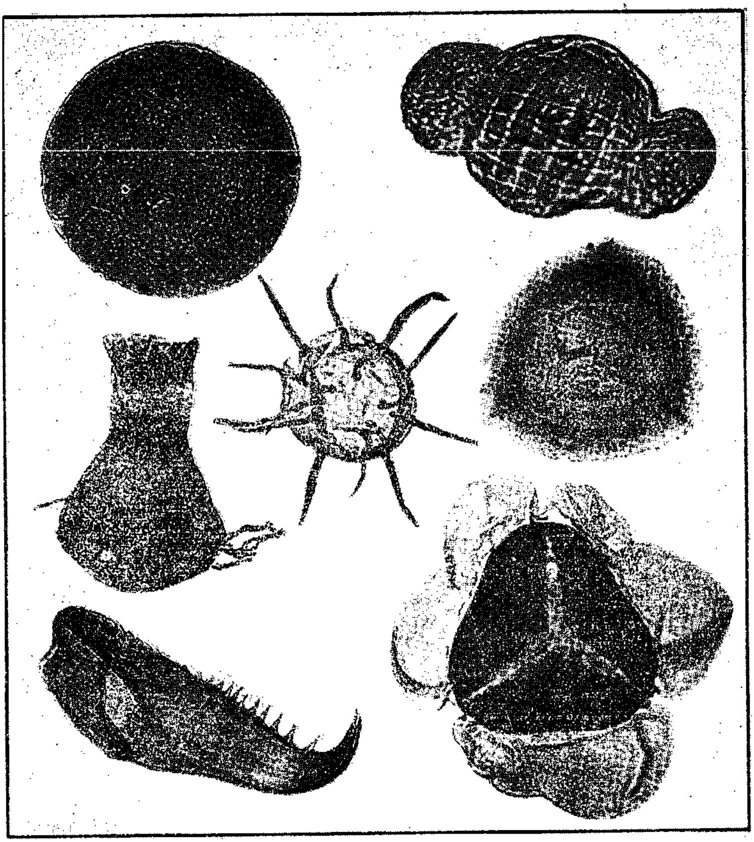
OKLAHOMA GEOLOGY NOTES



OKLAHOMA GEOLOGICAL SURVEY

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MINERAL PRODUCTION IN OKLAHOMA[1]

Mineral	1958		1959 (Preliminary)	
	Thousand short tons (unless otherwise stated)	Value (thousands)	Thousand short tons (unless otherwise stated)	Value (thousands)
Clays[2]	576	$ 579	587	$ 588
Coal	1,629	10,858	1,441	........[3]
Helium .... thousand cubic feet	....	....	93,751	1,541
Lead (recoverable content of ores, etc.)	3,692	864	275	65
Natural gas .... million cubic feet	696,504	70,347	701,500	72,300
Natural-gas liquids:				
Natural gasoline and cycle products ....thousand gallons	440,798	26,029	441,000	26,100
LP-gases........do.	657,114	25,822	683,300	27,300
Petroleum (crude) ....thousand 42-gallon barrels	200,699	594,069	196,704	570,442
Salt (common)	4	41	2	15
Sand and gravel	7,232	5,859	7,700	6,200
Stone	10,794	12,232	11,990	13,848
Zinc (recoverable content of ores, etc.)	5,267	1,074	494	113
Value of items that cannot be disclosed: Asphalt (native), bentonite, cement, gypsum, lime, pumice and tripoli		16,023		25,941
Total Oklahoma[4]		761,937		742,232

[1] Production as measured by mine shipments or mine sales (including consumption by producers).
[2] Excludes bentonite, value of which is included with "value of items that cannot be disclosed".
[3] Included with value of items that cannot be disclosed.
[4] Total adjusted to avoid duplication in values of clays and stone.

THE MINERAL INDUSTRIES OF OKLAHOMA IN 1959[1]

(Preliminary Report)

Peter Grandone[2] and William E. Ham[3]

Ten of Oklahoma's 17 minerals, including mineral fuels, showed a gain in 1959 value over 1958, and one more commodity, helium, was added to the State's mineral list in 1959.

The total value of 1959 mineral production in Oklahoma is estimated at $742 million, 2.6 percent less than the 1958 value and 8.3 percent less than the 1957 record value of $809 million. Mineral fuels accounted for nearly 95 percent of the 1959 value, nonmetals for 5 percent, and metals less than 1 percent.

MINERAL FUELS

Coal. Coal production in Oklahoma declined 12 percent from 1958. The estimated 1,441,000 tons reported in 1959 was from 9 counties. The largest tonnage was from Rogers County. The Ben Hur Co. mine near Henryetta, the only one in the area, was closed from March 1 to September 1.

Natural Gas. Marketed production of natural gas from 64 counties continued to grow. Impressive discoveries and added huge reserves were credited to the northwestern counties. Attention in the stepped-up drilling program was focused on the Hunton group, formerly untapped in the area, and this resulted in Oklahoma's most significant gas discovery in 5 years, Magnolia Petroleum Co.'s No. 1 Miller, first producer in Custer County. The big Laverne and Mocane gas fields in Harper and Beaver Counties were enlarged, suggesting that they may merge into one large producing area. To market these huge gas reserves, new pipelines were completed in northwestern Oklahoma. One of these is a 52-mile, 20-inch feeder line, built by Michigan-Wisconsin Pipeline Corp. It connects Laverne, Okla., to the company's trunk line in Meade County, Kans., which supplies the Detroit-Milwaukee areas. Another gas-transmission line under construction was Northern Oklahoma Gas Co.'s 75-mile, 12-inch line from Cherokee in Alfalfa County to Ponca City in Kay County.

Because these huge gas reserves also contain large reserves of helium that otherwise would be lost to fuel markets, the United States Department of the Interior placed in operation in August a new $12-million helium-extraction plant at Keyes, Cimarron County. This plant, largest of five plants operated by the Government, is designed to extract helium from as much as 50-million cubic feet of gas daily. Helium-bearing gas from the Keyes gas field was being supplied under a long-term agreement directly from the transmission line of Colorado Interstate Gas Co.

1 Prepared under a cooperative agreement for the collection of mineral statistics, except mineral fuels, between the Bureau of Mines, United States Department of the Interior, and the Oklahoma Geological Survey. Slightly amended from U. S. Bureau of Mines Area Report IV-103.

2 Commodity-Industry Analyst, Division of Mineral Industries, Region IV, Bartlesville, Oklahoma.

3 Geologist, Oklahoma Geological Survey, Norman, Oklahoma.

Natural-Gas Liquids.—The value of natural-gas liquids produced in Oklahoma in 1959, estimated to be $53.4 million, gained slightly over 1958. This gain was attributed mostly to production of LP-gases as markets for these products remained strong.

Sun Oil Co. completed its $3.5 million natural-gasoline plant at Laverne, Harper County. The plant has capacity to process 100 million cubic feet of gas daily from the big Laverne gas field for pipeline transmission to Detroit and Milwaukee. Natural-gas liquids extracted at the Sun plant are being carried by a new 45-mile pipeline, opened August 1 by Wheat Belt Pipe Line Co., to a terminal at Harper Ranch Station in Clark County, Kans. This line, which connects with the Jayhawk Pipe Line at Harper Station, also handles condensate and crude oil from other fields in northwestern Oklahoma.

Other natural-gasoline plants constructed in 1959 include the Sunray Mid-Continent Oil Co.'s $1-million plant near Purcell in McClain County, and the Kerr-McGee Oil Industries, Inc. Laffoon plant No. 16 near Stroud in Lincoln County. The Sunray plant will process 5 million cubic feet of gas daily to recover 32,000 gallons of liquids; Kerr-McGee's plant also will process 5 million cubic feet of gas daily to recover about 20,000 gallons of liquids. Cities Service Oil Co. was expanding its Ambrose plant near Blackwell.

Petroleum—Production of crude petroleum in Oklahoma declined slightly in 1959 to an estimated 197 million barrels. This quantity made the State the fourth largest oil producer in the Nation for the 14th consecutive year. Value of petroleum produced, estimated at $570 million, was 77 percent of Oklahoma's total mineral value in 1959. Production was reported from 63 of the State's 77 counties—Osage and Garvin were the leading producers. Oklahoma's oil allowable of 560,000 barrels daily at the beginning of the year was cut to 525,000 barrels daily in July where it remained to the end of the year.

According to the Oil and Gas Journal, 5,359 wells were drilled in 1959, 16 percent fewer than in 1958. Drilling interest was continued on the north flank of the Anadarko basin in the northwestern counties. Production in the area is mostly from Morrow, Hoover, Red Fork, Chester, and Hunton pay zones at depths ranging from 5,000 to 14,000 feet. Present indications are that the area has assumed the proportions of a major gas-condensate reserve. The area's future has been enhanced by increased development of marketing and transportation facilities. At least six companies have built pipelines into the area, yet more facilities will be required to take care of present production. Elsewhere in the State, Cosden Petroleum Co. built a 47-mile, 6-inch products pipeline from Wichita Falls, Tex., to Duncan, Okla., where it connects with existing lines to move fuels to eastern markets. Sunray Mid-Continent Pipe Line Co. built a line to carry crude oil from Alfalfa and Grant Counties to the Company's refineries at Tulsa and Duncan.

In 1959, Oklahoma had 14 refineries operating. According to the Oil and Gas Journal, these refineries had a total capacity of 391,780 barrels of crude oil daily. At its West Tulsa refinery, the Texas Co. was constructing an alkylation and an isomerization unit. The first unit will have a capacity of 2,050 barrels of high-octane alkylate daily; the second will have a capacity of 600 barrels of isobutane daily.

The Air Force announced plans to keep open the Callery Chemical Co. plant at Muskogee to produce high-energy rocket fuel—"HiCal". The move reversed a previous decision to maintain the plant on a standby basis to June 30, 1960.

NONMETALS

The estimated value of nonmetals (native asphalt, cement, clays, gypsum, lime, pumice, salt, sand and gravel, stone, and tripoli) produced in Oklahoma in 1959 was $37 million, a 12-percent gain over 1958. This gain was attributed mostly to cement production and a lesser amount to stone. The only nonmetals that underwent production declines in 1959 were asphalt rock and salt. One salt plant at Sayre remained closed during the year.

The cement industry in the State took a forward step in 1959. Dewey Portland Cement Co. was building a new $13-million plant near Tulsa. This plant, to be completed in the spring of 1960, will have an initial capacity of 1.2 million barrels of cement yearly and an ultimate capacity of 3.7 million barrels yearly. Oklahoma Cement Co., a newly formed corporation, was constructing a $7-million plant near Pryor. This plant, also scheduled for completion in the spring of 1960, has a capacity of 3,000 barrls of cement daily. At Ada, Ideal Cement Co. put in operation its new $19-million plant which has a capacity of 3 million barrels of cement yearly. The older plant, recently modernized at a cost of $4 million, will be kept on a standby basis.

METALS

Mine production of recoverable lead and zinc, all from Ottawa County, underwent drastic reductions in 1959 as all mines remained closed. Concentrates recovered only from mill slimes during the last five months of the year, amounted to only 275 tons of recoverable lead and 494 tons of recoverable zinc.

Smelters.—Three retort smelters were operating in Oklahoma in 1959—the Bartlesville smelter of National Zinc Co., Inc., the Henryetta smelter of Eagle-Picher Co. and the Blackwell smelter of American Metal Climax, Inc. The Blackwell smelter cut production of slab zinc by 4,000 tons annually effective July 1. The Henryetta smelter operated 6 of its 10 furnace blocks from April to July; then 8 furnace blocks for the remainder of the year.

Tri-State District.—All mines in the Tri-State District remained closed in 1959 and only mill slimes were processed at the Central Mill during the last five months. Concentrates recovered from these slimes, credited to Kansas and Oklahoma only, amounted to only 435 tons of recoverable lead and 800 tons of recoverable zinc. Prices per pound paid for these metals averaged 11.9 cents for lead and 11.4 cents for zinc.

SPIRIFER GRIMESI FROM THE ST. JOE LIMESTONE NEAR TAHLEQUAH, OKLAHOMA

George G. Huffman and John M. Starke, Jr.

School of Geology, Norman, Oklahoma

The St. Joe limestone of Early Mississipian age is well developed in the Oklahoma Ozarks where it disconformably overlies the Chattanooga black shale (Noel equivalent) and is succeeded disconformably by the Reeds Spring formation. The St. Joe has been recognized and described in northeastern Oklahoma by several geologists including Taff (1905), Snider (1915), Cram (1930), Ireland (1930), and Montgomery (1951). It has been mapped as an independent unit by Gore (1952) in the Spavinaw and Salina Creek areas of Delaware and Mayes County and by Huffman et al. (1958) in parts of Craig, Mayes, Cherokee, Adair and Sequoyah Counties. Detailed mapping along the Illinois River northeast of Tahlequah is in progress by the authors.

The term St. Joe was applied by Hopkins (1893, p. 253) to a noncherty development of limestone at the base of the Boone formation near St. Joe, Searcy County, Arkansas. Taff (1905 p. 3) correlated the lower part of the "Boone" of northeastern Oklahoma with the St. Joe of Arkansas. The St. Joe was raised to formational rank by Cline (1934 p. 1137) and divided into a "reef phase" and a "non-reef phase" by Laudon (1939 p. 326). The biohermal or reef phase of the upper part of the St. Joe has been described by Harbaugh (1957, p. 2530-2544) in Mayes and Delaware Counties.

Kaiser (1950 p. 2157-60) considered the St. Joe of Missouri to be equivalent to the Pierson and suggested that the latter term be suppressed as a synonym. Clark and Beveridge (1952, p. 75) raised the St. Joe to group rank in southwestern Missouri to include from bottom to top, the Compton, Northview, and Pierson formations. Huffman et al. (1958) adopted the southwest Missouri terminology for equivalent rocks in northeastern Oklahoma.

The St. Joe group in northeastern Oklahoma includes three well-defined subdivisions. The uppermost (Pierson equivalent) includes a thickness of zero to 25 feet of gray, thick-bedded, finely crystalline limestone which locally passes into a thick, crinoidal reef facies. Below this is a zone of 3 to 5 feet of olive green, calcareous shale or marlstone (Northview equivalent). The basal portion (Compton) consists of zero to 10 feet of gray nodular-weathering, heavy-bedded limestone which becomes thin bedded in upper portions. The non-reef phase has a maximum thickness of about 40 feet and averages less than 10 feet. The "reef phase" locally exceeds 50 feet in thickness; where both the reef and non-reef phases are fully developed, total thickness of the St. Joe may approximate 100 feet.

The fauna of the St. Joe of Arkansas is well known through the work of Hopkins, Girty, Weller and others. The fauna of the St. Joe of southwestern Missouri has been listed by Moore (1928 p. 163-165); that of northeastern Oklahoma by Snider (1915, p. 223), Taff (1905, p. 3), Cline (1934 p. 1140), and Laudon (1939 p. 327). A microcrinoid fauna was collected by Strimple and Koenig (1956) from the green shaly phase northeast of Tahlequah, Oklahoma.

Characteristic forms listed by Laudon (1939, p. 327) include: *Cyathaxonia arcuata* Weller, *Schizoblastus moorei* Cline, *Evactinopora sexradiata* M. and W., *Rhipidomella oweni* Hall and Clarke, "*Dictyoclostus*" *fernglenensis* (Weller), *Spirifer rowleyi* Weller, *Spirifer vernonensis* Swallow, *Brachythyris suborbicularis* (Hall), *Athyris lamellosa* (Leveille), *Cliothyridina prouti* (Swallow), and *Platyceras paralius* W. and W.

One of the most striking and best preserved fossils from the St. Joe of northeastern Oklahoma is a large specimen of *Spirifer grimesi* Hall collected from the upper part of the St. Joe along the center of the line between secs. 18 and 19, T. 19 N., R. 21 E., Cherokee County, Oklahoma (figure 1).

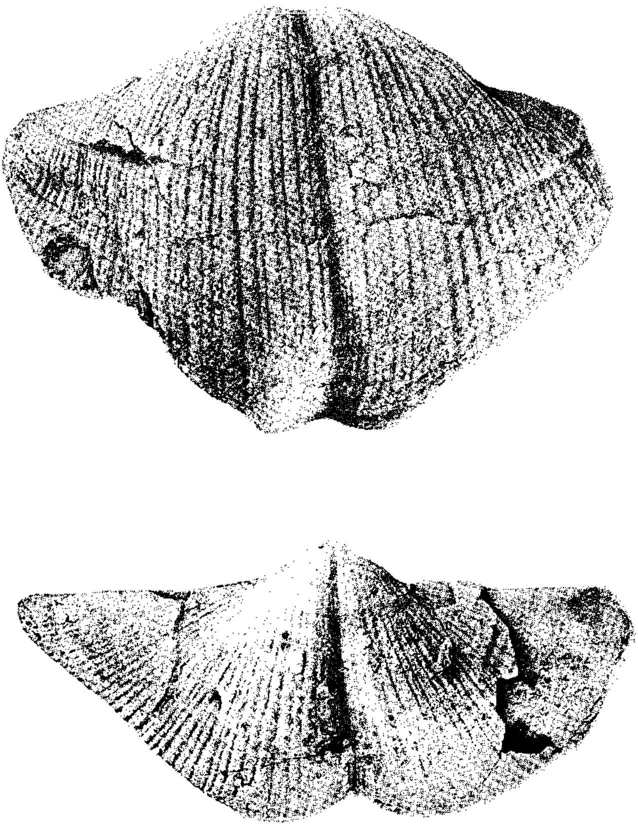

Fig. 1. Two views of the pedicle valve of *Spirifer grimesi* from the St. Joe limestone northeast of Tahlequah, Oklahoma (approximately ⅚ natural size).
(Photographs by Thomas W. Amsden)

This specimen consists of a well-preserved pedicle valve with only a portion of one cardinal extremity missing. This valve is highly convex and measures 120 mm in width and approximately 80 mm in length. The cardinal area is partially exposed and measures 12 mm in height. The mesial sinus is broad and slightly angular in the bottom and is filled with bifurcating plications. The lateral slopes are convex, flattened near the cardinal extremities, and covered by rounded, bifurcating plications. Concentric growth lines near the anterior margins show slight convergence as they approach the cardinal margin.

The matrix associated with this specimen is a gray, fine- to medium-crystalline, crinoidal limestone, a facies common to the upper part of the St. Joe.

The upper part of the St. Joe, the Pierson limestone, is classed as lower Osagean and correlated with the Fern Glen of eastern Missouri (Moore, 1928). The Compton-Northview equivalents are assigned to the upper part of the Kinderhook series. Microcrinoids in the Northview facies resemble those in a shale at the base of the Welden limestone near Ada (Strimple and Koenig, 1956).

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NEW EVIDENCE CONCERNING DALMANITES OKLAHOMAE

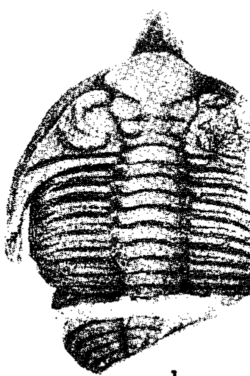
E. A. Frederickson

Richardson (1949, p. 43-45) described the new species, *Dalmanites oklahomae* from "a single, fairly well-preserved, partly exfoliated cephalon" that was found in the collections of the Chicago Natural History Museum. The specimen had been presented to the Museum in 1908 by Mr. W. W. Newberry, of Chicago, with a notation that it came from the Silurian Clinton group at Bromide, Oklahoma.

Although Richardson assigned the trilobite to the Silurian in the title of his paper, he does not make a positive statement as to the age of the specimen in the body of the paper. He examined the matrix that still adhered to the specimen and compared the lithology of the matrix to published descriptions of the rock types of the Henryhouse and Haragan formations of the Hunton group. He arrived at the following conclusion:

"Though the piece of matrix at hand is weathered and of somewhat earthy texture, it is not shaly. Such a small sample, of course, is not necessarily typical of the major features of the formation from which it was collected, so that whether this trilobite is Silurian rather than Devonian must remain uncertain."

Recently, while engaged in a study of the Devonian trilobites from the Haragan formation, I found two nearly complete specimens which appear to be identical with the fragmentary cephalon illustrated and described by Richardson. The trilobites are in a collection made by Dr. Thomas W. Amsden of the Oklahoma Geological Survey and are a part of a large trilobite collection from all known Haragan exposures.



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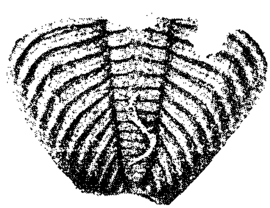

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Plate 1

Fig. 1. *Neoprobolium oklahomae* (Richardson). Dorsal view of specimen from the Oklahoma collections with portion of cephalon and pygidium missing, x2.

Fig. 2. *Neoprobolium oklahomae* (Richardson). Dorsal view of nearly complete pygidium from the same collection showing the prominent lateral nodes, x2.

(Photographs by Thomas W. Amsden)

One of the nearly complete specimens came from Devonian Haragan exposures northeast of Bromide in the NW¼ section 33, T. 1 S., R. 8 E., Coal County, Oklahoma. The other specimen came from the Haragan formation at the old Hunton townsite, NW¼ sec. 8, T. 1 S., R. 8 E., Coal County, Oklahoma. Associated with both specimens are numerous parts of trilobites including several complete pygidia.

It is apparent, then, that the trilobite specimen in the Chicago Natural History Museum is Devonian in age and came from the Haragan formation.

In many of the genera of the Dalmanitidae, i.e. *Dalmanites*, *Synphoroides*, *Odontochile* and *Neoprobolium*, the features of the cephalon are very similar to one another and the genera are mainly distinguished on the characteristics of the pygidium and of the frontal border.

Richardson, having only a portion of the cephalon at hand, naturally assigned the specimen to the genus *Dalmanites*, which the cephalon closely resembled.

However, *Dalmanites sensu stricto* has only 6 or 7 pairs of ribs on the pygidium, whereas the conspecific specimens in the Oklahoma collections have 11 pairs of ribs. In addition, the cephalon which Richardson noted was "about twice as wide (tr.) as long (sag)", the distinctive nodes on the distal extensions of the ribs adjacent to the border, and the frontal spine are all features found in the genus *Neoprobolium*.

It is therefore proposed that the name *Dalmanites oklahomae* Richardson be revised to *Neoprobolium oklahomae* (Richardson) and that the age be changed from Silurian to Devonian.

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SEVENTY COUNTIES IN OKLAHOMA PRODUCE HYDROCARBONS

At the beginning of 1960, 64 counties in Oklahoma produce oil and gas and six counties produce gas only. Those counties productive of gas only are Blaine, Custer, Haskell, Latimer, Le Flore and Sequoyah. Counties without production are Adair, Cherokee, Choctaw, Delaware, Harmon, Pushmataha and Roger Mills. The production of crude oil and lease condensate in Oklahoma in 1959 amounted to 194,731,000 barrels, a decrease of 5,968,000 barrels from the previous year. Marketed production of natural gas was 680,600 million cubic feet, a 2.3 percent decrease below 1958 production. Whereas estimated proved reserves of crude oil in Oklahoma decreased 24,000,000 barrels to a total of 2,204,000,000, reserves of both natural-gas liquids and of natural gas increased. Estimated proved reserves of natural-gas liquids increased 30,493,000 barrels to a total of 357,507,000 barrels; and those of natural gas, 1,033 billion cubic feet to that of 16,240 billion cubic feet. *Source*: *Oil and Gas Journal, vol.* 58, *no.* 4 *(January* 25, 1960) *p.* 157-161.

—L. J.

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Compiled by Neville M. Curtis, Jr.

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Worthing, H. W., see: Jaffee, H. W., and others.

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INDEX
PUBLISHED PAPERS ON OKLAHOMA GEOLOGY IN THE YEAR 1959

Prepared by Neville M. Curtis, Jr.

CASHING-IN ON BASIC RESEARCH

Basic research established the fact that each mineral responds to radiant heat waves in its own particular manner. Some minerals when exposed to infrared waves have the property of absorbing heat and thus show increase in temperature. Such minerals are called athermanous. Dolomite, anhydrite and shale fall into this class. On the other hand, some minerals allow infrared waves to pass through with little or no absorption. These minerals are called diathermanous and, of course, do not show appreciable increase in temperature. Halite (sodium chloride or common salt) is such a mineral.

What, you may ask, is such information worth in an era in which worth is measured in dollars and cents; that is, where the information finds industrial application. The basic information outlined above has now demonstrated its worth when applied to a serious problem that has bothered the rock salt industry for many years. Rock salt, being a natural mineral material, normally contains more or less impurities the removal of which has seldom been completely satisfactory. The undesirable matter commonly found associated with rock salt is dolomite, anhydrite, and shale.

Recently, International Salt Co. announced that they had a solution to the problem and that the first commercial installation to use the process would be in an underground mine at Detroit. The process is based upon research started seven years ago at Battelle Institute. The process involves subjecting crushed rock salt to radiant heat whereby the impure pieces became selectively heated and the pure pieces remained relatively cool. The actual separation of impurities from the salt takes place on a high-speed conveyor belt that has been coated with a heat-sensitive resin. After being subjected to infrared heat, the salt is run onto the coated belt. Due to the temperature difference between the pure salt and the impurities, when the crude material reaches the end of the belt the pure crystals fly off the end into a catch bin but the relatively warmer impurities cling to the resin-coated belt just long enough to drop into another bin, nearer the belt end. So—International Salt Co. "cashes-in" on basic research. Other applications of the basic information surely will follow.

—A. L. B.

INTERPRETATION OF AIR-DRILLED SAMPLES

As drilling with air and gas becomes more widespread and economic, geologists will need to become familiar with procedures for taking good samples and with methods of analysis of such samples obtained by these circulating media. J. K. Petty in *The Petroleum Engineer*, vol. 32, no. 1 (January 1960), p. B-88 to B-95, explained and illustrated an air-sampling jet. He discussed methods and problems of interpreting lithologic character of penetrated rocks and described formations in the Arkoma basin area.

—L. J.

SURVEY PUBLICATIONS PASS 20,000 PAGE MARK

With the release of Bulletin 84 on January 13, the Survey's total publication record passed 20,000 pages. The present total is 20,131 pages. In press are reports which will total approximately 600 pages. Divided into epochs of Survey existence the pages of publication are:

1908-1913	1,631 pages
1914-1922	2,052 pages
1924-1933	4,539 pages
1935-1952	5,700 pages
1953-1960	6,209 pages
Total	20,131 pages

The publications are 84 Bulletins (12,207 pages), 50 Circulars (2,102 pages), 36 Mineral Reports (756 pages), 20 volumes of The Hopper and Oklahoma Geology Notes (2,997 pages), 8 Biennial Reports (432 pages), 9 Guide Books (555 pages), and issues not in series (1,841 pages).

PROGRESS OF TOPOGRAPHIC MAPPING

In May of 1958 topographic maps of any real value were available for about one-fourth of the State. Progress in mapping has been rapid. Six 15-minute sheets and 14 7½-minute sheets were issued by the end of 1958. In 1959 many new sheets were issued and a large number were authorized. A summary of current status of mapping shows:

	to May 1958	to Dec. 31, 1960	in progress	authorized
15-minute quadrangles	45	66	27	10
7½-minute quadrangles	50	114	20	98

It would require 317 fifteen-minute quadrangles to cover the State. One hundred three are printed, in progress, or authorized, and 42 ¾ are or will be covered by larger scale maps.

At this time no topographic maps at a scale greater than four inches to the mile have been published or are authorized for Cimarron, Texas, Beaver, Harper, Ellis, Woodward, Woods, or Grant Counties. This is the large untouched part of the State, and there is a wide unmapped belt adjacent to it in Texas and Kansas.

Mapping is done by the Topographic Branch of the U. S. Geological Survey. Work is mainly done on a match-funds basis from another agency. In Oklahoma the recent projects have been sponsored by the Tulsa Metropolitan Planning Board, the Oklahoma City water authority, the Air Force, and the Army.

—C. C. B.

ERRATUM

In Fig. 1, p. 24 of vol. 20, no. 2, *Oklahoma Geology Notes*, the symbol indicating sandstone was omitted from the section shown as Marlow formation.

NEW PUBLICATIONS

The final section of Dr. Amsden's report on the rocks and fossils of the Hunton group was released on January 14, 1960. The book is "Stratigraphy and paleontology of the Hunton group in the Arbuckle Mountain region, Part VI, Hunton stratigraphy": Oklahoma Geological Survey, Bulletin 84, 311 pages, 56 figures, 17 plates, 3 panels. The book is priced at $4.00 bound in blue cloth, $3.00 paper bound.

A report on the geology of northern Latimer County was released on January 25. The investigation was made by Dearl T. Russell as part of his Master of Science requirements at the University of Oklahoma. The book is "Geology of northern Latimer County, Oklahoma": Oklahoma Geological Survey, Circular 50, 57 pages, 12 figures, colored geologic map, price $2.50 bound, $2.00 in paper cover.

Other Survey reports in various stages of the press are:

Bulletin 85, Late Paleozoic rocks of the Ouachita Mountains

Bulletin 86, Geology and ground-water resources of southern McCurtain County

Bulletin 87, Ground-water resources of Canadian County

Bulletin 88, Geology of the Boktukola syncline

Circular 49, Microflora of the Flowerpot shale

Circular 51, Geology of the Cavanal syncline

Circular 53, Geology of the Featherston area