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Cover Picture

AAPG-SEPM Annual Convention

Oklahoma City, April 22-25, 1968

The 53rd Annual Meeting of the *American Association of Petroleum Geologists* and the 42nd Annual Meeting of the *Society of Economic Paleotologists and Mineralogists* will be held jointly at Oklahoma City this month. The general chairman is Edwin P. Kerr, Jr., Mobil Oil Corporation. The Oklahoma City Geological Society is host.

The principal theme for the convention is "Geology of the Giants." The site and theme of the meeting are most appropriate, for Oklahoma has about a score of giant oil fields (among them the venerable Oklahoma City field), and it is the birthplace and headquarters of both the AAPG and the SEPM. The appropriateness of the occasion is further enhanced by the fact that the welcoming speech at the AAPG-SEPM joint session will be given by Governor Dewey F. Barlett, himself a geologist and a 20-year member of the Association. The keynote address will be delivered by Dean A. McGee, Kerr-McGee Corporation, and the introduction to the theme will be given by Michel T. Halbouty, consulting geologist and Past-President of the AAPG.

In addition to the principal theme, the technical program includes symposia, panel discussions, a colloquium, and field trips, covering a remarkably wide range of subjects, with "something for everybody." Of the 128 addresses and papers to be given by the two organizations, 12 are related to Oklahoma geology (see abstracts on pages 84-91).

The *AAPG Technical Program* will focus on the more famous multimillion-barrel oil fields and giant gas fields of the world. Many noted speakers will present valuable insight into the geologic phenomena that produced these giants. Among the 38 papers to be presented, 5 are on Oklahoma fields.

The *AAPG Fuels Symposium* is a new and significant addition to the technical program. Authorities will discuss the outlook for the various geologic sources of energy.

The *AAPG Research Committee Symposium* will have as its theme "The Role of Evaporites in Petroleum Exploration." The symposium will be complemented by a subsequent panel discussion.

The *SEPM Technical Program* will comprise two concurrent programs, each consisting of five half-day sessions. Two sessions will be devoted to the theme "Fossil Populations—Their Relation to Stratigraphy and Sedimentary Environment." The various other session topics include ancient and recent carbonates, sedimentary processes, mineralogy, geochemistry, stratigraphy, and paleontology. An informal meeting of fusulinid specialists is also scheduled. Fifty-three papers will be presented at the technical sessions; five of them are on Oklahoma.

The *SEPM Research Symposium* topic is "Environmental Aspects of Clay Minerals," with emphasis on the origin and distribution of representative clay minerals and the effects of such factors as source

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Bibliography and Index of Oklahoma Geology
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Prepared by Patricia W. Wood

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Bibliography

Amsden, T. W., 1967a, Chimneyhill Limestone sequence (Silurian), Hunton Group, Oklahoma, revised: Amer. Assoc. Petroleum Geologists, Bull., vol. 51, p. 937-942.

__________1967b, Silurian and Devonian strata in Oklahoma: Tulsa Geol. Soc., Digest, vol. 35, p. 25-34, 3 figs.

Amsden, T. W., Boucot, A. J., and Johnson, J. G., 1967, *Conchidium* and its separation from the subfamily Pentamerinae: Jour. Paleontology, vol. 41, p. 861-867.

Amsden, T. W., and Rowland, T. L., 1967a, Geologic maps and stratigraphic cross sections of Silurian strata and Lower Devonian formations in Oklahoma: Okla. Geol. Survey, Map GM-14, 1 sheet.

__________1967b, Résumé of Silurian and Devonian strata in the subsurface of Oklahoma: Tulsa Geol. Soc., Digest, vol. 35, p. 22-24, 1 fig.

Anderson, K. F., *see* Weaver, L. K., and Anderson, K. F.

Aresco, S. J., Janus, J. B., and Walker, F. E., 1966, Analyses of tipple and delivered samples of coal collected during the fiscal year 1965: U. S. Bur. Mines, Rept. Inv. 6792, 38 p.

Ash, R. D., *see* Klinger, R. R., and Ash, R. D.

Atkins, R. L., 1967, Oklahoma [exploration], *in* International oil and gas development, review 1966: Internat. Oil Scouts Assoc., vol. 37, pt. 1, p. 273-292, 4 tables.

Baggett, B. G., *see* Culver, J. R., Bain, W. R., and Baggett, B. G.

Bain, W. R., *see* Culver, J. R., Bain, W. R., and Baggett, B. G.

Barbat, W. N., 1967, Crude-oil correlations and their role in exploration: Amer. Assoc. Petroleum Geologists, Bull., vol. 51, p. 1255-1292. Discusses stages of oil migration from Oklahoma into Kansas.

Barnes, V. E., 1967, Sherman quadrangle: Texas, Univ., Bur. Econ. Geology, Geol. Atlas Texas, map, scale 1:250,000. Includes part of southern Oklahoma.

Baskett, K. R., *see* Johnston, K. H., and Baskett, K. R.

Boardman, R. S., *see* Merida, J. E., and Boardman, R. S.

Boucot, A. J., and Johnson, J. G., 1967a, Paleogeography and correlation of Appalachian Province Lower Devonian sedimentary rocks: Tulsa Geol. Soc., Digest, vol. 35, p. 35-87, 5 figs., 2 pls., 5 tables. Oklahoma section discussed.

__________1967b, Species and distribution of *Coelospira* (Brachiopoda): Jour. Paleontology, vol. 41, p. 1226-1242.

Boucot, A. J., *see* Amsden, T. W., Boucot, A. J., and Johnson, J. G.

Bowsher, A. L., 1967, The Devonian System of New Mexico: Tulsa Geol. Soc., Digest, vol. 35, p. 259-276, 7 figs. Oklahoma section discussed.

Bowsher, A. L., *see* Walthall, B. H., and Bowsher, A. L.

Branson, C. C., 1967a, Frank Buttram, 1886-1966: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 23.

__________1967b, *Caryocaris* removed from Oklahoma faunal list: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 44.

__________1967c, Geographic and stratigraphic distribution of *Oklahomacrinus*: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 86.

__________1967d, Fresh-water sponges of Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 101-104, 1 pl.

__________1967e, Progress in topographic mapping in Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 131-134, 2 figs.

__________1967f, Trace elements in Oklahoma coals [review]: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 150.

__________1967g, Protest against names for trace fossils: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 151.

__________1967h, Geologic publications by Oklahoma organizations: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 195-200.

Branson, C. C., Jordan, Louise, and Roberts, J. F., 1967, Index to geologic mapping in Oklahoma—Supplement 2: Okla. Geol. Survey, 2 sheets. Contains Map I-B, Surface mapping, 1901-1966, and Map VII, Subsurface mapping, 1964-1966.

Brett, G. W., *see* Weld, B. A., Griffin, M. S., and Brett, G. W.

Briggs, G., and Cline, L. M., 1967, Paleocurrents and source areas of Late Paleozoic sediments of the Ouachita Mountains, southeastern Oklahoma: Jour. Sed. Petrology, vol. 37, p. 985-1000.

Brinlee, R. C., *see* Frie, J. W., Brinlee, R. C., and Graft, R. D.; *also* Mobley, H. L., and Brinlee, R. C.

Brown, A. R., *see* Logsdon, Truman, and Brown, A. R.

Brown, H. A., 1967, Structural control of Canadian River in western Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 135-149, 6 figs., 1 table. Reprinted in Oklahoma City Geol. Soc., Shale Shaker, vol. 18, p. 42-50.

Buchanan, R. S., 1959, New activity in southwest Kansas-Oklahoma Panhandle: World Oil, vol. 156, no. 6, p. 113-116.

Burbridge, P. P., 1967, *see* Felix, C. J., and Burbridge, P. P.

Campbell, K. S. W., 1967a, Geographic and stratigraphic implications of a study of the Henryhouse trilobite fauna: Tulsa Geol. Soc., Digest, vol. 35, p. 253-258, 2 figs.

__________1967b, Trilobites of the Henryhouse Formation (Silurian) in Oklahoma: Okla. Geol. Survey, Bull. 115, 68 p., 7 text-figs., 19 plates.

Caplan, W. M., *see* Wise, O. A., and Caplan, W. M.

Chenoweth, P. A., 1967, Unconformity analysis: Amer. Assoc. Petroleum Geologists, Bull., vol. 51, p. 4-27, 20 figs.; addendum, p. 623. Includes examples from Oklahoma stratigraphy.

Cline, L. M., 1966, Late Paleozoic rocks of Ouachita Mountains, a flysch facies: Kans. Geol. Soc., 29th Field Conf. (Ft. Smith, Ark.; Nov., 1966), Guidebook, p. 91-111.

Cline, L. M., *see* Briggs, G., and Cline, L. M.

Collins, A. G., and Egleson, G. C., 1967, Iodide abundance in oilfield brines in Oklahoma: Science, vol. 156, no. 3777 (May 19), p. 934-935, 1 fig., 1 table.

Coons, R. L., Woollard, G. P., and Hershey, Garland, 1967, Structural significance and analysis of Mid-Continent gravity high: Amer. Assoc. Petroleum Geologists. Bull., vol. 51, p. 2381-2399.

Culver, J. R., Bain, W. R., and Baggett, B. G., 1967, Soil survey of Kay County, Oklahoma: U. S. Dept. Agr. and Okla. Agr. Expt. Sta., 86 p., 25 figs., 10 tables, 83 maps.

DeGreer, W. D., *see* Redding, H. D., DeGreer, W. D., and Huber, C. A.

Denison, R. E., *see* Muehlberger, W. R., Denison, R. E., and Lidiak, E. G.

Desai, A. A., *see* Hagni, R. D., and Desai, A. A.

Dickey, P. A., *see* Koinm, D. N., and Dickey, P. A.

Downey, M. W., *see* Edwards, A. R., and Downey, M. W.

Edwards, A. R., and Downey, M. W., 1967, Cross section, Oklahoma, *pl. 1 of* Stratigraphic cross section of Paleozoic rocks Oklahoma to Saskatchewan: Amer. Assoc. Petroleum Geologists, Cross Sec. Pub. 5, p. 1-3.

Egleson, G. C., *see* Collins, A. G., and Egleson, G. C.

Felix, C. J., and Burbridge, P. P., 1967, Palynology of the Springer Formation of southern Oklahoma: Palaeontology, vol. 10, p. 349-425, 14 pls.

Feray, D. E., *see* Oetking, Philip, Feray, D. E., and Renfro, H. B.

Finch, W. I., 1967, Geology of epigenetic uranium deposits in sandstone in the U. S.: U. S. Geol. Survey, Prof. Paper 538, 121 p., 2 pls., 12 figs., 9 tables. Contains uranium mineral occurrences in Oklahoma sandstones.

Fisher, W. L., and Rodda, P. U., 1966, Nomenclature revision of basal Cretaceous rocks between the Colorado and Red Rivers, Texas: Texas, Univ., Bur. Econ. Geology, Rept. Inv., 58, 20 p.

__________1967, Lower Cretaceous sands of Texas: Stratigraphy and resources: Texas, Univ., Bur. Econ. Geology, Rept. Inv. 59, 118 p.

Flawn, P. T., et al., 1967, Basement map of North America: between latitudes 24° and 60°: Amer. Assoc. Petroleum Geologists and U. S. Geol. Survey, 1 sheet.

Frederick, W. S., 1967, Technology for detecting, defining, mapping doubtful zones should precede drilling: World Oil, vol. 164, no. 4, p. 74-77, 6 figs. Discussion of Anadarko basin.

Frie, J. W., Brinlee, R. C., and Graft, R. D., 1967, Soil survey of Greer County, Oklahoma: U. S. Dept. Agriculture, Soil Conserv. Serv., and Okla. Agr. Expt. Sta., 58 p.

Fronjosa, E., and Menzie, D. E., 1967, A study of Oklahoma waterflood statistics: Production Monthly, vol. 31, p. 16-19.

Gafford, E. L., Jr., 1967, Scolecodont carriers from the Lower Permian of Kansas: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 230-232. Specimens from the Fort Riley Limestone which crops out in north-central Oklahoma.

Ganser, R. W., 1967, Recent delta growth in the Butcher Pen, Lake Texoma, Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 232-233.

Glaenzer, J., *see* Walters, J. G., Ortuglio, C., and Glaenzer, J.

Graffham, A. A., 1967, Type locality of *Cordania falcata*: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 14-15, 1 fig.

Graft, R. D., *see* Frie, J. W., Brinlee, R. C., and Graft, R. D.

Gray, Fenton, *see* Stahnke, Clyde, and Gray, Fenton.

Grégoire, Charles, 1966, On organic remains in shells of Paleozoic and Mesozoic cephalopods (nautiloids and ammonoids): Institut Royal des Sciences naturelles de Belgique, Bull., vol. 42, 36 p. Figured specimens from the Upper Pennsylvanian Buckhorn asphalt, Sulphur, Oklahoma.

Griffin, M. S., *see* Weld, B. A., Griffin, M. S., and Brett, G. W.

Hagni, R. D., and Desai, A. A., 1966, Solution thinning of the M bed host rock limestone in the Tri-State district, Missouri, Kansas, Oklahoma: Econ. Geology, vol. 61, p. 1436-1442.

Ham, W. E., 1967, Basement rocks and structural evolution of southern Oklahoma: A summary, *in* The structure and igneous rocks of the Wichita Mountains, Oklahoma: Geol. Soc. America, South-Central Sec., 1st Ann. Mtg., Guidebook, p. 2-13.

Ham, W. E., and Wilson, J. L., 1967, Paleozoic epeirogeny and orogeny in the central United States: Amer. Jour. Science, vol. 265, p. 332-407, 12 figs., 1 table.

Ham, W. E., *see* McDougal, R. B., and Ham, W. E.; *also* Toomey, D. F., and Ham, W. E.

Hanke, H. W., 1967, Subsurface stratigraphic analysis of the Cherokee Group in north-central Creek County: Oklahoma City Geol. Soc., Shale Shaker, vol. 17, p. 150-167.

Harlton, B. H., 1966, Reply [to discussion by R. S. Tarr, 1966, of "Relation of buried Tishomingo uplift to Ardmore basin and Ouachita Mountains, southeastern Oklahoma"]: Amer. Assoc. Petroleum Geologists, Bull., vol. 50, p. 1519.

Hart, D. L., Jr., *see* Wood, P. R., and Hart, D. L., Jr.

Hartner, F. E., *see* Walker, F. E., and Hartner, F. E.

Hattin, D. E., 1967, Permian ophiuroids from northern Oklahoma: Jour. Paleontology, vol. 41, p. 489-491.

Hayes, C. J. (principal investigator), 1967, Engineering classification of geologic materials and (related soils), Division four: Research and Devel. Div., Okla. Hwy. Dept. and U. S. Bur. Public Roads, 284 p., 9 figs., 7 charts.

Hedlund, R. W., *see* Upshaw, C. F., and Hedlund, R. W.

Hendricks, L., 1967, Comanchean stratigraphy of North Texas, *in* Comanchean (Lower Cretaceous) stratigraphy and paleontology of Texas: Soc. Econ. Paleontologists Mineralogists, Permian Basin Sec., Pub. 67-68, p. 50-63. Includes part of southern Oklahoma.

Hershey, Garland, *see* Coons, R. L., Woollard, G. P., and Hershey, Garland.

Hill, J. G., 1966, Petrology and provenance of sandstones of the Stanley Group (Mississippian), southern Ouachita Mountains, Oklahoma: Kans. Geol. Soc., 29th Field Conf. (Ft. Smith, Ark.; Nov., 1966), Guidebook, p. 112-124.

Hilpman, P. L., 1967, Devonian stratigraphy in Kansas; a progress report: Tulsa Geol. Soc., Digest, vol. 35, p. 88-98, 10 figs.
Holbrook, D. F., *see* Sterling, P. J., Stone, C. G., and Holbrook, D. F.
Howe, Jane, 1967, Bibliography of Oklahoma geology, 1966: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 67-80.
Huber, C. A., *see* Redding, H. D., DeGreer, W. D., and Huber, C. A.
Hunter, H. E., 1967, Raggedy Mountain Gabbro Group, *in* The structure and igneous rocks of the Wichita Mountains, Oklahoma: Geol. Soc. America, South-Central Sec., 1st Ann. Mtg., Guidebook, p. 34-41.
Ireland, H. A., 1967, Regional depositional basins and correlation of Siluro-Devonian beds using arenaceous Foraminifera and acid residues: Tulsa Geol. Soc., Digest, vol. 35, p. 99-118, 6 figs., 1 table. Oklahoma section discussed.
Janus, J. B., *see* Aresco, S. J., Janus, J. B., and Walker, F. E.
Johnson, J. G., *see* Amsden, T. W., Boucot, A. J., and Johnson, J. G.; *also* Boucot, A. J., and Johnson, J. G.
Johnston, K. H., and Baskett, K. R., 1966, A thermal-recovery project and two waterflood projects in Carter, Garvin, and Stephens Counties, Oklahoma, 1966: U. S. Bur. Mines, Inf. Circ. 8311, 32 p.
Jordan, Louise, 1967, Geology of Oklahoma—A summary [reprint]: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 215-228. Reprinted with slight modification from the Proceedings of the Geophysical Society of Tulsa, vol. 8, 1961-1964.
Jordan, Louise, *see* Branson, C. C., Jordan, Louise, and Roberts, J. F.
Kerns, R. L., Jr., 1967a, Pickeringite in Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 112-120, 3 figs., 2 tables.
__________1967b, Chemical analyses by x-ray fluorescence: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 201-210, 3 figs., 3 tables. Beavers Bend illite analyzed.
Keroher, G. C., 1967, Some uses of fossil names in the evolution of stratigraphic nomenclature in the Mid-Continent: Kans., Univ., Dept. Geology, Spec. Pub. 2, p. 479-502.
Klapper, Gilbert, and Ziegler, Willi, 1967, Evolutionary development of the *Icriodus latericrescens* group (Conodonta) in the Devonian of Europe and North America: Palaeontografica, Abt. A, vol. 127, p. 68-83. Some specimens of *I. latericrescens huddlei* correlative with material from the Turkey Creek inlier, Marshall County.
Klinger, R. R., and Ash, R. D., 1967, Geologic studies can project stratigraphic trap trends: World Oil, vol. 164, no. 2, p. 65-70. Stratigraphic traps in Chester- and Morrow-aged rocks in the Anadarko basin.
Koenig, J. W., 1967, The Ozark uplift and Midcontinent Silurian and Devonian stratigraphy: Tulsa Geol. Soc., Digest, vol. 35, p. 119-147, 13 figs., list of wells.
Koinm, D. N., and Dickey, P. A., 1967, Growth faulting in McAlester basin of Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 51, p. 710-719.
Koontz, Terry, 1967, Petroleum geology of McIntosh County, *part II of* Geology and petroleum of McIntosh County, Oklahoma: Okla. Geol. Survey, Bull. 111, p. 50-65, figs. 9-13, pls. 3, 4.

Kornfeld, J. A., 1967a, Arkoma basin lateral conquers terrain problems in strip mining area: Pipeline Construction, vol. 32, no. 13, p. 23-24, 48.

__________1967b, Oklahoma's new 4-mile-deep tests grab spotlight in Anadarko basin: World Oil, vol. 164, no. 4, 127-135.

Ku, Chao-Cheng, Sun, Stanley, Soffel, Heinrich, and Scharon, LeRoy, 1967, Paleomagnetism of the basement rocks, Wichita Mountains, Oklahoma: Jour. Geophys. Research, vol. 72, p. 731-737.

Kunsman, H. S., 1967, Hunton oil and gas fields, Arkansas, Oklahoma, and Panhandle Texas: Tulsa Geol. Soc., Digest, vol. 35, p. 165-197, 3 tables, 1 map, list of Hunton oil and gas wells.

Lane, H. R., 1967, Uppermost Mississippian and Lower Pennsylvanian conodonts from the type Morrowan region, Arkansas: Jour. Paleontology, vol. 41, p. 920-942.

Lidiak, E. G., *see* Muehlberger, W. R., Denison, R. E., and Lidiak, E. G.

Logsdon, Truman, and Brown, A. R., 1967, "Hunton"—Hottest play in Oklahoma: Oklahoma City Geol. Soc., Shale Shaker, vol. 18, p. 63-70.

Lundin, R. F., 1967, Ostracoda and stratigraphy of the Henryhouse and Haragan Formations in south-central Oklahoma: Tulsa Geol. Soc., Digest, vol. 35, p. 198-208, 7 figs.

MacLachlan, M. E., 1967, Paleotectonic investigations of the Permian System in the United States: Oklahoma: U. S. Geol. Survey, Prof. Paper 515-E, p. 81-92, 1 pl.

McDougal, R. B., 1967, The mineral industry of Oklahoma in 1966 (Preliminary): Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 19-22, 1 table.

McDougal, R. B., and Ham, W. E., 1967, The mineral industry of Oklahoma, *in* Minerals yearbook 1965, vol. 3, Area reports: Domestic: U. S. Bur. Mines, p. 641-664, 1 fig.

McGinnis, H. J., 1967, The osteology of *Phlegethontia,* a Carboniferous and Permian aistopod amphibian: Calif., Univ., Pubs. Geol. Sciences, vol. 71, 49 p. Braincase and vertebrae from Ft. Sill (in Arbuckle ls.) extends range of Aistopoda into Early Permian.

McGlasson, E. H., 1967, The Siluro-Devonian of West Texas and southeast New Mexico: Tulsa Geol. Soc., Digest, vol. 35, p. 148-164, 14 figs. Oklahoma section discussed.

McKinney, C. M., and Shelton, E. M., 1967, Sulfur content of crude oils of the free world: U. S. Bur. Mines, Rept. Inv. 7059, 37 p.

Menzie, D. E., *see* Fronjosa, E., and Menzie, D. E.

Merida, J. E., and Boardman, R. S., 1967, The use of Paleozoic Bryozoa from well cuttings: Jour. Paleontology, vol. 41, p. 763-765, pl. 100. Bryozoa studied from well cuttings from the Bromide Fm. (Mid. Ord.), southern Oklahoma.

Merritt, C. A., 1967a, Mt. Scott Granite, *in* The structure and igneous rocks of the Wichita Mountains, Oklahoma: Geol. Soc. America, South-Central Sec., 1st Ann. Mtg., Guidebook, p. 22-33.

__________1967b, Names and relative ages of granites and rhyolites in the Wichita Mountains, Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 45-53, 2 figs.

Mesnard, M. L. (ed.), 1967, The oil producing industry in your state: Tulsa, Indep. Petroleum Assoc. America, 114 p.
Meyers, W. C., 1967, Palynological correlation of the Henryetta coal, Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 34-38, 2 figs.
Miller, R. D., *see* Moore, B. J., Miller, R. D., and Shrewsbury, R. D.
Miller, T. H., 1967, Techniques for processing and photographing chitinozoans: Kans., Univ., Paleont. Contr., Paper 21, 10 p., 1 fig., 4 pls.
Mobley, H. L., and Brinlee, R. C., Soil survey of Comanche County, Oklahoma: U. S. Dept. Agriculture, Soil Conserv. Serv. and Okla. Agr. Expt. Sta., 58 p., 20 figs., 9 tables, 47 maps.
Moore, B. J., and Shrewsbury, R. D., 1967, Analyses of natural gases, 1966: U. S. Bur. Mines, Inf. Circ. 8302, 130 p., 4 tables.
Moore, B. J., Miller, R. D., and Shrewsbury, R. D., 1966, Analyses of natural gases of the United States, 1964: U. S. Bur. Mines, Inf. Circ. 8302, 144 p., 1 fig. Analyses of some helium-bearing natural gases from Oklahoma.
Muehlberger, W. R., Denison, R. E., and Lidiak, E. G., 1967, Basement rocks in continental interior of United States: Amer. Assoc. Petroleum Geologists, Bull., vol. 51, p. 2351-2380, 13 figs.
Nicholson, Alex., 1967, Louise Jordan, 1908-1966: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 3-8.
Oakes, M. C., 1967, Geology and mineral resources of McIntosh County, *pt. I of* Geology and petroleum of McIntosh County, Oklahoma: Okla. Geol. Survey, Bull. 111, p. 5-49, 68-85, figs. 1-8, pls. 1, 2.
Odom, I. E., 1967, Clay fabric and its relation to structural properties in Mid-Continent Pennsylvanian sediments: Jour. Sed. Petrology, vol. 37, p. 610-623.
Oetking, Philip, Feray, D. E., and Renfro, H. B., 1966, Geological highway map of the Mid-Continent region—Kansas, Oklahoma, Missouri, Arkansas: Amer. Assoc. Petroleum Geologists, U. S. Geol. Highway Map Ser., Map 1, scale 1:1,875,000, sections, text.
Oklahoma Geological Survey, 1967a, Résumé of new nomenclature published in Oklahoma Geology Notes, January 1966 through December 1966: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 39.
__________1967b, Bibliography of Louise Jordan: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 107-111.
Oklahoma Water Resources Board, 1967, Oklahoma's water resources, 1967: Oklahoma City, Okla. Water Resources Board, 62 p., 10 illus., 3 tables.
Olson, E. C., 1967, Early Permian vertebrates of Oklahoma: Okla. Geol. Survey, Circ. 74, 111 p., 12 figs., 3 pls.
Ortuglio, C., *see* Walters, J. G., Ortuglio, C., and Glaenzer, J.
Padgett, Ward, 1967, 58th Annual report, Chief Mine Inspector: Okla., Dept. Mines, 55 p., 23 tables.
Peterson, E. C., 1966, Titanium resources of the United States: U. S. Bur. Mines, Inf. Circ. 8290, 65 p., 17 figs.

Qualls, B. R., *see* Tryggvason, E., and Qualls, B. R.
Redding, H. D., DeGreer, W. D., and Huber, C. A., 1967, Anadarko's deep play challenge to drillers: Oil and Gas Jour., vol. 65, no. 20, p. 84-86, 88.
Renfro, H. B., *see* Oetking, Philip, Feray, D. E., and Renfro, H. B.
Riley, L. R., 1966, The challenge of deep exploration—the Chitwood pool, Grady County, Oklahoma: Oklahoma City Geol. Soc., Shale Shaker, vol. 17, p. 66-73.
Roberts, J. F., 1967a, New Oklahoma core catalog issued: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 87.
__________1967b, Statistics of Oklahoma's petroleum industry, 1966: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 123-130, 4 figs., 4 tables.
Roberts, J. F., *see* Branson, C. C., Jordan, Louise, and Roberts, J. F.
Rodda, P. U., *see* Fisher, W. L., and Rodda, P. U.
Rowland, T. L., *see* Amsden, T. W., and Rowland, T. L.
Scharon, LeRoy, *see* Ku, Chao-Cheng, Sun, Stanley, Soffel, Heinrich, and Scharon, LeRoy.
Schemel, M. P., 1967a, Note on the Laverne Formation: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 15-16.
__________1967b, Investigation of selected Lower Pliocene and Pleistocene deposits in northwestern Oklahoma: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 24-33, 1 fig., 1 table, 9 meas. secs.
Schramm, M. W., Jr., 1967, Application of trend analysis to pre-Morrow surface, southeastern Hugoton embayment area: Oklahoma City Geol. Soc., Shale Shaker, vol. 18, no. 2, p. 27-33.
Sellars, R. T., Jr., 1967, The Siluro-Devonian rocks of the Ouachita Mountains: Tulsa Geol. Soc., Digest, vol. 35, p. 231-241, 1 fig.
Shaw, N. G., 1967, Cheilostomata from Gulfian (Upper Cretaceous) rocks of southwestern Arkansas: Jour. Paleontology, vol. 41, p. 1393-1432, 4 pls., 16 text-figs. Descriptions of several Oklahoma specimens.
Sheffey, N. B., *see* Zubovic, Peter, Sheffey, N. B., and Stadnichenko, Taisia.
Shelton, E. M., *see* McKinney, C. M., and Shelton, E. M.
Shrewsbury, R. D., *see* Moore, B. J., Miller, R. D., and Shrewsbury, R. D.; *also* Moore, B. J., and Shrewsbury, R. D.
Skvarla, J. J., *see* Wilson, L. R., and Skvarla, J. J.
Smith, Russell (ed.), 1967, Stratigraphic cross section of Paleozoic rocks Oklahoma to Saskatchewan: Amer. Assoc. Petroleum Geologists, Cross Sec. Pub. 5, 23 p., 1 fig., 6 pls. Plate 1 is a cross section of Oklahoma, *cited under* Edwards, A. R., and Downey, M. W.
Soffel, Heinrich, *see* Ku, Chao-Cheng, Sun, Stanley, Soffel, Heinrich, and Scharon, LeRoy.
Stadnichenko, Taisia, *see* Zubovic, Peter, Sheffey, N. B., and Stadnichenko, Taisia.
Stahnke, Clyde, and Gray, Fenton, 1966, A mineralogical study of thick-surfaced Brunizemic soils: Okla. Acad. Science, Proc. 1965, vol. 46, p. 72, 2 tables.

Sterling, P. J., Stone, C. G., and Holbrook, D. F., 1966, General geology of eastern Ouachita Mountains, Arkansas: Kans. Geol. Soc., 29th Field Conf. (Ft. Sill, Ark.; Nov., 1966), Guidebook, p. 177-194.

Stiles, M. F., Jr. (chm.), 1967, Oklahoma [production], *in* International oil and gas development, review 1966: Internat. Oil Scouts Assoc., vol. 37, pt. 2, p. 277-349.

Stone, C. G., 1966, General geology of the eastern frontal Ouachita Mountains and southeastern Arkansas Valley, Arkansas: Kans. Geol. Soc., 29th Field Conf. (Ft. Smith, Ark.; Nov., 1966), Guidebook, p. 195-221.

Stone, C. G., *see* Sterling, P. J., Stone, C. G., and Holbrook, D. F.

Stone, G. T. (ed.), 1967, The structure and igneous rocks of the Wichita Mountains, Oklahoma: Geol. Soc. America, South-Central Sec., 1st Ann. Mtg., Guidebook, 46 p., 11 figs., 4 tables. Contains articles by W. E. Ham, C. A. Merritt, and H. E. Hunter, cited elsewhere in this bibliography.

Strimple, H. L., 1967, Aphelecrinidae, a new family of inadunate crinoids: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 81-85, 1 pl.

Summers, F. C., Jr., 1967, Exploration in Oklahoma and the Panhandle of Texas in 1966: Amer. Assoc. Petroleum Geologists, Bull., vol. 51, p. 1048-1052.

Sun, Stanley, *see* Ku, Chao-Cheng, Sun, Stanley, Soffel, Heinrich, and Scharon, LeRoy.

Swafford, Bill, 1967, Soil survey of Garfield County, Oklahoma: U. S. Dept. Agriculture, Soil Conserv. Serv., 57 p., 12 figs., 8 tables, 92 maps (90 at 1:20,000, 2 at 1:190,080).

Swanson, D. C., 1967, Major factors controlling Anadarko basin production: World Oil, vol. 164, no. 1, p. 81-92.

Swinchatt, J. P., 1967, Formation of large-scale cross-bedding in a carbonate unit: Sedimentology, vol. 8, p. 93-120. Discussion of Lindsey Bridge Member, Moorefield Formation, northeastern Oklahoma.

Tanaka, H. H., 1966, Use of analog models in the Arkansas and Verdigris River Valleys, Oklahoma: Okla. Acad. Science, Proc. 1965, vol. 46, p. 76.

Tanner, J. H., 3d, 1967, Wrench fault movements along Washita Valley fault, Arbuckle Mountain area, Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 51, p. 126-134.

Tarr, R. S., 1966, Relation of buried Tishomingo uplift to Ardmore basin and Ouachita Mountains, southeastern Oklahoma—Discussion: Amer. Assoc. Petroleum Geologists, Bull., vol. 50, p. 1365-1374. See Harlton, B. H., 1966, for reply.

Thalman, A. L., 1967, Geology of the Oakdale Red Fork sand field, Woods County, Oklahoma: Oklahoma City Geol. Soc., Shale Shaker, vol. 18, no. 1, p. 3-11.

Taylor, F. B., 1967, Outlook for shallow oil exploration and development, United States: Amer. Assoc. Petroleum Geologists, Bull., vol. 51, p. 134-136. Data on Oklahoma exploration and development.

Toomey, D. F. (ed.), 1967, Symposium—Silurian-Devonian rocks of Oklahoma and environs: Tulsa Geol. Soc., Digest, vol. 35, 303 p. Contains articles by T. W. Amsden and T. L. Rowland; T. W. Amsden, A. J. Boucot, and J. G. Johnson; P. L. Hilpman; H. A. Ireland; J. W. Koenig; E. H. McGlasson; H. S. Kunsman; R. F. Lundin; R. T. Sellars, Jr.; O. A. Wise and W. M. Caplan; K. S. W. Campbell; and A. L. Bowsher, cited elsewhere in this bibliography.

Toomey, D. F., and Ham, W. E., 1967, *Pulchrilamina*, a new mound-building organism from Lower Ordovician rocks of West Texas and southern Oklahoma: Jour. Paleontology, vol. 41, p. 981-987.

Tryggvason, E., and Qualls, B. R., 1967, Seismic refraction measurements of crustal structure in Oklahoma: Jour. Geophys. Research, vol. 72, p. 3738-3740.

Tucker, V. M. (chm.), et al., 1966, Field conference on flysch facies and structure of the Ouachita Mountains: Kans. Geol. Soc., 29th Field Conf. (Ft. Smith, Ark.; Nov., 1966), Guidebook, 278 p. Contains articles by L. M. Cline; J. G. Hill; P. J. Sterling, C. G. Stone, and D. F. Holbrook; C. G. Stone; G. W. Viele; and B. H. Walthall and A. L. Bowsher, cited elsewhere in this bibliography.

U. S. Geological Survey, 1967a, Ground-water levels in the United States, 1960-64: South-central states: U. S. Geol. Survey, Water-Supply Paper 1824, 152 p., 5 illus.

——————1967b, Water resources data for Oklahoma, 1965; part 2, Water-quality records: Oklahoma City, U. S. Geol. Survey, Water Resources Div., 132 p.

——————1967c, Water resources data for Oklahoma, 1965, part 1, Surface-water records: Oklahoma City, U. S. Geol. Survey, Water Resources Div., 191 p.

Upshaw, C. F., and Hedlund, R. W., 1967, Microspores from the upper part of the Coffeyville Formation (Pennsylvanian, Missourian), Tulsa County, Oklahoma: Pollen et spores, vol. 9, no. 1, p. 143-170.

Venkatachala, B. S., *see* Wilson, L. R., and Venkatachala, B. S.

Viele, G. W., 1966, The regional structure of the Ouachita Mountains of Arkansas, a hypothesis: Kans. Geol. Soc., 29th Field Conf. (Ft. Smith, Ark.; Nov., 1966), Guidebook, p. 245-278.

Walker, F. E., and Hartner, F. E., 1966, Forms of sulfur in U. S. coals: U. S. Bur. Mines, Inf. Circ. 8301, 51 p.

Walker, F. E., *see* Aresco, S. J., Janus, J. B., and Walker, F. E.

Walters, J. G., Ortuglio, C., and Glaenzer, J., 1967, Yields and analyses of tars and light oils from carbonization of U. S. coals: U. S. Bur. Mines, Bull. 643, 91 p., 5 tables.

Walthall, B. H., 1967, Stratigraphy and structure, part of Athens Plateau, southern Ouachitas, Arkansas: Amer. Assoc. Petroleum Geologists, Bull., vol. 51, p. 504-528. Correlations with Oklahoma section.

Walthall, B. H., and Bowsher, A. L., 1966, Geology of part of southern Ouachitas, Arkansas: Kans. Geol. Soc., 29th Field Conf. (Ft. Smith, Ark.; Nov., 1966), Guidebook, p. 125-139.

Weaver, L. K., and Anderson, K. F., 1966, Oil recovery from gas-cap reservoirs: an engineering evaluation of conservation practices in six reservoirs: U. S. Bur. Mines, Mon. 13, 106 p., 70 figs. Data on West Cement field.

Weber, D. F., 1967, The East Washington-West Goldsby-Osborn trend, McClain County, Oklahoma: Oklahoma City Geol. Soc., Shale Shaker, vol. 17, p. 175-179.

Weld, B. A., Griffin, M. S., and Brett, G. W., 1967, Reports and maps of the U. S. Geological Survey released only in the open files: U. S. Geol. Survey, Circ. 528, 14 p.

Wilson, J. L., *see* Ham, W. E., and Wilson, J. L.

Wilson, L. R., and Skvarla, J. J., 1967, Electron-microscope study of the wall structure of *Quisquilites and Tasmanites*: Okla. Geol. Survey, Okla. Geology Notes, vol. 27, p. 54-63, 1 text-fig., 5 pls.

Wilson, L. R., and Venkatachala, B. S., 1967, *Circlettisporites* Miller, 1966, a synonym of *Leschikisporis* Potonié, 1958: Pollen et spores, vol. 9, no. 2, p. 363-365. Specimens from Dawson coal, Tulsa County, Oklahoma.

Wise, O. A., and Caplan, W. M., 1967, Silurian and Devonian rocks of northern Arkansas: Tulsa Geol. Soc., Digest, vol. 35, p. 242-252, 7 figs.

Withrow, P. C., 1967, The Red Fork sandstone in the Wakita trend, Grant and Alfalfa Counties, Oklahoma: Oklahoma City Geol. Soc., Shale Shaker, vol. 17, p. 198-205.

Wood, P. R., and Hart, D. L., Jr., 1967, Availability of ground water in Texas County, Oklahoma: U. S. Geol. Survey, Hydrol. Inv. Atlas HA 250, 3 sheets.

Woollard, G. P., *see* Coons, R. L., Woollard, G. P., and Hershey, Garland.

World Oil, 1966, Anadarko basin gas strike is one of world's giants: World Oil, vol. 163, no. 4, p. 104, 1 illus.

Wroblewski, E. F., 1967, Exploration problems in the "deep" Anadarko basin: Oklahoma City Geol. Soc., Shale Shaker, vol. 17, p. 131-136.

Ziegler, Willi, *see* Klapper, Gilbert, and Ziegler, Willi.

Zubovic, Peter, Sheffey, N. B., and Stadnichenko, Taisia, 1967, Distribution of minor elements in some coals in the western and southwestern regions of the Interior coal province: U. S. Geol. Survey, Bull. 1117-D, 33 p., 4 figs., 1 pl., 11 tables.

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PETROLEUM:

Differentiation of Beach, River, and Inland Dune Sands by Whole-Phi Textural Parameters

R. J. Moiola*, B. J. Phillips*, and Daniel Weiser*

Recent studies by Friedman (1961, 1967) and Moiola and Weiser (1968) have demonstrated that certain combinations of textural parameters (e. g., mean diameter vs. standard deviation) are environmentally sensitive and can be used effectively to differentiate between modern beach, river, and inland dune sands. Although best results are obtained when quarter-phi grain-size analyses are used to calculate the parameters, the data of Moiola and Weiser (1968) indicate that meaningful differentiation can also be obtained with parameters calculated from whole-phi data. The purpose of this study is to document the effectiveness of whole-phi textural parameters in differentiating between modern beach and river, between beach and inland dune, and between river and inland dune sands.

A total of 593 published and unpublished whole-phi grain-size analyses of modern beach, inland dune, and river sands from various

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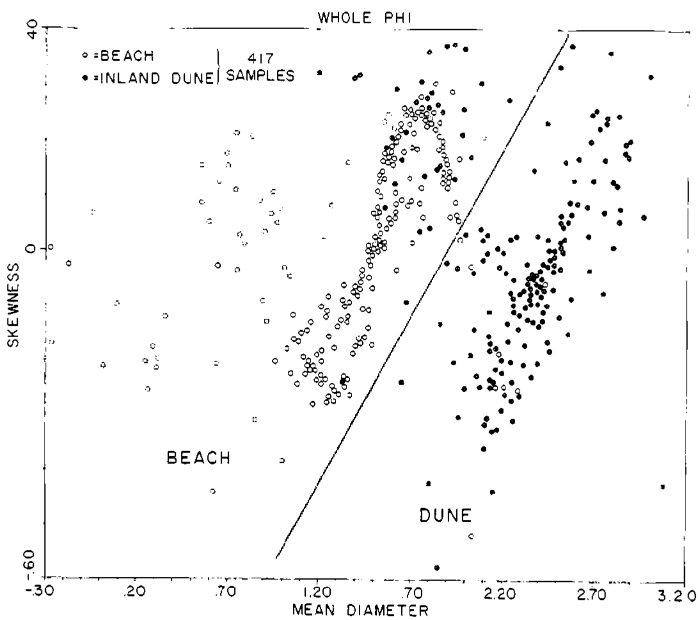

Figure 1. Plot of skewness versus mean diameter, using whole-phi data, for 229 beach-sand samples and 188 inland dune-sand samples.

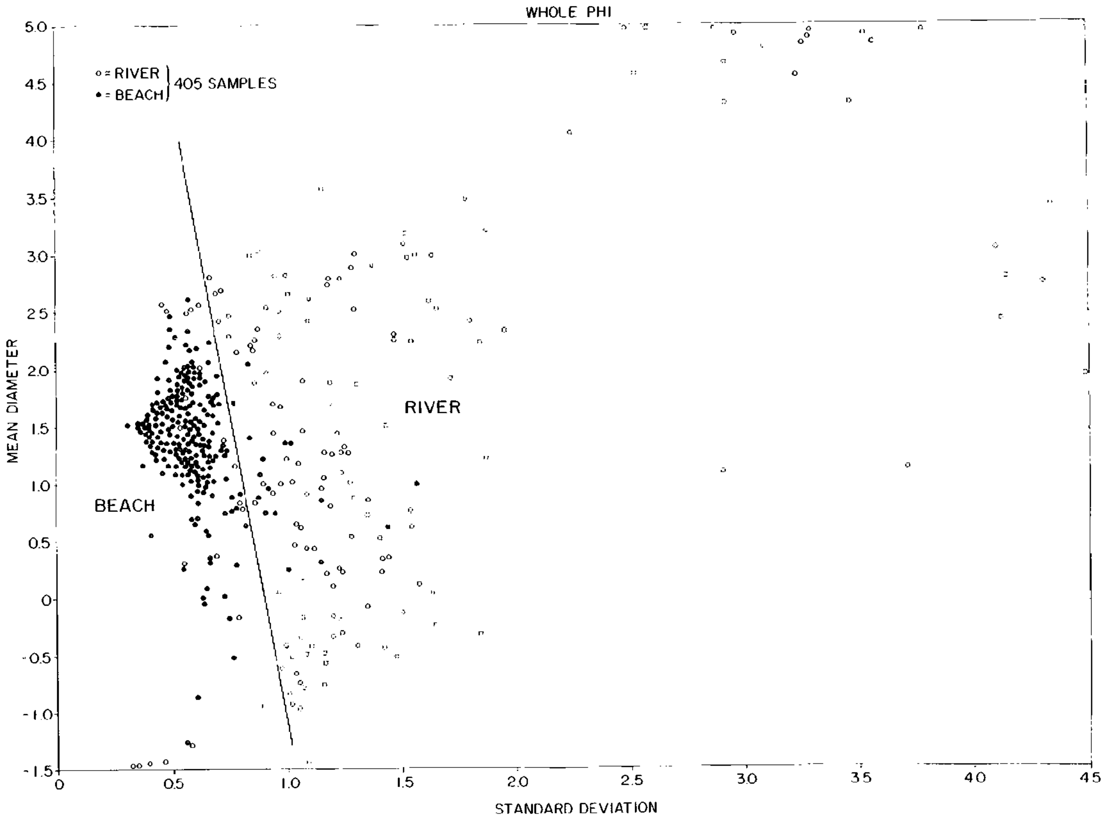

Figure 2. Plot of mean diameter versus standard deviation, using whole-phi data, for 176 river-sand samples and 229 beach-sand samples.

parts of the world were selected for the study. Using the formulas of Folk and Ward (1957), textural parameters (mean diameter, standard deviation, skewness, kurtosis) were computed and all possible combinations of parameters were plotted to evaluate the effectiveness of whole-phi parameters in differentiating the sands. Results of the study are summarized in figures 1-3. Only the most effective combination of textural parameters is presented for each case. The boundaries between the fields of the various sands are delineated by straight lines, and all boundary lines are placed so that as many samples as possible fall within their proper fields.

The data illustrate, as shown by Moiola and Weiser (1968), that: (1) textural parameters calculated from whole-phi data are useful in

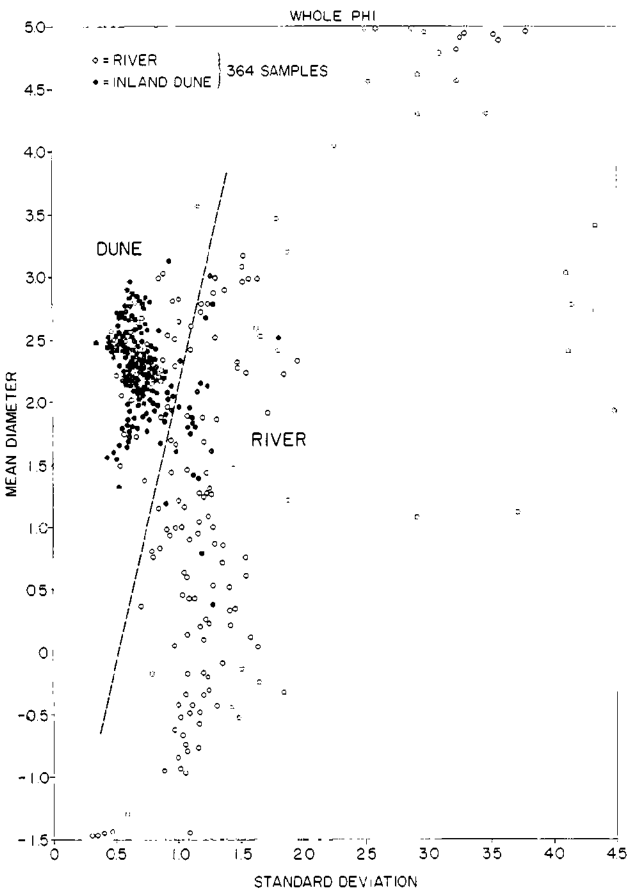

Figure 3. Plot of mean diameter versus standard deviation, using whole-phi data, for 176 river-sand samples and 188 dune-sand samples.

differentiating among beach, inland dune, and river sands, (2) the combination of mean diameter verses skewness is most effective in differentiating between beach and inland dune sands, and (3) the combination of mean diameter versus standard deviation is most effective in differentiating between beach and river and between river and inland dune sands.

Figure 1 (beach vs. inland dune sands) demonstrates that the combination of mean diameter versus skewness effectively differentiates between beach and inland dune sands. Out of a total of 417 samples only 42 fall outside their proper fields. Eight beach sands fall within the dune field and 34 dune sands are in the beach field. The combination successfully classifies 90 percent of the samples.

Figure 2 (beach vs. river sands) demonstrates that the combination of mean diameter versus standard deviation is effective in differentiating between beach and river sands. Sixteen beach sands fall within the river field and 21 river sands fall within the beach field. The combination correctly classifies 91 percent of the samples, with only 37 out of a total of 405 falling outside their proper fields.

Figure 3 (river vs. inland dune sands) shows that the combination of mean diameter versus standard deviation can be used to differentiate between river and inland dune sands. Twenty-one dune sands fall within the river field and 36 river sands fall within the dune field. The combination correctly classifies 84 percent of the samples, with 57 out of a total of 364 falling outside their proper fields.

These results indicate that whole-phi textural parameters are genetically meaningful and, if properly applied, can be useful in interpreting the depositional environments of ancient sands.

References Cited

Folk, R. L., and **Ward, W. C.**, 1957, Brazos River bar, a study of the significance of grain-size parameters: Jour. Sed. Petrology, vol. 27, p. 3-27.

Friedman, G. M., 1961, Distinction between dune, beach, and river sands from their textural characteristics: Jour. Sed. Petrology, vol. 31, p. 514-529.

_________1967, Dynamic processes and statistical parameters compared for size frequency distribution of beach and river sands: Jour. Sed. Petrology, vol. 37, p. 327-354.

Moiola, R. J., and **Weiser, Daniel**, 1968, Textural parameters; an evaluation: Jour. Sed. Petrology, vol. 38, p. 45-53.

Paleomagentism of Basement Granites of Southern Oklahoma and Its Implications; Progress Report*

Henry Spall†

INTRODUCTION

Direct information on the Earth's magnetic field is available to us from observatory data taken over the past few hundred years, and spherical harmonic analysis of these data has revealed several fundamental properties of the present magnetic field. Two of these properties are important for rock magnetism: (1) the Earth's magnetic field can best be represented by a geocentric dipole, (2) at the present time this dipole is inclined at 11° to the geographic axis. Good evidence indicates that, averaged over thousands of years, the dipole is in fact axial, approximating the geographic axis (Irving, 1964).

In the study of rock magnetism, the main assumption is that a rock can preserve a stable record of the geomagnetic field as it existed at the time the rock was formed. This fossil magnetism is called the *natural remanent magnetization* (NRM). Rock magnetism therefore gives us indirect information on the Earth's ancient field.

To interpret this information we must relate it to a model. In so doing, it is convenient to use the uniformitarian argument, as it allows us to use the observed characteristics of the present field in interpreting paleomagnetic observations in terms of a magnetic field in the geologic past.

Most igneous rocks acquire a *thermoremanent magnetization* (TRM) as the rock forms and cools through the Curie temperature of the magnetizable components (e. g., magnetite ca. 578°C, hematite ca. 675°C). At a later stage, this initial, or primary, magnetization may be destroyed or partially replaced by a *secondary magnetization* formed by a variety of geologic processes. Most common is the formation of new magnetic phases at temperatures below the Curie point, either by alteration (deuteric or metasomatic), oxidation, or exsolution. The term *chemical remanent magnetization* (CRM) is used for this and other magnetizations acquired by the formation of new minerals at temperatures below the Curie point. *Viscous remanent magnetization* (VRM) can be developed under various physical conditions, all of which involve changes in the magnetization due to thermal agitation. Most commonly, VRM is acquired as an *isothermal magnetization* (IRM) at low temperatures as a soft (easily removed) magnetization simply by the rock being subjected to a magnetic field for a long period of time. VRM can also form at higher temperatures (by being near an igneous body or by deep burial) so that a part of

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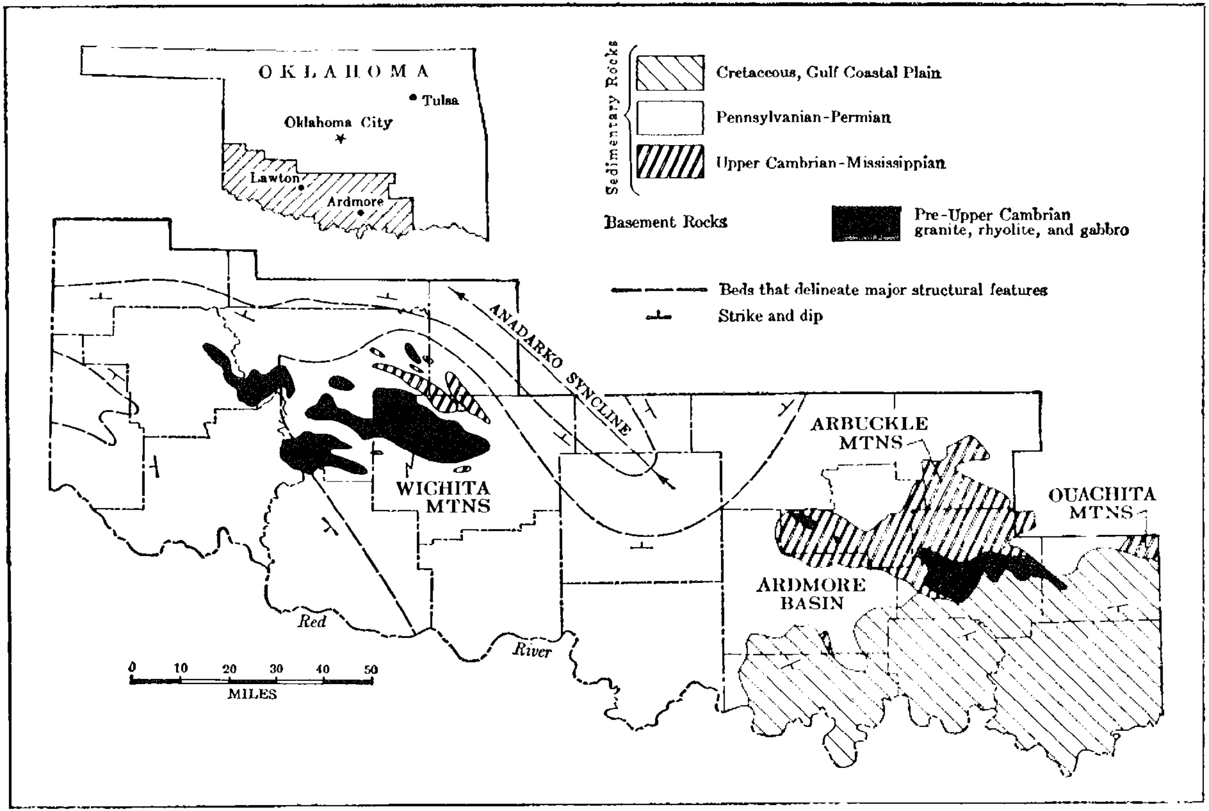

Figure 1. Index map of southern Oklahoma, showing major outcrops and structural features (from Ham, Denison, and Merritt, 1964). The rocks reported on in this study are Cambrian granites from the Wichita Mountains and Precambrian granites from the Arbuckle Mountains.

the primary magnetization is replaced by a secondary magnetization (*partial TRM*) that reflects the direction of the geomagnetic field at the time of reheating.

GEOLOGIC SETTING

As part of a regional paleomagnetic survey of basement rocks in the southwestern United States, collections have been made in the Wichita and Arbuckle Mountains of Oklahoma (fig. 1). All the major rock types have been sampled in both areas but, because the study is not yet complete, only data from the granites will be presented here.

Two methods of collecting were used. Wherever possible, cores were drilled in situ by means of a portable, water-cooled drill (Helsley, 1967a). Otherwise, hand specimens were marked and oriented with a tripod fitted with a plate, and the blocks were subsequently cored in the laboratory. About 300 cores were obtained from a number of sites at 15 locations in both areas.

The radiometric and stratigraphic ages of these basement rocks are given in table I. Ham, Denison, and Merritt (1964) placed the rhyolites and granites as the youngest rocks in the Wichita Province, dated at 525±25 million years (m.y.). The Wichita granites are considered to be the intrusive equivalents of the extrusive Carlton rhyolite. Intrusive and extrusive basic rocks represent slightly older Cambrian events.

In the Eastern Arbuckle Province the basement rocks are principally coarse-grained, mesozonal granites, forming part of a deeply eroded continental craton (Ham, Denison, and Merritt, 1964). Radiometric age determinations from the granites indicate that they are distinctly Precambrian and suggest that several periods of intrusion may be represented by the different igneous phases.

The spread of radiometric ages and their standard deviations are important considerations in rock magnetism. The Tishomingo granite

TABLE I.—RADIOMETRIC AND STRATIGRAPHIC AGES OF BASEMENT ROCKS IN SOUTHERN OKLAHOMA

	Wichita Mountains[1]	
Middle Cambrian	Carlton Rhyolite Group Wichita Granite Group	525±25 m.y.
Lower Cambrian	Navajoe Mountain Basalt-Spilite Group Raggedy Mountain Gabbro Group	535±30 m.y.
Precambrian	Tillman Metasedimentary Group	> 550 m.y.
	Arbuckle Mountains	
Precambrian	Tishomingo granite (Pb/Pb)[2] Troy granite (Rb/Sr)[3]	1320-1400 m.y. 1360 m.y.

[1] From Ham, Denison, and Merritt, 1964.
[2] From Tilton, Wetherill, and Davis, 1962.
[3] From Muehlberger et al., 1966.

gives Pb/Pb ages on zircon of 1320-1400 m.y. (without consideration of errors in the decay constants, or the mechanism of lead loss); biotite ages are 1250 m.y. (K/Ar) and 1350 m.y. (Rb/Sr) (Tilton, Wetherill, and Davis, 1962). The Troy granite yields a feldspar age of 1360 m.y. (Rb/Sr) (Muehlberger et al., 1966). Subsurface granite and diorite cores give consistently younger ages (1050-1160 m.y.), but these may be related to cataclastic structures (Muehlberger et al., 1966).

The available paleomagnetic data from North American Cambrian and younger rocks suggest movement of the magnetic pole at an average rate of about 1° in 5 m.y. (Irving, 1964). For a radiometrically dated rock, a spread in ages of 100 m.y. thus makes an uncertainty in its paleomagnetic pole of 20°, which is well outside the experimental error of the magnetic method. A large uncertainty in radiometric age thus diminishes the relevance of the paleomagnetic data.

The range of the ages of the granites of the Eastern Arbuckle Province shows a possible time span of 1050-1400 m.y. This spread overlaps both the St. Francois (1200-1350 m.y.) and Nemaha (1350-1450 m.y.) periods of major igneous activity which have been suggested by a recent survey of basement geochronology (Muehlberger et al., 1966). More radiometric determinations are obviously needed; at present, an age of 1350 m.y. for the Arbuckle granites must be considered to be near the maximum.

It should be remembered that both the magnetic and radiometric methods are dating fossil events. The magnetization of an igneous

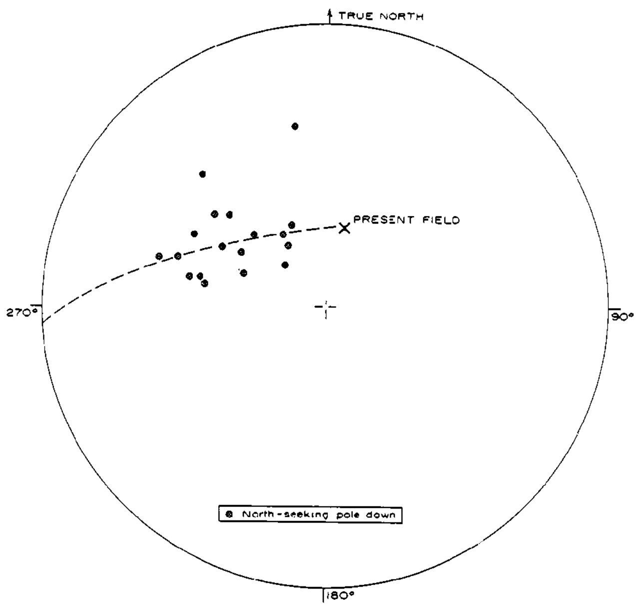

Figure 2. Initial directions of magnetization of site means for Wichita granites. Equal-area projection.

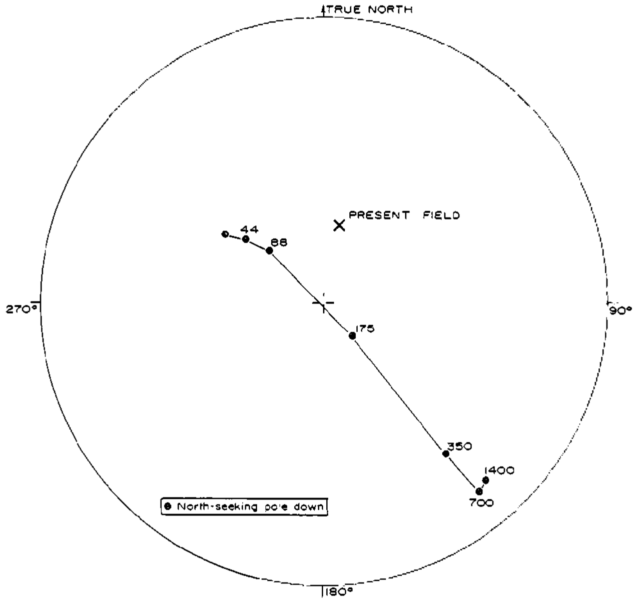

Figure 3. Site means for Wichita granites after AC demagnetization. AC field values are given in oersteds. Equal-area projection.

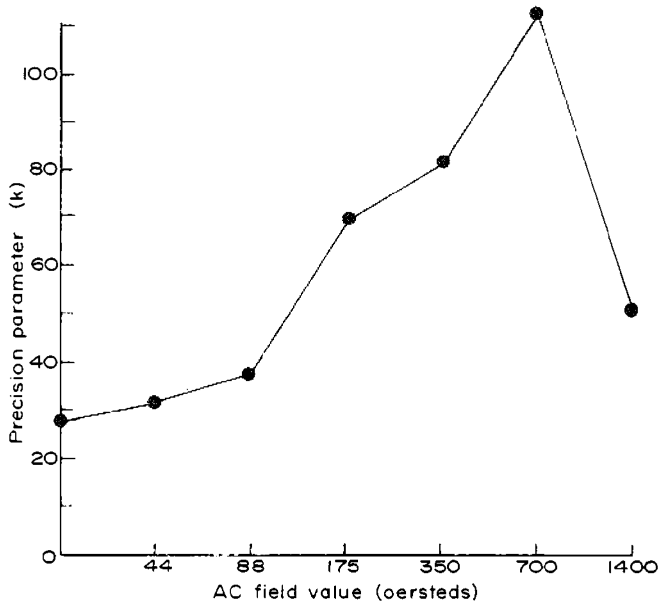

Figure 4. Precision of site means for Wichita granites after AC demagnetization.

rock records the time (and temperature) at which a magnetization was finally frozen in. The radiometric age records the time at which diffusion in the rock became negligible. Neither magnetic nor radiometric age need represent the age of formation. Likewise, the two ages need not necessarily represnt formation at equivalent moments in geologic time.

MAGNETIC MEASUREMENTS: WICHITA MOUNTAINS

Although material was collected from all the main rock types in the Wichita Mountains, data will be presented only for the granites. These represent about 120 cores from a number of sites in the Wichita Granite Group. The direction and intensity of the NRM were measured on a 270-cps spinner magnetometer designed and built by C. E. Helsley (Helsley, 1967b, 1967c). The 18 site means of these initial directions are plotted in figure 2. The present field, that of an inclined geocentric dipole, is also plotted. The array suggests a great circle (plotted by eye on a stereonet) passing through these site means and the present field. This streaking along an approximation of a great circle is a common effect for rocks that have soft magnetic components of secondary VRM that are aligned along the present field, so that the directions of measured NRM include components of VRM and true NRM.

As a necessary test of stability, alternating-current (AC) and thermal demagnetization techniques were applied to about half of the cores. Two different patterns emerged on demagnetization. Figure 3 shows the response to the AC method. Each specimen was demagnetized in progressively higher AC fields up to 2,800 oersteds. For each AC field value, an over-all mean was computed for all the site means. The path of demagnetization proceeds smoothly into the southeast quadrant. A measure of the agreement of the site means is given in figure 4, where k is an estimate of Fisher's precision parameter K, which determines the dispersion of points distributed on a sphere (Fisher, 1953). For $k \leqq 3$ the points are, in effect, randomly distributed; for large values of k, the points are confined to a small part of the sphere near the true mean. Fisher showed that the *true* mean of a population of N points lies within a cone whose axis is the estimated mean and whose semiangle (α) at the 95% level of confidence is given by:

$$\alpha_{95} \approx \frac{140}{\sqrt{kN}} \qquad (N \geq 3)$$

From figure 4, the precision parameter reaches a maximum (angular deviation from the mean is thus at a minimum) at 700 oersteds. All the cores behaved in this fashion on AC demagnetization.

The response to thermal demagnetization is shown in figure 5. Each core was heated by steps in a noninductive furnace to progressively higher temperatures as far as the Curie temperature. The direction of NRM remaining after each step was measured at room temperature (after cooling the core in a field-free space) and the means were plotted (fig. 5). At high temperatures both normal and

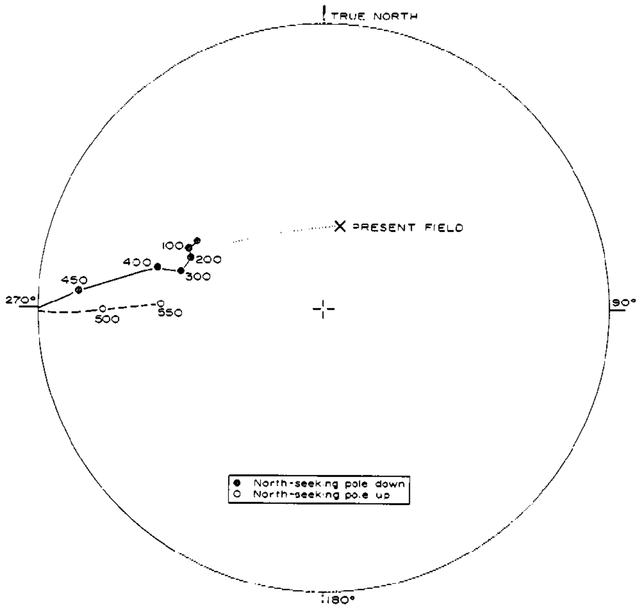

Figure 5. Site means for Wichita granites after thermal demagnetization. Values are temperatures in degrees centigrade. Dotted line is projection of demagnetization path through present field. Equal-area projection.

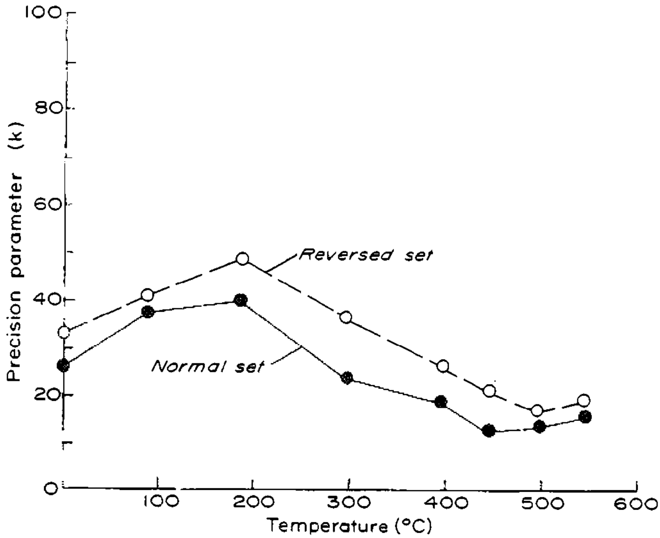

Figure 6. Precision of site means for Wichita granites after thermal demagnetization.

reversed directions of magnetization are present, but only the set leading to a reversed direction has been plotted. This combined demagnetization path resembles the "streaking" path observed in the initial directions of magnetization, suggesting the presence of unstable VRM at low temperatures, which is removed by heating.

The precision of the means computed for each temperature is given in figure 6. For both normal and reversed sets the precision reaches a peak at 200°C. Above this temperature the precision decreases, although it is obvious that components of magnetization are still being removed. At 500°C the precision increases again, and is still increasing at 550°C, at which temperature most of the unwanted secondary magnetization is considered to have been removed.

The different responses to demagnetization can be explained by consideration of the paleomagnetic poles for undemagnetized and demagnetized specimens (fig. 7; table II). These pole positions have been computed with the assumptions that the ancient field of the Earth was a geocentric dipole and that the Wichita block is in its original attitude (i. e., no tilting has occurred since its formation). Although the initial directions of NRM do seem to lie along a great circle, their mean yields a pole which does not relate to the mean magnetic pole path for North American rocks (Irving, 1964). The pole after AC demagnetization to 700 oersteds is near the Carboniferous-Permian part of the North American path. In fact, it represents a reversed geomagnetic pole because the north-seeking paleomagnetic pole on AC demagnetization moves into the southern hemisphere. This fact is significant because it has been found that the Earth's field was reversed throughout the Upper Carboniferous and Permian Periods (Irving, 1964; McMahon and Strangway, 1967).

The pole computed for rocks thermally demagnetized to 550°C is closer to a Cambrian position on the North American path of polar wandering, although the poles available for other Cambrian rocks are few and widely scattered (Helsley and Spall, 1966).

These alternate patterns of behaviour on demagnetization are interpreted as indicating two major magnetic phases in the Wichita granites. One phase has a high coercive force, since it persists during AC demagnetization but is not dominant at high temperatures. This

TABLE II.—PALEOMAGNETIC POLES FOR WICHITA GRANITES
(99.0°W, 34.8°N)

	Pole position	Semiaxes* δp	Semiaxes* δm
Undemagnetized	171°W, 35°N	9°	16°
After AC demagnetization	118°E, 34°N	4°	7°
After thermal demagnetization	147°E, 2°N	6°	9°

* δp and δm are the radial and transverse semiaxes of the oval of 95% confidence.

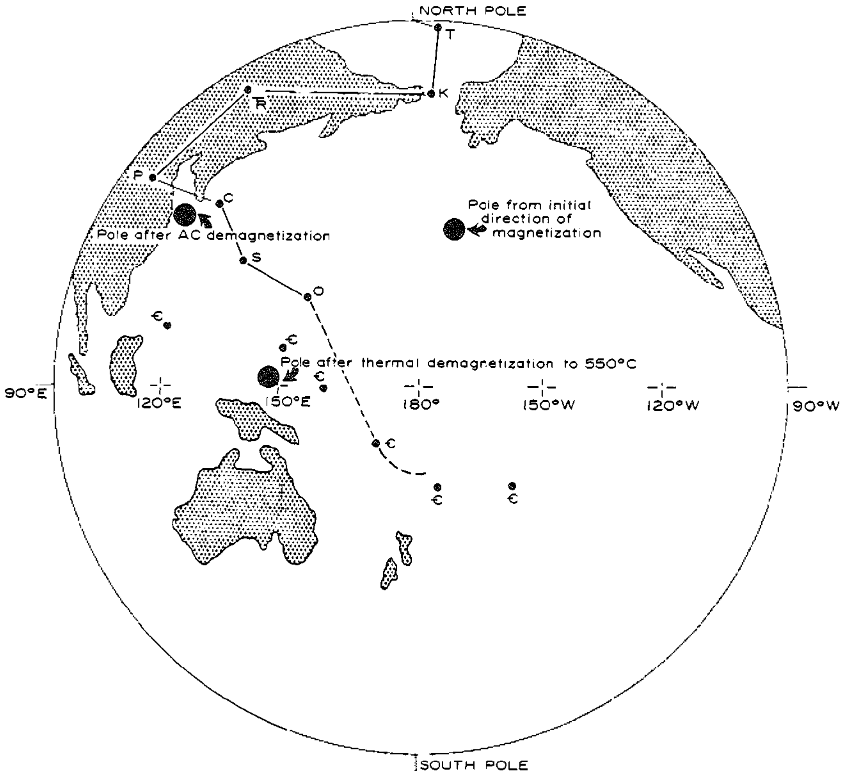

Figure 7. Paleomagnetic poles for Wichita granites (large dots) and mean pole path for North American rocks (small dots; after Irving, 1964). Equal-area projection.

T	**Tertiary**	**C**	**Carboniferous**
K	**Cretaceous**	**S**	**Silurian**
Ʀ	**Triassic**	**O**	**Ordovician**
P	**Permian**	**€**	**Cambrian**

phase is considered to be hematite, which yields a paleomagnetic pole suggesting that it was magnetized during the Late Carboniferous or Early Permian.

The other phase has a low coercive force, as it is destroyed by progressively higher AC fields. However, it persists at high temperatures, yielding a paleomagnetic pole near other North American Cambrian poles. It is believed that this phase is a form of titanomagnetite, which crystallized as a primary mineral when the granites were intruded. It therefore reflects a Cambrian pole position. Because of its low coercive force, this phase easily acquired secondary VRMs that are responsible for the streaking of NRM directions through the present field. Because of its high specific magnetic moment, titanomagnetite will always be dominant over hematite, unless its effect is removed by demagnetization.

At first sight, it is tempting to suggest that, because the hematite reflects a Carboniferous-Permian magnetization, it was formed at that time, either as an oxidation product of titanomagnetite or as a weathering product. Ku et al. have suggested that low-temperature alteration of the primary iron oxide took place during the Late Paleozoic and that this secondary hematite acquired a magnetization of chemical type (CRM). For three reasons it is considered that this is an oversimplified solution, and that the magnetic history of the Wichita granites may indeed be more complex.

1) In some cases during thermal demagnetization, a remanence could be measured above the Curie point of magnetite (578°C) that still reflected the Cambrian position, inferring the presence of primary Cambrian hematite.

2) R. E. Denison (personal communication) has observed petrographically that hematite exists in samples taken throughout the Frankfort Oil 1 Sparks Ranch well (total depth, 12,884 feet; C SE¼ SE¼ sec. 32, T. 1 S., R. 1 W., Murray County). The thickness penetrated included:

Cambrian sediments	6,830 feet
Carlton Rhyolite	4,525 feet
Wichita Granite	1,529 feet

During the Late Paleozoic these samples were thus at least 12,000 feet below the surface. It is unlikely that this hematite can be associated with a weathering process, again indicating a primary origin.

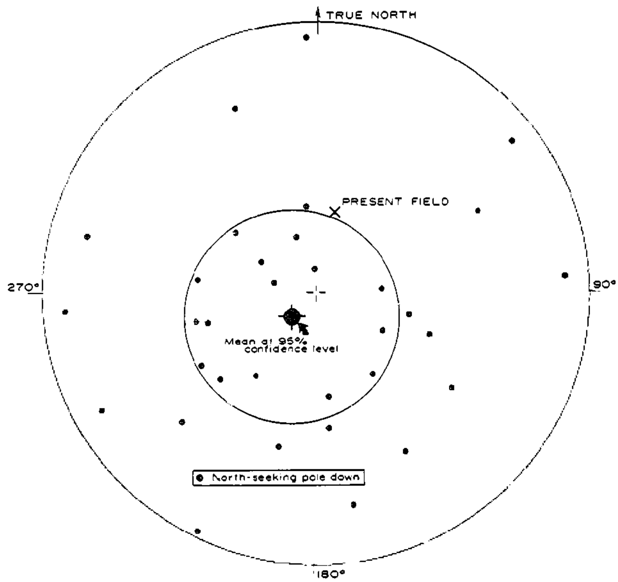

Figure 8. Initial directions of magnetization of sample means for Arbuckle granites. Equal-area projection.

3) Opaque petrography is being undertaken to try to resolve the magnetic history of the granites. At least three forms of hematite are present:

a. Small discrete grains.
b. Long "stringers" produced by the breakdown of silicate minerals. These stringers are associated with an over-all reddish color disseminated throughout the rock.
c. A product of completely oxidized, host titanomagnetite.

The possibility thus cannot be discounted that the Carboniferous-Permian direction represents a partial thermoremanence (TRM) in primary (Cambrian) hematite. This was associated with the periods of uplift of the Wichita block in Late Carboniferous time and the culmination of the Arbuckle orogeny (Ham, Denison, and Merritt, 1964; Ham and Wilson, 1967). It is possible to suggest a maximum temperature to which the granite may have been reheated, because during thermal demagnetization the minimum dispersion of directions of magnetization occurred at 200°C (fig. 6). Above this temperature the dispersion was greater even after secondary magnetizations were removed. This temperature value accords with the absence of metamorphic effects from the Late Paleozoic orogeny in southern Oklahoma. If a geothermal gradient of 30°C/km is assumed, it indicates an overburden of at least 20,00 feet during the Paleozoic.

MAGNETIC MEASUREMENTS: ARBUCKLE MOUNTAINS

More than 100 cores have been cut from samples collected from the Arbuckle region, and the initial directions of 33 sample means are shown in figure 8. The over-all mean is also shown, but it is of little significance because of the high dispersion ($\alpha_{95} = 36°$). The response to AC demagnetization does not always seem to be meaningful (fig. 9). Some specimens show erratic movement, others show little movement, even after being subjected to high AC fields. This varied response is interpreted as being due to the coarse grain size and thus the associated spectrum of coercive forces present in the magnetic constituents (Graham, 1953). Three criteria were therefore used in selecting the most reliable direction of magnetization after secondary components had been removed.

1) A useful parameter in rock magnetism is the Koenigsberger ratio Q (Koenigsberger, 1938), defined as:

$$Q = \frac{\text{Intensity of NRM}}{\text{Bulk susceptibility} \times \text{Strength of inducing field}}$$

Without the necessity of assuming a value for the inducing field, the modified ratio Q′ can be substituted, which is simply the ratio of intensity of NRM and bulk susceptibility. Q′ values of about 1 or more are associated with stable rocks; values below 0.1 usually indicate the presence of substantial unstable components (Irving, 1964). Thus only those specimens with Q′ ratios near unity were considered.

2) Only specimens that had nonerratic demagnetization paths were chosen.

3) After each demagnetization stage (i. e., each AC field value)

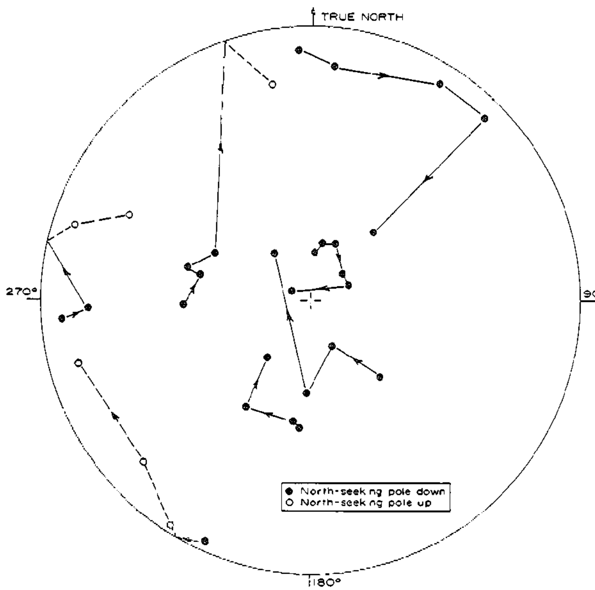

Figure 9. AC-demagnetization paths for selected samples of Arbuckle granites. Arrows indicate direction of progressive demagnetization. Equal-area projection.

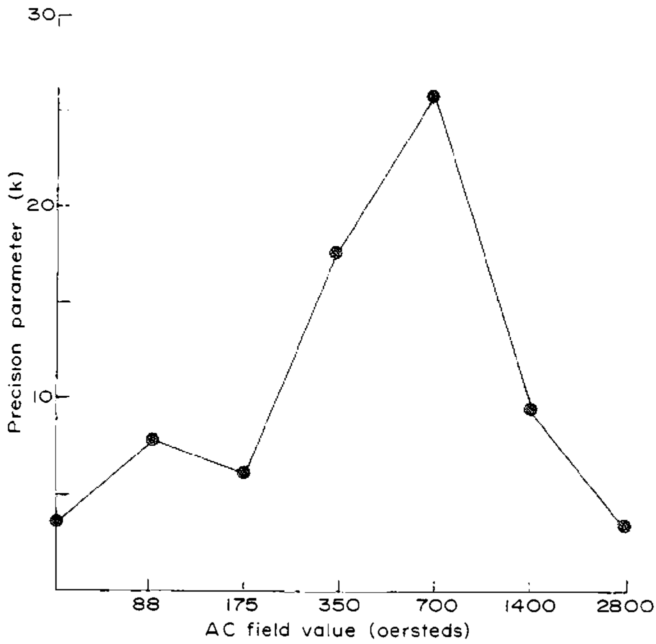

Figure 10. Precision of sample means for Arbuckle granites after AC demagnetization.

TABLE III.—PALEOMAGNETIC POLES FOR ARBUCKLE GRANITES (96.7°W, 34.3°N)

	POLE POSITION	SEMIAXES*	
		δp	δm
No tilting	142°W, 26°N	8°	13°
Tilting	150°W, 17°N	7°	11°

* δp and δm are the radial and transverse semiaxes of the oval of 95% confidence.

means were computed. The over-all mean was chosen at that field value for which the maximum precision parameter (best grouping) was obtained (fig. 10). This occurred in the 700-oersted field. Figure 11 shows the sample mean directions after this stage, and the circle of 95-percent confidence of the over-all mean.

Paleomagnetic poles have been computed from the mean direction assuming (1) tilting and (2) nontilting of the Arbuckle block (fig. 12; table III). The Arbuckle craton is considered to have been a stable element from the time of its formation (Ham, Denison, and Merritt, 1964). However, above the granites on their western flank a dip of about 12° to the west can be observed in the overlying Cambrian Reagan Sandstone. This dip may represent either a depositional slope or one due to tilting.

The only other paleomagnetic data available from material of

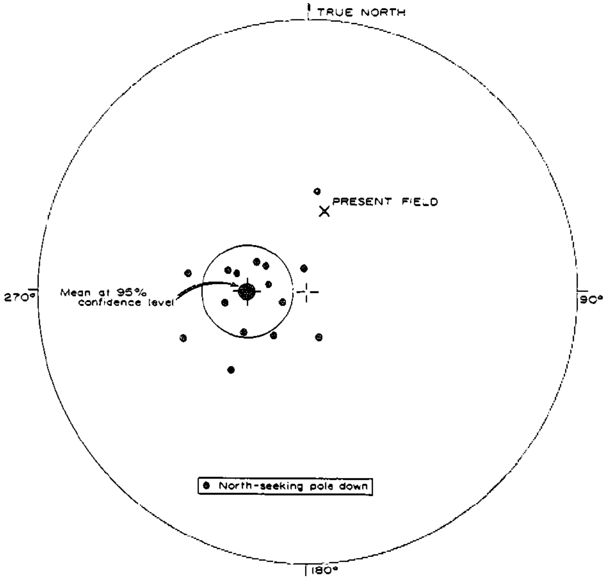

Figure 11. Sample means for Arbuckle granites after AC demagnetization to 700 oersteds. Equal-area projection.

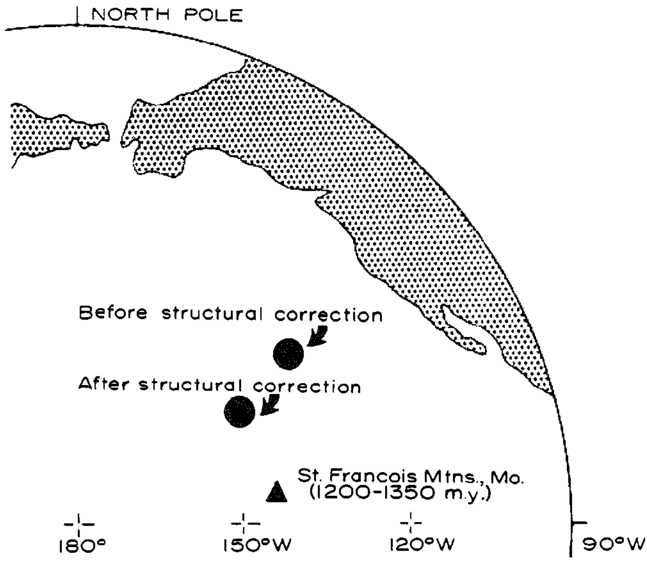

Figure 12. Paleomagnetic poles for Arbuckle granites.

comparable age, radiometrically dated at 1200-1350 m.y., is from the St. Francois Mountains, Missouri (Muehlberger et al., 1966; Hays and Scharon, 1966). Much more data are required before the position of the Earth's magnetic pole can be determined for this period of the Precambrian. Nevertheless, better agreement of the pole positions from these two igneous rocks is obtained by assuming that the dip of the Reagan Sandstone overlying the granites reflects tilting of the Arbuckle block.

CONCLUSIONS

1. The most reliable paleomagnetic data from the Wichita Mountains, Oklahoma, are obtained from the Wichita Granite Group (525 ± 25 m.y.).

2. The directions of NRM from the Wichita granites show a streaked distribution through the present field.

3. After thermal demagnetization of the granites, a paleomagnetic pole is obtained near other Cambrian poles from North American rocks. This is considered to reflect primary titanomagnetite formed when the granites were intruded.

4. After AC demagnetization of the granites, a reversed paleomagnetic pole is obtained near the mean Carboniferous and Permian poles for North America. This is interpreted as a magnetization acquired by hematite during the period of uplift of the Wichita block in Late Carboniferous time.

5. Hematite is found in well cores which were at least 12,000 feet below the Paleozoic surface. The "Late Carboniferous" hematite therefore cannot be a product of surface weathering.

6. The presence of primary hematite is indicated, in some cases, by the persistence of a "Cambrian" remanence above 600°C.

7. The Late Carboniferous direction may therefore be a partial TRM developed in primary (Cambrian) hematite at 200°C. It may in part be a CRM developed at that time by complete oxidation of host titanomagnetite.

8. Directions of NRM from granites (1320-1400 m.y.) in the Arbuckle Mountains, Oklahoma, show considerable dispersion. This is reduced by AC demagnetization, and a paleomagnetic pole for the granites is located near the pole for 1200-1350-m.y. rocks from Missouri. A better agreement of these two poles is obtained by assuming that the dip of the Reagan Sandstone overlying the granites reflects tilting of the Arbuckle block.

ACKNOWLEDGMENTS

I am indebted to Charles E. Helsley for directing the study, and for providing stimulating suggestions. I am grateful to Rodger E. Denison for his interest and valuable discussions. The study was financed by the American Chemical Society, Grant PRF 1829 A2.

References Cited

Fisher, R. A., 1953, Dispersion on a sphere: Royal Soc. London, Proc., Ser. A, vol. 217, p. 295-305.

Graham, J. W., 1953, Changes of ferromagnetic minerals and their bearing on magnetic properties of rocks: Jour. Geophys. Research, vol. 58, p. 243-260.

Ham, W. E., Denison, R. E., and **Merritt, C. A.**, 1964, Basement rocks and structural evolution of southern Oklahoma: Okla. Geol. Survey, Bull. 95, 302 p.

Ham, W. E., and **Wilson, J. L.**, 1967, Paleozoic epeirogeny and orogeny in the central United States: Amer. Jour. Science, vol. 265, p. 332-407.

Hays, W. W., and **Scharon, LeRoy**, 1966, A paleomagnetic investigation of some of the Precambrian rocks of southeast Missouri: Jour. Geophys. Research, vol. 71, p. 553-560.

Helsley, C. E., 1967a, Advantages of field-drilling of samples for paleomagnetic studies, **in** D. W. Collinson, K. M Greer, and S. K. Runcorn (eds.), Methods in paleomagnetism: Amsterdam, Elsevier Publishing Co., p. 26-30.

__________1967b, Design of spinner magnetometers, **in** D. W. Collinson, K. M. Greer, and S. K. Runcorn (eds.), Methods in paleomagnetism: Amsterdam, Elsevier Publishing Co., p. 115-118.

__________1967c, Design of a transistorized portable air-turbine spinner magnetometer, **in** D. W. Collinson, K. M. Greer, and S. K. Runcorn (eds.), Methods in paleomagnetism: Amsterdam, Elsevier Publishing Co., p. 142-148.

Helsley, C. E., and **Spall, H. R.**, 1966, Compilation of paleomagnetic investigations of rocks from North America: Amer. Geophys. Union, Trans., vol. 47, p. 291-302.

Irving, Edward, 1964, Paleomagnetism and its application to geological and geophysical problems: New York, John Wiley and Sons, Inc., 399 p.

Koenigsberger, J. G., 1938, Natural residual magnetism of eruptive rocks: Terres. Magnetism Atmos. Electricity, vol. 43, p. 119-127, 299-320.

Ku, Chao-Cheng, Sun, Stanley, Soffel, Heinrich, and **Scharon, LeRoy**, 1967, Paleomagnetism of the basement rocks, Wichita Mountains, Oklahoma: Jour. Geophys. Research, vol. 72, p. 731-737.

McMahon, B. E., and **Strangway, D. W.,** 1967, Kiaman magnetic interval in the western United States: Science, vol. 155, no. 3765, p. 1012-1013.

Muehlberger, W. R., Hedge, C. E., Denison, R. E., and **Marvin, R. F.,** 1966, Geochronology of the Midcontinent region, United States, 3: Southern area: Jour. Geophys. Research, vol. 71, p. 5409-5426.

Tilton, G. R., Wetherill, G. W., and **Davis, G. L.,** 1962, Mineral ages from the Wichita and Arbuckle Mountains, Oklahoma, and the St. Francois Mountains, Missouri: Jour. Geophys. Research, vol. 67, p. 4011-4019.

OKLAHOMA ABSTRACTS

The following are abstracts of papers related to Oklahoma geology presented at the meeting of the Southwestern Section of the American Association of Petroleum Geologists and at the annual meeting of the American Association of Petroleum Geologists—Society of Economic Paleontologists and Mineralogists.

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AAPG Southwestern Section Meeting, Wichita Falls, Texas February 7-9, 1968

Stratigraphy of Deeper Marietta Basin in Oklahoma and Texas

BRADFIELD, H. H., Independent Geologist, Dallas, Texas

The Marietta basin is in southern Oklahoma between the Muenster arch on the southwest and the Criner Hills uplift on the northeast; it extends from Love County, Oklahoma, southeastward through Cooke and Grayson Counties, Texas, the deepest part being known as the Gordonville trough.

The folded and faulted buried ridge (mid-basin ridge) on which the Southeast Marietta field is located has a more southward strike

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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.

than the present basin axis, and divides the basin into two parts. The thickest sections of Atoka and older sediments were deposited north of the ridge.

The Gordonville trough developed in Late Mississippian or Early Pennsylvanian time from a gentle downwarp into a deep, relatively narrow trough with steep, commonly faulted sides, growing progressively as it received up to 5,000 feet or more of sediments of Atoka, Morrow, and possibly Springer (Goddard?) ages.

The Atoka and Morrow boundaries are indefinite on the basis of present knowledge. Some geologists place the top of the Atoka at the base of the Davis Sand (Grayson County, Texas). The writer has placed the top at an oölitic limestone (Lester?) midway between the Baker and Davis Sands. Westheimer believes the "micaceous sand" in the Ardmore basin Dornick Hills correlates with the micaceous Hartshorne Sandstone of the Arkoma basin and the Davis Sand of Grayson County. The sandstone correlated as Davis or "micaceous" in the Southeast Marietta field is several hundred feet higher stratigraphically than the Davis Sand of Grayson County.

A thick section of pre-Atokan appears northward as well as eastward from the mid-basin ridge. This is believed to be mostly Morrowan-lower Dornick Hills, Springer (Goddard?), and Caney. The boundaries are indefinite and based on electric-log characteristics, related to early sample work. More qualified determinations are necessary in samples from later wells.

Post-Atokan Dornick Hills also thickens eastward and northward in Grayson County, but thins and disappears southwestward against the lower faulted margin of the Muenster uplift. The same components may be noted in the Des Moines or Strawn (Deese), although the thickening here may be more related to the development of the present Gordonville trough by foundering and filling during erosional destruction of the Ouachitas.

More intense folding and thrust faulting, even deep within the basin, complicate considerably the development of structure and stratigraphy because of the loss of section (a loss which is not the result of depositional factors). [193-194]

Recent Developments in Marietta Basin

HENRY, GARY E., Independent Geologist, Wichita Falls, Texas

During the past 10 years, a new search for significant reserves swept the Texas part of the Marietta basin and resulted in several important discoveries. The Ordovician Oil Creek Sandstone and numerous Strawn sandstones of Pennsylvanian age were the primary objectives.

The Marietta is primarily a Pennsylvanian basin, and oil occurrence is related closely to sedimentation and orogenies during this period. The presence of the southeast extension of the southern Oklahoma Criner Hills trend caused much deep exploration for Oil Creek gas-condensate production. The New Mag field was a significant result of this play. Much exploration remains to be done for fields of this type.

The 20-year-old Handy field, also on the Criner trend, was extended considerably and new pay zones were found in this multipay Strawn field. Reserves were increased several times.

On the southwest side of the basin, the Bob K field in Cooke County was an important find. A combination of structural and stratigraphic entrapment created this very prolific multipay Strawn field.

Histories of development and geological interpretations of these and other areas are presented. [196]

Geologic Development of Anadarko Basin and Its Deposits of Hydrocarbons

SWANSON, DONALD C., Esso Production Research Co., Houston, Texas

In the Anadarko basin, economic deposits of oil and gas are found in strata which range in age from Cambrian-Ordovician through Permian. The reservoirs range in composition from siltstone to dolomite and represent environmental facies as diverse as alluvial-stream deposits and shallow-marine carbonate banks.

A progressive analysis—through time—of the depositional and structural events which formed and filled the basin demonstrate the major factors controlling the occurrence of hydrocarbon deposits and how these deposits relate both to regional geologic phenomena and to local environmental events.

Comparisons made with the Anadarko basin could help exploration and exploitation in similar basins throughout the world. [198]

Critical Evaluation of Hardeman Basin and Its Environs

THORNTON, JOHN E., Geological Engineer, Wichita Falls, Texas

Geologically the Hardeman basin is the easternmost extension of the elongate, east-west-trending geologic province known as the Palo Duro basin. Although the Hardeman basin apparently has not been subjected to the same violent structural unrest as other parts of North Texas (therefore, almost no structure is related to faulting), it is an area of prolific oil fields having traps of a peculiar type. Except for Conley, the largest Hardeman County oil field, oil traps here have almost no primary porosity. They seem to be either erosion remnants or small biohermal reefs with 100-200 ft of relief which have been vigorously and effectively leached by dolomitizing waters, leaving the limestone with secondary porosity values ranging from pin-point vugular to cavernous.

Since the 1959 discovery of Conley, it and 14 smaller fields have produced almost 10 million bbl of oil. This added to the 20 million bbl of oil produced from the Fargo and Odell fields of northwest Wilbarger County, raise the total for the Hardeman basin to 30 million bbl.

Seismic methods still provide the most reliable evidence of structure in the Hardeman basin, though increased drilling continually adds to the possiblity of subsurface geological leads. As more fields are discovered, and more is understood of their structural form, there seems an increased demand for greater seismic accuracy which, because of the stratigraphic nature of the upper beds in the basin, is beyond the capacity of seismic tools. Most fields in the basin before discovery appeared on seismic maps as small low-relief closures or noses on positive structural trends. Many more such features are known, and must be explored.

Economically the Hardeman basin offers the highest return on investment of any area in North Texas. Because individual wells from various fields yield engineering reserve estimates as great as 1 million bbl of recoverable oil, a return as great as 30:1 is a reality. Such high returns normally are found, or anticipated, only in Gulf Coast exploration.

Though exploration costs are high in order to test the commonly cavernous Lower Mississippian "lime" at 8,500 ft (this is the prolific oil producer of Hardeman County), the Hardeman basin has a multiplepay stratigraphic section to that depth, as shown by the presence of producing reservoirs in the Cisco-Canyon section (beginning at 3,900 ft), the Canyon limestones (normally Palo Pinto) below 5,000 ft, the Des Moines (Strawn) section of sandstone and conglomerate (from 6,000-7,300 ft), the Mississippian conglomerate (Holmes Sand) at 7,700 ft, the Mississippian limestones (Chappel and Osage) from 8,000 to 8,500 ft, and the Ellenberger dolomite below 8,500 ft (now producing only at Conley).

Exploration in the past has been aided by acreage and "dry-hole" support from major companies which control large blocks of leases. It is hoped this support will continue, but even without it exploration will continue in the Hardeman basin and westward into the Palo Duro basin, because positive exploration results in the Hardeman basin are already too great, and the promise for future successful exploration too strong, to discourage those men of vision who search for new oil.

[196]

Surface Evidence of Deep Structure in Anadarko Basin

TROLLINGER, WILLIAM V., Consulting Geologist, Denver, Colorado

Surface geology has been neglected largely in the search for oil and gas in the Anadarko basin. This is understandable because the surface is composed essentially of Upper Permian strata laid down after the major mountain-building activities in the region. In places the Permian rocks are mantled by moderately indurated Tertiary continental beds and unconsolidated Quaternary deposits.

A recently completed detailed photogeologic-geomorphic evaluation study revealed considerable evidence that the surface offers numerous clues to subsurface geologic conditions. The study involved comprehensive stratigraphic and structural mapping by conventional photogeologic techniques supplemented by detailed geomorphic structural analysis.

This phase, or "applied geomorphology," deals with determining the degree of influence that structure and lithology have had on the morphologic development of the region. Basic geologic-geomorphic relations are established and "interruptions" to the regional geomorphic "norm" are interpreted commonly as diagnostic clues to anomalous subsurface geologic conditions. The results in the Anadarko basin indicate that many deep-seated structural anomalies are reflected at the surface in the *drainage, landform, erosional, photo-tonal,* and (or) *fracture patterns.*

The study was enhanced by the use of special-purpose aerial photography, taken with the Wild RC-9 camera. This photography has many advantages over conventional aerial photography and is especially well suited to low-dip areas. As a result of its 6.5 $\times$ exaggeration factor, an actual dip of 1° is exaggerated in the stereoscopic view to about 6.5°. This permitted reliable mapping of very low-relief features in the Anadarko basin, where the dip exceeds 1° in very few places.

Four producing areas, with subsurface control used for comparative purposes, are examined as examples of surface reflections of deep structure. These are the (1) Cement, (2) Apache, (3) Gageby Creek, and (4) Washita Creek fields.

The close correlations between surface and subsurface structure in these and several other areas reviewed indicate that the surface should no longer be ignored as a source for clues to potential oil/gas traps. [197-198]

AAPG-SEPM Annual Meeting, Oklahoma City, Oklahoma

April 22-25, 1968

Lower Devonian Brachiopod Faunas in Oklahoma

AMSDEN, THOMAS W., Oklahoma Geological Survey, Norman, Oklahoma

Three brachiopod faunas have been described from Lower Devonian strata in Oklahoma: Haragan-Bois d'Arc Formations of Helderbergian (Gedinnian) age, Frisco Formation of Deerparkian (Siegenian) age, and the Sallisaw Formation of early Onesquethawan (Emsian) age. Beds with the Haragan-Bois d'Arc fauna are confined to south-central Oklahoma, and those with the Sallisaw fauna to eastern Oklahoma. The Frisco fauna is distributed more widely, being present in strata which crop out in the Arbuckle Mountains of south-central Oklahoma and the Ozark region of eastern Oklahoma, and in the subsurface of central and southwestern Oklahoma. Cores from the central part of the state show Frisco strata with a well-developed Deerparkian brachiopod fauna resting on the Upper Silurian Henryhouse Formation bearing a fauna of pentamerid brachiopods. These two faunas make it possible to define the Silurian-Devonian contact with precision through a substantial area in the central part of the state. Frisco brachiopods also have been recovered from a core in southwestern Oklahoma where the Frisco rests on Ordovician strata. Oil production from the Devonian of central Oklahoma, notably the West Edmond field, is believed to be largely from the Frisco Formation. [517]

Sho-Vel-Tum Oil Field, Oklahoma

BECKER, ROBERT M., Consulting Geologist, Oklahoma City, Oklahoma

Prolific oil and gas production is obtained in the Sho-Vel-Tum area of eastern Stephens and western Carter Counties, Oklahoma, from rocks of Permian, Pennsylvanian, Mississippian, Siluro-Devonian, and Ordovician ages. This large, complexly folded and faulted area is in the northwest part of the Ardmore basin between the Arbuckle Mountains on the east and Wichita Mountains on the west. The first production was discovered in July 1914 from Permian rocks at a depth of 400 ft in sec. 21, T. 3 S., R. 2 W. The area has had two periods of major structural movement: post-Morrow, pre-Deese; and post-Hoxbar, pre-Cisco. Production is from stratigraphic traps, fault closures, anticlines, and combinations of these. Geologically this is one of the most interesting areas of the world, and economically it has produced 742,835,000 bbl of oil with an estimated reserve of 158,288,000 bbl. The area is still active and new reserves are being found. [520]

Anatomy of a Giant—Oklahoma City Field

GATEWOOD, LLOYD E., Consulting Geologist, Oklahoma City, Oklahoma

Oklahoma City field, Oklahoma County, Oklahoma, was discovered in 1928, by the drilling of a wildcat well on a mapped 100-ft surface closure. Today this field ranks among the largest 10 oil fields in the United States. Its structural growth is allied closely to the stages of evolution of the Anadarko basin. Growth probably commenced in Cambrian time, and definitely took place from Ordovician through Early Pennsylvanian time as a result of subsidence in the Anadarko basin. This subsidence caused faulting and compressional folding, the most pronounced of which took place near the northeast rim of the basin. In that area, folds and faults in the Anadarko basin intersected the southern end of a buried mobile basement feature, the Nemaha ridge. The presence of this ridge not only influenced the position of the Oklahoma City field structure, but also its size, shape, and structural complexity.

The structure was folded, faulted, and truncated more or less contemporaneously. Approximately 2,000 ft of Ordovician-Pennsylvanian sediments was removed from the top; Pennsylvanian sediments above the unconformity overlie rocks as old as Ordovician. The trap is big —12 mi long, and having 1,000 ft of closure. A 2,000-ft, down-to-the-east fault prevented lateral migration of oil from the fold. The Pennsylvanian above the unconformity allowed only limited upward migration. Relief was so prominent and growth so continuous, even after truncation and burial, that the fold provided an ideal environment for development and trapping of oil and gas in the numerous shallow Pennsylvanian sandstones on the irregular surface of the fold. Traps within the Pennsylvanian sandstones include pinchouts, fault traps, and channel deposits.

The discovery well produced from Ordovician Arbuckle dolomite, the oldest pre-Pennsylvanian rocks on the crest of the structure beneath the unconformity. The most prolific production has been from the Wilcox sand (basal Simpson) on the lowest part of the structure along the west flank, nearest the common water table. More than 20 different zones are productive from Ordovician Arbuckle to Late Pennsylvanian. Arbuckle and lower Simpson oil zones have a water drive.

Production from the Wilcox sand was 350 million bbl of oil and 820 Bcf of gas through 1939, at which time the pressure in the Wilcox zone was reduced to atmospheric. Since 1939 the natural water drive has not been effective and natural gravity drainage has resulted in the production of an additional 186,370,000 bbl of oil. Estimated Wilcox oil in place is 1,072,000,000 bbl.

This field is uniqle in that it has been for 40 years a model and proving ground for exploration techniques and producing technology; for modern proration rules and laws; for drilling and testing techniques in deep rotary wells; and for establishing the standards for formation evaluation and reserve estimates. Developments within a major city furnished the excitement caused by many "wild" wells like "Wild Mary Sudik," but joy accrued to the economic infusion which came during the worst days of the depression.

It is a billion-barrel field, having already produced more than that amount of oil and oil-equivalent gas. Of additional importance is the influence which this field has had in the finding and development of great quantities of oil and gas in adjacent areas of Oklahoma and throughout the world. [528]

Burbank Field, Oklahoma—A Giant Grows

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The Burbank field of Osage and Kay Counties, Oklahoma, a "giant" oil field by any standard, has dominated oil activity in northeastern Oklahoma since its discovery in the 1920's.

The major producing formation in the field is the Burbank sandstone which is in the Desmoinesian Cherokee Shale of Middle Pennsylvanian age. Several lenticular and semiblanket sandstone bodies comprise the Burbank sandstone whose maximum aggregate thickness is about 70 feet. The Burbank sandstone was deposited on a tectonically stable shelf bordering the Arkoma basin on the south; evidence suggests that the sand was deposited in a shallow marine environment.

The productive limits of the Burbank field are controlled by an updip facies change from sandstone to shale toward the east and a tilted oil-water contact on the downdip margin toward the west. These conditions have combined to form a stratigraphic trap of about 50,000 acres, covering all or parts of 12 townships. At present, more than 1,600 wells are producing approximately 26,000 bbl of oil per day, of which 76 percent is by waterflood. Cumulative production from the Burbank field is in excess of 500,000,000 bbl of oil.

During the past 40 years recurring cycles of field extensions and development followed by periods of relative inactivity have enlarged the Burbank field to what appears to be its complete areal extent. Intensive and imaginative geological investigation of more recently discovered stratigraphic-trap accumulations of oil and gas could reveal additional productive acreage that will put these fields in the "giant" category. [537-538]

Petroleum Geology of Healdton Field, Carter County, Oklahoma

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The Healdton field, in western Carter County, Oklahoma, is confined largely to the northeast half of T. 4 S., R. 3 W., but extends into adjacent townships. The townsite of Healdton is within the field's limits. Oil production is principally from the Hoxbar Group (Missourian) of Pennsylvanian age and the Arbuckle Group (Canadian) of Ordovician age.

Production was established first in 1913 with subsequent field development resulting in oil production from four shallow Pennsylvanian sandstones. These are the Healdton sandstones. All can be recognized across most of the field although local discontinuities exist. Approximately 2,600 wells had been drilled by 1955, covering a productive area of more than 7,100 acres..

Several of the earlier development wells were drilled into the pre-Pennsylvanian section where Ordovician oil was found in minor amounts.

In 1960, the discovery of a commercial reservoir within the Arbuckle brought renewed importance to this already prolific field. The new production is from three dolomite zones: Wade, Bray, and Brown. These zones are restricted to the upper 1,600 ft of a 5,000-ft carbonate section. The Brown zone is the lowermost unit and has proved to be the only zone of significance. It is a crystalline dolomite approximately 600 ft thick with good intercrystalline porosity and excellent permeability caused by a highly developed fracture system. The Arbuckle produces from 43 wells within an area of 1,800 acres.

Entrapment of hydrocarbons is attributed to a northwest-southeast structural trend which originated in Early Pennsylvanian time and was activated again during the Late Pennsylvanian. The Healdton area was subjected to intense uplift and faulting in Morrowan time by the Wichita orogeny. Associated high-angle faulting with a displacement of 10,000 ft placed Pennsylvanian shale and sandstone in juxtaposition with Ordovician carbonates. These younger sediments are believed to be the source and means of migration for the majority of, if not all, Arbuckle oil in the Healdton structure. Following an extensive period of erosion, Hoxbar sandstone and shale were laid down over truncated pre-Pennsylvanian rocks and later folded during the Arbuckle orogeny.

Because of the magnitude of stresses affecting pre-Pennsylvanian strata, the Arbuckle producing structure has closure in excess of 1,500 ft, whereas the overlying Pennsylvanian closure is approximately 500 ft.

Hoxbar sandstones, from an average depth of 1,000 ft, have yielded approximately 250,000,000 bbl of oil, and secondary-recovery methods are now being employed. The Arbuckle produces from an average depth of 4,000 ft and has a cumulative production in excess of 2,000,000 bbl. [538]

Paleontology and Paleoecology of Wann Formation, Northeastern Oklahoma

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The Wann Formation (Missourian) of northeastern Oklahoma is primarily a regressive marine sequence of calcareous shale, shale, and sandstone with a characteristic molluscan fauna traceable along much of the outcrop. The replacement of a crinoid-brachiopod fauna by the molluscan fauna in Washington County reflects the change from deeper water to a nearshore marine environment. This environmental change was caused by the northward expansion of a deltaic area which generally was on the south. The deltaic sediments are well developed in the southern outcrops of the Wann.

The rich molluscan fauna, a "Drum-type assemblage," is similar to those found in other Middle and Upper Pennsylvanian formations in Oklahoma indicating a repetition of environments. *Trepospira, Worthena, Euphemites,* and *Glabrocingulum* are the predominant elements of the fauna although other gastropods and pelecypods are prominent locally. The relative abundance of a species at any location within the assemblage zone appears to be depth controlled. [540-541]

Giant Oil Fields of North America

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A group of 45 oil fields in North America, each with reserves in excess of 500 million bbl, have been analyzed to determine their characteristics as an entity. The fields include 18 in the continental interior, 11 in California, 11 in the Gulf Coast area, 3 in Canada, and 2 in Mexico. They contain a total of 46 billion bbl of ultimate reserves, which is about 35 percent of the present total for the continent. The historical implications and future potential are discussed. [542]

Petrology and Sedimentation of Jackfork Sandstones, Arkansas

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A detailed field investigation along the intricately folded and faulted frontal Ouachitas for the first time permits accurate sampling of sandstones encompassing the entire Jackfork section. The resulting petrographic information supplements paleocurrent studies and sedimentary structures in postulating a provenance and dispersal system. Rocks of the frontal Ouachitas consist approximately 30 percent of sandstone deposited by mass flow or turbidity currents and 70 percent of shale, mostly controlled by downslope movement after deposition. Exposures along a southern belt consist of 75 percent of sandstone; only negligible amounts of gravity-deformed, argillaceous rocks are present in this southern belt.

Approximately 200 thin sections were analyzed from measured sections and isolated areas. Along the frontal Ouachitas, the sandstone is predominantly fine-grained quartz arenite and wacke (range 0.07 to 0.31 mm; average 0.14 mm), high in polycrystalline quartz, and having less than 1 percent feldspar, 2.5 percent unstable rock fragments, a stable heavy-mineral suite, and varying amounts of matrix. These rocks are moderately sorted to moderately well sorted although pressure solution has masked and altered the original texture. Stylolites along bedding planes and sutured, interlocking grain contacts indicate considerable removal of silica by postdepositional means, a small amount remaining as quartz overgrowths.

The more argillaceous wacke shows highly corroded quartz grains due to local increases in pH but with little grain interpenetration. Dominantly friable sandstone along the southern belt has comparable grain sizes but a marked increase in matrix and decreased postdepositional changes. The matrix probably reduced the flow of silica-removing waters, also forming a cushion that would reduce number of point contacts. Feldspar content may approach 10 percent but remains lower than that of the Stanley sandstone.

Basinal filling was mainly from the end (east), aided by sediment bypassing through the Illinois basin. A volcanic archipelago (Llanoria) probably contributed the feldspar. Rocks throughout the frontal Ouachitas apparently were deposited along a steep, south-dipping, unstable slope. West-flowing, bottom-hugging turbidity currents concentrated the sand in the deepest part of the east-west trending Ouachita trough which today is exposed as the rocks of the southern belt. Care must be taken when interpreting sandstone-shale ratios in flysch basins where the greatest sand content is along the basin axis. [542]

Panhandle-Hugoton Field, "First Fifty Years"

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A detailed study of the geometry and an understanding of the mechanics of entrapment are essential to unravel the complexities of the Panhandle-Hugoton field.

The reservoir in the Panhandle-Hugoton field is usually considered to be rocks of Wolfcamp age. Gas and oil appear to have migrated from Pennsylvanian marine shales in the Anadarko basin through granite wash into the Panhandle field.

The trap is primarily structural in the Panhandle field, and stratigraphic in the Hugoton field, with a hydrodynamic component in both.

Red Cave reservoirs above the Wolfcamp and Pennsylvanian reservoirs below the Wolfcamp usually are not considered to be a part of the Panhandle-Hugoton field pay. It is the writer's opinion, however, that these reservoirs could be considered to be Panhandle-Hugoton field pays, because they appear to have had the same source areas, initial pressure, and similar water contacts. [545]

Anomalous Morrowan-Chesterian Correlations in Western Anadarko Basin

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Fossils recovered from cores of a thin lignitic shale and a coal in two widely separated wells in the western Anadarko basin show that the shale and coal beds are time-equivalent. Spore-pollen assemblages from the two intervals are identical and indicate a late Morrowan age.

Coal from one well in the western Oklahoma Panhandle is from an interval generally considered as late Morrowan; the lignitic shale from a well near Liberal, Kansas, however, is from rocks widely accepted as early Chesterian—almost Meramecian.

Considering that there is a span of several million years between early Chesterian and late Morrowan, two possible interpretations are presented. Either (1) identical spore-pollen assemblages are not sufficient evidence to distinguish between early Chestrian and late Morrowan or (2) some rocks currently accepted as of Chesterian age in the western Anadarko basin actually are limestone-shale facies of the Morrow Formation, and the relation between Morrowan sandstone-shale and "Chester" limestone-shale would not be one of onlap on an unconformable surface but, instead, a major facies change. In the two wells the interval between the Meramecian St. Genevieve Limestone and the Atokan "Thirteen-Finger" limestone is nearly equal and analysis of the geologic history of this interval lends support to the facies interpretation. Either interpretation is provocative and could have economic consequences. [551]

Clay-Mineral Diagenesis in Atoka (Pennsylvanian) Sandstone, Crawford County, Arkansas

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Chemical and mineralogic evidence indicates significant clay-mineral diagenesis in a shallow (237 ft) core of Atoka (Pennsylvanian) sandstone from Crawford County, Arkansas. This core spanned a complex sequence of interbedded sandstone and shale that is at least partly marine.

Clay shales are dominated by illite with significant amounts of kaolinite and minor amounts of chlorite. Increasingly sandy shales contain progressively more chlorite and less kaolinite; illite remains the dominant clay-mineral component. The clay fractions ($<2\mu$) of sandstones are dominated by chlorite with lesser amounts of illite and no kaolinite.

The strong contrast between the clay-mineral contents of these closely interbedded sandstones and shales suggests a diagenetic change that occurred primarily in the sandstones because of their greater permeability. The chlorite of the sandstones most likely has been formed authigenically with concurrent destruction of kaolinite.

Elimination of kaolinite from sandstones by differential sedimentation seems unlikely because (1) it is doubtful that natural mechanical processes could produce the perfect separation of kaolinite found in these rocks, and (2) numerous studies of recent and ancient sediments indicate that kaolinite commonly is concentrated in sandstones rather than eliminated from them.

Clay-mineralogical changes in the sandstone may be part of an overall pattern of diagenesis in an alkaline, reducing environment that also includes the formation of siderite rhombohedra and significant solution of silica (as indicated by straight or embayed contacts of quartz grains).

Much of the discussion on the origin of clayey sediments in modern deposits has been devoted to the relative importance of provenance *versus* environmental alteration or segregation. With respect to ancient deposits, however, approaches confined to these factors are inadequate where diagenesis of clay minerals has occurred, as it apparently has in the Atoka sandstone and sandy shale. [553]

Palynological Stratigraphy and Succession of Oklahoma Pennsylvanian Coal Seams

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Palynomorphs occur abundantly in Pennsylvanian coals of Oklahoma and are usable as stratigraphic indices and indicators of ecological conditions which existed in the coal swamps during their accumulation. Climatic conditions during Pennsylvanian time in Oklahoma appear from several lines of evidence to have been remarkably uniform but certain genera and species of palynomorphs have restricted stratigraphic ranges which appear not to have been entirely ecologically controlled. Certain genera, *Knoxisporites, Densosporites, Savitrisporites,* and others, are more abundant in the Upper Mississippian strata than in Pennsylvanian and do not extend higher than the Morrow or Des Moines Series. The Missouri and Virgil Series are characterized by genera and species of saccate palynomorphs. Certain specific coals are characterized by suites of fossils, by paleoecological assemblages, and/or by stages of palynomorph succession. The last factor is based on at least three stages of palynomorph abundance which may be interpreted as representing stages in the paleoecological development of coal swamps. These successive abundance levels as high as the Mineral coal in the Des Moines Series are (1) *Laevigatosporites-Lycospora,* (2) *Calamospora-Florinites-Endosporites,* and (3) *Densosporites.* Above the Mineral coal the *Densosporites* stage is absent or is replaced by a stage dominated by saccate genera. In the Missouri and Virgil Series *Lycospora* is absent and *Laevigatosporites* commonly represents the first stage of palynological succession. All areal parts of most coal seams do not contain the complete series of stages or an abundance of specific assemblages. There is evidence that this variation is a function of geographic distribution of the particular coal seam and its geomorphic development. When factors of succession are combined with stratigraphic ranges of palynomorphs, greater knowledge of Pennsylvanian coal-swamp ecology is attainable. [555]

(Continued from page 38)

area and environment. The program comprises 10 papers (one on Oklahoma), and will terminate with a panel discussion.

Two pre-convention and one post-convention field trips are scheduled:

April 20-21—*Bartlesville-Bluejacket Sand.* The Bartlesville sand is one of the more prolific oil reservoirs in the world. The field trip will consist of visits to excellent outcrops of the unit, where lateral and vertical variations in textures, sedimentary structures, bedding relations, and depositional environments can be seen.

April 20-21—*Geology of Western Ouachita Mountains and Western Arkoma Basin*. The trip will cover a 22,000-foot-thick sequence of Upper Mississippian and Lower Pennsylvanian shales and sandstones that exhibit diagnostic characteristics of a flysch facies.

April 26-27—*Arbuckle Mountains*. The Arbuckle Mountains are composed of Paleozoic rocks ranging from Late Cambrian through Mississippian in age. The area is structurally complex and numerous carbonate reservoirs can be examined at the surface.

The staff of the Oklahoma Geological Survey and the faculty of the School of Geology and Geophysics of The University of Oklahoma are represented at all levels in the convention. Charles J. Mankin is chairman of the SEPM Research Symposium. William E. Ham is Vice-Chairman for SEPM on the Coordinating Committee and will lead the Arbuckle Mountains field trip. Patrick K. Sutherland is chairman for paleontology on the SEPM Technical Program Committee and will preside over one of the fossil-populations sessions. Thomas W. Amsden will present a paper and also preside over one of the SEPM paleontology sessions. L. R. Wilson will present a paper and Carl C. Branson will be one of the leaders of the Bartlesville sand field trip.

George G. Huffman is project director for the Educational Exhibits Committee, which is sponsoring a display of publications of affiliated societies.

In addition, the School and Survey will sponsor a joint exhibit, prepared by John F. Roberts.

It is 29 years since the convention was last held in Oklahoma City, which is too long a separation for old friends. The Survey is gratified to be able to welcome the out-of-state members and wishes them a wonderful time. The Oklahoma City Geological Society is due high praise for undertaking this complex project and for providing a first-class program.

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