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OKLAHOMA GEOLOGY NOTES

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Cover Picture

Hydraulic Dredging in Oklahoma

Hydraulic dredging, an economic method for mining loose material lying under water, is used by many Oklahoma mineral producers for recovery of sand and gravel. Hydraulic-dredging systems used in the State consist of a pump connected to a hinged suction pipe and a flexible discharge pipe supported on floats, as shown on the cover. A typical component of the system is a small barge, which houses the pump and provides mobility, permitting use of the suction pipe throughout the dredging area.

Pictured is the dredging system of Yahola Sand and Gravel Company, which is recovering sand from the channel of the Arkansas River north of Muskogee in Muskogee County. In such an operation, a slurry of water, sand, and gravel, usually about 20 percent solids by weight, is sucked up from under the water and pumped to the shore for sorting and stockpiling. The suction pipe, generally 6 to 12 inches in diameter, is fitted at its open end with a guard or screen to limit the size of material entering the pipe.

Nineteen Oklahoma sand and gravel companies are now using hydraulic dredging, according to the records of Ward Padgett, chief mine inspector, Oklahoma Department of Mines. Almost all of these companies are located on major rivers. Some dredge from the river channel itself, whereas others dredge from a pit excavated below the water table in the adjacent flood plain. One operator is dredging a 25-foot-thick terrace deposit of sand and gravel 100 feet above the Salt Fork of the Arkansas River north of Alva in Woods County: the terrace deposit, resting on Permian shales and siltstones, has a perched water table that was intersected after the pit was opened by conventional open-pit-mining methods.

—*Kenneth S. Johnson*

The Mineral Industry of Oklahoma in 1971[1]

(Preliminary)

L. G. Southard[2]

The value of mineral fuels, excluding helium, amounted to $1,096 million, a net gain of 2.7 percent over 1970, according to the Bureau of Mines, United States Department of the Interior. Principal gains in commodity value were made in natural gas and petroleum (crude). Principal decreases in commodity value were recorded in natural gasoline and cycle products in LP gases. Collectively, mineral fuels supplied 93.9 percent of the total value of minerals produced. Helium declined slightly in the quantity produced in 1971 compared to 1970. All nonmetallic mineral commodities increased in value with the exception of stone.

MINERAL FUELS

The value of mineral fuels, excluding helium, amounted to $1,096 million. The quantity of all mineral fuels decreased from that of the previous year; however, total mineral fuel value increased. Petroleum (crude), which accounted for 63.9 percent of the total value of all minerals, registered a 4.8 percent gain over 1970. Collectively, natural gasoline and cycle products and LP gases decreased in value 11.3 percent or about $10.5 million. The value of produced coal decreased slightly. A September announcement indicated that the Howe Coal Mine No. 1, near Heavener, Le Flore County, was closed for economic reasons and that it would not be reopened. Previously, in June, Howe had opened another slope mine, the Bokoshe No. 1, in northwestern Le Flore County.

NONMETALS

Nonmetals increased in value 5.3 percent over the previous year. Bentonite and stone showed a slight decrease in value while clays, gypsum, sand and gravel, cement, lime, volcanic ash, and tripoli increased in value. Total value of nonmetals production was 5.1 percent of the State total mineral value.

METALS

The value of metals increased 17.4 percent over 1970. Copper and silver were the only metals produced in 1971. Operations at the only zinc and lead mill in Oklahoma were discontinued in October 1970.

[1]Prepared December 29, 1971, in Division of Fossil Fuels, U.S. Bureau of Mines.

[2]Minerals specialist, U.S. Bureau of Mines, Washington, D.C.

TABLE 1.—MINERAL PRODUCTION IN OKLAHOMA[1]

Mineral	1970 Quantity	1970 Value (thousands)	1971 (preliminary) Quantity	1971 (preliminary) Value (thousands)
Clays[2] (thousand short tons)	769	$ 1,120	810	$ 1,179
Coal (bituminous) (thousand short tons)	2,427	15,211	2,365	15,136
Gypsum (thousand short tons)	874	2,616	945	2,855
Helium				
High-purity (million cubic feet)	149	5,214	150	5,250
Crude (million cubic feet)	245	1,935	240	2,880
Lead (recoverable content of ores, etc.) (short tons)	797	249	---	-----
Natural gas (million cubic feet)	1,594,943	248,811	1,594,000	251,852
Natural-gas liquids:				
LP gases (thousand 42-gallon barrels)	28,029	52,975	27,300	46,683
Natural gasoline and cycle products (thousand 42-gallon barrels)	14,813	39,933	14,646	35,736
Petroleum (crude) (thousand 42-gallon barrels)	223,574	712,419	218,900	746,449
Salt (thousand short tons)	13	78	W	W
Sand and gravel (thousand short tons)	5,675	7,258	5,867	7,520
Stone (thousand short tons)	18,177	23,701	17,086	22,753
Zinc (recoverable content of ores, etc.) (short tons)	2,650	812	-----	-----
Value of items that cannot be disclosed: bentonite, cement, copper, lime, salt (1971), silver, tripoli, and volcanic ash	XX	24,935	XX	29,214
Total	XX	$1,137,267	XX	$1,167,507

XX Not applicable. W Withheld.

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

[2] Excludes bentonite.

A Clastic Dike in Northwestern Arkansas

Royal H. Mapes[1]

INTRODUCTION

The only known dikes in northern Arkansas are composed of sedimentary rocks. In 1903 Newsom reported a fine-grained sandstone dike that cuts Carboniferous shales on the east bank of the Arkansas River, 2 miles south of Morrilton, Arkansas. Croneis (1930) noted several other occurrences in Carboniferous sediments. One, 5 or 6 miles north of Steve, Yell County, Arkansas, is described as fine-grained sandstone enclosed in shaly sandstone; the others are fine-grained, dark-brown sandstone dikes cutting coarse red sandstone in sec. 18, T. 8 N., R. 12 W., Faulkner County, Arkansas.

DESCRIPTION OF RECENTLY DISCOVERED DIKE

On the west bank of Chalybeate Creek (SW¼ NE¼ sec. 21, T. 21 N., R. 33 W.), Benton County, Arkansas, a clastic dike has been discovered (Mapes, 1968). The dike is composed of Chattanooga Shale and separates the hanging wall and the footwall of a small, unnamed normal fault in the St. Joe Limestone Member of the Boone Formation (fig. 1).

The Chattanooga Formation is characterized in the surrounding area by two members: the Sylamore Sandstone Member (Adams and Ulrich, 1905; Mapes, 1968) and an unnamed shale unit which Swanson and Landis (1962) referred to as the Chattanooga Shale (fig. 2). The Sylamore Sandstone Member overlies sediments of Ordovician age and is overlain by the unnamed shale unit. The quartz sandstone is usually well sorted, friable, and medium grained with secondary quartz overgrowths. The sandstone is reddish brown on case-hardened surfaces, but on freshly broken surfaces it is white. The unnamed shale unit is a black, fissile shale.

Swanson and Landis (1962) advanced a theory regarding the age and depositional history of the Chattanooga Formation. They regard the sand of the Sylamore Sandstone Member as a residuum from reworked older formations that was deposited at or near the shoreline. To the south, or deeper in the basin of deposition, the black mud of the Chattanooga Formation was deposited by a northward-

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The helpful criticism and advice of Ronald H. Konig, University of Arkansas, were invaluable in the preparation of this paper. Other persons who aided in this preparation are Thomas N. Taylor, University of Illinois at Chicago Circle, W. M. Furnish, University of Iowa, and W. Bruce Saunders, Bryn Mawr College.

advancing, time-transgressing sea. After a short period of local non-deposition and possible erosion, the St. Joe Limestone Member of the Boone Formation was deposited directly above the sand at some places and above the black shale at others.

Overlying the unnamed shale unit of the Chattanooga Formation is massive limestone of the St. Joe Member of the Boone Formation. The Boone also consists of one or more undifferentiated members composed of limestone and chert. The St. Joe Member is a fine- to medium-grained, gray, fossiliferous limestone which occasionally contains lenses of chert and/or argillaceous material.

The unnamed vertical fault associated with the clastic dike strikes

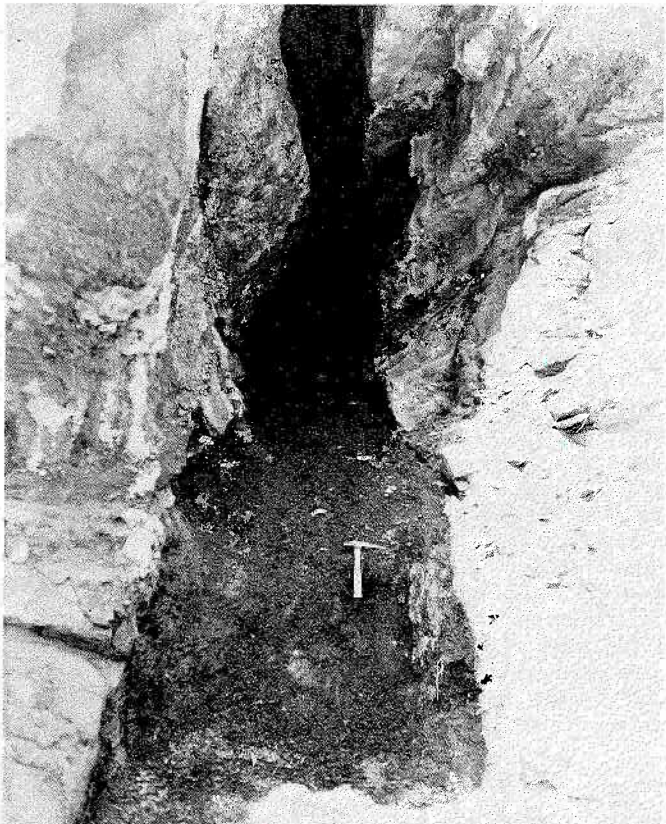

Figure 1. Contorted and sheared Chattanooga Shale intruded into limestone of the St. Joe Member of the Boone Formation.

N. 50° W. and has a throw of approximately 5 feet. A chert lens recognizable on both sides of the fault plane shows that the southwest side is downthrown.

The clastic dike pinches to knife-edge thickness at the top of the exposure and expands to approximately 6 feet at the St. Joe-Chattanooga contact below. This variation in thickness occurs over a vertical distance of about 35 feet. The length of the dike is unknown. Directly above the dike is a breccia zone composed of angular fragments of chert and limestone. These angular fragments are derived from undifferentiated members of the Boone Formation and are cemented by

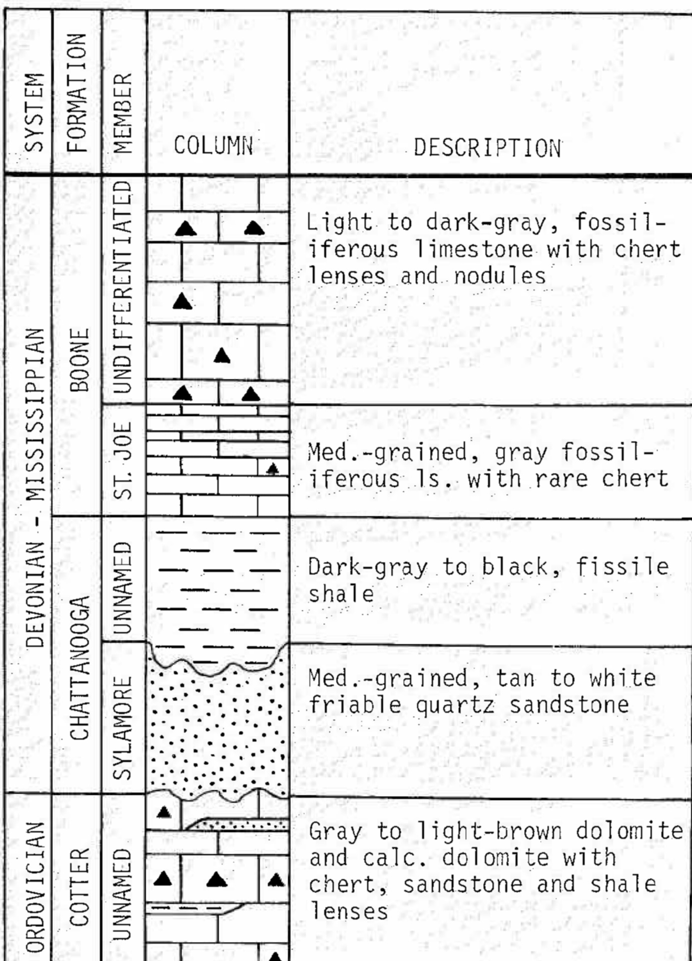

Figure 2. Generalized stratigraphic section of exposed rock units in the vicinity of Sulphur Springs, Benton County, Arkansas.

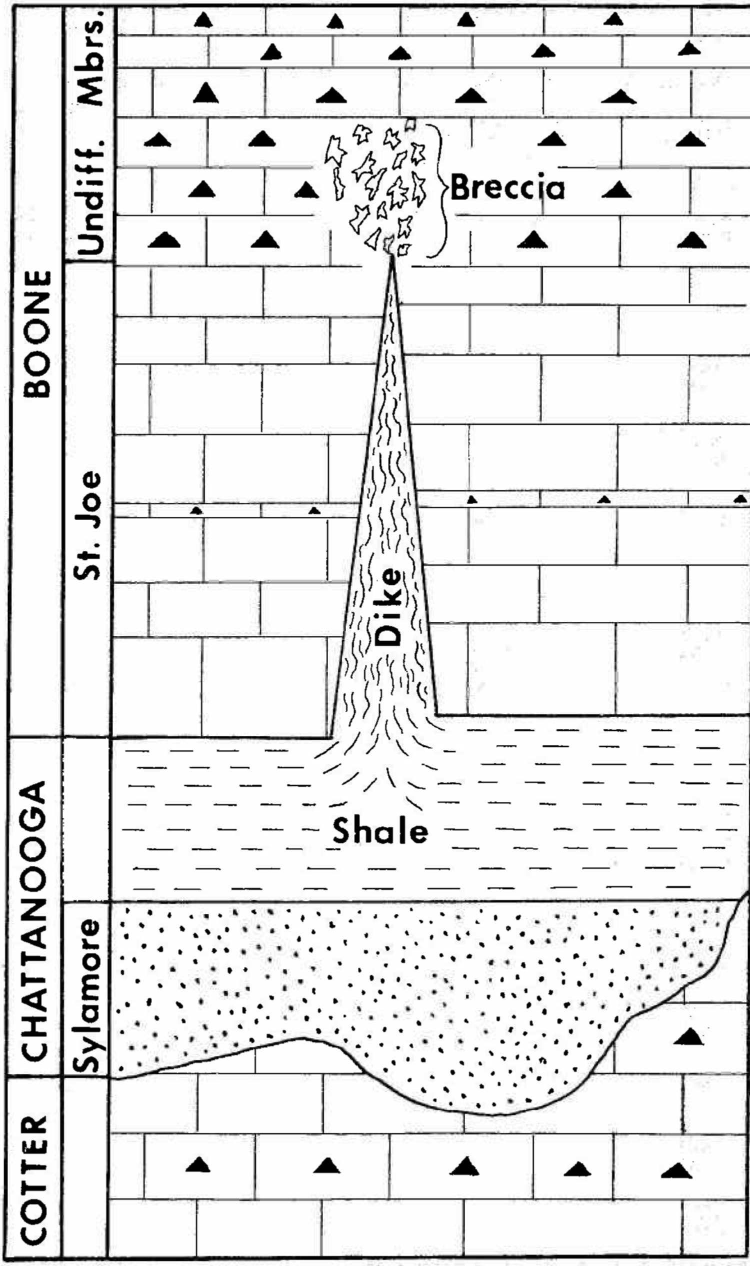

Figure 3. Generalized diagram of the clastic injection dike. (SW¼ NE¼ sec. 21, T. 21 N., R. 33 W.)

secondary calcite. The upper limit of this narrow breccia zone represents the dying out of the small fault vertically, and the base of the breccia zone also marks the upper limit of the clastic dike (fig. 3).

DISCUSSION

Newsom (1903) condensed the information known about clastic dikes by reviewing reports of other authors and summarized the ways in which clastic dikes can form. These methods are as follows:

(a) By injection of material from below along with water, petroleum, or petroleum residues. The injection has been due to hydrostatic pressure, pressure from overlying beds, pressure from gas, or combinations of these. Injection from below is the commonest method of their formation.

(b) By injection from above.

(c) By material dropping into open fissures from above with or without the aid of water.

(d) By material being let down gradually from above, synchronously with the slow formation (by leaching of water) of openings in underlying calcareous rocks.

(e) By deposition of sediments in fissures, partially or entirely under the sea.

Hills (1963) describes the formation of clastic injection dikes in a similar manner but adds that impervious strata are necessary to contain the pressure for injection.

The Chattanooga Shale dike on Chalybeate Creek apparently formed in the most common way, that is, the first way outlined by Newsom, as subsequently modified by Hills. The formation of this argillaceous injection dike required the Chattanooga mud to have been partly unconsolidated and to have retained enough water to enable it to behave like a semiplastic material after the overlying limestone of the St. Joe Member had been deposited. The weight of the overlying rock section produced fluid pore pressure within the underlying mud. Inasmuch as the mud directly overlaid the sand of the Sylamore Member, some fluid was undoubtedly lost to this porous and permeable underlying sand unit. As the mud adjacent to the sand lost water, it became more indurated, lost permeability, and trapped the remaining water in the upper portion of the formation. Fluids were probably not lost to the overlying limestone because of the impermeable nature of the accumulating St. Joe lime mud. When the limestone of the St. Joe Member fractured, the remaining water in the Chattanooga mud, which was still under pressure, moved into the fracture zone carrying with it the semiconsolidated Chattanooga mud.

Faulting of the fracture occurred simultaneously with injection because of fluid and clastic-material removal. As the fluids and argillaceous material moved into the fracture, the overlying limestone of the St. Joe Member settled differentially into the void created by the removal of underlying clastic material and fluids around the zone of injection. Apparently more fluid and argillaceous material were removed from the southwest side of the fracture than the northeast side, because the southwest side of the fault is downthrown.

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National Petroleum Council Releases Additional Energy Data

The National Petroleum Council (NPC), an industry advisory body to the Secretary of the Interior, has announced completion of the second volume of its initial appraisal of the energy outlook of the United States. The first volume, released last July, projects supply-demand relationships for the period 1971-85, assuming minimal changes in the economic climate of the energy industries and in government policies and regulations concerning those industries. Volume 2, just released, contains summaries of the detailed reports prepared by the group's subcommittees on energy demand, oil, gas, and other energy resources, based on data from the first volume. Charts indicating key findings of the individual fuel groups are included.

Both volumes represent the NPC's efforts in compliance with a broad request from the Department of the Interior, which calls for projection of the energy outlook in the Western Hemisphere as nearly to the end of the century as possible and emphasis on how Federal programs could effectively contribute to long-range national energy goals.

The study committee is chaired by John G. McLean, president of Continental Oil Company. Cochairman is the Hon. Hollis M. Dole, assistant secretary for mineral resources, Department of the Interior. The committee comprises more than 200 representatives of the oil, gas, coal, nuclear, and other energy-related fields as well as a number of financial experts.

Copies of the report are available from the National Petroleum Council, 1625 K Street, N.W., Washington, D.C. 20006, at a cost of $10. Prepayment is suggested.

Amchitka Blast Recorded at OU's Leonard Observatory

Jim Lawson[1] and Robert L. DuBois[2]

The 5-megaton Cannikin blast below Amchitka Island in the western Aleutians provided a rare opportunity for the newly designed seismograph system at The University of Oklahoma's Earth Sciences Observatory near Leonard, Tulsa County, Oklahoma, to produce exceptionally clear recordings of reflected longitudinal (P) waves. The underground nuclear blast of November 6, 1971, consisted of one sharp outward impulse which produced large P elastic waves. The shear (S) and surface waves produced by the complicated mechanism of a large earthquake frequently obscure reflected P phases, but the shear and surface waves are almost totally absent from a seismogram of an underground blast. Most seismograph systems, including the two standard systems at the Leonard Observatory, record only short-period waves or only long-period waves, and their magnification is sufficiently high to often be off scale during a large earthquake or blast. The new broadband seismograph system at Leonard is designed to record waves of all periods at three different gain levels for each direction of ground motion (vertical, north-south, and east-west).

Figure 1 shows the sharp initial arrival of the direct P wave 10 minutes and 5.8 seconds after the 4,150-mile-distant blast. The path of P, as indicated in figure 2, is slightly curved. The curvature of all the wave paths in figure 2 is due to refraction caused by changes in P velocity with depth. The P wave is extremely important for three reasons: the P arrival times from several different stations are the only usable data for reliably locating a blast or earthquake; an analysis of the first few seconds of the P arrival is usually sufficient to distinguish between an earthquake and a blast; and the amplitude of P is used in calculating one type of magnitude for the earthquake or blast. At Leonard, the vertical component of P from Cannikin had an amplitude of .001089 mm, signifying a magnitude of 7.1.

The next two phases recorded on the seismogram segment in figure 1 are PcP and PP, reflected off the earth's outer core and the surface, respectively. PP was reflected near British Columbia's Queen Charlotte Islands, which lie midway along the great circle path from Amchitka to Leonard. The wave motion was not channeled along the paths depicted in figure 2. Waves traveled outward in all directions from Cannikin; the outlined paths are simply the paths of the particular waves which were recorded at the observatory.

Thirty-eight minutes after the blast, a series of four short-period phases were recorded (fig. 3). These were the PKPPKP phases which,

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[2]Professor of geophysics and director of Leonard Earth Sciences Observatory, School of Geology and Geophysics, The University of Oklahoma, Norman, Oklahoma.

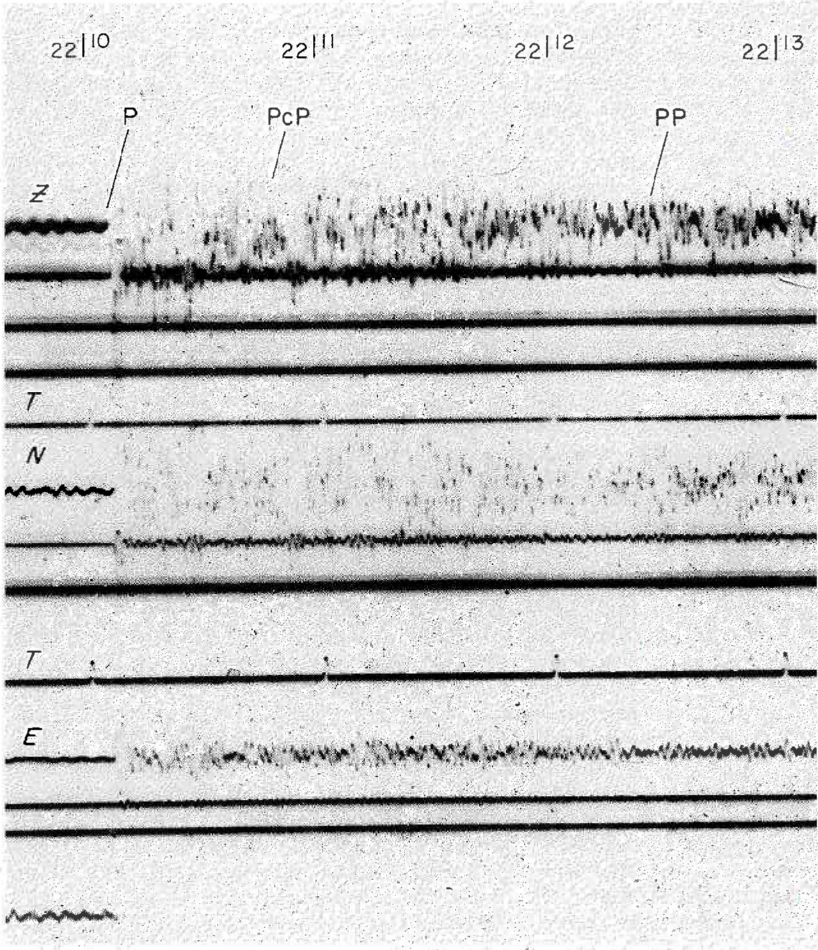

Figure 1. Broad-band seismograms of the P, PcP, and PP phases from the Cannikin blast. The traces marked Z, N, and E record vertical, north-south, and east-west ground motion, respectively. The magnification of ground motion on this illustration is $\times 19250$ for the Z and N traces. The magnification on trace E was lower, owing to a defective amplifier. The two traces immediately below Z, N, and E record Z, N, or E at 1/10 and 1/100 of the magnification of the Z, N, or E traces. The two traces marked T record minute marks from the master clock, with time increasing from left to right. The bottom trace, which is put off scale by the P arrival, is from a narrow-band, short-period vertical seismometer.

as traced in figure 2, passed entirely through the earth, were reflected at a point midway between the southern tip of Madagascar and the South Pole, and then traveled back through the globe to the OU observatory. The PKPPKP may take two slightly different paths through the core, accounting for two arrivals. Also, the PKPPKP waves may be reflected at the surface and at discontinuities (depths at which the wave velocity changes sharply) in the upper mantle. The reflections at discontinuities may account for the first two PKPPKP arrivals.

About the time the PKPPKP arrives, the traces begin a short series of gentle undulations of about 15 seconds' duration. These are

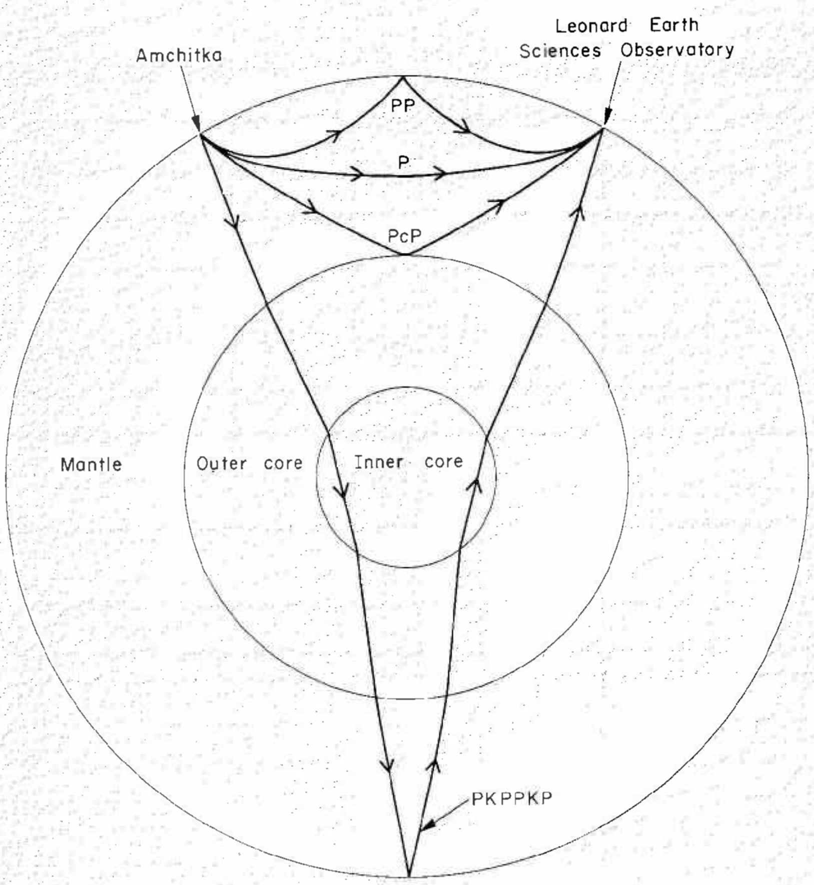

Figure 2. Cross section of the earth showing the paths of the P, PcP, PP, and PKPPKP phases from Amchitka to the OU Earth Sciences Observatory at Leonard. The letters PKPPKP indicate that this phase has six successive segments. P represents a mantle segment and K a core segment.

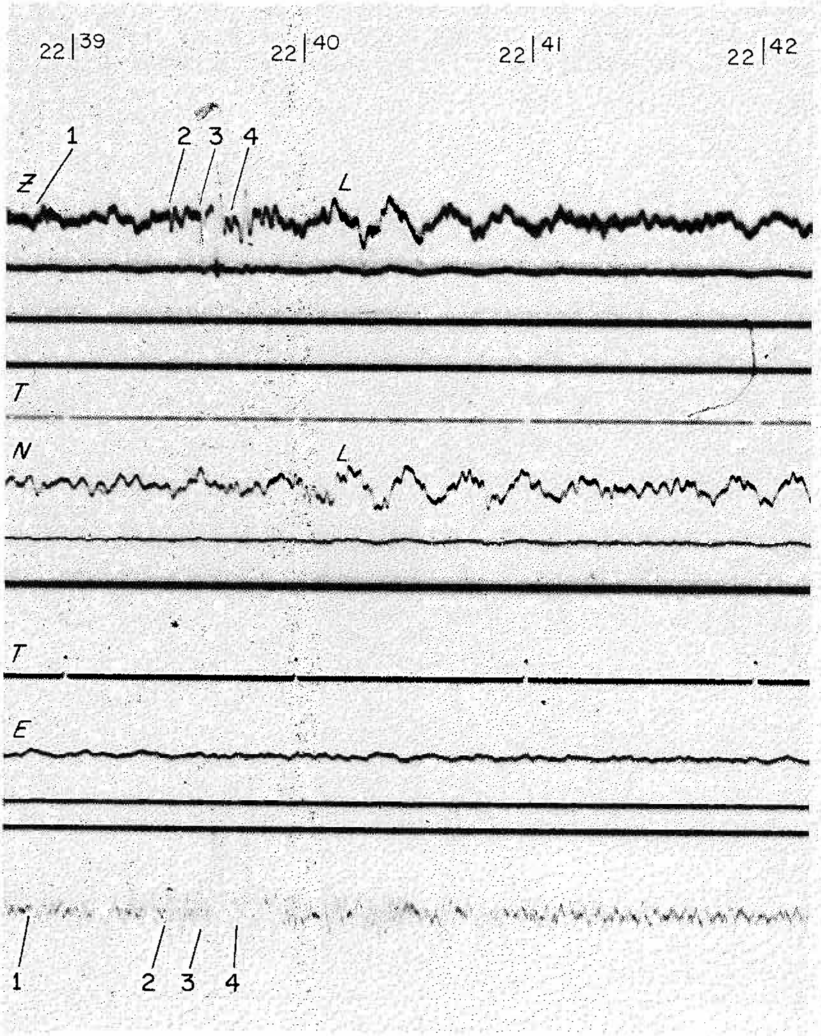

Figure 3. Broad-band seismograms of the Cannikin blast showing four PKPPKP arrivals (1, 2, 3, 4) and surface waves (L). The order of the traces is the same as in figure 1.

surface waves which have traveled at the earth's surface along the great circle path from the Aleutians to Oklahoma. The blast probably did not directly generate the surface waves, although they may have been generated from the impact and scattering of intense P waves at the surface near the blast. Another type of magnitude may be calculated from surface-wave amplitudes. Based on the amplitudes measured at Leonard, the surface-wave magnitude was 5.6. The discrepancy between the 7.1 P-wave magnitude and the 5.6 surface-wave magnitude is typical of both underground blasts and very deep earthquakes, neither of which generates appreciable surface-wave energy.

Vincent McKelvey New USGS Director

Dr. Vincent E. McKelvey was recently sworn in as the new director of the U.S. Geological Survey, succeeding Dr. William T. Pecora, who was named under secretary of the Interior Department last May. Dr. McKelvey was recommended for the position by the National Academy of Science, appointed by President Nixon, and confirmed by the Senate.

A career research scientist with the USGS since 1941, Dr. McKelvey received his B.A. with honors in geology from Syracuse University (1937) and his M.A. (1939) and Ph.D. (1947) from The University of Wisconsin. Most recently, he served as chief geologist for the USGS. In 1963, Dr. McKelvey received the Department of the Interior's highest award—the Distinguished Service Award.

Dr. McKelvey is internationally recognized for his studies of phosphate and uranium deposits, his investigations into problems related to long-range energy and mineral-resource needs, and his analyses and assessments of world seabed resources. He has served as a U.S. representative to the United Nations Seabeds Committee since its inception and, along with USGS colleague Dr. F. H. Wang, has compiled a set of maps showing the world distribution of seabed minerals.

Speaking of Dr. McKelvey's new appointment, Secretary of the Interior Rogers C. B. Morton stated that "never before has there been a greater need for mineral, energy, and water resources to support our Nation's economy and well-being and never before has there been such a need to avoid the degradation of our environment. To meet these needs, we look for evolving and expanding knowledge of the physical structure of the Earth, and to Dr. McKelvey and his colleagues to spearhead efforts to gain such knowledge."

Oklahoma Minerals Symposium—Final Announcement

A symposium entitled "Mineral-Development Opportunities in Oklahoma" will be presented Friday, March 10, 1972, at Norman in the Forum Building of the Oklahoma Center for Continuing Education on The University of Oklahoma campus. This event is being sponsored by the Oklahoma Industrial Development and Park Department, the Oklahoma Section of the American Institute of Professional Geologists, and the Oklahoma Geological Survey.

The 1-day symposium will review the mineral industry in Oklahoma, excluding petroleum and natural gas. Although Oklahoma ranks fourth in the Nation in value of mineral production ($1.168 billion in 1971), more than 90 percent of this total is derived from oil and gas. Thus more attention must be directed toward other minerals to broaden the economic base of the State's mineral production, a matter of some urgency in view of declining petroleum reserves. Mineral commodities considered to have potential for increased development include coal, clay, carbonate minerals, salt, dimension stone, gypsum, and several metallic minerals.

Seven papers will review the opportunities for investigating the extent, quality, and quantity of underdeveloped minerals known to exist in the State, with a view to establishing the economic feasibility of their production. The speakers, authorities in their fields, represent government agencies and industry.

Consulting geologists, company personnel, and other persons active or interested in the production of minerals in Oklahoma should profit considerably from this symposium. For further information, contact the Oklahoma Geological Survey, 830 Van Vleet Oval, Room 163, Norman, Oklahoma 73069.

Environmental Communication Workshop Scheduled

The St. Louis University School of Law and the Underwater Research Institute are sponsoring an Environmental Communication Workshop at St. Louis University the weekend of February 25, 1972. The purpose of the workshop is to bring together attorneys, scientists, and engineers in order to insure effective use of environmental research in American courts.

For additional information, inquiries should be addressed to: Environmental Communication Workshop, School of Law, St. Louis University, St. Louis, Missouri 63108.

Oklahoma Academy of Science Meets in Norman; Survey Director Selected as President-Elect

Oklahoma scientists met December 10-11, 1971, at the Oklahoma Center for Continuing Education on The University of Oklahoma campus in Norman for the 60th annual meeting of the Oklahoma Academy of Science.

William A. Carter of East Central State College, Ada, was named president of the organization for the upcoming year. The new president-elect is Charles J. Mankin, director of the Oklahoma Geological Survey and of OU's School of Geology and Geophysics. James R. Estes, associate professor of botany at OU, was chosen as secretary.

Other business conducted by the academy included honoring Florene C. Kelly, professor of microbiology at the OU Health Sciences Center, for her 20 years of service to the group; commending J. Teague Self, OU professor of zoology, for his faithfulness in acting as executive secretary for a number of years; and adopting a resolution expressing concern at the possible dumping of atomic wastes in Oklahoma.

The Oklahoma Academy of Science, an affiliate of the American Association for the Advancement of Science, will meet next year at Southwestern State College, Weatherford.

New Report Available on Geology, Engineering, and Oklahoma's Environment

The relation of geology and engineering to Oklahoma's environment is the subject of a recent publication of the Oklahoma Geological Survey in cooperation with the Oklahoma Academy of Science. The report comprises the proceedings of a symposium held at Stillwater on December 4, 1970, in conjunction with the annual Academy of Science meeting which was co-sponsored by Oklahoma State University. Co-chairmen of the symposium were John E. Stone, professor and head of the Department of Geology, and Phillip G. Manke, associate professor for the School of Civil Engineering, both of OSU.

Released as Annals No. 2 of the Oklahoma Academy of Science, the publication contains papers by eight Oklahoma scientists from OSU and Federal and State agencies. The Oklahoma Geological Survey is represented by Kenneth S. Johnson, whose contribution explores Oklahoma's mineral resources and mining-reclamation practices. Other papers embrace such diverse subjects as water pollution, foundation problems, erosion control, natural chloride pollution, highway-construction difficulties, and ground-water investigations.

The 70-page annals, entitled *Environmental Aspects of Geology and Engineering in Oklahoma,* may be ordered from the Oklahoma Geological Survey for $2.50 a copy.

OKLAHOMA ABSTRACTS

AAPG Regional Meeting, Mid-Continent Section
Oklahoma City, Oklahoma
September 29-October 1, 1971

The following abstracts are reprinted from the technical program and convention calendar for the regional meeting of the Mid-Continent Section of the American Association of Petroleum Geologists. Permission of the authors and of A. A. Meyerhoff, managing editor of the *Bulletin*, is gratefully acknowledged.

Surface Mineralogical and Chemical Evidence of Buried Hydrocarbons and the Vertical Migration of Oil and Gas, Cement Field, Oklahoma

TERRENCE J. DONOVAN, Department of Geology, Midwestern University, Wichita Falls, Texas

Striking mineralogical and chemical changes occur in surface outcrops of a Permian redbed sequence where they overlie in the oil productive parts of the prolific multi-reservoir oil accumulation of the Cement Anticline, Oklahoma. Gypsum beds of flank locations are altered abruptly to erosion-resistant carbonate rocks of the crestal Keechi hills. Associated sandstones, typically red and friable in the surrounding region, are altered to pink, yellow, and white on the flanks of the topographically expressed structure and to hard carbonate-cemented gray sandstone at the crest. The zone of mineralization extends to at least 2500 feet and is confined to sandstone intervals.

The carbonates have wide ranging isotopic compositions. They include at one extreme a light-carbon/heavy-oxygen carbonate precipitated from solutions concentrated by the evaporation of pore-waters into expanding vertically-migrating gases in the presence of much oxidized petroleum. At the other end of the spectrum is a "normal" oxygen cement precipitated from pore-waters whose solutes were concentrated by micropore filtration of water passing from sandstones to shales. The calcitized gypsum, exceptionally deficient in C^{13}, was formed by the reaction of gypsum with hydrocarbons according to reaction schemes such as:

a. $CaCO_4 + CH_4 \rightarrow CaS + 2H_2 + CO_2$

b. $CaS + CO_2 + H_2O \rightarrow CaCO_3 + H_2S$

There is a real regularity in the distribution of these carbonates

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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.

with calcitized gypsum and light-carbon/heavy-oxygen cements directly overlying petroleum-productive areas near regions of superior vertical fluid-communication (faults and a shallow buried major unconformity of restricted extent along the crest). Away from these avenues of concentrated leakage there is a systematic decrease in the influence of hydrocarbons on the isotopic composition of the carbonate cements.

Color changes in the sandstones, which also vary systematically with respect to position over the structure, are related to a loss of iron owing to reduction and dissolution.

Missourian age reservoirs which occur beneath the crestal unconformity appear to have supplied most of the leaked hydrocarbons. Crude from these stratigraphically discontinuous reservoirs located on the basinward flank of the structure is associated with relatively low salinity formation water and has been selectively depleted of gas and low-molecular-weight fractions through long-continued leakage.

Paraffinicity and salinity of waters systematically increases with decreasing depth. Water, vertically expelled along the crest during compaction and dehydration, was desalted in passing from sandstone to shales which resulted in cementing off large volumes of potential sandstone reservoirs that occur in the shallow Permian section in places over the crest but which are non-cemented and petroleum-productive down the flanks.

Abnormal-Subnormal Pressure Relationships in the Morrow Sands of Northwestern Oklahoma

ARTHUR F. BREEZE, Chevron Oil Field Research Company, La Habra, California 90631

A map showing the initial shut-in bottom-hole pressures of Morrow sand completions in the Anadarko Basin reveals a pressure transition from abnormally high to subnormal as one moves northwest across the Basin. The pressure transition does not coincide with easily recognizable geologic phenomena such as structure or sand thickness, and only slightly follows regional patterns of fluid migration. Because shale resistivity, travel time, and density values as taken from common well logs have proven to be sensitive indicators of compaction changes associated with overpressures in other areas, an explanation of the pressure transition was attempted by constructing plots of such data from representative wells. Although these plots indicated that undercompacted shale exists throughout the area, no evidence of compaction changes associated with pressure changes was noted. Likewise formation water salinity changes and geothermal gradient anomalies indicate a uniform layer of understressed sediments exists across the region. This is presently interpreted as evidence the overpressures are caused by a compaction phenomena, while a favorable stratigraphic environment and large salinity contrasts between permeable sands suggest that osmosis is a likely contributor to the pressure lowering observed in some areas.

A Groundwater Reconnaissance Study of the Upper Sugar Creek Watershed, Caddo County, Oklahoma

GARY WAYNE LEVINGS, Oklahoma State University, M.S. thesis, 1971

A general groundwater reconnaissance study of the Upper Sugar Creek Watershed, Caddo County, Oklahoma was conducted by correlating and combining the existing data, as well as supplementing it where necessary. The technique was to correlate aquifer characteristics from lower Sugar Creek alluvium to the Upper Sugar Creek Watershed. This was accomplished by establishing trends from comparison of the visual analysis made from cored samples to quantitative analysis by using the visual accumulation tube. Envelopes of grain size were developed to represent material which had been tested by the permeameter or evaluated by pump tests, thus aquifer constants could be applied to these materials. These were then applied to Sugar Creek by use of computer retrieval programs. A study of the hydrologic budget was made in which the amount of inflow, outflow, and change in storage were determined with the difference tentatively attributed to evapotranspiration. A lateral distribution of water quality samples was analyzed. Both groundwater and surface water data showed a direct correlation with the different geologic units in the area.

Geology and Geochemistry of the Mt. Antero Granite and Contiguous Units, Chaffee County, Colorado

ROBERT J. PULFREY, Oklahoma State University, M.S. thesis, 1971

The Mt. Antero region, which comprises the southeastern portion of the Sawatch Range, consists of gneisses, schists, and migmatite of Precambrian age, and Tertiary igneous rocks. The Tertiary igneous rocks include a gneissic quartz monzonite, an andesite, the Mt. Princeton quartz monzonite, a lamprophyre porphyry, the Raspberry Gulch rhyolite porphyry, and the Mt. Antero granite and its late-stage derivatives, locally covered by surficial Quaternary deposits. Particular attention is given to the Mt. Antero granite in this investigation as the petrology, petrography, petrogenesis, structure, geochemistry, and relationship to other rocks in the area were investigated.

The Mt. Antero granite is a homogenous leucogranite of Oligocene age (30.8 ± 1.1 million years, determined by the K-Ar method) that includes several late-stage cogeners, such as granite aplite dikes intruding the Mt. Antero granite and nearby Tertiary rocks, pegmatite bodies within the granite, and a fine-grained phase occurring as a marginal unit. In a nearby area, a pegmatite body, associated with the

Mt. Antero granite, contains significant molybdenum mineralization (Landes, 1934). Thus, the possibility of a more extensive deposit of molybdenum mineralization located within or associated with the Mt. Antero granite was investigated. Neither the geochemical survey results nor the geologic characteristics normally associated with the presence of molybdenum mineralization yielded evidence of molybdenum mineralization within or associated with the Mt. Antero granite.

Geology of Central Payne County, Oklahoma

JOHN SAWYER ROSS, Oklahoma State University, M.S. thesis, 1971

The study area, located in central Payne County, Oklahoma, includes all or part of Ts17, 18, 19, 20N and Rs2, 3, 4, 5E. Central Payne County is part of the transitional zone between the Central Redbed Plains and Northern Limestone Cuesta Plains physiographic regions. The area lies in the Cimarron River drainage basin, except for the extreme northern part which is in the Arkansas River drainage basin. Maximum elevation is 1,080 ft in the northwest, and minimum elevation is 780 ft in the southeast; average local relief is 100 ft. The major soil associations include the Kirkland-Zaneis, Vernon-Lucien, Doughtery-Teller-Vanoss, and Yahola-Port.

The age of surface rocks is Early Permian, and they become progressively younger in a westward direction. The stratigraphic section is almost entirely of Wolfcampian units. The section is characterized by red beds and a cyclic or repetitious sequence of shales, lenticular sandstones, and thin carbonates. In the lower 100 ft, the carbonates are continuous, fossiliferous limestone beds, representing transgressive units of conventional cycles. However, in the upper part, they are discontinuous, nonfossiliferous, nodular dolomites which formed during desiccation cycles. The lowermost and uppermost parts of the section are predominantly mudstone, but most of the formally named shale units are characterized by lenticular sandstones. The sandstones are fine- to very fine-grained, feldspar-rich quartzarenites, with an average paleocurrent trend of approximately N 50° W. The sandstones are present as single genetic units, 10 ft thick, multistoried complexes, 50 ft thick, and rather widespread multilateral units. They are characterized by an erosional base, although some with a gradational base are present in the lower part of the section.

Marine conditions with a relatively small influx of sand prevailed during deposition of much of the lower 100 ft of the section. In general, sand deposition and arid climatic conditions became increasingly prominent with time. The area then was part of the upper deltaic plain of a sand-rich, tide-dominated delta during regressions and the supratidal zone of a carbonate tidal flat during transgressions. Influx of sand decreased during Late Wolfcampian and Leonardian, and tidal flat conditions became more common.

The area is characterized by a west-dipping homocline, with an undulatory surface reflecting local structural noses which average 1 sq mi in areal extent. The average dip of the homocline is 40 to 50 ft/mi, but on some noses the dip is up to 100 ft/mi. Folds are largest and most numerous in the southern part, individual noses occur in groups or structural complexes, with areal extent of 10 to 35 sq mi. Local differential vertical movement is suggested by an increase in fold intensity with depth and two sets of extensional joints averaging N 50° W and N 60° E.

Petroleum is the major mineral resource, and some 41 million bbl and 60 billion cu ft of gas have been produced primarily from Pennsylvanian sandstone reservoirs in structural traps. Other resources include limestone for road metal, concrete aggregate, and rip-rap; sand for fills, asphalt, masonry purposes, and concrete; and clay for brick. Deposits of copper, silver, gold and radioactive minerals are present but their potential is uncertain. Potable ground water is best developed in terrace, floodplain deposits, and sandstones of the Eskridge, Garrison, Matfield, and Doyle shales. The thickness of fresh water is controlled by sandstone development, topography, and saline influent from the Cimarron River.

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Subsurface Stratigraphic Analysis, Morrow (Pennsylvanian) North Central Texas County, Oklahoma

JOHN W. BENTON, The University of Oklahoma, M.S. thesis, 1971

The Morrow Series in the area of the Postle Field, Township 5N, Range 13ECM, Texas County, Oklahoma is the subject of this paper. Numerous exploratory and development tests have been drilled in the area providing an abundance of subsurface data. This data was used to make a detailed study of the stratigraphy, geometry and petrography of the sediments which comprise the Morrow Series.

Maps and a cross section were prepared to illustrate structure, paleostructure and sandstone geometry found in the investigated area. An interpretation of the environments in which the Morrowan sediments were deposited was made based on this work. Lower Morrowan sediments were deposited in a transitional to marine environment. The area was uplifted and eroded. A drainage system cut channels in Lower Morrowan sediments. These channels were later filled with sandstones deposited in a fluvial environment which persisted in the area until Atokan time.

Thin sections were made from cores of the Upper Morrow sandstones and the long diameters of about 300 grains were measured from each thin-section. This data was grouped into 0.25 phi classes, corrected so that it would be equivalent to grain size data derived by conventional sieving and used to calculate statistical parameters. A plot of the mean diameter versus the standard deviation is the most effective combination in differentiating between river and beach sands according to Moiola and Weiser. Samples from all Upper Morrow sandstones fall in the river field of the above plot supporting the environmental interpretation based on subsurface mapping.

It is concluded that thin-section derived grain size data produce statistical parameters that can effectively be used to prepare environmentally sensitive plots.

The Size Distribution of Quartz in Mudrock

MARK G. R. FLEURY, The University of Oklahoma, M.S. thesis, 1971

Mudrock samples of various ages and from various locations in Oklahoma, New Mexico, and Arizona were carefully collected and subjected to ultrasonic disaggregation procedures. A sieving procedure employing both the standard sizes of Tyler sieves and micromesh sieves was found to be effective for the size distribution analysis of the quartz particles.

The composition of material larger than 10 microns, the practical lower limit for the employment of micro-mesh sieves by the procedures used in this study, was determined using a petrographic microscope. Material finer than 10 microns was subjected to x-ray diffraction analysis. The percentage of quartz was determined by an internal-standard method. All sieve size fractions were analyzed with a petrographic microscope to check the accuracy of size fractions and to determine the percentage of non-quartz grains.

The mean percentage of quartz in mudrocks was found to be 30.9 with a standard deviation of 8.0 percent. This result is consistent with that found by other workers. A linear regression relating the quartz size and percentage of quartz for the mudrock samples was significant at the 98.6 percent level.

$$Qz\ \% = 77.44 - 8.95\%\ (\text{Mean qz}) \pm 6.49\%$$

Extrapolation of this line resulted in a mean of zero percent quartz at 8.65 phi (2.5 microns) and 64.0 percent quartz for a medium-grained sandstone (1.5ϕ).

Folk's statistics were used to compute parameters of the size frequency distribution of quartz in each mudrock sample. The average size distribution has a graphic mean of 5.20 phi; inclusive graphic standard deviation of 1.01 phi; inclusive graphic skewness of -0.05; and graphic kurtosis of 1.02. The data define a Normally distributed, moderately to poorly sorted medium silt.

The average mudrock contains 13.0 percent sand-size quartz, 86.0 percent silt-size quartz, and 1.0 percent clay-size quartz. The standard deviations for these sizes are 10.6, 10,2, and 3.0 respectively.

New Theses Added to OU Geology Library

The following master's thesis and doctoral dissertation were recently added to The University of Oklahoma Geology and Geophysics Library:

Master of Science Thesis

A Geophysical study of the Eastern Equatorial Pacific, by Roger N. Anderson.

Doctoral Dissertation

Chitinozoa and Acritarcha of the Hamilton Group (Middle Devonian) of Southern Ontario, by Jocelyne A. Legault.

OKLAHOMA GEOLOGY NOTES

Volume 32 — February 1972 — Number 1

IN THIS ISSUE