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Cover Picture

Minor Fold in the Blaylock Sandstone (Silurian) Ouachita Mountains, Oklahoma

The Blaylock Sandstone of Silurian age crops out around the margin of the core area of the Ouachita Mountains in southeastern Oklahoma. Much of the Blaylock consists of rhythmically bedded graded sandstones and shales that contain many features characteristic of turbidite sequences. The Blaylock and enclosing formations are tightly folded into folds of several orders.

The cover photograph was taken along the east side of U.S. Highway 259 near the center of sec. 3, T. 4 S., R. 24 E., McCurtain County, and shows a portion of a tight minor fold in the overturned limb of a larger scale Blaylock fold. Most of the folds around the core area, both large- and small-scale, have sharp hinge zones and long, straight limbs and are overturned toward the south. One of the major problems in determining the structure of the Ouachita Mountains is the question of how the folds were overturned toward the south, when the inferred direction of tectonic transport during the principal Ouachita deformation was toward the north.

—Roger E. Feenstra

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 Oldest Well-Preserved Bryozoan Fauna in the World?

George T. Farmer, Jr.[1]

INTRODUCTION

In the fall of 1964, Dr. Richard S. Boardman of the Smithsonian Institution and the writer completed a massive collection of fossil bryozoans from the Simpson Group (Middle Ordovician) in the Arbuckle Mountains of Oklahoma. Approximately 6 tons of fossil Bryozoa and matrix was collected. The bulk of this material is housed in the Smithsonian Institution's paleobiology department.

Approximately 2,000 thin sections and acetate peels were prepared by the writer (with assistance from laboratory specialists at the Smithsonian) and studied following the procedures outlined by Boardman and Utgaard (1964). Individual taxa were determined for the bifoliate cryptostome element of the fauna. Six new genera and 26 new species were determined for the bifoliate cryptostomes. The other bryozoan elements of the fauna have not been studied extensively to date.

The Simpson Group is well-known by petroleum geologists because of petroleum and natural-gas occurrences in sandstone units of the group. Rocks of the Simpson Group have also been used for building stone in construction and as a source of glass sand (silica). The age of the Simpson Group has been determined to be Middle Ordovician on the basis of the brachiopods and ostracodes contained in these rocks (Cooper, 1956).

The Bryozoa of the Simpson Group are abundant and well preserved; prepared specimens can often be identified to species level on the basis of small fragments. These fragments are often found in well cuttings. Therefore, they may be useful subsurface-horizon indicators (Merida and Boardman, 1967).

STRATIGRAPHIC PLACEMENT OF THE SIMPSON GROUP

C. E. Decker (Decker and Merritt, 1931) recognized five formations as constituting the Simpson Group. These are, from base to top: Joins, Oil Creek, McLish, Tulip Creek, and Bromide. Cooper (1956) divided the Bromide into a lower shaly member, the Mountain Lake, and an upper limy member, the Pooleville. The other formations have not been subdivided.

The Simpson Group is underlain by the West Spring Creek Limestone of the Arbuckle Group (Lower Ordovician) and overlain by the Viola Limestone (Upper Ordovician, Trentonian), as shown in figure 1.

Rocks of the Simpson Group are predominantly clastic and consist mainly of organoclastic calcarenites, calcareous shales, and siliciarenites (sandstones). Four of the five formations that compose the group (all but the

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SYSTEM		STAGE	UNIT	
Ordovician	Upper	Trenton	Viola Limestone	
	Middle	Porterfield-Wilderness	Simpson Group	Bromide Formation
		Ashby		Tulip Creek Formation
		Marmor		McLish Formation
		Whiterock		Oil Creek Formation
				Joins Formation (*Hormotoma* bed)
	Lower		West Spring Creek Limestone	

Figure 1. Stratigraphic placement of formations constituting the Simpson Group.

Joins) are characterized by a basal siliciarenite and can be easily recognized in the field by superposition or by faunal content.

The earliest (oldest) bryozoans collected are from the Oil Creek Formation and have been tentatively assigned to the trepostome genus *Eridotrypa*. The oldest bifoliate cryptostome Bryozoa occur near the base of the McLish Formation, and they constitute a major element of the bryozoan fauna in the McLish, Tulip Creek, and Bromide Formations.

BRYOZOA FROM THE SIMPSON GROUP

Many bryozoan workers, including Fritz (1947), Bassler (1911), and Ross (1966), have indicated that the Simpson Group contains the oldest well-preserved bryozoan fauna yet discovered. Their reports deal largely with questionable material (either fossil or stratigraphic); at least one case is based on a single specimen. The bryozoans of the Simpson Group, however, are diverse morphologically and taxonomically, and even though they represent a thanatocoenosis, they can legitimately be described as a fauna. Therefore, they constitute the oldest well-preserved bryozoan fauna in the world that we know of at present.

Bryozoans are exclusively colonial organisms (coelomate protostomes, for the most part), and they build their exoskeletons from calcium carbonate (mainly calcite) physiologically extracted from their environment. While alive, the soft parts are generally surrounded by an exoskeleton in the form of a tube-shaped (or box-shaped) zooecium. After death, the zooecia show up as voids, because the soft parts decompose. During lithification these voids commonly are filled with calcite, and the entire colony becomes a mass of solid mineral material. Thus, they are commonly preserved as fossils and can be major rock-forming constituents, as they are in the rocks of the Simpson Group.

Historically, the Bryozoa are among the most neglected of all fossil groups, especially when one considers their potential usefulness (as illustrated by the rocks of the Simpson Group) and generally excellent preservation in the fossil record.

Naturally, most of the fossil Bryozoa described from the rock record have come from rocks younger than the Simpson Group. As of this writing, only two papers have discussed Bryozoa of the Simpson Group (Loeblich, 1942, Merida and Boardman, 1967). Other papers on the Simpson Group have merely listed the species and genera reported and are, therefore, suspect in their taxonomic assignments. It is well-known that bryozoan taxonomy at the specific and generic levels requires preparation of thin sections or peels, and there is no evidence that previous authors compiling faunal lists have done so.

Present bryozoan taxonomy is also based mainly on faunas younger than the Simpson Group (Bassler, 1911; Bork and Perry, 1967; McKinney, 1972; Ross, 1963, 1964a), and phylogenetic conclusions (Ross, 1964b, for example) have been drawn without the benefit of knowledge concerning the oldest well-preserved bryozoan fauna now known. Thus it is hoped that a better understanding of bryozoan phylogeny will be obtained after complete taxonomic descriptions have been made of Bryozoa from the Simpson Group.

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USGS and USBM Standardize Mineral-Resource Terminology

New definitions for mineral-resource terms have been announced jointly by the U.S. Geological Survey and the U.S. Bureau of Mines. The classification system adopted is based on the extent of geologic knowledge about mineral deposits, including fuels, and the economic feasibility of their recovery. The chart that accompanies this article was supplied by these agencies to help demonstrate relationships between the terms.

The Oklahoma Geological Survey has not yet adopted the new classification system but is evaluating its applicability to Oklahoma terminology. Terms of the new system are defined below. Please note that "measured," "indicated, and "inferred" are applicable for both the reserve and the identified-subeconomic components.

Resource—A concentration of naturally occurring solid, liquid, or gaseous materials in or on the earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.

Identified resources—Specific bodies of mineral-bearing material whose location, quality, and quantity are known from geologic evidence supported by engineering measurements with respect to the demonstrated category.

Undiscovered resources—Unspecified bodies of mineral-bearing material surmised to exist on the basis of broad geologic knowledge and theory.

Reserve—That portion of the identified resource from which a usable mineral and energy commodity can be economically and legally extracted at the time of determination. The term *ore* is also used for reserves of some minerals.

Measured—Material for which estimates of the quality and quantity have been computed, within a margin of error of less than 20 percent, from analyses and measurements from closely spaced and geologically well-known sample sites.

Indicated—Material for which estimates of the quality and quantity have been computed partly from sample analyses and measurements and partly from reasonable geologic projections.

Demonstrated—A collective term for the sum of materials in both measured and indicated resources.

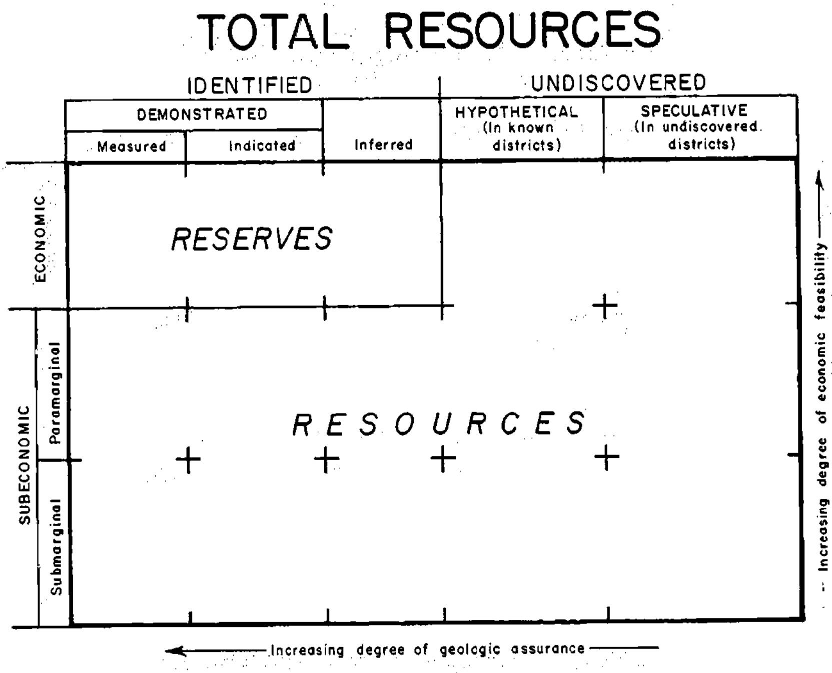
Inferred—Material in unexplored but identified deposits for which estimates of the quality and size are based on geologic evidence and projection.

Identified-Subeconomic resources—Known deposits not now minable economically.

Paramarginal—The portion of subeconomic resources that (a) borders on being economically producible or (b) is not commercially available solely because of legal or political circumstances.

Submarginal—The portion of subeconomic resources which would require a substantially higher price (more than 1.5 times the price at the time of determination) or a major cost-reducing advance in technology.

Hypothetical resources—Undiscovered materials that may reasonably be expected to exist in a known mining district under known geologic conditions. Exploration that



confirms their existence and reveals quantity and quality will permit their reclassification as a reserve or identified-subeconomic resource.

Speculative resources—Undiscovered materials that may occur either in known types of deposits in a favorable geologic setting where no discoveries have been made, or in as yet unknown types of deposits that remain to be recognized. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as reserves or identified-subeconomic resources.

Thomas Falkie Assumes Directorship of Bureau of Mines

Thomas V. Falkie, formerly head of the Department of Mineral Engineering at The Pennsylvania State University, has been appointed director of the U.S. Bureau of Mines. He succeeds Elburt Osborn, who resigned to assume the first Distinguished Professorship at the Carnegie Institution of Washington, D.C.

At Penn State, Dr. Falkie also served as chairman of the interdisciplinary graduate program in mineral-engineering management, and since 1971 he has been a consultant to the United Nations on mining economics and mine management. Prior to his university involvement, Dr. Falkie worked 8 years (from 1961 to 1969) for International Minerals and Chemical Corporation, serving in a variety of managerial, staff, and technical positions.

Dr. Falkie received B.S. (1956), MS. (1958), and Ph.D. (1961) degrees in mining engineering from Penn State, where he pioneered in the application of computers and operations-research techniques to mining and exploration problems. He is chairman-elect of the Mineral Engineering Division of the American Society for Engineering Education, a director of the Society of Mining Engineers (SME), and a director and chairman-elect of SME's Mining and Exploration Division. He served as chairman of the 1972 Engineering Foundation Research Conference on Coal Mine Safety and Survival and has been an arbitrator for the Joint Industry and Health Safety Committee of the Bituminous Coal Operators Association and the United Mine Workers.

Are You Flood-Prone?

Oklahoma has floods. Everyone who has lived in the state knows that, and with rainfall totals over the past year greatly exceeding the average, with freak-thunderstorm totals almost exceeding belief, everyone has become even more aware. The damage that followed a storm in Enid last year dramatizes the results of such disasters.

Everyone may not know, however, that maps are available showing areas susceptible to flooding.

The U.S. Geological Survey, in cooperation with the U.S. Department of Housing and Urban Development (HUD) and the Federal Insurance Administration, publishes a series of maps delineating flood-prone areas; such maps have been released recently for several cities in Oklahoma. The maps are based on 7.5-minute and 15-minute USGS quadrangle maps, i.e., at scales of 1:24,000 and 1:62,500, with flood boundaries estimated from regional stage-frequency relations, information that is obtained from data on past floods. The possible effects of existing or proposed flood-control structures are used where such effects can be evaluated, but in general the areas are determined from natural conditions. It is hoped that the maps will help in minimizing flood losses by identifying areas of potential hazard, information highly important to any agency or individual concerned with land-use planning.

Copies of the maps of flood-prone areas and an index map indicating which quadrangles are completed are available for inspection at the Oklahoma Geological Survey. Maps can be ordered from U.S. Geological Survey, Water Resources Division, Room 4301, 200 Northwest 4th Street, Oklahoma City, Oklahoma 73102. The price is 75 cents each.

Tadpole Nests in Oklahoma

Geologists define tadpole nests as true biogenic sedimentary structures produced by the activities of anuran tadpoles and known only from Holocene occurrences. Tadpole nests are composed of circular to nearly hexagonal interconnecting ridges with central depressions and are formed in soft layers of silt and fine sand in shallow, low-energy fresh-water pools at the sediment-water interface. Possible fossil tadpole nests are recorded throughout the literature, but all have been disputed.

During the past 6 years, I have observed over 30 temporary pools in Oklahoma and the anuran tadpoles inhabiting them. On one occasion, I noted the formation of tadpole nests in a pool basin newly formed by road construction, 25 km east of Norman, Cleveland County, Oklahoma. The entire basin of the temporary pool was covered randomly with circular depressions (see photograph). The depressions, 23-55 mm in diameter and 5-15 mm deep, were made by the feeding activities of tadpoles of the Dwarf American Toad, *Bufo americanus charlesmithi,* and Strecker's Chorus Frog, *Pseudacris streckeri*, and were modified or destroyed by aquatic beetles, snails, fairy shrimp, and other tadpoles.

Observations made in Tillman County, Oklahoma, revealed depressions formed during the egg-laying process of the tadpole shrimp, *Apus longicaudatus,* that appeared to be identical to those formed by anuran tadpoles.

No traces of tadpole nests remained in any of the pool basins after they dried. Bottom sediments go into suspension at the slightest disturbance, and in drying the ridges flatten out, the bottom breaks apart, and mud cracks or depression cracks result.

—*Jeffrey Howard Black*
Oklahoma Baptist University

Tadpole nests in basin of temporary pool east of Norman, Cleveland County, Oklahoma.

OKLAHOMA ENERGY ADVISORY COUNCIL ISSUES FINAL REPORT

The Oklahoma Energy Advisory Council, created by Senate Bill 386 to assist in the formulation of a State energy policy, has issued *Energy in Oklahoma, Final Report of Oklahoma Energy Advisory Council.* Under the leadership of Robert A. Hefner III, chairman, Alex P. Aven, vice-chairman, and William W. Talley II, executive director, the council was charged with the task of granting equal priority to development and conservation of energy resources. (See August 1973 *Oklahoma Geology Notes,* v. 33, p. 152-153, for additional information on composition of the council.) In addition to preparing estimates of Oklahoma's current energy requirements and the extent of energy resources available for future use, the council was expected to review alternate energy sources and to isolate economic factors that could change the energy situation favorably or adversely. They succeeded admirably, and the results are contained in their 2-volume, 335-page report.

Council members were able to look at both sides of a number of controversial issues. Their treatment of the two-headed coin of environmentalism offers an opportunity to demonstrate their unbiased appraisal. "Environmental concerns have . . . slowed energy development, the most obvious example being the four-year delay in the start of construction of the trans-Alaskan oil pipeline. . . . On the other hand, energy production and consumption have had a major impact on the nation's environment. Surface mining has scarred some land, oil spills have polluted some waters, and automobile exhausts have fouled the air in some areas." But "It does not need to become a choice between having clean air and water on one hand and having enough energy for our jobs, homes and cars on the other. However, there is little doubt that clean energy will cost more than dirty energy, and that consumers will have to pay this increased cost."

The council's Committee on Environmental Aspects recommended more stringent reclamation legislation than is now on the books, incorporating a requirement for restoration of topsoil after surface mining. The council's Coal Supply Committee concluded that the State's existing reclamation laws are less stringent than those of major coal-producing states but that they adequately protect the environment while providing incentive for increasing coal production in Oklahoma.

The Coal Supply Committee and the Committee on Environmental Aspects are but 2 of the 17 working committees established by the council. Other council committees were as follows: Energy Demand, Energy and Economic Growth, Requirements to Meet Demands for Electricity, Crude Oil Supply, Supply of Natural Gas, Supply of Natural Gas Liquids and Liquefied Petroleum Gas, Non-Depleting Resources, Economic Influences on Production and Resources, Nuclear Energy Resources, Natural Gas Processing and Oil Refining, Forecast for Synthetic Fuels, Energy Capital Requirements in Oklahoma to 1990, Energy Conservation, Logistics and Storage, and Statutes and Regulations. It is evident from the final report that the committee system was the dominant factor in the council's fair assessment of the energy situation in Oklahoma; it encouraged a variety of viewpoints and prevented domination of council recommendations by a few groups. More than 180 citizens participated in the committee work, and names of the council members, committee chairmen, and committee members are supplied in the report.

The council's policy recommendations and major findings were published as the first volume of *Energy in Oklahoma*. The committee reports were published as the second volume. They contain a wealth of technical information, and anyone who wants to know the basis for the council's decisions should refer to the complete report.

The Oklahoma Energy Advisory Council's basic policy recommendation, that the State establish and fund a Department of Energy that would encourage continuous surveillance of the energy situation, has already been acted upon by the State Legislature. Copies of the final report can be obtained at a cost of $5.00 for volume 1, $3.00 for volume 2, from Mr. Charles H. Hill, Oklahoma Department of Energy, 4400 North Lincoln, Suite 251, Oklahoma City, Oklahoma 73105.

—Rosemary L. Croy

AEC Releases Two New Reports

A new report, *Uranium Exploration Expenditures in 1973 and Plans for 1974-75,* has been issued by the Grand Junction, Colorado, office of the U.S. Atomic Energy Commission. The survey was compiled from data gathered from 89 companies involved in uranium exploration. It forecasts 29.1 million feet of surface exploration and development drilling in 1974 and 33.7 million feet in 1975, compared with 17 million feet in 1973 and 29.9 million feet in 1969, the peak year so far. Increases in exploration and land acquisition will entail necessary increases in expenditures. Single copies of the report can be obtained by writing J. C. Westbrook, Grand Junction Office, U.S. Atomic Energy Commission, P.O. Box 2567, Grand Junction, Colorado 81501.

The above report follows a related marketing survey by the AEC's Washington, D.C. office, which reflects data furnished by 64 utilities, 5 reactor manufacturers, and 20 uranium producers. In addition to information on deliveries and commitments prior to January 1, 1974, it includes data on buyer uranium inventories, unfilled needs for uranium for 1974-80, outstanding invitations to bid on January 1, 1974, and the degree to which first core and reloads for reactors have been procured. Single copies of *Survey of United States Uranium Marketing Activity, April 1974* can be obtained from the above address or from Elmo G. Knutson, Supply Evaluation Branch, Division of Production and Materials Management, U.S. Atomic Energy Commission, Washington, D.C. 20545.

USGS Estimates of Oil and Gas Resources Revised Downward

The U.S. Geological Survey has released revised estimates of crude oil and natural-gas liquids in our country. The estimates include and also extend those of the American Petroleum Institute and the American Gas Association. The new figures, summarized by USGS Director Vincent E. McKelvey for the U.S. Senate Interior and Insular Affairs Committee, are lower than those previously available. Dr. McKelvey explained that the higher figures, particularly for petroleum liquids, were based on studies made in the late 1960's and have been superseded because of data received from recent geophysical investigations.

Newly released estimates of measured reserves of crude oil and natural-gas liquids place United States totals at 48.3 billion barrels, with 40.7 billion barrels estimated as onshore and the remaining 7.6 billion barrels offshore (water depth less than 200 meters for all offshore estimates in the report). Measured reserves of gas are 266.1 trillion cubic feet, of which 218.3 trillion cubic feet is listed as onshore. Total indicated and inferred reserves of crude oil for the United States were estimated in the range of 25-45 billion barrels (onshore range of 22-38.5 billion barrels and offshore range of 3-5 billion barrels); gas estimates in this category were listed as 130-250 trillion cubic feet (onshore range of 97-205 trillion cubic feet and offshore range of 23-45 trillion cubic feet).

Estimates of undiscovered recoverable resources were also made; 200-400 billion barrels of crude oil and natural-gas liquids was posited, with 135-270 billion barrels listed as onshore and 65-130 billion barrels offshore; 1,000-2,000 trillion cubic feet of gas was estimated, 605-1,210 trillion cubic feet onshore and 395-790 trillion cubic feet offshore. McKelvey cautioned that with undiscovered resources, the USGS is definitely appraising the unknown. Not a single hole has been drilled on the Atlantic shelf, but undiscovered recoverable resources were estimated for the area.

A degree of uncertainty is evident even for the estimates in the measured category; recent price increases have not been taken into account, and they are expected to make recovery of petroleum possible from accumulations considered subeconomic a year ago. Another problem is that misinterpretations are bound to occur unless the terms employed in the report are understood (see separate article on p. 102-103). In spite of difficulties in obtaining and conveying reliable figures, however, the estimates supply valuable tools for planning our nation's future.

OKLAHOMA ABSTRACTS

AAPG-SEPM Annual Meetings, San Antonio, Texas April 1-3, 1974

The following abstracts are reprinted from The American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists *Annual Meetings Abstracts*, v. 1, April 1974. Page numbers are given in brackets below each abstract. Permission of the authors and of A. A. Meyerhoff, publications manager, is gratefully acknowledged.

Southern Margin of the Mid-Pennsylvanian Oologah Limestone Banks, Northeastern Oklahoma

ALLAN P. BENNISON, Geological Consultant, Tulsa, Oklahoma

Genesis of mid-Pennsylvanian limestone banks along the south margin of the Northern Oklahoma platform may relate to deeper water phases of the Arkoma trough. This interrelation of carbonate banks to the nearby marine trough is implied by facies studies between the late Desmoinesian Oologah Limestone banks and subjacent Labette mudstone-sandstone banks and the penecontemporaneous thick flyschoid clastics of the Calvin-Wetumka-Wewoka sequence farther south.

The northern Oologah Limestone bank facies consists of three recognizable formations, Pawnee Limestone, Bandera Shale, and Altamont Limestone in upward succession. The Pawnee Limestone is commonly transitional with the underlying Labette Shale. Locally the thin Bandera Shale unit contains more calcisiltite than black phosphatic nodular shale. Most of the algal and coralline biohermal facies are developed in the overlying Altamont Limestone. This limestone grades upward through transitional black phosphatic shale and bioclastic marl into the overlying ironstone banded Nowata Shale.

Southward all these formations diminish in thickness from about an accumulation of 100 meters in southwestern Rogers County to about 5 meters near Leonard, southern Tulsa County. The Labette is represented by about 3 meters of fine quartzose sandstone and siltstone, and the Oologah is reduced presumably to about 2 meters of grey concretionary shale capped by black phosphatic shale.

Still farther south in adjoining Okmulgee County this equivalent sequence appears to increase rapidly in thickness to about 300 meters of flyschoid sandstones and shales of the Calvin-Wetumka-Wewoka sequence. Sole marks and burrows suggest northward directed turbidite flows. [5]

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.

Relation of Geothermal Patterns to Major Geologic Features in U.S.

J. W. SHELTON, Oklahoma State University, Stillwater, Oklahoma, M. K. HORN, Cities Service Oil Company, Tulsa, Oklahoma, and R. H. LASSLEY, Cities Service Oil Company, Tulsa, Oklahoma

The geothermal gradient map prepared by the Geothermal Survey of North America displays gradients for which contoured values range from .6°F/100 ft. in southern Florida to 3.0°F/100 ft. in eastern Oregon. The most common values are from 1.0 to 2.0°F/100 ft.

The geothermal gradient map reflects the geothermal regime in sedimentary rocks, which is thought to represent a summation of a number of geologic and geophysical parameters expressed as thermal conduction and convection and hydrodynamics. Conduction is thought to be dominant where the stratigraphic framework consists of significant impermeable rocks, such as salt and shale. Convection plays a dominant role where continuity of vertical permeability reflects development of thick reservoirs or extensive fracturing. The more typical stratigraphic section, containing reservoirs alternating with impermeable units, and structural movements by uplift and/or subsidence are conditions for dominance by hydrodynamics in the sedimentary geothermal regime.

In general geothermal-gradient trends and patterns mapped by GSNA almost entirely from mud-temperature data correlate best with regional structural features. Correlation also exists in various areas with gross stratigraphic features, salinity patterns, gravity anomalies, and magnetic features. Selected correlations include the coincidence of high gradient values along part of the Texas Gulf Coast with a shale ridge and the inland geothermal maximum with the Lower Cretaceous reef trend. Also, the Central Basin platform corresponds to a geothermal minimum; a long geothermal maximum coincides with the Wichita-Amarillo-Cimarron uplift; the Arkoma basin is reflected by a geothermal maximum; two minima encompass an area of significant Lower Cretaceous oil production in the northwestern part of the Powder River basin; and the San Joaquin basin is characterized by centrally located geothermal minima. [82]

Stratigraphy of Buckhorn Limestone (Pennsylvanian) of Southern Oklahoma

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The Buckhorn district near Sulphur, in the north-central part of the Arbuckle Mountains, contains asphaltic rocks of diverse age. Along the edge of the asphalt district is an extensive area of Pennsylvanian sediments, of which one bed is an asphaltic limestone informally known as the "Buckhorn." It is famous for its fossil shells, chiefly cephalopods and gastropods, that retain their original iridescent colors and original skeletal aragonite. The asphalt was introduced shortly after limestone deposition, by displacement of connate waters, and has served as an embalming agent to preserve the skeletal mineralogy and geochemistry of a highly diversified marine fauna.

Correlation by cephalopods had earlier indicated a middle Pennsylvanian (Wewoka, late Desmoinesian) age for the Buckhorn limestone. Our investigations show the Pennsylvanian sequence of the Buckhorn district to be 1,200 feet thick and to contain four principal limestone beds, dominated first by primitive *Fusulina* and later by *Fusulina* and *Wedekindellina*. We obtained good correlation of species with the lower Deese of the Ardmore basin and reasonable correlation with the Boggy Formation of eastern Oklahoma. The Buckhorn sequence thus is early Desmoinesian, only slightly younger than the Kendrick Shale (Morrowan) of Kentucky, which also contains aragonite mollusks.

The Oklahoma limestone beds are chiefly thin fusulinid mudstones or molluskan mudstones, or rarely skeletal calcarenites. They accumulated in a sea of moderate depth, generally as discontinuous skeletal mud banks. The thickest bed is the Buckhorn limestone (100 feet), but it can not be traced outside the Buckhorn district. [94]

GSA Annual Meeting, South-Central Section Stillwater, Oklahoma, March 7-8, 1974

The following abstracts are reprinted from the *Abstracts with Programs* of The Geological Society of America, v. 5, no. 2. 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.

Geochemical Exploration for Redbed Copper Deposits in North-Central Oklahoma

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Copper mineralization has been reported from widely scattered areas in north-central Oklahoma (Payne, Pawnee and Noble Counties). The copper-bearing zone occurs in the Doyle, Matfield and Garrison Shales of Permian age. Chalcocite is the dominant unoxidized copper mineral, while malachite with subsidiary azurite are the most common oxidized minerals. Chalcocite is reported to contain minor quantities of silver and gold.

The initial field work revealed additional copper occurrences. Therefore, a geochemical exploration program was initiated to evaluate potential ore deposits in north-central Oklahoma. Stream sediments and bedrock samples were collected from an area approximately 350 square miles with a sampling density of 4 samples per square mile. The finer sieve fraction (<0.177 mm) of the samples was digested in aqua regia (3 nitric acid and one hydrochloric acid by volume) and then analyzed for copper content.

The preliminary results indicate that the geochemical copper anomalies seem to delineate the known occurrences of copper mineralization. Additional copper anomalies were found in areas where no copper mineralization was evident on the nearby bedrock outcrops. Presently these areas are under investigation. [94]

Transverse Braid Bars in the Triassic Sandstones of the Texas Panhandle

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The Triassic sandstones of the Texas Panhandle represent deposits from braided streams that flowed northwest from the Ouachita-Marathon Mountains (Dott and Batten, 1971, and Cramer, 1973).

The Triassic sandstones are characterized by a predominance of transverse braid bars with only minor longitudinal bars. The bars are 0.5 to 1.5 meters high with a distance of 5 to 10 meters between crests. They are composed of fine to medium grained sand with planar cross-laminations (0.5 to 1.5 meters thick) overlain by a thin (2-5 cm) layer of micro-trough cross-laminations and rip and furrow structures. The faces of the planar cross-lamination sets exhibit parting lineations and rill marks.

Some of the transverse bars have planar laminations and large scale trough cross-laminations, overlying the planar cross-laminations. However, the large scale trough cross-laminations are mainly restricted to the deep sections of the bar complex directly in front of the bar crests.

The predominance of transverse bars over longitudinal bars in the Triassic sandstones indicates deposition in the distal portions of a braided stream. This predominance of transverse bars over longitudinal bars in the distal positions of a braided stream has been reported by Smith (1970) in the Platte River of Nebraska. [94-95]

Comparison of Ecology and Sedimentation in Lower Pennsylvanian (Morrowan) Algal-Coral-Bryozoan Bioherms with Those in Modern Patch Reefs

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Examination of reef cavities in the inner and outer reef tracts of the Florida Keys suggests that cavities, crevasses, and irregular surfaces, which can comprise up to 70 percent of the total reef volume, may be of major importance in understanding the nature of sediment-organism interaction. Cavities provide a specialized habitat for reef organisms and serve as a trap for suspended and reef-derived sediments. In addition, the presence of cavity-dwelling organisms may profoundly affect the resistance of the substrate to later mechanical and chemical destruction. Ecologically, cavities enlarge the surface area available for colonization, resulting in an overall increase in biomass.

The interpretation of cavities and their inhabitants provides a new tool for understanding the nature of interrelation between organisms and sediments in both modern and ancient bioherms and reefs. Biohermal mounds of Morrowan age in Muskogee County, Oklahoma, have been examined in an attempt to study community development and relations of cavities within the bioherms. Preliminary studies suggest a complex faunal succession. This often shows a cyclic repetition with an algal boundstone core surrounded by solitary and michelinid corals, filamentous and encrusting bryozoans, and pelmatozoans. [96]

Dissepimental Corals of the Upper Pennsylvanian Missourian Rocks in the American Midcontinent

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Four genera of dissepimental rugose corals—*Dibunophyllum, Neokoninckophyllum, Geyerophyllum,* and *Caninia*—are present in limestones and accompanying shales of the Upper Pennsylvanian in the American Midcontinent. In all areas studied, dissepimental corals of the Missourian Series are restricted to relatively thick normal limestones or phylloid algal mound complexes and are accompanied by a varied marine invertebrate fauna. Four informal zones based on these genera have been recognized in Kansas: Zone 1 is based on corals from the Hertha, Swope, Dennis, and the Block limestone of the Cherryvale Formation; Zone 2 on corals of the Westerville limestone, Cherryvale Formation; Zone 3 on corals of the Cement City limestone (=?upper Drum Formation) and Zone 4 on corals of the Wyandotte, Plattsburg and Stanton Formations.

Elements of Zones 1, 3 and 4 are present in other states. The Lost City Member, Hogshooter Formation of Oklahoma has corals similar to those of Zone 1, as do the Hertha, Swope and Dennis Formations of Iowa. The Oklahoma Dewey Formation has corals related but not identical to forms from Zones 1 and 4 of Kansas. In Iowa, elements of Zones 3 and 4 are found in the Iola and Wyandotte Formation respectively.

Several limestones in Illinois contain rugose corals—the Shaw Point contains a dibunophyllid species which is characteristic of Zone 3 of Kansas and the Millersville and the Livingston have corals similar to those of Zone 4. Texas corals have not been collected extensively; however, Canyon and Cisco rocks there contain corals related to corals of Zone 4. [100]

The Rare-Earth Element Distributions in the Clay-Size Fraction of the Permian Havensville and Eskridge Shales of Kansas and Oklahoma

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The clay-size fraction (<2 microns) of samples from the Havensville and Eskridge shales of Kansas and Oklahoma were analyzed for their rare-earth element (REE) content using radiochemical neutron activation analysis. All samples analyzed have absolute and relative REE distributions very similar to composites of N. American and European shales. However, samples from both formations from Northern Oklahoma (Kaolinite-rich; chlorite and vermiculite-poor) have absolute REE concentrations and light/heavy REE ratios that are higher than the composite shale samples. Samples from Central and Northern Kansas (Kaolinite-poor; chlorite and vermiculite-rich) have absolute REE concentrations and light/heavy REE ratios that are lower than composite shale samples. REE concentrations in vermiculites and chlorites from other areas have been found to be quite low compared to the other clay minerals. Thus, the differences in the REE content between samples from Oklahoma and Kansas can most likely be attributed to differences in the amount of chlorite and vermiculite in these samples and/or to differences in initial REE concentrations in the source areas that supplied the sediment to these basins. [101]

Geology of the Creta Copper Deposit of Eagle Picher Industries, Inc., Jackson County, Oklahoma

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Copper mineralization is found in greenish gray marine shales and mudstones of Permian age. Copper, in the form of chalcocite, presently is being exploited from the deposit which occurs in a three inch to one foot zone at the top of a two foot shale/mudstone unit, and which has an areal extent of more than fifteen square miles. The chalcocite has been found to be the result of the replacement of pyrite and organic spores. In addition, chalcocite occurs as open space filling in thin silt laminae, as veinlets lining compaction fractures, and as linings along bedding planes. Sulfur isotope studies have indicated a biogenic origin for the sulfide ion.

The copper bearing bed is in close stratigraphic proximity to beds containing flora which correlates closely with flora from the Zechstein (Upper Permian) of Germany, in which the famous Kupferschiefer deposits are found. [101]

Ore Microscopy of Copper Ore at the Creta Mine, Southern Oklahoma

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Preliminary ore microscopic investigation of the copper ores at the Creta Mine in Southern Oklahoma has shown that the sulfide minerals consist of chalcocite, covellite, pyrite and rare sphalerite. Other opaque minerals present in the ore include native silver and hematite. The extremely fine-grained character of the ore requires microscopic techniques for the identification of the ore minerals and the determination of their textures.

Chalcocite, the principal sulfide mineral, occurs mainly as tiny, irregularly shaped grains, about 10 μ across, disseminated in the Permian Flowerpot claystone host rock. The fineness of these grains contributes to copper losses to the tail in the form of binary locked chalcocite-claystone particles in the milling of Creta ore. Chalcocite also occurs in larger grains, about 50 μ across, which commonly exhibit a nearly spherical shape. Some chalcocite spheres have hollow interiors. Less commonly, chalcocite forms tiny veinlets traversing the claystone.

Covellite forms irregular patches in chalcocite grains. Native silver is present rarely as grains associated with areas of abundant chalcocite.

Pyrite, the second most abundant sulfide, most commonly occurs as tiny, irregularly shaped grains disseminated in the claystone. Many pyrite grains are partially replaced by chalcocite in the form of caries, rim, and atoll textures. These intergrowths of pyrite and chalcocite contribute to the practical problem of milling the copper ore. An understanding of the manner of development of these textures may contribute to a better understanding of the genesis of Creta-type ore deposits. [104]

Brachiopod Biostratigraphy of the Morrow Series (Lower Pennsylvanian) of Northwestern Arkansas and Northeastern Oklahoma

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The Morrow Group in the southwestern Ozark Mountains region is a highly fossiliferous sequence of predominantly marine strata and is used as the standard of reference for the Early Pennsylvanian for western North America. Brachiopod faunas in this sequence are highly varied, and the Morrow Group includes three brachiopod zones established from the ranges of 45 species. These zones are based on the first occurrence of a number of brachiopod taxa and are, in ascending order, the *Sandia welleri* Range Zone, the *Plicochonetes*? *arkansanus* Range Zone, and the *Linoproductus nodosus* Range Zone.

The boundary between the *S. welleri* and *P.*? *arkansanus* Zones is accordant with the boundary between the *Idiognathoides noduliferus* Zone and the *Gnathodus bassleri symmetricus* Zone, conodont zones defined by Lane and Straka in 1971.

The upper boundary of the *P.*? *arkansanus* Zone marks the highest occurrence of nine brachiopod species that occur commonly in the lower part of the Morrow Group. This zonal boundary coincides with the regional unconformity that occurs at the base of the Dye Shale Member of the Bloyd Formation in northwestern Arkansas and that has now been traced into the Morrow Group in northeastern Oklahoma. The faunal change at this boundary is the most important in the Morrow Group and is the basis for proposing that the Morrow sequence be subdivided into two stages. [107]

Permian Copper Shales of Southwestern Oklahoma

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Many stratiform copper deposits are known in Permian shales and sandstones of western Oklahoma, but the most important of these are two copper-bearing shales in the Flowerpot Formation in exposures near Creta and Mangum in the southwest part of the State. The two copper shales commonly range in thickness from 6 to 18 inches, and their grade is 0.5 to 4.5 percent copper. The Creta deposit is being strip mined; it averages 7 inches thick, and the mined ore is about 2.3 percent copper. The Mangum deposit is currently under development; it averages about 14 inches thick and about 1.4 percent copper.

The flat-lying ore beds are medium-gray, laminated, silty shales containing chalcocite as the primary ore mineral and malachite at and near the outcrop. They are interbedded with red-bed clastics and evaporites deposited on the east side of the broad epicontinental Permian sea that covered much of southwestern United States. The two copper shales extend 3 to 6 miles along the outcrop. They are several feet apart, stratigraphically, and their exposures are about 15 miles apart.

The host shales apparently were deposited in a brackish-water or shallow-marine environment, and syngenetic or early diagenetic copper mineralization may have occurred by replacement of pyrite. [108-109]

Ground-Water Geochemistry of a River Alluvium and Related Environmental Implications

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The general purpose of the project is to characterize the ground-water chemistry of the Washita River alluvium near Chickasha, Oklahoma. The chemical characteristics of the ground water are compared with the mineralogy and chemistry of the associated alluvial sediments, surface water chemistry, and land use practices involving chemical applications and waste disposal. Analysis of both common and trace chemical constituents are made. Trace constituents include zinc, lead, copper, cadmium, and manganese. Maps are used to show the areal distribution of the ionic constituents and used to identify anomalies which indicate possible sources of pollution from sediments in the subsurface or from highly mineralized surface water, land treatment practices, or waste disposal such as of oil field brines. [109]

Mineralogy and Microtextures of Sulfides in the Flowerpot Shale of Oklahoma and Texas

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Copper and iron sulfides are widely distributed within the Flowerpot shale (Guadalupian age) of southwestern Oklahoma and north-central Texas. However, significant amounts of copper are restricted to individual beds generally less than one foot thick.

Chalcocite (including digenite) is the most abundant copper sulfide mineral and occurs in three ways: (1) octahedral crystals of 1 to 25 microns diameter, (2) pellets and crystal aggregates up to 200 microns diameter, and (3) fillings of pore spaces in sandy laminae.

Chalcopyrite occurs in the form of sparse crystals and pellets less than 200 microns diameter in the shales overlying the richest chalcocite. Chalcocite and chalcopyrite can occur in the same sample or independently. There is no evidence that chalcocite has been derived from the chalcopyrite.

Pyrite forms octahedra in the 1 to 25 micron range and pellets up to 200 microns. Pyrite is absent in the richer chalcocite beds but occurs with chalcocite in some of the overlying beds.

Other primary minerals that occur sparingly are galena and barite. Surface secondary minerals include covellite, malachite, azurite, cuprite, goethite, and brochantite.

Detailed study of individual mineral particles at high magnifications with the scanning electron microscope and its auxiliary X-ray fluorescence equipment has provided information on the nature and origin of the individual minerals. It indicates that most of the chalcocite is an early replacement of syngenetic pyrite. [110]

Central European Versus South Central U.S.A. Geologic Settings of the Permian Basins and Associated Copper Mineralization

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A thorough study of the Permian basin in central Europe, including the North Sea, and of the Permian basin in south central U.S.A. indicates that despite their geographic separation by the vast Atlantic Ocean, both basins have numerous geologic features in common.

One of the most important features common to both basins is the presence of a variety of economic mineral resources. In the European basin enormous reserves of copper and associated economic minerals are known, while in the U.S. basin, although we cannot talk yet in term of reserves, the frequency of copper and other mineralization is very encouraging.

An interesting observation which should be mentioned is the possible relationship between nonferrous metallic mineralization, the potassium-magnesium salts and hydrocarbons.

One of the differences between the two basins is in their structural development and igneous activity. During Variscan orogeny the region later to be occupied by the European Permian basin was strongly deformed and invaded by volcanic and plutonic rocks. Volcanic activity, however, continued into Permian, but ended in mid-Rotliegendes (mid-Lower Permian). On the other hand, it appears that the south central U.S. region was much less deformed, mainly during the Pennsylvanian.

It is interpreted and considered significant that both Permian basins are located within Precambrian foreland *(sensu lato)* and are nearly surrounded by crystalline masses.

In both Permian basins there is evidence of paleoenvironmental similarities at regional but not local scale.

Also from a metallogenic point of view there are similarities as well as differences. The presence of copper mineralization associated with similar types of sediments in both basins is considered important. A significant difference is that in the central European Permian basin prosperous mines have been known and operated since the XIII-th century (e.g. Mansfeld mining district, East Germany) while in the south central U.S. Permian basin copper-silver mineralization has been known for over a century, but deposits of similar magnitude are yet to be found. It is also interesting to note that although the economic mineral deposits of central Europe are known and have been exploited for so long, it is only recently that the largest polymetallic ore deposit was discovered in the Lubin area (southwestern Poland). This is undoubtedly the result of persistent exploration in a relatively well known region.

In conclusion it is considered that the difference in magnitude is only apparent. Based upon the data available, it is considered that there is still good potential for additional discoveries in the European Permian basin. More importantly, even greater potential exists for discovery of similar, large, economic mineral deposits in the Permian basin of the south central U.S.A. [111]

Depositional Environment of the Hartshorne Sandstone (Pennsylvanian), Arkansas Valley Area, Arkansas

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The Hartshorne sandstone is the basal unit of the Desmoinesian Series in Arkansas. It rests on the Atoka Formation and is overlain by the McAlester Formation. The Hartshorne coal beds, which occur with shale in Arkansas, are variously classed as the top of the Hartshorne Formation or the base of the McAlester. Size analyses were made on 83 thin sections from 22 measured sections, measuring maximum grain diameters of sand and coarse silt sizes and Rosiwal analyses of fine silt and clay fractions. Size isopleth maps were constructed and indicate that the sand was deposited in a restricted seaway with tidal flats to the north and south abutting the positive Ozark area and the rising Ouachita Mountains. Although restricted to the west by the State Line Arch, deposition was continuous over that shallow barrier into Oklahoma. The coarsest sands are concentrated in a belt along the axis of the outcrop area. Small scale channeling, cross bedding and ripple lamination are common here. Sand becomes finer and clay more abundant to the north, south, and far west of the area. Thin lenticular bedded fine sand with clay lamellae increase to north and south. It appears that the Hartshorne sand represents a transitional deposit from predominantly marine Atoka sediments to continental McAlester sediments and represents an estuary-like environment. [113]

Lower Pennsylvanian (Morrowan) Ammonoids from the Primrose Member, Golf Course Formation, South-Central Oklahoma

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An ammonoid assemblage including *Arkanites relictus* and new species of *Bilinguites* and early *Gastrioceras* occurs in the lower portion of the Primrose Member, Golf Course Formation, near Ardmore, Oklahoma (Elias, 1956). *Arkanites* is a provincial reticuloceratid, abundant at several localities in northwestern Arkansas, but at present unknown outside the southern midcontinent. The joint occurrence of *Arkanites* and *Gastrioceras* in the Primrose assemblage suggests correlation with the *Arkanites relictus* Zone, *Gastrioceras* Subzone, of the Morrowan Series. The *Arkanites relictus* Zone occurs in the upper portion of the Prairie Grove Member, Hale Formation, in the type Morrowan succession of northwestern Arkansas. The presence of *Bilinguites* with an *Arkanites relictus* Zone assemblage supports earlier suggestions that this zone is equivalent to the British R_{2c} ammonoid Zone, Marsdenian Stage, Namurian Series, Upper Carboniferous (Silesian) Subsystem.

Conodonts recovered with the Primrose ammonoid assemblage characterize the *Idiognathoides noduliferus* Zone of the midcontinent Pennsylvanian System (Lane, *et al.*, 1971). In northeastern Oklahoma and northwestern Arkansas, the *Gastrioceras* Subzone encompasses portions of the next higher *Neognathodus bassleri symmetricus* conodont Zone. [115-116]

Centonites—A Stratigraphically Useful Palynomorph Restricted to Upper Pennsylvanian Rocks

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Centonites is a distinctive palynomorph of uncertain origin. It was first described by Peppers (1964), who found it restricted to non-coal lithologies from Missourian Cyclothems in Illinois and from the lower part of the Henshaw Formation (Missourian-Virgilian) of western Kentucky. In Oklahoma *Centonites* has a wide geographic distribution. The writers have found this distinctive palynomorph in surface outcrops of the Seminole Formation (Basal Missourian Series) of the Tulsa area and restricted to a narrow zone within the Hoxbar Group in the subsurface of the Anadarko Basin, Comanche County, Oklahoma. *Centonites* has been used for subsurface correlation in the Elk City Field and in Beaver and Harper Counties of the Oklahoma Panhandle. The wide distribution, including several counties of northwest Texas, one recorded occurrence from Europe (Stephanian of the St. Etienne area, southeastern France), and the limited stratigraphic range make *Centonites* a very useful palynomorph for correlating Upper Pennsylvanian rocks. [117-118]

Evaluating the Effects of Permeability Distribution on Downstream Ground-Water Flow Using a Mathematical Model

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Hydrogeologic field studies have been conducted in the Washita River Basin between Alex and Anadarko, Oklahoma and on a small tributary watershed of Sugar Creek within the river basin. A mathematical model is used to describe the impact of dam seepage on downstream ground-water and surface-water flow.

Permeability values used in the model were determined by field pump tests and from samples obtained at two pump test sites. These values are used as input to a mathematical model which distributes the permeabilities over the test area. A comparison is made between the mathematically generated distribution of permeabilities and that determined from maps representing data obtained from other drill cuttings and cores in the test area. Using this comparison, a selection is made of those synthesized flow net patterns which more accurately reflect both the water-table surface and the geology of the test area. The model is used to test the assumption that most of the ground water from dam seepage will emerge in a relatively short distance downstream as effluent flow to the stream channel. Estimates of effluent flow based on the selected model output are compared with measured stream flow and evaporation. [118]

Palynology and the Vertical Profile of Sedimentation of Lower Missourian Strata, Tulsa County, Oklahoma

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A lower Missourian outcrop section in Tulsa County, Oklahoma is correlated by palynomorph content with Upper Pennsylvanian strata of Illinois. The taxa are related to lithologies and the data is subjected to the diversity/equitability analysis (Beerbower and Jordan, 1969). Diversity is a useful technique for depicting environmental gradients that appear to be related to transgressive and regressive cycles of sedimentation. [122]

Significance of the Stratigraphic Distribution of Colonial Rugose Corals in the Pennsylvanian System of North America

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Colonial rugose corals form a characteristic element in both Mississippian and Lower Permian faunas in North America. In contrast, corals of this type are extremely rare in this continent in the intervening Pennsylvanian System during which time suitable environments were mostly lacking. The known occurrence of such corals is limited to a few genera in the Morrow and Atoka Series only, as follows: *Lithostrotionella* in the Morrowan of northeastern and southern Oklahoma; *Orygmophyllum*? in the Morrowan of eastern Nevada and in the Atokan of central Texas; and *Lithostrotionella* and *Corwenia* in the Atokan of northeastern Alaska. No confirmed occurrences of colonial rugose corals have been reported from the Des Moines, Missouri and Virgil Series in North America and the last representatives of this group are presumed to have become extinct in Atokan times.

In contrast, highly varied colonial rugose coral faunas, including many different genera, are widely distributed in the Lower Permian, Wolfcampian Series throughout western North America, from Alaska to western Texas. These Lower Permian faunas cannot represent descent from provincial ancestors but they document instead major migrations from outside North America, presumably from Russia where colonial rugose corals of many types are common throughout the Upper Carboniferous. [124]

Observations on the Morphology and Stratigraphic Distribution of Hamiapollenites

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Hamiapollenites, a bisaccate palynomorph of uncertain affinity, was originally described from the Flowerpot Formation (Lower Permian) of Oklahoma and has become an important index to Permian rocks in various parts of the world. Since its initial description, several additional species have been reported, some of which should be assigned to one or more other genera. The stratigraphic range of the genus has been extended downward to near the middle of the Des Moines Series (Pennsylvanian) in Oklahoma and upward into the Lower Triassic, but its greatest abundance appears to be in the earliest unquestioned Permian strata. [130]

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Late Cambrian Matthevia **(Mollusca, Matthevida) in North America**

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Matthevia is now known from Upper Cambrian carbonate rocks in New York State, Maryland, Oklahoma, Missouri, Arizona, Utah, and Nevada in the United States and Alberta(?) in Canada. A Trempealeauan Age for most occurrences is inferred from rarely associated trilobites or from subjacent and superjacent occurrences of trilobites. A late Franconian Age can be neither proved nor ruled out for some occurrences where trilobites are absent.

A *Matthevia* faunule in the Great Basin is characterized by an association with high-spired gastropods and by the exclusion of other invertebrate fossils. This *Matthevia*-gastropod association commonly occurs with oncolites and channel deposits between large hemispherical stromatolites which suggest an intertidal to shallow subtidal environment of deposition.

Morphological features of *Matthevia* specimens from part of the type lot, hitherto misplaced, support an interpretation that the longitudinal cavities in the terminal plates were insertion sites for large muscles. Thus, the presence of heavy shells, large muscles, the associated rock type, and the geographic distribution support a warm shallow-water, high-mechanical-energy environment for *Matthevia.* [88]

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Unusual Fossil Cephalopod Jaws from Nevada

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The term rhyncholite is the vernacular for several genera accommodating calcified portions of cephalopod mandibles, e.g. *Rhyncolites, Conchorhynchus*.

Mesozoic and Tertiary rhyncholites attain nearly a mundial distribution (Teichert & Spinosa, 1971) whereas undoubted Paleozoic occurrences are limited to a single locality of Permian-Pennsylvanian ammonoid mandibles from South America (Closs, 1967). Mesozoic ammonoid mandibles from Europe are known (Lehmann, 1971) to lack calcified beak regions; similarly, modern coleoid chephalopod mandibles are not calcified. Additionally, coleoid and ammonoid cephalopods have similar radulae composed of seven longitudinal rows of teeth. By contrast, nautilids possess mandibles with a calcified beak region (rhyncholites) and radulae comprising 13 longitudinal rows of teeth.

Our collection of Paleozoic cephalopod jaws consists of several representatives from Mexico, Texas, Oklahoma, Arkansas, Kansas and over 500 specimens from Nevada. In all known Paleozoic representatives, no calcification is observable, and close association with ammonoids is invariable; some mandibles have been extracted from body chambers of ammonoids and are preserved as articulated upper and lower jaws.

Reasons for the rarity of Paleozoic cephalopod mandibles are two-fold: Ammonoids without calcified mandibles are abundant, whereas nautilids are relatively rare; hence, Paleozoic rhyncholites are rare. Secondly, ammonoid mandibles may have been misidentified as polyplacophoran plates and anaptychi. [248]

[Abstract revised at authors' request.]

GSA Annual Meeting, Southeastern Section
Atlanta, Georgia, April 3-6, 1974

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The Enigma of Late Paleozoic Orogeny in Southeastern North America

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Clastic sequences of Carboniferous age, from the Marathons to Pennsylvania, demonstrate a rough synchroneity recording uplift and erosion from supply lands to the east and south. The last major deformations of the Marathon region, Wichita-Ardmore-Anadarko complex, Ouachitas, and Appalachians also are largely Carboniferous in age. With deformation intensity increasing in directions toward the present Gulf and Atlantic, these regions represent buckling and faulting against the rigid, stable cratonic shelf of Paleozoic nuclear North America.

This orogenic episode was formerly termed the Appalachian (Ouachitan, Marathon) Revolution, and its character and history were but vaguely described. Now, this event is popularly related to a supposed Late Paleozoic suturing of North America to Africa and Europe through plate movements. In the latter process, a subduction zone presumably developed along the line of suture.

Major difficulties confront both explanations. They include: 1) A near-absence of Late Paleozoic igneous events, especially volcanic activity, around the continent's southeastern border, and this is a presumed close associate of subduction zones; 2) stringent geographic requirements in the positioning of orogenic activity which result in deformation in the Ouachitas-Arbuckles-Ardmore Basin region and the Marathon region without seriously affecting the Llano Region; and 3) accounting for the stratigraphic equivalents of the one million-plus km^3 of clastic deposits shed over the North American cratonic shelf and its bordering areas during the Carboniferous. The highlands supplying these clastics presumably eroded on both sides, but volumetric equivalents are not yet known in Europe, Africa, or South America. [336-337]

Transform Faults as Explanation for Offsets in the Southern Appalachian-Ouachita Tectonic Belt

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Apparent offsets of the southern Appalachian-Ouachita tectonic belt in Mississippi and Arkansas and in west Texas have been interpreted as reflecting (1) a continuous structural trend which changes direction sharply, (2) two structural trends which intersect at a large angle, or (3) offset of a formerly continuous tectonic belt by later strike-slip faulting of large dimensions. In contrast, we suggest that these apparent offsets are the manifestations of ancient transform faults.

Proposed transform movement began in late Precambrian or early Cambrian time, in conjunction with the initial splitting of a super-continent. Movement continued until late Pennsylvanian or early Permian time, ceasing with the termination of sea-floor spreading in the region of the present Gulf of Mexico. This chronology is in accord with the general plate-tectonic interpretation of the Ouachita system by Keller and Cebull (1973).

The apparent finite length of the structural offsets, especially in the southern Appalachian-Ouachita region, is uniquely explained by the transform-fault model. The model also explains the probable age of initial movement along the Texas Lineament, sedimentary rock distribution in the vicinity of offsets, and geographic distribution of oceanic-type upper-mantle and crustal structure beneath the Gulf Coastal Plain. In addition, the model implies that the shape of the Ouachita-Marathon orogenic belt was largely determined by the geometry of initial parting within the supercontinent. [341-342]

GSA Annual Meeting, North-Central Section
Kent, Ohio, May 8-11, 1974

The following abstracts are reprinted from the *Abstracts with Programs* of The Geological Society of America, v. 6, no. 6. 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.

Ostracode Paleoecology in Shales of the Wreford Megacyclothem (Lower Permian; Kansas and Oklahoma)

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The numerous shale units in the Wreford Megacyclothem yield ostracodes whose mutual and exclusive occurrences and distributions suggest six apparent ostracode assemblages.

A low-species diversity *Carbonita-inflata*-dominated assemblage occurs in Speiser green shales and gray-yellow mudstones, thus implying fresh to brackish estuarine paleoenvironments. A moderate- to high-species diversity *Bairdia beedei-Amphissites centronotus-Knightina texana-Hollinella bassleri* assemblage characterizes the uppermost Speiser marine calcareous shales. A low-species diversity *Kelletina-robusta*-dominated assemblage occurs in the middle Threemile marine calcareous shale. A high-species diversity *Bairdia beedei-Pseudobythocypris pediformis-Cavellina edmistonae-Knoxina bolliaformis-Hollinella bassleri-Knightina bassleri* assemblage characterizes the entire Havensville, both marine calcareous shales and marine gray-yellow mudstones. Schroyer marine calcareous shales contain a low- to moderate-species diversity *Bairdia beedei-Knoxina bolliaformis-Hollinella bassleri* assemblage. Finally, the lower Matfield green shale bears an assemblage consisting only of *Paraparchites kansasensis*, perhaps indicative of restricted conditions.

Morphological and ecological comparisons with similar Recent ostracodes, speculations concerning possible modes of life and feeding types, and biotic associations all suggest that probably salinity and perhaps also substrate conditions influenced the occurrence and distribution of Wreford ostracode species. [492]

Ordovician Conodonts from Black Knob Ridge, Oklahoma

LAEL E. BRADSHAW, Department of Geology, Wittenberg University, Springfield, Ohio

Black Knob Ridge represents the western extension of the Ouachita fold belt in southeastern Oklahoma. The ridge is part of a thrust sheet that has moved Ordovician rocks northwestward onto Upper Paleozoic strata. Mapping and stratigraphic studies by Hendricks, Knechtel and Bridge in 1935 indicated the presence of conodonts in most of the Paleozoic formations. Samples from a reconnaissance trip to this area by the present author yielded an Ordovician conodont fauna characterized by a small number of species and specimens.

The conodonts were recovered from siliceous limestone beds in the Upper Ordovician Big Fork Chert. The fauna is dominated by representatives of *Panderodus, Belodina, Drepanodus, Oistodus* and *Phragmodus*. Samples from the underlying Womble Shale were barren. Samples from the overlying Polk Creek Shale produced no conodonts but graptolites belonging to the *Dicellograptus complanatus ornatus* zone were collected. The area suggests promise as one that may yield small but significant conodont faunas associated with a graptolite sequence. [494]

Explaining the Trace-Fossil Community in DSDP Cores

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Deep-sea benthos are diverse, soft-bodied, loosely spiculated or poorly ossified forms that are not readily preserved. The fossil community found in DSDP cores, however, is not diverse and is made up of grazing and feeding burrows. *Zoophycos, Chondrites,* composite burrows, and *Teichichnus* are the most abundant trace fossils found; *Helminthoida,* rind burrows, and halo burrows are less common.

Extensive reworking of older superficial and shallow burrows by a few deep burrowers during slow sedimentation in the deep sea resulted in the low diversity of trace fossils that represent the deep-sea fossil community. Recognition of more burrows, especially the numerous large ones such as rind, some halo, and some composite burrows, is hampered by the small core size (2½ inches maximum).

Zoophycos, Chondrites, and *Teichichnus* are surprisingly abundant in deep-sea cores. Surprising because they are known primarily from shallow-water lutite deposits, but trace fossils in deep-water shales in-the-continent have received insufficient attention because they require special treatment. Furthermore, most deep-water trace fossils have been studied from back-arc basins found in-the-continent, such as the Ouachita Geosyncline, rather than from open ocean sediments like those in most DSDP cores.

Further examination of DSDP cores, obtaining larger cores, study of deep-water lutites in-the-continents, and study of known open ocean sediments found in-the-continent will all be necessary for an improved understanding of deep-sea fossil communities. [498]

Biostratigraphic Aspects of Type Morrowan Ostracods

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Some 50 species (4 new) of ostracods distributed among 27 genera (1 new) were found in the type Morrowan rocks of northwestern Arkansas and northeastern Oklahoma. This large and diversified fauna is of particular importance because of the general faunal shortcomings of the type Morrowan rocks, especially in the lack of fusulinids, upon which so much continent-wide application of Midcontinent series terminology is based. Many samples of the upper half of type Morrowan rocks do not yield fusulinaceans of any kind, neither *Millerella* nor fusiform types. Yet it is common practice to extend the Zone of *Millerella* to the top of Morrowan rocks. A series recognized by the presence of a fauna (ostracods) rather than on the absence (fusulinaceans) is appealing.

One ostracod assemblage zone encompassing the type Morrowan rocks is recognized. The former partly indirect correlations of the following rocks and ostracod faunas with the type Morrowan appear firm: the Johns Valley Shale, the Wapanucka Limestone, and the lower part of the Dornick Hills Group, all of Oklahoma; the lower part of the Glen Eyrie Formation of Colorado; the Poverty Run Member (Pottsvillian Series) of eastern Ohio; and the Lead Creek Limestone and other Lower Pennsylvanian rocks of Kentucky and Indiana.

Profusulinella has been found with this same fauna in other areas by Robert Shaver and M. L. Thompson. Thus, the paucity of fusulinaceans in the type Morrowan rocks and lower Atokan rocks enhances the significance of the ostracod fauna. It also casts doubt on the common North American practice of recognizing the Morrowan-Atokan boundary on the basis of the first appearance of *Profusulinella*. [522-523]

The Brachiopod Genus Composita from the Wreford Megacyclothem (Lower Permian) in Nebraska, Kansas, and Oklahoma

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The Lower Permian Wreford Megacyclothem crops out in a north-south belt extending through Kansas from southernmost Nebraska into northern Oklahoma. Many well-preserved fossil groups occur within the Wreford and are abundant and widely distributed. Brachiopod groups recognized are chonetids, *Cleiothyridina, Composita, Derbyia, Enteletes, Lingula, Orbiculoidea, Petrocrania,* productids, and *Wellerella.*

The Wreford *Composita* group was studied in detail. Because the *Composita* population there consists of an intergradational series of individuals which cannot be separated into clearly distinct groups interpretable as separate species, these fossils are best included in a single species, *Composita subtilita* (Hall, 1852). Two distinct morphotypes can be recognized as end members of this intergrading population. These two end members do not differ significantly in distribution and abundance, occurrence in rock types, stratigraphic horizons, or geographic regions in the study area; thus they cannot be explained as ecotypes, evolutionary populations, or subspecies, but can be regarded most appropriately as intraspecific morphotypes. Eleven numerical morphological characters were measured on each well-preserved specimen of *Composita subtilita*. When summarized for the entire Wreford population, these measurable characteristics indicate that no systematic morphologic variations exist which are attributable to ecologic, evolutionary, or clinal differences. Paleoecologic investigations of *Composita subtilita* in the Wreford suggest: 1) salinity or sediment influx or both were important limiting environmental factors for this species; 2) large shell beds including this species covered the southern reaches of the Wreford sea floor at certain times during deposition. [527]

The Lower Middle Ordovician Multielement Conodont Genus Multioistodus

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The genus *Multioistodus* contains 5 multielement species; *M. subdentatus, M. compressus, M. cryptodens,* and two new species which contain among others *Pteracontiodus aquilatus* Harris and Harris and *Acodus auritus* Harris and Harris in one species and *Tricladiodus clypeus* Mound in the other. Each species of *Multioistodus* contains a cordylodus-roundya transition series as described by Lindstrom (1964) with addition of an oistodiform element at lease in *M. compressus*. The range of *M. subdentatus* is extended down to the base of the Whiterock by samples from the uppermost West Spring Creek and Joins Formation of the Arbuckle Mountains. Two additional multielement species which display a cordylodus-roundya transition series may be closely related to *Multioistodus*. One species has denticulate processes and includes *Tetraprioniodus costatus* Mound while the other consists entirely of costate "simple cones". The cordylodus-roundya transition series is considered a valid criterion for establishing suprageneric affinities in the lower Middle Ordovician. Conclusions are based upon a study of approximately 36,000 conodonts from the Joins Formation of Oklahoma, type specimens, and additional collections from Oklahoma, Arkansas, Missouri and Utah. [529]

Remote Sensing of Earth Resources Annual Meeting Tullahoma, Tennessee, March 26-27, 1973

The following abstract is from a paper presented at the Remote Sensing of Earth Resources meeting, held March 26-27, 1973, at the University of Tennessee Space Institute, Tullahoma, Tennessee. The author's permission to print it is gratefully acknowledged.

The Application of Radar and Infrared Imagery to Quantitative Geomorphic Investigations[1]

PHILIP JAN CANNON, Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas

Quantitative geomorphic data were derived from airborne radar and thermal infrared imagery of an area in south-central Oklahoma. These data were carefully compared and contrasted with quantitative data taken from a detailed topographic and photographic study of the area. The usefulness of radar imagery as a quantitative geomorphic tool depends on the size of the area to be investigated, the relief, and the distribution of vegetation. Radar imagery provides usable areal information for basins greater than 30 square miles in area. From the areal parameters meaningful elongation ratios, bifurcation ratios, drainage densities, and crenation ratios can be calculated. Infrared imagery can provide excellent geomorphic information for small basins. The detail of the information is dependent upon the altitude of acquisition. Predawn imagery can provide details of channel-ways in areas of dense vegetation that cannot be seen on aerial photographs. It can also provide a means to make an extremely accurate inventory of surface water distribution.

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[1]Publication authorized by Director, Bureau of Economic Geology, The University of Texas at Austin.

REMOTE SENSING OF EARTH RESOURCES ANNUAL MEETING TULLAHOMA, TENNESSEE, MARCH 25-27, 1974

The following abstract is from a paper presented at the Remote Sensing of Earth Resources meeting, held March 25-27, 1974, at the University of Tennessee Space Institute, Tullahoma, Tennessee. The author's permission to print it is gratefully acknowledged.

Rock Type Discrimination Using Radar Imagery[1]

PHILIP JAN CANNON, Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas

Geologic mapping from radar imagery of the Wichita and Arbuckle Mountains of southern Oklahoma indicates that in areas of sparse to moder-

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[1]Publication authorized by Director, Bureau of Economic Geology, The University of Texas at Austin.

The author wishes to acknowledge the U.S. Geological Survey, which provided the radar imagery for this project.

ate vegetation, certain rock types can be readily discriminated on the radar imagery. They can be distinguished because the returns of radar energy from rock outcrops are strongly influenced by the geometry of the rock surfaces. The angular configuration exhibited by the outcrop is the most important factor in returning the propagated radar energy to an airborne receiver. The outcrop geometry can vary greatly between rock types due to the differences in grain size, rates of weathering, and structure. The scale of the outcrop geometry in relation to the wavelength of the propagated radar energy is also an influencing factor of importance.

AMERICAN CHEMICAL SOCIETY, OKLAHOMA SECTION MEETING STILLWATER, OKLAHOMA, MARCH 2, 1974

The following abstract is reprinted from the program for the 20th tetrasectional American Chemical Society meeting, Oklahoma Section, held March 2, 1974, at Oklahoma State University, Stillwater, Oklahoma. The author's permission to reprint it is gratefully acknowledged.

Coal Resources of Eastern Oklahoma, January, 1974

S. A. FRIEDMAN, Oklahoma Geological Survey, The University of Oklahoma, 830 Van Vleet Oval, Norman, Oklahoma

Data from increased coal exploration by industry, coupled with continuing geological investigations, indicate an estimate of 4 billion short tons of remaining resources of 3 sub-ranks of bituminous coal in eastern Oklahoma. Half of this quantity is recoverable with present mining technology. The principal coal-bearing area of 8,000 square miles contains 15 coals of commercial value. Most of Oklahoma's 1973 production of 2.1 million short tons of coal was used for out-of-state electric-power generation and coke manufacture.

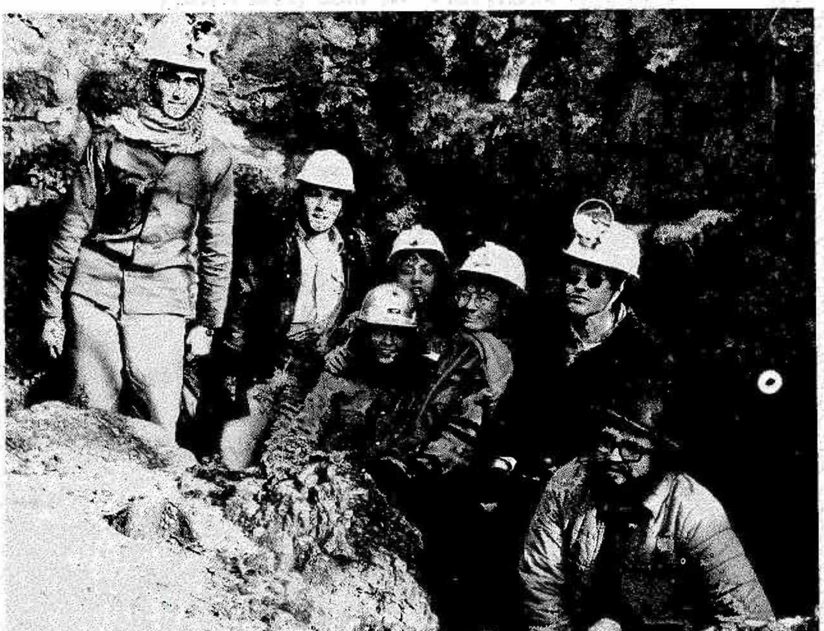
Low- and medium-volatile bituminous coal best suited for coke, metallurgical, and other industrial uses contains 0.4-1.5% sulfur, 18-28% volatile matter, 4-12% ash, 2-3% moisture, and 14,000 Btu. High-volatile bituminous coal, best suited for electric-power generation, contains 1-6% sulfur, 30-39% volatile matter, 6-15% ash, 2-7% moisture, and 11,600-13,600 Btu. Oklahoma coal with a medium sulfur and ash content is best suited for gasification and liquefaction. Coal with a high sulfur and ash content is best for cement manufacture.

Students Spelunk in Oklahoma

During the month of January, students at Oklahoma Baptist University, Shawnee, concentrate on a single subject. This year Jeffrey H. Black, assistant professor of biology and member of the Central Oklahoma Grotto of the National Speleological Society, taught The Silent World of Perpetual Night, a course in speleology (the scientific study of caves).

Oklahoma Geological Survey publications were used to provide basic information, after which the class explored, mapped, and analyzed the geology and biology of sandstone and conglomerate caves in Seminole County, limestone caves in Seminole, Murray, Adair, and Delaware Counties, and gypsum caves in Woodward and Major Counties. The class found several caves badly vandalized. Students cleaned and removed sackfuls of trash—everything from shoes to jars of peanut butter and mayonnaise—from caves. Writing was cleaned from cave walls, and human damage to geological formations was repaired.

Each student in the class was responsible for submitting a map and a report on one cave to *Oklahoma Underground*, a publication of the Central Oklahoma Grotto.



Oklahoma Baptist University speleology class, shown before descent to a limestone cave in the Arbuckle Mountains.

Petroleum Encyclopedia Expands Coverage

The publishers of *International Petroleum Encyclopedia 1974* promise that this seventh edition of the work has successfully made the transition to a yearbook format with statistics for a full calendar year. Information is supplied on production, refining capacity, consumption, gasoline quality, current reserves, and vehicle population for 104 countries, conveniently grouped as Africa, Asia Pacific, Latin America, Near East, North America, Sino-Soviet, and Western Europe. Fiscal data are included on the world's 54 major oil companies—gross income, expenditures, net assets, profit, wells drilled, production, and refinery runs. New techniques and equipment used in all phases of the petroleum industry are outlined. Nuclear power, coal, and hydroelectric capacity are examined on a worldwide basis with a view to correcting future energy shortages, and a country-by-country tabulation of crude-oil movement will accompany a global map showing crude-oil flow patterns.

The 124-page atlas section makes up almost a third of the volume and contains 40 maps, all using topographic relief to create a three-dimensional effect. Oil and gas fields, refineries, and petrochemical plants can be located easily on these eight-color maps. A two-page spread on the Gulf Coast and a foldout (measuring 24 by 11½ inches) of the area around the North Sea increase the usefulness of the edition, but none of the new geographical area maps will be of more interest than the new geologic map of North America, which shows the ages of outcrops from Mexico to the Arctic.

The encyclopedia sells for $32.50 and is available from The Petroleum Publishing Company, IPE 74, P.O. Box 1260, Tulsa, Oklahoma 74101. Shipment is scheduled for July 1, 1974.

National Cartographic Information Center Created

A new cartographic-information center now exists at the U.S. Geological Survey's national headquarters in Reston, Virginia. The center's initial funding was about $1 million, and it is expected to be fully operational by July of this year. Future plans call for establishing additional National Cartographic Information Center (NCIC) offices in Denver, Colorado; Menlo Park, California; and Rolla, Missouri.

The nucleus for the NCIC was provided by the USGS Map Information Office, established by executive order in 1919, which handles 80,000 requests annually. Much more than a name change has been initiated, however. Other major agencies utilizing information on mapping, charting, and geodetic control have reported comparably increased demands for data, and NCIC hopes to serve as an interagency coordinator, accommodating new technology to user needs. For instance, requests for space imagery and aerial photographs will be transmitted directly from NCIC offices to the computer at the Survey's EROS (Earth Resources Observation Systems) Data Center in Sioux Falls, South Dakota.

The goal of the National Cartographic Information Center is not to take over or subordinate other organizations furnishing cartographic information but to expedite its flow, providing users with effective and timely service.

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