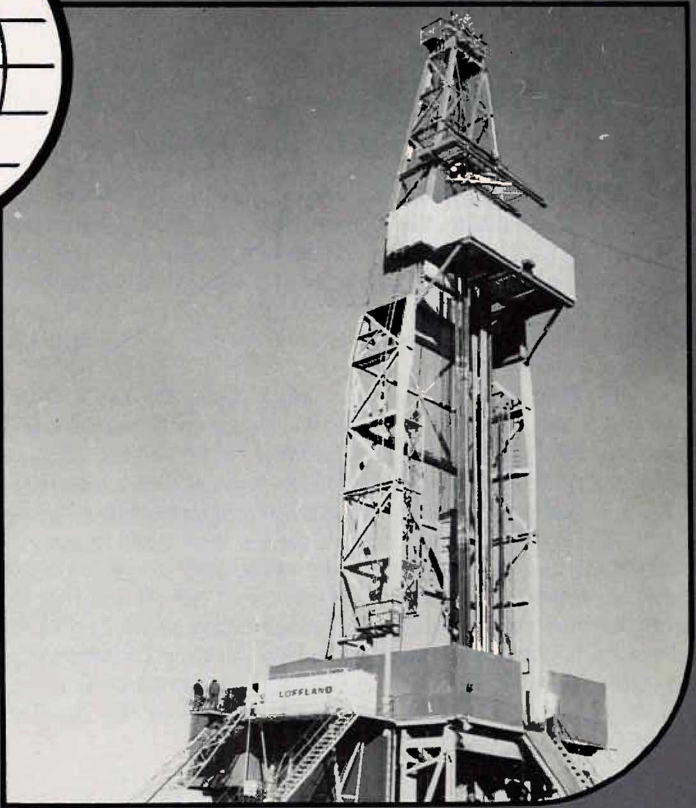

OKLAHOMA GEOLOGY NOTES

VOLUME 34 NUMBER 1 FEBRUARY 19

Cover Picture

WORLD'S LARGEST LAND-BASED DRILLING RIG USED FOR RECORD WELL

Loffland Brothers Rig 32, which belongs to a Tulsa drilling company, is the largest land-based rig in the world. Shown on location for the Lone Star Producing Co. 1 E. R. Baden Unit, the rig has a 142-foot mast and a 30-foot substructure, for a total height of 172 feet. Its gross nominal capacity is 2 million pounds, and the 3,000-horsepower draw works is powered by three 1,350-horsepower motors. Mud is circulated by two 650-horsepower mud pumps.

Rig 32's size made it the logical choice for the 1 E. R. Baden Unit, drilled in sec. 28, T. 10 N., R. 22 W., Beckham County, Oklahoma. The well was spudded on August 4, 1970, and on February 29, 1972, reached a total depth of 30,050 feet in the Viola Limestone of Ordovician age. This depth is the greatest any company has attained in exploration for oil and gas.

The Baden well set many records other than depth; for instance, it called for the biggest casing and cementing job on record. The well was drilled without any major problems, and new technology derived from it will undoubtedly be used for further exploration. Rig 32 is currently on location for Lone Star, going for a total depth of 29,000 feet in the 1 Rogers, to the east in Washita County. (For a more detailed account of the 1 E. R. Baden Unit and the outlook for exploration in the Anadarko basin, see related story, p. 3 of this issue.)

—T. L. Rowland

(Photograph Courtesy of Lone Star Producing Co.)

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.

THE HISTORIC 1 BADEN UNIT AND A BRIEF LOOK AT EXPLORATION IN THE ANADARKO BASIN

T. L. ROWLAND[1]

INTRODUCTION

Western Oklahoma has been the target area for oil and gas exploration for many years. Most of this activity has been in northwestern Oklahoma, on the shelf portion of the Anadarko basin (fig. 1). In the last few years, the deeper part of the basin has become the focal point of exploration.

Lone Star Producing Company has been actively involved in the search for oil and gas throughout western Oklahoma for several years. In 1969 this search was intensified as the company undertook the largest exploration program in the Anadarko basin up to that time. This program was designed to evaluate the gas potential of rocks of the Hunton Group (Late Ordovician through Early Devonian) on the deep structures along the axis of the basin (fig. 2). The program commenced with the acquisition of extensive acreage from Glover, Hefner, Kennedy Oil Company on several seismically defined structures in the Elk City area (fig. 2).

In August 1970, Lone Star began drilling on one of the acquired acreage blocks what resulted in the world's deepest hole: the 1 E. R. Baden Unit, 1,320 feet FSL and 1,220 feet FWL of the SE¼ sec. 28, T. 10 N., R. 22 W., Beckham County (fig. 2). This drill site was selected for the initial test in Lone Star's program because it appeared to have the greatest magnitude of structural relief, based on the deepest mappable unit at the time (the Springer). Hydrocarbon traps were anticipated, because the area is just north of the Mountain View fault zone, which separates the Anadarko basin from the Wichita Mountain uplift to the south.

The well reached a total depth of 30,050 feet on February 29, 1972, in the Viola Limestone of Ordovician age. Rocks of the Hunton Group were found to be tight, so the well was plugged back and completed as a small gas producer from limestone conglomerates of the Atoka Formation through perforations from 16,190 to 17,382 feet. The total cost of the well was about $5.5 million.

This enormous project was initiated by Lone Star's Oklahoma City exploration office, particularly through the efforts of Tommy H. Atkins and Franklin C. Jones, exploration managers, Robert J. McCall, district geologist, and Bill J. Jezek, senior geologist.

GEOLOGY AND HISTORY OF EXPLORATION

The general outline of the Anadarko basin is shown in figure 1. The basin is a strongly defined synclinal fold encompassing western Oklahoma, part of northwestern Oklahoma, and parts of the northeastern Texas

[1]Geologist, Oklahoma Geological Survey.

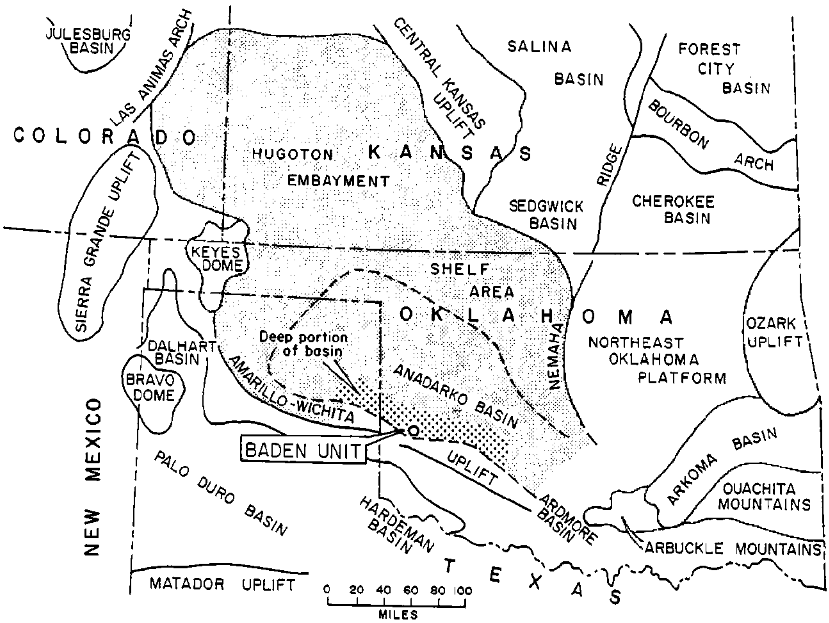

Figure 1. Generalized tectonic map of Midcontinent region showing location of Lone Star Producing Co. 1 E. R. Baden Unit.

Panhandle. The slope into the basin from the shelf areas on the west, north, and northeast may be characterized as gentle, but on the south the basin is bounded by a complex set of faults about 200 miles long that extends across Oklahoma into Texas. The most northerly of these faults is the Mountain View fault zone, shown in figure 2. As much as 30,000 feet of vertical displacement occurs along this fault zone. To the southeast the Anadarko basin merges into the Ardmore basin (fig. 1).

Early exploration was essentially confined to the shelf area of the Anadarko basin, where production is principally from rocks of Morrowan age. In more recent years, as drilling technology has improved, the exploration play has been not only on the shelf area but southward into the basin proper. The first deep well drilled was the Howell and Howell 1 Anadarko Basin (21,021 feet); it was followed by the Shell Oil Co. 5 Rumberger (24,002 feet). The Elk City field (Pennsylvanian) was discovered, and deeper, pre-Pennsylvanian production was found in the Custer City, Aledo, Washita Creek, Buffalo Wallow, and Gageby Creek fields. These fields produce at depths to 20,600 feet. Production in the basin is from Morrowan (Lower Pennsylvanian), Springer (Upper Mississippian), Lower Mississippian, Hunton, and Arbuckle (Lower Ordovician-Upper Cambrian) reservoirs (fig. 2).

As a result of the exploration efforts in the deeper part of the Anadarko basin by Lone Star and others, an enormous amount of information has

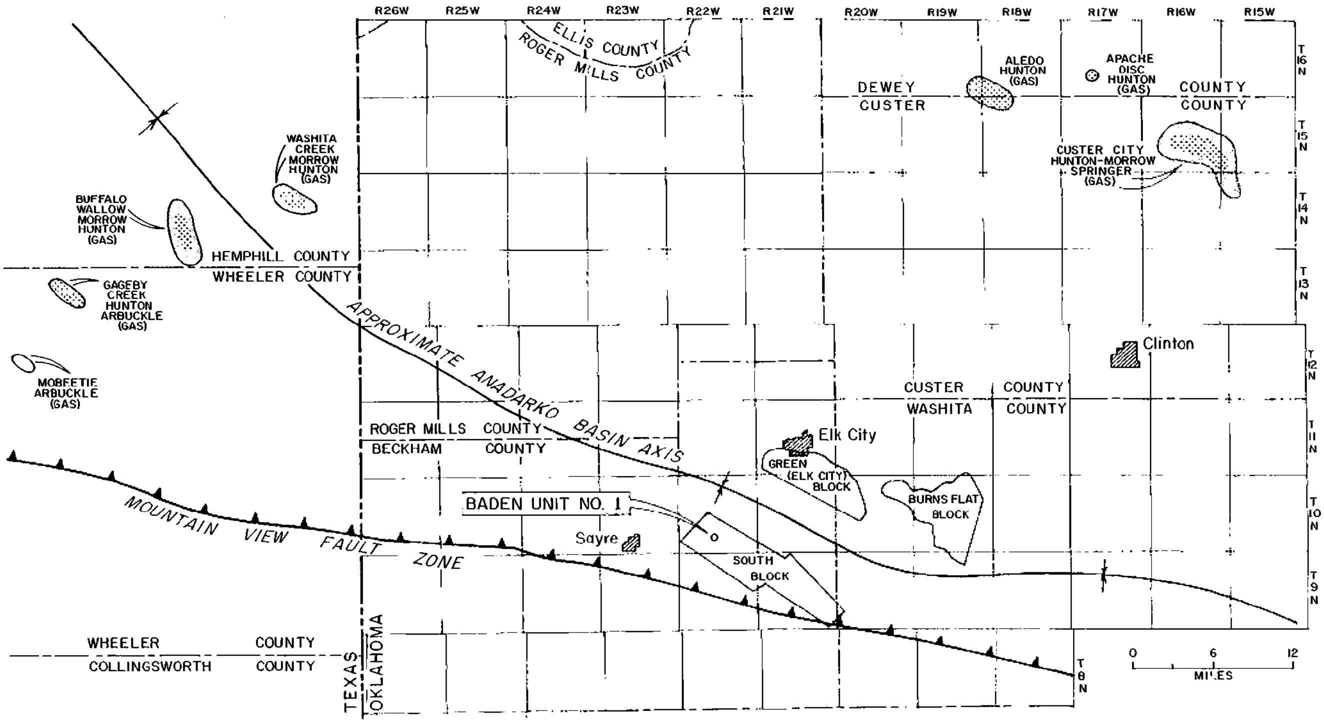

Figure 2. Map of western Oklahoma and eastern Texas Panhandle showing location of Lone Star Producing Co. 1 E. R. Baden Unit with respect to major tectonic elements, acreage blocks, and producing fields. Morrow-Springer production shown by fine stippling, and Hunton production by coarse stippling.

become available concerning the subsurface geology of the basin. Definition of structures through refined seismic techniques and increased understanding of basin structure and stratigraphy are types of information gained from the deeper drilling. Among the more useful stratigraphic information is the realization of what had been postulated for many years: the thickening of Paleozoic units into the basin.

Table 1 lists the tops and thicknesses of Paleozoic units drilled in the Baden well. Using this information, an approximate thickness of the sedimentary package in the deeper portion of the basin can be postulated. The maximum thickness of sedimentary rocks measured on the outcrop in the Arbuckle Mountain area from the base of the Reagan Sandstone of Late Cambrian age to the top of the Viola Limestone is 10,575 feet (Reagan, 450 feet; Honey Creek, 225 feet; Arbuckle Group, 6,700 feet; Simpson Group, 2,300 feet; Viola, 900 feet). Thus, as the top of the Viola Limestone was

TABLE 1.—GEOLOGIC UNITS PENETRATED BY LONE STAR 1 BADEN UNIT

AGE	UNIT	TOP	SUBSEA ELEVATION	THICKNESS
Permian	Brown dolomite	4,728	−2,745	1,812
	Pontotoc	4,858	−2,875	
Pennsylvanian	Virgil	6,670	−4,687	2,130
	Heebner	8,052	−6,069	
	Hoxbar marker	8,526	−6,543	
	Missouri	8,800	−6,817	2,910
	Deese	11,040	−9,057	
	Des Moines	11,710	−9,727	1,892
	Atoka	13,602	−11,619	4,092
	Morrow	17,694	−15,711	3,970
Mississippian	Springer	21,664	−19,681	
	Goddard	22,398	−20,415	
	Chester limestone marker	23,196	−21,213	
	Meramec	25,626	−23,643	
	Kinderhook	27,930	25,947	
Mississippian-Devonian	Woodford	28,130	−26,147	318
Devonian-Silurian-Ordovician	Hunton	28,448	−26,465	1,320
Ordovician	Sylvan	29,768	−27,785	212
	Viola	29,980	−27,997	70 feet drilled
	TOTAL DEPTH	30,050	−28,067	

encountered at 29,980 feet in the Baden well, a minimum of 40,555 feet of sedimentary rocks is thought to be present in this part of the basin. Since many of the units are somewhat thicker than their surface equivalents, there might be a corresponding increase in thickness of the pre-Viola units by as much as 10 percent. Volcanic rocks of Middle and Early Cambrian age underlie the sedimentary rocks and are probably more than 5,000 feet thick, so the total package of rocks in the deeper Anadarko basin to the Precambrian basement should be at least 45,000 feet. This thick sedimentary package, which contains many potential reservoir units, makes the Anadarko basin a good geologic province in which to explore for hydrocarbons, especially gas.

DRILLING THE 1 BADEN UNIT

The 1 Baden Unit was drilled by Loffland Brothers Company of Tulsa, using the world's largest land-based rig (see this issue's cover picture). The well spudded on August 4, 1970, and reached total depth on February 29, 1972. The various hole sizes and the casing record are given in table 2, as are the records of logs run, testing data, and other pertinent statistics.

The hole was monitored continuously, using a mud-logging unit that cost $325 a day. This unit recorded and analyzed any oil or gas shows and controlled the drilling mud. With each 10 feet of depth, all drilling and lithologic characteristics were transmitted by telephone to computer tape and printed out simultaneously in Lone Star's Oklahoma City and Dallas offices. The company's geologist then examined the printout to see if a trip to the location was necessary. A 3-bedroom trailer provided the "home away from home" for the well-site geologist and the drilling engineer. The drilling mud was supplied by Magcobar Operations of Dresser Industries.

Some of the problems with logging included running 30,000 feet of cable in a hole with temperatures that reached 426°F at bottom. Because of these extremely high temperatures, the logging devices usually worked only on a one-time basis.

Other details of the drilling and technology of the well are given in articles listed in the references.

OUTLOOK

Advances in drilling technology have made exploration for deeper targets in the Anadarko basin a reality. Deeper production has been obtained, and many tests either have been drilled or are being drilled. Lone Star Producing Company has led the way in the deepest part with the Baden well and is currently drilling another deep Hunton test, the 1 Rogers, in sec. 27, T. 10 N., R. 19 W., Washita County, which is slated for a total depth of 29,000 feet; on February 4, the Rogers well was drilling at 28,080 feet. Certainly it is hoped that production will be found along these axial structures, so that this part of the basin will remain an active exploration area.

TABLE 2.—DRILLING AND COMPLETION DATA ON LONE STAR 1 BADEN UNIT

Location:	1,320′ FSL and 1,220′ FWL of SE¼ sec. 28, T. 10 N., R. 22 W., Beckham County, Oklahoma.
Elevation:	Ground level, 1,953′; derrick floor, 1,982′; kelly bushing, 1,983′.
Hole size:	17½″ to 15,408′; 11-7/8″ to 23,400′; 7-7/8″ to 30,050′.
Total depth:	30,050′.
Bottom-hole temperature:	426°F.
Casing depths:	30″ conductor to 42′; 20″ to 4,920′; 13-3/8″ to 15,416′; 9-5/8″ to 23,392′; 5″ 21,091′-28,572′.
Well objective:	Hunton Group.
Types of logs:	Dual laterolog 9 (deep) curve, 23,391-30,034′; Gamma ray-neutron, 23,380-30,042′. Compensated neutron, 23,150-30,038′. Integrated borehole compensation sonic, 23,403-30,040′. Compensation formation density, 23,378-29,978′. Dipmeter, directional survey calibration, 23,388-30,046′. Seismic reference service-velocity control surface to total depth.
Testing:	To test Hunton, set 5″ liner 21,091′-28,572′ and combination 7″ and 5″ production string from 21,091′ to surface; set 2-7/8″ and 2-3/8″ kill string to 21,838′. Acidized with 5,000 gals. of 7.5% acid and 10,000 gals. of 15% acid, and tested open hole. No gas, no water, tight formation; pulled kill string and production string, and abandoned Hunton. To test Atoka, set bridge plug at 20,012′, set 2-7/8″ production tubing from surface to 16,195′. Acidized with 6,000 gals. of 15% acid and 6,000 gals. of mud acid. Fractured with 80,000 gals. of 5% gelled acid, 25,500 lbs. of 20/40 sand, and 14,500 lbs. of 12/20 glass beads. Tested for 24 hours; flowed 200 MCFGPD, with a flowing pressure of 600 lbs. Perforated the following intervals, 1 perforation per foot: 17,380-17,382′ 17,312-17,324′ 17,010-17,012′ 16,954-16,958′ 16,824-16,828′ 16,502-16,512′ 16,396-16,416′ 16,190-16,191′
Completion:	Shut-in gas well in Atoka. IPF 200 MCFGPD.

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The Mineral Industry of Oklahoma in 1973[1] (Preliminary)

L. G. Southard[2]

The value of minerals produced in Oklahoma in 1973 was $1,306 million, a net gain of 7.9 percent over 1972. Fossil fuels remained the State's dominant minerals and accounted for 93.3 percent of the total mineral value. Nonmetallic mineral value increased 9.9 percent and accounted for 6.5 percent of the State's gross mineral value. The value of metals declined slightly and was less than 0.2 percent of the total value of minerals produced in Oklahoma during 1973.

MINERAL FUELS

The value of mineral fuels rose to $1,219 million, 7.9 percent above the value in 1972. The value of all fossil fuels, excluding helium, increased in 1973. The production and value of helium decreased below 1972 amounts by 16.9 percent and 6.8 percent, respectively.

NONMETALS

The value of nonmetals amounted to $84.7 million, compared with $77.1 million in 1972. The largest gains in value came from stone and masonry cement.

METALS

Copper and silver, the only metals produced in Oklahoma in 1973, declined 16.0 percent in combined value, compared with the previous year's figures.

[1]Prepared December 19, 1973, in Division of Fossil Fuels, U.S. Bureau of Mines.
[2]Minerals specialist, U.S. Bureau of Mines, Washington, D.C.

TABLE 1.—MINERAL PRODUCTION IN OKLAHOMA[1]

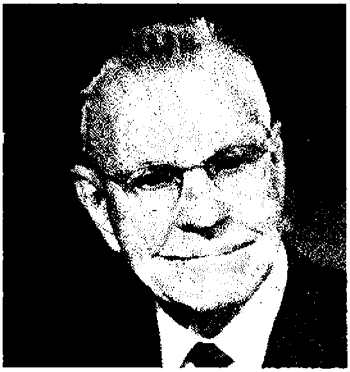
Mineral	1972 Quantity	1972 Value (thousands)	1973 (preliminary) Quantity	1973 (preliminary) Value (thousands)
Clays[2] (thousand short tons)	938	$ 1,398	981	$ 1,458
Coal (bituminous) (thousand short tons)	2,624	19,112	2,624	20,330
Gypsum (thousand short tons)	1,196	3,888	1,231	4,866
Helium				
High-purity (million cubic feet)	174	6,090	180	6,300
Crude (million cubic feet)	163	1,956	100	1,200
Natural gas (million cubic feet)	1,806,887	294,523	1,771,626	327,751
Natural-gas liquids:				
LP gases (thousand 42-gallon barrels)	27,148	57,011	28,270	65,000
Natural gasoline and cycle products (thousand 42-gallon barrels)	14,559	42,709	14,230	45,500
Petroleum (crude) (thousand 42-gallon barrels)	207,633	709,033	193,107	753,117
Sand and gravel (thousand short tons)	7,901	11,138	7,979	11,504
Stone (thousand short tons)	19,448	26,574	22,232	32,588
Zinc (recoverable content of ores, etc.) (short tons)	W	W	—	—
Value of items that cannot be disclosed: bentonite, cement, copper, lime, pumice, salt, silver, and tripoli	XX	37,296	XX	36,654
Total	XX	$1,210,728	XX	$1,306,268
Total 1967 constant dollars	XX	1,007,205		

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed." XX Not applicable.

[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2]Excludes bentonite.

M. King Hubbert Launches Energy Series at OU



M. King Hubbert,
AAPG Distinguished Lecturer

U.S. Geological Survey geologist M. King Hubbert recently launched a seven-part energy series for The University of Oklahoma with an address on "The World's Energy Economy." Jointly sponsored by the OU School of Geology and Geophysics and The American Association of Petroleum Geologists' Distinguished Lecture Committee, Dr. Hubbert's talk was enthusiastically received by an audience of about 150 persons. In introducing him, Dr. Mankin stated that Dr. Hubbert had long ago pointed out the finite nature of energy resources and predicted the decline of reserves now felt throughout our nation and the world. While critics scoffed and other leading scientists postulated that no significant shortages would occur within our lifetime or those of our children's children, Dr. Hubbert "was not overawed by the opposition, nor was he silenced."

Dr. Hubbert likened oil exploration to fishing in a murky pond. Every fisherman accepts certain signs as indicators of likely or unlikely spots, but until he pulls the first fish out of the water, he doesn't know just what to expect. And pulling them out, he doesn't know how many remain. Yet he knows that in a particular pond, as more fishermen are attracted to the spot, more and more fish are extracted. Then the day comes when the number declines and the fish come so far apart that the spot is abandoned for a more attractive locale. Dr. Hubbert said that he is asked over and over again how long United States or world supplies of coal or oil will last. He considers it a nonsense question. The supply will last forever—in the sense that it will never be completely exhausted. It is both technologically and economically impossible to do so. Probably only 80 percent of the resources could be used before a fisherman would turn to hunting something else as a source of food or sport.

In all exploration and production, two distinct phases emerge: first the rise and then the decline of resources. The most important single date is not that of the beginning or the end but of the peak, the shift from one phase to the other. The amount of energy in our world can be considered static; the amount of power changes, but the amount of energy does not. Most of the coal and gas ever produced has been produced in the past 150 years. In fact, the amount of coal produced in the past 10 years is equal to that produced in all previous history. On the other hand, no significant increase in the amount of existing coal or gas is possible—even in the next 1,000 years. What's more, Dr. Hubbert believes that the peak in the oil and gas depletion cycle falls in the 1970's. If the date is not already past, it soon will be. He bases his prediction on years of calculation using statistics for proved reserves and production figures dating back to 1860.

Dr. Hubbert suggests that research be undertaken immediately on other energy resources. He holds no great hopes for nuclear power plants, because of the danger involved in handling radioactive wastes (particularly because one saboteur with a bomb could destroy a nuclear power plant as easily as he could blow up an airplane but with much more disastrous consequences). He suggests that solar energy, on the other hand, is truly inexhaustible, and he calls for more research into the possibilities of transforming solar energy into a liquid or gaseous form so it can be piped from arid regions and used anywhere it is needed.

M. King Hubbert's lecture was especially appropriate to initiate OU's university-wide energy-awareness program, because it stimulated interest in energy research while providing a background for understanding current problems. A variety of viewpoints should be available from future speakers in the series, because the faculty committee that scheduled speakers contained representatives from the Graduate College, the Science and Public Policy Program, the Colleges of Business Administration and Engineering, and the departments of finance and economics—as well as the School of Geology and Geophysics. Subsequent lectures will be delivered as follows:

"Energy In The United States: Is There A Crisis?"
Dr. Morris A. Adelman, Professor of Economics
Massachusetts Institute of Technology
Tuesday, February 12, 1974
Adams Hall—150
3:00 p.m.

"The Energy Outlook: An Assessment of Alternatives"
Dean A. McGee, Chairman, Kerr-McGee Corporation
Friday, February 22, 1974
Adams Hall—150
3:00 p.m.

"National Energy Policy"
Dr. Stephen Gage, Council on Environmental Quality
Wednesday, February 27, 1974
Botany and Microbiology Bldg.—Room 123
2:00 p.m.

"Energy and the Economy"
Dr. W. Nelson Peach
George L. Cross Research Professor of Economics, The University of Oklahoma
Friday, March 8, 1974
Adams Hall—150
3:00 p.m.

"Energy in Oklahoma—Past, Present, and Future"
Dr. Charles J. Mankin, Director, Geology, The University of Oklahoma
Friday, March 22, 1974
Adams Hall—Room 150
3:00 p.m.

"Energy and its Social Impacts"
Dr. Richard Carpenter, National Academy of Sciences
Friday, April 5, 1974
Botany and Microbiology Bldg.—Room 123
2:00 p.m.

—Rosemary L. Croy

AAPG-SEPM Activities On Tap for San Antonio

Oklahoma geologists are in luck this year; they can journey to The American Association of Petroleum Geologists-Society of Economic Paleontologists and Mineralogists annual meetings without expending an unconscionable amount of energy, because the convention site is just south of our border, down Texas way. Mark April 1-3 as the dates for frolic in San Antonio. Our hosts (South Texas Geological Society and Gulf Coast Association of Geological Societies) promise "The Excitement of Geology in a Relaxed Atmosphere." Floating mariachis have been arranged for Tuesday night's Mexican extravaganza, along with tamales, tacos, nachos, and plenty of good fellowship.

In the midst of the merriment, however, time has been allotted for an outstanding program of technical sessions, and 4 AAPG and 2 SEPM field trips have been planned around the conference. The American Association of Petroleum Geologists has decided to make stratigraphic traps the subject for special emphasis this year. Papers on facies analysis in stratigraphic exploration, application of isopach maps and cross sections to exploration in the Midcontinent, oil-column calculation in stratigraphic traps, detailed examples of stratigraphic exploration programs, fracture porosity and permeability in stratigraphic traps, environmental log analysis, stratigraphic models, and the use of new tools and methods in the search for stratigraphic accumulation will be featured. In addition, a special symposium entitled "Delta Systems: Significance of Stratigraphy and Facies in Exploration" will be presented, and a session on the "Application of Computers in Stratigraphic Exploration" will be held.

A stratigraphic and structural analysis of petroleum geology on the international level will be offered; AAPG President Dan Busch (also a visiting professor of geology at The University of Oklahoma) will present a paper on northeastern Mexico as part of the session on foreign developments.

The AAPG research symposium for this year will be "Geologic Significance of Geothermal Studies"; the results of the AAPG geothermal study of North America will be discussed. The SEPM research symposium will be "Genesis of Deep-Sea Sediments." This day-long symposium will attempt to sift through a mass of data accumulated over the past several years from the deep-sea drilling project. Papers for the SEPM technical sessions cover the areas of sedimentation and sedimentary petrology, carbonates, paleontology, mineralogy and geochemistry, stratigraphy, and sediments of the Gulf Coast. A special symposium on Bryozoa will be held in honor of the late Dr. Tom Perry.

AAPG and SEPM members alike should welcome a chance to discuss the burning political-energy and geologic problems of today and tomorrow, so discussion groups will meet Monday evening to air feelings on the controversial topic "Petro Politics and Other Tectonics." Altogether, a fitting combination of activities for work and play has been lined up for the annual meetings, so geologists are advised to take notice. For additional information, contact AAPG headquarters, Box 979, Tulsa, Oklahoma 74101.

USGS Releases Hydrologic Maps of Oklahoma Panhandle

The U.S. Geological Survey, in cooperation with the Oklahoma Water Resources Board, has released two sets of reconnaissance maps, covering two counties in the Oklahoma Panhandle, as part of its Hydrologic Investigations Atlas series. The first is HA-373, *Reconnaissance of the Ground-Water Resources of Cimarron County, Oklahoma,* by D. B. Sapik and R. L. Goemaat, and the second is HA-450, *Reconnaissance of the Water Resources of Beaver County, Oklahoma,* by R. B. Morton and R. L. Goemaat. Each set of maps contains three sheets, recording information on surface geology, water wells of all kinds drilled in the areas, saturation data, water quality, and potentials for irrigation. The other atlas in the Panhandle series, covering Texas County, was published in 1967. These atlases are available for $1.25 a set from the U.S. Geological Survey, Federal Center, Denver, Colorado 80225.

Since 1965 the Oklahoma Geological Survey has been involved in a 10-year cooperative project with the Water Resources Division of the U.S. Geological Survey to conduct a comprehensive water investigation of the State exclusive of the Panhandle. The Fort Smith and Tulsa 1:250,000 quadrangles (HA-1 and HA-2) are now available from the Oklahoma Survey. The Ardmore-Sherman sheet (HA-3), which includes the Arbuckle Mountains, will be available soon; HA-4, the Oklahoma City sheet, is in cartographic preparation; and field work has been completed on the Enid, Woodward, and Lawton sheets. When completed, this series will number nine atlases.

Paleoecology of the East Manitou Site Southwestern Oklahoma

Larry C. Simpson[1]

Introduction

The East Manitou site was first described by Olson (1967, p. 24), who suggested that the fossiliferous beds found there were of nearshore-marine origin. A recent study of the site has produced evidence that the origin of the sediments is fluvial, which necessitates changing earlier conclusions concerning the paleoecology of the locality.

The East Manitou site consists of a roadcut 4.6 miles east of U.S. Highway 183 on a secondary road that goes through the southwestern Oklahoma town of Manitou (fig. 1), in Tillman County. An unusually large assemblage of vertebrate and plant fossils has been found at this site. Most of the fossils collected were from the south side of the roadcut and in the contiguous area (NW¼ sec. 5, T. 1 S., R. 16 W.), although fossiliferous material was also found in the outcrop on the north side of the road.

The rocks exposed in the roadcut are basal red shale, overlain by gray to tan shales and siltstones. These fine-grained clastic sedimentary rocks incorporate lenticular beds of dark, coarse-grained sandstone and conglomerate that contain vertebrate remains as well as logs and other plant remains.

The basal red shale is the uppermost bed of the Garber Formation, which makes up much of the Permian section exposed in Tillman County. The fossiliferous shales and lenses of coarse clastic rocks overlying the red shale form the basal part of the Purcell Sandstone Member of the Hennessey Group, according to R. O. Fay of the Oklahoma Geological Survey (see Simpson, 1973a, p. 191), and as the Purcell Sandstone is the lowest unit of the Hennessey Group in southwestern Oklahoma, the exposure at this locality is positioned stratigraphically in the Garber-Hennessey transition zone, a zone known to yield a large number of vertebrate remains across Oklahoma (Olson, 1967, p. 13).

Lithology

The southeast part of the roadcut offers the best exposure for examining the stratigraphic succession (fig. 2). The lithology at that location, shown in table 1, is typical of the exposures in the area. The sandstone classification used follows McBride (1963). Parenthetical descriptions in units 3 and 6 are of thin sections identified by Duncan Sibley (a graduate teaching assistant at The University of Oklahoma).

[1]Graduate teaching assistant, School of Geology and Geophysics, The University of Oklahoma, Norman.

The coarse sandstone found throughout the section is the most variable rock unit. In some outcrops the shale clasts are so numerous and large that the unit requires identification as a conglomerate. The feldspar-quartz ratios vary within these beds, but generally the rocks can be termed a feldspathic litharenite.

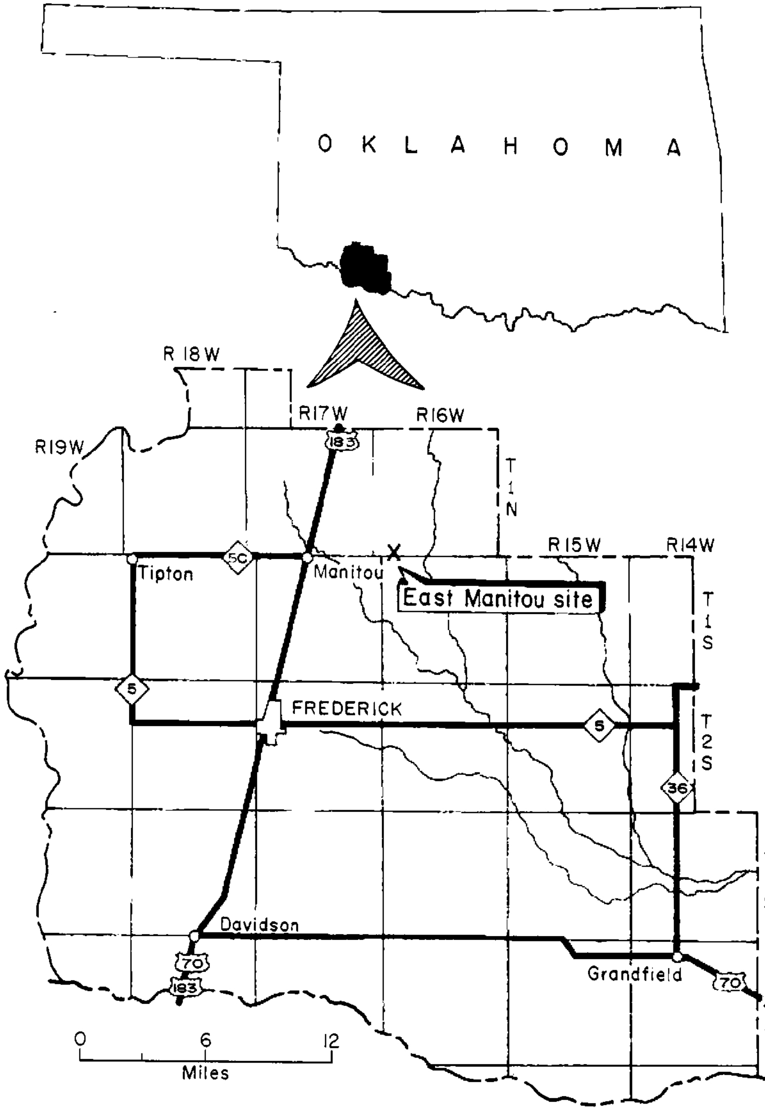


Figure 1. Index map of Oklahoma showing Tillman County and East Manitou site.

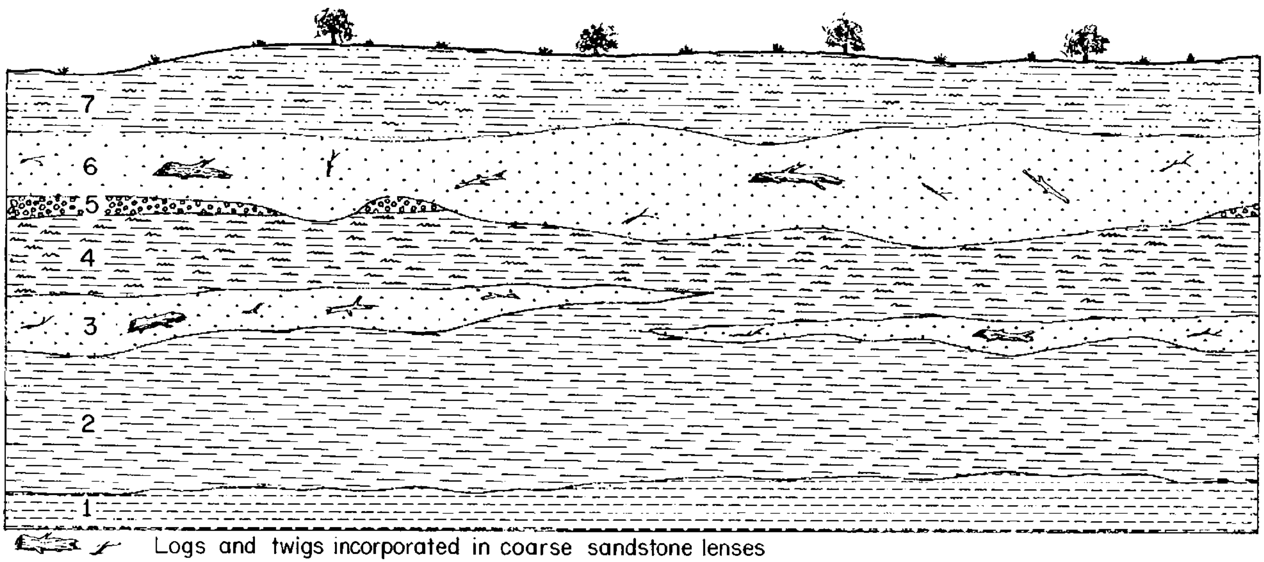


Figure 2. Generalized stratigraphic section of southeast part of roadcut, East Manitou site. Numbers represent lithologic units described in table 2.

Units 3 and 6 (and all the dark sandstones in the area) are lenticular. The tops and bottoms of the lenses are generally irregular, forming an undulating contact with surrounding beds, and the beds thin rapidly at the perimeters, grading into lighter colored fine-grained sediments.

In the section described, unit 5 is not continuous but is present only in the concave portions of the undulating bottom surface of unit 6 (fig. 2). The convex portions of the bottom contacts of unit 6 truncate unit 5, extending into the shale unit (4) below it. Many examples can be found where bedding surfaces and structures in the shale are truncated by these coarser rocks. All the coarse-grained sedimentary units contain imperfectly shaped spherical to elliptical clasts of shale that appear to be derived from underlying shale units. This indicates that the dark sandstones were deposited in an erosion channel.

Fine-grained rocks make up much of this sedimentary sequence and contain coarse clastic lenses. The fine-grained rocks are a lighter color than the coarser deposits and show more definite stratification. In no place do they truncate the coarse sandstone lenses.

TABLE 1.—LITHOLOGIC DESCRIPTION OF SEVEN ROCK UNITS IN DESCRIBED SECTION (FIG. 2), EAST MANITOU SITE

LITHOLOGIC UNIT	DESCRIPTION	THICKNESS (INCHES)
7	Interbedded shale, siltstone, and sandstone: shale, tan to gray, laminated to cross-bedded, poorly sorted, subrounded, calcareous; sandstone, tan, very fine-grained, subrounded, fairly well-sorted; contains scarce vertebrate and plant fossils	24
6	Sandstone, steel-gray, weathers black, unsorted, cross-bedded, subangular, calcareous, common vertebrate fossils (feldspathic litharenite, 30% shale clasts, 22% highly altered, granophyric, orthoclase feldspar, 50% polycrystalline quartz, 3% calcite cement)	14
5	Mudball conglomerate, tan, medium-bedded, unsorted, rounded interclasts 5-150 mm of tan and gray shale; approximately 60% shale to sand-sized clasts of quartz and feldspar; approximately 40% calcareous; rare vertebrate fossils	3
4	Shale and siltstone, tan to gray, laminated to cross-bedded, common plant fossils	20
3	Sandstone, steel-gray, weathers black, thin-bedded to cross-bedded, unsorted (feldspathic litharenite 45%, polycrystalline quartz 25%, granophyric orthoclase 25%, shale clasts 5%, calcite cement), calcareous, abundant vertebrate and plant fossils	18
2	Shale, grayish-green, weathers gray, laminated to thin-bedded, noncalcareous, nonfossiliferous	65
1	Shale, red, laminated, calcareous, nonfossiliferous	?

All available paleontological evidence was explored in an attempt to determine the paleoecology of the site. Although vertebrate remains were the most common fossils recovered, some well-preserved plant material and some spores were collected and prepared. No invertebrates were found. The identification of fossils follows, table 2.

The flora and fauna consist exclusively of nonmarine forms.

The palynomorph *Nuskiosporites* is a spore of a wet, lowland seed fern. *Stroterosporites* and *Taeniasporites* are pollen from conifers that grew on higher ground (L. R. Wilson, The University of Oklahoma, oral communication, 1973). The most abundant palynomorphs are the spores of an unde-

TABLE 2.—PALYNOMORPHS, FLORA, AND FAUNA DISCOVERED DURING EAST MANITOU INVESTIGATION

Flora
- Palynomorphs
  - *Nuskiosporites* sp.
  - *Stroterosporites* sp.
  - *Taeniasporites* sp.
  - fungus spores
- Plant megafossils
  - *Calypteris* sp. (leaves)
  - *Calamites* sp. (stems)
  - *Gigantopteris* sp. (leaves)
  - *Taeniopteris* sp. (leaves)
  - *Cardiocarpus* sp. (seeds)
  - *Dadoxylon* sp. (wood)

Fauna
- Pisces
  - Elasmobranchii
    - *Xenacanthus* sp.
    - *Orthacanthus* sp.
    - *Hybodus* sp.
  - Acanthodii
    - *Acanthodes* sp.
  - Palaeonisciformes
    - *Platysomus* sp.
    - *Palaeoniscoidea* sp.
    - palaeoniscoid scales
  - Dipnoi
    - *Sagenodus* cf. *S. porrectus*
- Amphibia
  - Temnospondyli
    - *Eryops* sp.
    - *Trimerorhachis* sp.
- Reptilia
  - Pelycosauria
    - *Ophiacodon* cf. *O. major*
    - *Dimetrodon* sp.

scribed species of fungus. The absence of marine palynomorphs in the samples supports the conclusion that the sedimentation was fluvial.

Megafossil plant remains are common in the section, with almost every bedding plane above unit 1 containing plant detritus or twigs. The black color of the coarse sandstones appears to have resulted from the incorporation of a large amount of carbonaceous plant material, although only in the shales is delicate plant tissue preserved well enough to be identified. A quarry in unit 4 yielded specimens of *Calypteris, Calamites, Gigantopteris* (fig. 3), *Taeniopteris, and Cardiocarpus;* all but one, *Cardiocarpus,* are fern-like plants requiring a damp environment such as could be found along the boundaries of a stream or swamp. These fragile plants were preserved only because they were buried quickly; otherwise, mechanical or bacterial decomposition would have destroyed them (L. R. Wilson, oral communication, 1973).

Figure 3. *Gigantopteris* branch from quarry in unit 4 (see fig. 2), East Manitou site, ×1.

Wood tissues, some carbonized and others silicified, occur mainly in the coarse sandstones. Branches and trunks as large as 11 inches in diameter have been observed. Thin sections made from the larger trunks were identified as species of *Dadoxylon,* an upland cordaitelean gymnosperm (Wilson, 1963, fig. 2). The trunks had been well abraded and were missing roots, limbs, and bark. *Cardiocarpus,* preserved in the shale deposits, is a cordaitelean seed. Stratigraphically, this appears to be the highest occurrence of cordaitelean megafossils in the State.

Among the vertebrates, the fish are not only the largest, most common, and most diverse groups but are represented by the most-nearly-complete specimens. Hundreds of individual specimens were identified as belonging to this subphylum, constituting the most varied fish assemblage yet discovered from the Permian of Oklahoma (table 3).

The pleuracanth sharks, which are usually common in Lower Permian vertebrate localities, are relatively scarce, with only a few teeth and spines recovered. Of special interest is the discovery of an *Orthacanthus* tooth that equals in size the largest pleuracanth teeth known to have been found in Oklahoma (1 inch long and 3/4 inch wide at the base).

Palaeonisciformes are common in every fossiliferous bed. Separate "Ganoid-type" scales were found throughout the coarse clastics, although in one part of the roadcut articulate palaeoniscoids were discovered in association with a "bone bed." The bone bed is in a 3-inch shale and sandstone body at the west end of the roadcut and is restricted horizontally to a few square yards. The bottom 2 inches of the unit is a compact rock composed of 80 percent palaeoniscoid scales and dental plates along with acanthodian scales and spines. The remaining 20 percent of the rock is made up of shale- to sand-sized particles, with the top inch of the deposit a shale containing complete palaeoniscoid specimens. A quarry at this locality produced articulated specimens of *Platysomus* (fig. 4) and a palaeoniscoid (Moy-Thomas and Miles, 1971, p. 91-97). The perimeter of the lens grades into coarse clastic rocks in which fish remains are not found.

The lungfish *Sagenodus* cf. *S. porrectus* (Romer and Smith, 1934, fig. 7), which is a nonaestivating form, is represented by a delicate, well-preserved tooth (fig. 5). A few of the skull fragments found appear to be dipnoan.

These lower Hennessey beds correspond to the Vale Formation of Texas and are younger than the Dunkard Group of the northeastern United States (Simpson, 1973a, p. 194; 1973b, fig. 2). *Sagenodus* has been found in the Dunkard Group (Romer, 1952) and as high as the Lueders Limestone of Texas (Berman, 1970, p. 26) but not as high as the East Manitou specimen. Thus this find increases the vertical range of the genus (fig. 6).

Worthy of note is the discovery of spines, scales, and scapulae that proved to be from *Acanthodes* and *Hybodus*. *Hybodus* is represented by 2 partial spines, the larger of which is 3 inches long (fig. 7). As were most of the other fish remains, these spines were preserved in a coarse sandstone lens. The acanthodians are represented by many spines, scales, and scapulae (Simpson, 1973a). Many of the acanthodian spines are unusually

TABLE 3.—PERMIAN FISH FROM OKLAHOMA, AFTER ZIDEK (1972, TABLE 2)

Stratigraphic unit		*Xenacanthus*	*Orodus*	*Platysomus*	*Palaeoniscoidea* sp.	*Sphaerolepis*	Ganoids	*Sagenodus*	*Gnathorhiza*	Crossopterygii	*Acanthodes*	*Hybodus*
Middle Flowerpot Fm.	KF-1	X										
	BC-9	X										
Lower Hennessey Gr.	E Manitou	Z C?	X	Z	Z		Z	Z			Z	Z
	Norman								X			
Garber Fm.	N. Manitou	X, C?										
	W. Grandfield	X, C?										
	Hayward	X										
	Pond Creek	X		X		?		X	X	X		
	Deep Red Run	X										
	Bean Farm	X										
	S. Grandfield	X			X				X	X		
	Lucien #1-4	X(1-4)										
Wellington Fm.	Lucien #5	X										
	Orlando	X				X		?	X			
	McCann	X				X	X					
	Perry #1-6	X(3,4,6)Z(5)					X(4,6)		X(1,2,4,5)	?(6)		
Age uncertain	Cummins			X								
	Richard's Spur	X										

C=coprolites
?=uncertain
(1-6)=site nos.
X previously mentioned occurrences
Z=new occurrences

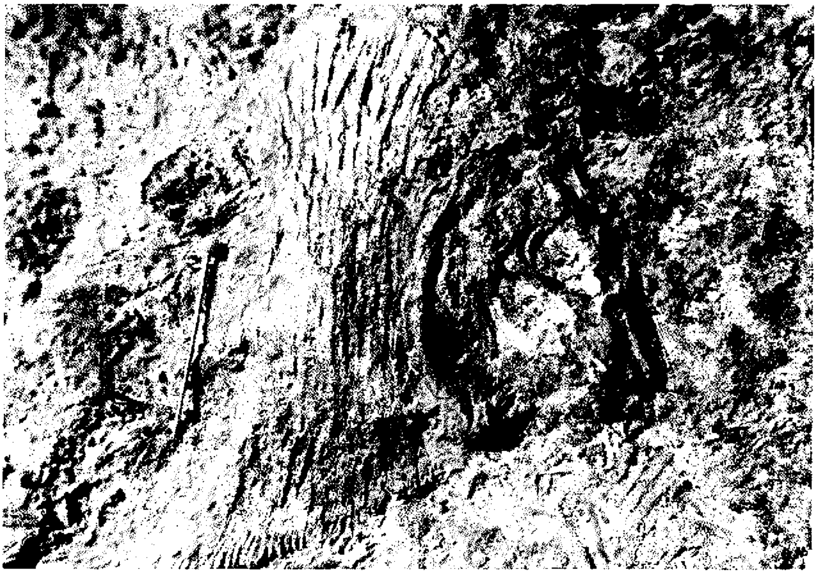


Figure 4. Articulate *Platysomus* specimen from "bone bed," East Manitou site, ×1.

Figure 5. Top view of tooth (1½ inches long) from *Sagenodus* cf. *S. porrectus,* ×3.8.

large, over 2½ inches long, which is more than twice the length of any other *Acanthodes* spines reported from the Permian of North America (fig. 6).

Among the higher vertebrates are remains of the amphibians *Trimerorhachis* and *Eryops*, which were found scattered throughout the coarse rocks. *Trimerorhachis* is the most abundant, and skull fragments as well as complete shoulder-girdle elements were preserved.

Reptile remains are scarce. Fragments and one large vertebra of *Ophiacodon*, a semiaquatic, fresh-water pelycosaur (Romer and Price, 1940, p. 172-173) were found in units 3 and 6. These are the only remains of this genus known to exist this high in the Permian anywhere in the world (fig. 6). Because of the vertebra's large size (4½ inches high, 1½-inch-long centrum) and the specimen's high stratigraphic range, it will tentatively be placed in the species *Ophiacodon* cf. *O. major*.

Fossils of one of the most common Permian reptiles, *Dimetrodon* (Romer and Price, 1940, p. 35), are scarce, but this lowland terrestrial reptile is represented by a few identifiable teeth and spine fragments. These fossils came from the tan shales and siltstones and are the only vertebrate elements not associated with the coarse sandstone lenses.

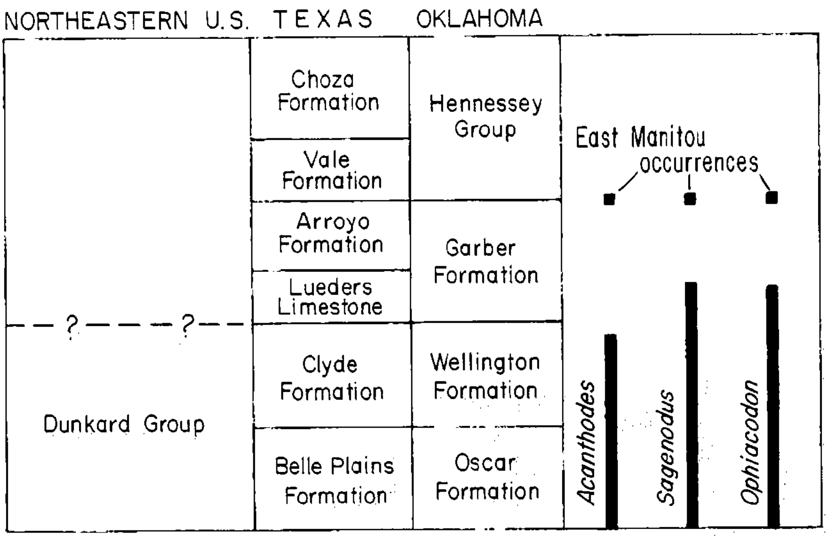


Figure 6. Comparison of former vertical ranges of *Acanthodes, Sagenodus,* and *Ophiacodon* with ranges based on East Manitou occurrences. Correlation of formations after Simpson (1973a, b).

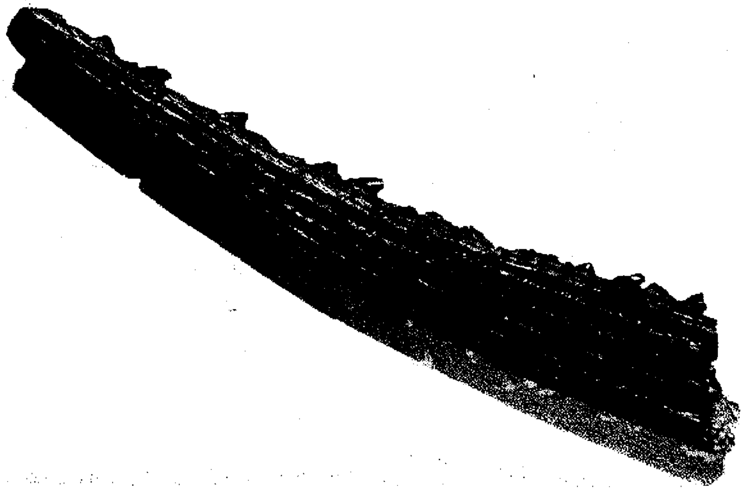


Figure 7. *Hybodus* spine, almost complete, from East Manitou site, ×1.5.

DISCUSSION

As has been shown in table 2, the coarse sandstones in which most of the fossils were found are composed of angular clasts of granitic minerals. The Wichita Mountains contain the only granitic outcrops in southwestern Oklahoma or in adjacent areas of Texas (Ham and others, 1964, pl. 5). The East Manitou site is just south of the Wichita Mountains, and only 9 miles to the north of the site large resistant knobs of granite from the Wichita Granite Group stand as inliers above the Hennessey deposits that blanket the area.

The angularity of the large sand grains in the deposits at the site suggests a nearby source for the sediments with abrasion limited by short transportation. Imbrication in the rocks indicates a source to the north-northwest. Also, the coarse rocks contain granophyric feldspar and polycrystalline quartz. This evidence, combined with the coarse texture of the granite cropping out north of the collection area, indicates that granite from the Wichita Mountains is the source of the coarse Permian clastics.

The fossils offer strong support for the belief that these beds were deposited in a terrestrial environment. Olson (1967) based his interpretation of marine origin on discovery of one *Orodus* tooth. The shark *Orodus* is a marine fish; however, the fossils collected during the present study —vertebrates and plants and pollen—are exclusively terrestrial. It seems to me that the presence of one *Orodus* tooth must be considered a freak event rather than an environmental determinant. For one thing, the strong marine current suggested by Olson to have carried in the coarse clastics and logs would have destroyed the delicate fish and plant remains before burial. It is possible the tooth could have been incorporated in the deposits after the fish's remains were carried inland by a carnivore or scavenger.

Furthermore, the coarse clastic lenses appear to be channel-fill deposits with finer grained sediments associated with them—the flood-plain deposits of a postulated fluvial system. Coarse sandstones are the source beds for most of the vertebrate remains, and the aquatic vertebrates found (fish, amphibians, and a reptile) are all types restricted to fluvio-lacustrine environments. The relative lack of bedding and internal structure and the channel-like shape of the coarse sedimentary lenses indicate a fluvial rather than a lacustrine origin for the sediments in the area under investigation (Olson, 1962, p. 106), although temporary ponding might easily occur.

Trunks of trees, twigs, and plant detritus were preserved along with the vertebrates. This terrestrial plant material, including even such large plants as *Dadoxylon* logs, could have been washed into the stream from adjacent upland areas during heavy flooding. Deposition and burial in the channel could have occurred as floodwater subsided and carrying capacity decreased.

Also, during floods, a sediment- and debris-choked stream could deposit layers of fine sediment and light organic material outside the limits of the channel. These sediments, deposited quickly during periods of high water, could bury and allow preservation of not only the delicate plants growing near the stream but plant material transported from other areas. A concentration of fish material, such as is found in the "bone bed," could have formed in a backwash or overbank deposit where the fish were trapped by receding floodwaters. The finer sediments constitute the flood-plain deposits. During times of normal runoff, terrestrial carnivores, such as *Dimetrodon,* could be expected to have roamed the flood plains in search of food, and therefore the presence of *Dimetrodon* remains in such deposits is quite credible.

SUMMARY

The East Manitou site is composed of a complex sequence of fluvial flood-plain and channel-fill deposits, possibly of a deltaic-distributary system. The river contained a diverse assemblage of fish and higher vertebrates. Along the boundaries of the stream, flora varied from small, delicate ferns to large plants, and fauna included at least a few carnivorous reptiles. tiles. The presence of many fish, some very large, all nonaestivating, indicates streams which were fairly deep as well as constant. The evidence indicates a Permian fluvial system that flowed from the Wichita Mountains to the north to a marginal sea area an unknown distance to the south. The environment of the area must have been unusual, because it not only sustained a large and varied fauna but was also a haven for genera that had become extinct elsewhere in the world.

I thank Dr. Jiri Zidek, Dr. Leonard R. Wilson, and Dr. Harvey Blatt, all of The University of Oklahoma School of Geology and Geophysics, for critically reviewing the manuscript and for helping me to identify the fossils and evaluate the sedimentation of this area.

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Proceedings of Energy Forum Now Available

The proceedings of the forum, "Living Energy in Our Future," held September 29 at the Oklahoma State Fair (see December 1973 issue of *Oklahoma Geology Notes,* p. 217-220), have recently been published in a limited edition by Oklahoma State University. Edited by Robert C. Fite, the 112-page volume contains the remarks of 15 speakers as well as a list of everyone who attended. Single copies of the proceedings volume can be obtained free by writing Dr. Fite, Programs for Professionals, 201 Whitehurst, Oklahoma State University, Stillwater 74074.

SEPM Offers Special Publications 18 and 19

Modern and Ancient Geosynclinal Sedimentation, edited by Robert H. Dott, Jr., and Robert H. Shaver, will be released this spring by the Society of Economic Paleontologists and Mineralogists as Special Publication 19. The 400-page volume contains the proceedings of a symposium dedicated to Marshall Kay, eminent sedimentologist and stratigrapher from Columbia University. It includes 30 papers by more than 40 specialists. The publication is available through SEPM, Box 4756, Tulsa, Oklahoma 74104, at a price of $9.50 to members of SEPM and AAPG, $11.50 to others. Oklahoma deliveries require a 2-percent sales tax (4 percent in Tulsa).

Special Publication 18, also to be issued by SEPM soon, is entitled *Reefs in Time and Space* and is edited by Leo F. Laporte. A 250-page cloth-bound volume comprising 7 papers and 150 illustrations, it analyzes various aspects of reef form and development, both recent and ancient, and joins new thought with older ideas and historical evolution. Authors contributing to the work are A. L. Bloom, E. G. Purdy, T. F. Goreau, L. S. Land, P. H. Heckel, W. Krebs, A. Bosellini, D. Rossi, and R. K. Matthews. The book is priced $8.50 to SEPM and AAPG members, $10.50 to others, and can be ordered from SEPM at the address given above. Sales tax should be included if applicable.

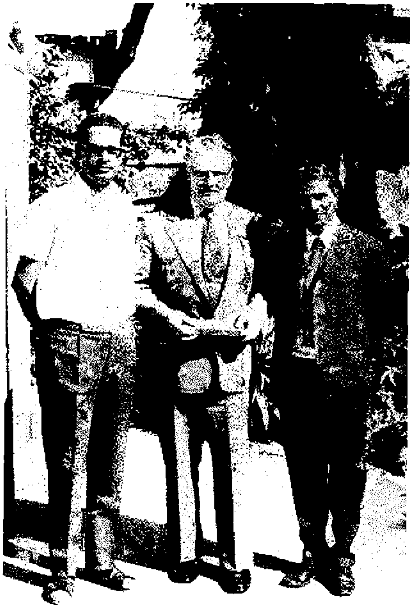
Donald Orth Named Leader of Geographic Names Committee

Donald J. Orth, formerly chairman of the U.S. Geological Survey's Geographic Names Section, has been appointed executive secretary of the Domestic Geographic Names Committee of the federal government's interagency Board on Geographic Names. He replaces Lester F. Dingman, who held the post from 1971 through 1973 but has recently retired.

The interagency committee has the responsibility of standardizing place names in the United States, resolving in an average year over 1,200 questions of nomenclature involving decisions both on new names and differences in previously established usages. As executive secretary, Orth will manage and coordinate the activities of the body.

In addition to his USGS career, Orth is a part-time professorial lecturer in cartography, geomorphology, air-photo interpretation, and climatology at George Washington University. In his former position, he had been working with the national topographic-mapping program and had done field investigations on geographic names in the western United States, including Alaskan Indian and Eskimo nomenclature. He is the author of over a dozen books and reports, including a comprehensive 1,100-page *Dictionary of Alaska Place Names*.

L. R. Wilson Receives International Medal in India



Dr. L. R. Wilson, wearing his new Professor Gunnar Erdtman International Medal for Palynology, flanked by Dr. S. Chanda, scientist-in-charge of the Palynological Section, Bose Institute (left), and Dr. P. K. K. Nair, general-secretary of the Palynological Society of India (right).

L. R. Wilson, George Lynn Cross Research Professor in the School of Geology and Geophysics at The University of Oklahoma and geologist with the Oklahoma Geological Survey, was honored by the Palynological Society of India by being named recipient of the sixth Professor Gunnar Erdtman International Medal for Palynology. The medal was bestowed on Dr. Wilson November 26 at Bose Institute in Calcutta, following his address on "Palynomorph Floras and the Drifting Continents" to a specially convened seminar. The occasion also marked his election to the College of Fellows of the Palynological Society of India, which has its headquarters at the National Botanic Gardens in Lucknow.

The medal, given in recognition of Dr. Wilson's "academic eminence and distinctions, and by virtue of his significant contributions towards international understanding and goodwill in Palynological Science," was established in 1968 by the Indian society to further research in this specialized field. It was named to honor the late Gunnar Elias Erdtman, founder of the renowned Palynological Laboratory at Solna, Sweden. (Dr. Wilson wrote the memorial to Dr. Erdtman, which appeared in the July 1973 issue of *Micropaleontology,* published by the American Museum of Natural History.)

Previous recipients of the medal include scientists from the U.S.S.R., the United States, Norway, and the United Kingdom.

INFLATION BOOSTS PRICE OF *Notes*

Because of ever-rising printing costs, we have been forced, reluctantly, to raise the price of *Oklahoma Geology Notes*. So, beginning with this issue, the price of single copies has been increased from 50 cents to 75 cents and annual subscriptions (six issues) from $2.00 to $3.00.

Perhaps this is an appropriate time to invite you, our readers, to let us know how you like the *Notes*, what areas need improvement, in what ways we can serve you better. We need your contributions, too, since we rely on unsolicited material for most of our articles. We recognize the need for a better balance in covering all aspects of Oklahoma geology. For instance, with all the practicing petroleum geologists in Oklahoma, we have wondered why we have had such a dearth of petroleum-related articles; we would welcome such contributions. We have prepared a brief set of guidelines for contributors, which we'll be happy to supply on request.

Remember, now, let us hear from you.

—*The Editors*

An anonymous donor was inspired to present this sketch after reading the symposium topic "Geological Applications of Remote Sensing," scheduled for the GSA South-Central Section Meeting. Perhaps geologists will likewise be inspired to attend the sessions at Stillwater in hopes of putting new knowledge to immediate use.

OSU Site Selected by GSA South-Central Section

The eighth annual meeting of the South-Central Section of The Geological Society of America will be held on the Oklahoma State University campus at Stillwater, March 7-8. Conference facilities will be provided by the OSU Student Union, and lodging for participants will be available in the Student Union Hotel.

The Section's annual banquet will be Thursday night (March 7), when Frank B. Conselman of Texas Tech University, president of the American Institute of Professional Geologists, will be the speaker. An impressive list of symposia has also been prepared: "Applied Geology, 1984"; "Geological Applications of Remote Sensing"; "Pennsylvanian and Permian Corals"; "Stratiform Copper Deposits of the Midcontinent Region"; "Sedimentological Interpretation of Sandstones and Limestones"; and "Palynology." Technical sessions will also be held on geochemistry; sedimentology; hydrogeology and environmental geology; stratigraphy, paleontology, and paleoecology; and geomorphology.

Three field trips will be offered in conjunction with symposia. The first, which concerns environmental geology of the Tulsa area, is scheduled for Wednesday, March 6, and serves as an introduction to the applied-geology symposium. Another group will leave Friday afternoon for a 2-day trip to northeastern Oklahoma to study the regional distribution and the nature of Upper Pennsylvanian (Missourian) coral- and algae-bearing beds in that area. This trip is sequential to the symposium on Pennsylvanian and Permian corals. The final trip focuses on depositional environments of Pennsylvanian carbonates and sandstones in Oklahoma and is scheduled for the weekend (March 9-10) after the meeting. Planned to demonstrate criteria for recognition of representative environments for these two rock types, the trip is a natural follow-up for participants in the symposium on sedimentological interpretation of sandstones and limestones. It leaves from the OSU Student Union and ends at Eufaula Dam, south of Muskogee.

Faculty members from the OSU Department of Geology have played a prominent part in planning the GSA South-Central Section Meeting; John E. Stone serves as meeting chairman, Gary Stewart is chairman of the program committee, John Shelton is field-trip-committee chairman, and Alex R. Ross is in charge of the local-arrangements committee. In addition, Zuhair Al-Shaieb is co-chairman for two technical sessions, and Douglas C. Kent is chairman of another.

Geologists from the Oklahoma Geological Survey and The University of Oklahoma also play an active part in the meeting. Charles J. Mankin, Harvey Blatt, Kenneth S. Johnson, and Patrick K. Sutherland each serve as chairman for one or more sessions; T. L. Rowland is a field-trip leader, and L. R. Wilson and S. A. Friedman plan to present papers.

For additional information or advance-registration forms, please contact the Department of Geology, Oklahoma State University, Stillwater, Oklahoma 74074.

Earthquake and Geomagnetic Programs Move to USGS

The final move of seismological, geomagnetic, and earthquake research programs from the National Oceanic and Atmospheric Administration (NOAA), Department of Commerce, to the U.S. Geological Survey, Department of the Interior, was announced in late October. The move involves about 175 scientists, engineers, and technicians, as well as property and equipment at NOAA labs, offices, and observatories.

Dr. V. E. McKelvey, director of the U.S. Geological Survey, said that the consolidation is aimed at developing a strong national program of earthquake-hazards reduction and at intensifying efforts to achieve the ability to predict and control earthquakes.

Administratively, the change will involve the Earthquake Mechanism Laboratory and the Seismological Field Survey in San Francisco; the Special Projects Party in Las Vegas; the Seismological Research Group, the Seismological Investigations Group, and the Geomagnetic Investigation Group, all of Boulder; the Albuquerque Seismological Laboratory; the Fredericksburg Geomagnetic Center; and the Observatories Group (which operates geophysical observatories in nine states and in Guam and Puerto Rico. They will all be restructured within the USGS Geologic Division. Geomagnetic programs will be assigned to the Office of Geochemistry and Geophysics, while the seismology programs will become part of the Office of Earthquake Research and Crustal Studies, soon to be reorganized in order to accommodate the expanded earthquake program.

Patrick Sutherland Co-Author of New Mexico Publication

Patrick K. Sutherland, professor in The University of Oklahoma School of Geology and Geophysics, curator of invertebrate paleontology for the Stovall Museum, and part-time geologist with the Oklahoma Geological Survey, is co-author with Francis H. Harlow of an outstanding paleontological paper recently released as Memoir 27 by the New Mexico Bureau of Mines and Mineral Resources.

The 173-page publication, entitled *Pennsylvanian Brachiopods and Biostratigraphy in Southern Sangre de Cristo Mountains, New Mexico,* contains 18 fossil plates of excellent clarity as well as numerous measured sections, a correlation chart, a range chart, photographs, and other figures. A microfiche of statistical tables and specimen measurements is included.

The memoir can be purchased for $10.00 from the bureau at Socorro (87801).

GSA ANNUAL MEETINGS, DALLAS, TEXAS NOVEMBER 12-14, 1973

The following abstracts are reprinted from the Annual Meetings Program of The Geological Society of America and Associated Societies, v. 5, no. 7. Page numbers are given in brackets below each abstract. Permission of the authors and of Mrs. Jo Fogelberg, managing editor of GSA, to reproduce these abstracts is gratefully acknowledged.

Depositional Systems in the Canyon Group (Pennsylvanian) of North-Central Texas

ALBERT W. ERXLEBEN, The University of Texas at Austin, Austin, Texas

The Canyon Group (Missourian Series) comprises a sequence of westward-dipping carbonates, and terrigenous clastic rocks that are component facies of high-constructive delta systems. Surface and subsurface studies in 13 North Texas counties indicate that the "Perrin Delta System" repeatedly prograded westward from sources in the Ouachita Folded Belt; at times it was flanked by algal-crinoid banks. A typical vertical sequence within the outcropping deltaic complex includes, in ascending order: (a) organic-rich prodelta mudstones; (b) thin, distal delta-front sandstones and mudstones displaying graded beds, sole marks, and flow rolls; (c) thicker proximal delta-front sandstones exhibiting contorted beds, flow rolls, and penecontemporaneous faults; (d) highly contorted distributary-mouth bar sandstones; and (e) distributary channel sandstones typified by trough cross-stratification and clay-chip conglomerates. Following delta abandonment and during delta destruction, shallow bay-lagoon environments developed. Destructional facies include bioturbated sandy mudstones and argillaceous platy carbonates containing abundant invertebrate fossils. Fossiliferous mudstones grade upward into transgressive shelf carbonates composed principally of phylloid algal biomicrudites and biosparites.

The "Henrietta Fan Delta System," occurring exclusively in the subsurface, comprises thick wedges of arkosic sandstones and conglomerates deposited by high-gradient fluvial systems that built southwestward into Texas from source areas in the Wichita—Arbuckle Mountains of southern Oklahoma. [613-614]

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

Selection of a Coal Gasification Plant Site in Oklahoma

S. A. FRIEDMAN, Oklahoma Geological Survey, Norman, Oklahoma

Feasibility studies by the energy industry have demonstrated that it is economically workable to construct a solvent-refined coal gasification plant producing 500 million cubic feet per day of high-Btu (±975) pipeline gas (CH_4) in Oklahoma, using Oklahoma coal.

Plant requirements are (1) 200 million short tons of recoverable reserves of high-volatile bituminous coal for a 20-year amortization; (2) raw coal whose typical analysis is 5.5% hydrogen, 72.3% carbon, 1.4% nitrogen, 8.6% oxygen, 3.2% sulfur, and 9% ash; and (3) minimum fresh water availability of 25,000 gallons a minute.

Geological and economic evaluation indicates that sufficient coal could be supplied from 20 mines if each averaged ½ million short tons of coal production annually. Half of this production would be from underground mines and half from surface mines with a maximum stripping ratio in feet of overburden to coal of 60:1. Suitable resources for gasification are in the Lower and Upper Hartshorne, McAlester, Rowe, Secor, Mineral, Croweburg, Iron Post, and Dawson coals (of Middle Pennsylvanian age). Only surface-water reservoirs would be adequate for a suitable water supply. Estimated, maximum economically feasible transportation distances of coal to plant by rail or truck are 125 miles from surface mines and 50 miles from underground mines.

Meeting best these physical, chemical, geologic, and economic requirements would be a gasification-plant site near Eufaula Reservoir in north-central Pittsburg County, Oklahoma, and alternate sites in McIntosh and Wagoner counties. [627]

Ratios of Zircon Crystals within Feldspars as an Indication of Rock Origin and History

RAE L. HARRIS, JR., WILLIAM R. LEES, Department of Geoscience, and DAVID A. HOWE, Department of Physics, Texas Tech University, Lubbock, Texas

Zircon crystals are not chemically broken down and reformed during metamorphism, and thus give evidence of the original concentrations and specific crystal locations. Suites of zircons separated from Precambrian granites collected in New Mexico, Colorado, Oklahoma, and Texas show variations between crystals recovered from phenocrysts and those found in porphyroblasts. Zircons from coarse-grained igneous granites are primarily within groundmass as compared to phenocrysts by average ratios of 14 to 1. In contrast, comparable ratios between groundmass and porphyroblasts in granitic gneisses are 4 to 1. Conclusions drawn from this study are: Zircons form early in igneous granites. Relic crystals are both enveloped and shoved aside by the growing porphyroblasts. Even-grained igneous granites in their late cooling stage often develop porphyroblastic feldspars and therefore have metamorphic textures. Ionic diffusion is significant during porphyroblast formation, and much of the biotite "wrapped around" feldspar augen has been formed by recrystallization rather than having been pushed aside. The specific location of zircon crystals within the mineral framework of a rock is a valuable aid to the identification of granitized rock vs. single stage igneous origin. [652-653]

North American Paleozoic Foldbelts and Deformational Histories: A Plate Tectonics Anomaly?

ROBERT D. HATCHER, JR., Department of Chemistry and Geology, Clemson University, Clemson, South Carolina

Foldbelts having significant Paleozoic deformational histories producing craton-directed structures flank North America on all sides. The Appalachians were deformed in the Late Precambrian, Ordovician-Silurian, Late Devonian, and Mississippian-Permian. The Ouachitas were deformed from the Ordovician until the Late Pennsylvanian. Paleozoic deformation occurred in the Cordillera in the Late Precambrian, Devonian-Mississippian, and Permo-Triassic. Deformation in the Innuitian foldbelt occurred from the Middle Devonian to Early Mississippian while the East Greenland foldbelt was deformed during the Silurian-Devonian and the Late Devonian. Plate tectonic models have been proposed for all of the foldbelts. Each devised a system of lithospheric plates that simultaneously converged on North America during the Middle to Late Paleozoic. Three options, based upon foldbelt tectonics, are outlined to rationalize this anomaly: (1) North American continental crust-lithosphere existed as a separate plate during this time. (2) North America was a passenger on a larger eastward moving plate compressed from the west by a more rapidly moving segment of oceanic crust-lithosphere. (3) The North American continent was assembled during the Paleozoic from smaller continental blocks which were part of other plates. Each solution encounters significant difficulties. Paleoclimatic information leads to an additional solution, that North America underwent counterclockwise rotation and northeastward translation during much of the Paleozoic. Early to Middle Paleozoic rotation could account for the early deformation in the Innuitian, Appalachian-East Greenland and Ouachita foldbelts. Late Paleozoic Cordilleran deformation may have resulted from reversal of the trailing edge as the Proto-Atlantic was closed by collision. [656]

Inventory of Strip-Mined Lands in Oklahoma Coal Field

KENNETH S. JOHNSON, Oklahoma Geological Survey, Norman, Oklahoma

A total of 34,193 acres of land in 16 counties of eastern Oklahoma were strip mined for coal through June 1972: 2,928 acres have been reclaimed in accordance with the State's Mining Lands Reclamation Act, 4,931 acres have been partly reclaimed, and 26,334 acres are unreclaimed. The inventory was conducted mainly by using detailed topographic maps and by stereoscopic examination of aerial photographs made in the spring of 1972. Supplemental study of critical sites was done by aerial reconnaissance and oblique photography.

About 200 man-hours were needed to conduct the inventory and transfer

data to a base map at a scale suitable for publication. The inventory, one of the first complete state-wide inventories in this part of the country, is the necessary first step in implementing a program designed to restore orphan mined lands. [683-684]

Consolidation Structures in Turbidites

ROBERT D. LOPICCOLO, Department of Geology, Louisiana State University, Baton Rouge, Louisiana, and DONALD R. LOWE, Department of Geology, Louisiana State University, Baton Rouge, Louisiana

Based on research done largely with sandstones of the Jackfork Group of the Ouachita Mountains, hypotheses have been formulated relating the formation of three common post-depositional structures in turbidites to processes associated with sediment consolidation.

Consolidation of a bed requires that some interstitial fluid be expelled. Processes of liquefaction and elutriation, associated with water expulsion, can result in the formation of convolute bedding, dish structure, and pillar structure.

Liquefaction occurs when a significant portion of the overburden pressure is shifted rapidly from the grain framework to the interstitial fluid. This shift of stress can result from overburden pressures or by cyclic loading, such as might be caused by earthquakes. Convolute bedding almost always involves climbing ripples and results when a liquefied bed is subjected to a differential stress. This differential stress may be caused by a number of factors, such as: gravity acting on the mass of the bed; shear stress from a current flowing over the bed; or, if liquefaction occurs before the bed is completely deposited, the stress may arise from uneven loading due to a non-uniform deposition of sediment on top of the liquefied lower portion of the bed.

Dish and pillar structures result from localized elutriation of the sediment by water expulsion. Dishes form when the water being expelled from within the bed is forced to move laterally by pre-existing structures. Clay is winnowed from the sediment by the moving water and is deposited at the upper boundary of the zone of water movement. Pillars form when the fluid pressure is great enough to force the fluid vertically through the sediment in columns or sheets. Pillars are frequently formed in association with dishes but can also form independently. [717]

Quartz Grain Surface Textures from Various Source Rocks

PETER A. SCHOLLE, Geosciences, University of Texas at Dallas, Dallas, Texas, and DAVID E. HOYT, Geosciences, University of Texas at Dallas, Dallas, Texas

Although studies on quartz grain surface textures have been conducted for more than 10 years virtually no data exists on the "original" textures of quartz grains being released from primary (non-sedimentary) sources. It is difficult therefore to accurately interpret the work of those who claim that the surface textures are produced very rapidly in depositional environments. It would be at least conceptually possible that the different environmental criteria proposed by various workers relate more to differing sources than to depositional regimes.

Quartz grains from untransported decompositional grus derived from granitic to granodioritic plutons, pegmatites, high-grade metamorphics, and rhyolitic volcanics have been analyzed in this study. The samples come from areas of Oklahoma, Texas, California and Nevada and reflect a wide range of source lithologies and a moderate range of climates. The most common features which characterize these grains are crystal faces and fracture surfaces with V-shaped indentations, semiparallel steps, arc-shaped steps, graded arcs, parallel striations, and bifurcating ridges and grooves. Many other features are found in lesser abundance. Most of these textures have been described previously as being characteristic of various depositional environments, especially glacial and fluvial. Clearly this conclusion is premature. Because each source-rock type is characterized by a distinctive suite of surface textures it may in fact be possible to explain the distribution of quartz surface textures in Recent sediments partially in terms of source-rock distribution, or even to recognize source lithologies from surface textures where only slight abrasion has occurred. [797-798]

The Wichita Complex, Oklahoma

NANCY SCOFIELD, Department of Geology and Geological Engineering, Michigan Technological University, Houghton, Michigan, and GEORGE T. STONE, School of Geology and Geophysics, The University of Oklahoma, Norman, Oklahoma

The core of the Wichita Mountains of Oklahoma is a layered igneous intrusion, exposed over 175 square km. Rhythmic layering is present on several scales, and igneous lamination of plagioclase is prominent.

The rocks are plagioclase cumulates, predominantly anorthosite with some olivine-bearing anorthosite, gabbro, and olivine gabbro. The average composition, in weight percent, of the rocks studied is: 47.0 SiO_2, 31.3 Al_2O_3, 1.7 Fe_2O_3 (total iron), 14.4 CaO, 1.7 MgO, and 2.6 Na_2O. Some chemical trends indicate reverse cryptic layering. The anomalous position of highly calcic plagioclase near the top of the intrusion, as shown by field relationships, coupled with reverse cryptic layering suggests a separation of anorthosites by flotation of plagioclase.

If the layered anorthosites are cumulates separated from parental basaltic magma, it is possible to estimate limits for a probable hidden mafic series. Geologic constraints and assumptions indicate the exposed 150 m of anorthositic rocks represent 3 to 20 percent of the total intrusion. Residual chemical compositions and cationic norms were calculated by using the Stillwater magma as a suitable parent magma. Because gravitational separation would probably have operated on the crystallizing mafic phases, a wide range of layered peridotitic and gabbroic assemblages are likely to be present in the proposed hidden series. [800]

Lower Middle Ordovician Biostratigraphy in the North American Midcontinent: Relations between Sequences in Oklahoma, the Cincinnati Region, and the Western Appalachians

W. C. SWEET, S. M. BERGSTRÖM, and JOHN B. CARNES, Department of Geology and Mineralogy, The Ohio State University, Columbus, Ohio

Selected sections through the relatively thick successions of dominantly calcareous Middle Ordovician rocks in the Arbuckle Mountains, Oklahoma, the Cincinnati Region of Kentucky, Indiana, and Ohio, and in the westernmost three thrust belts in the Appalachians of Tennessee and Virginia, have been sampled in detail for conodont studies. Very large collections of these fossils have provided important new data on the relations between these well-known and widely discussed sequences of Ordovician rocks.

The lowermost part of the Oklahoma Middle Ordovician succession (Joins, Oil Creek, McLish) lacks equivalents in the other areas studied but strata coeval with the Tulip Creek may possibly be present in the Kentucky subsurface and in the western Appalachians.

The lower half of the lower Bromide of Oklahoma can be tied closely to the lower part of the western Appalachian succession (*Phragmodus* n. sp. "Zone", upper part). The upper part of the lower Bromide has yielded *Prioniodus gerdae* Subzone conodonts as well as *Phragmodus inflexus,* which indicates correlation with the Lincolnshire of eastern Tennessee and the lower part of the Cincinnati Region succession (Camp Nelson, Tyrone).

The new data now available provide the framework for a close correlation between these key sequences and contribute to a better regional understanding of Middle Ordovician rocks and of the Early Middle Ordovician transgression in the Midcontinent region. [833]

California Institute of Technology

Burial Environment, Diagenesis, Mineralogy, and Mg & Sr Contents of Skeletal Carbonates in the Buckhorn Asphalt of Middle Pennsylvanian Age, Arbuckle Mountains, Oklahoma

RICHARD LANE SQUIRES, California Institute of Technology, Ph.D. dissertation, 1973

The Buckhorn asphalt quarry in the northern part of the Arbuckle Mountains, Oklahoma, contains chemically well preserved marine invertebrate fossils of Middle Pennsylvanian age. The main purpose of this investigation was to study the chemistry of these fossils, and at the same time analyze the geologic setting of the deposits containing the fossils.

Due to early sealing by oil, many of the shells still have the original aragonite and nacreous luster. The oil prevented the grainstones from becoming well cemented and allowed them to become compacted during the Arbuckle orogeny. Deformation related to this orogeny probably caused the devolatization of the oil and, hence, conversion into asphalt.

Most of the fossils occur as fragments in several skeletal debris grainstones which are shallow, turbulent water inferred channel deposits. The ancient shoreline was only 6 miles to the northeast. Underlying calcareous sponge spicule-echinoderm-brachiopod-fusulinid mudstones and wackestones were deposited in less turbulent water environments.

Mineralogical data were obtained by means of x-ray diffraction, infrared spectroscopy, and chemical staining. Quantitative analyses of the elemental constituents for various shell layers were obtained with an electron microprobe.

The original mineralogy of skeletal carbonates was established for the first time in the following. Aragonite occurs in the inner layers of the gastropods *Naticopsis wortheni* and *Trachydomia whitei,* whereas their outer layers consist of calcite. Aragonite also occurs in the shell walls of the scaphopod *Plagioglypta?* sp., the coiled nautiloids *Metacoceras cornutum* and *Domatoceras* sp., and the ammonoids *Pseudoparalegoceras* sp. and *Wellerites mohri?*. The orthocone nautiloid *"Orthoceras" unicamera* has aragonitic shell walls, septa, and cameral deposits. Skeletons of the foraminifera *Globivalulina* sp. and *Wedekinellina?* sp., the presumed tabulate *Chaetetes* cf. *favosus,* the cryptostome bryozoans *Penniretepora?* sp. and *Streblotrypa?* sp., the brachiopod *Anthracospirifer opimus,* four ostracodes, and the spines of the echinoid *Archaeocidaris megastyla?* consist of calcite.

As reported by others, calcitic outer layers and inner aragonitic layers were also found in *Bellerophon (Bellerophon)* sp., *Straparollus (Euomphalus)* sp., and *Chaenocardia ovata.* The shell walls and cameral deposits of *Pseudorthoceras knoxense* also are aragonitic.

Previously unreported moderately high Mg contents occur in the calcite of *Chaetetes* cf. *favosus.* The spines of *Archaeocidaris megastyla?* are inferred to have been originally Mg-calcite.

Diagenetic effects were detected in the skeletal carbonates. The amount of replacement calcite and degree of obliteration of shell microarchitecture in the skeletal aragonites increase with decreasing asphalt content. Asphalt-impregnated skeletal calcites contain more Mg and usually less Sr than corresponding nonasphalt-impregnated specimens.

Data obtained on the Mg and Sr concentrations of the best preserved specimens indicate the following. The Sr/Ca ratio for the coiled nautiloid *Metacoceras cornutum* is similar to that for the modern-day *Nautilus* sp. The Mg contents in the calcites of the foraminifera, bivalve, and ostracodes are similar to those in related Recent forms. The shell walls of the extinct orthocone nautiloids have lower Sr contents relative to the cameral deposits. These large differences are apparently due to the "vital effect" of the organism.

(Reprinted from *Dissertation Abstracts International,* Pt. B, v. 34, p. 2100-B)

Texas Tech University

Depositional History of Cisco-Wolfcamp Strata, Bend Arch, North-Central Texas

EARL PRESTON HARRISON, Texas Tech University, Ph.D. dissertation, 1973

Cisco-Wolfcamp strata of the Eastern Shelf interval accumulated in the following spectrum of depositional environments: (1) coastal plain consisting of clastic meandering river and floodplain deposits, (2) transitional deposits consisting of carbonate and clastic supratidal, intertidal and deltaic deposits, (3) subtidal, open marine deposits consisting of carbonates and clastics which accumulated under high, low, and moderate conditions of wave and current agitation. A broad coastal plain of low relief separated the uplifted Ouachita system to the east and a shallow sea in the subsiding Permian Basin to the west.

Paleozoic sedimentary strata of the Ouachita system to the east served as the source area for clastic sediments deposited on the Eastern Shelf of the Permian Basin. Shale is the dominant lithology represented in the study area, and certain red-brown to maroon, nonfossiliferous claystone intervals are interpreted as paleosoils.

Intercalated with shales are lenticular and sheet-like sandstones. Lenticular sandstones represent river channels, tidal channels or deltaic distributary channels. Sheet-like sandstones represent tidal flat deposits, or delta front sheet sands resulting from the destructional phase of delta building.

Carbonates comprise a small portion of the rock column. Most limestones are thin, extensive, represent maximum submergence of the shelf, and were deposited as shallow normal marine, open shelf deposits. Dominant fossil materials in carbonates are phylloid algae, fusulinids, bryozoans, brachiopods, pelecypods and crinoids.

Coal beds and carbonaceous shales are common in Upper Cisco strata and decrease in number and aerial extent in the Lower Wolfcamp interval. Some Cisco coal beds and carbonaceous shales can be correlated over an area of several counties and represent accumulation in widespread paralic swamps. The Pennsylvanian-Permian boundary is placed at the top of the uppermost extensive coal bed; approximately 25-30 feet below the Saddle Creek Limestone.

Alternating emergence and submergence of the Eastern Shelf area, caused by eustatic changes in sea level in Late Pennsylvanian-Early Permian Time, were superimposed upon continuous subsidence and produced well-developed depositional cycles. Periods of emergence are evidenced by subaerial channel deposits, coal beds, and widespread paleosoils; intervals of submergence are recorded by accumulation of widespread, open marine limestones. Depositional cycles are markedly asymmetrical with regressive phases being much thicker than transgressive phases, and it is inferred that transgressions occurred much more rapidly than regressions. The coastline is inferred to have been tide-dominated and prevailing winds are inferred to have blown offshore.

Red-brown paleosoils are interpreted as latosols which were formed from diverse parent materials under warm, subhumid to humid climates during periods of emergence.

Evidence has been presented to suggest that the mechanism for cyclic deposition of sediments was glacio-eustatic changes in sea level and not tectonics or sediment economics.

(Reprinted from *Dissertation Abstracts International*,
Pt. B, v. 34, p. 1588-1589-B)

The Structure of the Interlayer Water in Montmorillonite

GARRETT LOUIS MORRISON, The University of Oklahoma, Ph.D. dissertation, 1973

A purified sample of essentially monomineralic montmorillonite (A.P.I. #23) was size fractioned to obtain the 1/8 - 1/16 micron size material. This was split into six portions each of which was exchanged for one of the six cations Li, Na, K, Mg, Ca, and Ba.

The six samples were chemically analyzed and investigated by x-ray diffraction and gravimetric methods at controlled temperature and partial pressure of water.

A change in the b-axis dimension is found and correlated with c-axis dimension and with water content.

A structure of initially adsorbed water is suggested in which the oxygen of the adsorbed water is bonded to both the interlayer cation and the silicon of the clay structure.

It is suggested that this structure is responsible for rapid proton exchange and explains the high hydrogen ion activity in the interlayer space and the hydrogenation of some materials adsorbed by the clay. The decrease in entropy of adsorbed water is also explained as due to the strong bond between the adsorbed water and the silicon of the clay structure.

An explanation in terms of the number of coordinated water molecules in the suggested structure, is given for the relative maximum expandability of montmorillonite as a function of the type of interlayer cation.

Subsurface Stratigraphic Analysis of Morrow Sandstones, Portions of Harper and Woods Counties, Oklahoma, and Clark and Comanche Counties, Kansas

GREGORY W. MANNHARD, The University of Oklahoma, M.S. thesis, 1972

Regional and detailed paleogeologic and structural studies serve as a basis for determining the stratigraphic relations of some Lower Pennsylvanian oil and gas bearing sandstones in northwestern Oklahoma and adjacent Kansas. Establishment of the Mississippian-Pennsylvanian unconformity was accomplished by making detailed electrical log correlations, supplemented by microscopic studies of numerous sets of rotary cuttings. The identity of the Inola Limestone, and other Desmoinesian marker beds, was determined by correlating named Desmoinesian units of a type stratigraphic profile into the thesis area. Confirmation of the Thirteen Finger lime was obtained by extending correlations to the south and west into the main area of the Anadarko Basin. Six stratigraphic cross sections serve as a basis for relating the distribution and configuration of the lowermost Pennsylvanian sandstones to pre-Pennsylvanian topography. Most of the sandstones lie within the interval between the base of the Thirteen Finger lime and the Mississippian-Pennsylvanian unconformity and are of Morrowan age.

A map of the pre-Pennsylvanian topography reveals that a modified trellis drainage system was developed on subaerially exposed Mississippian

strata. Southwesterly tilted resistant limestones of the Chesterian Series stood out as subparallel cuestas; intervening valleys were eroded into interbedded nonresistant shales.

Morrowan strata were deposited under conditions of cyclic transgression to the northeast which was interrupted by several minor regressions. Sands were deposited during the regressive phases, interbedded shales during transgressive phases.

Small scale structural noses and closures on a structure map of the Inola Limestone are largely the result of differential compaction of shales deposited over buried pre-Pennsylvanian topography.

Detailed mapping affords a logical explanation for each dry hole and producing well in the Second Morrow sand of the Harper Ranch field of Clark County, Kansas. The anomalous distribution of some gas accumulation is explained by the use of Gussow's principle, modified to apply to a stratigraphic trap situation.

Trapping Mechanism for Production of Oil from Meramec (Mississippian) Rocks on the Sooner Trend of North Central Oklahoma

SHERROD A. HARRIS, The University of Oklahoma, M.S. thesis, 1971

The Meramec is defined for this thesis as all of the Mississippian section from the top of the Kinderhook to the base of the Chester in north-central Oklahoma.

The Sooner Trend (Meramec) Field is a large Mississippian stratigraphic trap. While the productive area is well known, the trapping mechanism of this field has never been adequately explained in the literature. As shown by a paleosubcrop map, the updip limit of the field is associated with the updip limit of the overlying Chester, which is removed further updip by the pre-Pennsylvanian unconformity. The Chester apparently provides an overlying seal to vertical fracture permeability within the unit. However, there is no updip truncation of the Meramec, no known form of permeability barrier within the unit, and no other mechanism previously presented which explains termination of the reservoir at the updip limit of the Chester. Such a termination must exist, as large amounts of water are known in the Meramec short distances updip to the production.

This thesis demonstrates that the reserves in this trap are located in a combination of fracture porosity and trends of matrix porosity. The fracture system porosity is widespread, and the trend porosity more or less localized. This combination of porosity types leads to a distinctive form of well behavior which can be related to permeability being mainly controlled by the fractures. By further evidence, permeability in the fractures can be shown to be limited as a lateral system in the formation, while very effective through the unit in a vertical direction. This situation accounts for the trap. The discontinuous nature of lateral permeability terminates the reservoir in updip areas. Where the Chester top seal is removed by erosion in the updip areas, oil and gas have escaped through the more effective vertical permeability system. Beneath the Chester seal, oil and gas are unable to migrate updip because of the discontinuous nature of permeability laterally in the fractures, and are retained in the downdip area.

Rogues' gallery for GSA Field Trip No. 6, "Igneous Geology of the Wichita Mountains and Economic Geology of Permian Rocks in Southwest Oklahoma." Trip was held in conjunction with annual meetings of The Geological Society of America in Dallas, November 12-14, 1973. Backdrop is highwall containing copper shales in Eagle-Picher Industries mine near Altus.

Standing, from left: Felix Mendelsohn, Doug Brockie, Fred McDowell, Bill Rose, David Mossman, Richard Brown, James Grubb, Charles Hutchins, H. Stanley Hanson, George Moore, Ken Johnson, Nancy Scofield, Walter Koop, Claren Kidd, Richard Bowen, A. C. Freeze, Paulo Bahia-Guimares, Dan Barker, Leon Long, and John Lufkin.

Kneeling, from left: Paulo Ferreira, Leslie Coleman, Bruce Parker, Bob Martin, Joe Fischer, Raymond Grant, Phillip Matter, Herb Hudgens, Jacques Renault, Paul Buehrle, and Bob Levich.

Not present: Tim Denison and M. Charles Gilbert.

New Theses Added to OU Geology Library

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

An Evaluation of the Biofacies of the Francis Formation (Upper Pennsylvanian) in the Vicinity of Ada, Oklahoma, Using Cluster Analysis, by Mary Glenn Lockwood.

Hydrocarbon Accumulation in "Meramec-Osage" (Mississippian) Rocks, Sooner Trend, by Sherod A. Harris.

Subsurface Stratigraphic Analysis, "Cherokee" Group (Pennsylvanian), Northeast Cleveland County, Oklahoma, by Michael Anthony Albano.

Subsurface Stratigraphic Analysis of Morrow Sandstones, Portions of Harper and Woods Counties, Oklahoma, and Clark and Comanche Counties, Kansas, by Gregory W. Mannhard.

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

Biostratigraphy and Reptile Faunas of the Upper Austin and Taylor Groups (Upper Cretaceous) of Texas, with Special Reference to Hunt, Fannin, Lamar and Delta Counties, Texas, by Betty Joan Echols.

Experimental Weathering of Chlorite Using Soxhlet-Extraction Apparatus, by Ben D. Hare.

Geochemistry and Petrology of Some Oklahoma Redbed Copper Occurrences, by Richard Patrick Lockwood.

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