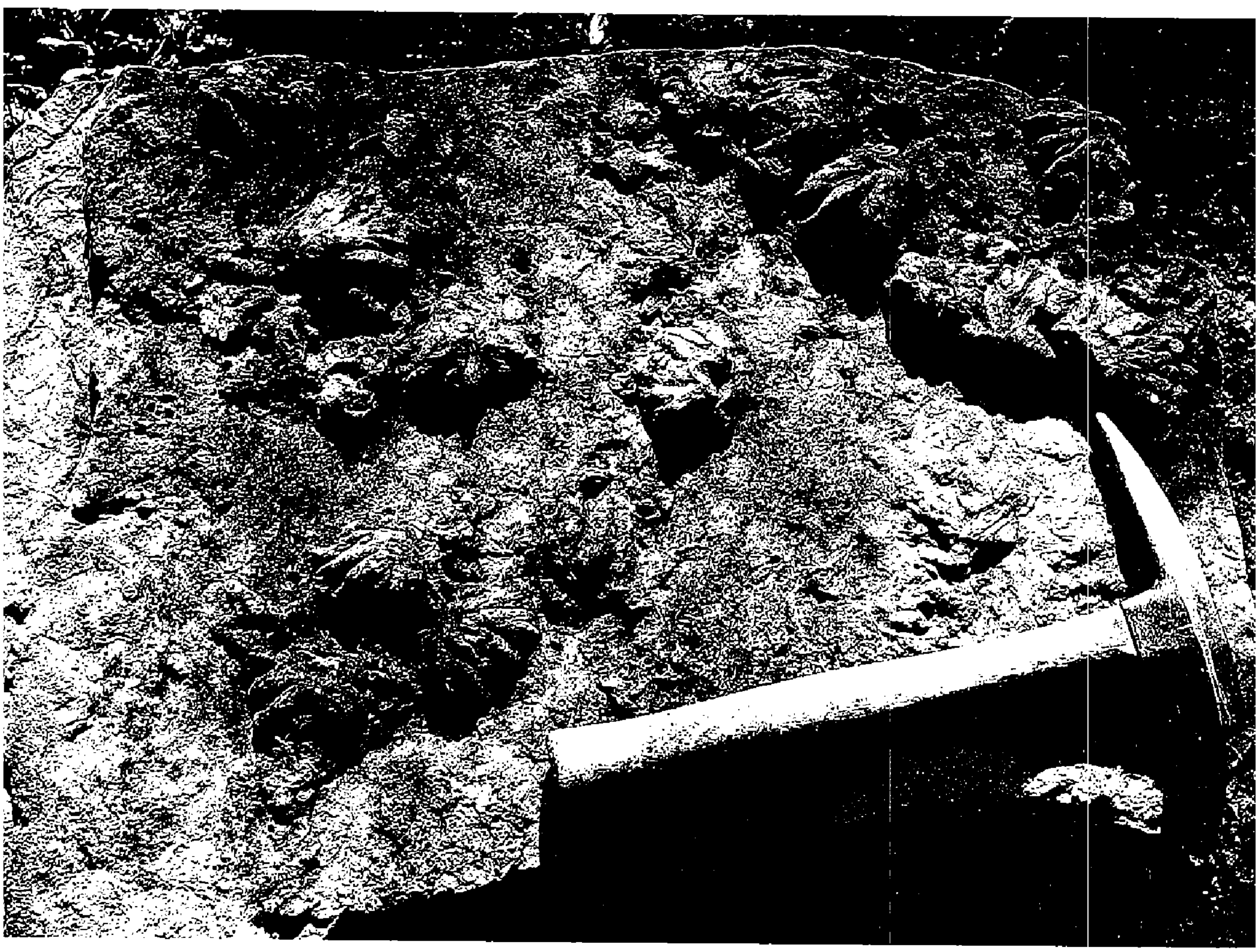
Oklahoma Geology Notes

OKLAHOMA GEOLOGICAL SURVEY / VOL. 47, NO. 1—FEBRUARY 1987



On the cover—

Ichnofossils in the Ouachitas

The cover photo shows the underside of an 8-cm-thick bed of medium-grained quartzose sandstone. The star-shaped lumps, which project 2 to 3 cm below the bottom of the bed, are *Asterosoma* ichnofossils. *Asterosoma* are thought to be feeding traces of a wormlike creature that lived in the near-shore shallow marine environment.

These fossils are from an interval of thin- to medium-bedded sandstone that intertongues with the Lower Pennsylvanian Wapanucka Limestone. The sequence crops out as a low ridge about 1 km south of the Choctaw fault in the northwestern Ouachita Mountains near Hartshorne, Oklahoma. This sequence is overlain to the south by Atoka Formation sandstones and shales, which are interpreted as deep-water turbidites.

Charles Ferguson

Photo by Charles Ferguson

Oklahoma Geology Notes

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Editorial Clerk: Eileen Hasselwander

Oklahoma Geology Notes, ISSN 0030-1736, is published bimonthly by the Oklahoma Geological Survey. It contains short technical articles, mineral-industry and petroleum news and statistics, reviews, and announcements of general pertinence to Oklahoma geology. Single copies, $1.50; yearly subscription, $6. All subscription orders should be sent to the Survey at 830 Van Vleet Oval, Room 163, Norman, Oklahoma 73019.

Short articles on aspects of Oklahoma geology are welcome from contributors. A set of guidelines will be forwarded on request.

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A MORPHOMETRIC ANALYSIS OF NORTH- AND SOUTH-FACING SLOPES, GLASS MOUNTAINS, OKLAHOMA

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Abstract

Biogeographic characteristics reflect microclimatic contrasts along east–west-trending portions of the Glass Mountains in west-central Oklahoma. Measurements of hillslope morphologic characteristics on north- and south-facing aspects below gypsum caprock were collected to ascertain relationships. Statistical analysis revealed that the morphology of the north- and south-facing slopes was not significantly different. North-facing slopes were longer and higher than south-facing slopes in response to control by a larger drainage basin.

Introduction

The Glass Mountains, a portion of the Gypsum Hills physiographic region in Major County (Fig. 1), frequently surprise travelers who do not expect butte and mesa topography in western Oklahoma. The presence of gypsum caprocks creates an area of distinctive relief and slopes (Fig. 2). Microclimate conditions on north- and south-facing slopes should contribute to observable differences. South-facing slopes (south aspects) in the northern hemisphere receive larger amounts of solar radiation than north aspects. They therefore have higher soil temperatures, are drier, and undergo a greater number of wetting and drying cycles (Franzmeier and others, 1969). Microclimatic effects are demonstrated by juniper trees (*Juniperus virginiana*), which tend to populate the cooler and moister north-facing slopes, whereas few junipers are located on south-facing slopes.

Because such biogeographic variations can be attributed to microclimatic variation, an examination of these slopes may provide a better understanding of microsite slope morphology and any variability observed. Because slope-aspect studies have typically focused on the comparison of north-facing and south-facing profiles (Melton, 1960; Churchill, 1981,1982), the

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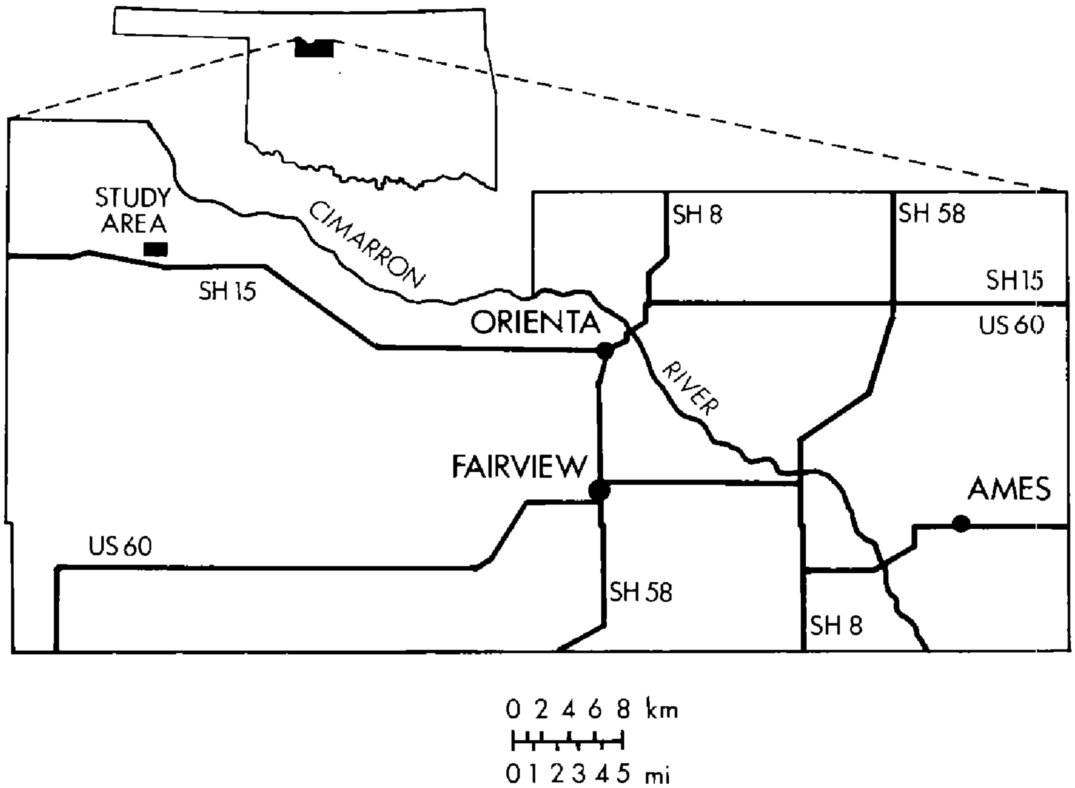

Figure 1. Location of the Glass Mountains study area in Major County, Oklahoma.

objective of this study was to test for significant differences between hillslope morphologic variables taken from north- and south-facing slopes in the Glass Mountains.

The Study Area

The study area in Major County is approximately 19 km south of Waynoka, and 1–3 km north of State Highway 15. In the 13-km^2 area lies an east–west-trending, gypsum-capped escarpment.

The massive Medicine Lodge Gypsum, oldest and stratigraphically lowest gypsum member of the Blaine Formation (Fay, 1964), forms the butte/mesa caprock within the study area (Fig. 2). A thin bed of dolomite underlies the caprock. This dolomitic material also may be incorporated within the gypsum, resulting in a caprock that may be described as a "dolomitic gypsum." As a result of these differences, two separate caprock-forming materials may be designated, each possessing certain properties that may influence hillslope morphology.

The massive gypsum usually forms the thicker caprock unit. Linear joints form parallel to the cliff face at a distance approximately equal to the thickness of the gypsum. The jointing contributed to the mass wasting of large blocks of gypsum onto the gentler slopes below (Fig. 2). The dolomit-

Figure 2. Typical slope in the Glass Mountains: 1, gypsum caprock; 2, straight segment; 3, break in slope; 4, concave segment.

ic gypsum usually forms a thinner caprock, and is extensively fractured by joints. The joints do not have a dominant orientation. Mass-wasted dolomitic gypsum typically mantles the upper portions of the underlying slopes.

The Flowerpot Shale underlies the gypsum caprocks (Fay, 1964). It forms the gentler slopes such as seen in Figure 2, and is characterized by numerous thin beds of alternating red and grayish-blue shales. The lower, gentle slopes exhibit a well-developed soil on colluvium, the accumulation of slope-washed debris at the foot of an escarpment. Incorporated within the Flowerpot Shale are beds of shales, silts, and very fine sands, and thin beds of gypsum. The beds of the coarser-grained sediments do not appear thick enough to dominate slope profiles. Over time, soil of varying thicknesses has developed on the shale throughout the study area.

Present-day climatic conditions may be considered semi-arid, with hot summers and cool winters. Maximum precipitation occurs in May (average 119 mm), usually in conjunction with convective storms that exhibit moderate to heavy rains of relatively short duration. January is the coldest (average 1.8°C) and driest (average 18 mm) month (Nusz, 1985).

Fluvial processes, specifically sheet and gully erosion, dominate the straight segments, the breaks in slope, and basal concave segments on the north-facing and south-facing slopes. Mass-wasting of the gypsum caprock has not occurred recently with high frequency. Based upon a comparison of low-altitude aerial photographs of the study area taken in 1937 and 1966, large boulders of caprock origin have remained on the underlying slopes in static positions. No new falls of caprock were observed on the 1966 photos, and only one clearly recent boulder movement was observed.

Methodology

In order to test for significant differences in hillslope morphology in the Glass Mountains, variables were measured on 28 north-facing and 28 south-facing slopes. The slopes selected for study were located along a single E–W escarpment, each within a 5° range of geographic north or south. Only those slope profiles that were beneath a gypsum caprock cliff face and that possessed the three distinct morphologic units (straight segment, major break in slope, and basal concavity) were selected. These components, commonly present on arid and semi-arid slope profiles (Carson and Kirkby, 1972), set the stage for comparing changes with those observed elsewhere. Profile measurements were extended from the base of the caprock to the base of the first major erosional terrace illustrating transition from slope processes (mass movement and overland flow) to predominantly fluvial erosion at the point gullying has been initiated. Slope stations for data collection were positioned at constant 5-m intervals, as suggested by Young (1974).

Variables measured at slope stations, or calculated from these measurements, included (1) length of the hillslope; (2) height of the hillslope; (3) hillslope curvature; (4) geographic position of the maximum slope angle on the slope profile; (5) slope steepness; (6) maximum slope angle; and (7) percentage of the total length of the hillslope above and below the major break in slope. Measurement or calculation of these variables identifies hillslope dimension, shape, and steepness (Parsons, 1977). Details of the methodology of collection and calculation of the seven morphologic variables are found in Nusz (1985).

Results

Along the 28 north-facing slopes, a total of 403 slope-angle measurements were collected. A total of 286 slope-angle measurements were obtained from the 28 south-facing slopes. For north-facing slopes, slope angles ranged from 5° to 59°, with a mean of 25° (standard deviation 11.2). Slope angles for south-facing slopes ranged from 5° to 52°, with a mean of 23° (standard deviation 10.7).

From the data on north- and south-facing slopes, four classes with common angles were identified: (1) 9° to 10°, (2) 14° to 16°, (3) 24° to 26°, and (4) 34° to 36°. To compare the angle values obtained from north- and south-facing slopes with reference to the three morphologic units (straight segment, break in slope, and lower concavity), the mean angle was calculated for each segment from both aspects. Table 1 lists the resultant values.

For the straight segments, the mean angle for north-facing slopes was 32°, and for the south-facing slopes was 31°. The break in slope was not

TABLE 1.—MEAN SLOPE-SEGMENT ANGLE VALUES CALCULATED FOR NORTH- AND SOUTH-FACING SLOPES

	North-facing slopes	
	Mean slope angle (degrees)	Standard deviation
Straight segment	32	5.23
Break in slope	26/15	5.75/2.56
Basal concavity	16	3.23
	South-facing slopes	
	Mean slope angle (degrees)	**Standard deviation**
Straight segment	31	5.10
Break in slope	26/15	4.25/2.60
Basal concavity	15	4.19

considered to be an areal unit, but a point of discontinuity located between the straight segment and the lower concavity. Therefore, in order to provide representative angular values for this point, the mean angles above and below this point were calculated. With means of 26° above and 15° below the break in slope, the values were calculated to be the same for north- and south-facing slopes. The mean angles calculated for the lower concavity were 16° for north-facing slopes and 15° for south-facing slopes. Using t-tests, a conclusion was derived that no significant difference occurred for any of the three slope-segment companions at a 95% confidence level.

Field observations revealed that each of the four classes of angles described above characterize certain features inherent to both north- and south-facing slopes. Usually, the upper angle class (34° to 36°) was found along moderately vegetated to well-vegetated positions of the straight slope segment. If it is assumed that characteristic angles are related to limiting angles for slope processes (Young, 1972), then it may be concluded that this angle class represents the upper region of slope angles that exist along the stable portion of the straight segment.

Angles greater than 36° were associated with small, isolated slope failures, mainly along nonvegetated, homogeneous shale portions of the straight segment. These observations are consistent with Koons's (1955) findings from similar conditions in the southwestern United States. Koons (1955) concluded that parallel retreat of slope occurred when slide-rock accumulations (typically at 34°) were removed, which resulted in the establishment of bare rock slopes at the angle of friction (typically at 38°). This removal was also followed by cliff removal that retained the angle of the previous slide-rock material.

Angles associated with the 24° to 26° angle class usually were associated with two separate slope localities. Segments associated with this angle class may represent areas of long-term stability (Carson and Petley, 1970). These angles usually were found just above the break in slope along slopes capped by the massive gypsum material. However, along slopes capped by dolomitic gypsum, these angles were found both above the break in slope and just below the caprock material. Stabilization of material above the break in slope may be attributed to the establishment of vegetation and/or the retention of material caused by an accumulation of larger-sized debris at this slope position.

Along the slopes capped by dolomitic gypsum, the existence of angles in the 24° to 26° class could be attributed to the formation of a rock mantle on the slope surface. This rock mantle results from slabs of caprock material being dislodged from the cliff face: it typically occurs along the upper portion of the straight segment. The rock mantle contributes to the stabilization of the upper slope.

The angle class 14° to 16° represents angles associated with the slope segment just below the break in slope. This class may indicate the point at which surface wash begins to be the dominant slope process. Kirkby and Kirkby (1974) have stated that the break in slope can be produced by the gradual transition from only gravity forces above the break in slope to surface wash combined with mass wasting below.

Slope segments that possess angles associated with the 9° to 10° class are typically located near the termination point of the slope profile. The first slope position that indicated the presence of alluviation determined the termination point. Areas that are currently receiving alluvial deposits are located at similar slope-angle positions along the basal concavity for both north- and south-facing slopes.

Tables 2 and 3 display the other measured or calculated hillslope morphological variables determined for north- and south-facing slopes. From these data, t-tests were calculated to assess the relationships between slope-grouped morphologic variables as a function of aspect. The results of the t-tests are shown in Table 4. Of the eight tested hillslope morphologic variables, only mean slope length and mean slope height were determined to be significantly different as a function of aspect at the 95% confidence level.

Parsons (1977) described length and height as "dimensional components" of a hillslope. Because a slope profile is related to the change in slope geometry with distance downslope, slopes with different lengths and heights may still have similar profiles. According to the t-test results, north- and south-facing slopes appear to have similar profiles but with different dimensions; i.e., no basic difference in slope morphology exists between north- and south-facing slopes in the study area, but north-facing slopes were usually higher and longer than south-facing slopes.

The observed difference in profile dimensions is attributed to the characteristics of the two drainage basins on either side of the E–W-trending escarpment. The basin north of the escarpment is much larger than the southern basin. The northern basin is influenced by the Cimarron River, which runs along the basin's floor, whereas the southern basin does not possess a dominant river valley system. The north-facing slopes trend into a valley that represents an older basin or one that has undergone more-

TABLE 2.—CALCULATED VALUES FOR THE NORTH-FACING HILLSLOPE MORPHOLOGIC VARIABLES

Slope number	Slope length (m)	Slope height (m)	Maximum slope angle (degrees)	Slope steep-ness	Distance to maximum angle (%)	Percent top slope	Percent bottom slope	Curva-ture index
1	35	21.5	49	0.614	0.03	0.86	0.14	−0.150
2	40	21.2	46	0.530	0.31	0.87	0.13	−0.060
3	40	21.9	46	0.547	0.44	0.87	0.13	−0.187
4	60	40.0	42	0.516	0.37	0.69	0.31	−0.099
5	80	31.3	37	0.392	0.09	0.56	0.44	−0.209
6	90	29.8	37	0.332	0.19	0.50	0.50	−0.240
7	105	34.9	41	0.333	0.07	0.29	0.71	−0.178
8	75	23.1	36	0.308	0.03	0.47	0.53	−0.098
9	80	32.4	45	0.406	0.22	0.44	0.56	−0.266
10	100	36.1	48	0.361	0.12	0.30	0.70	−0.209
11	145	48.3	45	0.333	0.09	0.24	0.76	−0.217
12	70	37.0	46	0.529	0.11	0.43	0.57	−0.204
13	60	25.6	47	0.427	0.04	0.54	0.46	−0.306
14	105	32.3	35	0.308	0.17	0.24	0.76	−0.083
15	75	36.6	42	0.488	0.10	0.60	0.40	−0.169
16	70	27.7	38	0.396	0.32	0.79	0.21	−0.113
17	60	25.3	36	0.421	0.46	0.58	0.42	−0.041
18	45	19.7	40	0.439	0.39	0.78	0.22	−0.153
19	70	26.1	33	0.373	0.25	0.43	0.57	−0.146
20	85	35.0	38	0.411	0.26	0.59	0.41	−0.198
21	65	38.2	46	0.587	0.11	0.86	0.14	−0.029
22	30	18.3	46	0.609	0.58	0.99	0.01	0.002
23	55	24.4	45	0.444	0.32	0.29	0.71	−0.212
24	55	27.5	45	0.500	0.32	0.64	0.36	−0.096
25	45	17.7	26	0.394	0.28	0.44	0.56	0.062
26	55	16.9	24	0.307	0.41	0.64	0.36	−0.010
27	105	44.8	59	0.427	0.12	0.57	0.43	−0.338
28	90	42.9	45	0.476	0.03	0.61	0.39	−0.425

intense erosional processes. As a result, the north-facing slopes possess higher and longer slope profiles than do the south-facing slopes. The values for mean slope angles obtained from different slope segments also support a conclusion that north- and south-facing slope profiles are similar. In each case, the values for the mean slope angles were nearly identical for north- and south-facing slopes.

Summary and Conclusions

This study has shown that slope profiles positioned along north- and south-facing slopes within the Glass Mountains possess the same profile characteristics but have different dimensions. North-facing slopes are longer and higher than south-facing slopes.

TABLE 3.—CALCULATED VALUES FOR THE SOUTH-FACING HILLSLOPE MORPHOLOGIC VARIABLES

Slope number	Slope length (m)	Slope height (m)	Maximum slope angle (degrees)	Slope steep-ness	Distance to maximum angle (%)	Percent top slope	Percent bottom slope	Curva-ture index
1	30	9.7	28	0.387	0.10	0.80	0.20	−0.081
2	25	10.0	29	0.400	0.10	0.60	0.40	−0.115
3	40	16.4	35	0.410	0.56	0.87	0.13	0.007
4	50	16.0	30	0.320	0.15	0.50	0.50	−0.181
5	45	17.8	29	0.396	0.50	0.89	0.11	0.145
6	65	20.3	32	0.313	0.27	0.38	0.62	−0.205
7	40	17.0	38	0.426	0.19	0.75	0.25	−0.165
8	70	24.2	34	0.346	0.01	0.50	0.50	−0.201
9	35	12.9	30	0.368	0.36	0.57	0.43	−0.183
10	45	15.3	26	0.339	0.28	0.44	0.46	−0.134
11	105	27.3	35	0.260	0.21	0.29	0.71	−0.310
12	40	16.5	35	0.413	0.19	0.50	0.50	−0.097
13	25	8.5	27	0.342	0.11	0.54	0.46	−0.023
14	105	35.0	44	0.334	0.02	0.43	0.57	−0.314
15	90	27.1	40	0.302	0.03	0.22	0.78	−0.267
16	50	22.7	45	0.455	0.35	0.70	0.30	−0.175
17	45	22.2	52	0.494	0.17	0.67	0.33	−0.286
18	100	34.3	44	0.343	0.22	0.35	0.65	−0.234
19	60	26.3	50	0.438	0.29	0.58	0.42	−0.254
20	50	21.2	43	0.425	0.35	0.70	0.30	−0.212
21	60	19.7	39	0.329	0.04	0.25	0.75	−0.189
22	40	19.1	44	0.476	0.87	0.87	0.13	−0.004
23	35	16.1	44	0.468	0.03	0.35	0.65	−0.050
24	30	13.0	34	0.434	0.08	0.44	0.56	−0.146
25	45	20.3	43	0.452	0.06	0.56	0.44	−0.281
26	40	21.7	52	0.543	0.06	0.75	0.25	−0.242
27	45	20.3	43	0.452	0.06	0.56	0.44	−0.277
28	25	12.9	40	0.515	0.10	0.95	0.05	−0.046

Recent works on climatic conditions during the Holocene (Hall, 1982; Hall and Lintz, 1984) reveal that significant climatic fluctuations occurred in western Oklahoma. These past climates, or fluctuations from one climatic type to another, may have been responsible for the apparently greater past importance of mass-wasting on hillslopes. Using soil criteria developed by Hall and others (1982)—relatively high amounts of organic matter and clay accumulation, well-formed soil structure, and the presence of well-formed genetic soil horizons—the soils on the stable slope segments could be nearly 10,000 years old (formed on late Wisconsin colluvium). Therefore, present slope forms in the Glass Mountains are derived from a combination of past and present processes.

TABLE 4.—t-TEST RESULTS

Variable: Distance to maximum angle				
Type	Mean	Std. dev.	t_c	t_t
North	0.22	0.15	0.36	2.00
South	0.21	0.19	0.36	2.00

Variable: Percent top slope				
Type	Mean	Std. dev.	t_c	t_t
North	0.57	0.21	0.06	2.00
South	0.57	0.20	0.06	2.00

Variable: Percent bottom slope				
Type	Mean	Std. dev.	t_c	t_t
North	0.42	0.21	0.00	2.00
South	0.42	0.20	0.00	2.00

Variable: Curvature index				
Type	Mean	Std. dev.	t_c	t_t
North	−.156	0.11	0.18	2.00
South	−.161	0.11	0.18	2.00

Variable: Slope length*				
Type	Mean	Std. dev.	t_c	t_t
North	71.10	25.0	3.00	1.67
South	51.20	23.3	3.00	1.67

Variable: Slope height*				
Type	Mean	Std. dev.	t_c	t_t
North	29.87	8.62	5.09	1.67
South	19.42	6.61	5.09	1.67

Variable: Maximum slope angle				
Type	Mean	Std. dev.	t_c	t_t
North	41.5	7.17	1.77	2.00
South	38.0	7.61	1.77	2.00

Variable: Slope steepness				
Type	Mean	Std. dev.	t_c	t_t
North	0.44	0.09	1.68	2.00
South	0.40	0.07	1.68	2.00

*Significant difference at 95% confidence level.
Notes: t_c = calculated t value; t_t = tabulated t value; Std. dev. = standard deviation.

References Cited

Carson, M. A.; and Kirkby, M. J., 1972, Hillslope form and process: Cambridge University Press, London, 475 p.

Carson, M. A.; and Petley, D., 1970, The existence of threshold hillslope in the denudation of the landscape: Institute of British Geographers Transactions, v. 49, p. 71–96.

Churchill, R. R., 1981, Aspect-related differences in badlands slope morphology: Association of American Geographers Annals, v. 71, p. 374–388.

——— 1982, Aspect-induced differences in hillslope processes: Earth Surface Processes and Landforms, v. 7, p. 171–182.

Fay, R. O., 1964, The Blaine and related formations of northwestern Oklahoma and southern Kansas: Oklahoma Geological Survey Bulletin 98, 238 p.

Franzmeier, D. P.; Pederson, E. J.; Longwell, T. L.; Bryne, J. G.; and Losche, C. J., 1969, Properties of some soils in the Cumberland Plateau as related to slope, aspect, and position: Soil Science Society of America Proceedings, v. 33, p. 755–761.

Hall, G. F.; Daniels, R. B.; and Foss, J. E., 1982, Rate of soil formation and renewal in the USA, *in* Determinants of soil loss tolerance: ASA and SSSA Special Publication No. 45, chap. 3.

Hall, S., 1982, Late Holocene paleoecology of the southern plains: Quaternary Research, v. 17, p. 391–407.

Hall, S.; and Lintz, C., 1984, Buried trees, water table fluctuations, and 3000 years of changing climate in west-central Oklahoma: Quaternary Research, v. 22, p. 129–133.

Kirkby, A.; and Kirkby, M. J., 1974, Surface wash at the semi-arid break in slope: Zeitschrift für Geomorphologie, Supplement Band 21, p. 151–176.

Koons, D., 1955, Cliff retreat in the southwestern United States: American Journal of Science, v. 253, p. 44–52.

Melton, M. A., 1960, Intravalley variation in slope angles related to microclimate and erosional environment: Geological Society of America Bulletin, v. 71, p. 715–729.

Nusz, R. A., 1985, Statistical analysis of morphologic variables on north- and south-facing slopes, Glass Mountains, Oklahoma: Oklahoma State University unpublished M.S. thesis, 89 p.

Parsons, A. J., 1977, A technique for the classification of hillslope forms: Institute of British Geographers Transactions (new series), v. 3, p. 432–443.

Young, A., 1972, Slopes: Oliver and Boyd, London, 288 p.

——— 1974, Slope profile survey: British Geomorphological Research Group Technical Bulletin No. 11, 52 p.

SCIENCE SERIES WINS EMMY

Planet Earth, a seven-part public television series produced with input from Oklahoma Geological Survey director Charles J. Mankin and a number of other scientists, received a prime-time Emmy award from the Academy of Television Arts and Sciences.

Mankin and the other scientists who advised the program producers were appointed by the National Academy of Sciences in an unprecedented effort designed to assure scientific accuracy and the most up-to-date ideas in the earth sciences.

The series documented the revolution in the earth sciences with location filming on all seven continents, at the bottom of the sea, and in space, and was distinguished by elaborate special visual effects. *Planet Earth* was called "television at its best" by *TV Guide.*

Mankin said it was difficult for the earth scientists to decide which material would be selected from the vast amount of footage shot for the series. The scientists were involved in the project from the initial development of the story line through final editing and fine-tuning of the finished product. When the segments were initially developed, the scientists suggested people and locations for the film crews. Teams were then sent all over the world to obtain the necessary footage.

"Even after the segments were put together, we went over them again and again to see that the narration fit the activities in the footage," Mankin said. "I spent hour upon hour on the telephone and at various meetings to go over the text and see the film."

In conjunction with the series, a hardbound companion book by Jonathan Weiner has sold more than 70,000 copies nationwide, and was a main selection of the Book-of-the-Month Club. The book, also titled *Planet Earth,* is now available in paperback as well.

Dr. Frank Press, president of the National Academy of Sciences, said that the Academy looks forward to a continued association with public television to bring science to a popular audience.

"We are pleased that *Planet Earth* has been honored with such an esteemed award. *Planet Earth* is a testament to the fact that science and the media can work together to produce a series that is innovative, informative, and successful."

BRINE CONTAMINATION NEAR AQUIFER SUBJECT OF NEW SURVEY CIRCULAR

A study of brine contamination of water resources in an area embracing parts of the Vamoosa–Ada aquifer in east-central Oklahoma is the subject of a new publication released by the Oklahoma Geological Survey. The report—*Effects of Brine on the Chemical Quality of Water in Parts of Creek, Lincoln, Okfuskee, Payne, Pottawatomie, and Seminole Counties, Oklahoma*—concludes that brine effects are of a local rather than extensive nature. The study was conducted by the OGS in cooperation with the U.S. Geological Survey.

Water samples were collected for chemical analysis from 347 sites. Of these, 167 were surface-water sites and 180 were ground-water sites. Degradation of water quality by brine was indicated at 63 of the surface-water sites and 20 of the ground-water sites. Selection of sample sites was based on a 2- to 3-mi grid. Two methods, chemical-graphical and geophysical, were used for detecting the presence of brine in the water resources.

Author Robert B. Morton, of the USGS, said that, while not all sites with degraded water necessarily show visual effects of oil and gas operations, "evidence of the incursion of oil and gas activity is apparent at other sites."

Morton cites examples such as leaking pipes from salt-water storage tanks and unlined pits containing brines or brine and crude oil as possible sources of localized contamination.

Circular 89 is 38 pages long and contains 10 figures and 5 tables. A plate comprises three geohydrologic maps of the study area.

Circular 89 can be obtained from the Oklahoma Geological Survey at the address given inside the front cover of this issue. The price is $7 for paperbound copies, $11 for hardbound.

OIL GENERATION IN THE ANADARKO BASIN SUBJECT OF NEW SPECIAL PUBLICATION

A new publication of the Oklahoma Geological Survey examines oil generation in the Anadarko basin of Oklahoma and Texas. Hydrocarbons have been generated in the Anadarko basin for more than 300 million years, in an unusually long and continuous history that has contributed to the high oil and gas productivity of that area, author James W. Schmoker said.

In OGS Special Publication 86-3, *Oil Generation in the Anadarko Basin, Oklahoma and Texas: Modeling Using Lopatin's Method,* Schmoker discusses a number of variables such as geothermal gradient, surface temperatures, burial depth, and decomposition in examining the basin. Schmoker has compared Lopatin's time-temperature index of thermal maturity to published vitrinite-reflectance data in order to specifically calibrate the model to the study region. In this 40-page paperbound book, he included 18 figures to accompany the text.

SP 86-3 was prepared for the U.S. Geological Survey's Evolution of Sedimentary Basins Program. The work was part of a joint effort between the USGS and the OGS to study the Anadarko basin and its petroleum occurrences. Schmoker is with the USGS office in Denver.

Oil Generation in the Anadarko Basin, Oklahoma and Texas: Modeling Using Lopatin's Method, is available from the Oklahoma Geological Survey at the address given inside the front cover of this issue. The price is $3.

STUDY OF ORDOVICIAN, SILURIAN STRATA RELEASED

The biostratigraphy, lithostratigraphy, and paleoenvironment of the latest Ordovician (Hirnantian) and Early Silurian strata in the southern Midcontinent region of the United States is the subject of Bulletin 139, a recent Oklahoma Geological Survey publication. Brachiopod faunas of Keel and Edgewood strata are correlated with the upper part of the Gamachian Stage of Anticosti Island, Quebec, and the Hirnantian Stage of Europe, the U.S.S.R., and the People's Republic of China.

Bulletin 139, *Late Ordovician–Early Silurian Strata in the Central United States and the Hirnantian Stage*, is composed of two papers. Part I, by Thomas W. Amsden, reviews the biostratigraphy-lithofacies-biofacies of the Keel–Edgewood strata. Amsden discussed the paleoenvironment and its possible relationship to eustatic changes in sea level associated with Late Ordovician–Early Silurian glaciation.

Part I concludes with a review of the Hirnantian faunas from other parts of the world, and examines paleoenvironment implications that can be derived from these occurrences.

Amsden retired from the OGS in 1985 but is continuing his work on a part-time basis. He is the author of a number of landmark studies of the Hunton Group, and is currently involved in an evaluation of the Anadarko basin in cooperation with the U.S. Geological Survey.

In part II, James E. Barrick describes the taxonomy and biostratigraphy of conodonts from the Keel Formation of Oklahoma and the Cason oolite of Arkansas. These faunas are compared to those in the Edgewood Group of the Mississippi Valley. Although conodonts have been described from the Cason oolitic limestone in Arkansas, and the Noix Oolite in Missouri, this is the first study of their distribution in the Keel Formation of Oklahoma.

Barrick is with Texas Tech University at Lubbock.

Bulletin 139 is illustrated with 40 figures, 7 plates, and 7 tables. It can be obtained from the Survey at the address given inside the front cover of this issue. The price is $8 for paperback, $12 for hardbound.

COAL RESERVES AND RESOURCES EVALUATED IN CRAIG, NOWATA COUNTIES IN NEW OGS BULLETIN 140

The Oklahoma Geological Survey has just published the first in a series of studies that will evaluate the coal reserves and resources of Oklahoma on a county basis. Issued as Bulletin 140, this first report covers an 890-square-mile area of Craig County and eastern Nowata County in Oklahoma.

Author LeRoy A. Hemish, a coal geologist at the OGS, conducted this study to determine the location, amounts, and chemical character of the coal beds and associated strata. While some 29,827,000 tons of coal have been mined or lost in mining in the area, he has estimated the remaining resources at 669,737,000 tons of coal, with estimated reserves of 47,674,000 tons of coal. "Remaining resources" is the term used for all the coal still in the ground that has the potential for economic extraction. Current price levels, however, may not be sufficient to make mining of all resources economical. The term "reserves" is used for that portion of the resources that can be mined currently at a profit.

The three largest beds of commercial importance in the area are the Weir-Pittsburg coal, with reserves of about 18,730,000 tons; the Croweburg coal, with reserves of about 9,153,000 tons; and the Iron Post coal, with reserves of about 8,730,000 tons. These coal beds occur in rocks of Desmoinesian age, particularly the Krebs and Cabaniss Groups.

Summary information on reserves and resources is contained in tables and is listed according to township, coal thickness, county, and coal bed. Detailed data on estimated original, mined, and remaining coal resources and reserves are tabulated by township for each county according to coal thickness, overburden thickness, and reliability category. The text covers coal quality, coal rank, and geology, with emphasis on stratigraphy, mining methods, and economics. The book is illustrated with photographs of active and abandoned coal mines and includes histograms showing reported coal production from 1917–78.

Included with Bulletin 140 are four plates that show the outcrop boundaries of seven commercially important coal beds. The maps show the thickness of both the beds and the overburden. One plate shows structure contours drawn on the Croweburg and Weir-Pittsburg coal beds, and three plates contain seven stratigraphic cross sections that form a crisscrossing network throughout the study area.

Listed in the appendixes are 97 sections measured by the author in active and abandoned coal mines and on outcrops.

Bulletin 140, *Coal Geology of Craig County and Eastern Nowata County, Oklahoma,* can be obtained from the Oklahoma Geological Survey at the address given inside the front cover of this issue. The price is $22.

Charles A. Ferguson

Patronalia M. Hanley

RESEARCH ASSISTANT, CHEMIST JOIN OGS

Research assistant Charles A. Ferguson and chemist Patronalia M. Hanley are the two most recent additions to the staff of the Oklahoma Geological Survey.

Ferguson is working with OGS stratigrapher Neil H. Suneson on a detailed mapping project of the frontal Ouachita Mountains in southeastern Oklahoma. The project, COGEOMAP, is a cooperative program of the Oklahoma Geological Survey, the Arkansas Geological Commission, and the U.S. Geological Survey. During the course of this project, Ferguson will help construct balanced geologic cross sections across the frontal belt.

Before coming to Oklahoma, Ferguson worked in the cartographic department of the New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico. During the summers of 1981, 1982, and 1984, he mapped a Proterozoic volcanic-sedimentary terrane in the Wopmay orogen, Northwest Territories, Canada. In July and August of 1986, he took a leave of absence from New Mexico to work as a field assistant mapping and describing the upper Proterozoic turbidites of the Windermere Group in the Cariboo Mountains of east-central British Columbia, Canada.

Ferguson has an M.S. in geology from the New Mexico Institute of Mining and Technology in Socorro, New Mexico, and a B.S. in geology from the University of Kansas at Lawrence. His master's thesis is a structural-stratigraphic study of Oligocene volcanic and volcaniclastic rocks in the northeast corner of the Datil–Mogollon volcanic field of southwest New Mexico. The work established the regional volcanic stratigraphy along the southern margin of the Mt. Withington cauldron. For the thesis, Ferguson also completed a stratigraphic study of fanglomerates and eolian sandstones within a moat-like basin along the cauldron margin.

At the OGS, Hanley will be the primary person working with an inductively coupled plasma emission spectrometer (ICP) unit. She will analyze water samples that are part of a continuing cooperative project involving the OGS and the U.S. Geological Survey. Two other continuing projects are centered around carbonate rocks and coal. In addition to these duties, she will participate in the wide variety of analyses run regularly by the OGS chemistry lab.

Prior to joining the Survey, Hanley worked with the City of Tulsa and Dowell Division of Dow Chemical, where she was involved with water analyses and the development of organic and inorganic analytical techniques in support of research, chemical plant production, and field operations.

Hanley has a B.S. from Huston-Tillotson College in Austin, Texas, and has done postgraduate work at the University of Tulsa. She has had training in ion chromatography, plasma arc emission spectroscopy, infrared spectrometry, and oil-well service technology, and was certified as a first-responder emergency medical technician.

USGS DEVELOPS GUIDELINES FOR NAMING AQUIFERS

Guidelines for more systematically naming aquifers have been developed for authors of U.S. Geological Survey reports. These guidelines, contained in Open-File Report 86-534 by the USGS, are expected to help reduce confusion caused by a proliferation of conflicting or imprecise aquifer names.

Aquifer names traditionally have been based on a variety of physical, geologic, geographic, and age designations. It is recommended now that aquifers be named only after lithologic terms, rock-stratigraphic units, or geographic names.

The report contains examples of comparison charts and tables used to define the hydrogeologic framework. Aquifers are defined in 11 hypothetical examples that characterize hydrogeologic settings throughout the country.

Copies of Open-File Report 86-534, *Aquifer-Nomenclature Guidelines*, by Robert L. Laney and Claire B. Davidson, can be purchased from the U.S. Geological Survey, Books and Open-File Reports, P.O. Box 25425, Federal Center, Bldg. 1, Denver, CO 80225. The price is $8 for each paper copy and $4 for microfiche. Orders must include the report number (OFR 86-534) and checks or money orders payable to the U.S. Department of the Interior—USGS.

COAL RANK AND PRESENT GEOTHERMAL GRADIENT EXAMINED IN NEW OGS PUBLICATION

A new study published by the Oklahoma Geological Survey concludes that the rank of coal in the Arkoma basin of Oklahoma is not a result of the present geothermal gradient in that area. The authors believe that heat from a thermal anomaly in Arkansas was the determining factor in the coal rank; the authors believe that the thermal anomaly developed during the late Paleozoic, possibly in connection with the Ouachita orogeny.

These findings have just been published as OGS Special Publication 86-4, *The Relationship Between Coal Rank and Present Geothermal Gradient in the Arkoma Basin, Oklahoma*. The OGS authors are organic petrologist Brian J. Cardott, coal geologist LeRoy A. Hemish, research assistant Charles R. Johnson, and engineering geologist Kenneth V. Luza.

Cardott used vitrinite-reflectance techniques to test the relationship between the present geothermal gradient and coal rank. Samples from three coal beds in high-geothermal-gradient areas were compared with samples from the same coal beds in low-geothermal-gradient areas. The three coal beds selected for the study were the Hartshorne, McAlester (Stigler), and Secor. Samples were obtained from core holes drilled by the OGS in Pittsburg, Haskell, Latimer, and Muskogee Counties, as well as from active coal mines and an outcrop.

The 65-page Special Publication 86-4 contains 16 illustrations and 3 tables. Along with the book are two large plates that are packaged in a separate slipcover.

Plate 1 consists of a detailed cross section that demonstrates the correlation between subsurface structure and stratigraphy and the present geothermal gradient in the Arkoma basin. Geophysical logs of holes ranging in depth from 2,500 ft to 19,000 ft were used to construct this north-south cross section across the basin.

Plate 2 consists of larger-scale cross sections showing the relationships of the various stratigraphic units encountered at shallower depths in the basin. The cross sections demonstrate that the three coal samples cored in the low-geothermal-gradient areas correlate with the three coal samples cored in the high-geothermal-gradient areas.

Background information on the geology, pre-Desmoinesian and Desmoinesian stratigraphy, and coal geology of the Arkoma basin, Oklahoma, is presented in the text to supplement the information provided in the plates.

Special Publication 86-4 is available from the Oklahoma Geological Survey at the address given inside the front cover of this issue. The price is $7.

UPCOMING MEETINGS

Workshop to Develop Scientific Drilling Initiatives in the South Atlantic and Adjacent Southern Ocean, April 6–8, 1987, Woods Hole, Massachusetts. Information: J. A. Austin, Jr., Institute for Geophysics, University of Texas, 4920 North I.H. 35, Austin, TX 78751.

Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Spring Field Conference, April 29–May 2, 1987. Information: Chris Chandler, P.O. Box 2990, Midland, TX 79702; (915) 675-0575.

Midwest Friends of the Pleistocene, Annual Meeting, May 15–17, 1987, Mansfield, Ohio. Information: John P. Szabo, Department of Geology, University of Akron, Akron, OH 44325; (216) 375-7630.

Short Summer Course in X-Ray Spectrometry, June 1–12 and August 17–21, 1987, Albany, New York. Information: Henry Chessin, Department of Physics, State University of New York at Albany, 1400 Washington Ave., Albany, NY 12222; (518) 442-4512.

Short Summer Course in X-Ray Powder Diffraction, June 15–26, 1987, Albany, New York. Information: Henry Chessin, Department of Physics, State University of New York at Albany, 1400 Washington Ave., Albany, NY 12222; (518) 442-4512.

GSA Penrose Conference, "Geological Decisions for the 21st Century," July 12–17, 1987, Steamboat Springs, Colorado. Information: David A. Stephenson, Dames & Moore, Pointe Corporate Centre, 7500 North Dreamy Draw Dr., Suite 145, Phoenix, AZ 85020; (602) 371-1110.

Society of Economic Paleontologists and Mineralogists, Annual Midyear Meeting, August 20–23, 1987, Austin, Texas. Information: SEPM, P.O. Box 4756, Tulsa, OK 74159; (918) 743-9765.

UPCOMING AAPG FIELD SEMINARS AND SHORT COURSES

Field Seminars

The following AAPG field seminars, covering a wide array of subjects in various geographical areas, will be offered in 1987.

"Classic Mississippian to Permian Reefal Carbonates: Deposition, Diagenesis, and Reservoir Geology" (formerly "Upper Paleozoic Depositional and Diagenetic Facies—Exploration Models in a Mature Petroleum Province"), April 5–10, 1987. Begins and ends in El Paso, Texas.

"Structural Styles in Foreland Fold and Thrust Belts," April 11–16, 1987. Begins in Washington, D.C.; ends in Lynchburg, Virginia.

"Modern Clastic Depositional Environments," April 24–30, May 23–29, September 5–11, 1987. Begins in Columbia, South Carolina; ends in Charleston, South Carolina.

"Ancient Carbonate Rock Sequences," May 3–9, October 4–10, 1987. Begins in San Antonio, Texas; ends in Austin, Texas.

"Cretaceous Transgressive-Regressive Cycles in Utah—Preservation in the Stratigraphic Record and Controls on Distributions of Fossil Fuels," May 10–17, 1987. Begins and ends in Salt Lake City, Utah.

"Cretaceous Wave-Dominated Deltas, Shelf Sands, and Turbidite Systems: Depositional Models for Hydrocarbon Exploration," June 8–17, 1987. Begins and ends in Salt Lake City, Utah.

"Petroleum Geology, Tectonics and Sediments of the French Pyrenees and Associated Aquitaine Basin" (A Geological/Cultural Field Seminar), July 2–11, 1987. Begins in Pau, France; ends in Bordeaux, France.

"Georoots" (A Geological/Cultural Field Seminar), July 4–12, 1987. Begins and ends in Edinburgh, Scotland.

"Overthrust Belt," August 10–14, 1987. Begins in Salt Lake City, Utah; ends in Las Vegas, Nevada.

"Modern Deltas," August 21–25, 1987. Begins in Baton Rouge, Louisiana; ends in New Orleans, Louisiana.

"Eolian Sandstones as Hydrocarbon Reservoirs," August 30–September 5, 1987. Begins in Rock Springs, Wyoming; ends in Rapid City, South Dakota.

"Modern and Ancient Clastic Depositional Systems," September 4–18, 1987. Begins in San Antonio, Texas; ends in Albuquerque, New Mexico.

"Fluvial Systems: Their Economic and Field Applications," September 7–11, 1987. Begins and ends in Salt Lake City, Utah.

"Paleozoic Carbonate Continental Margin: Facies Transitions, Depositional Processes, and Exploration Models—The Basin and Range Province," September 11–19, 1987. Begins in Salt Lake City, Utah; ends in Las Vegas, Nevada.

"Tectonics and Sedimentation of Turbidites in California," September 12–20, 1987. Begins in San Francisco, California; ends in San Diego, California.

"Florida–Bahamas Modern Carbonates," October 4–10, 1987. Begins and ends in Miami, Florida.

"Ancient Clastics," October 18–23, 1987. Begins and ends in Lexington, Kentucky.

Short Courses

AAPG is initiating in 1987 a new concept of grouping short courses in broadly related topics. These modules will have three short courses back to back and will be three or four days in length. The participants may take the courses singly or as a module. The modules will be rotated over a two-year period between Houston, Dallas, and Denver.

Module One—Development, Production Geology, Reservoir Engineering

"How to Evaluate Carbonate Reservoirs from Well Logs." March 11, Dallas; October 5, Denver.
"Practical Petrophysics for Exploration and Development." March 12, Dallas; October 6, Denver.
"Geological Applications of Reservoir Engineering Tools." March 13, Dallas; October 7, Denver.

Module Two—Seismic Application, Interactive Interpretation

"Seismic Expression of Structural Styles." April 13, Houston; September 16, Dallas.
"Seismic Stratigraphy." April 14, Houston; September 17, Dallas.
"Interactive Interpretation of Seismic and Well Data." April 15, Houston; September 18, Dallas.

Module Three—Exploration Techniques

"Creative Exploration." May 12, Denver; November 9, Houston.
"Defining a Prospect." May 13, Denver; November 10, Houston.
"Oil and Gas Property Evaluation." May 14–15, Denver; November 11–12, Houston.

For further information about field seminars, short courses, or other AAPG educational programs, contact: Education Department, American Association of Petroleum Geologists, P.O. Box 979, Tulsa, OK 74101-0979; (918) 584-2555.

COLLAPSE PROBLEMS IN PICHER FIELD ADDRESSED BY NEW CIRCULAR

Surface-collapse problems of the old Picher Field mines in northeastern Oklahoma, southeastern Kansas, and southwestern Missouri were among the problems addressed in a recent joint study of the area undertaken by the geological surveys of the three states. From this work comes the Oklahoma Geological Survey's new Circular 88, *Stability Problems Associated with Abandoned Underground Mines in the Picher Field, Northeastern Oklahoma.*

In Circular 88, OGS engineering geologist Kenneth V. Luza outlines collapse problems that have occurred in an area of approximately 2,540 acres underlain by the abandoned underground lead-zinc mines. Maps and field surveys indicate that at least 1,064 shafts existed in the Oklahoma portion of the Picher Field. Currently, 481 shafts in that area of the State are either open or in some state of collapse, and 55 non-shaft-related collapses have been reported. A shaft-filling program is outlined in Circular 88 and is recommended as the best method of controlling the ongoing problem.

The report also includes a discussion of the mine- and mill-waste materials that have affected approximately 3,000 acres in Oklahoma. This discarded mill-waste material is chiefly composed of chert aggregate. Today, approximately 900 acres of the State are overlain by chat piles. Another 800 acres of land in the district was used for tailings ponds, most of which are now dry.

Zinc and lead ores were mined from the district for more than 60 years. Almost every year from 1918 through 1945, Oklahoma led the nation in zinc production. Because of depressed metal markets, many operations were cut back or suspended in 1957. By midyear of 1958, all major mining operations were closed. Mining resumed at a reduced rate in 1960, and the last significant production was recorded in 1970. More than 1.3 million tons of lead and 5.2 million tons of zinc were produced since mining began in 1891.

The 114-page book has 20 figures (including 4 color photographs) and 3 large maps in a pocket. Eight tables list summaries of the mines, shafts, waste ponds, and chat piles. Volume and void-space estimates for various collapse features also are included. Along with the mining history and geologic setting, the text discusses water resources, hazard potential, shaft and surface collapses, mine and mill waste, and regulations and laws that govern mining in Oklahoma.

Circular 88 is available from the Oklahoma Geological Survey at the address given inside the front cover of this issue. The price is $18 for hardbound and $14 for paperbound copies.

NOTES ON NEW PUBLICATIONS

Mineral Revenues: The 1985 Report on Receipts from Federal and Indian Leases

The 1985 activities of the Department of the Interior's Minerals Management Service Royalty Management Program are reported in this booklet, including collection of $6.5 billion in bonuses, rents, and royalties from Indian and federal (offshore and onshore) minerals leases. The report also offers tables and statistics relating to the generation, distribution, and history of revenues obtained under this program.

Order from: Public Affairs Office, Royalty Management Program, Minerals Management Service, P.O. Box 25165, MS-651, Denver, CO 80225. Copies are available free of charge.

Union List of Geologic Field Trip Guidebooks of North America, 4th Edition

As an aid in locating guidebooks prepared for the field trips held at geology meetings each year, the Geoscience Information Society produces the Union List, which functions as both a bibliography and a finding tool. The new edition of this publication includes the holdings of 134 libraries in the U.S. and Canada with strong geoscience collections. A user can determine which libraries own a copy of any guidebook cited, as well as the lending policies of those libraries. This edition cumulates guidebooks for field trips held from the 5th International Geological Congress in 1891 through the end of 1979. It lists 212 more guidebook series than contained in the 3rd edition, and its geographic index has been expanded.

Order from: American Geological Institute, Customer Services, 4220 King St., Alexandria, VA 22302. The price is $47.50.

Land Use and Land Cover and Associated Maps for Oklahoma City, Oklahoma

This data set consists of one map keyed to USGS topographic map Oklahoma City at 1:250,000 (1 in. = about 4 mi). This map is coded for statistical data development. The map shows political unit, hydrological units, and census county subdivision. Also included is one positive of the cultural base for Oklahoma City.

Order OF 79-0910 from: U.S. Geological Survey, Mid-Continent Mapping Center, 1400 Independence Rd., Rolla, MO 65401.

Land Use and Land Cover and Associated Maps for McAlester, Oklahoma

This data set consists of one map keyed to USGS topographic map McAlester at 1:100,000 (1 in. = about 1.6 mi). This map is coded for statistical data development. The map shows land use and land cover, political unit, hydrological units, and census county subdivision. Also included is one positive of the cultural base for McAlester.

Order OF 85-0321 from: U.S. Geological Survey, Mid-Continent Mapping Center, 1400 Independence Rd., Rolla, MO 65401.

The National Earthquake Hazards Reduction Program; Scientific Status

On the basis of letters and discussions by numerous scientists from government, academia, and industry, author T. C. Hanks sets forth the significant scientific accomplishments of the National Earthquake Hazards Reduction Program in this 40-page report. Stimulated by several major earthquakes in the early 1970s, the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124) established the program with funding to four federal agencies, including the U.S. Geological Survey. The objectives of this program are not only the advancement of scientific knowledge but also the application of this knowledge in effective implementation of hazard-reduction policies and emergency-preparedness plans.

Order B 1659 from: U.S. Geological Survey, Books and Open-File Reports, Federal Center, Bldg. 41, Box 25425, Denver, CO 80225. The price is $1.75.

Land Use and Land Cover and Associated Maps for Sherman, Texas; Oklahoma

This data set consists of five stable base reproducibles keyed to USGS quadrangle map Sherman at 1:250,000 (1 in. = about 4 mi). The maps show land use and land cover, political unit, hydrological units, census county subdivision, and include a planimetric base map. Order OF 83-0115 from: U.S. Geological Survey, Rocky Mountain Mapping Center, Box 25046, Federal Center, Denver, CO 80225.

Goals of the U.S. Geological Survey

Citing the importance of the earth sciences in meeting the resource needs of the nation, the U.S. Geological Survey recently outlined current goals to meet its mission to provide essential geologic, topographic, and hydrologic information in service to the public.

USGS Director Dallas L. Peck, in a foreword to a new report, said, "The material needs of society are ultimately met by using the resources of the Earth—its land, water, and mineral endowment."

USGS goals designed to meet national needs in the earth sciences involve the following areas: energy and mineral resource assessment, energy and mineral resource processes, hazards assessment, geologic framework, global and international geoscience, timely reporting of events and conditions, water-resources assessment, hydrologic processes, information dissemination, topographic mapping, and geographic information systems.

Order C 1010 from: U.S. Geological Survey, Books and Open-File Reports, Federal Center, Bldg. 41, Box 25425, Denver, CO 80225. The circular is available free of charge.

OKLAHOMA ABSTRACTS

AAPG Annual Convention
Atlanta, Georgia, June 15–18, 1986

The following abstracts are reprinted as published in the *Bulletin* of the American Association of Petroleum Geologists, v. 70, no. 5. Page numbers are given in brackets below the abstracts. Permission of the authors and of the AAPG to reproduce the abstracts is gratefully acknowledged.

Ordovician Platform, Slope, and Basin Facies in Subsurface of Southern North America

LEONARD P. ALBERSTADT, GEORGE COLVIN, Vanderbilt University, Nashville, TN; and JUDITH SAUVE, Exxon, New Orleans, LA

Ordovician carbonates of the Nashville dome and Ozark dome regions have long been considered typical shelf deposits. In the subsurface to the south, in the Black Warrior basin, Mississippi Embayment, and Arkoma basin, these shelf carbonate units changed facies. The most significant change is the occurrence of a thick limestone unit characterized by a faunal and floral assemblage of *Nuia, Girvanella* (isolated long strands), *Sphaerocodium*, a delicate stacked-chambered organism (?algal), and sponge spicules and sponge mudstone clumps. In ascending order, the complete Ordovician sequence consists of: a lower dolostone, the *Nuia*-sponge limestone, a dolostone, and a limestone. The upper part of this four-fold sequence changes character westward into the Arkoma basin. The lower two units maintain their character for long distances along depositional strike and occur in parts of the Appalachians as far north as Newfoundland, and on the opposite side of the continent in Nevada. The *Nuia*-sponge assemblage is a distinctive petrographic marker and seems to be a persistent Ordovician rock and fossil assemblage of widespread occurrence. In Nevada, it occurs on the surface where it is associated with slump and slide features that suggest that it is an outer shelf or upper slope deposit. Coeval carbonates in the Ouachita Mountains are different and show indications of being deep water (basinal).

Biostratigraphic evidence indicates that the succession in the subsurface is continuous; the regional Lower Ordovician–Middle Ordovician un-

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OKLAHOMA ABSTRACTS is intended to present abstracts of recent papers relating to the geology of Oklahoma and adjacent areas of interest. The editors are therefore interested in obtaining abstracts of formally presented or approved documents, such as dissertations, theses, and papers presented at professional meetings.

conformity is absent. The Lower Ordovician–Middle Ordovician boundary falls near the top of the *Nuia*-sponge mudstone unit and not at the top of the underlying thick dolostone unit. [559]

Southeast Hoover Field: Model of Foreland Tectonics of Arbuckle Region, Southern Oklahoma

JOHN H. BECK, Baylor University, Waco, TX

The Southwest Hoover field, located on the northern side of the Arbuckle Mountains, typifies the structural style common to the foreland of southern Oklahoma. This oil field, which produces primarily from the upper Arbuckle Group carbonates, was created in response to the Late Pennsylvanian Arbuckle orogeny. Various interpretations of the mode of deformation have been proposed such as wrench faulting, gravity sliding, and overthrusting. This research supports the idea of moderately dipping thrust faults created by northeast-southwest compression. Paleozoic rocks, originally deposited on the northern edge of the Southern Oklahoma aulacogen, have been transported to the northeast on southwest-dipping thrust faults, and now comprise the leading edge of the Arbuckle Mountains.

In a detailed study, the Southeast Hoover field was reinterpreted in light of the compressional thrust-fault theory. Large-scale structural closure controls the location of hydrocarbon accumulation in the Arbuckle Group. Structures in the shallower horizons are characterized by detached anticlines that were created as a response to volume adjustments in adjacent upward-tightening synclines. Fault cutoff lengths and hanging-wall cutoff angles provide clues to predeformation fault-plane geometry.

Comparison of the Southeast Hoover field with other structures in the Arbuckle region indicates a close similarity of style, which suggests this study can be used as a geologic model for interpreting foreland oil fields throughout southern Oklahoma. [563]

Pennsylvanian Fan-Delta Deposition Resulting from Tectonic Uplift Along Southwestern Margin of Anadarko Basin

ALAN R. CARROLL, Sohio Petroleum Co., Dallas, TX

Pennsylvanian sedimentation on the southwestern margin of the Anadarko basin was dominated by a clastic wedge of conglomeratic alluvial fan-delta deposits, referred to locally as "washes." Chert, carbonate, and granite (arkosic) washes were shed basinward in response to thrusting and uplift of the Ancestral Wichita Mountains. Chert and carbonate washes were deposited in the Early Pennsylvanian, as lower Paleozoic limestones and dolomites eroded from the Wichitas. Arkosic washes predominated during the Middle and Late Pennsylvanian, as drainage basins composed primarily of Precambrian–Cambrian crystalline rocks eroded.

The detailed stratigraphy available from well control in the Anadarko basin permits relatively precise timing of orogenic events along the Ancestral Wichitas. Wash deposition in the basin began in the Morrowan and continued episodically in seven major pulses through the Missourian. These wash sequences range from 200 to 1,500 ft thick; each terminates with an unconformity. Wash sequences are further subdivided into as many as nine conformable subsequences, 100–400 ft thick and correlative for 10–20 mi, which appear to record individual drainage-basin erosional cycles. Subsequences generally coarsen upward abruptly, then gradually fine upward to the next subseqence.

Basinal marine shales interfinger with the wash sequences and are a possible source of structurally and stratigraphically entrapped gas and condensate. Optimal reservoir quality occurs in braided channels and fan-delta fronts. Reserves average 2–5 bcf and 50,000–200,000 bbl/well, making granite wash an economically attractive target at present Anadarko drilling costs. [571–572]

Depositional Environment, Stratigraphy, Paleogeography, and Organic Maturation of Desmoinesian Cyclothemic Excello Black Shale in Oklahoma, Kansas, and Missouri

OMER ISIK ECE, University of Tulsa, Tulsa, OK

The thick, laterally continuous Excello black shale was studied along the 400-mi-long outcrop belt from Oklahoma to Iowa. The Excello is perhaps the best example of a Pennsylvanian cyclothemic black shale in the Mid-Continent area. The distribution of total organic carbon (TOC) and kerogen types indicate that the Excello Shale was deposited in an epeiric, highly productive sea with bottom anoxia. Thin laminations and grain-size analysis indicate stagnant water conditions, whereas gentle undulations suggest a flat bottom topography. The TOC content averages about 10 wt. %, but can be as high as 17 wt. %. The changes in shape and size of phosphate nodules along the outcrop belt (spherical, bladed, elongated, and laminated) appear to be related to changes in the seawater chemistry, fluctuations in productivity, terrestrial input, and local diagenetic effects.

Vitrinite reflectance (R_o = 0.51–0.63%) and elemental kerogen analysis indicate that the outcrop samples are immature, but cores from west-central and northwestern Oklahoma are mature (R_o = 0.61–1.44%) with respect to hydrocarbon generation. This study suggests that a humid, warm paleoclimate with high rainfall and abundant terrestrial vegetation produced structured kerogen, which was transported into the Excello sea. The Excello was probably deposited in less than 60 m (197 ft) of water. Surface temperature of the seawater was above 28°C (82°F) at the time of deposition in the ice-free polar regions. The anoxic episode lasted approximately 10 k.y. with the cyclicity every 500 k.y./cycle. The cyclic changes in atmospheric conditions corresponding with cyclic shifts in the earth's axis may have caused the anoxic episode. [585]

Laboratory Study of Effects of Shear Stress on Fracture Permeability

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Single-fracture hydraulic properties must be well understood before multifracture reservoir systems can be modeled with confidence. However, subsurface fractures cannot be observed or measured directly. Therefore, in-situ reservoir conditions must be simulated in the laboratory for reservoir modeling.

In the past, such studies used a uniform confining pressure while measuring fracture permeability. This pressure is adequate for determining the effects of normal stress on fracture permeability; however, since most subsurface stress states are distinctly nonhydrostatic, many fractures in natural reservoirs are subject to shear stresses in addition to normal stresses. Therefore, in this study fracture permeabilities are measured while applying both shear and normal stresses to the fracture in ratios that simulate true subsurface conditions. The resulting measurements indicate that shear stresses do affect fracture permeability. Specifically, the data show that: (1) fracture permeability reduction due to shear stresses is more likely permanent than permeability reduction due to normal stresses; (2) the effect shear stress has on fracture permeability is lithology dependent; (3) the shear stress effect depends on the magnitude of the normal stress applied; and (4) the amount of shear stress effect on fracture permeability depends on fracture surface roughness.

These data imply that in the subsurface, fracture orientation may affect fracture permeability. Further, repressuring a reservoir may affect certain fractures more than others. [611–612]

Exploration for Fractured Reservoirs in Precambrian Basement Rocks of Texas Panhandle: An Integrated Approach

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This paper describes a detailed integrated study of the buried basement rocks of the Gray County, Texas, area. The study area comprises parts of Gray, Carson, and Wheeler Counties in the Texas Panhandle. We mapped faults and basement structure by integrating aerial photographs and enhanced Landsat structural interpretations with various data, including magnetics, gravity, geomorphic, paleogeologic, well-log, fracture core, well-top, subsurface structural, and isopach mapping data. The present structural configuration of the basement is a complex system of faults, bounding horst, graben, and tilted fault blocks. Most deformation resulted from left-lateral, oblique-slip faulting during the Pennsylvanian through Early Permian. Fractures in several orientations have experienced multiple episodes of opening and fluid circulation. The local relief of the basement results

from a combination of structural deformation and paleoweathering. Basement production ranges from 1 to 700 BOPD. This variable rate primarily results from the fractured nature of the basement rocks. Depth to production averges 3,500 ft. Oil probably migrated from the Woodford Shale in the Anadarko basin into the basement along ubiquitous fractures, and accumulated in open fracture zones associated with faults. However, drilling within a fault zone does not assure basement production. Other geologic factors that are equally important to basement oil accumulations and production are fault orientation, fracture type, fracture mineralization, degree of weathering, basement subcrop elevation, lithology, fault intensity, proximity to fault-associated fracture zone, and treatment procedures.

The approach used in this study is significant. By integrating a variety of data types with more than 10 orders of magnitude of scale difference, we obtained a reliable picture of the geology, and defined the areas most likely to have oil accumulations. [616]

Pennsylvanian Foreland Deformation of Wichita Uplift, Southwest Oklahoma

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Pennsylvanian foreland deformation associated with the Ouachita orogene reactivated a west-northwest–east-southeast Cambrian basement trend, the southern Oklahoma aulacogen, to form the Wichita uplift, southwest Oklahoma. The 30-km-wide subsurface Frontal fault zone separates the uplift from the Anadarko basin to the north. Horizontal shortening across this fault zone is estimated at 7–15 km (20–40%), vertical displacement totals 9–10 km from the uplift to the basin.

Under the assumed deformation conditions (effective pressure 50 MPa, strain rate 10^{-15} sec^{-1}, temperature 100°C), the basement rocks were brittle and rigid. Shortening of the basement occurred along moderate angle (30°–60°) reverse faults with no apparent folding of the upper basement surface. The overlying Paleozoic sedimentary rocks were represented by (1) a well-bedded, 3,500-m Cambrian–Devonian dominantly carbonate section, (2) a 1,250-m Silurian–Mississippian clastic section. Strain was accommodated within these rocks by displacement along the basement reverse faults (mountain flank thrusts) and by northeast-verging asymmetric folds with planar limbs and moderate–tight hinges. These folds are mapped on an interformational scale within the Frontal fault zone, and on an intraformational scale (Cambro–Ordovician Arbuckle Group) in the Slick Hills, southwest Oklahoma. Additional shortening occurred along southwest dipping mountain flank thrusts and on bedding plane thrusts, respectively.

Hanging wall blocks of major faults contain the shallow dipping limb and anticlinal hinge zone of the interformational scale folds. Oil and gas production is generally restricted to these anticlinal crests within Paleozoic rocks. Deep wells (>6,000 m) that have penetrated footwall imbricates of the mountain flank thrusts have drilled through steep-overturned beds and tight recumbent folds before passing through faults into a normal stratigraphic sequence. Basement thrust loading of the southern margin of the Anadarko basin controlled the trend (west-northwest–east-southeast) of the axis of maximum deposition within the basin during the Pennsylvanian. [618]

Detecting Hydrocarbon Microseepage Using Remotely Sensed Data

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Many petroleum reservoirs leak, and the upwardly migrating hydrocarbons and associated fluids can produce a series of chemical changes that may affect plant physiology and the mineralogical and physical attributes of the overlying strata. Alterations manifested [at] the surface depend on the composition of both the upwardly migrating fluid and the strata overlying the leaking reservoir. These alterations may appear on airborne spectroradiometric or satellite multispectral data as tonal (mineral or plant spectral) or textural (geomorphic or plant ecological) anomalies, or both. Examples include: (1) bleaching of red beds due to loss of hematite and/or anomalous clay mineral distributions in strata overlying petroleum accumulations at Lisbon Valley, Utah, and at Cement and Velma fields, Oklahoma; (2) mineral alterations such as replacement of calcium sulfates by calcite at Cement, Oklahoma, and Limestone Buttes, Gypsum Plain, Texas, resulting in anomalous geomorphology; and (3) geobotanical manifestations caused by soil chemistry variations resulting in anomalous plant communities above Lost River gas field, West Virginia, or physiological alteration (stunting) of plant communities such as at Patrick Draw field, Wyoming. The diagnostic visible and near-infrared absorption features exhibited by iron oxides, clay minerals, and botanical assemblages permit airborne and satellite-borne sensors to be used to distinguish and map spatial patterns of these materials, and form the basis for remote detection of surficial phenomena that may indicate hydrocarbon microseepage. The ability to detect these anomalies using remotely sensed data depends on the susceptibility of the surface to alteration, the inherent heterogeneity of the surface, and the degree of exposure. [620]

Stratigraphic Sequence of Transgressive Barrier Bar Complex and Model for Hydrocarbon Exploration, Red Fork Sandstone, Wakita Trend, Grant County, Oklahoma

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The Desmoinesian Red Fork sandstone (Boggy Formation, Krebs Group), on the northern shelf of the Anadarko basin, Oklahoma, represents a

transgressive barrier bar system. The base of the Red Fork interval is marked by the Inola Limestone (Boggy Formation); the top is marked by the Tiawah ("Pink") Limestone (Senora Formation, Cabaniss Group). Upper shoreface and foreshore deposits, in which porosity and permeability range from 8 to 18% and 0.03 to 9.7 md, respectively, produce significant amounts of oil and natural gas along the east-west Wakita trend. Effective porosity (mainly secondary dissolution porosity) is well developed in these deposits. Successful hydrocarbon exploration requires a solid understanding of the stratigraphic sequences and depositional environments within the barrier system.

Cored sequences, from bottom to top, include: (1) Inola biomicrite, containing brachiopod, trilobite, and echinoderm fragments, and worm tubes (shallow marine); (2) black fossiliferous shale and nonfossiliferous variegated claystone (lagoonal? open marine); (3) coarsening upward sequences of fine- to medium-grained sandstone showing low-angle (<15°) bidirectional cross-stratification and flat laminae (shoreface to foreshore); and, locally, (4) very fine-grained sandstone showing flaser and current-ripple laminae (sand flats). Enclosed in the inferred shoreface or foreshore deposits is a local, 1-ft-thick, flat-laminated, very fine-grained sandstone that may represent washover deposits. Lateral facies equivalents of the shoreface and foreshore deposits include ripple-laminated, very fine-grained sandstone, some of which is overlain by glauconitic siltstone and shale (back barrier or lower shoreface?). [628]

Field Study of Fracture Characteristics as Function of Bed Curvature in Folded Dolomites

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In exploring for fractured reservoirs, it is a common practice to construct second-derivative curves (rate of change of dip) from cross sections or seismic lines and imply that high values correspond to the location of a high fracture frequency on a fold. Another common, but more direct, method for projecting fracture frequency into the subsurface is to use whole-core analysis. In order to assign both confidence and caution limits to these practices, fractures which should respond to curvature were studied in the field on very well exposed folds.

Results indicate that though subtle changes in curvature may not result in significant increases in the number of fractures, large changes do. Further, the ratio of extension fractures to shear fractures may increase with increased curvature. Both of these observations may be lithologically dependent.

Other results from this study indicate that specific numbers from core analysis may be poor estimates of true fracture frequency. Field data indicate that even in highly fractured dolomites, 9-ft line lengths are required to stabilize standard deviations of fracture-frequency measurements. However, even though small volumes of rock, such as cores, may not give a good measure of the fracture frequency in the larger volume of rock surrounding the borehole, core data may faithfully depict local fracture orientations. [636]

Hydrocarbon Reservoir Exploration Strategies Applied to Paleozoic Calcite Sea: Example from Mississippian Chester "J" Limestone, Southwest Trivoli Field, Oklahoma

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Secular tectonically linked changes in Phanerozoic ocean-atmospheric CO_2 affect the primary mineralogy of marine carbonate precipitates (e.g., times of high P_{CO_2} are times of widespread low-Mg calcites, and times of low P_{CO_2} are generally times of high-Mg calcite-aragonites). Owing to differences in diagenetic susceptibilities, hydrocarbon reservoir exploration strategies in "calcite seas" are different from those applied to "aragonite seas." Our example of the former is derived from a detailed subsurface study of the late Mississippian Chester "J" limestone, Southwest Trivoli field, Dewey and Major Counties, Oklahoma. The open marine shelf carbonate buildup is documented by a vertical regressive sequence of lithofacies. Toward the top of the Chester "J," terrigenous quartz increases with a gamma-ray distinctive shale marking the Mississippian–Pennsylvanian unconformity.

Interparticle and secondary vuggy porosity are the dominant porosity types with lithofacies-dependent permeability-porosity correlations. Suggested diagenetic controls upon porosity are the presence of lime mud and the amount of bryozoan versus crinoid skeletal allochems. The former prevents extensive sparry calcite cementation, the latter affects the amount of early syntaxial cement. Rim cemented barriers and impermeable bedding planes control the formation of localized porosity and permeability zones, one diagenetic hydrocarbon trapping mechanism.

The five major distinguishable diagenetic environments are (1) marine phreatic, (2) mixing zone, (3) meteoric phreatic, (4) meteoric vadose, and (5) complex shallow to deep subsurface. Diagenetic overprinting is ubiquitous.

Changes in acoustic impedance as a function of porosity in Southwest Trivoli field can be forward seismic modeled. The models demonstrate the potential applicability of geophysical mapping on existing seismic lines of diagenetic porosity in these carbonates. [641]

Origin of Buckhorn Asphalt, Deese Group (Pennsylvanian), Central Arbuckle Mountains, Oklahoma

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Asphalt-impregnated sediments of the Pennsylvanian Deese Group (Buckhorn asphalt), in the Mill Creek syncline asphalt district, share many similarities with the nearby tar-sand bitumens of the Ordovician Oil Creek Formation. Both originated as oils emplaced during Middle to Late Pennsylvanian orogenesis (Arbuckle event) when the two formations were juxtaposed by combined wrench and dip-slip faulting. Sterane patterns indicate that the two oils were generated from similar source rocks, both rich in terrestrial plant organic matter; terpane patterns suggest source rock deposition in marine deltaic to shallow-shelf conditions. Both oils were subjected to varying degrees of biodegradation and formation water washing. Saturate and aromatic fractions were removed more completely than the NSO fraction; asphaltenes were generated and/or added during alteration. Certain biomarker terpanes (e.g., C_{27} hopane, gammacerane) were more resistant to biodegradation than previously reported. Deese asphalts differ from the Oil Creek bitumens in important ways. They are two to three times richer in asphaltenes (to 78%) and show considerable variation in sterane alteration at a given level of saturates and aromatics depletion, suggesting that formation water washing was more important to Deese alteration. Formation of some of the asphaltene-rich asphalts may have been accompanied by gas deasphalting of the parent oil resulting in asphaltene precipitation within the Deese section. This hypothesis is favored by the abundance of mature Type III (woody, herbaceous) kerogen in the asphaltic section and by physical evidence of overpressuring during petroleum emplacement, including concordant seams of asphaltite and of passively precipitated calcite (calcite beef). [643]

Watch Out for the Ouachitas—New Frontier in an Old Area

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The Ouachita overthrust belt is a 1,000-mi long trend of Paleozoic rocks lying between the oil prolific Gulf Coast, West Texas, and Mid-Continent regions. Competitive successes from these adjacent regions coupled with the extreme structural complexity of the trend itself have relegated it to a no-man's land position for exploration since the 1930s, yet the few scattered attempts to find oil in these rocks have persistently turned up hydro-

carbon shows without a significant discovery until the Isom Springs field was found in 1977.

Capped for the most part by a thin veneer of Cretaceous sediments, geologic windows do occur which display the intensely folded and thrusted Paleozoic sediments beneath. In addition to structural style, these windows have allowed studies of source rocks, thermal maturity, and reservoir quality which reflect encouraging exploratory attributes. Occurrences of shallow oil in immature overlying sediments suggest the possibility of many oil-filled structures below with few breached structures along the trend beneath the thin Cretaceous veneer. [643]

Depositional Investigation and Analysis of Porosity Development in a Northwestern Oklahoma Cherokee Sandstone, Using Petrographic Image Analysis

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Recent technological advances allow image analysis of porosity networks in rock, using a computer-based Petrographic Image Analysis System (PIA) developed at the University of South Carolina. PIA processes digitized scenes of the porosity network, quantifying the characteristics of each pore. Pattern recognition and/or classification algorithms (CABFAC and QMODEL) are used to determine the mixing components that define the pore complex. Comparisons of the quantified pore attributes to petrophysical values (e.g., permeability) enable us to predict these values with high precision. This procedure identifies the variables that control the value of the petrophysical parameter.

A study of the Bartlesville sandstone member, Cherokee Group, Pennsylvanian System in northwestern Oklahoma, used the procedures as outlined in defining characteristics of this petroleum reservoir. The investigation identified the reservoir as deltaic. PIA and the unmixing algorithms determined the existence of five pore types that contribute to the reservoir's development. Statistically derived relationships predicted the permeability with an R^2 value of 0.93. The highest prediction resulted from the pore type and quantified pore attributes that characterize small pores occurring in high density and exhibiting small to moderate perimeter roughness. This pore type occurs in quartz sandstone laminations with alternate layers containing a small percentage of calcite, fossil fragments, and clay. This type of lamination occurs in very fine cross-bedded and contorted sedimentary deposits. This type of sedimentary structure also restricts permeability. Reservoir production seems related to a system of fractures and micro-fractures. [645]

Evolution of Subsurface Appalachian–Ouachita Fold–Thrust Belt Beneath Gulf Coastal Plain

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A continuous belt of deformed rocks defines the curved trace of the Appalachian–Ouachita fold–thrust belt beneath the Gulf coastal plain between Appalachian outcrops in Alabama and Ouachita outcrops in Arkansas. Both the structural style and stratigraphic composition of the belt change along trend in central Mississippi. The Appalachian succession of Cambrian–Mississippian shallow shelf facies and Mississippian–Pennsylvanian shallow marine to deltaic foreland-basin clastic-wedge rocks contrasts with the Ouachita succession of Ordovician–Mississippian deep-water offshelf facies and Mississippian–Pennsylvanian turbidite clastic-wedge strata. Appalachian structures, in response to a thick competent carbonate unit, are large-scale, internally coherent thrust sheets detached near the base of the Paleozoic section. In contrast, Ouachita structures include internally disharmonic, less continuous thrust sheets in a section characterized by thick incompetent units, and a central uplift of slaty lower Paleozoic rocks. The Ouachita thrust faults and central uplift follow a cratonward-convex arcuate trace from the Arkansas outcrops to east-central Mississippi. The thrust front approximately parallels a large down-to-the-south basement fault system that displaces foreland-basin rocks, and the central uplift evidently is thrust over downthrown shelf-facies rocks. Appalachian thrust faults can be traced in a cratonward-concave curve into central Mississippi where west-trending Appalachian thrusts diagonally truncate southeast-trending Ouachita structures. The distribution of rock types in the subsurface thrust sheets indicates that the thrust front crosses the old shelf edge diagonally eastward from the deepwater facies into the shelf facies. Clastic-wedge stratigraphy and structural geometry document: (1) initial thrusting along the Ouachita front in Mississippi during the Mississippian, (2) progression of thrusting westward to the Ouachita outcrops during the Pennsylvanian, and (3) thrusting along the Appalachian structures during the Pennsylvanian. [655]

Thermal History of Sedimentary Basins and Kinetics of Oil and Gas Generation

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Reconstruction of the thermal history is essential for basin modeling because temperature is the most sensitive parameter in hydrocarbon generation.

No measurable parameter can be directly converted to paleotemperature. Maturation indices, such as vitrinite reflectance, pyrolysis temperature

T_{max}, or concentrations of biologic markers offer an indirect approach. However, all of them are a function of the thermal history through rather complex kinetics with a frequent influence of the type of organic matter. Thus, they only provide a qualitative evaluation of the onset of the oil and gas generation zones. Another approach is to use a geodynamic model where structural and thermal histories are connected. When used alone, the precision of these models is relatively low; therefore, they must be further calibrated against the present distribution of temperatures and the present values of maturation indices, thus providing a better evaluation of temperature history. Hydrocarbon generation can be roughly evaluated by using an empirical index, such as the Lopatin method, or explicitly calculated by using a kinetic model. The simple Lopatin method does not allow such a quantitative evaluation. Furthermore, a calibration made in a particular basin cannot be transferred to other geologic situations. A kinetic model based on a specific calibration can simulate all types of organic matter, and burial and temperature histories, and it provides a quantitative evaluation of oil and gas generated. Further improvements may be expected to describe the composition of hydrocarbon products and simulate gas generation better. [656]

New Views on Frontal Thrust Belt of Ouachita Mountains, Arkansas and Oklahoma

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The Ouachita frontal thrust belt is comprised of several north-verging thrusts such as the Y-City, Ti-Valley, Ross Creek, and Choctaw faults. Even though the deformed strata appear to be coeval throughout (upper Morrow to middle Atoka), structural fabrics change markedly along the strike of the thrust belt. Early phase (prethrust) deformation in Arkansas is evident, but it is not pervasive. Instead, the structural style is dominated by regional-scale upright folds and smaller mesoscopic folds, which verge parallel with the thrusts. West of the Arkansas–Oklahoma border, however, a broad zone, termed the "Holson Valley corridor," resembles the older Maumelle chaotic zone (Morrowan) of Arkansas, as well as melange terranes of the circum-Pacific. Structural fabrics include web structure, scaly argillite, isoclinal folds, pinch and swell, and dismembered bedding. Many folds display steeply plunging hinge lines and/or axial planes that are strongly discordant to regional thrust trends. The melange-style deformation is tectonic in origin but clearly predated regional thrusting.

Overall, the frontal thrust belt typifies a transition from subduction-accretion to collisional-foreland tectonics. An abrupt structural boundary (Y-City fault) separates melange style from foreland style through most of Arkansas; this fault likely served as the master decollement along which the Ouachita accretionary complex was obducted onto the southern edge of North America. A more gradual transition in tectonic regime is preserved across the Holson Valley corridor; this zone probably represents the final gasp of subduction-accretion prior to suturing. [658]

Deep Potential of Hugoton—Evaluation of Unexplored and Underexplored Areas

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Structurally, the Hugoton embayment is a large, southward-plunging syncline that represents a northerly extension of the Anadarko basin. It is bounded on the east by the Pratt anticline, on the northeast by the Central Kansas uplift, on the northwest by the Las Animas arch, on the west by the Sierra Grande uplift, and on the southwest by the Amarillo uplift. The embayment is approximately 150 mi wide and 250 mi long. Subsidence began during the Early Ordovician and reached a maximum from the middle Mississippian through the early middle Permian. Rocks of Paleozoic, Mesozoic, and Cenozoic ages are present in the embayment. The section thickens toward the axis of the embayment where it is about 9,500 ft. The Ordovician through Cambrian section attains a thickness of about 650 ft. The Devonian and Silurian are largely absent from the area. The Mississippian and Pennsylvanian sections are about 3,000 ft thick. Excluding the Permian, the Mississippian and Pennsylvanian contain the highest exploration potential. An evaluation of the deeper zones in the underexplored areas of the embayment identified several structural and stratigraphic trends that are presently untested or remain underexplored. The trends can be separated into those controlled by early structural developments which persisted through the section and later structural stratigraphic events. The probability of finding new fields in the 500,000 to 5,000,000-bbl range is good. [664]

American Association of Petroleum Geologists

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Oil and Gas Developments in Oklahoma and Panhandle of Texas in 1985

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Declining oil prices, curtailed gas sales, and uncertain tax law changes contributed to a 9.1% decrease in drilling, a 25.3% drop in gas production,

and a 5% drop in oil production in Oklahoma and the Panhandle of Texas (Texas Railroad Commission District 10) in 1985.

Exploration focused on development and extension of existing fields, with development wells outnumbering exploratory wells 20 to 1.

Operators completed 14.3% fewer exploratory wells and 9.1% fewer development wells. The success rate for exploratory wells declined to 28.9%, and the success rate for development wells dropped to 72.3%.

The Cherokee shelf was the most active trend, with 90 exploratory wells completed in 1985.

Geological Society of America

The following abstract is reprinted as published in the *Bulletin* of the Geological Society of America, v. 97, p. 1239. Permission of the author and of the GSA to reproduce the abstract is gratefully acknowledged.

Calcareous Nannofossil Paleoceanography of the Cretaceous Greenhorn Sea

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Two distinctive, laterally traceable bentonite beds were used to construct three isochronous time slices through the marine sediments of the Upper Cretaceous Greenhorn Cyclothem of the Western Interior Basin. Calcareous nannofossil assemblages from these time slices were analyzed from >40 localities to examine the paleoceanographic conditions in the basin.

Deposition of the lower time slice (X bentonite) approximately corresponded to the time at which free communication between the basin and open oceanic systems first occurred. The most striking trend is the presence of common to abundant nannofossils in the center of the basin and their absence from the eastern and western margins. This indicates that open oceanic conditions conducive to large standing crops of calcareous nannoplankton existed only in a narrow, centrally located channel. Conditions at the basin margins were probably unsuitable for large populations due to salinity constraints. Multivariate analyses indicate two distinct biofacies (northern and southern) which are interpreted to represent distinct surface-water masses. The geometry of the water-mass boundary suggests that the northern surface-water mass actively flowed southward into or over the relatively passive southern water mass.

The upper time slice (HL-3 bentonite) samples the nannofossil distributions at or near the maximum transgression of the Greenhorn Sea. In this time slice, nannofossils occur beyond the limits of the study area except in proximity to the Frontier delta system. Diversities are significantly higher,

indicating water-mass conditions more similar to those in open oceanic settings. Multivariate analyses indicate three distinct surface-water masses (northern, southern, and western). The northern and southern water masses exhibit relationships similar to those during the X bentonite time slices. The interaction between the northern and southern water masses promoted vertical stratification of the water column and resultant sediment anoxia. The western biofacies may be indicative of a surface-water mass with significant contributions from nearby fresh-water influx.

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Petrologic Evolution of Plagioclase-Rich Cumulates from the Wichita Mountains, Oklahoma: Effects Upon Magnetic Remanence Properties

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The Glen Mountains layered complex (GMLC) of the Wichita Mountains of Oklahoma is a coarse-grained analog to Layer 3 gabbros of the sea floor. The slowly cooled, mafic, layered complex developed in the site of an aulacogen, which is interpreted as a failed, intracontinental rift. The remanent magnetism of rocks of the layered complex is extremely stable due to the presence of magnetic inclusions in the major phases, primarily plagioclase. The early formation of plagioclase facilitated the formation of these magnetically important inclusions. Petrologic processes that promote the formation of magnetically stable mineralogic inclusions in coarse-grained gabbros should be operative in oceanic slow-spreading ridges. Therefore, the contribution of magnetization of Layer 3 gabbros should be greater in slower spreading ridges than in faster spreading ridges because of their differences in petrologic evolution. [v. 14, p. 908]

Genetic Link Between Ouachita Foldbelt Tectonism and the Mississippi Valley-Type Lead-Zinc Deposits of the Ozarks

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Fluids expelled from the Arkoma basin in response to Late Pennsylvanian–Early Permian orogenesis in the Ouachita foldbelt may have been ultimately responsible for formation of the Mississippi Valley-type lead-zinc

deposits in the Ozark region of Missouri, Arkansas, Kansas, and Oklahoma. Fluid inclusions in both mineralized and barren rock record the passage of hot, saline fluids regionally throughout most of the Paleozoic section in the Ozarks. Dating studies in addition to structural and geologic observations provide further evidence for fluid migration and mineralization approximately coincident with the Ouachita orogeny.

Formation of foreland basins, such as the Arkoma, during convergent tectonism creates conditions exceptionally favorable to the migration of fluids from deep sedimentary basins. Proximity to a basin whose margin has undergone some form of tectonic deformation or uplift may be the unifying factor in the genesis of Mississippi Valley-type deposits in geologically diverse settings. [v. 14, p. 931]

Permian Salt Dissolution, Alkaline Lake Basins, and Nuclear-Waste Storage, Southern High Plains, Texas and New Mexico

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Areas of Permian salt dissolution associated with 15 large alkaline lake basins on and adjacent to the Southern High Plains of west Texas and eastern New Mexico suggest formation of the basins by collapse of strata over the dissolution cavities. However, data from six other alkaline basins reveal no evidence of underlying salt dissolution. Thus, whether the basins were initiated by subsidence over the salt dissolution areas or whether the salt dissolution was caused by infiltration of overlying lake water is conjectural. However, the fact that the lacustrine fill in Mound Lake greatly exceeds the amount of salt dissolution and subsidence of overlying beds indicates that at least Mound Lake basin was antecedent to the salt dissolution. The association of topography, structure, and dissolution in areas well removed from zones of shallow burial emphasizes the susceptibility of Permian salt-bed dissolution throughout the west Texas–eastern New Mexico area. Such evidence, combined with previous studies documenting salt-bed dissolution in areas surrounding a proposed high-level nuclear-waste repository site in Deaf Smith County, Texas, leads to serious questions about the rationale of using salt beds for nuclear-waste storage. [v. 14, p. 939]

Trace-Element Anomalies at the Mississippian/Pennsylvanian Boundary in Oklahoma and Texas

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Trace-element abundance anomalies have been found at the Mississippian/Pennsylvanian boundary at sites in Oklahoma and Texas where the boundary has been precisely located on the basis of an abrupt change in conodont diversity and species composition. Enriched elements include osmium, iridium, platinum, chromium, most chalcophiles, rare earths, and uranium. The anomalies are more intense (e.g., Os = 4 ppb, Ir = 0.38 ppb, Pt = 6 ppb, Cr = 12,000 ppm, U = 380 ppm) and persist through a thicker interval at the south-central Texas locality than in Oklahoma, and in both locations the anomalies are associated with an increase in phosphate content of the rocks. There is no tangible evidence of an asteroid or comet impact source for the excess Pt-group elements and faunal crisis. The cause of the elemental enrichments and the biological disturbance may possibly be related to a change in the ocean chemistry of the Paleozoic seaway, such as increased upwelling, stagnation, or nearby submarine volcanism.

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