THE BERWYN CONGLOMERATE

The cover photograph shows an exposure of the Berwyn Conglomerate, just above the Berwyn coal smut at the type section, about 2 miles south of Gene Autry (formerly Berwyn), Carter County, Oklahoma (SW¼NE¼SE¼NW¼ sec. 36, T. 3 S., R. 2 E.). Here, the Berwyn lies about 200 feet above the Confederate Limestone.

The Berwyn Conglomerate was first named by Birk (1925, AAPG Bulletin, v. 9, p. 987). At that time, the conglomerate was thought to contain arkose and was correlated with the Pontotoc Group (now Oscar and Vanoss Groups) around the west and north edges of the Arbuckle Mountains. The type section is 74 feet thick and consists of alternating beds of greenish-gray and reddish-brown shales, tan fine-grained sandstones, and algal limestone and chert conglomerates. About 6 feet above the base is a 5-foot gray shale and siltstone containing coal smuts and yielding a lower Hoxbar (early Missourian) flora. Many of the limestone and chert pebbles are covered with algal layers as much as 2 inches thick, and in many places the Pontotoc overlies the Berwyn and contains reworked Berwyn rocks. When the Berwyn Conglomerate is traced southward and westward from the type section, the conglomeratic portions of the Berwyn disappear, indicating a northeastern origin.

—Robert O. Fay

Editorial staff: William D. Rose, Rosemary Croy, Elizabeth A. Ham

Oklahoma Geology Notes is published bimonthly by the Oklahoma Geological Survey. It contains short technical articles, mineral-industry and petroleum news and statistics, an annual bibliography of Oklahoma geology, reviews, and announcements of general pertinence to Oklahoma geology. Single copies, seventy-five cents; yearly subscription, $3.00. All subscription orders should be sent to the address on the front cover.

Short articles on aspects of Oklahoma geology are welcome from contributors. A set of guidelines will be forwarded on request.

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Statistics of Oklahoma’s Petroleum Industry, 1973

John F. Roberts

Total drilling of wells in search of oil and gas decreased slightly in 1973, from the 1972 total of 2,300 to 2,281 (table 1, fig. 1). A sizable increase in development gas wells was recorded (from 286 in 1972 to 470 in 1973), owing to a substantial price increase, particularly in intrastate contracts.

Table 1.—Drilling Activity in Oklahoma, 1973

<table>
<thead>
<tr>
<th></th>
<th>1973</th>
<th></th>
<th></th>
<th>1972</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CRUDE</td>
<td>GAS</td>
<td>DRY</td>
<td>TOTAL</td>
<td>TOTAL</td>
</tr>
<tr>
<td>All wells</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of completions</td>
<td>898</td>
<td>539</td>
<td>844</td>
<td>2,281</td>
<td>2,300</td>
</tr>
<tr>
<td>Footage</td>
<td></td>
<td></td>
<td>12,434,227</td>
<td>12,297,180</td>
<td></td>
</tr>
<tr>
<td>Average footage</td>
<td></td>
<td></td>
<td>5,451</td>
<td>5,347</td>
<td></td>
</tr>
<tr>
<td>Exploration wells</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of completions</td>
<td>35</td>
<td>69</td>
<td>248</td>
<td>352</td>
<td>416</td>
</tr>
<tr>
<td>Percentage of completions</td>
<td>30</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Footage</td>
<td></td>
<td></td>
<td>2,279,089</td>
<td>2,907,925</td>
<td></td>
</tr>
<tr>
<td>Average footage</td>
<td></td>
<td></td>
<td>6,475</td>
<td>6,990</td>
<td></td>
</tr>
<tr>
<td>Development wells</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of completions</td>
<td>836</td>
<td>470</td>
<td>596</td>
<td>1,929</td>
<td>1,884</td>
</tr>
<tr>
<td>Percentage of completions</td>
<td>69</td>
<td></td>
<td>68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Footage</td>
<td></td>
<td></td>
<td>10,155,138</td>
<td>9,389,255</td>
<td></td>
</tr>
<tr>
<td>Average footage</td>
<td></td>
<td></td>
<td>5,264</td>
<td>4,984</td>
<td></td>
</tr>
</tbody>
</table>

Source: Oil and Gas Journal, v. 72, no. 16, April 22, 1974.

The number of oil wells did not keep up the pace, because higher oil prices arrived so late in the year that increased drilling was reflected only in the number of active locations at year’s end, not in completions. Sixty-two counties were explored for new reserves (fig. 2). Woodward County was the site of the most activity—25 tries, 5 of which were successful gas discoveries. As usual, Osage County had the highest total wells, 178; Kingfisher was second with 127 tests. The statewide success ratio for development wells was 69 percent; exploratory wells, 30 percent.

Natural-gas development and exploration activities in the western and northwestern counties of the State, involving Morrow (Pennsylvanian) and Springer (Mississippian) sands and the Hunton Limestone, accounted for two sizable portions of the State’s effort. Similar activity occurred with good

1Geologist, Oklahoma Geological Survey.
Figure 1. Graph showing total wells drilled, oil wells completed, and gas wells completed in Oklahoma, 1946-73. Source: Oil and Gas Journal.

results in the same formations in Canadian, Grady, and Caddo Counties, central Oklahoma. The Sycamore Limestone (Mississippian) discovery made in Stephens County during 1972, under the old Hewitt Field (Pennsylvanian production), expanded in all directions and now extends into Carter County. This one reservoir is becoming a major source of reserves within the State.

A recently received publication, National Stripper Well Survey, January 1, 1974, a joint project of the Interstate Oil Compact Commission and the National Stripper Well Association, indicates that at the close of 1973, Oklahoma had approximately 57,000 stripper wells, a 4.2 percent increase over 1972 figures. A stripper well, for the purpose of this survey, is a well capable of producing 10 barrels of oil per day or less during the year under consideration. In Oklahoma, stripper wells produced 74,109,932 barrels of oil during 1973, accounting for about 38 percent of the State’s total liquid hydrocarbon production. There is a sensitive relationship between the increasing value of oil and rising operating expenses, and the relative changes in each have considerable impact on the amount of remaining reserves that can be recovered economically.

Table 1 summarizes drilling activity during 1973 and compares it with that of the previous year. The average total depth of all wells increased from 5,347 feet to 5,451 feet. The average total depth for exploratory drilling decreased, owing to fewer completions in the deep Anadarko basin. Several
Figure 2. Exploratory drilling by counties during 1973. Upper figures give the number of exploratory wells drilled; lower figures give the number of successful completions. Source: American Petroleum Institute in cooperation with the U.S. Bureau of Mines.
wells in that area were still drilling at year's end. The average footage of
development wells increased significantly, from 4,984 to 5,264.

The 21 giant fields of Oklahoma are listed in table 2. (A giant field is
one that has an estimated recovery of more than 100 million barrels of oil.)
These giant fields produced 41 percent of the year's total oil and accounted
for 48 percent of the estimated ultimate yield and 41 percent of the remain-
ing recoverable reserves in the State. This production came from 35 percent
of the State's total number of producing wells.

<table>
<thead>
<tr>
<th>FIELD</th>
<th>1973 PRODUCTION (1000 BBLS)</th>
<th>CUMULATIVE PRODUCTION (1000 BBLS)</th>
<th>ESTIMATED RESERVES (1000 BBLS)</th>
<th>NUMBER OF WELLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allen</td>
<td>2,645</td>
<td>124,381</td>
<td>15,619</td>
<td>1,495</td>
</tr>
<tr>
<td>Avant</td>
<td>410</td>
<td>106,242</td>
<td>2,758</td>
<td>625</td>
</tr>
<tr>
<td>Bowlegs</td>
<td>1,750</td>
<td>156,827</td>
<td>8,173</td>
<td>180</td>
</tr>
<tr>
<td>Burbank</td>
<td>3,870</td>
<td>500,354</td>
<td>40,646</td>
<td>1,075</td>
</tr>
<tr>
<td>Cement</td>
<td>2,470</td>
<td>138,956</td>
<td>16,044</td>
<td>1,475</td>
</tr>
<tr>
<td>Cushing</td>
<td>3,245</td>
<td>460,217</td>
<td>24,783</td>
<td>1,715</td>
</tr>
<tr>
<td>Earlsboro</td>
<td>460</td>
<td>215,804</td>
<td>4,196</td>
<td>190</td>
</tr>
<tr>
<td>Edmond West</td>
<td>715</td>
<td>154,522</td>
<td>5,478</td>
<td>455</td>
</tr>
<tr>
<td>Eola-Robberson</td>
<td>4,355</td>
<td>104,257</td>
<td>35,743</td>
<td>485</td>
</tr>
<tr>
<td>Pitts</td>
<td>2,180</td>
<td>148,308</td>
<td>11,692</td>
<td>610</td>
</tr>
<tr>
<td>Glenn Pool</td>
<td>2,150</td>
<td>307,441</td>
<td>12,559</td>
<td>1,015</td>
</tr>
<tr>
<td>Golden Trend</td>
<td>9,875</td>
<td>393,876</td>
<td>106,124</td>
<td>1,235</td>
</tr>
<tr>
<td>Healdton</td>
<td>6,880</td>
<td>286,665</td>
<td>33,335</td>
<td>1,520</td>
</tr>
<tr>
<td>Hewitt</td>
<td>6,880</td>
<td>212,391</td>
<td>37,609</td>
<td>1,180</td>
</tr>
<tr>
<td>Little River</td>
<td>365</td>
<td>159,571</td>
<td>5,429</td>
<td>170</td>
</tr>
<tr>
<td>Oklahoma City</td>
<td>1,860</td>
<td>731,896</td>
<td>18,104</td>
<td>280</td>
</tr>
<tr>
<td>Seminole, Greater</td>
<td>1,190</td>
<td>198,446</td>
<td>11,554</td>
<td>260</td>
</tr>
<tr>
<td>Sho-Vel-Tum</td>
<td>33,320</td>
<td>968,206</td>
<td>181,794</td>
<td>8,025</td>
</tr>
<tr>
<td>Sooner Trend</td>
<td>11,480</td>
<td>189,604</td>
<td>60,396</td>
<td>2,920</td>
</tr>
<tr>
<td>St. Louis</td>
<td>1,185</td>
<td>215,045</td>
<td>9,955</td>
<td>635</td>
</tr>
<tr>
<td>Tonkawa</td>
<td>275</td>
<td>134,937</td>
<td>2,063</td>
<td>200</td>
</tr>
</tbody>
</table>

Totals       | 97,560                       | 5,907,946                         | 644,054                       | 25,745          |

Source: Oil and Gas Journal, v. 72, no. 4, January 28, 1974.

Table 3 lists cumulative and yearly production and the value of all
petroleum products to January 1, 1974. Table 4 compares the petroleum
production of the past 2 years. Crude-oil and natural-gas production de-
clined, while the total value of each product increased owing to increased
unit prices (especially in the last quarter of the year). Production rates
failed to meet market demands, even though maximum effort was made.
### Table 3.—Cumulative (through 1955) and Yearly (1956-1973) Marketed Production and Value of Petroleum, Natural Gas, Natural Gasoline, and Liquefied Petroleum Gas in Oklahoma

<table>
<thead>
<tr>
<th>Year</th>
<th>Crude Petroleum</th>
<th>Natural Gas</th>
<th>Natural Gasoline and Cycle Products</th>
<th>Liquefied Petroleum Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume (1,000 BBLS)</td>
<td>Value ($1,000)</td>
<td>Volume (MMCF)</td>
<td>Value ($1,000)</td>
</tr>
<tr>
<td>Through</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1955</td>
<td>7,230,010</td>
<td>11,443,269</td>
<td>12,977,332</td>
<td>1,378,370</td>
</tr>
<tr>
<td>1956</td>
<td>215,862</td>
<td>600,096</td>
<td>678,603</td>
<td>54,288</td>
</tr>
<tr>
<td>1957</td>
<td>214,661</td>
<td>650,423</td>
<td>719,794</td>
<td>59,743</td>
</tr>
<tr>
<td>1958</td>
<td>200,699</td>
<td>594,069</td>
<td>696,504</td>
<td>70,347</td>
</tr>
<tr>
<td>1959</td>
<td>198,090</td>
<td>578,423</td>
<td>811,508</td>
<td>81,151</td>
</tr>
<tr>
<td>1960</td>
<td>192,913</td>
<td>563,306</td>
<td>824,266</td>
<td>98,088</td>
</tr>
<tr>
<td>1963</td>
<td>201,962</td>
<td>587,709</td>
<td>1,233,883</td>
<td>160,405</td>
</tr>
<tr>
<td>1964</td>
<td>202,524</td>
<td>587,320</td>
<td>1,323,390</td>
<td>166,747</td>
</tr>
<tr>
<td>1965</td>
<td>203,441</td>
<td>587,944</td>
<td>1,320,995</td>
<td>182,297</td>
</tr>
<tr>
<td>1966</td>
<td>224,539</td>
<td>654,281</td>
<td>1,351,225</td>
<td>189,172</td>
</tr>
<tr>
<td>1967</td>
<td>230,749</td>
<td>676,095</td>
<td>1,412,952</td>
<td>202,052</td>
</tr>
<tr>
<td>1968</td>
<td>223,623</td>
<td>668,202</td>
<td>1,390,884</td>
<td>197,506</td>
</tr>
<tr>
<td>1969</td>
<td>224,729</td>
<td>701,155</td>
<td>1,523,715</td>
<td>223,128</td>
</tr>
<tr>
<td>1970</td>
<td>223,574</td>
<td>712,419</td>
<td>1,594,943</td>
<td>248,811</td>
</tr>
<tr>
<td>1971</td>
<td>213,312</td>
<td>725,610</td>
<td>1,684,260</td>
<td>273,945</td>
</tr>
<tr>
<td>1972</td>
<td>207,633</td>
<td>709,033</td>
<td>1,806,887</td>
<td>294,523</td>
</tr>
<tr>
<td>1973</td>
<td>193,107</td>
<td>753,117</td>
<td>1,771,626</td>
<td>327,751</td>
</tr>
<tr>
<td>Totals</td>
<td>10,997,541</td>
<td>22,946,314</td>
<td>35,076,181</td>
<td>4,452,112</td>
</tr>
</tbody>
</table>

Figures from: Minerals Yearbook 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 USBM and API compilations of an estimated production of 26,355,000 barrels for the years 1905-1906.

Figure 3 shows a decrease in natural-gas reserves from 14.5 trillion cubic feet to 14.1 trillion cubic feet. Extensions and revisions increased, as did discoveries, owing to the accelerated search for higher priced natural gas in all portions of the State, particularly in western Oklahoma. The remaining-reserves ratio to production was 7.9, compared to 8.25 the previous year.

Figure 3. Graph showing statistics on estimated proved reserves of natural gas in Oklahoma, 1946-73. Source: American Gas Association, annual reports.
Figure 4 displays a slight increase in extensions and revisions of total liquid hydrocarbons. The decline of production from 240 million barrels in 1972 to 220 million barrels in 1973 accounts for the decline of remaining reserves to 1,560 million barrels, a ratio of 7.1.

Figure 4. Graph showing statistics on estimated proved reserves of total liquid hydrocarbons in Oklahoma, 1946-73. Source: American Petroleum Institute, annual reports.
Oklahoma continues to rank third in the nation in gas production (with 7.9 percent of the total U.S. production) and fourth in crude-oil production (5.6 percent of the total). The State ranks fourth in terms of natural-gas reserves and fifth in oil reserves.

<table>
<thead>
<tr>
<th>TABLE 4. — HYDROCARBON PRODUCTION IN OKLAHOMA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crude oil and lease condensate</strong></td>
</tr>
<tr>
<td>Total annual production (1,000 bbls)</td>
</tr>
<tr>
<td>Value ($1,000)</td>
</tr>
<tr>
<td>Cumulative production 1891-year (1,000 bbls)</td>
</tr>
<tr>
<td>Daily production (bbls)</td>
</tr>
<tr>
<td>Total number of producing wells</td>
</tr>
<tr>
<td>Daily average per well (bbls)</td>
</tr>
<tr>
<td>Oil wells on artificial lift (estimated)</td>
</tr>
<tr>
<td><strong>Natural gas</strong></td>
</tr>
<tr>
<td>Total annual marketed production (MMCF)</td>
</tr>
<tr>
<td>Value ($1,000)</td>
</tr>
<tr>
<td>Total number of gas and gas-condensate wells</td>
</tr>
<tr>
<td><strong>Natural-gas liquids</strong></td>
</tr>
<tr>
<td>Total annual marketed production (1,000 bbls)</td>
</tr>
<tr>
<td>Value ($1,000)</td>
</tr>
</tbody>
</table>

1Item for 1972 is U.S. Bureau of Mines final figure. Item for 1973 is U.S. Bureau of Mines preliminary figure.

USGS to Set Up Regional Core Libraries

An important segment of a new 5-year program instituted by the U.S. Geological Survey to develop new exploratory ideas and techniques for use by the oil and gas industry involves setting up regional well-core libraries. The program is under the direction of C. Keith Fisher of the USGS Denver office, and the first of these repositories will be developed in the Denver area to store all core material available from the Rocky Mountain states. Material is expected to come from exploration-company libraries, academic institutions, state groups, and from outcrops currently drilling wells—in short, from all sources where it is in jeopardy of being lost through lack of space or facilities. Successful development will depend on cooperation and coordination from state surveys and from industry.

Future plans for the core libraries call for the USGS to phase out its supervision of the regional facilities and turn them over as self-sustaining operations supported by state survey agencies, professional societies, private companies, and individuals.

Comments on the core library project are solicited by the USGS and should be addressed to C. Keith Fisher, U.S. Geological Survey, Federal Center, Denver, Colorado 80225.
Facies and the Reconstruction of Environments

A Review

ELIZABETH A. HAM


Emphases change, in geology as in other realms of man's search after knowledge, and it seems now as if the earth sciences are caught up in a wave of nostalgia. Geology, almost by definition, has always been concerned with the way things were, but there are more and more current releases dealing with paleoenvironments, paleogeography, tectonics, paleotemperatures, paleocurrents, paleoecology, and facies, facies, facies.

No. 10 in the AAPG Reprint Series is educational, reeducational, and, at the risk of committing a pun, timely.

This paperback publication, made up of 8 selected articles by 9 well-selected authors, reprinted from the AAPG Bulletin, is evolutionary in its structure of proceeding from the concept of facies to the methodology of study of the concept and then to the practical applications of the results obtained. The book is time-progressive, however, in the structure of its presentation of papers, moving from Thomas G. Payne's 73-page article, "Stratigraphical Analysis and Environmental Reconstruction," first published in the Bulletin in 1942, to Gary A. McDaniel's "Application of Sedimentary Directional Features and Scalar Properties to Hydrocarbon Exploration," which appeared in the September 1968 issue.

Time stops with that issue, and although the reason for terminating the reprints in 1968 is explained succinctly by Jules Braunstein in his excellent brief preface—"newer volumes are readily available to interested readers"—this reader was left with the letdown feeling experienced at the termination of an absorbing series. One hopes that some day there will be a follow-up.

In addition to the sudden ending, another unfortunate but necessary detraction from the excellence of this volume is the omission of material on carbonate rocks; as Braunstein states in the preface, the AAPG plans other reprint volumes on carbonates.

The most comprehensive paper, a refresher course in itself, is Payne's lengthy article, already mentioned. The terminology is expansive, with full descriptions of concepts leading to the choice of terms. Categories, subcategories, methods of study, methods of application, and numerous illustrated and tabular examples of processes and contributing conditions from living organisms to geographical factors to dynamism are included.

Were the volume arranged in logical progression, however (from the concept through methodology to the practical application in resource explo-

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1Assistant Editor, Oklahoma Geological Survey.
ration), rather than chronologically, it would have begun with either J. Marvin Weller's article, "Stratigraphic Facies Differentiation and Nomenclature," or Curt Teichert's "Concepts of Facies." Weller's paper is really a beginning, a definition, and Teichert's is loaded with the history of the subject, from Steno in 1669 through modern-day sedimentologists. Both of these papers offer a plethora of valuable references, making them doubly significant.

An article by W. C. Krumbein and F. G. Nagel, "Regional Stratigraphic Analysis of 'Upper Cretaceous' Rocks of Rocky Mountain Region," is valuable for its instructions on the preparation of maps. This paper offers a good footing for the approach taken in the articles by John M. Andrichuk, Robert W. Stapp, and Gary McDaniel, all of which are concerned primarily with applying the study of facies and paleoenvironments to the recovery of fossil fuels. Charles D. Masters' short article (10 pages) with a long title, "Use of Sedimentary Structures in Determination of Depositional Environments, Mesaverde Formation, Williams Fork Mountains, Colorado," anticipates some of the recent work published by several scientists, including John Shelton, who authored Oklahoma Geological Survey Bulletin 118, which sets forth a methodology for determining sand genesis and which was published in October 1973.

Facies and the Reconstruction of Environments is nostalgic in more ways than one. It is bound to take readers back to an academic time when they studied these concepts in a classroom, perhaps under one of the authors included, perhaps even under Professor G. E. Anderson at The University of Oklahoma.

U.S. Board on Geographic Names Decisions

*Ivanhoe Creek* (variants: Lyranhae Creek, Manbee Creek) has been adopted by the U.S. Board on Geographic Names to identify a 26-mile-long (42 km) stream which heads in Lipscomb County, Texas, at 36°27'29" N., 100°10'30" W., and flows northeast into Wolf Creek 3.5 miles (5.6 km) west northwest of Shattuck in Ellis County, Oklahoma (sec. 24, T. 21 N., R. 26 W., Indian Meridian; 36°17'21" N., 99°56'38" W.). (U.S. Board of Geographic Names, *Decisions on Geographic Names in the United States*, Decision List 7401, January through March 1974, p. 12.)

*Seneca Creek* (variants: Cieneguilla Creek, Cieneguilla Creek, Cieneguilla Creek, Cieneguilla Creek, Cieneguilla Creek) has been adopted by the U.S. Board on Geographic Names to identify a stream 50 miles (80 km) long, which heads in Union County, New Mexico, at 36°37'10" N., 103°38'30" W., and flows eastward to join Corrumpa Creek to form the Beaver River 4.5 miles (7.2 km) northwest of Felt, in Cimarron County, Oklahoma (sec. 32, T. 2 N., R. 2 E., Cimarron Meridian; 36°35'52" N., 102°52'00" W.). (U.S. Board on Geographic Names, *Decisions on Geographic Names in the United States*, Decision List 7402, April through June 1974, p. 16.)
New Brachiopod Bulletin Released by Survey

Bulletin 119, an investigation of Late Ordovician-Early Silurian brachiopods, has just been released by the Oklahoma Geological Survey. Written by Survey geologist Thomas W. Amsden, the report describes articulate brachiopods from the Keel Formation of the Arbuckle Mountain region of Oklahoma and from correlative units in the Edgewood Group of southwestern Illinois and eastern Missouri, in the Mississippi River valley.

The study is of special significance, because faunas of this general age (Late Ordovician and Early Silurian) have been little known, not only for the central United States but for many parts of the world. An interesting characteristic of the faunas described in this report is their similarity to the *Hirnantia* fauna of Europe.

The combined faunas of the Keel Formation and the Edgewood Group total 29 species, of which 8 are new; 27 genera are represented, of which 4 are new: *Leptoskelidion*, *Biparetis*, *Brevilamnulella*, and *Thebesia*. The 26 fossil plates included in the report illustrate silicified specimens of excellent preservation, showing exterior and interior structure in detail.

Additional illustrations comprise 2 plates of photomicrographs of Edgewood thin sections and 51 text-figures of various kinds. An appendix containing detailed descriptions of collecting localities and 13 tables of biometric data rounds out the publication.

The 154-page Bulletin 119, *Late Ordovician and Early Silurian Articulate Brachiopods from Oklahoma, Southwestern Illinois, and Eastern Missouri*, can be ordered from the address on the front cover of the *Notes*. Paperbound copies are $6.50 apiece, and hardbound copies, $8.50.

***Notes Available in Microform***

The Oklahoma Geological Survey has entered into an agreement with Xerox Corporation that makes *Oklahoma Geology Notes* available through the Xerox University Microfilms Serials Program. Since 1949, Xerox University Microfilms has produced microfilm and microfiche of the world's leading serials for libraries and for scholars. The collection includes approximately 7,000 periodicals, dating from 1668 to the present.

Under the terms of our agreement, current issues of the *Notes* will be sold in miniature form only to bona fide subscribers to the publication. These copies will not be distributed until the end of the volume year, at which time the entire volume will be delivered. Back issues (dating back from 1941-73) will be available in miniature form to all who request them regardless of whether they subscribed to the original edition.

For additional information about the micro-edition of the *Notes*, please contact Xerox University Microfilms, 300 North Zeeb Road, Ann Arbor, Michigan 48106 (phone: 313, 761-4700).
U.S. BUREAU OF MINES AND STATE LEGISLATIVE COUNCIL
SPONSOR FIELD TRIP

The U.S. Bureau of Mines Liaison Office in Oklahoma, cooperating with the State Legislative Council, sponsored a field trip September 18-19 to the coal-mining area of eastern Oklahoma. Robert Arndt, USBM Liaison Officer-Oklahoma, was the principal organizer, and Senator Leon Field, Senator Bob Funston, and Representative Earnest Isch, members of the State Legislative Council's Committee on Soil and Water Resources, were in attendance, along with representatives of several State agencies, personnel from certain federal agencies, and persons from various concerned citizens groups who were invited to attend.

People sometimes overlook opportunities to influence or consult with State legislators by forgetting that these elected officials work for them even during the 7 months of the year when the Legislature is not in session. The work of the State Senate and House of Representatives is carried on during the legislative interim by committees that are organized under the auspices of the State Legislative Council. The committees are assigned to gather data on specific issues and make recommendations on what and whether legislation needs to be enacted when the State Legislature convenes.

State Senator Bob Funston, a member of the State Legislative Council's Committee on Soil and Water Resources, examines unreclaimed coal land in eastern Oklahoma. The committee chairman, Senator Leon Field, and Representative Earnest Isch also participated in the 2-day field trip.
Participants on the USBM-State Legislative Council field trip examine an area northeast of Stigler that has been surface mined and then reclaimed by Garland Coal and Mining Company. Mrs. H. H. Holman, who represented the League of Women Voters on the trip, photographs grasses growing from the shaly terrain.

The field trip to eastern Oklahoma enabled members of the Committee on Soil and Water Resources to compare, firsthand, the dramatic differences in the appearance of land mined before Oklahoma passed reclamation laws versus that reclaimed under the Reclamation Act of 1968 and the 1971 act. The legislators also talked to employees of several coal companies and to fellow trip participants about current mining practices. Pertinent aspects of surface mining for coal—including technology, geology, applied and natural reclamation, the reasons for the existence of unreclaimed land in Oklahoma and the problems caused thereby, the potential for utilization of reclaimed land, standards for environmental quality and their relationship to existing and pending national and state laws and legislation—were considered during the 2 days. Material passed out to all participants included Oklahoma Geological Survey map GM-17, Description of Disturbed and Reclaimed Surface-Mined Coal Lands in Eastern Oklahoma, by Kenneth S. Johnson. State Legislators, state and federal employees, mining personnel, and interested citizens had an opportunity to learn from each other, and the consensus seemed to be that more beneficial action, finer representation, and more cooperation between all parties would result if opportunities for interaction could somehow be devised for all persons involved whenever state or federal legislation is contemplated.

—Rosemary L. Croy
GSA Special Papers Deal with Ammonoids and Conodonts from Arkansas and Oklahoma

Two recent publications by The Geological Society of America are of special interest to Oklahoma geologists. Special Paper 145, *Upper Mississippian Ammonoids from Arkansas and Oklahoma*, by W. Bruce Saunders, concerns itself with the Imo Formation of northeastern Arkansas and the Rhoda Creek Formation of south-central Oklahoma, which contain rich ammonoid assemblages of approximately equivalent age. Studies such as this one are providing refined standards for detailed regional and worldwide biostratigraphic correlations.

Special Paper 152, *Late Mississippian and Early Pennsylvanian Conodonts, Arkansas and Oklahoma*, by H. Richard Lane and Joseph J. Straka II, presents a comprehensive systematic treatment of conodonts from Late Mississippian and Early Pennsylvanian rocks exposed in the type Springerian and Morrowan regions. One important contribution of the 144-page report is that it demonstrates that the Springerian Series is not a viable time-stratigraphic subdivision of the Lower Pennsylvanian.

The 110-page Special Paper 145 sells for $6.50, and Special Paper 152 costs $12.50. Both can be ordered from The Geological Society of America, Publication Sales Department, 3300 Penrose Place, Boulder, Colorado 80301.

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New Thesis and Dissertations Added to OU Geology Library

The following M.S. thesis has been added to The University of Oklahoma Geology and Geophysics Library:

*Evolution of Folds in the Blaylock Formation (Silurian), Ouachita Mountains, Southeastern Oklahoma*, by Roger E. Feenstra.

The following Ph.D. dissertations have also been added to the library:

*Brachiopod Biostratigraphy and Faunas of the Morrow Series (Lower Pennsylvanian) of Northwestern Arkansas and Northeastern Oklahoma*, by Thomas Wood Henry.

*The Structure of the Interlayer Water in Montmorillonite*, by Garrett Louis Morrison.
SUMMARY OF OCTOBER 1973 RAINSTORM
ENID AND VICINITY, NORTH-CENTRAL OKLAHOMA

U.S. GEOLOGICAL SURVEY

Heavy and intense rainfall centered over the urban area of Enid, Oklahoma, on October 10 and 11, 1973, resulting in record-breaking floods and extensive damage along many streams in north-central Oklahoma. This report shows the distribution of the intense rainfall and briefly describes the flooding and damage from that storm. The data presented are a summary of U.S. Geological Survey Water-Resources Investigations 27-74, entitled Flood of October 1973 in Enid and Vicinity, North-Central Oklahoma, by R. H. Bingham, D. L. Bergman, and W. O. Thomas, Jr.

The National Weather Service at Enid recorded 15.68 inches (39.83 cm) of rainfall in 13 hours, and 12 inches (30 cm) of that amount fell between 6:45 and 9:45 p.m. on October 10. The maximum amount registered for a 1-hour period was 5.3 inches (13.5 cm) between 8:00 p.m. and 9:00 p.m. Supplemental rainfall data collected by the National Weather Service and the U.S. Geological Survey were used to delineate an area of approximately 500 square miles (1,300 km²) that received more than 10 inches (25 cm) of rainfall and an area of approximately 100 square miles (260 km²) that received 15 to 20 inches (38 to 51 cm; fig. 1).

Rainfall during the October 1973 storm represented 54 percent of the mean annual precipitation of 29.15 inches (74.0 cm) at the Enid weather station, and it was approximately 7 times greater than the normal October rainfall of 2.27 inches (5.77 cm). The total rainfall for the 13-hour storm, 15.68 inches (39.83 cm), exceeded the State's previous 24-hour record of 12.3 inches (31.2 cm) for any October since the State first began recording weather information in 1892.

Peak discharges at one crest-stage partial-record station and at 15 miscellaneous sites were determined by indirect methods using hydraulic formulas for flow in open channels, flow over road embankments, and flow through contracted openings at bridges and culverts. Peak-unit discharge, which generally is expressed in cubic feet per second per square mile or cubic meters per second per square kilometer, is an indication of flood intensity. During the October 1973 flood, the peak-unit discharge at the indirect-discharge-measurement sites ranged from 140 cubic feet per second per square mile (1.53 cubic meters per second per square kilometer) for Osage and Pond Creeks at Jefferson to 1,660 cubic feet per second per square mile (18.09 cubic meters per second per square kilometer) for the Sand Creek tributary near Kremlin. The peak discharges for many streams within the storm area exceeded the calculated 100-year flood. The 1957 flood was larger in areal extent, and certain isolated storms have caused higher peak-unit discharges, but the October 1973 flood is documented as having the highest magnitude or peak-unit discharge over such a large area. All flood runoff from the storm drained into Keystone Lake at the
confluence of the Arkansas and Cimarron Rivers about 90 miles east of Enid. The lake stage and amount of water stored during this flood was the peak of record; however, the lake had adequate capacity to store and regulate all the storm runoff and thus prevented damage downstream.

Runoff from the storm resulted in record-breaking floods on many streams in north-central Oklahoma. Long-time residents of areas where flooding was the most severe reported that stream stages during the Oc-

![Rainfall map of 1973 storm, Enid and vicinity, north-central Oklahoma. Lines show areas of equal rainfall; numbers show amount of rainfall, in inches.]
October 1973 flood were higher than any previous stages since at least 1889. The long-term gaging stations on Turkey Creek near Drummond and on the Salt Fork of the Arkansas River near Tonkawa showed all-time maximum stages and discharges. The 1923 peak stage was higher than the 1973 peak stage on the Arkansas River at Ralston, about 30 miles east of the area shown in figure 2; however, the peak discharge of the October 1973 flood was greater, as a result of channel scour that developed during the intervening years. The Chikaskia River at Blackwell reached its highest recorded stage since 1923, and it caused extensive flooding in the town of Blackwell.

The October 1973 flood was memorable in terms of devastation. The rainfall centered over the large urban area of Enid, which made flood damage especially severe (figs. 2, 3). The towns of Blackwell, Dover, Jefferson, and Tonkawa were also badly damaged. Nine lives were lost in the floodwaters, 7 of the 9 within the city of Enid. In addition, highways, county roads, bridges, city streets, and railroads were damaged considerably. Thousands of acres of winter wheat and topsoil were lost by erosion. Total flood damage was estimated at $78 million by the Oklahoma State Civil Defense Agency. Because of intensive residential and agricultural damage,
Figure 3. Flooded area and damage along Skeleton Creek in vicinity of Willow Road, near Enid. Photograph by Kenneth Gill, U.S. Army Corps of Engineers.

the President of the United States declared the City of Enid, plus Garfield, Grant, Kay, Kingfisher, and Noble Counties, disaster areas. Parts of Pawnee and Osage Counties were also declared disaster areas by the President, because there was so much agricultural damage.

Reference Cited


AAPG Releases Film Index

The American Association of Petroleum Geologists' Public Information Committee, chaired by Gary A. McDaniel, has compiled Index to Films Related to Geology and Energy Exploration. The catalog was prepared to assist in locating audiovisual aids pertaining to the earth sciences. The films are listed by subject matter (178 films, classified by categories such as earthquakes, glaciology, oceanography, and outer-space geology). A brief description of each film is included, as is the source for each and information about rental charges. The price of the index is $3.50, prepaid, and it is available in loose-leaf form, ready for insertion in a 3-ring notebook.
Some 50 earth-science editors, including Bill Rose, Oklahoma Geological Survey editor, and Rosemary Croy, OGS associate editor, were persuaded to take a few days from their regular duties to attend the Association of Earth Science Editors eighth annual meeting October 13-16 at Asilomar Conference Grounds near Pacific Grove, California. For Bill, the sacrifice was more complete than for most of the editors, because his daughter and son-in-law live in nearby Monterey, and he was absolutely forced to take a few days of vacation time and prolong his stay.

Asilomar, a unit of the California State Park system, is situated on the tip of the Monterey Peninsula amid acres of pine trees, a breathtaking setting for any meeting. A welcoming address by James E. Slosson, California State Geologist, a seminar on “Paper,” highlighted by contributions from Crown Zellerbach representatives, and panel discussions on “Innovations” and the “Impact of Rising Costs on the Future of Publications” consumed much of the daylight hours, but time was allowed before and after technical sessions for a barbecue at the ocean’s edge and walks along the beach or through the forest. In addition, a field trip planned in conjunction with the meeting featured a view of the San Andreas fault, a tour of a local winery, and a hike in Point Lobos State Reserve, a 1,250-acre area along the south shore of Carmel Bay that the National Park Service has designated a Registered Natural Landmark.

The AESE Award for Outstanding Contributions in the Earth Sciences went to Marie Siegrist this year. When the Bibliography and Index of Geology Exclusive of North America was first initiated, in 1934 (published by The Geological Society of America with funds from the Penrose Bequest), Marie was hired as an assistant to the late John M. Nickles, although he was reported to have had grave reservations about hiring a woman. With Mr.
Nickles' death in December 1945, Marie became editor. Early volumes of the *Bibliography* contained translations of article titles and occasional explanations, but beginning about 1947 brief annotations or abstracts were added to the citations, and several volunteers, known as farmees, were recruited to assist the two staff members with the abstracting. Volumes 11-30 of the *Bibliography*, with Marie as editor, contain approximately 124,000 abstracts that have been read, edited, and proofread by her. In reporting on the award committee's selection of Marie Siegrist as the second recipient of the AESE Award, the chairman, Pete Wilshusen, commended her "ability to write a concise précis, her linguistic talents, wise observation of rules, immeasurable patience, judicious use of time . . . good humor, ingenuity, and sincere dedication."

New AESE officers introduced at the Asilomar conference were George E. Bercraft, chief of the Office of Scientific Publications for the U.S. Geological Survey, president; Patricia Wood Dickerson, editor, Bell & Murphy & Associates, Houston, vice-president and president-elect; John L. Heller, chief, Denver Editorial Section, U.S. Geological Survey, secretary-treasurer; and John D. Haun, Department of Geology, Colorado School of Mines, director (John Haun is also the new president-elect of the American Institute of Professional Geologists).

Next year the Association of Earth Science Editors will hold its annual meeting November 16-19 in Hershey, Pennsylvania. Pete Wilshusen and the Pennsylvania Geological Survey will serve as hosts.

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**Kansas to Host Conference on Remote Sensing**

The research committee of The American Association of Petroleum Geologists and the U.S. Geological Survey have teamed with The University of Kansas in planning a research conference on remote sensing, which will be held February 18-20 at the university's Space Technology Center in Lawrence.

The stated objective of the conference is dissemination of specific applications of remote-sensing technology, with stress on exploration for and exploitation of natural resources. The conference speakers, drawn from industry, government, and academic institutions, will present case histories that have utilized ERTS, side-look-airborne-radar (SLAR), thermal-infrared, conventional, low-altitude, snow-enhanced, low-sun-angle, multi-spectral, and sonar imagery.

For information on registration and other details, contact Dr. Louis Dellwig, Remote Sensing Laboratory, The University of Kansas, 2291 Irving Hill Drive, Lawrence, Kansas 66044.
Gravity Tectonic Model for Development of Junction between Appalachian and Ouachita Orogenic Systems

JOHN M. DENNISON, Department of Geology, University of North Carolina, Chapel Hill, North Carolina

Gravity tectonics have been recently advocated for the Ouachitas (Viele, 1973) and the Appalachians (Dennison, 1974). Their junction in central Alabama probably formed by this succession of events:

1. The region was Middle Ordovician-Middle Mississippian craton margin, accumulating limestone, chert, and dolomite, some sandstone from an eastern source (Ordovician and Silurian) and the craton (Devonian), and shale. Four regional unconformities occur in this time span.

2. Late Mississippian eastern and southwestern source areas rapidly rose, with the tilting developing a trough between the uplifted areas and the craton margin. Pennington Formation red shale and sandstone came from the east, and from the southwest came Floyd Shale, Hartselle-type sandstone, and Parkwood Formation.

3. Pottsville clastics indicate both sources, with over 9,000 feet accumulation in a broad basin near the juncture of the two downward-tilted blocks, with syndepositional structures that influenced later tectonic fragmentation patterns of the broad basin.

4. More rapid uplift of the southern block resulted in unstable slopes displaced northward by Ouachita gravity tectonics. Folds and faults trend east in the Alabama subsurface and crop out in Chilton County.

5. Northwestward tilting of the eastern block resulted in Alleghany orogeny gravity tectonics, with northeast-trending folds and faults overprinting the Ouachita trend in Chilton County. The broad depositional basin was fragmented by the Alleghany orogeny, producing the separate Warrior, Cahaba, and Coosa basins.

The Ouachita-Appalachian junction is angular because the two orogenic belts formed at different times, probably mid-Pennsylvanian and Permian.
U-Pb Ages of the Spavinaw and Tishomingo Granites, Oklahoma

R. D. LEWIS and M. E. BICKFORD, Department of Geology, University of Kansas, Lawrence, Kansas

Exposures of Precambrian basement rocks in Oklahoma include the Spavinaw Granite in the northeastern part of the state and the Tishomingo Granite in the Arbuckle Mountains region. U-Pb ages of suites of cognetic zircons from both rocks are about 1400 m.y. Previously reported mineral ages from these granite bodies are about 1350 m.y. and a Rb-Sr isochron derived from whole-rock samples from the northeastern Oklahoma basement has yielded an age of about 1320 m.y.

The zircon ages reported here suggest that the rock bodies studied are somewhat older than previous measurements indicated, but they are significantly younger than the 1500 m.y. zircon ages of rocks from the St. Francois Mountains of Missouri, which are petrographically similar to the Spavinaw Granite and many other rocks in the Oklahoma basement. Although basement rocks of major segments of the midcontinent region are petrographically similar, they are apparently not coeval and may record a complex history of crustal evolution.

[844-845]

U.S. Department of the Interior Energy Data Files


Interior Department energy-related data files are maintained in the Bureau of Mines and Bureau of Land Management and in the Geological Survey. Most such files were operational or in process of construction before the recent oil embargo accentuated their need. The files cover leasing, production, reserves, and geological occurrence of petroleum liquids, natural gas, oil shale, nuclear fuels, coal, and geothermal resources. Most of the files are built and maintained in-house, such as the Geological Survey's CRIB system but others are operated through contract. An example of the latter is the Survey's Petroleum Data System. The CRIB file is comprised of 25,000 records of 150 entries each and utilizes IBM 360/370 hardware with GIPSY software. This file is in the process of being made publicly available. The Petroleum Data System was built under contract to the University of Oklahoma, uses hardware and software compatible with CRIB, is open to the public, and consists of 65,000 oil and gas pool records as well as a separate file of well records. The oil and gas pool records are derived from published documents and are continually up-dated. The other energy-related files are similarly prepared, with major efforts now being made to make them compatible in both hard- and software. Significant steps are being taken within Government to identify existing and proposed data systems and coordinate their inputs as well as outputs.

[868]
Correlation of Tremadocian Conodont and Trilobite Faunas, Europe and North America

JAMES F. MILLER, Earth and Planetary Sciences, University of Pittsburgh at Johnstown, Pennsylvania, RICHARD A. ROBISON, Department of Geology, University of Kansas, Lawrence, Kansas, and DAVID L. CLARK, Department of Geology and Geophysics, University of Wisconsin, Madison, Wisconsin

Further study of faunas from the Tiñu Formation of Oaxaca, Mexico, provides new evidence for correlation of Tremadocian faunas. Trilobites from the lower calcareous member of the formation show strong similarity to Lower Tremadocian faunas in Europe, but little similarity to North American faunas. However, the presence of *Pseudagnostus, Richardsonella* and *Saukia* was used to correlate with the Upper Cambrian *Saukia* Zone elsewhere in North America (Robison & Pantoja-Alor, 1968). Restudy of conodonts from the Tiñu Formation now allows more precise comparison with conodont faunas from Texas, Oklahoma, Utah, and Alberta, and in combination with trilobites, improves the correlation between North America and Europe. The lower part of the lower member of the Tiñu Formation contains *Proconodontus notchpeakensis*, *Cordylogus proavus*, and *C. oklahomensis*, a conodont assemblage known elsewhere from the Cambrian *Corbinia apopsis* and Ordovician *Missisquequa* and *Symphysurina* trilobite zones. The upper part of the lower member contains *Cordylogus iindstromi*, *C. prion*, and *C. intermedius*. Elsewhere these species first occur somewhat above the base of the *Symphysurina* Zone. The upper shaly member of the Tiñu has an Upper Tremadocian trilobite fauna but no conodonts.

These data indicate: 1) at least part of the Lower Tremadocian of Europe correlates with the Lower Ordovician of North America; 2) the Lower-Upper Tremadocian boundary falls within the *Symphysurina* Zone; 3) the base of the Tremadocian probably is closer in age to the base of the North American Ordovician than has usually been suggested; and 4) the *Saukia* from Oaxaca, which has an Asiatic aspect, is probably Early Ordovician by North American standards.

[1048-1049]

THE LOUISIANA STATE UNIVERSITY

Tephrochronology, Petrology, and Stratigraphy of Some Pleistocene Deposits in the Central Plains, U.S.A.

JOHN DAVID BOELLSTORFF, The Louisiana State University, PhD. dissertation, 1973

A simplified method of fission-track dating rhyolitic volcanic glasses has been developed. Eleven deposits of volcanic ash of Pleistocene age from the Central Plains have been dated by means of this technique. The Pearlette Ash (previously assigned late Kansan in age) consists of four significantly different ages of ash—about 0.61 m.y., 0.74 m.y., 1.21 m.y., and 1.97 m.y. The diverse ages of these ash deposits demonstrate some regional correlations are in error.

A new terminology for Pleistocene volcanic ashes in Central Plains is presented. This terminology requires knowledge of the age and the iron,
manganese, and samarium content of the ash. This terminology includes both the Pearlette and non-Pearlette ashes.

<table>
<thead>
<tr>
<th>Ash Name</th>
<th>Age Criterion</th>
<th>Chemical Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearlette</td>
<td>≈ 0.61 m.y.</td>
<td>≈ 1.1% Fe, 280 ppm Mn, 12 ppm Sm</td>
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<tr>
<td>(restricted)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hartford</td>
<td>≈ 0.74 m.y.</td>
<td>≈ 1.1% Fe, 280 ppm Mn, 13 ppm Sm</td>
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<tr>
<td>Bishop</td>
<td>≈ 0.82 m.y.</td>
<td>≈ 0.6% Fe, 200 ppm Mn, 5 ppm Sm</td>
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<tr>
<td>Coleridge</td>
<td>≈ 1.21 m.y.</td>
<td>≈ 1.0% Fe, 240 ppm Mn, 11 ppm Sm</td>
</tr>
<tr>
<td>Borchers</td>
<td>≈ 1.97 m.y.</td>
<td>≈ 1.2% Fe, 280 ppm Mn, 14 ppm Sm</td>
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Heavy minerals and pebble types are useful for correlating tills over a large area. New correlations made with the aid of these types of data show several generally accepted till correlations may be in error. The new correlations indicate the Nebraskan Till of Shimek (1909) correlates with the upper till (Kansan of Bain, 1896 and Chamberlin, 1896) near Afton, Iowa, rather than the lower till (pre-Kansan). In addition, these correlations indicate Reed and Dreeszen's (1965) Nebraskan sequence in eastern Nebraska is older than the lower till (pre-Kansan or Nebraskan) near Afton, Iowa, and several formally designated till names with separate age-assignments have been applied to a single till sheet in Nebraska.

A chronology of early and middle Pleistocene deposits in the Central Plains, U.S.A., has been inferred from the till correlations and volcanic ash dates. This chronology indicates that the Nebraskan of eastern Nebraska is older than about 1.2 m.y. and is older than Shimek's (1909) Nebraskan Till and the pre-Kansan or Nebraskan till of the Afton, Iowa, area. The base of the Pleistocene in the Central Plains is at least about 2.0 m.y. old.

A comparison of the inferred chronology for the Central Plains with that of the Gulf of Mexico (Beard, 1969) suggests sediments termed Nebraskan in the Gulf of Mexico are older than those termed Nebraskan in the Central Plains.

As they stand, the new correlations and dates on volcanic ashes indicate much of the current terminology used to communicate information about early and medial Pleistocene events in Nebraska and adjoining areas may not be useful. In addition, the stage names Nebraskan, Aftonian and Kansan need reevaluation and possibly redefinition.


THE UNIVERSITY OF OKLAHOMA

Algae and Paleoecology of Algal and Related Facies, Morrow Formation, Northeastern Oklahoma

DAVID ARTHUR KOTILA, The University of Oklahoma, Ph.D. dissertation, 1973

The Morrow Formation (Lower Pennsylvanian) in the Tenkiller-Ferry and Greenleaf Lake area of northeastern Oklahoma includes those strata
unconformably overlying the Pitkin Formation and unconformably underlying the Atoka Formation. These two unconformities define the boundaries of the Morrow.

In the studied area the Morrow Formation is informally divided into four members which are, in ascending order: (1) Sandy Member, (2) Mixed Carbonate and Shale Member, (3) Algal Limestone and Shale Member, and (4) Black Shale and Carbonate Member.

Nine species of calcareous algae from six genera are described including one proposed new species and one proposed new genus.

The abundance and distribution of certain calcareous algae, corals, carbonate lithologies, and the stratigraphic framework of these within the Algal Limestone and Shale Member are interpreted as representing an algal bank environment in the south, southwest, and western parts of the studied area. Similarly the abundance of carbonate muds, intraclastic carbonates, burrows, and desiccation features within the same member are interpreted as representing a tidal-flat environment for the north-central part of the studied area.

Cessation of prolific carbonate deposition was caused by influx of large amounts of terrigenous clay, silt, and sand.

INDEX

Volume 34, 1974

abstracts

AAPG-SEPM annual meetings 109
AAPG-SEPM Rocky Mountain Section meeting 164
American Chemical Society Oklahoma Section meeting 129
California Institute of Technology 38
GSA annual meetings 33, 215
GSA Cordilleran Section meeting 122
GSA North-Central Section meeting 124
GSA Northeastern Section meeting 121
GSA South-Central Section meeting 111
GSA Southeastern Section meeting 122

1Reference is to first page of article containing indexed item.
Louisiana State University, The
Oklahoma, The University of
Remote Sensing of Earth Resources annual meeting, 1973
Remote Sensing of Earth Resources annual meeting, 1974
Texas Tech University
Adelman, Morris A., energy-series lecturer
algae
Al-Shaieb, Zuhair, and Heine, Richard R.—Geochemical Exploration
for Redbed Copper Deposits in North-Central Oklahoma [abs.]
Al-Shaieb, Zuhair, see Kent, Douglas C., Al-Shaieb, Zuhair, and Silka, Lyle
American Association of Petroleum Geologists, The
annual meeting
conference on remote sensing
geological highway maps
Index to Films Related to Geology and Energy Exploration
Memoir 21
new president, John E. Kilkenny
Reprint Series No. 9 (review)
Reprint Series No. 10 (review)
Reprint Series No. 11
sectional meeting
SEPM Special Publications 18 and 19
American Chemical Society, sectional meeting
American Institute of Professional Geologists, Oklahoma Section
annual meeting
new president, Thomas L. Thompson
officers
Amsden, Thomas W., author of new bulletin on brachiopods
Anadarko basin
Carboniferous orogeny
exploration
Hunton studies
Morrow sands, stratigraphy
palynomorph index fossil
annual report, Oklahoma Geological Survey
Arbuckle Mountains
Arbuckle Group dolomites
bryozoan fauna
Buckhorn asphaltic limestone
conodont
Dougherty anticline
field trip, 1911 photo
hydrology
Ordovician biostratigraphy
Paleozoic orogeny
radar imagery
source of Texas sediments
Spavinaw Granite
Tishomingo Granite
Ardmore basin
Dornick Hills Group
Paleozoic orogeny
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ardmore Geological Society</td>
<td>162</td>
</tr>
<tr>
<td>Ardmore quadrangle, hydrologic atlas</td>
<td>183</td>
</tr>
<tr>
<td>Arkoma basin</td>
<td></td>
</tr>
<tr>
<td>geothermal pattern</td>
<td>110</td>
</tr>
<tr>
<td>relation to Pennsylvanian carbonate facies</td>
<td>109</td>
</tr>
<tr>
<td>Asquith, George B.—Transverse Braid Bars in the Triassic Sandstones</td>
<td>112</td>
</tr>
<tr>
<td>of the Texas Panhandle [abs.]</td>
<td></td>
</tr>
<tr>
<td>Association of American State Geologists, Charles J. Mankin,</td>
<td></td>
</tr>
<tr>
<td>president-elect</td>
<td>155</td>
</tr>
<tr>
<td>Association of Earth Science Editors, annual meeting</td>
<td></td>
</tr>
<tr>
<td>Beckham County, exploration</td>
<td>213</td>
</tr>
<tr>
<td>Bennison, Allan P.—Southern Margin of the Mid-Pennsylvanian Oologah</td>
<td>2, 3</td>
</tr>
<tr>
<td>Limestone Banks, Northeastern Oklahoma [abs.]</td>
<td>109</td>
</tr>
<tr>
<td>Bergström, S. M., see Sweet, W. C., Bergström, S. M., and Carnes, John B.</td>
<td></td>
</tr>
<tr>
<td>Berwyn Conglomerate</td>
<td>194</td>
</tr>
<tr>
<td>bibliography of Oklahoma geology, 1973</td>
<td>47</td>
</tr>
<tr>
<td>Bickford, M. E., see Lewis, R. D., and Bickford, M. E.</td>
<td></td>
</tr>
<tr>
<td>Bifano, Francis V., Guber, Albert L., and Cuffey, Roger J.—Ostracode</td>
<td>124</td>
</tr>
<tr>
<td>Paleoeology in Shales of the Wreford Megacyclothem (Lower Permian; Kansas and Oklahoma) [abs.]</td>
<td></td>
</tr>
<tr>
<td>Black, Jeffrey Howard—Tadpole Nests in Oklahoma</td>
<td>105</td>
</tr>
<tr>
<td>Black Knob Ridge</td>
<td>125</td>
</tr>
<tr>
<td>Blaylock Sandstone</td>
<td>98</td>
</tr>
<tr>
<td>Boellstorff, John David—Tephrochronology, Petrology,</td>
<td></td>
</tr>
<tr>
<td>and Stratigraphy of Some Pleistocene Deposits in the Central Plains, U.S.A. [abs.]</td>
<td>217</td>
</tr>
<tr>
<td>Bonem, Rena Mae—Comparison of Ecology and Sedimentation in Lower</td>
<td></td>
</tr>
<tr>
<td>Pennsylvanian (Morrowan) Algal-Coral-Bryozoan Bioherms with</td>
<td></td>
</tr>
<tr>
<td>Those in Modern Patch Reefs [abs.]</td>
<td>112</td>
</tr>
<tr>
<td>Bowen, Richard L.—The Enigma of Late Paleozoic Orogeny in</td>
<td></td>
</tr>
<tr>
<td>Southeastern North America [abs.]</td>
<td>123</td>
</tr>
<tr>
<td>Bower, Richard R., see Kidwell, Albert L., and Bower, Richard R.</td>
<td></td>
</tr>
<tr>
<td>Bradshaw, Lael E.—Ordovician Conodonts from Black Knob Ridge,</td>
<td>125</td>
</tr>
<tr>
<td>Oklahoma [abs.]</td>
<td></td>
</tr>
<tr>
<td>Buckhorn asphaltic limestone</td>
<td></td>
</tr>
<tr>
<td>38, 110</td>
<td></td>
</tr>
<tr>
<td>Busch, Daniel A., author of AAPG Memoir 21</td>
<td>167</td>
</tr>
<tr>
<td>California Division of Mines and Geology, California fault map</td>
<td>154</td>
</tr>
<tr>
<td>California Institute of Technology</td>
<td>38</td>
</tr>
<tr>
<td>Cannon, Philip Jan—Dougherty Anticline, Arbuckle Mountains</td>
<td>46</td>
</tr>
<tr>
<td>Rock Type Discrimination Using Radar Imagery [abs.]</td>
<td></td>
</tr>
<tr>
<td>The Application of Radar and Infrared Imagery to Quantitative</td>
<td></td>
</tr>
<tr>
<td>Geomorphic Investigations [abs.]</td>
<td>128</td>
</tr>
<tr>
<td>Canyon Group, Texas</td>
<td>33</td>
</tr>
<tr>
<td>Carnes, John B., see Sweet, W. C., Bergström, S. M., and Carnes, John B.</td>
<td></td>
</tr>
<tr>
<td>Carpenter, Richard, energy-series lecturer</td>
<td>11</td>
</tr>
<tr>
<td>Carter County, Berwyn Conglomerate</td>
<td>194</td>
</tr>
<tr>
<td>Transform Faults as Explanation for Offsets in the Southern</td>
<td></td>
</tr>
<tr>
<td>Appalachian-Ouachita Tectonic Belt [abs.]</td>
<td>123</td>
</tr>
<tr>
<td>Chamberlain, C. K.—Explaining the Trace-Fossil Community in DSDP</td>
<td></td>
</tr>
<tr>
<td>Cores [abs.]</td>
<td>125</td>
</tr>
</tbody>
</table>
Clark, David L., see Miller, James F., Robison, Richard A., and Clark, David L.

coal
Cisco-Wolfcamp beds, Texas 39
gasification site 34
Hartshorne beds, Arkansas 118
Interstate Mining Compact Commission meeting 189
inventory of surface-mined lands 35, 158, 171
New Mexico field trip 148
Oklahoma coal-area field trips 189, 206
resources, eastern Oklahoma 129, 171
short course 158
Coal County, crinoid 160
Cocke, J. M.—Dissepimental Corals of the Upper Pennsylvanian Missourian Rocks in the American Midcontinent [abs.] 113
Conselman, Frank B. 31, 159, 192
copper, copper mineralization, copper shales 111, 114, 115, 116, 117, 171
Cromwell, David—Stratigraphy and Environment of Deposition of the Lower Dornick Hills Group (Lower Pennsylvanian), Ardmore Basin, Oklahoma [abs.] 166
Croy, Rosemary L.—M. King Hubbert Launches Energy Series at OU 11
Oklahoma Energy Advisory Council Issues Final Report 106
U.S. Bureau of Mines and State Legislative Council Sponsor Field Trip 206
Croy, Rosemary, L., see Ham, Elizabeth A., Croy, Rosemary L., and Rose, William D.
Cullers, Robert L.—The Rare-Earth Element Distributions in the Clay-Size Fraction of the Permian Havensville and Eskridge Shales of Kansas and Oklahoma [abs.] 113
Dennison, John M.—Gravity Tectonic Model for Development of Junction between Appalachian and Ouachita Orogenic Systems [abs.] 215
Dingess, Paul R.—Geology of the Creta Copper Deposit of Eagle Picher Industries, Inc., Jackson County, Oklahoma [abs.] 114
Donovan, T. J.—Mineralogic Evidence for Buried Hydrocarbons—New Exploration Tool [abs.] 164
Dornick Hills Group 166
Dougherty anticline 46
energy resources
AAPG Abnormal Subsurface Pressure 167
AAPG Index to Films Related to Geology and Energy Exploration 212
AAPG Stratigraphic Traps in Sandstones—Exploration Techniques 167
AEC reports, uranium 107
coal-area field trips 189, 206
coal-geology short course 158
data files 216
energy forum, Oklahoma State Fair 27
Facies and the Reconstruction of Environments (review) 203
geothermal-gradient map 110
geothermal studies, AAPG annual meeting symposium 13
International Petroleum Encyclopedia 1974 131
New Mexico field trip 148
OGS annual report 171
Origin of Petroleum II (review) 149
OU energy-fuels field course 95
OU energy series 11
record-depth wells 2, 3, 185
surface mineralization as hydrocarbon indicator 164
trans-Alaska pipeline 147
USGS oil and gas estimates 108
Enid, Oklahoma, flood report 209
environmental geology
  Climates of the States 154
  coal-lands field trips 189, 206
  Enid flood report 209
  environmental-mapping program 171
  flood-prone-area maps 104
  GSA Tulsa-area guidebook 148
  inventory of surface-mined coal lands 35, 158, 171
  OCGS short course 171
  Oklahoma Energy Advisory Council report 106, 171
  Texas environmental-geology colloquium 94
  USGS land-use folio 184
  USGS soils-minerals report 191
Erickson, Ralph L., new USGS central-region geologist 96
Erxleben, Albert W.—Depositional Systems in the Canyon Group
  (Pennsylvanian) of North-Central Texas [abs.] 33
Eskridge Shale 113
Falkie, Thomas V., new director of U.S. Bureau of Mines 103
Farmer, George T., Jr.—The Oldest Well-Preserved Bryozoan Fauna
  in the World? 99
Fay, Robert O.—Origin of Petroleum II, A Summary Review
  The Berwyn Conglomerate 194
Feenstra, Roger E.—Minor Fold in the Blaylock Sandstone (Silurian),
  Ouachita Mountains, Oklahoma 98
Flowerpot Shale 116, 121
Friedman, S. A., offers coal-geology short course 158
Friedman, S. A.—Coal Resources of Eastern Oklahoma, January, 1974 [abs.] 129
  Interstate Mining Compact Commission Views Oklahoma Operations 189
  Selection of a Coal Gasification Plant Site in Oklahoma [abs.] 34
Gage, Stephen, energy-series lecturer 11
Gann, Delbert E., and Hagni, Richard D.—Ore Microscopy of Copper Ore
  at the Creta Mine, Southern Oklahoma [abs.] 114
Geological Society of America, The
  annual meetings 33, 215
  field trips and guidebooks 31, 43, 148
  sectional meetings 30, 31, 111, 121, 122, 124
  Special Papers 145 and 152 208
Geophysical Society of Oklahoma City 162
Geophysical Society of Tulsa 162
Greer County, grooved granites 170
Guber, Albert L., see Bifano, Francis V., Guber, Albert L., and Cuffey,
  Roger J.
guidebooks
  GSA South-Central Section meeting 148
Haas, Merrill W., AAPG president 157
Hagni, Richard D., see Gann, Delbert E., and Hagni, Richard D.
Ham, Elizabeth A.—Facies and the Reconstruction of Environments, A Review 203
State of the State on Topo Map Coverage 155
Ham, Elizabeth A., Croy, Rosemary L., and Rose, William D.—Bibliography and Index of Oklahoma Geology, 1973 47
Ham, W. E., see Waddell, D. E., Sanderson, G. A., and Ham, W. E.
Haragan Formation 160
Harper County, subsurface stratigraphy 41
Harrell, James A.—Mysterious Grooved Granites of the Wichita Mountains, Oklahoma 170
Harris, Rae L., Jr., Lees, William R., and Howe, David A.—Ratios of Zircon Crystals within Feldspars as an Indication of Rock Origin and History [abs.] 34
Harris, Sherrod A.—Trapping Mechanism for Production of Oil from Meramec (Mississippian) Rocks on the Sooner Trend of North Central Oklahoma [abs.] 42
Harrison, Earl Preston—Depositional History of Cisco-Wolfcamp Strata, Bend Arch, North-Central Texas [abs.] 39
Hartshorne Sandstone 118
Hatcher, Robert D., Jr.—North American Paleozoic Foldbelts and Deformational Histories: A Plate Tectonics Anomaly? [abs.] 35
Havensville Shale 113
Heine, Richard R., see Al-Shaieb, Zuhair, and Heine, Richard R.
Henry, Thomas W.—Brachiopod Biostratigraphy of the Morrow Series (Lower Pennsylvanian) of Northwestern Arkansas and Northeastern Oklahoma [abs.] 115
Horn, M. K., see Shelton, J. W., Horn, M. K., and Lassley, R. H.
Howe, David A., see Harris, Rae L., Jr., Lees, William R., and Howe, David A.
Hoyt, David E., see Scholle, Peter A., and Hoyt, David E.
Hubbert, M. King, energy-series lecturer 11
hydrogeology, hydrology
Ardmore-Sherman quadrangles, OGS HA-3 14, 171, 183
Beaver County maps, USGS HA-450 14
Cimarron County maps, USGS HA-373 14
Climates of the States 154
Enid flood report 209
flood-prone-area maps 104
Fort Smith quadrangle, OGS HA-1 14, 171, 183
South Canadian River system, sand deposition 164
Tulsa quadrangle, OGS HA-2 14, 171, 183
Washita River alluvium 116
Washita River basin, ground-water flow 119
indexes
Oklahoma geology, 1973 47
Oklahoma Geology Notes 217
International Petroleum Encyclopedia 1974 131
Interstate Mining Compact Commission, fall meeting 189
Ivanhoe Creek, geographic-names decision 204
Jackson County, copper 114
Jackson, Kern C., see Lines, William B., and Jackson, Kern C.

Johnson, Kenneth S., author of GM-17, inventory of mined coal lands 158

Johnson, Kenneth S., leader of energy-fuels field course 95

Johnson, Kenneth S.—Inventory of Strip-Mined Lands in Oklahoma Coal Field [abs.] 35

Permian Copper Shales of Southwestern Oklahoma [abs.] 115

Jones, David L., new USGS western-region geologist 96

Kansas, The University of, host of remote-sensing conference 214

Keller, G. R., see Cebull, S. E., Keller, G. R., Shurbet, D. H., and Russell, L. R.

Kent, Douglas C., Al-Shaieb, Zuhair, and Silka, Lyle—Ground-Water Geochemistry of a River Alluvium and Related Environmental Implications [abs.] 116

Kent, Douglas C., see Naney, James W., and Kent, Douglas C.

Kessler, L. G., II—Braided Rivers and Related Terrigenous Depositional Systems—Useful but Enigmatic Exploration Models [abs.] 164


Kilkenny, John E., president-elect of AAPG 157

Knox, Larry W.—Biostratigraphic Aspects of Type Morrowan Ostracods [abs.] 126

Kotila, David Arthur—Algae and Paleoeocology of Algal and Related Facies, Morrow Formation, Northeastern Oklahoma 218

Kraon, Jan—Central European Versus South Central U.S.A. Geologic Settings of the Permian Basins and Associated Copper Mineralization [abs.] 117

Lassley, R. H., see Shelton, J. W., Horn, M. K., and Lassley, R. H.

Latimer County, Potato Hills 135

Lees, William R., see Harris, Rae L., Jr., Lees, William R., and Howe, David A.

Lewis, R. D., and Bickford, M. E.—U-Pb Ages of the Spavinaw and Tishomingo Granites, Oklahoma [abs.] 216

Lines, William B., and Jackson, Kern C.—Depositional Environment of the Hartshorne Sandstone (Pennsylvaniaian), Arkansas Valley Area, Arkansas [abs.] 118

LoPiccolo, Robert D., and Lowe, Donald R.—Consolidation Structures in Turbidites [abs.] 36

Lowe, Donald R., see LoPiccolo, Robert D., and Lowe, Donald R.

Lutz-Garhan, Anne B.—The Brachiopod Genus Composita from the Wreford Megacyclothem (Lower Permian) in Nebraska, Kansas, and Oklahoma [abs.] 126

McCurtain County, Blaylock Sandstone 98

McGee, Dean A., energy-series lecturer 11

McHargue, Timothy R.—The Lower Middle Ordovician Multielement Conodont Genus Multioistodus [abs.] 127

Manger, Walter L., Saunders, W. Bruce, and Quinn, James H.—Lower Pennsylvanian (Morrowan) Ammonoids from the Primrose Member, Golf Course Formation, South-Central Oklahoma [abs.] 118
Mankin, Charles J.
energy-series lecturer 11
president-elect of AASG 155
maps
AAPG geological highway map 167
California fault map 154
flood-prone-area quadrangle maps 104
géothermal-gradient map 110
OGS GM-17, surface-mined Oklahoma coal lands 35, 158, 171
OGS hydrologic atlases, HA-1, HA-2, HA-3 14, 171, 183
USGS earthquake map 154
USGS hydrologic atlases, HA-373, HA-450 14
USGS land-use maps 184
USGS new cartographic center 131
USGS Oklahoma topographic-quadrangle maps 155
Meramec (Mississippian) rocks 42
Meyers, William C., and Simpson, H. M.—Centonites — A Stratigraphically Useful Palynomorph Restricted to Upper Pennsylvanian Rocks [abs.] 119
minerals industry
base metals and fluor spar, New Mexico symposium and field trip 94
copper, see coal 111, 114, 115, 116, 117, 171
Interstate Mining Compact Commission meeting 189
Mineral Resources: Potentials and Problems 153
mineral-resource terminology 102
production statistics, Oklahoma 9
uranium reports 107
Morrison, Garrett Louis—The Structure of the Interlayer Water in Montmorillonite [abs.] 41
Morrowan bioherms 112
Morrow Formation, algal facies 218
Morrow sandstones 41
Murray County, Dougherty anticline 46
Muskegee County, bioherms 112
National Cartographic Information Center 131
New Mexico Bureau of Mines and Mineral Resources, paleontology paper 32
New Mexico Geological Society field trips 94, 148
226
fluorspar and metals symposium
Noble County, copper
officers
American Association of Petroleum Geologists, The
American Institute of Professional Geologists
Ardmore Geological Society
Association of American State Geologists
Geophysical Society of Oklahoma City
Geophysical Society of Tulsa
Oklahoma City Geological Society
Tulsa Geological Society
Okcol
Oklahoma Baptist University, speleology course
Oklahoma City Geological Society
environmental-geology course
officers
Oklahoma Energy Advisory Council
annual report
coal-geology short course
hydrologic maps
inventory of Oklahoma surface-mined coal lands
publications
staff
Oklahoma Geology Notes
micro-edition
price increase
Oklahoma Panhandle
hydrologic maps
Pennsylvania palynomorph
Oklahoma State University, GSA sectional-meeting host
Oklahoma, The University of
abstracts
coal-geology short course
energy-fuels field course
energy series
new theses and dissertations
Oklahoma Water Resources Board
Oologah Limestone banks
Orth, Donald J., Geographic Names Committee leader
Ouachita Mountains, Ouachita geosyncline
Black Knob Ridge, conodonts
Blaylock Sandstone
foldbelts
mineral investigations
Potato Hills, structure
source of Permian-basin sediments
source of Texas Pennsylvanian sediments
source of Texas Triassic deposits
tectonics
trace fossils
Ozark Mountains, Morrow brachiopod biostratigraphy

227
paleobotany, East Manitou site (Permian) 15
paleoecology 218
algal facies, Morrow Formation 15
East Manitou site 112
Morrowan bioherms 112
ostracode paleoecology, Wreford Megacyclothem 124
vertebrates 15
Paleozoic foldbelts 35
paleozoology 112
algal-coral-bryozoan bioherms (Morrowan) 112
ammonoids 118
Morrowan 208
Upper Mississippian
brachiopods 115
Composita, Wreford Megacyclothem 32
Late Ordovician and Early Silurian 205
Morrowan 115
Pennsylvanian, New Mexico
bryozoans 38, 110
Morrowan 112
Simpson Group 99
Buckhorn asphalt 122
cephalopod jaws, Paleozoic
condonts 208
Late Mississippian and Early Pennsylvanian 118
Morrowan 127
Multioistodus, Ordovician 217
Ordovician
Tremadocian
corals 125
Missourian 113, 148
Missourian coral and algae beds (guidebook) 148
Morrowan 112
Pennsylvanian rugose colonies 120
crinoid, Abyssocrinus, Devonian 160
Matthemia, Upper Cambrian mollusk 121
Middle Ordovician biostatigraphy 37
ostracodes 126
type Morrowan 124
Wreford Megacyclothem 125
trace fossils, deep-sea 217
trilobites, Tremadocian
vertebrates, East Manitou site 15
palynology 119
Cenotonites, Upper Pennsylvanian palynomorph 119
East Manitou site (Permian deposits) 15
Erdtman medal, L. R. Wilson, recipient 29
Hamiapollenites, distribution 121
Missourian palynomorphs, Tulsa County 120
mountant for specimens 190
Pawnee County, copper 111
Payne County, copper 111
Peach, W. Nelson, energy-series lecturer 11
228
Pearljet ash
Permian basins
petroleum and natural gas
Abnormal Subsurface Pressure
Anadarko basin exploration

data files
energy forum, Oklahoma State Fair
energy series, OU
fluvial deposits
fuels course
Index to Films Related to Geology and Energy Exploration
International Petroleum Encyclopedia 1974
Morrow sandstones, analysis
Oklahoma Energy Advisory Council
Origin of Petroleum II (review)
record-depth wells
Sooner Trend trapping mechanism
statistics
stratigraphic traps, AAPG annual-meetings theme
Stratigraphic Traps in Sandstones—Exploration Techniques
surface mineralization
trans-Alaska pipeline
USGS core libraries
USGS resource estimates

Pitt, William D.—Structure of the Western End of the Potato
Hills, Latimer and Pushmataha Counties, Oklahoma
Pittsburg County, proposed coal-gasification site
Potato Hills
Primrose Member, Golf Course Formation
Pushmataha County, Potato Hills
Quinn, James H., see Manger, Walter L., Saunders, W. Bruce,
and Quinn, James H.
rare-earth elements, Havensville and Eskridge Shales
Remote Sensing of Earth Resources, annual meetings
remote-sensing research conference
Roberts, John F.—Statistics of Oklahoma’s Petroleum
Industry, 1973
Robison, Richard A., see Miller, James F., Robison, Richard
A., and Clark, David L.
Rose, William D., AIPG Oklahoma Section president
Rose, William D.—Field Excursion, Circa 1911
Rose, William D., see Ham, Elizabeth A., Croy, Rosemary L.,
and Rose, William D.
Roseboom, Eugene H., Jr., new USGS eastern-region geologist
Rowland, T. L.—Lone Star 1 Rogers Unit Captures World
Depth Record
The Historic 1 Baden Unit and a Brief Look at Exploration
in the Anadarko Basin
World’s Largest Land-Based Drilling Rig Used for Record Well
Russell, L. R., see Cebull, S. E., Keiler, G. R., Shurbet, D. H.,
and Russell, L. R.

Sargent, Kenneth Aaron—Chemical and Isotopic Investigation of Stratigraphic and Tectonic Dolomites in the Arbuckle Group, Arbuckle Mountains, South-Central Oklahoma [abs.] 165

Saunders, W. Bruce, and Spinosa, Claude—Unusual Fossil Cephalopod Jaws from Nevada [abs.] 122

Saunders, W. Bruce, see Manger, Walter L., Saunders, W. Bruce, and Quinn, James H.

Scholle, Peter A., and Hoyt, David E.—Quartz Grain Surface Textures from Various Source Rocks [abs.] 36

Scofield, Nancy, and Stone, George T.—The Wichita Complex, Oklahoma [abs.] 37

Seneca Creek, geographic-names decision 204


Sherman quadrangle, hydrologic atlas 183

Shurbet, D. H., see Cebull, S. E., Keller, G. R., Shurbet, D. H., and Russell, L. R.

Silka, Lyle, see Kent, Douglas C., Al-Shaieb, Zuhair, and Silka, Lyle

Simpson, H. M.—Palynology and the Vertical Profile of Sedimentation of Lower Missourian Strata, Tulsa County, Oklahoma [abs.] 120

Simpson, H. M., see Meyers, William C., and Simpson, H. M.

Simpson, Larry C.—Paleoecology of the East Manitou Site, Southwestern Oklahoma 15

Society of Economic Paleontologists and Mineralogists annual meeting 109

Special Publications 18 and 19 28

Special Publication 22 184

Sooner Trend 42


Spavinaw Granite 216

Spinosa, Claude, see Saunders, W. Bruce, and Spinosa, Claude

Squires, Richard Lane—Burial Environment, Diagenesis, Mineralogy, and Mg & Sr Contents of Skeletal Carbonates in the Buckhorn Asphalt of Middle Pennsylvanian Age, Arbuckle Mountains, Oklahoma [abs.] 38

Stone, George T., see Scofield, Nancy, and Stone, George T.

Strimple, Harrell L.—Abyssocrinus from the Haragan Formation (Devonian) of Southern Oklahoma 160

Sutherland, Patrick K., co-author of New Mexico paleontology publication 32

Sutherland, Patrick K.—Significance of the Stratigraphic Distribution of Colonial Rugose Corals in the Pennsylvanian System of North America [abs.] 120

Sweet, W. C., Bergström, S. M., and Carnes, John B.—Lower Middle Ordovician Biostratigraphy in the North American
Midcontinent: Relations between Sequences in Oklahoma, the Cincinnati Region, and the Western Appalachians [abs.]

Tadpole nests

Taylor, Michael E., see Yochelson, Ellis L., and Taylor, Michael E.

Texas Bureau of Economic Geology, environmental-geology colloquium

Texas Tech University

theses and dissertations in OU geology library

Thompson, Thomas L., new president of Oklahoma Section, AIPG

Tillman County, East Manitou site

Tishomingo Granite

Tulsa County, palynology

Tulsa Geological Society

Uranium-lead dating, Arbuckle Mountain granites

U.S. Atomic Energy Commission, uranium reports

U.S. Bureau of Mines

coal-area field trip

mineral-resource terminology, standardization

new director, Thomas V. Falkie

U.S. Department of the Interior, energy-data files

U.S. Geological Survey

conference on remote sensing

core libraries

earthquake map

Enid flood report

flood-prone-area maps

Geographic Names Committee decisions

new leader, Donald J. Orth

hydrologic maps

land-use maps

mineral-resources report, Circular 698

mineral-resource terminology, standardization

new cartographic-information center

new national center

new regional geologists

oil- and gas-resources estimates

seismological, earthquake, and geomagnetic programs

soils-minerals report, Circular 692

topographic-quadrangle maps of Oklahoma


Washita County, exploration

Washita River basin, hydrologic studies

Water Information Center, Climates of the States

Water Resources Division, USGS

Wichita complex

Wichita Mountains

grooved granites
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>JOHN F. ROBERTS</td>
<td></td>
</tr>
<tr>
<td>Facies and the Reconstruction of Environments, A Review</td>
<td>203</td>
</tr>
<tr>
<td>ELIZABETH A. HAM</td>
<td></td>
</tr>
<tr>
<td>Summary of October 1973 Rainstorm, Enid and Vicinity, North-Central Oklahoma</td>
<td>209</td>
</tr>
<tr>
<td>U.S. GEOLOGICAL SURVEY</td>
<td></td>
</tr>
<tr>
<td>The Berwyn Conglomerate</td>
<td>194</td>
</tr>
<tr>
<td>USGS to Set Up Regional Core Libraries</td>
<td>202</td>
</tr>
<tr>
<td>U.S. Board on Geographic Names Decisions</td>
<td>204</td>
</tr>
<tr>
<td>New Brachiopod Bulletin Released by Survey</td>
<td>205</td>
</tr>
<tr>
<td>Notes Available in Microform</td>
<td></td>
</tr>
<tr>
<td>U.S. Bureau of Mines and State Legislative Council Sponsor</td>
<td>206</td>
</tr>
<tr>
<td>Field Trip</td>
<td></td>
</tr>
<tr>
<td>GSA Special Papers Deal with Ammonoids and Conodonts from Arkansas and Oklahoma</td>
<td>208</td>
</tr>
<tr>
<td>New Thesis and Dissertations Added to OU Geology Library</td>
<td>208</td>
</tr>
<tr>
<td>AAPG Releases Film Index</td>
<td>212</td>
</tr>
<tr>
<td>Earth Science Editors Bask on California Beaches</td>
<td>213</td>
</tr>
<tr>
<td>Kansas to Host Conference on Remote Sensing</td>
<td>214</td>
</tr>
<tr>
<td>Oklahoma Abstracts</td>
<td>215</td>
</tr>
<tr>
<td>GSA Annual Meetings, Miami Beach, Florida</td>
<td>215</td>
</tr>
<tr>
<td>The Louisiana State University</td>
<td>217</td>
</tr>
<tr>
<td>The University of Oklahoma</td>
<td>218</td>
</tr>
<tr>
<td>Index to Volume 34</td>
<td>219</td>
</tr>
</tbody>
</table>