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OKLAHOMA GEOLOGY NOTES

Cover Picture

Laminated Mudstones in the Morrow Formation Muskogee County, Oklahoma

The lower portion of the Morrow Formation (Lower Pennsylvanian) contains a sequence of laminated spiculiferous mudstones intercalated with shale. The unit is 19 feet thick and occurs on the east bank of Betsy Lee Creek in the SW¼, SW¼, sec. 33, T. 13 N., R. 20 E., Muskogee County, Oklahoma. This sequence is unique, being the only such occurrence of this rock type in the Morrow Formation in northeastern Oklahoma. The mudstones represent deposition in a deeper water regimen than the remaining carbonate rocks of the Morrow Formation and are unconformably underlain by shallow-water-derived oölitic grainstones of the Mississippian Pitkin Formation and overlain by shallow-shelf-derived, quartz-sandy skeletal grainstones of the Morrow Formation. This is the first such occurrence of deeper water carbonates noted in the Pennsylvanian of northeastern Oklahoma.

—*T. L. Rowland*

Statistics of Oklahoma's Petroleum Industry, 1969

John F. Roberts

Total drilling of wells related to the oil and gas industry increased in all categories in 1969 and exceeded the slight increases forecast (table 1, fig. 1). Sixty-five counties were explored for new reservoirs, and 40 had successful completions (fig. 2), making a statewide success ratio for exploratory wells of 40 percent. The Anadarko basin and its north flank, in the northwestern part of the State, continued to be the most active. Major County had the most exploratory tests, 31, of which 26 were successful, for an 84-percent success ratio. Discoveries were in sandstone reservoirs of Pennsylvanian and Mississippian ages and carbonates of Mississippian and Silurian-Devonian units.

The 22 giant oil fields of Oklahoma are listed in table 2. (A giant field is one that has an estimated ultimate recovery of more than 100 million barrels of oil.) These giants produced approximately 50 percent of the yearly total of oil and accounted for about the same percent of the estimated ultimate yield and remaining reserves. This production came from 38 percent of the total number of producing oil wells in the State.

Table 1 summarizes drilling activity during 1969. The average drilling depth of exploratory wells continued to increase: 5,940 feet compared to 5,780 feet in 1968. The *Oil and Gas Journal* forecasted increased exploratory drilling and less development for 1970.

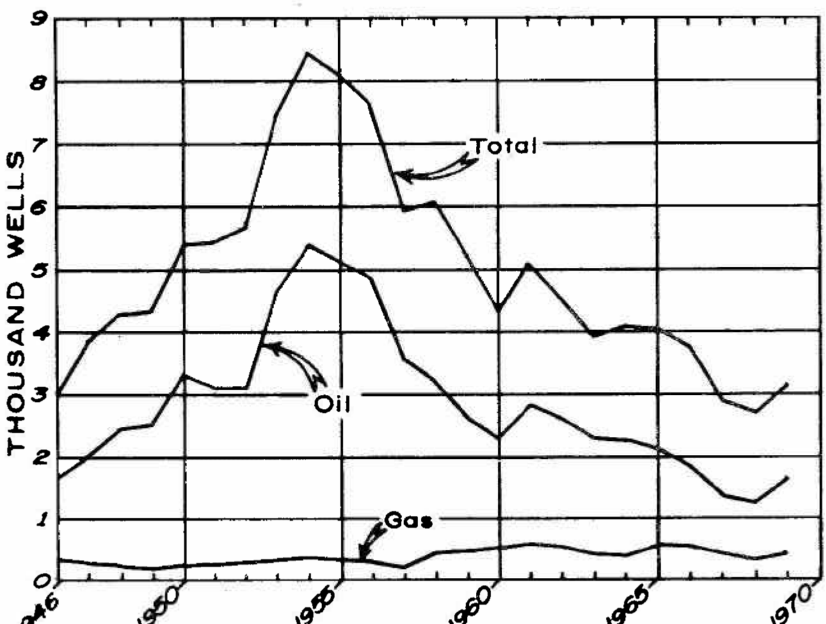

Figure 1. Graph showing total wells drilled, oil wells completed, and gas wells completed in Oklahoma, 1946-1969. Source: Oil and Gas Journal.

TABLE 1.—DRILLING ACTIVITY IN OKLAHOMA, 1969

	1969					1968	1970
	CRUDE	GAS	DRY	SERVICE	TOTAL	TOTAL	FORECAST
All wells							
Number of completions	1,604	397	1,112	282	3,395	2,996	3,244
Footage					16,696,892	14,025,607	16,664,000
Average footage					4,918	4,681	5,137
Exploration wells							
Number of completions	110	57	379		546	422	597
Percentage of completions	20.1	10.5	69.4		100		
Footage					3,243,121	2,439,242	
Average footage					5,940	5,780	
Development wells							
Number of completions	1,494	340	733	282	2,849	2,574	2,647
Percentage of completions[1]	58.2	13.2	28.6		100		
Footage					12,904,613	11,009,726	
Average footage					4,529	4,277	

Source: **Oil and Gas Journal,** annual forecast and review issue, vol. 68, no. 4, January 26, 1970, and vol. 68, no. 12, March 23, 1970.

[1]Excludes service wells and stratigraphic tests.

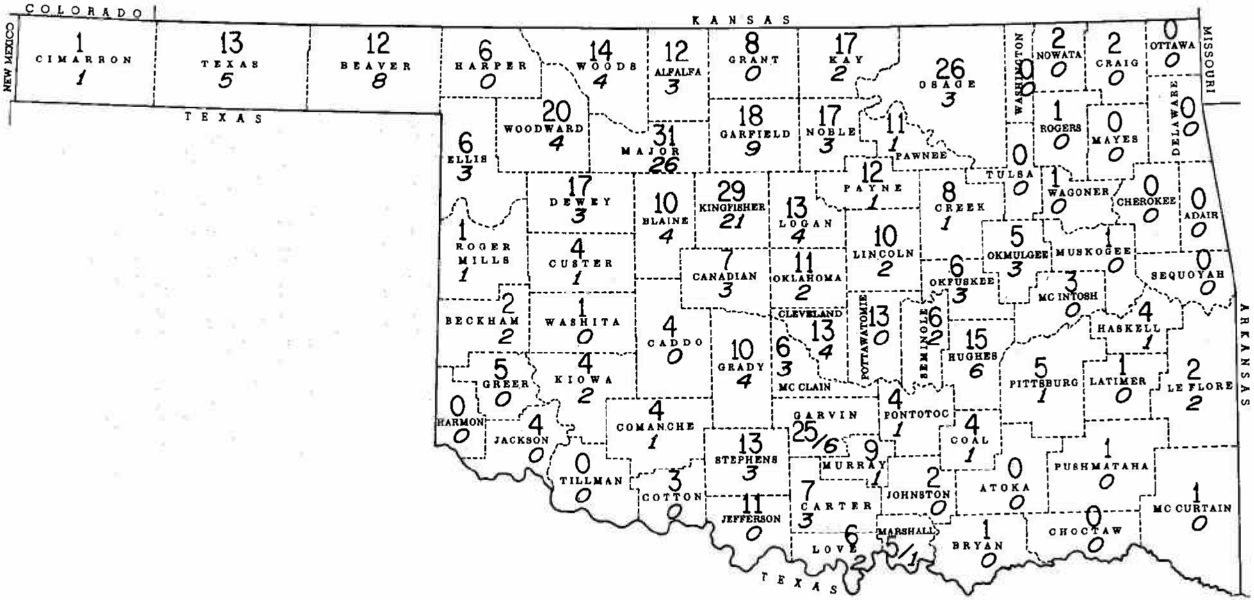

Figure 2. Exploratory drilling, by counties, during 1969. Upper figures give the number of exploratory wells drilled; lower figures give the number of successful completions. Source: American Association of Petroleum Geologists in cooperation with the U.S. Bureau of Mines.

TABLE 2.—GIANT OIL FIELDS OF OKLAHOMA, 1969

FIELD	1969 PRODUCTION (1000 BBLS)	CUMULATIVE PRODUCTION (1000 BBLS)	ESTIMATED RESERVED (1000 BBLS)	NUMBER OF WELLS
Allen	3,260	108,160	11,840	1,529
Avant	196	105,756	1,245	578
Bowlegs	1,116	149,409	10,591	155
Burbank	6,550	480,763	19,237	1,272
Cement	2,536	128,308	6,692	1,526
Cushing	5,095	444,593	12,407	1,861
Earlsboro	694	140,332	4,348	1,933
Edmond West	922	120,948	9,052	2,209
Elk City	142	59,678	40,313	266
Eola-Robberson	5,019	85,496	39,504	490
Fitts	1,334	126,804	7,306	631
Glenn Pool	3,106	297,849	22,151	1,111
Golden Trend	11,661	346,874	148,126	1,619
Healdton	3,861	264,616	15,384	2,138
Hewitt	3,332	188,997	16,003	1,452
Little River	317	133,538	1,462	112
Oklahoma City	1,892	735,598	34,402	371
Seminole	1,296	173,167	13,833	258
Sho-Vel-Tum	33,483	841,161	59,962	7,995
Sooner Trend	17,244	102,198	130,000	2,631
St. Louis	1,674	204,459	5,541	620
Tonkawa	392	130,473	2,858	186

Source: **Oil and Gas Journal**, vol. 68, no. 4, January 26, 1970.

Table 3 lists cumulative and yearly production and the value of all petroleum products to January 1, 1970. The total value of all these items is $27.3 billion.

Table 4 compares petroleum production of the past 2 years. The increase in crude-oil production was due to application of a 100-percent proration factor most of the year. This rate of production failed to meet market demands. Natural gas and natural-gas liquids had increases in production.

Figure 3 shows a decrease in natural-gas reserves from 18,368 trillion cubic feet in 1968 to 17,593 trillion cubic feet in 1969, owing to increased production despite slight increases in discoveries, extensions, and revisions.

Figure 4 displays an increase in the total liquid-hydrocarbon reserves from 1,843 billion barrels in 1968 to 1,856 billion barrels in 1969. The increase is in discoveries, extensions, and revisions of natural-gas liquids. Crude-oil-reserve estimates were lower than in 1968.

The most notable well drilled and completed in Oklahoma in many years was the Glover, Hefner, Kennedy Oil Co. 1-1 Green in the northwest quarter of sec. 1., T. 10 N., R. 21 W. Drilled just north of the prolific Elk City field in Beckham County, the 1-1 Green established many records. It is the deepest well drilled in Oklahoma (total depth, 24,453 feet), the deepest producer in Oklahoma (productive to 22,652 feet), and the third deepest both in total depth and production known in the world. For a short time in 1969 it was second in both of the latter categories. The well set additional records in the drilling phase and added extensively to technology of deep drilling. The largest spacing order known was given by the Oklahoma Corporation Commission when it granted application for 1,440-acre drilling units to

TABLE 3.—CUMULATIVE (THROUGH 1955) AND YEARLY (1956-1969) MARKETED PRODUCTION AND VALUE OF PETROLEUM, NATURAL GAS, NATURAL GASOLINE, AND LIQUEFIED PETROLEUM GAS IN OKLAHOMA[1]

YEAR	CRUDE PETROLEUM		NATURAL GAS		NATURAL GASOLINE AND CYCLE PRODUCTS		LIQUEFIED PETROLEUM GAS	
	VOLUME (1,000 BBLS)	VALUE ($1,000)	VOLUME (MMCF)	VALUE ($1,000)	VOLUME (1,000 GALS)	VALUE ($1,000)	VOLUME (1,000 GALS)	VALUE ($1,000)
Through 1955	7,230,010	11,443,269	12,977,332	1,378,370	14,420,482	890,729	3,673,364	120,097
1956	215,862	600,096	678,603	54,288	489,963	26,543	579,101	23,427
1957	214,661	650,423	719,794	59,743	460,644	25,329	587,140	21,824
1958	200,699	594,069	696,504	70,347	440,798	26,029	657,114	25,822
1959	198,090	578,423	811,508	81,151	448,353	29,443	675,869	27,070
1960	192,913	563,306	824,266	98,088	531,995	33,074	762,258	32,409
1961	193,081	561,866	892,697	108,016	521,237	33,358	817,082	30,141
1962	202,732	591,977	1,060,717	135,772	552,795	35,764	838,903	25,223
1963	201,962	587,709	1,233,883	160,405	555,467	35,131	810,894	28,981
1964	202,524	587,320	1,323,390	166,747	554,053	34,011	880,804	28,055
1965	203,441	587,944	1,320,995	182,297	570,129	34,561	894,665	32,208
1966	224,839	654,281	1,351,225	189,172	576,124	35,715	968,254	44,381
1967	230,749	676,095	1,412,952	202,052	568,905	35,846	1,005,633	49,276
1968	223,623	668,202	1,390,884	197,506	584,010	38,829	1,070,874	39,520
1969[2]	225,050	704,407	1,510,801	220,578	621,600	41,950	1,150,800	53,980
Total	10,160,236	$20,049,387	28,205,551	$3,304,532	21,896,555	$1,356,312	15,372,755	$582,414

[1]Figures from: **Minerals Yearbook** of the U.S. Bureau of Mines. Totals for crude petroleum differ from those compiled by the U.S. Bureau of Mines and the American Petroleum Institute principally because of the exclusion from USBM and API compilations of an estimated production of 26,355,000 barrels for the years 1905-1906.
[2]Preliminary figures for 1969.

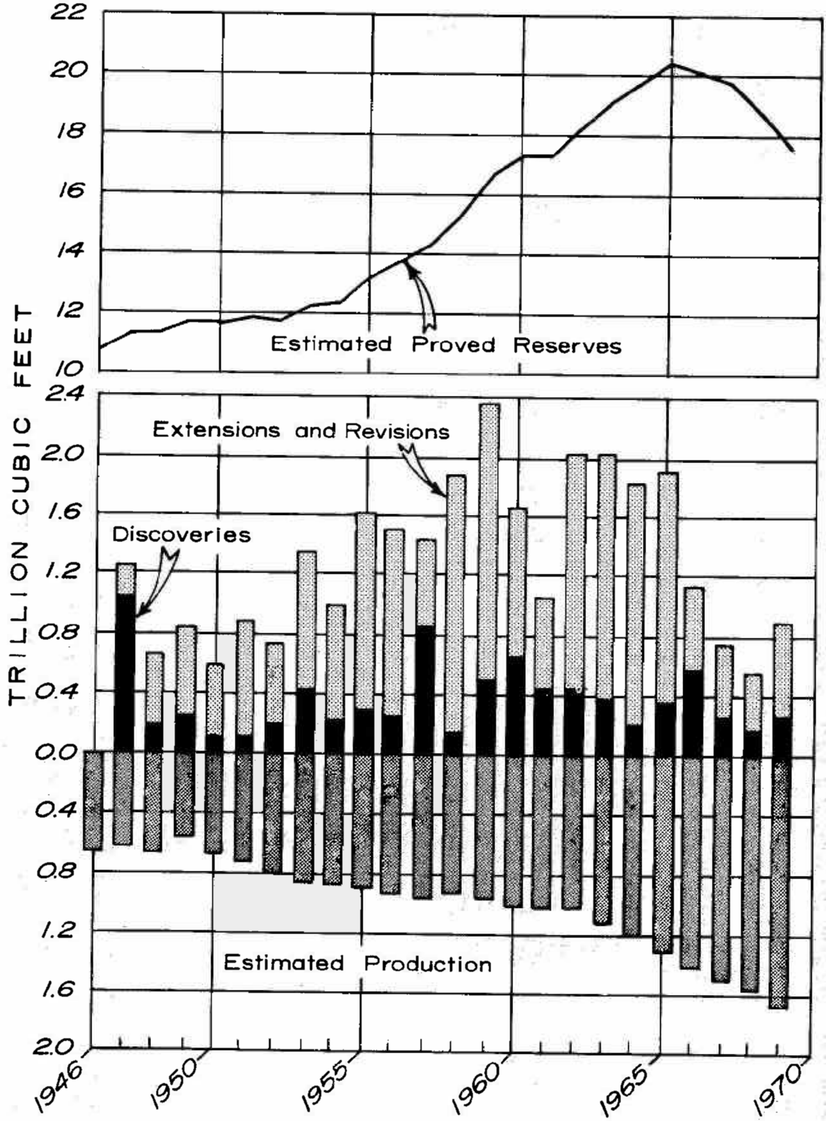

Figure 3. Graph showing statistics on estimated proved reserves of natural gas in Oklahoma, 1946-1969. Source: American Gas Association, annual reports.

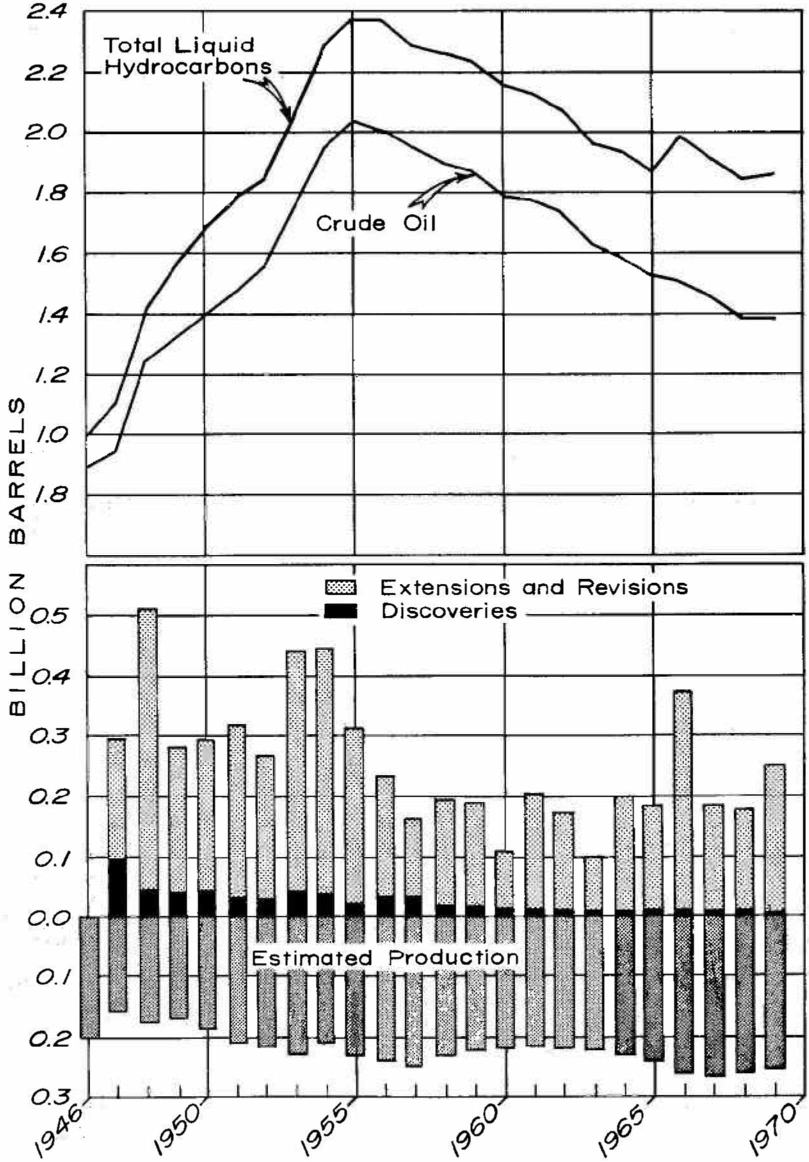

Figure 4. Graph showing statistics on estimated proved reserves of total liquid hydrocarbons in Oklahoma, 1946-1969. Source: American Petroleum Institute, annual reports.

TABLE 4.—HYDROCARBON PRODUCTION IN OKLAHOMA

	1968	1969
Crude oil and lease condensate		
Total annual production (1,000 bbls)[1]	223,623	225,050
Value ($1,000)[1]	668,202	704,407
Cumulative production 1891-year (1,000 bbls)	10,135,936	10,360,986
Daily production (bbls)[2]	610,992	616,575
Total number of producing wells[2]	80,999	80,947
Daily average per well (bbls)	7.5	7.6
Oil wells on artificial lift (estimated)[2]	76,999	76,947
Natural gas		
Total annual marketed production (MMCF)[1]	1,390,884	1,510,810
Value ($1,000)[1]	197,506	220,578
Total number of gas and gas-condensate wells[2]	8,144	8,429
Natural-gas liquids		
Total annual marketed production (1,000 bbls)[1]	39,402	42,200
Value ($1,000)[1]	78,349	95,570

[1]Item for 1968 is U.S. Bureau of Mines final figure. Item for 1969 is U.S. Bureau of Mines preliminary figure.
[2]**World Oil**, annual forecast and review issue, vol. 170, no. 3, February 15, 1970.

cover 7,200 acres around the 1-1 Green. The well was completed for a calculated open-flow potential of 24.3 million cubic feet of gas per day from perforations between 21,604 and 22,652 feet opposite sandstones of Early Pennsylvanian and Late Mississippian ages.

Oklahoma continues to rank third in the nation in production and estimated reserves of natural gas and fourth in reserves and production of crude oil.

Coal Strip-Mine Operators Work on Land Reclamation[1]

In the last decade, U. S. coal strip-mine operators reclaimed 64,263 acres of mined land—more than 100 square miles. Four states, Indiana, Oklahoma, Ohio, and West Virginia, led the way in 1969 by reclaiming more land than was disrupted with mining. New reclamation laws were added in Montana, Alabama, Colorado, North Dakota, and Wyoming, thus bringing almost all major strip-mining states under some type of official regulation.

During their second year of operation under Oklahoma's 1968 reclamation law, coal strip-mine operators affected 550 acres and aerial-seeded 723 acres to grasses and legumes with 12,440 pounds of seed.

[1]Data taken from **Mined-Land Conservation,** v. 5, no. 9, 1970, a newsletter published by the Mined-Land Conservation Conference.

Development of Palynological Computer Information at The University of Oklahoma

L. R. Wilson,[1] J. L. Morrison,[2] and W. E. Reid[2]

A team of eight University of Oklahoma personnel from the School of Geology and Geophysics and the Merrick Computer Center have, during the past 3 years, conducted a feasibility study of the computerization of palynological information. The results were positive and have led to the development of the palynological computer program at The University of Oklahoma, the objective of which is to develop an information system and place all pertinent information of Paleozoic (Cambrian-Permian) palynological literature in detailed data-retrieval form.

At present the data base covers virtually all of the published Paleozoic and Mesozoic palynological literature that relates to the Permian Period and consists of bibliographic citations as well as geographic, stratigraphic, lithologic, morphologic, taxonomic, nomenclatural, floristic, and commentary materials (quantitative data, misspellings, and notations about faulty translations). These data are useful in basic research and will be made available on a nonprofit basis to the scientific community through a search service made possible by the Generalized Information Processing System (GIPSY), a user-oriented data storage and retrieval system developed at the Merrick Computer Center (Blackwell and others, 1969). Retrieval of palynological information by the use of a computer has been utilized in research relative to the publication by Wilson and others (1969), and subsequent studies have further proved the practicability of this project. Several extensive demonstrations of the remote terminal have been given for academicians and oil-company personnel.

The explosion of scientific and technical information over the past few years makes it impossible for any individual to completely keep abreast and mentally retain all published information in his own area of interest. The field of palynology is a good example of this, especially because most of the literature is published outside the United States and refers to earlier publications that are generally difficult to obtain (Wilson, 1968; Kremp and Methvin, 1968).

In 1966 records showed that an average of 2.7 palynological publications per day or 986 publications for the year were received by The University of Oklahoma Palynology Laboratory. In late 1968, 4.0 publications per day were received. This growth rate continues, and in the last 6 months of 1969, 1,142 papers were received, or 6.2 papers per day. Manten (1968) recently calculated that 20,300 palynological papers were published between 1916 and 1965.

Prior to the present computer input program, approximately 11 years were spent by members of The University of Oklahoma Palynology Laboratory abstracting literature and recording reported palynological assemblages. This effort has resulted in establishing the following five categories of records.

1. An author-subject cross-reference file of general palynological

[1]Oklahoma Geological Survey and School of Geology and Geophysics, The University of Oklahoma.
[2]Oil Information Center, The University of Oklahoma.

TABLE 1.—TOTAL DATA-REDUCTION TREATMENT GIVEN EACH PALYNOLOGICAL PUBLICATION

Palynology Study No.	Lithology (Stratigraphic Unit)	Sp. Nov.	Morphologic Descriptions
Author(s)	Quantitative Data in Publication—Yes No	Comb. Nov.	Generic Diagnosis
Date of Publication	Palynomorphs Reported with Taxonomic Treatment	Original Author	Genera Emend. Diagnosis
Other Date on Publication	Genus	Date (Original)	Specific Diagnosis
Title	Gen. Nov.	Date (Translation)	Species Emend. Diagnosis
Publication	Original Author	Translation Author	Palynomorphs Reported Without Taxonomic Treatment
Translation	Date (Original)	Original Generic Assignment	Genus
Geographic Location	Emend.	Emend.	Species
Longitude	Emend. Author	Emend. Author	Spelling Text
Latitude	Date (Emend.)	Date (Emend.)	Palynomorph Breakdown by Geologic Age
Library No.	Ex	Ex	Comments
Reprint No.	Ex Author	Ex Author	Synonymy
Subject of Publication	Date (Ex)	Date (Ex)	Genus
Taxonomy and Nomenclature	Nom. Nov.	Nom. Nov.	Species
Techniques	Nom. Nov. Author	Nom. Nov. Author	Author(s)
Floral Assemblage	Date (Nom. Nov.)	Date (Nom. Nov.)	Date
Other	Original Name	Original Name	Page(s)
Total No. Palynomorphs	Species	Type Species (Check Off)	Synonyms
Comments		Species Text and Illustrations	Homonyms
Stratigraphy			

literature on 3- × 5-inch cards. This file contains more than 21,000 cards.

2. A North American palynological literature file of McBee Keysort cards numbering approximately 3,200. This file permits key-sorting by author, date, subject, geologic age, and geography within North America.

3. A 5- × 8-inch card file containing the original generic and specific taxonomic descriptions and treatment of spores, pollen, acritarchs, chitinozoans, and other palynomorphs. Many cards include photographic or line-drawing illustrations. More than 18,000 cards are in this file.

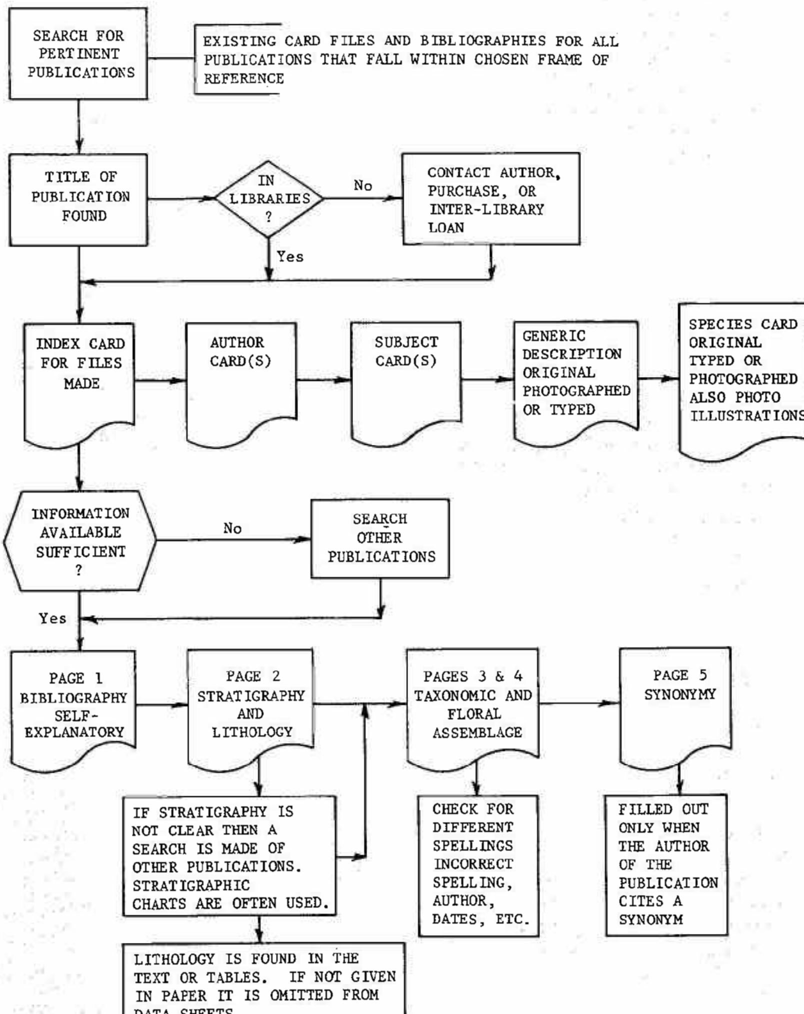

Figure 1. Steps in data reduction.

4. A file of general palynological literature on 5- × 8-inch cards with citation and subject matter, including the reported palynological assemblages. More than 2,000 cards are in this file.

5. A file of McBee Keysort cards containing Paleozoic spore and pollen generic morphological characters to be used to identify palynomorphs unknown to the researcher or to help determine when an undescribed taxon is being examined. This file consists of more than 2,100 cards. Although the key-sort morphologic file was found to be useful in locating unknown palynomorphs to the generic level or to groups of several genera having nearly similar morphographic characters, cards from this file lack enough key-sort spaces to include detailed morphographic descriptors and are thus inferior in storage space and by no means comparable to the computer data base. However, when used in conjunction with card file no. 3 of generic and specific descriptions, they are exceedingly helpful for gross identification of palynomorphs and preliminary evaluation of taxonomic, nomenclatural, stratigraphic, and geographic knowledge.

All these files are being used as a basic source of information for the current computer program input data.

One thing is certain, the palynologist requires immediate assistance if he is to properly pursue his field. Because palynology is a literature-dependent science, one answer to the apparent dilemma of literature reference is a computerized data depository that will enable immediate and accurate recall of literature content for the user.

The future of palynology is definitely associated with sophisticated computer techniques and statistical analysis with which the researcher can find reported palynomorph occurrences and utilize the quantitative data. The qualities of palynology that require this development are listed.

1. An almost unlimited number of palynomorphs are present in many sedimentary rocks throughout most of the geologic column.
2. Specific forms of palynomorphs with wide geographic ranges are restricted within geologic units and therefore are important stratigraphic fossils.
3. Continued investigation of palynomorph taxonomic and nomenclatural relations causes great problems in complete citing and reporting of floral assemblages.
4. Paleoecological affinities of palynomorph types are being recognized.
5. Continual discovery of natural affinities of many palynomorphs makes correlation possible with megafossil equivalents.

Problems confronting palynologists in the development of the science are:

1. A deluge of scattered literature of often restricted distribution and mostly outside the United States.
2. Taxonomic, nomenclatural, and morphological problems arising from inadequate and inaccurate publication. The international codes of botanical and zoological nomenclature require, for validation of a palynomorph, the publication of an adequate morphological description, an illustration, a type specimen, a binomial name consisting of generic and specific epithets, and certain geological and geographic information.
3. The lack of communication between many commercial laboratories has resulted in the duplication of studies, perpetuation of artificial systems of nomenclature, and confusion of terminology.

Following the rules of an international system of nomenclature

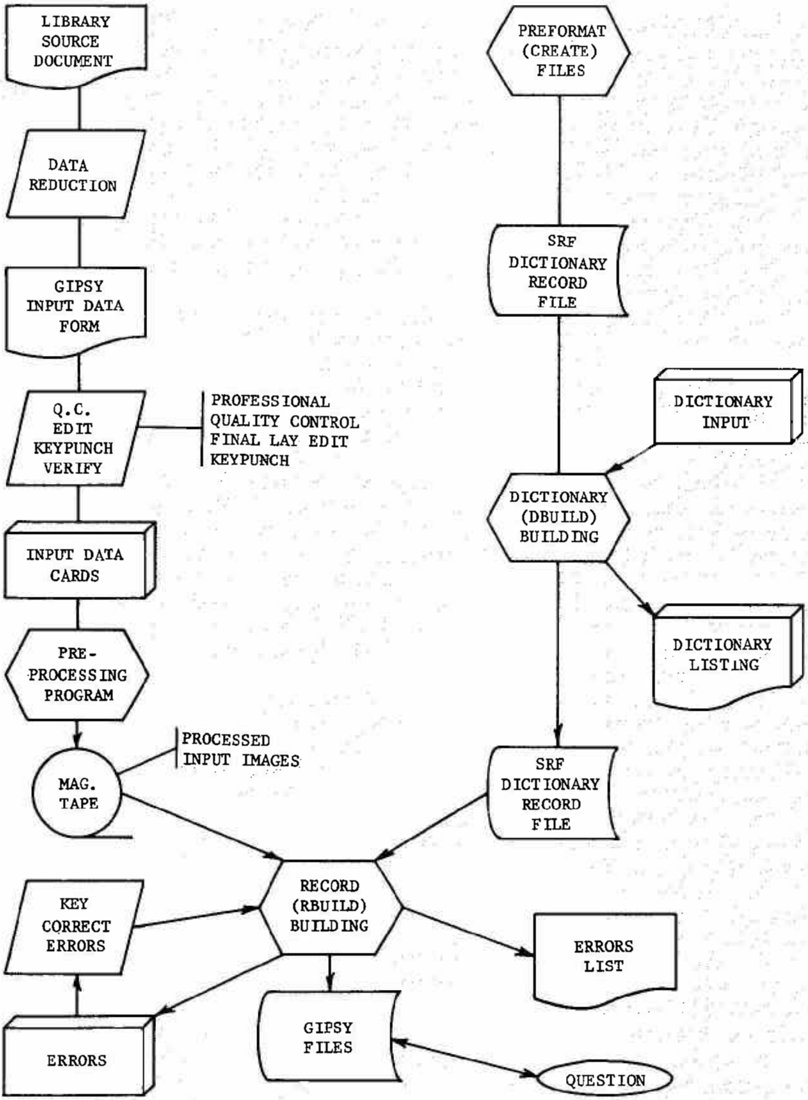

Figure 2. Data-base preparation.

places the science of palynology upon a firm foundation. The adherence to the existing codes by most palynologists has already resulted in the description of an extensive cross section of palynologic knowledge, and eventually all important forms will be described, illustrated, and named.

The existence of nonconforming and, consequently, invalid systems of taxonomic procedure employed in palynological research retards best development of the science. Most of these systems are company oriented and have been based upon expediency. They were developed when palynological literature was relatively scarce and when most of the palynomorphs found were undescribed and without binomial names. These systems are useful within the bounds of their respective laboratories, but unless there is some equating of such systems to the vast number of validly published species, only limited information can be gathered from the published record.

The apparent effectiveness of communication between palynologists has been declining in recent years for several reasons, including:

1. The great increase of information and data, thus increasing the search and review time.

2. The greatly increased need for interdisciplinary information, particularly from associated scientific fields and new technologies.

3. The increasing number of new journals and allied publications, and difficulties in securing obscure foreign publications.

Some of the most common deviations from good practice in palynology are listed, and steps should be taken to see that they are corrected.

1. Failure on the part of certain palynologists to publish all taxonomic description requirements at one time. For example, some have published names and illustrations but have omitted descriptions or other requirements until subsequent publication.

2. Inadequate taxonomic type specimens are commonly chosen and their illustrations published. An amazing number of new genera or species have been based upon a single specimen. This has led to confusion and later to corrections, all of which complicates the literature and increases needless work.

3. Inferior paper stock is still being used by certain journals, resulting in inadequate illustrations for taxonomic understanding. At present no international agreement exists on quality of illustrations, but every author should be professionally responsible for producing the best illustrative material that modern technology can supply.

4. Incorrect spelling of names in the original descriptions occurs. Misspelled names, incorrect citations, and other errors indicate careless proofreading on the part of some authors and editors.

5. Stratigraphic and geographic information is often inadequate because of brevity and lack of documentation or understanding by the author.

6. An appalling misunderstanding of numerous morphologic terms used in descriptions of palynomorph taxa exists among certain workers. The need for an international vocabulary of defined morphologic descriptors is one of the pertinent problems of palynology.

7. Fundamental to all palynologic work is an understanding by the palynologist of what he is viewing under the microscope. Many published descriptions of palynologic taxa make subsequent observers wonder if the original author was aware of the techniques of high- and low-level plane microscopy and the inversion that occurs in phase microscopy. These and other misunderstandings lead to erroneous taxonomic descriptions, and to correct these requires, many times, the original author's temporal involvement.

During the building of The University of Oklahoma palynological data base we have experienced all the foregoing problems. Their resolutions have been varied. Most of the problems have been noted in the commentary portion of the input data forms. At present, the data base consists of 238 publications with a total of 5,210 pages abstracted and information concerning approximately 12,000 reported palynomorph occurrences.

One basic goal of the program at The University of Oklahoma will be to strive for consolidation of morphologic terms, descriptive adjectives, and synonyms used in all languages to a basic common morphologic descriptor. This will be accomplished during the introspective research and evaluation phase of the project and will result in a consistent data-input structure giving the researchers more ease in querying the data depository by decreasing the number of multivariable questions. Equally important, it will give a consistent and uniform recall

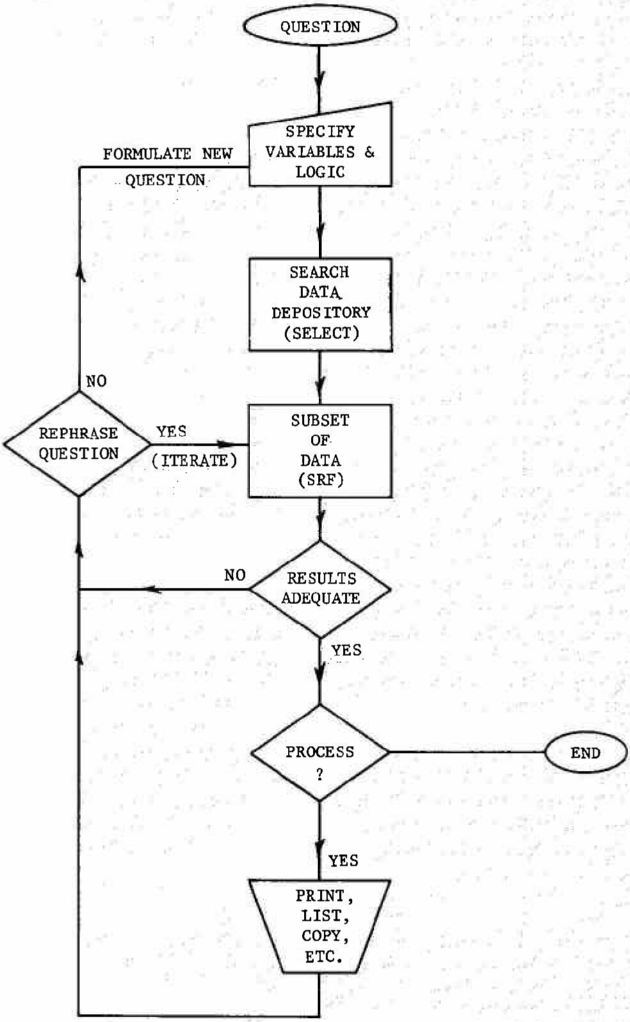

Figure 3. Dialogue sequence in palynology using GIPSY.

from the data base. Existing computer programs written for the NSF-GS-1605 funded project "Computer Support of Linguistic Field Research" (Grimes and others, 1968) will be utilized to prepare dictionaries and concordances for this standardization effort.

During preparation of a comprehensive data base of Permian palynological information, it was necessary to include in-depth information concerning geographic locations, stratigraphic positions, and lithology. It is now apparent that not only palynological morphology, taxonomy, and floristic information is in storage but also a nearly equal amount of geographic, stratigraphic, and lithologic information. This information is available for search in conjunction with palynological questions or as it applies to other fields of knowledge. Thus, although the palynological aspect of the data base is the primary feature, at least three additional information categories are included in this data depository.

Morphologic descriptions are presently entered into the data base in their original form, if in English, German, French, or Latin, to maintain the original description for study. Consequently, the use of a multi-lingual glossary type of external dictionary for search questions, particularly in the field of morphology, will be necessary in order to recall and analyze descriptions written by the original authors. Until a standard international terminology of palynological terms has become established and currently used taxonomic descriptions are assimilated into that vocabulary, reference to original published descriptions is necessary. To expedite the search for similar meanings of terms used in several languages and to aid in the development of an international technical vocabulary, a multi-lingual external dictionary is now being written and will be completed as soon as possible. This task will be greatly aided by word-occurrence analysis made possible with GIPSY. This analysis records all words used in the data base as well as their numerical occurrence. In a printout of the current Permian data base, most of the Paleozoic terms are available. As the project is expanded to include the remaining parts of the Paleozoic Era and as new terms come into use, these too will be included in the external dictionary. Many words with similar roots in several languages now can be searched by prefix, suffix, or other syllables. These root syllables will be included in the external dictionary and will thus greatly reduce the variables that presently appear necessary to recall information in various languages. Foreign-language descriptions are being paraphrased in the data base with key words in English, which will further reduce the number of initial multivariable questions for subsets of data. After more detailed examination of key words used in titles and lithologic descriptions, expansion of the external dictionary may be desirable. A further desirable feature and important by-product of a multi-lingual glossary type of external dictionary is its value in translation.

The steps in data reduction, data-base preparation, and technique of data-base introspective research in palynology, stratigraphy, lithology, and geographic information are illustrated in table 1 and figures 1, 2, and 3.

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Recent U.S. Geological Survey Report Describes Picher Mining Field

The world-famous Picher zinc-lead mining field is the subject of a report recently issued by the U.S. Geological Survey. The report, *Geology and Ore Deposits of the Picher Field, Oklahoma and Kansas,* by Edwin T. McKnight and Richard P. Fischer, published as Professional Paper 588, describes the geology, mineralogy, and mining history of the field. The Picher field lies astride the easternmost part of the Oklahoma-Kansas line and is the westernmost and last developed of the many subdivisions constituting the Tri-State mining region. It has yielded more than a billion dollars' worth of zinc and lead since the first ore was marketed in 1904. Production remained fairly high until the late 1950's, when it dropped sharply owing mainly to the depletion of reserves.

The report points out that, in most of the mining field, surface rocks consist of Pennsylvanian shales, which cover the ore-bearing Mississippian limestone beds and partially mask their structural features. The deposits are chiefly tabular bodies of ore minerals (sphalerite and galena) and gangue minerals (dolomite and jasperoid) that replace limestone beds. Several possible theories of the deposits' origin are discussed, with emphasis on the magmatic-hydrothermal process.

Continued development is forecast for the field, although on a relatively small scale, mainly in areas already productive. Possibilities for further development include exploring for mineralization in the deeper Cambrian and Ordovician formations beneath the Mississippian ore bodies and investigation of the Miami trough, a conspicuous northeast-trending fracture, as a locus for significant mineralization. Geophysical and geochemical prospecting is also mentioned as a possible exploration tool.

The 165-page report, which is well illustrated with geologic maps, cross sections, and text figures, can be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, at a cost of $7.25.

AAPG-SEPM Annual Meeting, Calgary, Alberta June 22-24, 1970

The following abstracts are reprinted from the May 1970 issue, v. 54, of the *Bulletin* of the American Association of Petroleum Geologists. Page numbers appear in brackets below each abstract.

Principles of Deltaic Prospecting

DANIEL A. BUSCH, Consultant, Tulsa, Oklahoma

Deltas generally are formed at river mouths during stillstands of sea level under conditions of either cyclic transgression or regression. Consequently, they are seldom isolated phenomena but, rather, occur in multiples in a predictable fashion. Reservoir facies consist of both continuous and discontinuous, bifurcating channel sandstones which thicken downward at the expense of the underlying pro-delta clays.

All of the lithologic components of a deltaic complex are related to each other and are collectively referred to as one type of *Genetic Increment of Strata* (G.I.S.). The G.I.S. is a sequence of strata in which each lithologic component is genetically related to all the others. It is defined at the top by a time-lithologic marker bed (such as a thin limestone or bentonite) and at the base by either a time-lithologic marker bed or a facies change from marine to non-marine beds. It generally consists of the sum total of all marginal marine sediments deposited during one stillstand stage of a shoreline, or it may be a wedge of sediments deposited during a series of cyclic subsidences or emergences. An isopachous map of a G.I.S. clearly shows the bifurcating trends of the individual distributaries and the shape of the delta, regardless of the variable lithology of the channel fills.

A *Genetic Sequence of Strata* (G.S.S.) consists of two or more G.I.S.'s and, when isopached, clearly defines the shelf, hingeline, and less stable portion of a depositional basin. An isopachous map of the McAlester Formation of the Arkoma basin is a good example of a G.S.S. The oil-productive Booch Sandstone is a good example of a deltaic complex occurring within a G.I.S. of this G.S.S. The upper Tonkawa, Endicott, and Red Fork Sandstones of the Anadarko basin are identified as deltaic accumulations within different G.I.S.'s.

OKLAHOMA ABSTRACTS is intended to present abstracts of recent unpublished papers on Oklahoma geology. 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.

A hypothetical model serves as a basis for establishing the criteria for: (1) recognizing successive stillstand positions of a shoreline; (2) predicting paleo-drainage courses; (3) predicting positions of a series of deltaic reservoirs; (4) locating isolated channel sandstone reservoirs; and (5) tracing related beach sandstone reservoirs.

[Author's revision of abstract that appears on page 839]

Geology of Oil and Gas Occurrence in Pennsylvanian Rocks, Mid-Continent Region

PHILIP A. CHENOWETH, Consulting Geologist, Tulsa, Oklahoma

Oil production in the Mid-Continent began in 1860 with a discovery near Kansas City. The initial find was in rocks of Pennsylvanian age, and reservoirs in that system are still the most important in the region. Hundreds of pools produce from it at depths which range from the surface "tar sands" of western Missouri and southern Oklahoma to sandstones 3 mi or more deep. Several major fields produce mainly from Pennsylvanian rocks.

The geologic history which accounts for this prolific production is punctuated by 3 distinct orogenic episodes: the widespread post-Morrowan Wichita orogeny, the early Desmoinesian Ouachita orogeny, and the Late Pennsylvanian Arbuckle uplift. Activity centered in a belt extending from southern Arkansas across Oklahoma and into the Texas panhandle. Between the major orogenic pulses there were lesser and somewhat more localized movements. Repeated folding is common in the area.

Orogeny actually began in Late Mississippian time with the uplift of an area in northern Texas and southern Oklahoma and the development of a foredeep on the north. Earliest Pennsylvanian rocks are a flysch laid down in this southern Oklahoma geosyncline. In the beginning of the Pennsylvanian most of the Mid-Continent was above sea level and subject to erosion, but by Desmoinesian time shallow seas had spread across the shelf as far north as central Nebraska. Two large topographic highs in Kansas were the last to be submerged.

Cyclic sedimentation characterized the entire period so that alternating marine and nonmarine rocks occupy most of the region north of the geosyncline. Relatively thin and persistent carbonate rocks and shale are most abundant on the north, siliceous clastic rocks predominate and attain great thicknesses on the south. A shelf-edge zone of marine banks and algal reefs occupies the boundary between the two regions. Redbeds and some evaporites are present in Upper Pennsylvanian strata.

Oil and gas are produced from all types of stratigraphic and structural traps. Reservoirs include conglomerate, arkose, sandstone, siltstone, limestone, dolomite, and shale. To date, only dry gas has been found in the southeast Oklahoma-western Arkansas part of the province; elsewhere gas and oil generally are found in close association. Liquids range from nearly solid hydrocarbons to very light naturally refined oils.

Prospecting in the region uses all the conventional techniques but subsurface geology is the most popular and most effective in the more densely drilled parts. Success for exploratory wells in recent

years has been as high as 26% in Oklahoma and Kansas where virtually all wildcat drilling is based on geologic advice.

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Occurrence and Significance of Ribbing Variations in Late Ordovician Brachiopods

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Brachiopods are among the most common elements of marine Paleozoic faunas. Many species are suitable for study of widely separated basins.

Costate specimens representing 11 species were obtained from Upper Ordovician (Richmondian) strata in the Ohio Valley, Illinois, Iowa, Minnesota, Missouri, Oklahoma, Tennessee, and Texas in order to examine geographic patterns in costation and to determine whether observed variations were uniform within each sedimentary province. Regardless of wide variations in costae between different species, most species showed some tendency toward geographic variation in costation. In the Ohio Valley, the variations generally followed a trend toward lower costation. Specimens of *Lepidocyclus capax* (Conrad), *Austinella sooyellei* (Miller), *Plaesiomys subquadrata* Hall, *Zygospira kentuckiensis* James, and *Z. modesta* (Hall) are typically less costate than related members in adjacent basins. These relations support earlier observations of provincialism in the type Richmond fauna. Exceptions to this general pattern were noted in *Glyptorthis insculpta* (Hall) and *Rhynchotrema dentatum* (Hall), both of which exhibited little geographic variation in their costation. Observations for the widespread species, *Lepidocyclus capax,* are somewhat contradictory. Representatives from the Ohio Valley generally are less costate than those observed in Tennessee, Iowa, and Minnesota, but are somewhat more costate than the "Fernvale" variant in Oklahoma. The latter may be an older form.

Preliminary results suggest that ecologic factors, operating within a sedimentary basin, did affect costation but not uniformly for all species. Studies are continuing to determine more precisely the degree of uniformity of costation patterns and whether such patterns are related to variations in lithology.

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Pennsylvanian Delta Patterns and Oil Occurrences in Eastern Oklahoma

GLENN S. VISHER, Department of Earth Sciences, University of Tulsa, Tulsa, Oklahoma; SANDRO SAITTA-BERTONI, Texaco Maracaibo, Maracaibo, Venezuela; and RODERICK S. PHARES, Mobil Oil Corp., Tripoli, Libya

Data from modern deltas have made it possible to interpret the origin of the Pennsylvanian "shoestring sands" of Kansas and Oklahoma. Objective criteria from cores and outcrops are used to define specific areal and vertical depositional patterns. Criteria include: (1) vertical patterns of sedimentary structures, bedding, and grain size, (2) clay mineralogy and detrital clasts, (3) trace fossils, and (4) detailed analysis of textures.

The historic development of a delta provides the insight for interpreting the deposition patterns observed in ancient deltaic sandstone bodies. The processes of progradation and maturation are used to develop a 4-dimensional deltaic model. Six subdivisions are distinguishable: (1) lower alluvial plain, (2) upper deltaic plain, (3) lower deltaic plain, (4) subaqueous sand sheet, (5) marginal basin, and (6) marginal plain.

The lower alluvial plain is characterized by stream meandering, point bars, and unidirectional channel flow. Development of the lower deltaic plain is controlled by crevassing of natural levees, by tides, and by floods. The subaqueous sand sheet is developed by shallow-water currents, modified by progradation and commonly replaced by deltaic-plain environmental units. The marginal basin and depositional plain are produced by longshore drift, and reflect a balance between subsidence, sediment supply, and wave energy. These environmental units may be modified or replaced by other deltaic elements.

The Bluejacket-Bartlesville Sandstone of eastern Oklahoma was selected as a model because of its importance as an oil reservoir, the large amount of available subsurface data, and the simplicity of the stratigraphic and structural framework. The model is used for interpreting many other oil-productive Pennsylvanian sandstones in eastern Oklahoma.

Lower Pennsylvanian strata were deposited during an overall transgression; but, the transgression is marked by extensive regressions. These are represented by widespread sandstone sheets commonly underlain and overlain by marine shale or limestone. Particular sandstone units are distributed across thousands of square miles, but locally the sands are lenticular. Each regression is in response to the outbuilding of sediment under static sea-level conditions. The supply of sediment is related genetically to a river system, and deltaic patterns from the same river can be traced through Morrowan, Atokan, and Desmoinesian strata.

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THE UNIVERSITY OF OKLAHOMA

Carbonate Petrography and Lithostratigraphy of the Morrow Formation (Pennsylvanian) in the Braggs-Cookson Area, Northeastern Oklahoma

TOMMY LEE ROWLAND, The University of Oklahoma, Ph.D. dissertation, 1970

The Morrow Formation crops out in bluff and cliff exposures rimming the Ozark dome in northeastern Oklahoma. The rocks of the Morrow consist of limestones, shales, siltstones, and sandstones, with the limestones dominant. These rocks are overlain unconformably by the Atoka Formation and underlain unconformably by Mississippian rocks. For convenience of discussion, the Morrow rocks are divided into three stratigraphic sequences consisting of a lower limestone and associated strata (sequence A), a middle limestone and associated strata (sequence B), and an upper shale and associated strata (sequence C).

The limestones of sequence A consist of quartz-sandy, skeletal grainstones dominated by debris of bryozoans and pelmatozoans. Interbedded with and forming distinct facies within the skeletal grainstone framework are oölitic grainstones and beds of sandstone. An upper shale and siltstone unit forms the upper portion of the sequence over most of the area. Laminated mudstones intercalated with shales occur in the western part of the area.

Sequence B consists of a lower skeletal grainstone and packstone, a middle algal mudstone that contains the coral *Lithostrotionella*, and an upper skeletal grainstone and packstone with some wackestones. Debris of bryozoans and pelmatozoans dominates as the skeletal element in the grain-supported rocks, whereas algae are dominant organic contributors in the middle mudstone unit. In the western portion of the study area, this middle mudstone forms an algal bank.

Sequence C consists of shale with thin interbeds of limestone and a thicker upper unit of limestone that is erratic in its distribution. This upper limestone is dominated by mud-supported rocks, with bryozoans, pelmatozoans, and algae the essential organic contributors.

The limestones of the Morrow Formation represent deposition in a shallow marine shelf, with the exception of the laminated mudstones, which possess characteristics of deeper water deposition. The grain-supported rocks were deposited in a high-energy subtidal environment with strong current activity, whereas the mud-supported rocks represent lower energy conditions. The karst surface of the underlying Mississippian limestone could have produced the hydrologic conditions for current activity that gave rise to oölitic and other well-washed grainstones. The middle mudstone unit of sequence B represents deposition in a tidal-flat or very shallow subtidal environment.

Influx of fine to coarse terrigenous clastics gave rise to sandstones, siltstones, and shales. The fine terrigenous clastics interrupted carbonate deposition and formed thicker units of shale and siltstone in the upper portion of sequence A; they formed the main rock type in sequence C. Many thin shale interbeds occur with the limestone and in some of the thicker sandstones.

Silicification of skeletal debris, mud matrix, and calcite cement is common, and recrystallization, though generally minor, has occurred in many of the limestones.

University of Arkansas

Clay Mineralogy and Engineering Properties of a Shale-Derived Soil

WENDELL RAY COSTON, University of Arkansas, Ph.D. dissertation, 1969

The Enders stoney loam, a Typic Hapludult, was investigated in this study to characterize its chemical, physical, mineralogical, and engineering properties and to determine if various chemicals could be used to stabilize it. Enders has adverse physical properties that result in poor engineering properties. It occurs extensively in the Ozark Highlands and is frequently used as subgrade material for building foundations and highway roadbeds.

The above-mentioned properties showed wide variation with depth and location. A sharp contrast for these properties was frequently noted between the A- and B-horizons. In the A-horizon, the average values were plasticity—9 percent, clay content—20 percent, total cations—15 meq/100g, and expandables—10 percent. In the B-horizons, the average values were plasticity—25 percent, total cations—25 meq/100g, clay content—55 percent, and expandables—20 percent.

The dominant clay minerals ($<5\mu$ reaction) were kaolinite, illite, vermiculite, and montmorillonite. Analysis of X-ray diffraction patterns revealed that these amounts varied with depth, location, and soil fraction. In the A- and B-horizons, kaolinite and illite averaged 5 and 15 percent, and expandables (vermiculite plus montmorillonite) averaged 7 and 25 percent, respectively.

In the A- and B-horizons, kaolinite averaged about 10 percent in the fine silt ($5\text{-}2\mu$), 35 percent in the coarse clay ($2\text{-}0.2\mu$), 20 percent in the medium clay ($0.2\text{-}0.8\mu$), and was not observed in the fine clay ($<0.08\mu$). Illite averaged about 10 percent in the fine silt, 25 percent in the coarse clay, and 20 percent in the medium clay but was present only in trace amounts in the fine clay. Vermiculite averaged 5 percent in the fine silt, 30 percent in the coarse clay, and 45 percent in the medium and fine clay. Montmorillonite (80 percent) was observed in only the medium and fine clay but occurred in the medium clay of only one profile.

Stabilization was effected by the application of hydrated lime, phosphoric acid, sulfuric acid, NaOH, brown mud, KOH, colloidal silica, hematite, and alumina. These chemicals were then mixed in various combinations. Stabilization was measured in terms of liquid limit, plastic limit, plastic index, cation-exchange capacity, and shear strength. Colloidal silica, hematite, and alumina added in conjunction with the other treatments did not increase the soil stability. Alkaline treatments increased the stability over that for the untreated and acid-treated soil. The greatest stability occurred with lime.

Multiple linear-regression analysis for the characterization study revealed the Atterberg limits could be predicted by the following equations (0.01P):

(1) $Y_{LL} = 0.21 + 1.04\,PL + 0.95\,(LL\text{-}PL)$ $\qquad R^2 = 0.00$

(2) $Y_{TC} = 1.52 + 0.42\,LL$ $\qquad R^2 = 0.87$

(3) $Y_{CL} = -8.54 + 1.94\,PL$ $\qquad R^2 = 0.91$

The results of equation (1) revealed that one Atterberg limit can be measured and then used to calculate the other two values. Equations (2) and (3) show that total-cations (TC) and percent-clay (CL) determinations can be used to predict liquid and plastic limit, respectively. Values for Atterberg limits obtained in this manner will be more reliable because values for TC and CL are more reproducible between laboratories than are the former values. Similar equations were obtained for the stabilization data.

(Reprinted from Dissertation Abstracts, Pt. B,
v. 30, no. 7, p. 3308-B)

Morrowan (Lower Pennsylvanian) Conodonts from Northwestern Arkansas and Northeastern Oklahoma

HAROLD RICHARD LANE, The University of Iowa, Ph.D. dissertation, 1969

The type area for the Morrowan (Lower Pennsylvanian) stratigraphic sequences is in northwestern Arkansas. It is difficult to trace equivalent strata to northeastern Oklahoma, but the conodont succession permits correlations between the regions. The association of *Idiognathoides noduliferus* and *Adetognathus lautus* with *Spathognathodus muricatus* exists in the Cane Hill Member of the Hale Formation and indicates basal Morrowan. An evolutionary complex within *Idiognathoides noduliferus* and a newly named taxon occurs in the lower part of the Prairie Grove Member of the Hale Formation. *Neognathodus bassleri symmetricus* was derived from the aforementioned evolutionary complex and ranges into the lower part of the Brentwood Limestone Member of the Bloyd Formation. *Neognathodus bassleri bassleri* appears in the upper part of the Brentwood and persists into the Woolsey Member of the Bloyd Formation, where it is associated with *Idiognathodus humerus*. A newly described species of *Idiognathodus* is restricted to the Dye Shale Member of the Bloyd Formation. The form-species *Idiognathoides convexus* first occurs at the base of the Kessler Limestone Member of the Bloyd Formation.

The two form-species constituting an asymmetrical pair are synonymized, thus, placing the species concept on an element-pair basis. Three taxa are newly described.

(Reprinted from Dissertation Abstracts, Pt. B, v. 30, no. 7, p. 3242-B)

Age and Correlation of the Goddard and Springer Formations in Southern Oklahoma as Determined by Conodonts

JOSEPH JOHN STRAKA II, The University of Iowa, Ph.D. dissertation, 1969

The conodont species *Cavusgnathus unicornis* and *Cavusgnathus naviculus* range through the lower Goddard Formation to the top of the Tiff Member and support a correlation with some part of Menard through Kinkaid C strata in the type Chesterian region. *Adetognathus unicornis* characterizes the middle and upper Goddard Formation and ranges into the Rod Club Member of the Springer Formation. These units are correlative with the Grove Church Shale (uppermost Mississippian) of the Illinois basin, and the upper part of the Pitkin Limestone of north-central Arkansas. The presence of *Gnathodus girtyi intermedius* in the lower part of the shale interval between the Overbrook and Lake Ardmore Members of the Springer indicates that the lower two-thirds of this formation is also Mississippian in age.

The simultaneous first appearances of *Idiognathoides noduliferus,*

Adetognathus lautus and *Spathognathodus muricatus* in the Target Limestone Lentil of the Springer Formation mark the base of the Pennsylvanian in the Ardmore basin. These species substantiate correlation of the Lake Ardmore Member and the unnamed shale overlying it with the lowermost type Morrowan (Cane Hill and lower Prairie Grove Members of the Hale Formation) in northwest Arkansas.

Consequently, the faunas of the Goddard and Springer Formations are represented in the type Chesterian and type Morrowan successions. Continued usage of the term Springer in a time-stratigraphic sense, therefore, is invalid.

The conodont fauna of the Primrose Member of the Golf Course Formation indicates equivalency with the middle part of the Prairie Grove Member of the Hale Formation through the lower Woolsey Member of the Bloyd Formation in the type Morrowan region. Lowermost Primrose rocks contain a unique, "evolutionary burst" fauna from which five stratigraphically significant conodont species evolved.

(Reprinted from Dissertation Abstracts,
Pt. B, v. 30, no. 9, p. 4285-B)

New Theses Added to OU Geology Library

The following masters' theses and doctoral dissertation have been added to The University of Oklahoma Geology Library recently:

Master of Science Theses

Areal geology and Cretaceous stratigraphy of northwestern Bryan County, Oklahoma, by Thomas A. Hart.

Magnetic survey, Lexington Game Management Area and vicinity, Cleveland County, Oklahoma, by Carl B. Kaup III.

Doctoral Dissertation

Marine communities of a portion of the Wewoka Formation (Pennsylvanian) in Hughes County, Oklahoma, by Ronald Robert West.

U.S. Board on Geographic Names Decision

North Carrizo Creek (variants: Carrizo Creek, Carrizozo Creek, Carrizzo Creek, North Carrizozo Creek) has been adopted as the name for a stream 15 miles long that heads in Colorado at the junction of its east and west branches at 37°04′55″ N, 103°01′30″ W, and flows south-southeast into Oklahoma to the Cimarron River 2 miles north-northeast of Kenton, 36°56′30″ N, 102°56′30″ W; 1915 decision revised.

OGS to Adopt USGS Editorial Style

After careful consideration and consultation, the editors of the Oklahoma Geological Survey have decided to make the Survey's editorial style conform more closely, with only minor exceptions, to that shown in the U.S. Geological Survey's *Suggestions to Authors of the Reports of the United States Geological Survey*. This policy will not cause any radical change but will affect manuscript style especially in the setup of bibliographic material. The editors hope that this will be acceptable to the majority of readers; however, if you have any comments you wish to express, we would be happy to hear from you.

—*William D. Rose*
—*Carol R. Patrick*

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