OKLAHOMA GEOLOGY

Oklahoma Geological Survey Vol. 51, No. 6 December 1991

On the cover—

Parasitic "Z" Fold in the Arkansas Novaculite, Potato Hills

The cover photograph illustrates a "Z" fold in the Arkansas Novaculite on the south limb of a major, W-plunging anticline located in the central Potato Hills (SE¼ NW¼ NE¼ sec. 31, T. 3 N., R. 20 E., Latimer County, Oklahoma). The axis of the "Z" fold plunges 35°/269°, bedding attitudes on either side are approximately N. 90° E., 73° N. (overturned), and stratigraphic up is to the left (south).

The major anticline contains other parasitic folds that probably formed during an early layer-parallel shortening event. Layer-parallel shortening before the onset of significant folding can create minor symmetrical folds in a layered sequence. These minor folds may be transformed into asymmetric folds on the limbs of major structures.

The development of asymmetric parasitic folds indicates that an early layer-parallel shortening event occurred in the Potato Hills area before thrust faulting and major folding. As folding occurred, differential shear modified the initial symmetric folds into asymmetric folds. The presence of layer-parallel shortening in the Potato Hills supports the hypothesis that the North Potato Hills thrust is a major back thrust created by layer-parallel shortening prior to frontal ramp formation (Allen, 1990). Therefore, the North Potato Hills thrust is not the north boundary fault of a window; this evidence supports the conclusion that a window is nonexistent.

Reference

Allen, M. W., 1990, An analysis of mesoscopic structures in selected areas within the Potato Hills, Ouachita Mountains, Oklahoma: Shale Shaker, v. 41, p. 4–21.

Mark W. Allen
MASERA Corp., Tulsa, Oklahoma

OKLAHOMA GEOLOGICAL SURVEY

CHARLES J. MANKIN
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Editor
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NOTES
OKLAHOMA GEOLOGY

C O N T E N T S

186
Parasitic "Z" Fold in the Arkansas Novaculite, Potato Hills

188
Structural Analysis of the Northeastern Potato Hills, Ouachita Mountains, Oklahoma
Mark W. Allen

198
New OGS Publication: Arbuckle Group Core Workshop and Field Trip

198
Notes on New Publications

199
Structural Styles Workshop Norman, Oklahoma, March 31–April 1, 1992

202
GSA South-Central Section Meeting Houston, Texas, February 23–25, 1992

203
Upcoming Meetings

204
Oklahoma Abstracts

212
Index

OKLAHOMA
GEOLOGICAL
SURVEY

VOL. 51, NO. 6

DECEMBER 1991

STRUCTURAL ANALYSIS OF THE NORTHEASTERN POTATO HILLS, OUACHITA MOUNTAINS, OKLAHOMA

Mark W. Allen[1]

Abstract

Structural relationships in the northeastern Potato Hills indicate the North Potato Hills thrust was intersected by the South Potato Hills thrust. Subsurface relationships encountered in the Sinclair No. 1 Coussens well support the intersection. The two faults are separate and distinct implying a window is nonexistent. The Potato Hills are an allochthonous, faulted anticlinorium, and the overall geometry resembles an imbricate-fan thrust system.

Introduction

The structural geology and origin of the Potato Hills have been controversial for more than 60 years. Miser (1929) interpreted the Potato Hills to be a window in the Windingstair thrust sheet. Miller (1955), Roe (1955), and Arbenz (1968) also suggested the Potato Hills were a window in the Jackfork Mountain thrust sheet. Opponents of the window hypothesis include Kramer (1933), Misch and Oles (1957), Tomlinson (1959), Pitt (1971,1974), Pitt and others (1982), and Allen (1990,1991b).

Determining the structural relationships in the northeastern Potato Hills (Fig. 1) is critical when interpreting the overall structure. Two major thrust faults, the North and South Potato Hills thrusts, have been interpreted as (1) the same fault in this area (Roe, 1955; Arbenz, 1968), and (2) separate faults with the South Potato Hills thrust truncating the North Potato Hills thrust (Misch and Oles, 1957; Tomlinson, 1959). Detailed field mapping and surface and subsurface structural and stratigraphic relationships indicate the North Potato Hills thrust was intersected and offset by the South Potato Hills thrust.

Geologic Setting and Location

The Ouachita Mountains in Oklahoma are divided into three zones based on structure and stratigraphy: the frontal, central, and core zones. The Potato Hills, located in southern Latimer and northern Pushmataha Counties, Oklahoma (Fig. 1), are in the central zone, which is characterized by broad synclines separated by tight, thrust-faulted anticlines. The Potato Hills form a series of low, isolated hills ~3 mi south of the Windingstair fault.

Rocks that crop out in the study area range from middle Ordovician Womble Shale to Mississippian Stanley Group (Fig. 2). The hills are supported by the resistant Bigfork Chert and Arkansas Novaculite. The surrounding valley is cut in the Stanley Group by the drainage of the Kiamichi River and its tributaries.

[1]MASERA Corp., Tulsa, Oklahoma.

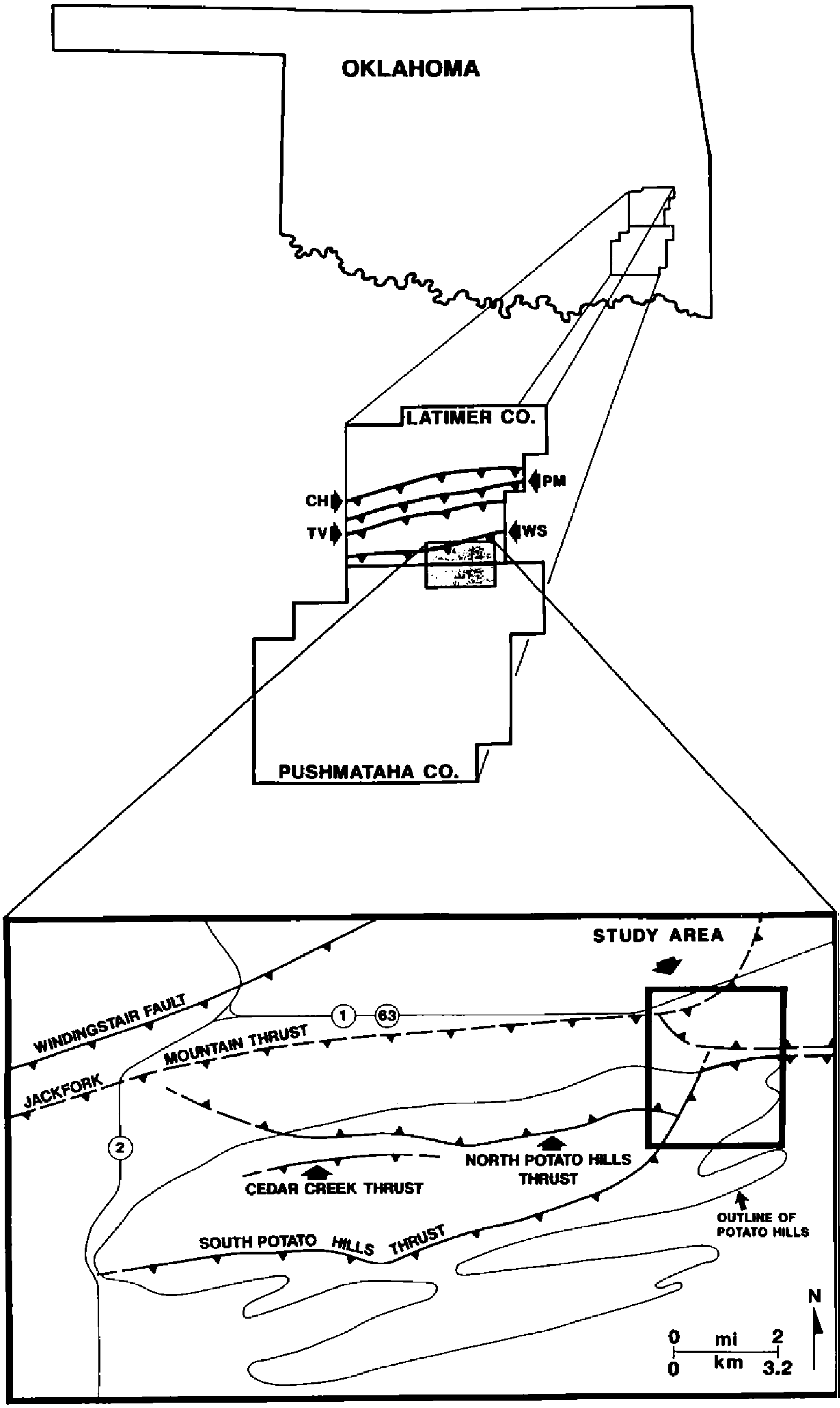

Figure 1. Location of the Potato Hills in relation to the Ouachita Mountains of Oklahoma. CH = Choctaw fault, PM = Pine Mountain fault, TV = Ti Valley fault, WS = Windingstair fault.

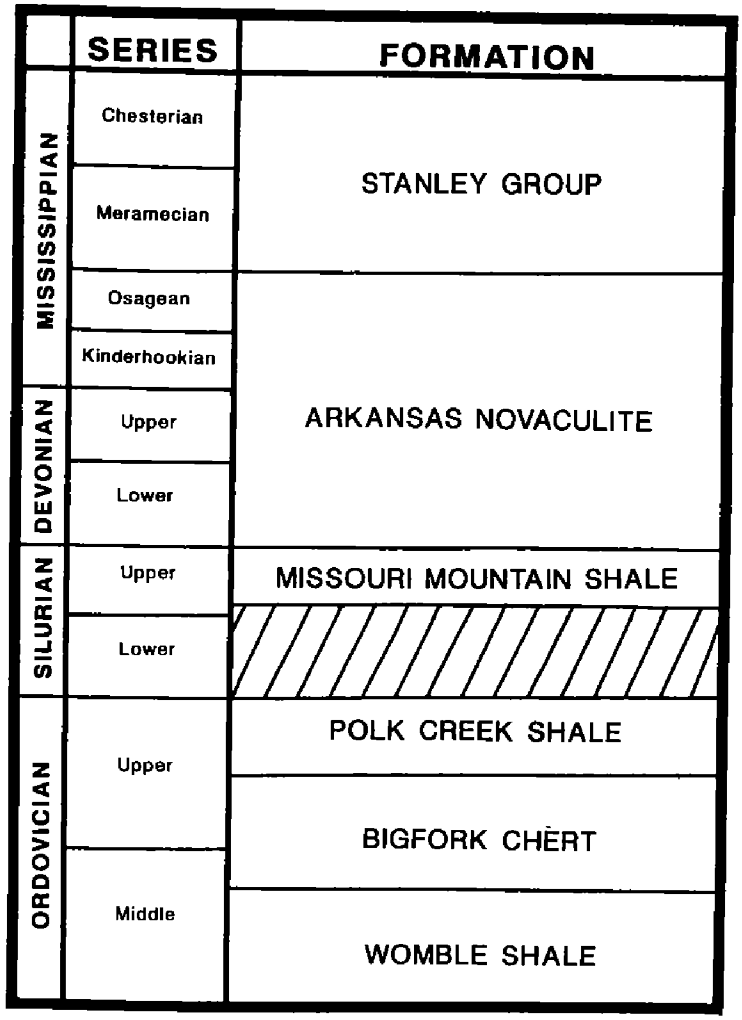

Figure 2. Stratigraphy in the Potato Hills. Modified from Suneson and others (1990).

Structural Geology

The study area contains three major faults: the North Potato Hills thrust, the South Potato Hills thrust, and the Jackfork Mountain thrust (Fig. 3A). The North Potato Hills thrust is a back thrust that resulted from an early, overall layer-parallel shortening event before significant folding (Allen, 1990,1991b).

The South Potato Hills thrust clearly truncates the North Potato Hills thrust (Figs. 3A,B), indicating movement on the southern fault continued later than on the northern fault. The North and South Potato Hills thrusts are separate faults with opposite transport directions implying the window is nonexistent.

The North and South Potato Hills thrust sheets have consistent bed attitudes in the study area. Strata above the North Potato Hills thrust generally strike E–W and dip N (Fig. 3A). In the South Potato Hills thrust sheet, strata generally strike NE and dip SE. The exception occurs to the northeast where beds strike approximately E–W and dip N. The change in bed attitudes is related to three major folds in the South Potato Hills thrust hanging wall (Fig. 3A). These folds have orientations, from north to south, of 089°/20°, 084°/20°, and 092°/18° (Fig. 3A) with axial-surface dips of

59° S, 86° S, and 77° S, respectively. Therefore, compression was north directed and the folds were tectonically related to the South Potato Hills thrust.

The Jackfork Mountain thrust, present in the northern part of the study area (Fig. 3A), juxtaposes Stanley against Stanley making the exact trace of the thrust uncertain. However, the thrust appears to change strike to the northeast as determined by bed attitudes and corresponds to the thrust mapped by Suneson and Ferguson (1990) that truncates the eastern end of the Buffalo Mountain syncline. These two thrusts, in conjunction with the South Potato Hills thrust which also changes strike to the northeast, indicate a northeast structural alignment in the eastern Potato Hills. The northernmost exposure of Arkansas Novaculite is fault bounded on the south and southwest (Fig. 3A). Displacement on this thrust, which juxtaposes Polk Creek–Missouri Mountain shale and Arkansas Novaculite against Stanley, was south directed as indicated by stratigraphy and bed attitudes. Therefore, this thrust is a minor back thrust that possibly acted as a connecting splay between the North Potato Hills thrust and the Jackfork Mountain thrust. The relationship between the connecting splay and the South Potato Hills thrust is unclear. The map pattern suggests either the connecting splay overrides, and is younger than, the South Potato Hills thrust, or more likely, displacement on the South Potato Hills thrust was reduced as the thrust changed strike and the connecting splay was not intersected. An intersection between the two faults cannot be identified in the field or on aerial photographs. However, northwest-directed compression was present in the area as indicated by joint attitudes (maximum stress direction = N. 67° W.) and an overturned syncline (Fig. 4) with an E-dipping axial surface. This indicates the connecting splay is older than the South Potato Hills thrust. The nonintersection and evidence of northwest-directed compression suggests displacement on the South Potato Hills thrust (1) terminated and was replaced by folding, (2) was diverted on a splay off of the main thrust (Fig. 3A), or (3) was subjected to a combination of the two.

The Sinclair No. 1 Coussens, drilled in 1960, is important for defining the subsurface relationships in the study area. The well, located in the SW¼SW¼SE¼ sec. 21, T. 3 N., R. 21 E. (Fig. 3A), reached a total depth of 2,500 ft. The scout ticket identified the following tops: Polk Creek–Missouri Mountain shale at the surface, Bigfork Chert at 382 ft, Womble at 1,188 ft, and faulted Bigfork at 1,862 ft to total depth. Based on surface interpretations, the following relationships exist: (1) the well drilled through a normal sequence of Polk Creek–Missouri Mountain shale to Womble in the South Potato Hills thrust hanging wall, (2) the fault penetrated at 1,862 ft is interpreted as the gently dipping South Potato Hills thrust as reflected in the gently plunging major folds, and (3) Bigfork Chert encountered below the fault is in the North Potato Hills thrust hanging wall (Fig. 3B).

The significance of this interpretation is the North and South Potato Hills thrusts are not the same fault. If they were, a normal sequence of Arkansas Novaculite through Womble Shale would be in fault contact with underlying Stanley. Instead, Womble is in fault contact with underlying Bigfork. If the Sinclair No. 1 Coussens had been drilled deeper, the North Potato Hills thrust would have been penetrated.

Discussion

Parasitic folds, best accounted for by an early layer-parallel shortening event (Ramsay and Huber, 1987), are present in the central Potato Hills (Allen, 1991b)

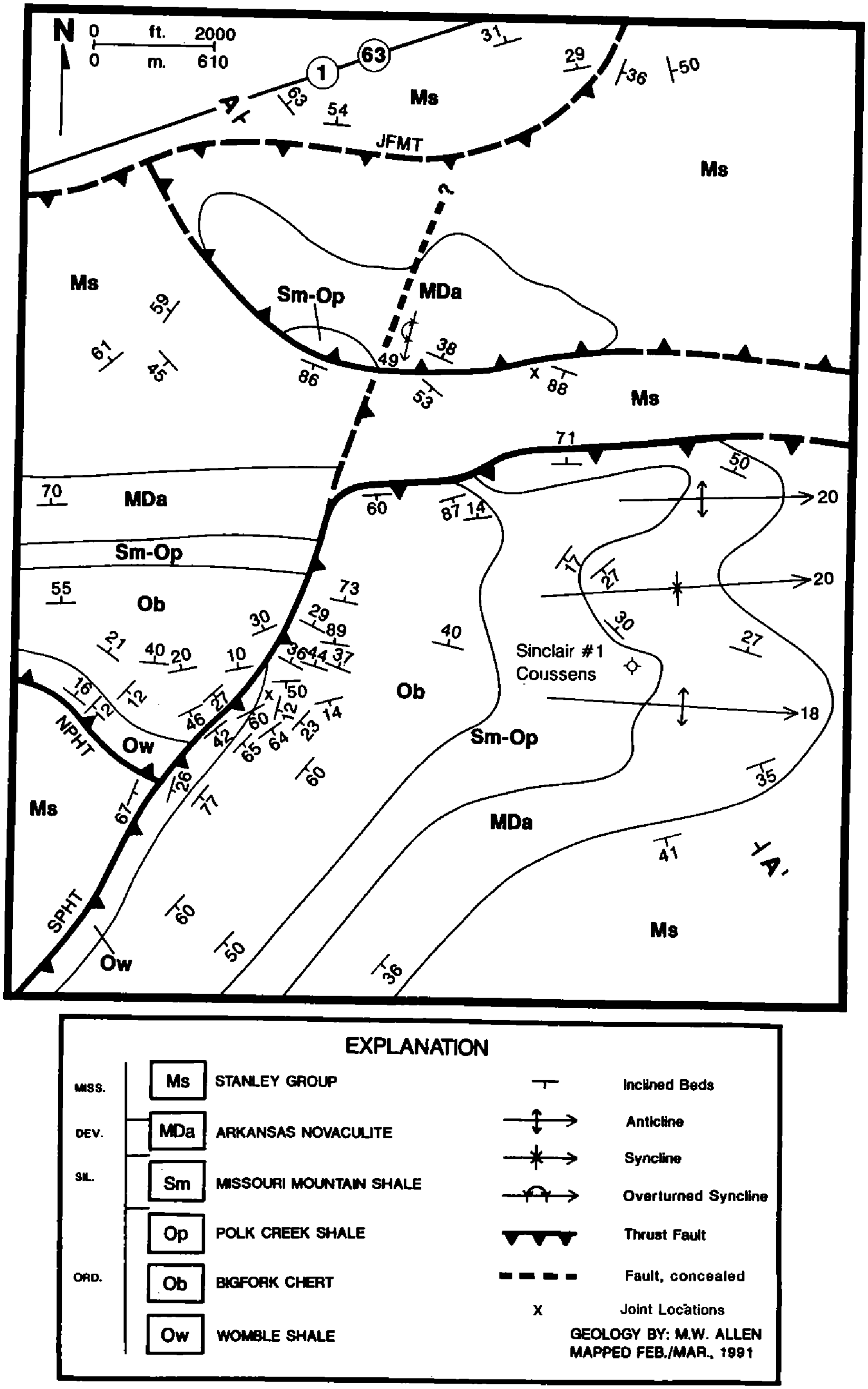

Figure 3A. Geologic map of the study area. JFMT = Jackfork Mountain thrust, NPHT = North Potato Hills thrust, SPHT = South Potato Hills thrust.

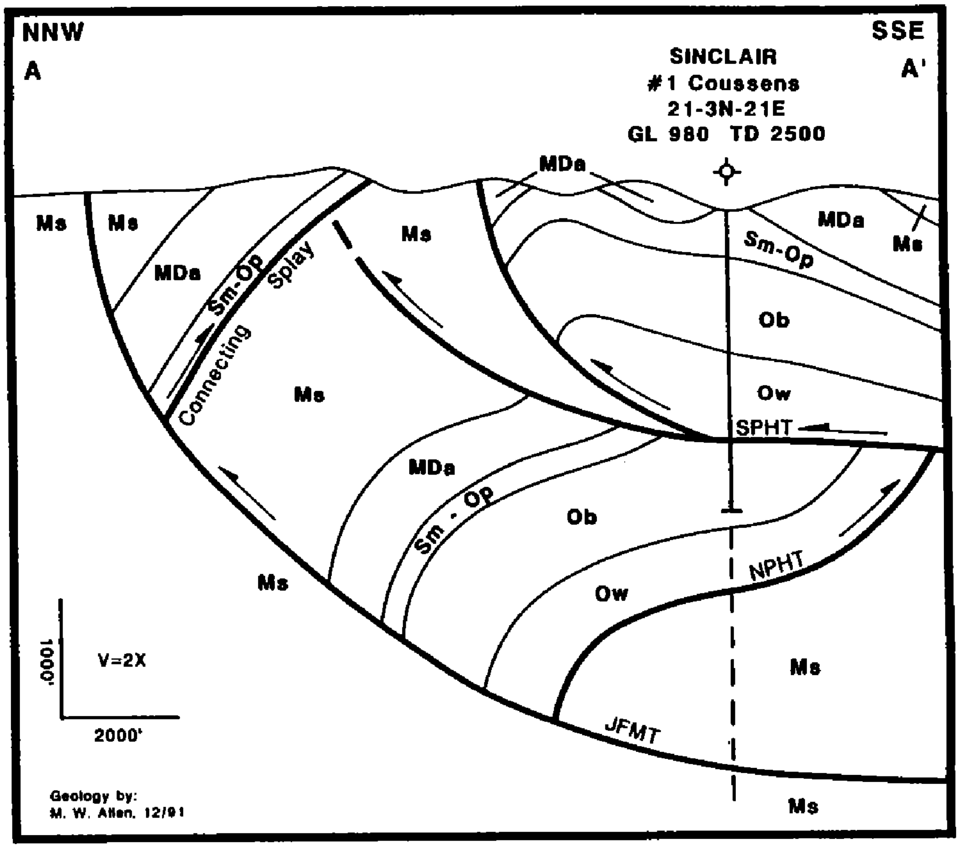

Figure 3B. Structural cross section through study area. Section is approximately parallel to regional transport direction. See Figure 3A for symbol definition.

and indicate the same type of tectonic style occurred in the Potato Hills. A back thrust model incorporating layer-parallel shortening is a "pop-up" back thrust (Fig. 5), developed by layer-parallel shortening prior to frontal ramp formation (Butler, 1982). The connecting splay indicates an apparent structural and tectonic relationship between the North Potato Hills thrust and the Jackfork Mountain thrust and supports the application of a modified "pop-up" model. The Jackfork Mountain thrust is the primary thrust associated with the Potato Hills. Back thrusts can appear at the same time as the main reverse-fault structure (Ramsay and Huber, 1987). This, in conjunction with the pop-up model and the mapped intersection, indicates the North Potato Hills thrust developed before the South Potato Hills thrust.

The timing relationship between the Jackfork Mountain thrust and the South Potato Hills thrust is uncertain due to a lack of timing indicators and the inability to exactly locate each thrust to the northeast. The standard practice of assuming break-forward sequencing as a working hypothesis (Marshak and Woodward, 1988) suggests the South Potato Hills thrust is older than the Jackfork Mountain thrust. However, out-of-sequence faulting is another possible hypothesis. The "pop-up" back thrust model suggests the North Potato Hills thrust and Jackfork Mountain thrust developed at approximately the same time. The parasitic folds imply these thrusts developed during the early stages of tectonic evolution. The South Potato Hills thrust is younger than the North Potato Hills thrust and is therefore probably younger than the Jackfork Mountain thrust. This evidence suggests the possibility of out-of-sequence faulting.

Figure 4. Overturned syncline in the Arkansas Novaculite. The fold axis is oriented 191°/49° and the east limb (right) is overturned 59° SE indicating northwest compression. View is north.

Deformation resulted from a north-directed, progressive deformational event. Allen (1990) estimated a maximum compressional stress direction between N. 9° W. and N. 6° E. The N. 9° W. value represents north-directed compression; however, the N. 6° E. value represents compression created by back thrusting directed S. 6° W. Three compressional directions were indicated in the study area: south, northwest, and north. Joints in the South Potato Hills thrust hanging wall (Fig. 3A) indicate a maximum stress direction between N. 63° W. and N. 67° W., which corresponds to the transport direction of the South Potato Hills thrust in the study area. This differs from the western Potato Hills where the South Potato Hills thrust has an E–NE strike that indicates a N–NW (N. 9° W.) transport direction. The change in strike of the South Potato Hills thrust indicates either (1) a late orogenic compressional shift from the north to the northwest, or (2) the presence of an oblique ramp (Fig. 6). A regional compressional shift is discounted by the trends of the major fold axes. The splay off of the South Potato Hills thrust is indicated by the juxtaposition of Bigfork and Missouri Mountain–Polk Creek shales against Stanley (Fig. 3A). This thrust is interpreted to represent north-directed compression that was not affected by the oblique ramp. Therefore, the tectonic setting, the change in strike of the South Potato Hills thrust and the Jackfork Mountain thrust, and the northeast structural alignment in the study area favor the existence of an oblique ramp and suggest the indications of localized northwest compression were effects of north-directed compression as the South Potato Hills thrust sheet moved over the oblique ramp.

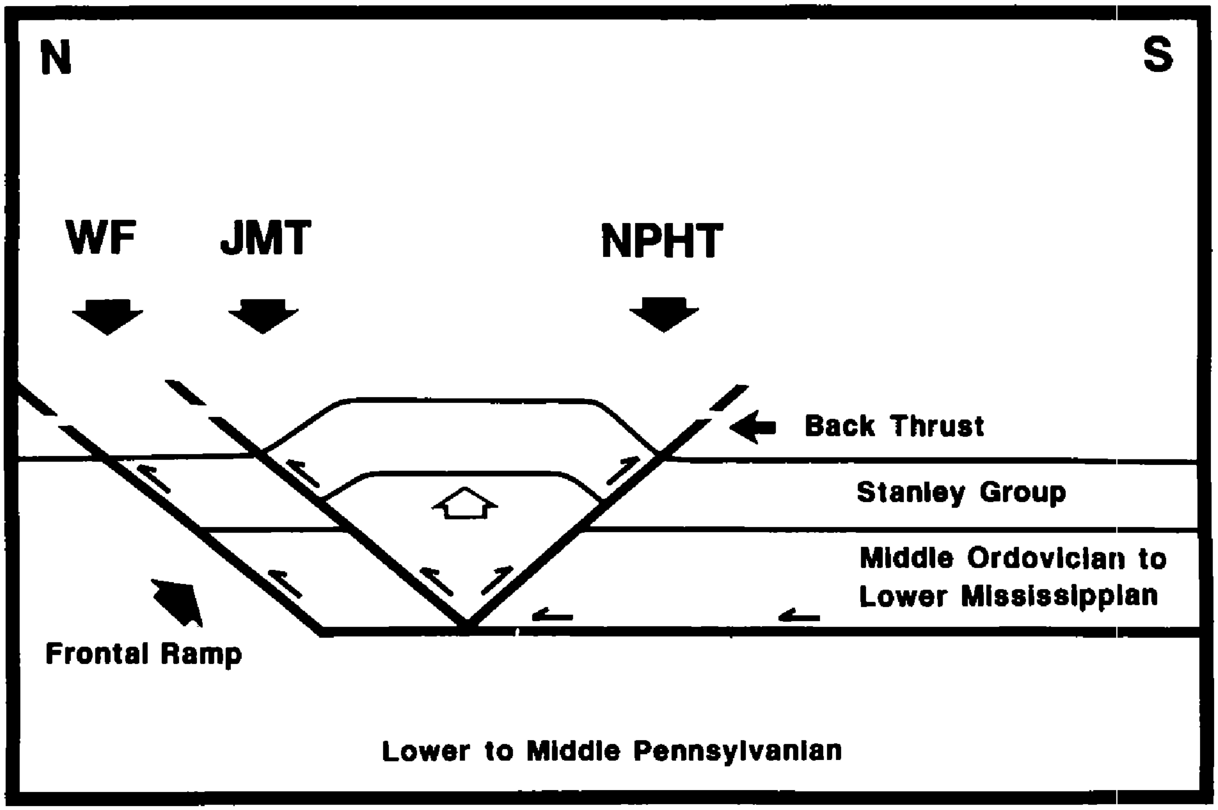

Figure 5. "Pop-up" back thrust model proposed for the North Potato Hills thrust (NPHT) in conjunction with the Jackfork Mountain thrust (JMT). This diagram is meant to demonstrate the proposed tectonic mechanism responsible for the overall structure. It is not meant to explain or illustrate structural relationships in the northeastern Potato Hills. WF = Windingstair fault. Modified from Butler (1982).

Conclusions

Structural relationships in the northeastern Potato Hills resulted from thrust-fault intersection. The timing of back thrusting indicates the North Potato Hills thrust developed before and was offset by the South Potato Hills thrust. This is supported by subsurface relationships in the Sinclair No. 1 Coussens well. The North and South Potato Hills thrusts are separate, distinct thrusts indicating a window is nonexistent. The Potato Hills are an allochthonous, faulted anticlinorium, the major north-directed thrust faults are imbrications of the Jackfork Mountain thrust, and the overall geometry resembles an imbricate-fan thrust system.

The main contribution of this paper is to add argument for the allochthonous vs. autochthonous controversy concerning the Potato Hills. The window hypothesis, used for the allochthonous interpretation, is no longer valid. Other evidence does substantiate the allochthonous nature of the Potato Hills. This evidence includes seismic data (J. Roberts, personal communication, 1991), displacement values (Allen, 1991a), and the Sinclair No. 1 Reneau, which encountered Carboniferous strata at total depth (Arbenz, 1968).

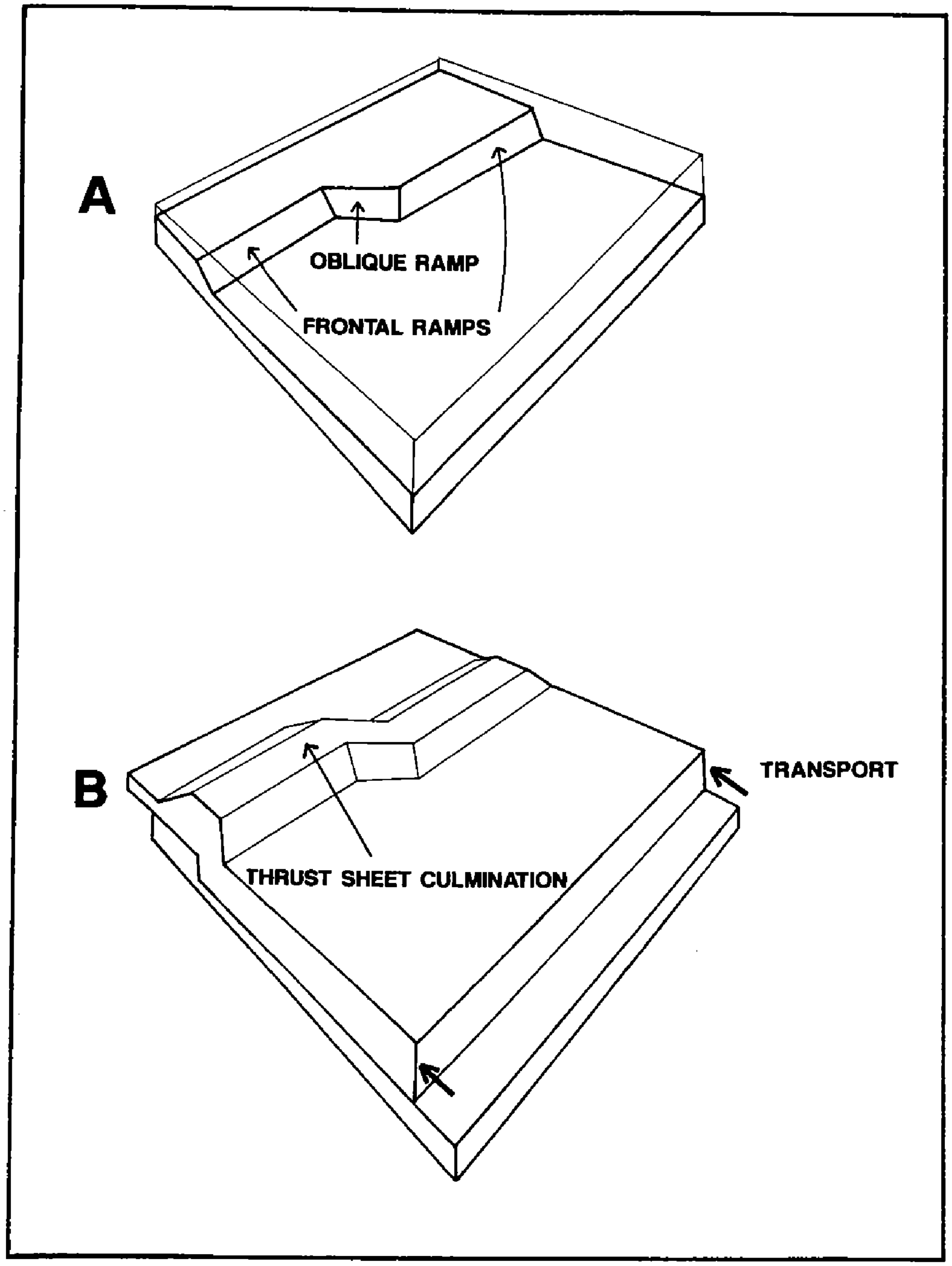

Figure 6. Footwall (A) and hanging wall (B) diagrams indicating how footwall geometry influences hanging wall structures. The change in strike of the fault is related to the oblique ramp and not to a change in compression. Modified from Ramsay and Huber (1987).

Acknowledgments

This paper has greatly benefited from discussions with and critical reviews by Neil Suneson. I thank J. Campbell and A. Ontko for reviewing and Vickie Hulstine for typing the manuscript. I am grateful to landowner Gene Handelman for allowing me access to his property and David Allen for his assistance in the field.

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NEW OGS PUBLICATION

SPECIAL PUBLICATION 91-3. *Arbuckle Group Core Workshop and Field Trip*, edited by Kenneth S. Johnson. 266 pages. Price: $10.

From the editor's preface:

The Late Cambrian–Early Ordovician Arbuckle Group is a thick sequence of shallow-marine carbonates deposited on the south edge of the North American craton. This rock unit is a major target for petroleum exploration and reservoir development in the southern Midcontinent. The workshop was held to display cores and outcrop samples of the Arbuckle Group, along with cores of the equivalent Ellenburger Group of Texas and the Knox Group of Mississippi and Alabama.

The field trip was organized to compliment the workshop by allowing examination of excellent outcrops of the Arbuckle Group in both the Arbuckle and Wichita Mountains.

The core workshop and the field trip cover such topics as: petroleum-reservoir characterization; deposition, diagenesis, paleokarst, and structure of the Arbuckle Group as a carbonate reservoir; and interpretation of Arbuckle Group geology based upon petrologic, petrographic, and geochemical studies. To facilitate the exchange of information on these important topics, the Oklahoma Geological Survey (OGS) and the Bartlesville Project Office of the U.S. Department of Energy (BPO–DOE) co-sponsored this workshop and field trip. The ultimate goal of this program is to increase activity in the search for, and the production of, our oil and gas resources.

Special Publication 91-3 can be obtained over the counter or by mail from the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031. Add 10% to the cost of publication(s) for mail orders, with a minimum of 50¢ per order.

NOTES ON NEW PUBLICATIONS

Water Resources Data—Oklahoma, Water Year 1990

Records on both surface water and ground water in Oklahoma are contained in this 517-page report by R. L. Blazs, D. M. Walters, T. E. Coffey, D. K. White, and D. L. Boyle. Specifically, it includes (1) discharge records for 132 streamflow-gaging stations and six partial-record or miscellaneous streamflow stations, (2) stage and content records for 30 lakes and reservoirs, (3) water-quality records for 46 streamflow-gaging stations and two lakes, and (4) water-level records for 34 observation wells.

Order USGS Water-Data Report OK-90-1 from: U.S. Geological Survey, Water Resources Division, 202 N.W. 66th St., Bldg. 7, Oklahoma City, OK 73116; phone (405) 231-4256. A limited number of copies are available free of charge.

STRUCTURAL STYLES WORKSHOP
Norman, Oklahoma, March 31–April 1, 1992

A workshop on "Structural Styles in the Southern Midcontinent," co-sponsored by the Okahoma Geological Survey and the Bartlesville Project Office of the U.S. Department of Energy, will be held March 31–April 1, 1992, at the Oklahoma Center for Continuing Education (OCCE) of the University of Oklahoma in Norman.

The workshop will present current and ongoing research and studies dealing with structural styles, structural development, and tectonic evolution within the region. The workshop is designed to transfer technical information that will aid in the identification and characterization of oil and gas plays, and thus improve our ability to search for and produce our petroleum resources. Provisional titles and speakers are listed below:

March 31

Basement Influence on the Structural Geology of Southern Oklahoma Inferred from Residual-Aeromagnetic Maps, by Thomas L. Thompson and James R. Howe, Consulting Geologists, Boulder, CO; and Bronson Hawley and S. Parker Gay, Applied Geophysics, Inc., Salt Lake City, UT

A North American Continental-Scale Fracture Zone, by Donald L. Baars, Kansas Geological Survey, Lawrence, KS; and William A. Thomas, University of Kentucky, Lexington, KY

Structural Styles in the Southern Arkoma Basin–Ouachita Mountains, Arkansas, by Boyd R. Haley and Charles G. Stone, Arkansas Geological Commission, Little Rock, AR

Two-Decked Structure of the Ouachita Mountains, by George W. Viele, University of Missouri, Columbia, MO

Seismic Investigations of the Ouachita Trend from Arkansas to North Texas, by Richard E. Schneider, Schneider Strata Science, Inc., Oklahoma City, OK

The Interpretation of Structure Along the Ouachita Frontal Belt from Surface-Geology Evidence in Southeastern Oklahoma, by Colin Mazengarb and LeRoy Hemish, Oklahoma Geological Survey, Norman, OK

Dyer Mountain Fault Zone: Southerly Directed Thrusting in the Broken Bow Uplift, by Kent C. Nielsen, University of Texas at Dallas, Richardson, TX

At the Ouachita–Arbuckle Crossroads, Oklahoma, by William McBee, Jr., Independent Geologist, Tulsa, OK

The Wichita and Arbuckle Orogenies: Plate Collison or Aulacogen Collapse, by Raymon Brown, Oklahoma Geological Survey, Norman, OK

Regional Sedimentation Patterns Associated with the Passive- to Active-Margin Transition During the Ouachita Orogeny, by Paula Noble, University of Texas, Austin, TX

April 1

Deformation Style in the Arbuckle Uplift—A Re-evaluation of Structural/Tectonic Models for the Southern Oklahoma Aulacogen, by Bryan Tapp, University of Tulsa, Tulsa, OK

The Significance of Air-Photo Linears in Basement Rocks of the Arbuckle Mountains, by Rodger E. Denison, Mobil Research and Development, Dallas, TX

The Collings Ranch Conglomerate of the Oklahoma Arbuckles: Its Origin and Tectonic Significance, by Kevin Pybas and Ibrahim Cemen, Oklahoma State University, Stillwater, OK

Structural Evolution of the Criner Hills Trend, Ardmore Basin, Oklahoma, by J. Calvin Cooper, Shell Western E&P, Houston, TX

Thermal Uplifting of the Harper Field, Central Basin Platform, Ector County, Texas, by Jack G. Elam, Independent Geologist, Midland, TX

Connections Between Laramide Foreland Arches, by Eric Erslev and Philipp Molzer, Colorado State University, Fort Collins, CO

The Structure of the Wichita Uplift, by R. Nowell Donovan, Texas Christian University, Fort Worth, TX

Magnetically Determined Geometry and History of the Meers Fault within the Frontal Wichita Fault Zone, by Meridee Jones-Cecil, U.S. Geological Survey, Denver, CO; and R. Nowell Donovan, Texas Christian University, Fort Worth, TX

Structural Development of the Nemaha Tectonic Zone, by Pieter Berendsen and Kevin Blair, Kansas Geological Survey, Lawrence, KS

Neotectonic Relationships of the Nemaha Uplift in Oklahoma, by Kenneth V. Luza, Oklahoma Geological Survey, Norman, OK

Poster Session, March 31

Structural Geology, Tectonic Evolution, and Hydrocarbon Potential of the Potato Hills, Ouachita Mountains, Oklahoma, by Mark W. Allen, MASERA Corp., Tulsa, OK

Structure, Timing, and Tectonic Interpretation of Ancestral Rocky Mountain Deformation within Central New Mexico, by William C. Beck and Charles E. Chapin, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM

A Structural and Petrographic Study of the Womble Formation along the Western Flank of the Broken Bow Uplift, McCurtain County, Oklahoma, by Steven Erickson, Samson Resources Co., Tulsa, OK; and Bryan Tapp, University of Tulsa, Tulsa, OK

Structural and Stratigraphic Framework of the Wapanucka Formation (Pennsylvanian), Southeastern Oklahoma, by Victoria L. French and Robert C. Grayson, Jr., Baylor University, Waco, TX

Structural Styles in the Southern Arkoma Basin–Ouachita Mountains, Arkansas, by Boyd R. Haley and Charles G. Stone, Arkansas Geological Commission, Little Rock, AR

Surface Structures in Permian Rocks of Southwestern Oklahoma as Indicators of Deep-Seated Structures, by Kenneth S. Johnson, Oklahoma Geological Survey, Norman, OK

Relationships of Southern Midcontinent Structures to a Postulated Late Precambrian Transcontinental Fault, by Gary L. Kinsland, University of Southwestern Louisiana, Lafayette, LA

Wapanucka Limestone (Morrowan) Reservoirs: Passive Margin Oolitic Grainstone and Fractured Spiculitic Packstone, Frontal Ouachita Mountains, Oklahoma, by Darrell Mauldin and Robert C. Grayson, Jr., Baylor University, Waco, TX

Structural Interpretations of the Ouachita Frontal Zone near Hartshorne, Oklahoma, Based on Reprocessed Seismic–Reflection Data, by W. J. Perry and W. F. Agena, U.S. Geological Survey, Denver, CO; and N. H. Suneson, Oklahoma Geological Survey, Norman, OK

Surface to Subsurface Study of the Northwest Plunge of the Arbuckle Anticline, by Christopher P. Saxon, Baylor University, Waco, TX

The Deese and Vanoss Conglomerates Exposed Between the Sulphur and Reagan Faults, Murray County, Oklahoma: Their Sedimentology, Sedimentary Environment, and Tectonic Implication, by Craig Stafford, Ibrahim Cemen, and Zuhair Al-Shaieb, Oklahoma State University, Stillwater, OK

Evidence for Recurrent Left-Lateral Deformation from the Vicinity of the Depew Field, by Dorothy L. Swindler, University of Tulsa, Tulsa, OK

Basement Influence on the Structural Geology of Southern Oklahoma Inferred from Residual-Aeromagnetic Maps, by Thomas L. Thompson and James R. Howe, Consulting Geologists, Boulder, CO; and Bronson Hawley and S. Parker Gay, Applied Geophysics, Inc., Salt Lake City, UT

Stratigraphy and Structural Styles of the Lower Stanley Tuffs: Northwest Flank of the Broken Bow Uplift, McCurtain County, Oklahoma, by Charles A. O. Titus and Thomas E. Legg, Tex-Con Oil and Gas Co., Houston, TX

Imaging of Basement Block Configuration in the Wichita Mountain Frontal Zone, by Roger Young, University of Oklahoma, Norman, OK

Advance registration (prior to March 6) is $50, which includes two lunches and a copy of the proceedings. Late and on-site registration will be $65 per person. Lodging will be available on the OU campus or at local motels.

Contact Kenneth S. Johnson, General Chairman, Oklahoma Geological Survey, University of Oklahoma, 100 E. Boyd, Room N-131, Norman, OK 73019, phone (405) 325-3031, for more information. Contact Linda Nero or Tammie Creel at the same address and phone number for registration forms.

GSA SOUTH-CENTRAL SECTION MEETING
Houston, Texas, February 23–25, 1992

Sponsored by Rice University, the University of Houston, and the Houston Geological Society, the 26th annual meeting of the GSA South-Central Section will take place on the campus of Rice University. The meeting will be held jointly with the Midcontinent Section of the National Association of Geology Teachers and the South-Central Section of the Paleontological Society of America. The following meetings and field trips are planned.

Symposia

Tectonics and Evolution of the Gulf of Mexico Basin
Late Pleistocene–Holocene Climatic Record of the Gulf Coast
Comparison of North American and Eastern European Folded Belts
Response of Carbonate Platform to Sea-Level Fluctuations: Cases in the Caribbean and the Gulf of Mexico
Sequence Stratigraphy of the Gulf Coast Paleogene: A Global Comparison
Evolution of Grenville Basement
Hydrogeologic Controls on Contaminant Transport
Mesozoic/Cenozoic Micropaleontology
The Role of Planetary Geology in the Undergraduate Geology Curriculum
Magellan to Venus

Field Trips

Mid-Cretaceous Carbonates in Central Texas and Sea-Level Variations
NASA Johnson Space Center
United Salt Corp. Hockley Mine, Hockley, Texas
Recent Sediments of Southeast Texas
Holocene Sea-Level Rise and Its Impact on Evolution of East Texas Coastal Environments
Environmental/Engineering Geology in the Houston Metropolitan Area
Paleogene Sequence Stratigraphy of the Brazos River Valley, Texas
Modern Mixed Carbonate/Siliciclastic Systems, Belize

Short Courses

Geologic Interpretation of Seismic Profiles
Geochronology and Thermochronology

For further information about the meeting, contact Hans G. Avé Lallemant (General Chairman), Dept. of Geology and Geophysics, Rice University, P.O. Box 1892, Houston, TX 77251; (713) 527-4880. The pre-registration deadline is January 20.

UPCOMING MEETINGS

Petro-Safe Meeting and Exhibit, January 27–29, 1992, Houston, Texas. Information: PennWell Conference and Exhibitions, 3050 Post Oak Blvd., Suite 200, Houston, TX 77056; (713) 621-9720, fax 713-963-6284.

V. E. McKelvey Forum on Energy Resources, February 18–20, 1992, Houston, Texas. Information: Christine Turner, U.S. Geological Survey, Box 25046, MS 939, Federal Center, Denver, CO 80225; (303) 236-1561.

U.S. Geological Survey, Conference on Ground-Water Quality of the Central Oklahoma (Garber–Wellington) Aquifer, February 20, 1992, Oklahoma City, Oklahoma. Information: Kathy D. Peter, District Chief, USGS Water Resources Division, 202 N.W. 66th St., Bldg. 7, Oklahoma City, OK 73116; (405) 231-4256.

Lunar and Planetary Science, Annual Meeting, March 16–20, 1992, Houston, Texas. Information: Pamela Jones, Lunar and Planetary Institute, Program Services Dept., 3303 NASA Road 1, Houston, TX 77058; (718) 486-2150.

Geological Society of America, Southeastern Section Meeting, March 18–20, 1992, Winston-Salem, North Carolina. Information: Paul D. Fullager, Dept. of Geology, CB 3315 Mitchell Hall, University of North Carolina, Chapel Hill, NC 27599; (919) 962-0677.

Oklahoma Geological Survey and U.S. Department of Energy, Workshop on Structural Styles in the Southern Midcontinent, March 31–April 1, 1992, Norman, Oklahoma. Information: Kenneth S. Johnson, OGS, 100 E. Boyd, Room N-131, Norman, OK 73019; (405) 325-3031, fax 405-325-3180.

Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Annual Field Trip, "Paleokarst, Karst-Related Diagenesis, and Reservoir Development: Examples from Ordovician–Devonian-Age Strata of West Texas and the Midcontinent," April 9–11, 1992. Information: Magell Candelaria, ARCO Oil and Gas Co., P.O. Box 1610, Midland, TX 79702; (915) 688-5254, fax 915-688-5756.

American Association of Petroleum Geologists, Southwest Section Meeting, April 12–14, 1992, Midland, Texas. Information: West Texas Geological Society, P.O. Box 1595, Midland, TX 79702; (915) 683-1573.

Ground-Water Resources Meeting, April 12–16, 1992, Raleigh, North Carolina. Information: Michael C. Fink, American Water Resources Association, 5410 Grosvenor Lane, Suite 220, Bethesda, MD 20814; (301) 493-8600.

Seismological Society of America, Annual Meeting, April 14–16, 1992, Santa Fe, New Mexico. *Abstracts due January 15.* Information: SSA, 201 Plaza Professional Bldg., El Cerrito, CA 94530; (415) 525-5474.

Mid-America Paleontology Society, Fossil Exposition, April 24–26, 1992, Macomb, Illinois. Information: Allyn Adams, 612 W. 51st St., Davenport, IA 52806; (319) 391-5443.

Project PANGEA (GSGP) Research Workshop, May 24–29, 1992, Lawrence, Kansas. Information: Project Pangea, P.O. Box 5061, Station A, Champaign, IL 61825; (217) 333-2076.

OKLAHOMA ABSTRACTS

The following are abstracts from theses and dissertations prepared by graduates of the University of Oklahoma, University of Texas–Dallas, Baylor University, and Southwest Missouri State University. Permission of the authors to reproduce the abstracts is gratefully acknowledged.

Magnetizations of Reddened Carbonate Rocks at Paleo-exposure Surfaces

KEVIN EUGENE NICK, University of Oklahoma, Norman,
Ph.D. dissertation, 1990

The origins of magnetization in three Paleozoic carbonate units that exhibit reddening due to subaerial exposure were determined and compared using sedimentologic and paleomagnetic methods. The Cambrian Royer Dolomite in the Arbuckle Mountains, Oklahoma, contains an early Paleozoic magnetization (Dec. = 109°, Inc. = 10°, tilt corrected) and a non-pervasive Pennsylvanian–Permian chemical remnant magnetization (CRM) residing in hematite (Dec. = 147°, Inc. = 4°, in situ) that is associated with dedolomitized rocks in an alteration zone around and below karst features. Clasts of the Royer in the Pennsylvanian Collings Ranch Conglomerate, correlated to the parent rock by petrographic, isotopic, and rock magnetic methods, also contain predepositional magnetizations in their centers while the clast margins contain a post-depositional CRM (Dec. = 152°, Inc. = 4°, in situ).

In a second study, an early, synsedimentary, CRM is found in and below terra rosa paleosols which cap regressive carbonate cycles in the Pennsylvanian (Morrowan) Black Prince Limestone in southeastern Arizona. Authigenic hematite, occurring in fractures between soil nodules, in Liesegang bands, and replacing allochems is related to the soil-forming processes. Northwesterly and southeasterly magnetizations from the soil zones are interpreted to be antipodal equivalents and show a stratigraphic distribution with at least three reversals. The mean direction (Dec. = 308°, Inc. = 9°) corresponds to a pole position at Lat. = 34°N, Lon. = 143°E similar to other pre-Kiaman, Carboniferous poles. Interbedded, gray marine limestones contain unstable magnetizations. Terra rosa paleosols are likely to have preserved the hematite and associated magnetizations that formed as a result of soil forming processes.

A third study of laterally continuous ferruginous beds in the Upper Pennsylvanian Holder Formation, Sacramento Mountains, New Mexico, by stepwise thermal demagnetization, yields two stable components (Dec. = 10°, Inc. = 61° and Dec. = 180°, Inc. = −49°). These directions are interpreted to be due to modern (post Bruhnes and Bruhnes) weathering and reside in goethite. The goethite is associated with calcitized dolomite which is the result of modern weathering and the CRM is also a result of modern, not syndepositional, diagenetic processes. Comparison of the petrographic and paleomagnetic characteristics of these modern-age, laterally continuous reddened beds with ancient reddened carbonates suggests criteria for identifying primary magnetizations.

Syndeformational Magnetization in the Ordovician Bigfork Chert at Black Knob Ridge, Western Ouachita Mountains, Southern Oklahoma

TONY K. HILLEGEIST, University of Oklahoma, Norman, M.S. thesis, 1991

Paleomagnetic and rock magnetic results from unweathered samples of the Ordovician Bigfork Chert at Black Knob Ridge in southern Oklahoma indicate the presence of a pervasive magnetization that resides in magnetite. The magnetization has a steep, southeast direction. Small- and medium-scale folds acquired magnetization during or after Carboniferous folding. The declination in sites along Black Knob Ridge also shows a north to south 28° counter-clockwise shift.

The Bigfork Chert at Black Knob Ridge was folded and thrusted along the Ti Valley fault system in the late Paleozoic. A pervasive late Paleozoic magnetization with a shallow inclination occurs in the laterally equivalent Viola Limestone in front of the thrust and in the Arbuckle Mountains. This direction is used as a reference for comparison with the Bigfork Chert Formation at Black Knob Ridge. The steep inclinations in the rocks at Black Knob Ridge are interpreted to be primarily the result of rotation around a horizontal axis as a result of thrusting. The declination change along the ridge is also interpreted to be the result of rotational movements during thrusting.

The pervasive magnetization at Black Knob Ridge is interpreted to have been acquired during the deformation. The results of fold tests and an incremental test correcting for both strike and dip suggest remanence acquisition during late stage folding and during an early stage of thrusting. The low thermal history of the Bigfork Chert suggests that the pervasive component is a chemical remanent magnetization (CRM) although a strain-related mechanism cannot be definitely ruled out. The proposed CRM may be related to fluid migration through fractures produced during folding and thrusting. Alternatively, an in situ chemical process (e.g., maturation of hydrocarbons) may have caused the remagnetization.

Conodont Biostratigraphy of Late Mississippian Shale Sequences, South-Central Oklahoma

RICHARD STEPHEN KLEEHAMMER, University of Oklahoma, Norman, M.S. thesis, 1991

The Late Mississippian strata of the Arbuckle Mountains region are dominated by dark, organic-rich shales. The shales of the southwestern flank of the Arbuckle Mountains are part of a thick basin sequence, nearly four times as thick as the equivalent sequence of the northeastern flank. Stratigraphic sections were measured within the shale sequences of each flank and conodont samples were precisely located stratigraphically. While the northeastern flank section yielded the greatest number of conodonts, faunas from both sections are best described as sparse.

Three conodont assemblages are recognized: *Gnathodus texanus–Gnathodus girtyi, Gnathodus bilineatus–Lochriea commutata*, and *Declinognathodus noduliferus–Gnathodus higginsi* assemblages.

Two major shale lithologies can be consistently recognized: the black, hard shales of the Caney Shale and the overlying softer, lighter-colored sideritic shales. The Caney Shale cannot be lithologically subdivided. Use of the subdivisions Ahloso, Delaware Creek, and Sand Branch, which are primarily paleontological in concept, is not warranted. The overlying lighter-colored sideritic shales, termed "Rhoda Creek" Formation on the northeastern flank, can be correlated with the upper Goddard and Springer Formations on the southwestern flank.

Discovery of *Declinognathodus noduliferus* in the unnamed shales 117 m below the Lake Ardmore Member (Springer Formation) lowers the previous placement of the Mississippian–Pennsylvanian boundary in the northern Ardmore Basin.

Biostratigraphic Investigations of Late Paleozoic (Upper Devonian to Mississippian) Radiolaria within the Arbuckle Mountains and Ardmore Basin of South-Central Oklahoma

JON A. SCHWARTZAPFEL, University of Texas, Dallas, Ph.D. dissertation, 1990

In recent years, detailed Mesozoic and Cenozoic radiolarian zonations have demonstrated their usefulness in interpreting the stratigraphy, structure, and tectonic history of complex orogenic belts and tectonostratigraphic terranes. In order to develop a detailed radiolarian zonation for the early Late Paleozoic, Upper Devonian and Lower Carboniferous Radiolaria-bearing samples were collected from the Arbuckle Mountains and Criner Hills of Oklahoma. Using the event line method, biostratigraphically useful taxa were selected and described. Sampling from these areas included the Woodford, Sycamore and "Caney" Formations as well as the basal portion of the Goddard Formation. Two new subfamilies, four new genera, and fifty-three new species are described. Also, radiolarian biostratigraphic data from a third area, the Ouachita Mountains of Oklahoma (provided by Cheng, 1986), was re-examined and integrated with this study.

A preliminary system of radiolarian zonation (including ten zones) is proposed for the Upper Devonian (Famennian) and Lower Carboniferous (Mississippian) of the southern United States. This system of zonation has been correlated with biostratigraphic data supplied by conodonts and goniatites. The biostratigraphic data serves as a bridge, linking the proposed zonation to North American and European standard zones as well as the geochronometric time scale.

In addition, this study reports the following:

1) New radiolarian and conodont faunas recovered from the upper part of the Woodford Formation indicate a considerably higher chronostratigraphic position for the top of this unit than previously thought;

2) A single limestone bed displaying an incomplete Bouma (B, C, D, E?) sequence discovered within the Upper Limestone unit (*sensu*, Fay, 1969) of the Sycamore Formation indicates that this formation is partially (if not entirely) turbiditic in origin;

3) Reworked conodont assemblages (containing *Cavusgnathus charactus* Rex-

road, *Taphrognathus–Cavusgnathus* transitional forms, and *Gnathodus texanus* Roundy) reported from 4′0″–4′3″ above the base of the Sycamore Limestone (USGS colln. 30815–PC; North flank Interstate 35 section, Arbuckle Anticline) indicate that at least 98% of this unit is "no older than middle Meramecian" (A. Harris, personal comm., 1989);

4) Radiolarian biostratigraphic data from the Ouachita John's Valley Shale indicate that this deep water sequence underwent partial (rather than complete) mixing of its sediments by hydrologic processes; and

5) Radiolarian assemblages obtained from the John's Valley shale represent displaced faunas (i.e., *not* in situ). The distribution of these assemblages *do not* reflect their chronostratigraphic position in the fossil record.

Gravity Investigation of a Portion of the Ouachita Central Zone, Southeastern Oklahoma and Western Arkansas

BETTY CATHERINE SIMS RAGLAND, University of Texas,
Dallas, M.S. thesis, 1988

The Ouachita Mountains of southeastern Oklahoma and west-central Arkansas represent the largest exposure of the Late Paleozoic Ouachita Foldbelt, which extends along the southern margin of the North American craton. The Oklahoma portion of the Ouachita Mountains has been subdivided from north to south into three structural provinces; the Frontal Thrust Zone, the Central Zone, and the Broken Bow Uplift, or Core Zone. The Central Zone is characterized by two large, asymmetric synclines and associated east–west-trending high angle reverse faults. The major Central Zone Faults, the Octavia Fault and the Boktukola Fault, have been traced only as far east as the exposures of resistant sandstones in the cores of the synclines. Near the Arkansas state line, the Mississippian Stanley Shale Formation is poorly exposed throughout the Central Zone, and surface mapping is not possible. In the absence of subsurface data, two alternative interpretations of the timing, eastward extent, and geometry of these faults are possible. In the first interpretation, the faults are listric thrusts on which significant northward translation occurred, emplacing basinal clastic and siliciclastic sediments over foreland shelf carbonates. In the second interpretation, they are steeply dipping in the subsurface, and represent reactivation of old basement faults. In this interpretation, they are late-stage faults which may offset earlier thrust faults, and are likely to continue into Arkansas.

A regional gravity model of a north–south profile across the Central Zone in easternmost Oklahoma, and a micro-gravity survey of the Boktukola Fault Zone support the second interpretation. The regional model, which was based on surface mapping and constrained by rock density measurements, shows that gravity anomalies can be produced by small density contrasts within a thick sedimentary package which has been broadly folded and cut by steeply dipping faults.

Detailed profiles across the inferred fault trace, indicate that small negative gravity anomalies associated with the low density Boktukola Fault Zone can be traced eastward into Arkansas. The fault trace, as mapped by gravity, follows the structural grain of the core zone to the south and east. Variations in the orientation of the fault zone, as determined by gravity modelling, indicate that the fault was involved in the final fold event of the Ouachita orogeny, which produced uplift in the Core Zone about a northeast-trending axis.

Two Dimensional Elastic Pseudo-Spectral Modeling of Wide-Aperture Seismic Array Data with Application to the Wichita Uplift–Anadarko Basin Region of Southwestern Oklahoma

IK BUM KANG, University of Texas, Dallas, M.S. thesis, 1990

Full-wavefield modeling of wide-aperture data is performed with a pseudo-spectral implementation of the elastic wave equation. This approach naturally produces 3-component stress and 2-component particle displacement, velocity, and acceleration seismograms for compressional, shear, and Rayleigh waves. It also has distinct advantages in terms of computational requirements over finite-differencing when data from large-scale structures are to be modeled at high frequencies.

The algorithm is applied to iterative 2-D modeling of seismograms from a survey performed in 1985 by The University of Texas at El Paso and The University of Texas at Dallas across the Anadarko basin and the Wichita Mountains in southwestern Oklahoma. The results provide an independent look at details of the velocity distribution and reflector configurations. Near-surface (<3 km deep) structure and scattering effects account for a large percentage (>70%) of the energy in the observed seismograms.

The interpretation of the data is consistent with the results of previous studies of these data, but provides considerably more detail. Overall, the P-wave velocities in the Wichita Uplift are more typical of the middle-crust than the upper crust (5.3–7.1 km/s). At the surface, the uplift is either exposed as weathered outcrop (5.0–5.3 km/s) or is overlain with sediments of up to 0.4 km in thickness, ranging in velocity from 2.7 to 3.4 km/s generally increasing with depth. The core of the uplift is relatively seismically transparent. A very clear, coherent reflection is observed from the Mountain View Fault which dips at ≈40 degrees to the southwest, down at least 12 km depth. Velocities in the Anadarko Basin are typical of sedimentary basins; there is a general increase from ≈2.7 km/s at the surface, to ≈5.9 km/s or ≈16 km depth, with discontinuous reflections at depths of ≈8, 10, 12 and 16 km.

A Comparison Between the Depositional Environment of the Arkansas Novaculite in Atoka and McCurtain Counties, Oklahoma

KERRY ALEXIS SWEENEY, University of Texas, Dallas, M.S. thesis, 1990

The stratigraphy, petrography, and sedimentology of the Arkansas Novaculite in Black Knob Ridge, Atoka County, and in the Broken Bow Uplift, McCurtain County, Oklahoma, provides insight into the origin and depositional environment of the Arkansas Novaculite.

Four stratigraphic sections were measured. One hundred and forty-eight hand samples were described, and 127 thin sections were analyzed. X-ray diffraction was utilized to determine mineralogy and crystallite size of 110 samples.

Lithologic changes such as composition, texture, weathering pattern, bed thickness, and structural relationships were documented. Lithologic differences are indicated by changes in paleontological and structural data.

Sponge Spicules are abundant in novaculite whereas radiolaria are abundant in chert and shale. In addition, cherts with a high carbonate percentage are consistently faulted near fold hinges, and cherts with a low carbonate percentage are tightly folded.

Textural changes, such as, grain size of the microcrystalline quartz reflects the temperature during diagenesis and is determined by the thermal history. The crystallinity index of the samples from Atoka County (0.22–2.17) and McCurtain County (3.64–10.99) vary greatly, indicating a more thermally intense history in McCurtain County.

During the diagenesis of silica minerals effects of secondary minerals or impurities are significant to rock type and rate of change related to maturity and increasing crystallinity. The mineral impurities and the amount of these impurities control the color, texture, and rate of diagenetic change. Textures of chert and novaculite are useful as a practical, geologic thermometer for estimating the maximum temperature the rocks have experienced since deposition.

Subsurface Structural Study of the Buried Ouachita Thrust Front, Southeastern Oklahoma

WILLIAM E. HARDIE, Baylor University, Waco, Texas, M.S. thesis, 1990

The unusual trace of the buried segment of the Ouachita system in Oklahoma has been the topic of speculation among geologists for many years. The discovery of the Isom Springs Field along with the increased interest in thrust belt exploration has made available new subsurface data, allowing a more detailed investigation than was previously possible. This study examines the effects of the temporal and spatial convergence of the Ouachita Thrust Belt with the Arbuckle Foreland now buried beneath Cretaceous cover in southeast Oklahoma.

In the Ouachita Mountains, the interaction between the Frontal Thrust Belt and the adjacent Arkoma Basin is characterized by an incipient "triangle zone," with a basal detachment at –7,000 ft. The interaction between the frontal thrust of the Bryan Salient and the adjacent Ardmore Basin is characterized by a steep-sided triangle zone, with a basal detachment at –10,000 ft.

Thrust belt geometries in both the Bryan Salient and the Central Ouachita Province consist of broad, detached synclines, each carried on the hanging wall of a major thrust. In these areas, Ordovician Womble Shale provides the "gliding" horizon and is carried at the base of the allochthonous sheets. In the Frontal Thrust Belt, structural style is characterized by steeply dipping thrust imbricates and tight folds, with "Springer" Shales providing the primary detachment horizon. In the Bryan Salient, the thrust belt style has been overprinted with a foreland style con-

sisting of dominantly southwest-vergent, tightly folded synclines, which are sometimes overturned, and out-of-the-syncline faults. The Isom Springs Field is developed along the steeply dipping leading imbricate of the Bryan Salient. Production is from hanging wall anticlines and imbrications developed in two thrust sheets which repeat the Devonian Arkansas Novaculite-through-Ordovician Womble Shale interval, and which extend the length of the field.

The reentrant in the Ouachita system southeast of the Tishomingo Uplift is interpreted as having resulted from the buttressing effects of the Tishomingo block, a later episode of uplift on the Tishomingo Uplift, and from subsequent erosion of the Ouachita thrusts prior to Cretaceous deposition. Effects of the Frontal Thrust Belt impinging on the Tishomingo Uplift include: (1) an elevation of the basal sole thrust, and (2) development of a transfer zone such that displacement on leading edge imbricates is transferred to older, overlying thrusts by duplex development as they pass southward around the southeast end of the Tishomingo Uplift.

Major thrusts in the Ouachita system developed sequentially in the direction of tectonic transport, in a "higher-to-lower" or "insight-out" fashion. Total shortening in the Ouachita system north of the Tishomingo Uplift is approximately 42%. Shortening in the Bryan Salient is approximately 63%, some of which is probably due to a later northeast–southwest-directed compression.

Structural relationships, as shown in this study, clearly indicate two stages of deformation for rocks in the Bryan Salient: first, northwest-directed thrusting of the Ouachita system, and second, northeast–southwest-directed compression during the Arbuckle Orogeny, downwarping the area between the Tishomingo and Criner Hills Uplifts. Although, initially, there may have been some temporal overlap in the two deformational events, the compression of the Arbuckle Orogeny was the culminating event.

Middle Carboniferous Conodont Biostratigraphy: Frontal Ouachita Mountains, Pittsburg, Latimer, and Le Flore Counties, Oklahoma

JOSEPH ROY WHITESIDE, Baylor University, Waco, Texas,
M.S. thesis, 1990

Carboniferous conodont faunas from the northwestern Ouachita Mountains, Oklahoma, represent six assemblages: two Mississippian (Meramecian?–Chesterian) and four Pennsylvanian (Morrowan–Atokan). The distribution of these assemblages suggests tentative modifications of previous biostratigraphic estimates for ages of stratigraphic units. Usage of the terms Caney and "Springer" Formations as equivalent to the chronostratigraphic subdivisions Mississippian and Pennsylvanian is unwarranted because the Caney is partly Pennsylvanian. The lower Johns Valley Formation is Pennsylvanian, but can now be shown to include rocks slightly older than previously estimated. Although observations are preliminary, Carboniferous stratigraphic units are demonstrably diachronous. Thus, the Mississippian/Pennsylvanian and Morrowan/Atokan boundaries cross lithostratigraphic boundaries. Future work should further refine the present work and more precisely locate chronostratigraphic boundaries.

Land Use Conflicts in Tulsa County, Oklahoma: Urban Expansion vs. Petroleum Development

PHILLIP L. PUMPHREY, Southwest Missouri State University, Springfield, M.S. thesis, 1988

The rapid outward expansion of America's metropolitan areas is causing land use conflicts to develop in previously rural regions. These conflicts are intensified when economically valuable natural resources occur in areas undergoing urban expansion. An example of this problem is found in Tulsa County, Oklahoma, where significant petroleum deposits are found in rapidly expanding suburban communities. This study focused on the southwest quadrant of Tulsa County, which contains the communities of Jenks, Bixby, and Glenpool. The goal of this study was to develop a recommended pattern of future land uses, based upon analyzing physical and economic variables, that will permit urban expansion to continue without restricting the petroleum production potential of the study area. The study area was divided into a 160 acre grid cell system, and numerical scores were assigned to each grid cell, based upon their suitability for residential, commercial, or industrial land use. The results of this analysis showed that even though the variables considered in this study often imposed significant limitations of future urban development, the study area contains enough suitable undeveloped land to allow population growth to continue at a healthy pace. The methodology employed in this study can be a useful tool for planners who must make land use recommendations in urbanizing areas.

INDEX[1]

Volume 51, 1991

Abdalla, Azhari, *see* Al-Shaieb, Zuhair; Puckette, James; Ely, Patrick; and Abdalla, Azhari
abstracts
American Association of Petroleum Geologists 72,102,145,174
Baylor University 204
European Association of Organic Geochemists 145
Geological Association of Canada 102
Geological Society of America 72,102,145,174
Society for Sedimentary Geology 174
Southwest Missouri State University 204
University of Oklahoma 26,204
University of Texas–Dallas 204
Alberty, Mark W., *see* Kaczmarek, Edward L.; and Alberty, Mark W.
Allen, Mark W.—Parasitic "Z" Fold in the Arkansas Novaculite, Potato Hills [cover-photo description] 186
Structural Analysis of the Northeastern Potato Hills, Ouachita Mountains, Oklahoma 188
Al-Shaieb, Zuhair; Puckette, James; Ely, Patrick; and Abdalla, Azhari—Mega Compartment Complex in the Anadarko Basin: A Completely Sealed Overpressured Phenomenon [abstract] 79
American Association of Petroleum Geologists
abstracts 72,102,145,174
annual convention 21
Mid-Continent Section meeting 135
Arbuckle Group core workshop 132
Arkansas Novaculite, parasitic "Z" fold 186
Babcock, Loren—Paleoecologic and Taphonomic Controls on Conulariid Distributions: Example from Pennsylvanian Cyclothems of Kansas and Oklahoma [abstract] 149
Bagley, D. S., *see* Elmore, R. D.; Bagley, D. S.; London, D.; and Nick, K.
Bagley, Donald Shepherd, II—Pervasive In Situ Remagnetization and Localized Fluid-Related Remagnetization, Ordovician Viola Limestone, Southern Oklahoma [abstract] 27
Barker, C. E., *see* Wojcik, K. M.; Barker, C. E.; Goldstein, R. H.; and Walton, A. W.
Barker, Charles E.; and Dalziel, Mary C.—Using Cathodoluminescence to Map Regionally Zoned Carbonate Cements Occurring in Diagenetic Aureoles above Oil Reservoirs, Velma Oil Field, Oklahoma [abstract] 181
Barrick, J. E., *see* Heckel, P. H.; Barrick, J. E.; Boardman, D. R.; Lambert, L. L.; Watney, W. L.; and Weibel, C. P.
Baylor University, theses abstracts 204

[1]Reference is to first page of article containing indexed item.

Blackwell, David D., *see* Kelley, Shari A.; Gallardo, Jaquidon D.; Carter, Larry S.; and Blackwell, David D.
Boardman, D. R., *see* Heckel, P. H.; Barrick, J. E.; Boardman, D. R.; Lambert, L. L.; Watney, W. L.; and Weibel, C. P.
Bowers, Kristine B.—A Coiled Nautiloid from the Holdenville Formation, Collinsville, Oklahoma [cover-photo description] 158
Brown, David P.—View from Space of the Oklahoma Ouachita Mountains [cover-photo description] 82
see Suneson, Neil H.; Brown, David P.; and Mycek-Memoli, Anne C.
Butaud, Todd; and Donovan, R. Nowell—The Vanoss Conglomerate—Upper Pennsylvanian Detritus Shed from the Arbuckle Uplift [abstract] 174
Canter, L. W.—Ground-Water and Waste Management: Teaching and Research Programs at the University of Oklahoma 160
Cardott, Brian J.—Organic Petrology of Epi-Impsonite at Page, Oklahoma, USA [abstract] 151
Cardott, Brian J.; Ruble, Tim E.; and Suneson, Neil H.—Thermal Origin of Impsonite Demonstrated in Sample Suite, Ouachita Mountains, Oklahoma, U.S.A. [abstract] 116
Carter, Larry S., *see* Kelley, Shari A.; Gallardo, Jaquidon D.; Carter, Larry S.; and Blackwell, David D.
Cates, K., *see* Totten, M.; Cates, K.; Hillegeist, T.; and Elmore, R. D.
Cates, Steven William—Fault Distribution in the Sulphur, Oklahoma, Area Based on Gravity, Magnetic and Structural Data [abstract] 28
Cecil, C. Blaine; and Edgar, N. Terence—Climatic Influence on Basin Sedimentation: Peru–Chile Trench as an Analogue for the Ouachita Basin [abstract] 102
Cetin, Hasan—The Northwest Extension of the Meers Fault, Oklahoma [abstract] 152
Chase, Charles Burnham—Analysis of Two-Dimensional Finite Fracture Accommodated Strain in a Fractured Carbonate Rock [abstract] 30
Chesnut, Donald R., Jr.—Eustatic and Tectonic Control of Sedimentation in the Pennsylvanian Strata of the Central Appalachian Basin [abstract] 103
Marine Transgressions in the Central Appalachian Basin During the Pennsylvanian Period [abstract] 103
Coal Creek, unconformity 34
coal forum 128
COGEOMAP program 84
Comer, John B.—Potential for Producing Oil and Gas from Woodford Shale (Devonian–Misissippian) in the Southern Mid-Continent, USA [abstract] 148
Couples, G. D., *see* Frye, M. W.; Lane, H. R.; and Couples, G. D.
Curiale, Jospeh A.—Petroleum Geochemistry of Texas and Oklahoma Oils from the Marathon/Ouachita Fold Belt [abstract] 107
Dalziel, Mary C., *see* Barker, Charles E.; and Dalziel, Mary C.
Dickinson, William R.; Soreghan, Gerilyn S.; and Goebel, Katherine A.—Stratigraphic Cyclicity in Foreland Geologic Systems of Permo–Carboniferous Age [abstract] 106
Diehl, S. F., *see* McKeown, F. A.; Hamilton, R. M.; Diehl, S. F.; and Glick, E. E.
Dix, Fred A.—AAPG—The Formative Years (1915–1926) [abstract] 184
Donovan, R. Nowell, *see* Butaud, Todd; and Donovan, R. Nowell

see also Ragland, Deborah A.; and Donovan, R. N.
see also Stephenson, Michael D.; and Donovan, R. Nowell
Doyle, Jim D.; Sweet, Michael L.; and Thomas, Kimberly K.—Three-Dimensional Fluvial Architecture of the Gypsy Sandstone (Pennsylvanian), Central Oklahoma [abstract] 182
Dunbar, Robyn Wright; Lucas, Spencer G.; and Holbrook, John M.—Reference Sections and Sequence Stratigraphic Model: Albian to Turonian Strata of Northeast New Mexico and Oklahoma Panhandle [abstract] 77
earthquakes
New Madrid region 2,4
Oklahoma, 1990 50
Edgar, N. Terence, *see* Cecil, C. Blaine; and Edgar, N. Terence
Elmore, R. D.; Bagley, D. S.; London, D.; and Nick, K.—Paleomagnetic Dating of Diagenesis by Basinal and Meteoric Fluids, Ordovician Carbonates, Arbuckle Mountains, Southern Oklahoma [abstract] 74
Elmore, R. D.; Sutherland, P. K.; White, P.; and Liesch, A.—Sedimentologic Evidence for Uplift of the Ouachitas [abstract] 109
Elmore, R. Douglas, *see* Fruit, David; Elmore, R. Douglas; Engel, Michael; Imbus, Scott; and Leach, M.
see also Nick, Kevin E.; and Elmore, R. Douglas
see also Totten, M.; Cates, K.; Hillegeist, T.; and Elmore, R. D.
Ely, Patrick, *see* Al-Shaieb, Zuhair; Puckette, James; Ely, Patrick; and Abdalla, Azhari
Engel, Michael, *see* Fruit, David; Elmore, R. Douglas; Engel, Michael; Imbus, Scott; and Leach, M.
environmental studies, teaching and research programs at OU 160
Esteban, M., *see* Wilson, J. L.; Fritz, R. D.; Esteban, M.; and Shelton, J. W.
European Association of Organic Geochemists, abstract 145
Ewing, Thomas E.—Late Paleozoic Deformation of the Texas Foreland: Styles and Phases [abstract] 106
Ferebee, Clive—Subsidence and Basin Development in the Southern Oklahoma Aulacogen [abstract] 151
Ferguson, Charles A.—Balanced Cross-Section, Northern Ouachita Orogen, Oklahoma [abstract] 114
see Suneson, Neil H.; and Ferguson, Charles A.
Friedman, Samuel A.—OGS Hosts Coal Forum 128
Fritz, R. D., *see* Wilson, J. L.; Fritz, R. D.; Esteban, M.; and Shelton, J. W.
Fritz, Richard D.—Exceptional Marine Sand Bodies in the Paleozoic of Oklahoma [abstract] 76
Fruit, David; Elmore, R. Douglas; Engel, Michael; Imbus, Scott; and Leach, M.—Hydrocarbons and Magnetizations in Sedimentary Rocks [abstract] 73
Frye, M. W.; Lane, H. R.; and Couples, G. D.—Biothem-Based Mississippian Transect for the Basin and Range Province to the Anadarko Basin [abstract] 180
Gallardo, Jaquidon D., *see* Kelley, Shari A.; Gallardo, Jaquidon D.; Carter, Larry S.; and Blackwell, David D.
Gao, Guoqiu; and Land, Lynton S.—Early Ordovician Cool Creek Dolomite, Middle Arbuckle Group, Slick Hills, SW Oklahoma, U.S.A.: Origin and Modification [abstract] 177
Gas Research Institute, sponsors compartment and seal symposium 71
Geological Association of Canada, abstract 102

Geological Society of America
abstracts 72,102,145,174
annual meeting 139
DNAG volume review 63
Rocky Mountain and South-Central Sections annual meeting 25
South-Central Section annual meeting 202
Gilbert, M. C., *see* Hogan, J. P.; and Gilbert, M. C.
see also Weaver, Barry L.; Gilbert, M. C.; and Lambert, D. D.
Glick, E. E., *see* McKeown, F. A.; Hamilton, R. M.; Diehl, S. F.; and Glick, E. E.
Goebel, Katherine A., *see* Dickinson, William R.; Soreghan, Gerilyn S.; and Goebel, Katherine A.
Goldhaber, M. B., *see* Reynolds, R. L.; Goldhaber, M. B.; and Tuttle, M. L.
Goldstein, R. H., *see* Wojcik, K. M.; Barker, C. E.; Goldstein, R. H.; and Walton, A. W.
Hamilton, R. M., *see* McKeown, F. A.; Hamilton, R. M.; Diehl, S. F.; and Glick, E. E.
Hardie, William E.—Subsurface Structural Study of the Buried Ouachita Thrust Front, Southeastern Oklahoma [abstract] 209
Harris, J. P.—Origin of Porosity Development in a Mixed Terrigenous-Carbonate Reservoir Unit, Batson Field Area, Arkoma Basin, Arkansas [abstract] 111
Hauser, Ernest C.—Layered Rocks Beneath the Phanerozic Platform of the U.S. Midcontinent [abstract] 146
Heckel, P. H.; Barrick, J. E.; Boardman, D. R.; Lambert, L. L.; Watney, W. L.; and Weibel, C. P.—Biostratigraphic Correlation of Eustatic Cyclothems (Basic Pennsylvanian Sequence Units) from Midcontinent to Texas and Illinois [abstract] 145
Heckel, Philip H.—Evidence for Glacial-Eustatic Control Over Pennsylvanian Cyclothems in Midcontinent North America and Tests for Tectonic Effects [abstract] 105
Hemish, LeRoy A., author of OGS COGEOMAP Leflore Quadrangle map 62
author of OGS Geologic Map GM-33 18
Fossil Linguoid Ripple Marks in Sandstone of the Savanna Formation [cover-photo description] 118
Great Unconformity along Coal Creek, Northwestern Le Flore County, Oklahoma [cover-photo description] 34
Hemish, LeRoy A.; and Lawson, James E., Jr.—Soviet Seismic Compound at the OGS Observatory, Leonard, Oklahoma, and Shallow Subsurface Stratigraphy of the Area 36
Hester, Timothy C.; and Schmoker, James W.—Porosity Trends of Nonreservoir and Reservoir Sandstones, Anadarko Basin, Oklahoma [abstract] 79
Regional Geologic Characteristics Relevant to Horizontal Drilling, Woodford Shale, Anadarko Basin, Oklahoma [abstract] 179
Hillegeist, T., *see* Totten, M.; Cates, K.; Hillegeist, T.; and Elmore, R. D.
Hillegeist, Tony K.—Syndeformational Magnetization in the Ordovician Bigfork Chert at Black Knob Ridge, Western Ouachita Mountains, Southern Oklahoma [abstract] 205
Hinde, Lawrence K.—Sand Distribution, Facies Relationships, and Structural Styles of the Spiro Formation, Frontal Ouachita Mountains, Southeastern Oklahoma [abstract] 75
Stratigraphic Facies Relationships and Structural Trends of the Spiro Forma-

tion, Frontal Ouachita Mountains, Southeastern Oklahoma [abstract] 76
Hofstra, A. H., *see* Leach, D. L.; Plumlee, G. S.; Hofstra, A. H.; Landis, G. P.; Rowan, E. L.; and Viets, J. G.
Hogan, J. P.; and Gilbert, M. C.—Contrasting Cystallizations Styles of Sheet Granites from the Wichita Magmatic Province: Implications for Source Region Heterogeneity [abstract] 153
Holbrook, John M.—Sequence Stratigraphic Interrelationships of Lower Cretaceous Dakota and Purgatoire Formations in Northeast New Mexico/Southeast Colorado and Correlative Strata (Muddy, Skull Creek, Plainview) of the Denver Basin [abstract] 78
see Dunbar, Robyn Wright; Lucas, Spencer G.; and Holbrook, John M.
Holdenville Formation, coiled nautiloid 158
Houseknecht, David W.; and McGilvery, T. A.—Red Oak Gas Field, Arkoma Basin, Oklahoma [abstract] 113
hydrogeology, teaching and research programs at OU 160
Imbus, Scott, *see* Fruit, David; Elmore, R. Douglas; Engel, Michael; Imbus, Scott; and Leach, M.
Jackfork Group 120
Johnson, Kenneth S., author of OGS Circular 92 134
editor of OGS Special Publication 91-3 198
Kaczmarek, Edward L.; and Alberty, Mark W.—The Physical Response of Dip-Measuring Logging Devices to Clastic Sedimentary Structures: A Case Study [abstract] 183
Kang, Ik Bum—Two Dimensional Elastic Pseudo-Spectral Modeling of Wide-Aperture Seismic Array Data with Application to the Wichita Uplift–Anadarko Basin Region of Southwestern Oklahoma [abstract] 208
Keller, G. Randy—Deep Exploration Possibilities along the Ouachita Trend [abstract] 110
Kelley, Shari A.; Gallardo, Jaquidon D.; Carter, Larry S.; and Blackwell, David D.—Thermal Conditions in the Anadarko Basin, Oklahoma [abstract] 178
Kendall, Jerome J.—Application of a Transpressive Tectonic Model to a Shallower Pool Development, Eola Field, Garvin County, Southern Oklahoma [abstract] 182
Kish, Stephen A.; Ragland, Paul C.; and Mutschler, Felix E.—Geochemical Correlation Between Latest Precambrian–Early Paleozoic Mafic Rocks in Eastern North America and the Southern Rocky Mountains [abstract] 152
Kleehammer, Richard Stephen—Conodont Biostratigraphy of Late Mississippian Shale Sequences, South-Central Oklahoma [abstract] 205
Lambert, D. D., *see* Weaver, Barry L.; Gilbert, M. C.; and Lambert, D. D.
Lambert, L. L., *see* Heckel, P. H.; Barrick, J. E.; Boardman, D. R.; Lambert, L. L.; Watney, W. L.; and Weibel, C. P.
Lambert, Michael W.—Internal Stratigraphy and Organic Facies of the Devonian–Mississippian Chattanooga Shale in Kansas and Oklahoma [abstract] 148
Land, Lynton S., *see* Gao, Guoqiu; and Land, Lynton S.
Landis, G. P., *see* Leach, D. L.; Plumlee, G. S.; Hofstra, A. H.; Landis, G. P.; Rowan, E. L.; and Viets, J. G.
Lane, H. R., *see* Frye, M. W.; Lane, H. R.; and Couples, G. D.
Latimer County
linguoid ripple marks 118
parasitic "Z" fold in Arkansas Novaculite 186

structural analysis of the Potato Hills 188
Lawson, James E., Jr.—Effect of Future New Madrid Region Earthquakes on Oklahoma 4
New Madrid Region Earthquake Recorded by the OGS Digital Seismic System [cover-photo description] 2
see Hemish, LeRoy A.; and Lawson, James E., Jr.
Lawson, James E., Jr.; Luza, Kenneth V.; and Moss, Dan—Oklahoma Earthquakes, 1990 50
Leach, D. L.; Plumlee, G. S.; Hofstra, A. H.; Landis, G. P.; Rowan, E. L.; and Viets, J. G.—Origin of Late Dolomite Cement by CO_2-Saturated Deep Basin Brines: Evidence from the Ozark Region, Central United States [abstract] 154
Leach, M., *see* Fruit, David; Elmore, R. Douglas; Engel, Michael; Imbus, Scott; and Leach, M.
Le Flore County, unconformity along Coal Creek 34
Liesch, A., *see* Elmore, R. D.; Sutherland, P. K.; White, P.; and Liesch, A.
linguoid ripple marks 118
London, D., *see* Elmore, R. D.; Bagley, D. S.; London, D.; and Nick, K.
Loomis, J. L.; and Weaver, B. L.—Geochemistry of Mississippian–Pennsylvanian Volcaniclastics in the Ouachita Mountains, Oklahoma and Arkansas: Implications for Tectonic Environment [abstract] 115
Lucas, Spencer G., *see* Dunbar, Robyn Wright; Lucas, Spencer G.; and Holbrook, John M.
Lutz, Anne B.—The Distribution of Chonetid Brachiopods in the Lower Permian Wreford Megacyclothem (Nebraska, Kansas, and Oklahoma) [abstract] 146
Luza, Kenneth V., *see* Lawson, James E., Jr.; Luza, Kenneth V.; and Moss, Dan
McConnell, David A.—Tectonic Evolution of the Wichita Uplift, Oklahoma Implications for Linkage of Deformation Between the Ancestral Rocky Mountains and Ouachita–Marathon Orogen [abstract] 109
McGilvery, T. A., *see* Houseknecht, David W.; and McGilvery, T. A.
McKeown, F. A.; Hamilton, R. M.; Diehl, S. F.; and Glick, E. E.—Diapiric Origin of the Blytheville and Pascola Arches in the Reelfoot Rift, East-Central United States: Relation to New Madrid Seismicity [abstract] 72
mineral industry of Oklahoma, 1990 98
Moss, Dan, *see* Lawson, James E., Jr.; Luza, Kenneth V.; and Moss, Dan
Musselman, Judith L.—Paleokarstic Phenomena of the Lower Ordovician Red Bed Sequences of the Arbuckle Group, Southern Oklahoma [abstract] 177
Mutschler, Felix E., *see* Kish, Stephen A.; Ragland, Paul C.; and Mutschler, Felix E.
Mycek-Memoli, Anne C., *see* Suneson, Neil H.; Brown, David P.; and Mycek-Memoli, Anne C.
Natural Resources Information System 84
nautiloid, Holdenville Formation 158
New Madrid region, earthquakes 2,4
Nick, K., *see* Elmore, R. D.; Bagley, D. S.; London, D.; and Nick, K.
Nick, Kevin Eugene—Magnetizations of Reddened Carbonate Rocks at Paleoexposure Surfaces [abstract] 204
Nick, Kevin E.; and Elmore, R. Douglas—Paleomagnetism of the Cambrian Royer Dolomite and Pennsylvanian Collings Ranch Conglomerate, Southern Oklahoma: An Early Paleozoic Magnetization and Nonpervasive Remagnetization by Weathering [abstract] 72

Nielsen, Kent C.—Structural Linkage: Ouachita and Ancestral Rocky Mountains [abstract] 108
Oklahoma City Geological Society, new officers 133
Oklahoma Geological Survey
co-sponsors Arbuckle Group core workshop 132
co-sponsors petroleum-reservoir geology workshop 15
co-sponsors structural styles workshop 127,199
Geophysical Observatory 2,4,36,50
hosts coal forum 128
Oklahoma Geology Notes, results of survey 19
publications 18,62,134,198
Ouachita Mountains
Landsat image 82
petroleum exploration and development update 84
re-evaluation of Jackfork Group type section 120
structural analysis of the Potato Hills 188
paleontology, nautiloid 158
Peace, Hugh William—Mississippian Facies Relationships, Eastern Anadarko Basin, Oklahoma [abstract] 28
Perry, Charles C., Jr.—New Exploration Frontier for Southwestern Oklahoma, Mountain View–Meers Valley Area [abstract] 74
petroleum
reservoir geology workshop 15
update on Ouachita Mountains exploration and development 84
Plumlee, G. S., *see* Leach, D. L.; Plumlee, G. S.; Hofstra, A. H.; Landis, G. P.; Rowan, E. L.; and Viets, J. G.
Potato Hills
parasitic "Z" fold 186
structural analysis 188
Puckette, James, *see* Al-Shaieb, Zuhair; Puckette, James; Ely, Patrick; and Abdalla, Azhari
Pumphrey, Phillip L.—Land Use Conflicts in Tulsa County, Oklahoma: Urban Expansion vs. Petroleum Development [abstract] 211
Pushmataha County
structural analysis of the Potato Hills 188
Ragland, Betty Catherine Sims—Gravity Investigation of a Portion of the Ouachita Central Zone, Southeastern Oklahoma and Western Arkansas [abstract] 207
Ragland, Deborah A.; and Donovan, R. N.—Bedded Cherts in the Early Ordovician Arbuckle Group of Southwestern Oklahoma [abstract] 174
Ragland, Paul C., *see* Kish, Stephen A.; Ragland, Paul C.; and Mutschler, Felix E.
Reynolds, R. L.; Goldhaber, M. B.; and Tuttle, M. L.—Sulfidization and Magnetization above Hydrocarbon Reservoirs [abstract] 179
rock clubs in Oklahoma 101
Rowan, E. L., *see* Leach, D. L.; Plumlee, G. S.; Hofstra, A. H.; Landis, G. P.; Rowan, E. L.; and Viets, J. G.
Ruble, Tim E., *see* Cardott, Brian J.; Ruble, Tim E.; and Suneson, Neil H.
Savanna Formation 118
Schmoker, James W., *see* Hester, Timothy C.; and Schmoker, James W.
Schwartzapfel, Jon A.—Biostratigraphic Investigations of Late Paleozoic

(Upper Devonian to Mississippian) Radiolaria within the Arbuckle Mountains and Ardmore Basin of South-Central Oklahoma [abstract] 206
seismology
New Madrid region earthquakes 2,4
Oklahoma earthquakes, 1990 50
Soviet compound at OGS Observatory 36
Shelton, J. W., *see* Wilson, J. L.; Fritz, R. D.; Esteban, M.; and Shelton, J. W.
Society for Sedimentary Geology, abstract 174
Society of Economic Paleontologists and Mineralogists
Midcontinent Section meeting 137
new officers 99
Soreghan, Gerilyn S., *see* Dickinson, William R.; Soreghan, Gerilyn S.; and Goebel, Katherine A.
Southwest Missouri State University, thesis abstract 204
Soviet Union, seismic compound at OGS Observatory 2,36
Stephenson, Michael D.; and Donovan, R. Nowell—Pennsylvanian Deformation in the Eastern Slick Hills, Southwestern Oklahoma [abstract] 175
structural geology
Potato Hills 186,188
structural styles in the southern Midcontinent workshop 127,199
Suneson, Neil H., author of OGS COGEOMAP Blackjack Ridge Quadrangle map 62
Re-evaluation of Jackfork Group Type Section along Indian Nation Turnpike, Oklahoma 120
Review: Appalachian–Ouachita Orogen 63
see Cardott, Brian J.; Ruble, Tim E.; and Suneson, Neil H.
Suneson, Neil H.; Brown, David P.; and Mycek-Memoli, Anne C.—Update on Ouachita Mountains Frontal Belt Exploration and Development 84
Suneson, Neil H.; and Ferguson, Charles A., authors of OGS COGEOMAP Talihina Quadrangle map 62
Sutherland, P. K., *see* Elmore, R. D.; Sutherland, P. K.; White, P.; and Liesch, A.
Swartz, James Fredrick—Depositional Environments and Pedogenic Alteration of Palustrine and Lacustrine Deposits: An Example from the Lower Cretaceous Baum Limestone, South-Central Oklahoma [abstract] 26
Sweeney, Kerry Alexis—A Comparison Between the Depositional Environment of the Arkansas Novaculite in Atoka and McCurtain Counties, Oklahoma [abstract] 208
Sweet, Michael L., *see* Doyle, Jim D.; Sweet, Michael L.; and Thomas, Kimberly K.
Thomas, Kimberly K., *see* Doyle, Jim D.; Sweet, Michael L.; and Thomas, Kimberly K.
Thomas, William A.—The Appalachian–Ouachita Rifted Margin of Southeastern North America [abstract] 104
Threshold Test Ban Treaty 2,36
Totten, M.; Cates, K.; Hillegeist, T.; and Elmore, R. D.—Origin of Magnetization in the Lower Arbuckle Group, Southern Oklahoma [abstract] 176
Tuttle, M. L., *see* Reynolds, R. L.; Goldhaber, M. B.; and Tuttle, M. L.

unconformity along Coal Creek 34
U.S. Department of Energy, Bartlesville Project Office
co-sponsors Arbuckle Group core workshop 132
co-sponsors petroleum-reservoir geology workshop 15
co-sponsors structural styles workshop 199
University of Oklahoma
abstracts 26,204
ground-water and waste management programs 160
University of Texas–Dallas, abstracts 204
Vader, Debra E.—Diagenetic History of a Calcareous Quartzarenite: Implications for Porosity Distribution in a Natural Gas Reservoir, Northern Arkoma Basin, Arkansas [abstract] 114
Viets, J. G., *see* Leach, D. L.; Plumlee, G. S.; Hofstra, A. H.; Landis, G. P.; Rowan, E. L.; and Viets, J. G.
Walton, A. W., *see* Wojcik, K. M.; Barker, C. E.; Goldstein, R. H.; and Walton, A. W.
Warwick, Richard Alan—Porosity Determination Using Amplitude Variation with Offset and Velocity Analysis in the Mississippian Chappel Formation, Hardeman County, Texas 29
Watney, W. L., *see* Heckel, P. H.; Barrick, J. E.; Boardman, D. R.; Lambert, L. L.; Watney, W. L.; and Weibel, C. P.
Weaver, B. L., *see* Loomis, J. L.; and Weaver, B. L.
Weaver, Barry L.; Gilbert, M. C.; and Lambert, D. D.—Trace Element and Isotopic Geochemistry and Petrogenesis of Mafic Igneous Rocks from the Southern Oklahoma Aulacogen [abstract] 150
Weber, Jane—*Notes* Readers Reply to Questionnaire 19
Weibel, C. P., *see* Heckel, P. H.; Barrick, J. E.; Boardman, D. R.; Lambert, L. L.; Watney, W. L.; and Weibel, C. P.
White, P., *see* Elmore, R. D.; Sutherland, P. K.; White, P.; and Liesch, A.
White, Perry B.—Boggy–Thurman (Middle Pennsylvanian) Relationships—Sedimentological Evidence in the Arkoma Basin, Oklahoma, for the Time of Recurrent Uplift in the Ouachita Fold Belt [abstract] 27
Whiteside, Joseph Roy—Middle Carboniferous Conodont Biostratigraphy: Frontal Ouachita Mountains, Pittsburg, Latimer, and Le Flore Counties, Oklahoma [abstract] 210
Wilson, J. L.; Fritz, R. D.; Esteban, M.; and Shelton, J. W.—Paleokarst and Fracture Overprints in Mid-Continent Carbonates in Evaluation of Horizontal Drilling Potential [abstract] 147
Wojcik, K. M.; Barker, C. E.; Goldstein, R. H.; and Walton, A. W.—Elevated Thermal Maturation in Pennsylvanian Rocks, Cherokee Basin, Southeastern Kansas: Importance of Regional Fluid Flow [abstract] 112
Zachry, D. L.—Tide-Generated Sand Bodies in a Mixed Terrigenous-Carbonate Sequence, Lower Pennsylvanian (Morrowan) of Northwest Arkansas [abstract] 111