragments); **Pe** = pelecypods; **Ga** = gastropods; **Ar** = arthropods (other than ostracodes); **Od** = ostracodes; **Fr** = foraminifers; **Al** = green algae; **Os** = **Osagia**; **Br** = brachiopods.

† 30 percent skeletal material too fine for identification.

pod fragments are the dominant skeletal elements encrusted by *Osagia*. Oölite content increases in the upper Lester from the base of the unit to the top; at stratigraphic section 4 the increase is from 3 percent to 10 percent.

INSOLUBLE RESIDUES

Insoluble-residue analyses were made for Lester limestone samples from the five stratigraphic sections and the data are given in table II. Following initial hydrochloric acid digestions, residues were wet-sieved to determine percentages coarser and finer than 4.5 phi (1/24 mm diameter); the residues are composed essentially of terrigenous material.

The stratigraphic sections are separable into three fairly distinct groups, based upon generalizations regarding the relative abundance of insoluble residues in the samples and the proportions of the insoluble residues represented in the coarse fractions (coarser than 4.5 phi). The groups are:

(1) *Stratigraphic sections 1 and 2:* Percentages of insolubles lower than those of sections 3 and 5 but similar to those of section 4. Coarse fractions smaller than those of sections 3 and 5 but larger than those of section 4.

(2) *Stratigraphic section 4:* Percentages of insolubles about the the same as those of sections 1 and 2 but lower than those of sections 3 and 5. Coarse fractions smaller than those of

TABLE II.—INSOLUBLE-RESIDUE DATA AND ESTIMATED PERCENTAGES OF OÖLITES AND SKELETAL FRAGMENTS

UNIT	SAMPLE NUMBER	PERCENT RESIDUE	PERCENT OF RESIDUE >1/24 MM	PERCENT OÖLITES	PERCENT SKELETAL FRAGMENTS
U. Lester	L-1-1	15.2	61.9	40	29
U. Lester	L-1-3	8.8	61.0	45	27
U. Lester	L-1-4	7.2	48.7	40	29
U. Lester	L-1-5	8.1	53.4	45	25
U. Lester	L-2-1	5.1	26.3	30	30
U. Lester	L-2-2	4.1	15.8	55	29
U. Lester	L-2-3	6.7	28.7	50	30
U. Lester	L-2-4	7.9	12.0	35	35
U. Lester	L-3-1	15.7	56.9	5	67
U. Lester	L-3-2	34.6	75.0	5	48
L. Lester	L-4-1	9.6	1.8	0	69
L. Lester	L-4-2	7.8	1.4	0	68
U. Lester	L-4-3	7.6	1.1	1	53
U. Lester	L-4-4	13.9	15.5	3	62
U. Lester	L-4-5	6.4	3.4	3	64
U. Lester	L-4-6	24.4	69.2	10	52
L. Lester	L-5-1	29.7	88.5	5	60
U. Lester	L-5-2	35.1	82.4	10	52
U. Lester	L-5-3	29.3	78.6	15	44
Frensley	L-5	22.5	74.4	0	45

sections 3 and 5 and, except for the uppermost sample, of sections 1 and 2.

(3) *Stratigraphic sections 3 and 5:* Higher percentage of insolubles and larger coarse fractions than those of sections 1, 2, and 4.

In general, residues of samples from stratigraphic section 4 contain much less coarse terrigenous material than do residues from the other four sampling localities. The uppermost sample from stratigraphic section 4 (table II) shows an appreciable increase in percentage of total residue and a marked increase in percentage of coarse terrigenous material accompanied by an increase in oölite content.

Except for the anomalous uppermost sample from stratigraphic section 4, the content and coarseness of insoluble residues show no

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Explanation of Plate I

Photomicrographs of Lester Limestone

Figure A. **Slightly sandy, bryozoan oösparite. Excellent large fragment of fenestrate bryozoan near bottom of photograph; relatively few oölites have quartz sand nuclei. Sample L-1-3.**

Figure B. **Slightly sandy, bryozoan-crinoidal oösparite. Good examples of bryozoan fragments in upper part of photograph; probable Osagia encrusting pelecypod fragment near bottom of photograph; possibly some microspar in "hazy" areas. Sample L-2-3.**

Figure C. **Slightly sandy, bryozoan oösparite. Excellent example of encrusting bryozoan; as in figures A and B, no quartz sand grains which are not concentrically coated with carbonate. Sample L-2-2.**

Figure D. **Sandy, bryozoan-brachiopodal-crinoidal biosparrudite. Note increase in terrigenous content compared to figures A, B, and C; bryozoan fragments not as massive as those in previously discussed photographs; skeletal material highly fragmented. Sample L-3-1.**

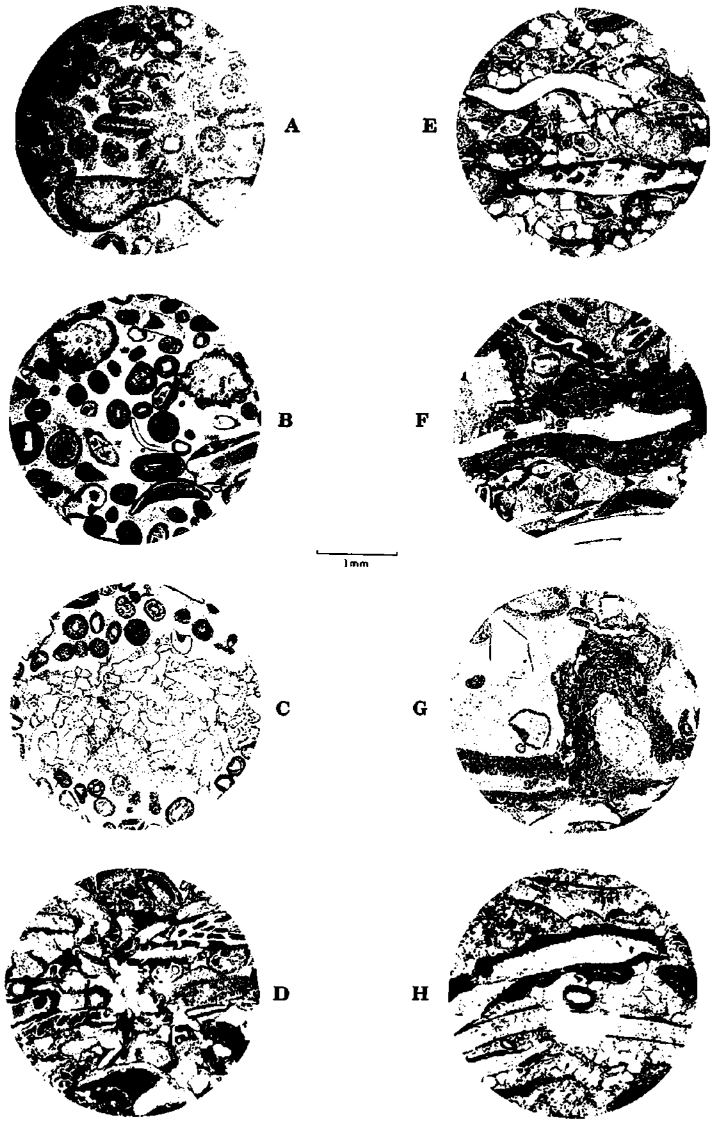
Figure E. **Sandy, bryozoan-brachiopodal-crinoidal biosparrudite. Trace of oölites; abundant terrigenous material; crinoid fragments abraded. Sample L-5-2.**

Figure F. **Osagia-brachiopodal-bryozoan-crinoidal biomicrudite. Much of micrite has been recrystallized to microspar; spines still attached to Osagia-encrusted brachiopod fragment near center of photograph; Osagia more extensively developed on one side of crinoid fragment in upper left part of photograph. Sample L-4-1.**

Figure G. **Slightly sandy, slightly oölitic, Osagia-bryozoan-brachiopodal-crinoidal biomicrosparrudite. Recrystallization of micrite to miscrospar and coarser sparry calcite is suggested by "hazy" area near left-central part of photograph; gradation from finer grained calcite occurs in above-mentioned area of photograph; Osagia colony developed primarily on one side of skeletal fragment. Sample L-4-5.**

Figure H. **Fine sand, pelecypodal-bryozoan-brachiopodal biosparrudite. Note occurrence of Osagia-encrusted brachiopod fragment near center of photomicrograph. Sample L-5-1.**

Plate I



discernible trend at this locality. This fact suggests that the factors controlling deposition of terrigenous material were relatively constant for particular areas throughout deposition of the upper Lester limestone. The differences between residues of the three groups suggests lateral variation in the factors influencing deposition of terrigenous material.

BIOLOGIC ASSEMBLAGES

As shown in table I, all thin sections contain some bryozoans, crinoids, and pelecypods. However, the percentages of these skeletal elements have a wide range among the different stratigraphic sections (table II). Samples from stratigraphic sections 1 and 2 contain less skeletal material (25-35%) than do samples from the other three localities (44-69%). The greatest percentages of skeletal material occur in the two thin sections of the lower Lester from stratigraphic section 4 (68% and 69%).

Bryozoans, crinoids, and brachiopods dominate the assemblage from stratigraphic sections 1 and 2, with smaller percentages of pelecypods, gastropods, arthropods, foraminifers, and *Osagia* (pl. I, figs. A-C). Although pelecypods and gastropods are less abundant than other skeletal elements (bryozoans, crinoids, and brachiopods), mollusks are generally more abundant at localities 1 and 2 than at other localities.

Crinoids, bryozoans, and brachiopods also dominate the skeletal material of samples collected from localities 3 and 5 (pl. I, figs. D, E). Considerably more skeletal material is incorporated into the rock framework of samples from these localities compared to samples from localities 1 and 2, and the molluscan element is smaller.

The widest range in the abundance of a single biologic element is that of *Osagia* at locality 4, where the range is from 10 to 30 percent. In samples collected from other localities, percentages of *Osagia* range from 0 to 2 percent. Figures F and G of plate I illustrate excellent examples of *Osagia* structures. These figures also show the manner in which the algal-foraminiferal colonies encrust skeletal elements more on one side than on another. This growth habit of the *Osagia* colonies suggests a low-energy depositional environment, as a higher energy environment would promote a pisolitic growth form of *Osagia*. In all the samples from sections 1, 2, 3, and 5 having smaller percentages of *Osagia*, the growth form was pisolitic. Laporte (1962, p. 535) interpreted a high-energy turbulent environment in the northern province of the Cottonwood Limestone (Permian) of Kansas and Nebraska partly upon the basis of abrasion and fragmentation of *Osagia* colonies. Conversely, the well-preserved *Osagia* colonies in Lester samples from stratigraphic section 4 suggests a low-energy, nonturbulent environment. Laporte (1962, p. 533) also discussed the growth form of *Osagia* in the silty *Osagia* facies of the Cottonwood Limestone of northern Oklahoma. In this turbulent Cottonwood environment, *Osagia* occurs as irregular coatings and concentrically arranged layers encrusting skeletal elements.

Molluscan percentages in samples from stratigraphic section 4 are relatively small compared with those from stratigraphic sections 1 and 2. Gastropod fragments are not present in the thin sections examined, and only minor percentages (1% and 2%) of pelecypods were observed.

Ostracodes and foraminifers are present in all samples. This widespread distribution in probably due to smallness of the ostracode carapaces and foraminifer tests and to susceptibility of these small shells to transportation by currents.

Much of the skeletal material has been influenced to some degree by current action. However, it is probable that the smaller fragments have been transported the greatest distances, with the larger elements possibly reflecting the biologic assemblage characteristic of the environment at particular localities. Biologic assemblages of the five stratigraphic sections vary slightly in a vertical direction but vary considerably in a lateral direction (lateral direction perpendicular to the basin margin).

Ginsburg (1956, p. 2419) concluded that most of the reef-tract sediments (east of Florida Bay and Lower Keys) larger than ⅛ mm accumulates in the same environment in which it develops. Biological elements and other allochemical constituents used to interpret and describe each particular Lester sample are commonly larger than ½ mm in length and diameter. Transportation of relatively large allochemical constituents is suggested by the association of small percentages of oölites with abundant skeletal material, such as those in samples collected from stratigraphic section 5 (oölites were probably transported to and deposited in a skeletal-rich environment). Somewhat coarser allochemical material (larger than ⅛ mm) may have been transported and deposited during Lester accumulation than that observed by Ginsburg in the reef-tract area.

Newell and others (1959, p. 217) noted that on the Bahama Banks a mixing of skeletal material, oölites, pellets, and grapestone occurs within the mixed skeletal sand facies in a bankward direction, whereas skeletal fragments are dominant in this facies away from the oölitc environment. The occurrence of oölites and other interior-bank constituents with skeletal elements was considered by Newell and others to be caused by seaward migration of these constituents from the bank interior. This same mechanism probably resulted in the association of oölites with abundant skeletal fragments in the upper Lester.

In upper Lester samples, much of the skeletal material associated with the scattered oölites (stratigraphic section 5) is much larger than the oölites. It is assumed that these larger skeletal fragments represent organisms that inhabited the environment to which the oölites were transported.

ABRASION AND FRAGMENTATION OF SKELETAL MATERIAL

The degree of abrasion and fragmentation of skeletal material ranges considerably within the Lester limestones. Bryozoan fragments from stratigraphic sections 1 and 2 are relatively large compared to fragments from other localities. The moderate degree of abrasion of these fragments suggests that they were not agitated extensively. It is possible that bryozoan material from localities 1 and 2 represent "robust" high-energy forms that were able to withstand much of the turbulence characteristic of an oölite environment.

The greatest degree of fragmentation and abrasion of skeletal elements occurs in samples from stratigraphic sections 3 and 5 (pl. I, figs. D, E). Most of the bryozoan material has been fragmented to a higher degree than has that from localities 1 and 2. The bryozoan structures characterizing the rocks from stratigraphic sections 3 and 5 appear to be considerably more delicate in structure than those from localities 1 and 2. Most crinoidal fragments observed in samples from localities 3 and 5 exhibit considerable abrasion; most of the crinoidal fragments have pronounced rounding of once-angular corners. The fragment edges might have been rounded by solution, but crinoidal material from stratigraphic section 4 does not exhibit this same degree of rounding of angular corners.

The least amount of abrasion and fragmentation of skeletal material occurs in samples from locality 4. In several cases, relatively fragile spines remain attached to brachiopod shells. In general, larger and more complete skeletal elements are preserved in samples from locality 4 than from localities 3 and 5. The lower Lester limestone at stratigraphic section 4 contains the least abraded and fragmented skeletal elements observed in the Lester limestones.

ENVIRONMENTAL INTERPRETATION OF LESTER LIMESTONES

Variations in limestone types, insoluble content and coarseness of terrigenous material, biologic assemblages, and abrasion and fragmentation of skeletal material suggest the development of three distinct facies within the upper Lester sequence: nearshore oölite facies, shelf facies, and lagoonal facies. These lateral variations within the upper Lester suggest a decrease in mechanical energy in the depositional environment in a basinward direction. The indicated decrease may have resulted from an increase in water depth from the nearshore oölite environment to the lagoonal environment. Figure 4 illustrates in map view and cross section the interpretation of upper Lester data previously discussed. Characteristics, such as excellent oölite structures, sparry calcite cement, and large "robust" skeletal elements, suggest that the nearshore oölite environment was one of considerable agitation and winnowing (this environment resembles strongly agitated-water environment of Plumley and others, 1962, p. 89-91). Percentages of insoluble material from this facies are not particularly large, but most samples show much coarser terrigenous material than that observed from the lagoonal environment (except for the uppermost sample from stratigraphic section 4). Most oölite nuclei from the nearshore oölite environment are composed of skeletal fragments, with relatively few possessing quartz sand nuclei. This fact suggests a scarcity of quartz grains in the nearshore environment. Nearly all of the terrigenous material associated with the oölitic rocks characterizing stratigraphic sections 1 and 2 is concentrically coated. The scarcity of

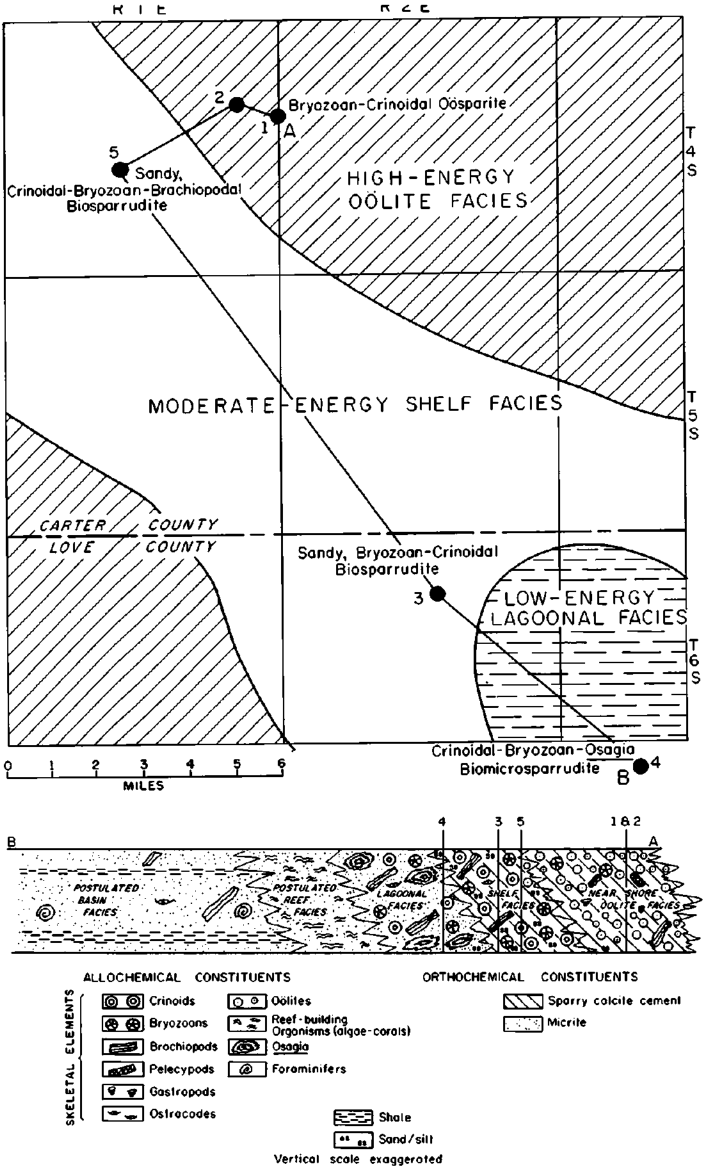


Figure 4. Map and diagrammatic cross section of upper Lester facies.

noncoated terrigenous particles suggests possible pronounced winnowing out or deficient deposition of terrigenous material in the oölite areas.

Considerably more and equally as coarse terrigenous material occurs in samples from the shelf environment. This occurrence of larger percentages and greater abundance of coarse terrigenous material in samples from the shelf environment than from the high-energy oölite environment is difficult to explain. This condition suggests that currents carried most of the terrigenous influx basinward beyond the nearshore oölite environment and deposited it in the shelf environment. Abundant large bryozoan and crinoid skeletal elements suggest that these animals probably attained maximum development in the shelf environment where depth and bottom conditions and energy factors were ideal for prolific growth. It is possible, even probable, that most of the larger skeletal fragments were deposited relatively close to the environment in which they thrived. Possibly the bryozoan and crinoid thickets acted as baffles which checked longshore currents transporting terrigenous material and relatively small skeletal fragments. The presence of small amounts of oölites in this facies suggests possible transportation of nearshore oölites into the more basinward shelf environment. In addition, winnowed terrigenous material from the oölite environment may have also accumulated in baffled areas. It is possible that these postulated bryozoan and crinoid growths acted in much the same manner as baffles discussed by Ginsburg and Lowenstam (1958, p. 312-314). Although a direct analogy is not made between the postulated upper Lester bryozoan and crinoid baffles and those discussed by Ginsburg and Lowenstam from modern seas, the same mechanisms, varying in degree, may be applied to upper Lester accumulations. The primary function of baffles is to stabilize the sea bottom and break the force of currents traveling into the baffled area (Ginsburg and Lowenstam, 1958). In the upper Lester shelf environment, suspended and tracted terrigenous particles and oölites may have been deposited in particular areas owing to reduction of current force by crinoid and bryozoan "thickets" in much the same manner as fine-grained carbonate particles and skeletal debris accumulate in areas protected by marine grasses in the Florida Bay area (Ginsburg and Lowenstam, 1958). Sufficient winnowing action occurred in the shelf environment to remove fine-grained carbonate particles (micrite) because sparry calcite cement occurs in rocks sampled from this environment (stratigraphic sections 3 and 5).

It is possible that stratigraphic section 5 is closer than stratigraphic section 3 to the nearshore oölite environment (fig. 4). Slightly more insoluble material and slightly larger percentages of coarse terrigenous material, as well as greater percentages of oölites, occur in samples from stratigraphic section 5 (table II).

Rock types from stratigraphic sections 3 and 5 are similar in terrigenous content, skeletal types, and oölite occurrence to those discussed by Plumley and others (1962, p. 88-89) from a moderately agitated-water environment.

The lower energy level of the depositional environment of the lagoonal rocks of stratigraphic section 4 is evidenced by the presence of microspar matrix, lesser degree of abrasion and fragmentation of skeletal elements, lower percentages of terrigenous material with smaller coarse fractions, and the restriction of *Osagia* growths to one side of skeletal fragments. The currents evidently were too weak to transport much terrigenous material into the environment, to remove fine-grained carbonate material, or to agitate the sediment particles sufficiently to permit *Osagia* growths to enclose them. These characteristics correspond in many respects with those of the quiet-water and intermittently agitated-water rock types described by Plumley and others (1962, p. 87-89).

Biologic associations also suggest that different energy conditions existed in the three depositional environments. The molluscan element is most abundant in the nearshore oölite environment. Cronoble and Mankin (1963) observed the dominance of mollusks (gastropods and pelecypods) in nearshore, high-energy environments of a Pennsylvanian (Missourian) limestone in northeastern Oklahoma. Newell and others (1959, p. 216-224) noted the dominance of mollusks in the biologic assemblage associated with high-energy environments (outer platform and oölite sand shoals of the barrier rim) on the Bahama Banks. Laporte (1962, p. 533, 539) discussed an increase in the molluscan element in rocks of the silty *Osagia* facies of the Cottonwood Limestone (Permian of northern Midcontinent area). Laporte postulated that this facies was deposited in a relatively high-energy, nearshore environment.

Bryozoans are ubiquitous in upper Lester samples, but thicker walled varieties adapted to withstand vigorous energy conditions occur in samples from the nearshore oölite environment. *Osagia* is most abundant in upper Lester samples from the lagoonal environment. Also, in nonlagoonal samples (localities 1, 2, 3, 5) *Osagia* encrustations are composed of relatively few laminae completely surrounding nuclei, whereas in lagoonal samples (locality 4) the form is of extremely irregular masses of numerous laminae, better developed on one side of the nucleus than on the others. The growth form described from nonlagoonal localities is indicative of a high-energy, turbulent environment in which the nuclei were continuously agitated, producing nearly symmetrical encrustations. Much quieter water, in which agitation of nuclei was not constant, thus producing irregular algal-foraminiferal encrustations, is suggested for the lagoonal environment.

It is possible that the sites of localities 3 and 5 are in what was a shoal environment between the Anadarko basin to the northwest and the Ouachita element to the southeast (fig. 5). (A basinward direction, as used by the writers, refers to the direction into the two basins.) However, no information is available regarding Lester rocks in the Anadarko basin northwest of locality 5. Possibly the sequence of facies in the direction toward the Ouachita element may be repeated in the direction toward the Anadarko basin to the northwest of locality 5. The Ardmore basin, during Lester deposition, was possibly a shoal environment or relatively shallow-water environment between the Anadarko basin and the Ouachita element. The lateral variations in the upper Lester which

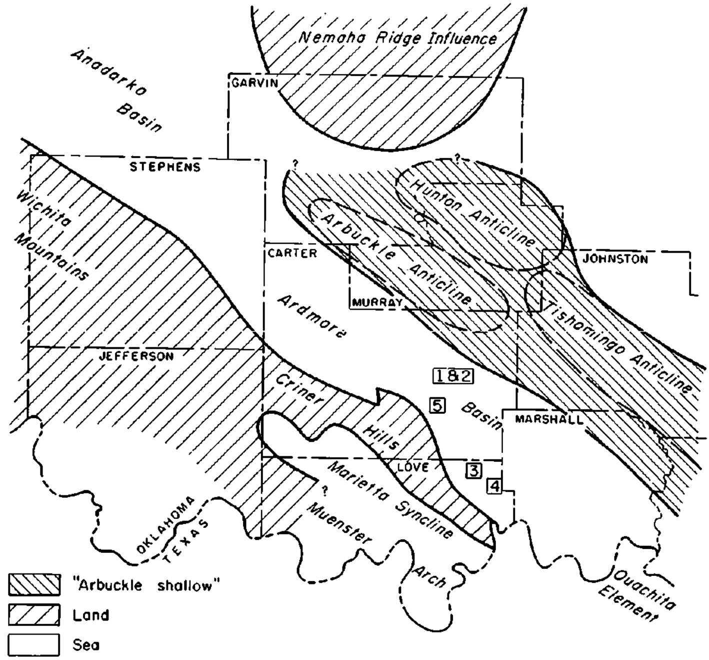


Figure 5. Paleogeography of south-central Oklahoma during deposition of Lester Member.

suggest a decrease in mechanical energy in the depositional environment toward the Ouachita element may be indicative of increased water depth in a basinward direction. It is possible that the water depth in the lagoonal environment was not too different from that of the other environments. The abundance of algae in this environment suggests relatively shallow water, probably less than 30 feet deep (Johnson, 1961, p. 205-206). In addition to slightly deeper water, lower energy conditions may indicate the presence of a protective buttress in the form of a reef that developed farther basinward (fig. 4, cross section). Although we have no direct evidence of a reef facies, analogy to the Hogshooter Limestone (Missourian) of northeastern Oklahoma (Cronoble and Mankin, 1963) suggests that such a reef facies is not inconceivable. The Hogshooter displays variations similar in many respects to those of the upper Lester. In the Hogshooter sequence, a reef facies occurs basinward from a lagoonal facies similar to that of the upper Lester lagoonal facies. Such a reef facies in the upper Lester would probably be characterized by patch reefs or fringing reefs (Cloud, 1952, p. 2139) because of the absence of factors, such as abnormal sulfate concentration, indicative of restriction by barrier-type reefing. The facies basinward from the postulated reef environment should be characterized by an abundance of micritic material (and possibly shale) and fine-grained skeletal fragments. This lower energy environment would be present basinward regardless of the presence or absence of the postulated reef environment within the upper Lester. An increase in water depth is probably the controlling factor for the accumulation of micrite and possibly shale in such an environment. Interestingly the lateral sequence of the upper Lester facies is similar to the hypothetical sequence discussed by Plumley and others (1962, p. 93-95).

Insufficient information is available for reliable interpretation regarding the lower Lester. However, certain speculations can be made. At stratigraphic section 4, the lower Lester is a lower energy rock type than is the upper Lester. The least amount of abrasion of skeletal elements and smallest percentages of terrigenous material occur in the lower Lester at locality 4. The absence of oölites and sparry calcite cement and the occurrence of abundant micrite (and microspar) suggest that this lithology accumulated in a low-energy environment. It appears that the lower Lester at stratigraphic section 4 represents a lagoonal facies deposited farther basinward than was the lagoonal facies of the upper Lester at this same locality. Although purely a speculation, the possibility is suggested that the lower Lester and part of the overlying shale sequence may represent a transgressive sequence in which a basin shale facies transgressed over the lagoonal carbonate facies. The upper Lester and the upper part of the underlying shale sequence probably represent a regressive sequence. The anomalous occurrence of large percentages of insoluble material and coarse terrigenous particles and an increase in oölite content in the uppermost sample from the upper Lester at locality 4 suggests an increase in energy in the depositional environment resulting from the encroachment of the shelf environment into the lagoonal environment owing to regression of the upper Lester sea. During upper Lester deposition, locality 4 may have been close to the energy boundary between shelf and lagoonal environments, and, therefore, slight shifts in these environments could have produced radical changes in deposition. The fairly uniform lithology displayed vertically at stratigraphic sections 1, 2, 3, and 5 suggests that these sequences were deposited fairly distant from facies boundaries, and hence slight shifts in energy conditions would be undetectable because like facies would be deposited on like.

Fusulinid studies substantiate the interpretation of lower energy conditions in the lagoonal environments of the lower Lester relative to those of the upper Lester at locality 4. There the lower Lester contains the inflated fusiform *Fusulina insolita,* whereas the upper Lester has the elongate fusiform *Fusulina mutabilis.* Ross (1961, p. 388-400), in studying Permian fusulinids, found that the more elongate forms inhabited nearshore, high-energy environments, whereas the inflated forms occurred in lower energy, less agitated environments. At locality 1, although no petrologic sample is available from the stratigraphic section, fusulinid samples from the lower Lester contain *Fusulina mutabilis,* suggesting a lateral increase in energy in the depositional environment toward this locality during deposition of the lower Lester. Petrographic examinations of the fusulinid slides support this suggestion, as the enclosing rock is dominantly a slightly sandy crinoidal-brachiopodal, fusulinid-bryozoan-ostracodal biosparrudite. It is interesting to note that *Fusulina mutabilis* is found in both the lower and the upper Lester and that the distribution of this fusulinid is environmentally controlled.

SUMMARY

Lateral variations in the upper limestone of the Lester Member suggest that this unit can be divided into three distinct facies: nearshore oölite, shelf, and lagoonal. Despite the absence of positive evidence, it is postulated that a reef facies and a quiet-water basin facies exist basinward from the lagoonal facies. Although speculations of this nature without adequate proof may appear precipitate, the writers regard geology as an interpretive science, and they have so proceeded with this study. The application of some of the techniques, concepts, and speculations used in this study to the investigation of oil provinces may prove fruitful in the discovery of new oil-bearing facies.

The writers are indebted to the Oklahoma Geological Survey for furnishing thin sections for this study and to W. W. Ballard and C. J. Mankin for helpful suggestions and critical reading of the manuscript.

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Pipeline Maps of Oklahoma

The pipeline network and oil and gas fields of Oklahoma are depicted in a series of four maps to be published this month by the Oklahoma Geological Survey. The maps, printed in color on sheets approximately 23 inches by 43 inches at a scale of 1:750,000, are a compilation of all information available as of December 31, 1965, regarding existing pipelines, petroleum refineries, gas-processing plants, underground storage facilities, and oil and gas fields. Because of the great number of such facilities in the State, it was necessary to depict them on four correlated maps, as follows:

Map GM-10. Oil and Gas Fields of Oklahoma, 1965
Map GM-11. Products Pipelines of Oklahoma, 1965
Map GM-12. Crude-Oil Pipelines of Oklahoma, 1965
Map GM-13. Natural-Gas Pipelines of Oklahoma, 1965

The maps of the series are the first to be produced by the Survey by the scribe-drafting technique. All maps have the same base printed in gray, with oil fields, gas fields, and oil-and-gas fields printed in green, red, and brown, respectively. Map GM-10 includes production and value statistics for crude petroleum, natural gas, natural gasoline and cycle products, and liquefied petroleum gas from 1891 through 1965.

Each pipeline map, in addition to showing the pipeline routes, labeled as to diameter and owner or operator, includes supplementary information as follows:

The products pipeline map (GM-11) shows the locations of and lists eighty-nine gas-processing plants, sixteen petroleum refineries, and seven underground liquefied-petroleum storage facilities. Twenty-two pipeline companies are listed.

The crude-oil pipeline map (GM-12) shows locations of and lists sixteen petroleum refineries and lists thirty-two pipeline companies.

The natural-gas pipelines map (GM-13) shows the locations of and lists eighty-nine gas-processing plants and nine underground natural-gas storage facilities. Sixty-seven pipeline companies are listed.

The set may be purchased for $3.00, folded in a sturdy envelope, 9½ inches by 12 inches. Single maps may be purchased unfolded for $1.00 each.

Basement and Near-Basement Tests in Oklahoma, 1965

Louise Jordan

The Oklahoma Geological Survey continues to be interested in the acquisition of basement-rock samples and of sufficiently large samples of Arbuckle rocks from basement tests. This material is needed for our continuing research on the basement in Oklahoma. Normal sample cuts, such as those packaged in standard paper envelopes, are not large enough, although they are most welcome if larger samples are not available. We should appreciate receiving sets saved in cloth sacks whenever possible. Sample sets should be sent collect to the Oklahoma Geological Survey, The University of Oklahoma, Norman, Oklahoma 73069. The paucity of basement and near-basement material available suggests a general negligence in the preservation of material needed for basic information. It is hoped that field workers will consider the potential value of collected samples for which they have no need.

Basement and Near-Basement Tests Drilled in Oklahoma, 1965

County (OGS No.)	Location Sec. T. R.	Well Name	Elevation Datum (ft)	Top Arbuckle (ft)	Top Basement (ft)	Location of Samples, Remarks
Pontotoc Pc-6	32 3N 5E C SE SW	Wirick & Crowell 1 Brown	1188	2054	5725	OGS: 20-5741
Seminole Sm-1	34 9N 6E NE NE	Magness Petr. (Keener) 1 L. Jones "A"	950	4830	7283	OGS: 4840-7380
Sequoyah	13 13N 23E C NW NW	Reserve Petroleum 1 Trott	714	514		OGS: 69-2093 2093 TD in Reagan
Muskogee	11 14N 17E C NE SW	Tidewater 25 Parker	617	2224		Shawnee: 850-3707 3707 TD in Reagan
Wagoner	18 17N 17E SW SW SW	Peter Henderson 1 Kelley	553	1128		Not located 2505 TD
Wagoner	6 18N 18E NW SE SE	Little Nick Oil Co. 2 Weldon (OWDD)	610	685	2216?	OGS
Rogers	25 19N 17E SW NE NE	Little Nick Oil Co. 1 Titus	620	720	2219?	OGS

Osage Os-35	24 20N 11E C NE SW	Texaco 1 Osage "C"	1004	2483	3635	OGS: Samples & core Shawnee: 330-3685
Osage	11 21N 10E NE NW NW	Burke & Sivils 1-A Wampumbush	906	2372	2906	Not located Drld. 1962
Osage Os-34	17 21N 10E NE SW NE	Sunday DX 8-Osage	869	2525	3351	OGS: 3360-3390
Rogers Rog-6	9 21N 15E SE NW NW	USSRAM 1 Minor	866	1397	2157	OGS: 230-2180
Osage	8 23N 8E SE SE NE	Pure & Sinclair 201 Osage-Hominy	932	2685	3151	Shawnee: 120-3165
Osage Os-36	24 24N 9E NE SW NW	Sunray DX S-1	980[1]	2534	3276	OGS: 2910-3325 Drld. 1964
Stephens	6 1N 8W C SE NW NW	Post Petroleum 1 Calloway	1154	Absent	4905?	Ardmore: 260-6510
Stephens	27 2N 9W C SE NE	Sun Oil Co. 1 Nunley	1151	Absent	5178	Ardmore: 240-5202
Greer	7 3N 22W SE SE SW	Calco, Inc. 1 Haddad	1610	Absent	4695	Ardmore: 1400-4768
Kiowa	26 5N 15W C SE SE NE	Roy Sammons 2 Evatt	?	Absent	173	None located
Greer	25 6N 22W C N/2 N/2 NE NW	Toto Gas Co. 1 Sappington	1621	Absent	931	None located
Greer	16 7N 21W C SE SW NW	Dobervich et al. 1 State	1713	Absent	1450	None located
Beckham	14 8N 26W C SW SW SE	Ferguson Oil Co. 1 Bartlett	2117	Absent	3180?	None located
Beckham	24 9N 23W C NE SW	T. K. Hendricks 1 Moss	1821	Absent	4514	Shawnee: 2000-4659
Garfield	31 23N 3W SE SE SW	J. T. Hoke 3 Ford	1132	5202	6595	Shawnee: 1500-6610

[1] Elevation from Osage Agency.

Isotopic-Age Dates from Basement Rocks in Oklahoma

R. E. Denison*, E. A. Hetherington, Jr.*, and G. S. Kenny*

INTRODUCTION

Eight rubidium-strontium ages have been determined on four samples of igneous rock in Oklahoma (table I). Two of these samples are from outcrops in the Wichita Mountains and two are from two widely separated drilled holes in Noble and Pottawatomie Counties (fig. 1). The ages of these samples were determined in order to define more accurately some geographical age provinces and the age range within these provinces.

All isotopic measurements were made on a 60°, 6-inch-radius mass spectrometer. Isotope dilution analysis procedures used are in general similar to those employed by other laboratories. Separate strontium measurements were made on unspiked and spiked aliquots (with the exception of sample 1). Radiogenic strontium content was determined by using the Sr^{87}/Sr^{86} ratios obtained from the unspiked measurements after correcting for fractionation by normalization to Nier's value of Sr^{86}/Sr^{88} = 0.1194. The analytical precision based upon replicate analyses is estimated to be ±0.2% for isotopic-ratio measurements and ±1% for both Rb and Sr concentrations. Spikes enriched in Sr^{86} and Rb^{87} were used. $Sr.^{85}$ and Rb^{83} tracers were used to identify the strontium and rubidium fractions in the ion-exchange-column effluent.

SAMPLE DESCRIPTIONS

The surface samples from the Wichita Mountains used in this study are of two different rock types, a granite porphyry and a biotite-bearing olivine gabbro, from nearby localities in Comanche County. The drill-hole samples from Noble and Pottawatomie Counties are a granite and an adamellite.

Sample 1.—The granite porphyry from the Wichita Mountains (sample 1) is from the Ira Smith quarry, SW¼ SE¼ SE¼ sec. 4, T. 3 N., R. 15 W., Comanche County, at the western entrance to the Wichita Mountains Wildlife Refuge. The rock is from the Mt. Scott Granite as defined by Merritt (1965). One age determination was made on biotite. The petrographic analysis of this sample is as follows:

> Perthite 48.6%, quartz 33.2%, plagioclase 12.3%, hornblende 3.5%, iron ore 1.1%, biotite 0.4%, hematite 0.4%, zircon 0.2%, chlorite 0.2%, sphene 0.1%, feldspar alterations trace, apatite trace. Phenocrysts of perthite and antiperthite are vague in outline and slightly zoned. Quartz is in round crystals, is mildly strained to unstrained, and is locally included within perthite as a vague

* Field Research Laboratory, Socony Mobil Oil Company, Inc., Dallas, Texas.

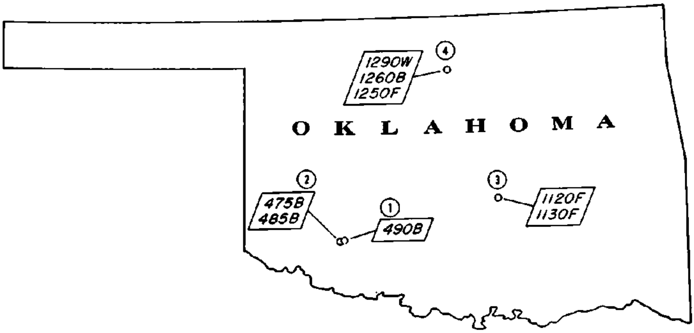

Figure 1. Locations and age determinations of samples used in this study. The material dated is indicated as follows: W = whole rock, B = biotite, F = microcline.

micrographic intergrowth of minor disorganized proportions. Fresh perthite is a string type and is lightly dusted with hematite. Hornblende and magnetite-ilmenite are in clots associated with minor biotite and sphene. Zircon is abundant generally in contact with iron ores. Hematite is found as a fine intergranular film and as an irregular replacement of some feldspar phenocrysts. Chloritic micas are in rare veinlets. Feldspar alterations are mainly sericite after plagioclase. Grain size: phenocrysts to 5 mm, groundmass average 1.5 mm. Texture: porphyritic-hypidiomorphic granular.

Sample 2.—Sample 2 is a biotite-bearing olivine gabbro of the Raggedy Mountain Gabbro Group from NE¼ SE¼ NW¼ sec. 9, T. 3 N., R. 15 W., Comanche County, about 0.25 mile southwest of the locality of sample 1. Like many rocks of the Raggedy Mountain Group this rock has a color index (<35) lower than average for gabbroic or basaltic rocks. Two age determinations were made on biotite. The petrographic analysis of this rock is as follows:

Plagioclase 65.5%, olivine 12.7%, pyroxene 9.5%, iron ore 3.8%, biotite 3.1%, iddingsite 3.0%, feldspar alterations, 1.3%, basaltic hornblende 0.7%, calcite 0.2%, apatite 0.1%. Calcic labradorite is fresh with only minor clay-zeolite replacement and is slightly zoned in certain crystals. Olivine is in subhedral crystals containing cracks filled by iddingsite and iron ore. Partial rims of mildly pleochroic orthopyroxene are found around olivine. Orthopyroxene is also found as discrete interlaths to subophitic crystals. Minor basaltic hornblende is associated with other femic minerals and not as discrete crystals. Biotite is moderately pleochroic, red brown, and exceptionally fresh. The biotite is present around and near other femic minerals and iron ores but is also as discrete intergranular books. Iron ores are in subhedral to anhedral grains as well as delicate symplektic intergrowths with pyroxene. Grain size: 3.5 mm average. Texture: hypidiomorphic.

Sample 3.—Sample 3 consists of granite cuttings recovered from beneath the Reagan Sandstone, between 7,755 and 7,775 feet, in the Hembree C-3 Hembree well in SE¼ SW¼ SE¼ sec. 19, T. 7 N., R. 5. W., Pottawatomie County. Two age determinations were made on microcline. The petrographic analyses follows:

> Microcline perthite 37.5%, quartz 28.6%, plagioclase 20.0%, biotite 6.2%, feldspar alterations 5.9%, chlorite 0.8%, iron ore 0.8%, carbonate 0.2%, sphene-leucoxene trace, apatite trace, zircon trace, rutile trace. Microcline is finely twinned, perthitic, and generally fresh. Plagioclase is sodic oligoclase and locally contains intense sericite-epidote alterations and hematite dust. Quartz is essentially unstrained. Biotite is olive green, but, where it is altered near the margins of books or is in contact with chlorite, it is a bright apple green. The biotite contains sphene-leucoxene granules and fine rutile needles, both of which are best developed in the more altered portions. Carbonate is sparse in fine films along cracks and in larger crystals around accessory minerals. Apatite and zircon are concentrated near biotite and iron ore. Grain size: 3 mm average. Texture: hypidiomorphic.

Sample 4.—Sample 4 also consists of cuttings of a granite rock, an adamellite, from beneath the Reagan Sandstone found in the Oklahoma Natural Gas 1 Hardrow well in NW¼ SE¼ sec. 15, T. 23 N., R. 2 W., Noble County. Three age determinations were made, one each on whole rock, biotite, and microcline. The sample is from a depth of about 5,508 feet and is described below.

> Plagioclase 40.0%, quartz 27.7%, microcline perthite 18.9%, feldspar alterations 7.7%, biotite 2.8%, chlorite 2.5%, sphene-leucoxene 0.2%, iron ore 0.1%, apatite trace. Plagioclase, ranging from intermediate oligoclase to intermediate albite in composition, is in part extensively replaced by sericite, particularly the more calcic portions. Microcline is fresh and in part perthitic. Quartz is mildly strained. Biotite is deep reddish olive green and strongly pleochroic. Chlorite replaces biotite extensively and is accompanied by sphene-leucoxene. Former sphene wedges have been replaced by calcite and sphene-leucoxene. Apatite is common as needle inclusions. Iron ores are rare. Grain size: to 1 cm. Texture: hypidiomorphic.

AGE DETERMINATIONS

The ages of the granite porphyry and the olivine gabbro from the Wichita Mountains were determined on biotite. The biotite from sample 1 was a miarolitic cavity filling in a hornblende-granite host rock containing only minor biotite. The miarolitic biotite is considered to have formed contemporaneously with the crystallization of the granite, which is of intermediate relative age in the series of granites found in the eastern part of the Wichita Mountains.

The determined age of the biotite is 490 ± 20 million years (m.y.). The sample is excellent from an analytical standpoint, containing abundant rubidium and a small amount of common strontium. The determined date compares well with other ages from granites in the Wichita Mountains* (see Ham, Denison, and Merritt, 1964, p. 24-31).

Two age determinations were run on a biotite separated from the biotite-bearing olivine gabbro of sample 2 from the Raggedy Mountain Gabbro Group. The determined ages of 475±20 m.y. and 485±20 m.y. are close to other dates determined on samples from this group (Tilton, Wetherill, and Davis, 1962; Muehlberger and others, in press). Pyroxene and olivine were separated and measured in order to determine the initial strontium-87/86 composition. The determined ratio of 0.706±0.001 is the same as is used in other age calculations in this work.

From field relations it is known that the granite is younger than the gabbro. Ham, Denison, and Merritt (1964) demonstrated that a period of uplift and erosion took place between the emplacement of the gabbro and the granite in the Wichita Mountains area. The average apparent age of the biotite from the gabbro is, however, 10 m.y. younger than the age of the granite biotite. The accuracy of the measurements is not high enough nor the samples analytically favorable enough for the apparent 10-m.y. age difference to be significant. This is an example of the effective limits of isotopic-age dating based upon results from a few samples. We conclude that the granite and gabbro are so closely related in time that they are not separable upon the basis of available isotopic measurements.

Age determinations of the drill-hole cuttings from Pottawatomie and Noble Counties (samples 3, 4) add supporting evidence to the work of Muehlberger and others (in press) on the geochronology of the Midcontinent.

The basement-rock granite of sample 3, from the Hembree well in Pottawatomie County, is petrologically similar to the 1,350-m.y. rocks of the Eastern Arbuckle Province of Ham, Denison, and Merritt (1964). However, this granite has no cataclastic or incipient metamorphic features that are common in rocks of the Eastern Arbuckle Province. The absence of these features prompted us to anticipate a date of about 1,200 m.y. because dates in this range have been determined along the Nemaha uplift in Oklahoma on two samples (Muehlberger and others, in press).

The determined dates of 1,120±60 m.y. and 1,130±60 m.y. by rubidium-strontium on microcline, although slightly low, indicate that this rock is related to the younger granites rather than to those of the Eastern Arbuckle Province. We believe that the 1,200-m.y. granites may be the agent responsible for the cataclastic features and incipient metamorphism found in the rocks of the 1,350-m.y. province.

Microcline, biotite, and whole-rock ages were determined by the rubidium-strontium method for the adamellite from Noble County. Of

* The decay constant used in our calculations is $\lambda_\beta = 1.47 \times 10^{-11}$/yr. These ages must be compared to the ages calculated with this constant. Ages calculated using the $\lambda_\beta = 1.39 \times 10^{-11}$/yr constant are 6% higher than those calculated here.

TABLE I.—ISOTOPIC MEASUREMENTS

SAMPLE	ROCK TYPE	MATERIAL DATED	Rb^{87} μGM/GM	NORMAL SR μGM/GM	Sr^{87}* μGM/GM	Sr^{87}/Sr^{86} ATOM RATIO	AGE (M.Y.)
1	granite porphyry	biotite	386.0	10.11	2.793	3.529	490±20
2	olivine gabbro	biotite	70.26	43.63	0.4942	0.8216	475±20
			69.20	44.09	0.4993		485±20
3	granite	microline	72.73	171.3	1.223	0.7790	1,130±60
			74.09	172.6	1.232		1,120±60
4	adamellite	whole rock	60.43	196.6	1.164	0.7664	1,290±100
		microcline	82.34	191.9	1.533	0.7877	1,250±50
		biotite	131.4	11.00	2.473	3.004	1,260±50

* Radiogenic
$Rb^{87}, \lambda_\beta = 1.47 \times 10^{-11}$/year
$Rb^{87} = 0.283$ gm/gm Rb

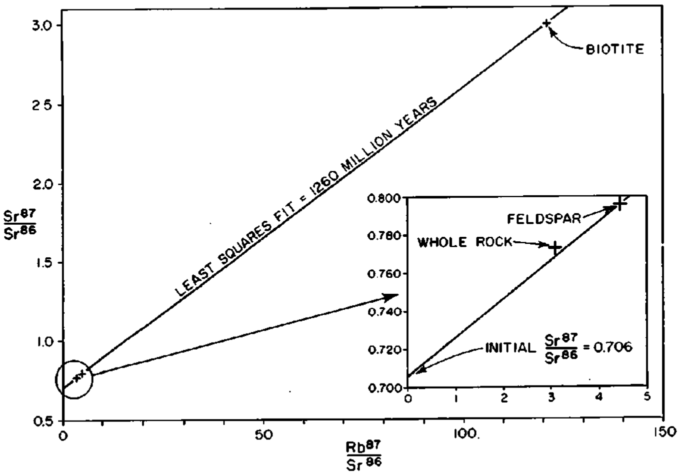

Figure 2. Isochron plot of Sr^{87}/Sr^{86}-Rb^{87}/Sr^{86} for fractions of adamellite (sample 4) from Noble County.

the minerals present in the rock, the biotite had by far the most favorable ratio of rubidium to strontium. The different fractions were dated in order to evaluate the possibility of reheating.

The results of this dating (fig. 2; table I), together with a lack of petrographic evidence for later thermal activity, demonstrate that reheating was not a significant factor in the apparent ages determined.

An isochron based upon a least-squares fit of the three determinations (fig. 2) yields an age of 1,260 m.y. and an initial strontium-87/86 value of 0.706. This falls between the 1,400-m.y. dates found in Kansas and the 1,200-m.y. dates common in northeastern Oklahoma (Muehlberger and others, in press). Although the ages determined here are slightly higher, they are still within the range of other determined ages from this area. This age difference may be real or apparent. In either case, sample 4 yielded the most analytically favorable determination from rocks of this petrographic type. If the difference between about 1,260 m.y. and 1,200 m.y. is real, we interpret the results to indicate that the rock penetrated in the Hardrow well was shielded from and was unaffected by the 1,200-m.y. Spavinaw igneous activity described by Muehlberger and others (in press).

CONCLUSIONS

The isotopic ages of these four rocks and minerals support two conclusions. First, the ages of the gabbroic and granitic rocks in the Wichita Mountains are extremely close and are essentially not resolvable upon the basis of present isotopic evidence. Second, the change in Paleozoic structural grain from west-northwest in the Arbuckle Mountains to essentially north-south along the Nemaha uplift (best shown in the pre-Pennsylvanian map of Jordan, 1962) is coincident with a change in basement-rock age from about 1,200 m.y. to 1,350 m.y. We suggest that the change in structural grain is directly related and at least in part dependent upon this basement-rock difference.

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ERRATUM

Oklahoma Geology Notes, April 1966, Volume 26, Number 4

Page 100, text-figure 1: For **Proallagecrinus** read **Isoallagecrinus**

OKLAHOMA GEOLOGY NOTES

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