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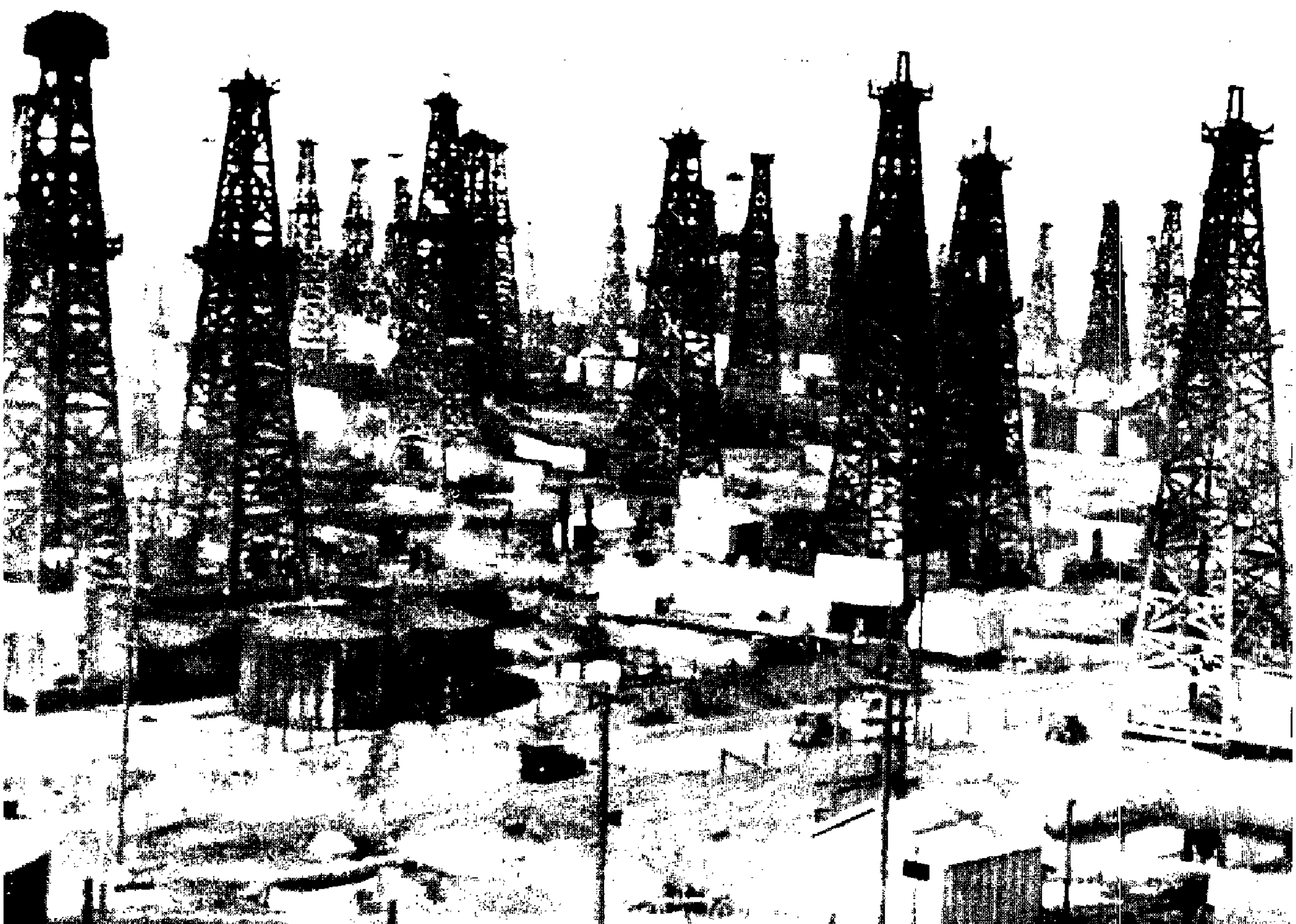

February 1999
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On The Cover —

The Healdton Oil Field, 1914, Northwestern Carter County, Oklahoma

In 1914, the Healdton oil field was a virtual forest of derricks, apparently without regular spacing. The largely wooden derricks were constructed on site and remained in place after drilling was completed, becoming essentially permanent structures. Note the small house on the crown block of the derrick at the far left. There is an oil storage tank in the extreme left foreground (corner of photograph) and many others in the distance.

Although 1913 is the date commonly given for the discovery of the Healdton field, oil was already known to occur in water wells locally, and a successful well had been drilled for oil as early as 1888. The apparent barrier to development of petroleum before 1913 was that leases were not available from the Chickasaw Nation, Indian Territory (Franks, 1980). However, the timing of oil development in the area was, no doubt, also influenced by low demand for additional supplies of crude oil and by the lack of a transportation system for the oil.

The formal discovery of the Healdton field in August 1913 is credited to the Red River Oil Company's No. 1 Apple-Franklin well (sometimes called the No. 1 Wirt Franklin); it found the first pay zone at 916–931 ft in the NE¼ of sec. 8, T. 4 S., R. 3 W. (Indian Meridian) and was completed for 25 bbls/day (Fay, 1997). The second well, however, was completed as a gusher for 300 bbls/day, and it started a rush to obtain leases in the area (Franks, 1980). Development at Healdton was rapid; by the end of 1914, there were 292 producing wells in the field, already ~1% of producing wells in Oklahoma (Fay, 1997).

(continued on p. 17)

OKLAHOMA GEOLOGICAL SURVEY

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OKLAHOMA GEOLOGY Notes

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The Healdton Field, Oklahoma—History of Development

Sean P. Terry[1]

Introduction

The Healdton oil field was discovered 1 mi west of Healdton, northwestern Carter County, in August 1913, early in Oklahoma's "black gold era" (Northcutt, 1985) (Fig. 1). This early discovery in southern Oklahoma of easily reached, shallow oil reserves in the Healdton sands (Pennsylvanian) quickly attracted oil prospectors from across the State of Oklahoma—and beyond—and the Healdton field led the way in the development of the Ardmore and Marietta basins. Between 1913 and 1915, the rich oil finds in the Healdton attracted several geologic field parties to map the surface geology of the area. Mapped anticlines, associated with oil seeps, were evidence for buried structures, below the Permian redbeds at the surface (Powers, 1917).

Less than a year after the first discovery, news of the rich oil finds at Healdton captured the attention of national and international oil companies such as the Magnolia Oil Company and Royal Dutch Shell (Robinson, 1937). Successful oil wells were drilled to the northwest (into Jefferson County) and to the southeast, and the area of production from the shallow Healdton sands grew rapidly to just over 30 mi^2 in 1917, when its boundaries had been defined (Fig. 2).

In 1916, the Healdton's oil production peaked at 37 million bbls/yr, and it was one of Oklahoma's most productive oil fields. In fact, in the early part of this century, the Healdton was considered one of the world's giant oil fields (Latham, 1970; Halbouty, 1970). In its heyday of the late 1910s into the 1920s, it was overshadowed only by the Cushing and Glennpool fields, and its impact on local and regional economies has been documented by geologists (Northcutt, 1985) and historians (Robinson, 1937).

The Healdton field had exceptional oil reserves, despite its relatively small geographic size. Although its production declined gradually from the 1916 peak, the field has continued to produce for more than 80 years, only recently tapering off to less than 2 million bbls/yr (Fig. 3). In 1985, Northcutt ranked the Healdton field in the top five in cumulative production for the State, and, by 1998, the field had produced nearly 350 million bbls of oil (Petroleum Information Corporation, 1999).

Associated and nonassociated natural gas also occur in the Healdton field, but gas has never been the primary target for Healdton drillers. During the early years of development, much of the discovered gas was flared or vented to the atmosphere. From 1979 to 1994, only about 5.7% of leases (14 of 247) produced gas for market, and production was only 977,050 Mcf (thousand cubic feet); in contrast, oil production for that period was 31.147 million bbls (NRIS, 1994, 1999).

Continuous production from the Healdton field was maintained over the years by a number of factors. Improved drilling and recovery techniques were intro-

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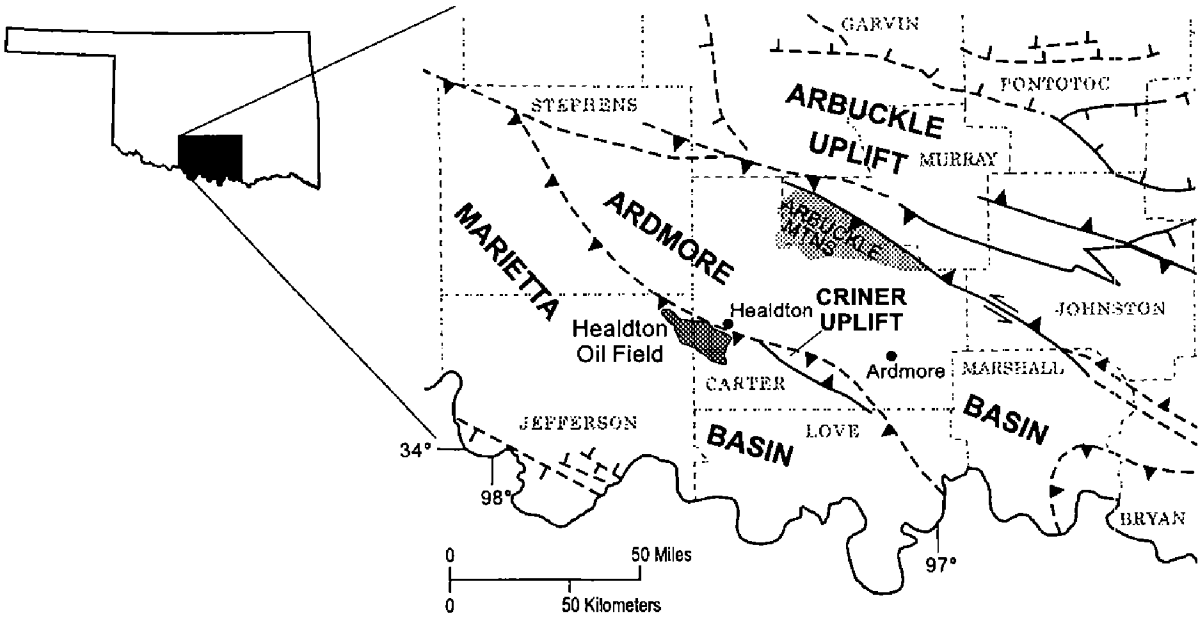

Figure 1. Location of the Healdton field in southern Oklahoma. Geologic provinces after Northcutt and Campbell (1996).

duced, and new, deeper reservoirs were discovered in the field—the Fusulinid and Tussy sands (Pennsylvanian) in the 1950s; the Arbuckle Group Brown, Wade, and Bray zones (Ordovician) in 1962; and the Simpson Group Oil Creek Formation (Ordovician) in 1981 (Fig. 4). The field continues to produce today at a declining rate. Annual production in 1998 was about 1.1 million bbls.

Geologic Setting

The Healdton field occurs to the west of the Criner uplift (Fig. 1). This uplift is the eastward extension of the much larger Wichita uplift, which lies to the west. Together they form the axis of the southern Oklahoma aulacogen, a linear (northwest-southeast) structural trend that extends from the Ouachita fold belt of southeastern Oklahoma and adjacent areas, northwest through Oklahoma, and into the Texas Panhandle. It originated in Early Pennsylvanian (Morrowan) time during the Wichita orogeny (Latham, 1968; Pruatt, 1975). The Healdton area was subjected to intense, high-angle faulting during the Wichita orogeny, with vertical displacements of as much as 10,000 ft; subsequently, Late Pennsylvanian (Missourian) sandstones and shales of the Hoxbar and Deese Groups were deposited over the deeply eroded and truncated Ordovician carbonates (Latham, 1968, 1970) (Figs. 5, 6). Later, in Virgilian time (Late Pennsylvanian), the Arbuckle orogeny folded the strata in the area of the Healdton field (Fig. 5) (Johnson and others, 1989).

Entrapment of hydrocarbons in the Healdton field has been the focus of considerable discussion (Powers, 1917; Bartram and Roark, 1921; Latham, 1968, 1970), and it has been difficult to account for development of the several major producing units in this field because of the complex faulting and folding of the Healdton anticline (Fig. 5). Pennsylvanian and Ordovician oil entrapment in the field occurred in anticlinal closures that were created during the Wichita and Arbuckle orogenies

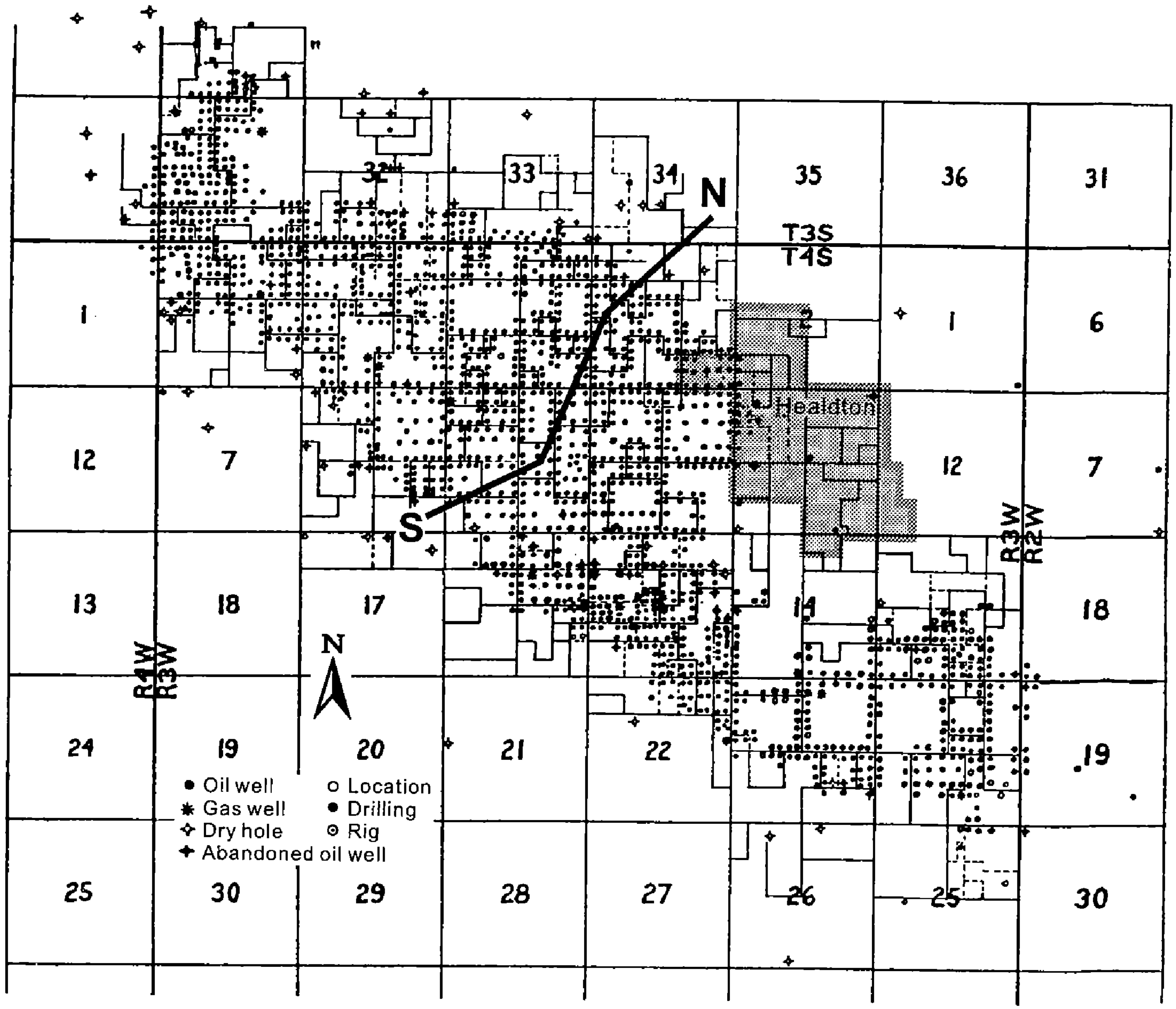

Figure 2. Wells drilled in the Healdton field, ca. 1916. Shaded area is the town of Healdton. (Geologic cross-section, S–N, is presented as Figure 5.) Modified from Powers (1917).

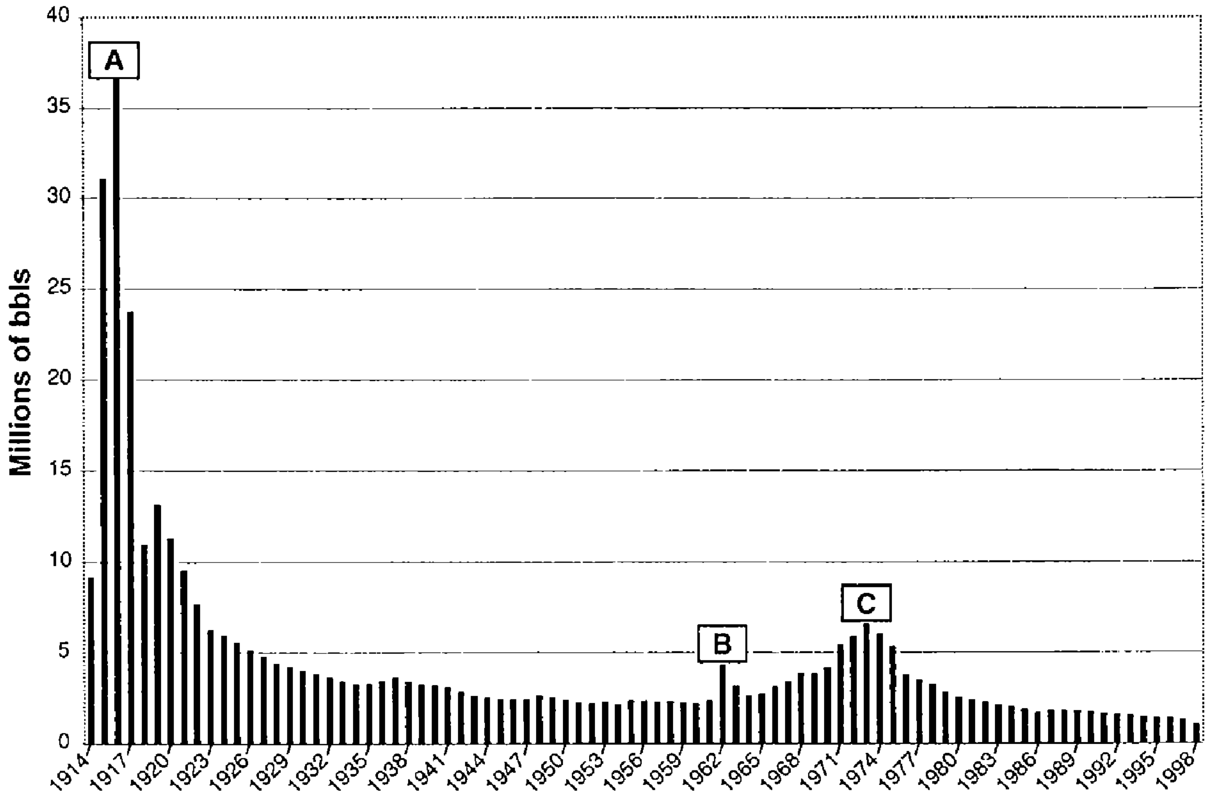

Figure 3. Annual oil production in the Healdton field, 1914–91: A—Maximum production in the boom period; B—Discovery of the Arbuckle Brown zone; C—Production peak that resulted from water flooding of the Healdton sand (Robinson, 1937; Petroleum Information Corporation, 1992).

Year(s)	Event
1913	Discovery of oil in the Healdton sand zone
1947–60	New wells and workovers in the Healdton sand zone
1950s	Discovery and development of the Fusulinid and Tussy sand zones
1962	Discovery of the Arbuckle Group reservoir (Brown, Wade, Bray zones)
Late 1960s–mid-1970s	Water flood in the Healdton sand zone
1970s	Acid completion method in carbonate reservoirs
1980s	Workovers and water flood in the Healdton sand zone (south-central part of the field)
1981	Discovery and development of the Simpson Group reservoir (Oil Creek Formation)

Figure 4. Chronology of major events in the Healdton field.

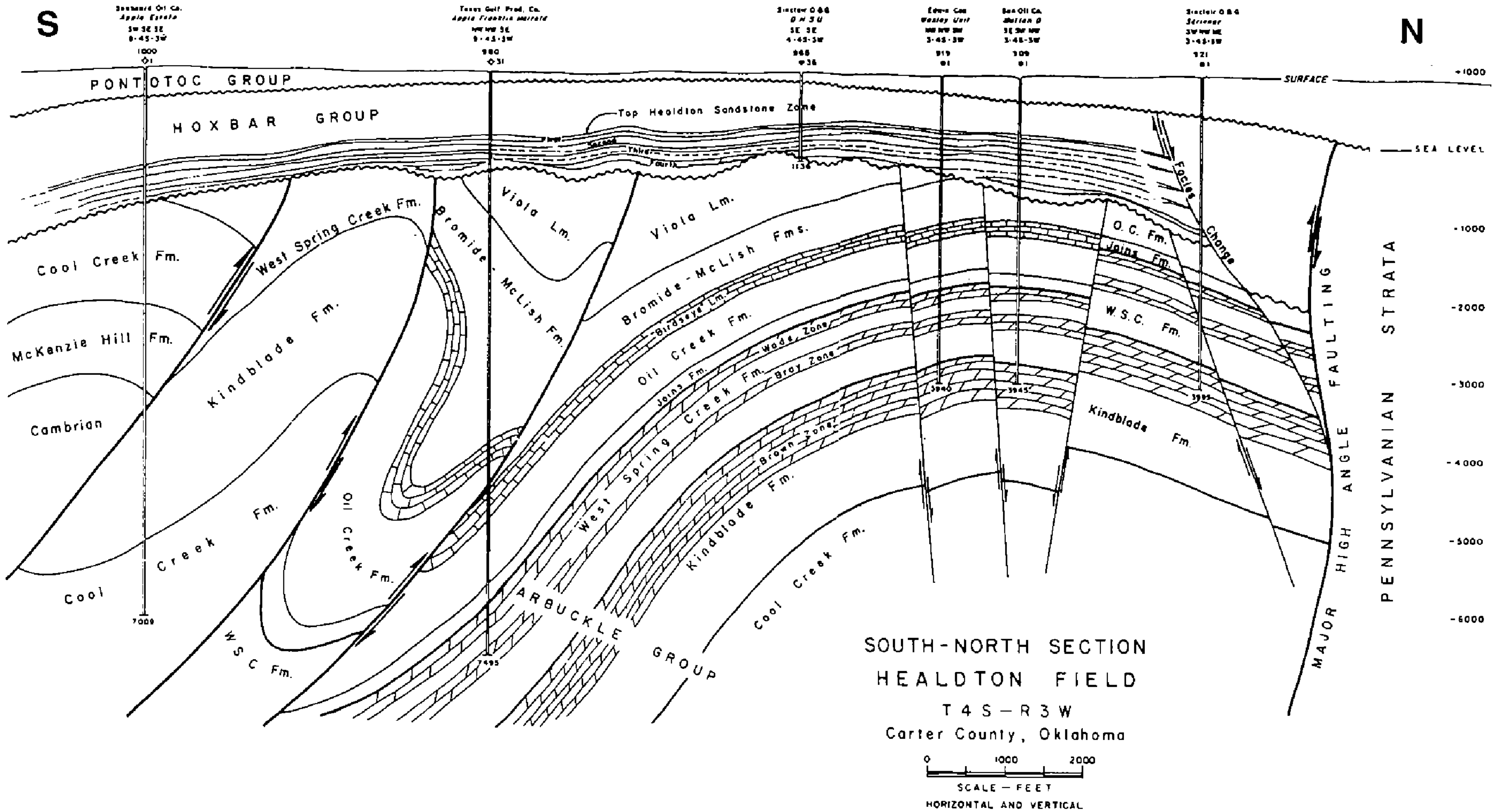

Figure 5. Geologic cross-section of the Healdton field. The location of the line, S–N, is shown on Figure 2. From Latham (1970).

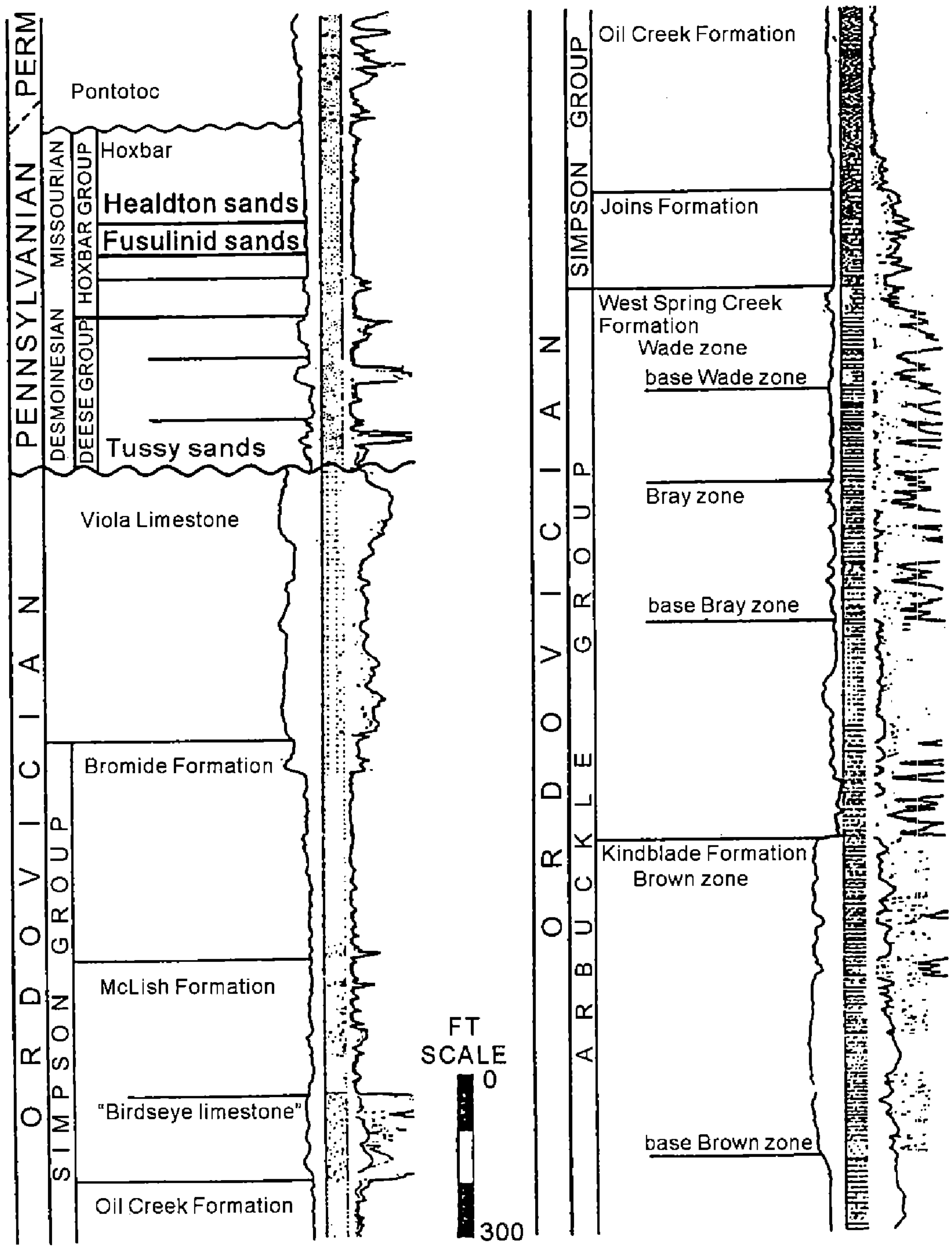

Figure 6. Generalized stratigraphic column for the Healdton field. Modified from Latham (1970).

(Latham, 1968). Originally, the younger sediments were thought to be the source rocks for most Arbuckle Group oil in the Healdton structure (Latham, 1968). More recently, Wavrek (1992) compared the chemical properties of oil in various reservoirs and concluded that oil in the Simpson Group (Middle Ordovician) had migrated laterally into the Healdton area from some distant source prior to faulting that resulted from the Wichita orogeny. Wavrek (1992) also found that oils in the Arbuckle Group (below the Simpson Group) had migrated into the Healdton area from a number of sources that are still under investigation.

Development of Producing Reservoirs

The Healdton Sands

Early production in the Healdton field was from the Healdton sands, relatively shallow Pennsylvanian sandstone reservoirs (average depth, ~1,000 ft) (Powers, 1917; Bartram and Roark, 1921; Latham, 1968) (Fig. 6). The Healdton sands are within the Missourian Series (Jordan, 1957) and are the source for nearly 85% of producing wells in the field (NRIS, 1994). Four sandstones have been identified as Healdton sands (Latham, 1970). They are in the lower part of the Hoxbar Group and comprise a gross producing section that is as much as 400 ft thick. Due to variations in the structure of the subsurface, the Healdton sands occur from 400-ft to 3,500-ft depths (Latham, 1968). The nonexistence of electric logs in the early days of drilling made it nearly impossible to determine the number of separate sandstone bodies, and early drillers used a variety of names to describe the producing sands they encountered. In addition to Healdton, the names Hoxbar, Daube, Hewitt, Chubbee, Bayou, Lone Grove, and Missouri all were applied to Pennsylvanian sandstones of the Missourian Series in the Healdton oil field.

The Healdton sands were developed very rapidly. By 1915, less than two years after the field was discovered, there were as many as 240 wells in some sections (Robinson, 1937). In 1916, the Healdton field reached its peak production of 37 million bbls/yr (Fig. 3), and, by 1917, the boundaries of the oil field had been established by the drilling of more than 1,800 wells (Robinson, 1937) (Fig. 2).

In those early years of intense drilling, there were many hazards in the Healdton field. Working conditions were crowded and rowdy. Competition was fierce, and vandalism was a threat because some drillers would do anything to get a well into production ahead of their neighbors (Fig. 7) (U.S. Department of Commerce, 1915). The constant risk of fire, and careless handling of hazardous materials made work in the field very dangerous. Tremendous amounts of oil were lost to fire and runoff because, before 1917, the production of oil far outstripped the availability of pipelines to transport it. Vast numbers of wooden tanks and earthen ponds were built for storage (Fig. 8), but there were not enough, and new wells pumped oil that had nowhere to go. Spills were so common that oil covered Whiskey Creek, the local stream, which was said to have burned for miles on at least one occasion (Robinson, 1937). Even stored oil was at risk, as neither tanks nor ponds protected the oil from the elements or from fire (Fig. 9). The fire hazard in the field was increased by the flaring or venting to the atmosphere of much of the natural gas, in order to maximize short-term oil production (U.S. Department of Commerce, 1915; Franks, 1980, 1981). Major fires in the Healdton field killed and injured workers, leveled the town of Healdton, and destroyed resources (Franks, 1980, 1981).

The dangerous conditions in the Healdton field received national attention in 1915 through a U.S. Department of Commerce report. Documentation of the loss of life, the pollution, and the waste of resources in the Healdton field helped to stimulate state and federal legislation concerning well spacing, oil storage, and production restrictions (U.S. Department of Commerce, 1915).

Once the initial period of intense drilling was over, development of the field slowed. Fewer than 10 wells per year were drilled from 1918 to 1946. Production declined gradually from the peak of 37 million bbls/yr in 1916, and, by the late 1940s, annual production was 2.4 million (Fig. 3). Cumulative production reached 213 million bbls by 1950 (Robinson, 1937; Petroleum Information Corporation, 1992).

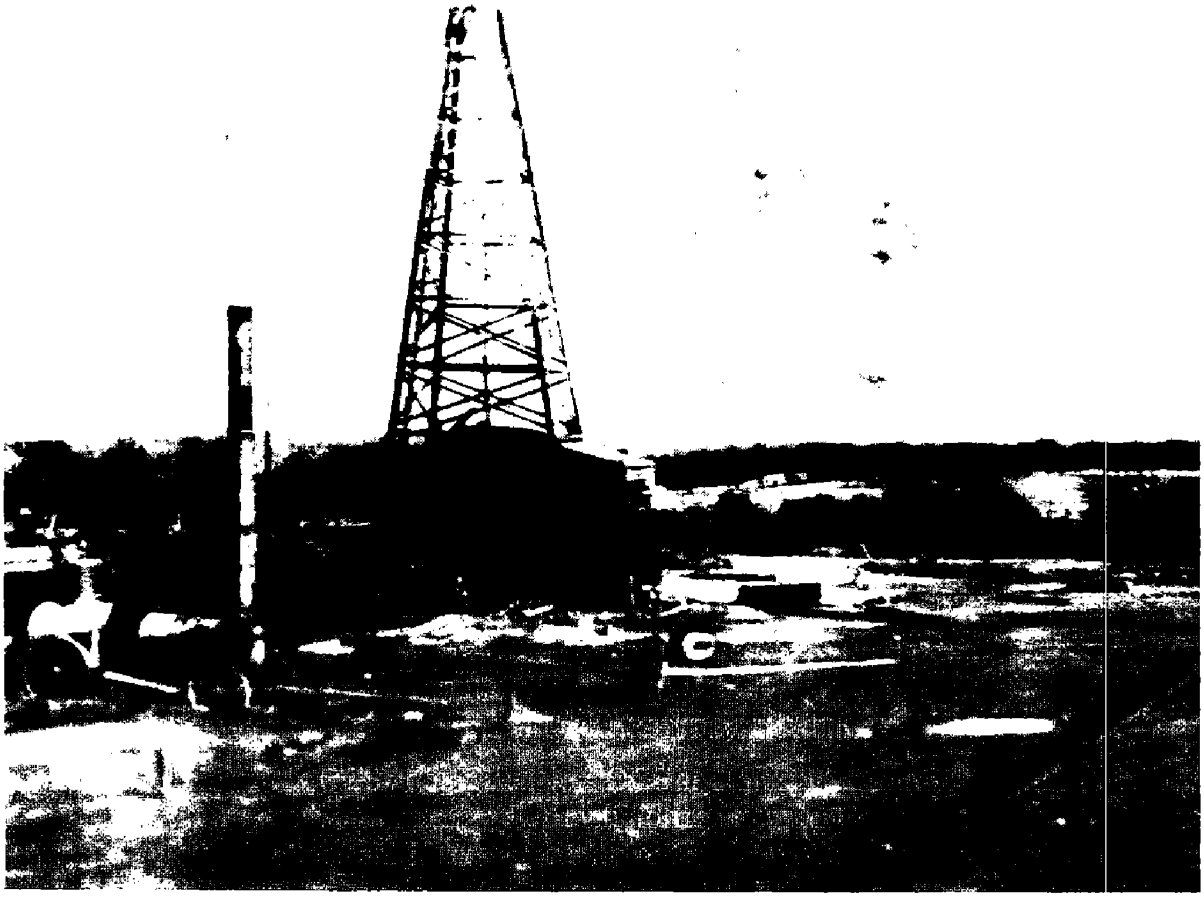

Figure 7. "Oil derrick with steam engine, Healdton field, 1915," is the label on this photograph of one of the earliest wells drilled in the Healdton field. A steam engine was one method of supplying power for drilling. The wooden enclosure at the base of the derrick may have had two purposes: (1) to protect workers from the elements; (2) to protect the well from vandalism, one of the hazards of drilling in the Healdton field. Photograph from the McGalliard Historical Collection, Ardmore Public Library, Oklahoma.

Activity in the field increased between 1947 and 1960, and new wells were drilled into the Healdton sand zone. During this period, many operators also ordered workovers of existing wells (NRIS, 1994). These workovers included drilling to deeper reservoirs as well as improving the producing capability of wells at existing depths. Although there was no major increase during this period, field production was relatively stable, in part because of production from newly discovered reservoirs in the Fusulinid and Tussy sands (Figs. 3, 4).

From the late 1960s through the mid-1970s, the use of water flood techniques, initiated by the Atlantic Richfield Company and the Sinclair Oil and Refining Company, revitalized production from the shallow Healdton sands (NRIS, 1994). The use of this secondary recovery technique led to a dramatic increase in field production, which peaked at >6 million bbls/yr in 1973, more than double 1965's production of 2.7 million bbls (Fig. 3). Annual production remained >5 million bbl/yr until 1976 (Petroleum Information Corporation, 1992).

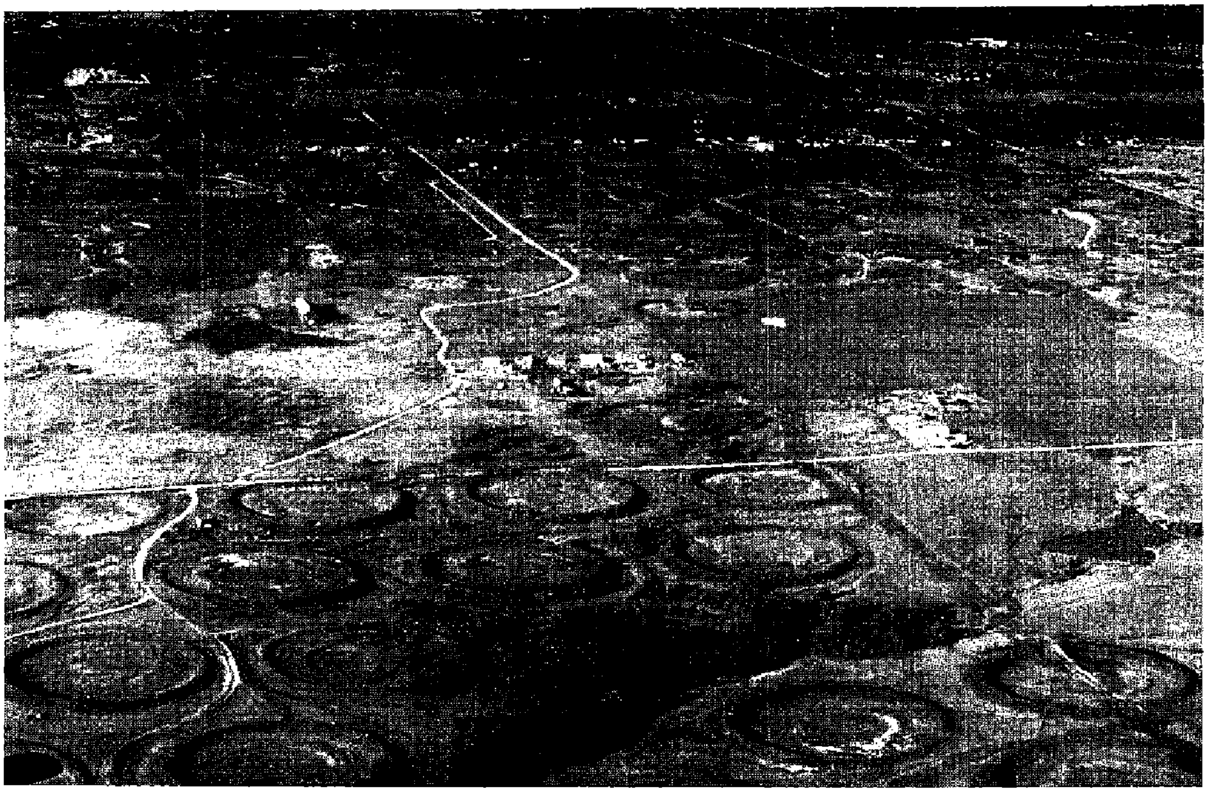

Figure 8. This February 1993 photograph (N½ sec. 17 and S½ sec. 8, T. 4 S., R. 3 W., looking northeast) shows an aerial view of an area that was formerly part of the Healdton oil field. Old sites of storage tanks, abandoned for more than 50 years, still show up prominently. Most tank sites are now used as pasture land, but some have been converted into stock or fishing ponds.

Fewer new wells have been drilled to the Healdton sands since 1976. Some successful wells were drilled into the reservoir between 1976 and 1993 (Petroleum Information Corporation, 1992), but there was no significant increase in production as a result (Fig. 3) (Robinson, 1937; Petroleum Information Corporation, 1992).

In the 1980s, most oil producers again turned their attention to the Healdton sand zone. About half of the Healdton sand wells drilled in this decade were workover wells; the other half were drilled in conjunction with water flood activity in the south-central part of the field (NRIS, 1994). This region had received little attention in 1950–79, but it was intensively developed by Unocal in the 1980s. Acid stimulation was applied to Unocal wells in order to accomplish the water flood. Unocal production, located primarily in secs. 10, 13–16, and 22–24, T. 4 S., R. 3 W., was from the Healdton sand at 800–1,300-ft depths (Petroleum Information Corporation, 1992). Despite increases in production from the southern part of the Healdton field, total production has declined since 1982 (Fig. 3).

The Fusulinid and Tussy Sands

Deeper, less extensive Pennsylvanian sandstone reservoirs, primarily in the Fusulinid and Tussy sands (Desmoinesian Series, Deese Group), were discovered by the Magnolia Oil Company and the Kingery Production Company in the 1950s (Fig. 6). Oil was found in these reservoirs at 3,000–4,000-ft depths. Unlike the

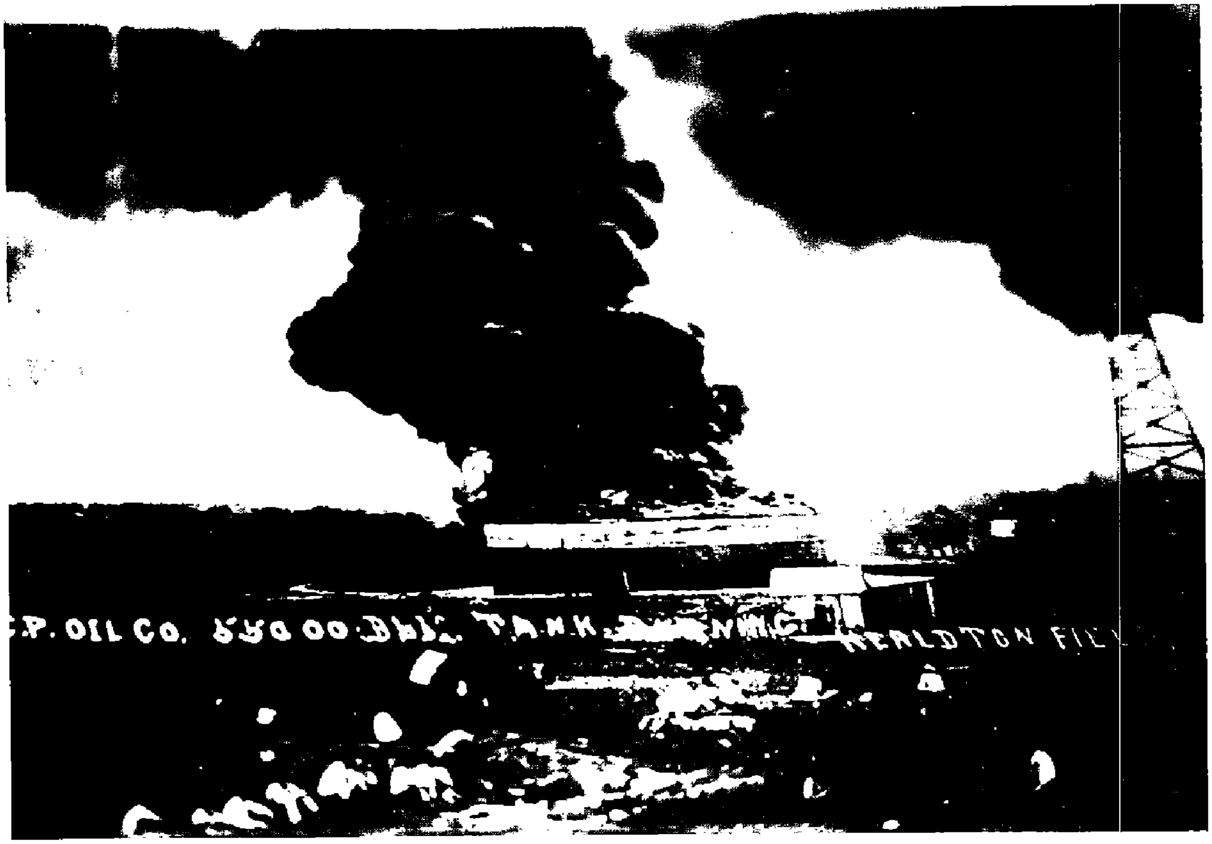

Figure 9. Major fires in the Healdton field injured workers, destroyed resources, and leveled the town of Healdton. In this 1914 photograph of a burning storage tank, oil field workers are casually watching the blaze. Photograph from the McGalliard Historical Collection, Ardmore Public Library, Oklahoma.

Healdton sands, which have produced throughout the oil field, the Fusulinid and Tussy sands have produced from localized reservoirs; most wells were drilled to these Desmoinesian sandstones in secs. 23–24, T. 3 S., R. 4 W.; secs. 6–7, T. 4 S., R. 2 W.; and sec. 1, T. 4 S. R. 3 W. (Fig. 10). Because the new reservoirs were localized, companies that had established production in those areas were able to monopolize production. Between 50 and 60 wells were drilled in the 1950s; in contrast, only 12 producing wells have been drilled into Fusulinid and Tussy sandstones since 1959.

In 1994, wells producing from the Desmoinesian reservoirs accounted for only about 6% of all producing wells in the Healdton field (NRIS, 1994). Although little increase to total field production can be attributed to these deeper Pennsylvanian reservoirs (Fig. 3), production from them during the 1950s probably balanced the expected decline in production from the Healdton sands (NRIS, 1994; Petroleum Information Corporation, 1992).

Arbuckle Group

In 1962, carbonate reservoirs of Ordovician age were discovered within the Arbuckle Group, which was found to contain three producing zones of dolomite: the Wade, Bray, and Brown zones (Fig. 6). Average depth of these reservoirs is 3,000–4,000 ft, with a structural closure of 1,500 ft and an oil column as much as 700 ft thick (Latham, 1968). Development of the deeper producing units led to a rejuve-

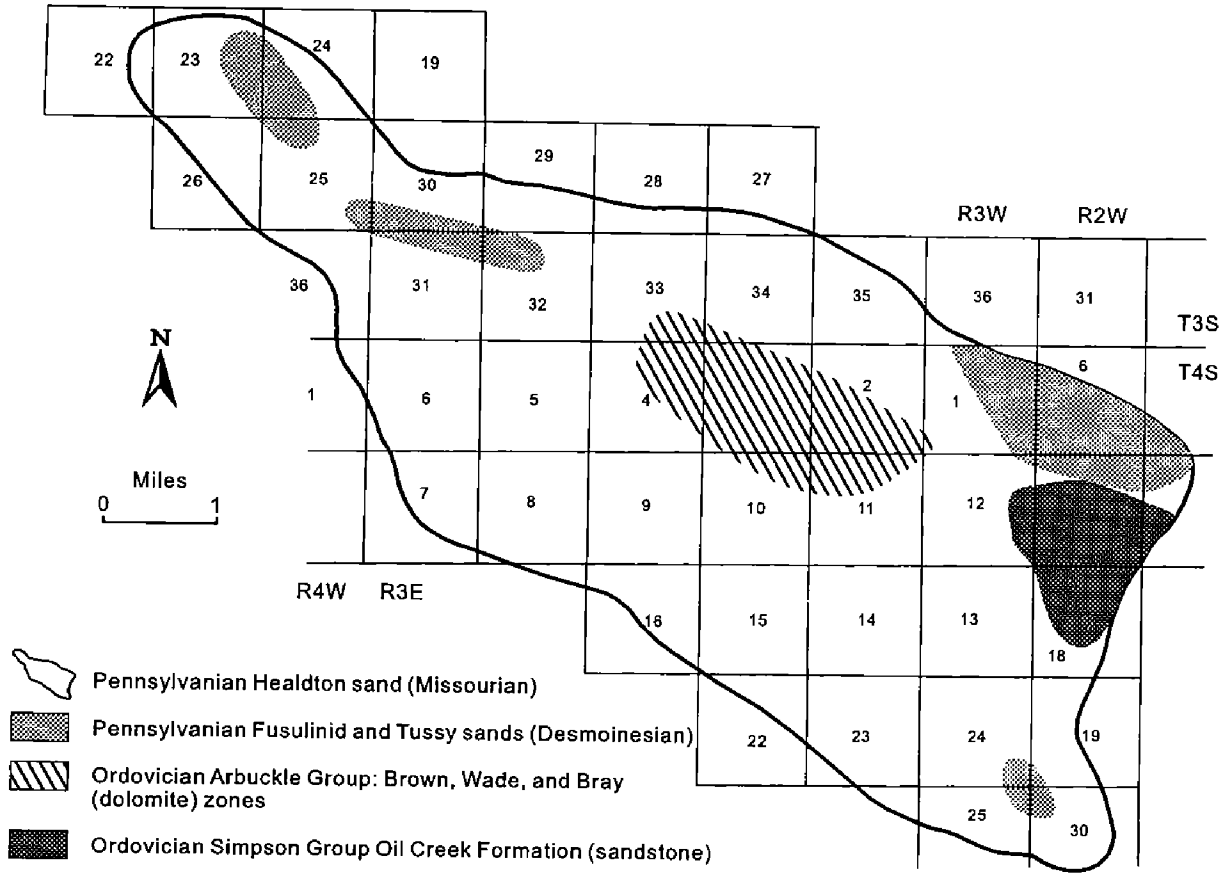

Figure 10. Geographic distribution of production from Pennsylvanian and Ordovician reservoirs in the Healdton field (Latham, 1970; NRIS, 1994). Note that the shallow Healdton sand produces throughout the field.

nation of the Healdton field, especially in the north-central part (Latham, 1968). Wells producing from the Ordovician Arbuckle Group were located primarily in secs. 2–4, T. 4 S., R. 3 W. (Fig. 10). The reservoir was very productive from 1962 to 1970.

The Brown zone, which accounted for the majority of Ordovician production (NRIS, 1994), was found to be exceptionally rich. It is 600 ft thick, and reservoir intervals are characterized by good intercrystalline porosity and excellent permeability resulting from a highly developed fracture system (Latham, 1968). Many companies—including the Atlantic Richfield Company, Sinclair Oil, Sun Oil, and Texaco—rushed to complete wells in, and produce from, the Brown zone (NRIS, 1994).

Development of the Arbuckle Brown zone increased the number of wells in production from 2,082 in 1959 to 2,198 in 1963 (Petroleum Information Corporation, 1992) and nearly doubled the Healdton field's annual oil production, from 2.3 million bbls in 1961 to 4.3 million bbls in 1962 (Fig. 3). The increase in production was short-lived, however. Production dropped off in 1962–63, then reached a transitory minimum of 2.6 million bbls/yr in 1964. Despite declining returns, a number of wells were drilled into the Brown zone through 1974.

From 1962 to 1974, a few successful wells were drilled into the Bray and Wade zones (NRIS, 1994). These reservoirs overlie the Brown zone (Latham, 1968). The Bray and Wade zones produced in the same part of the field as did the Brown zone, but their production was less impressive due to poor permeability (Latham, 1968, 1970).

Throughout the 1970s, hydrochloric acid treatment of Ordovician wells in carbonate reservoirs provided a significant increase in production (NRIS, 1994) (Fig. 10). Oil recovery from the field reached a high of 6.6 million bbls for 1973 (Petroleum Information Corporation, 1992), because of the use of acid treatment in the field's carbonate reservoirs, along with the use of water flooding in the Healdton sands.

Simpson Group

In 1981, Simpson Group sandstone reservoirs were discovered in the Oil Creek Formation, a part of the Ordovician System previously thought inconsequential for oil production (Powers, 1917) (Fig. 6). The Oil Creek Formation is characterized by a dark green, waxy, soft shale that is interbedded with off-white, mottled limestone (Latham, 1970). Near the base of the Oil Creek Formation, there is an increase in limestone containing traces of white, rounded, "floating" sand grains, which Latham (1970, p. 262) described as the equivalent of the basal Oil Creek sandstone that is productive in other areas of Oklahoma. In the Healdton field, production from the Oil Creek Formation occurs in secs. 7 and 18, T. 4 S., R. 2 W. (Fig. 10). MAPCO Production Company and Westheimer Oil Company were the primary drillers of this formation; their wells were drilled in 1981–82 (NRIS, 1994).

The Healdton Field in the 1990s

Oil production from the Healdton field has declined steadily since 1988. Production for 1998 totaled about 1.1 million bbls; cumulative production reached 349.6 million bbls by the end of 1998.

The principal shallow Pennsylvanian reservoirs have undergone water flood, but the deeper carbonate reservoirs in the Simpson and Arbuckle Groups are unlikely candidates for secondary recovery. The excellent permeability in those reservoirs is the result primarily of fractures, which allow water to move through the reservoir without sweeping oil from the rock volume between the fractures. However, the Healdton anticline is a complex structure; Figure 5 does not attempt to interpret the deeper or broader structure at Healdton. It is possible that deeper fault-block traps occur adjacent to the major fault boundaries of the Healdton anticline. The Cottonwood Creek field, discovered in late 1987, is such a trap (Read and Richmond, 1993), and is located adjacent to the larger Hewitt structure. In addition, Cooper (1995) has shown that such complex structures are common along the structural trend that includes the Criner uplift (Fig. 1). When warranted by higher crude oil prices, three-dimensional seismic studies may be undertaken in an effort to identify deeper traps in the Healdton field area.

Acknowledgments

I would like to recognize two people who were critical to the success of my research. Gary Thompson was the first person to take me out into the Healdton oil field and show me what a fascinating landscape and history an oil field has to offer. I would also like to thank Jock Campbell. His interest and enthusiasm kept this project rolling, and he always seemed to know where to find the best sources of information. Jock made significant contributions to this paper, with his knowledge of petroleum geology and skills as an editor. Thank you both for all your help.

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Healdton Oil Field *(continued from p. 2)*

The Healdton discovery, although not the first in southern Oklahoma, confirmed the Ardmore basin as a significant oil and gas province and played an important part in extending the search for petroleum from northeastern to southern Oklahoma. Extensive geologic mapping in the Healdton field—a large structural trap—also established geology as a tool in the search for oil in the region (Latham, 1970).

The increasing crude oil production from the Healdton field in 1913–14 (Terry, fig. 3, this issue) created an over-supply to the market. In March 1914, the Magnolia Pipe Line Company reduced both the quantity of crude it would accept and the price it would pay for it at Healdton. Producers protested that pipeline purchases were inadequate, and some claimed that they were being deprived of their individual rights to produce and sell their share of the field's production (Franks, 1980; Healdton Oil Museum [Healdton, Oklahoma], undated information from displays).

Later in 1914, the Oklahoma Corporation Commission ordered the Magnolia Pipe Line Company to increase purchases of oil, to provide facilities for rail shipment, and to build field storage tanks. The company was further ordered to purchase oil ratably and equitably from Healdton producers. Thus, Healdton became the first field in Oklahoma to be regulated by a state commission (Healdton Oil Museum [Healdton, Oklahoma], undated information from displays).

One of Oklahoma's worst oil disasters occurred in the Healdton field before daylight on August 27, 1914, when lightning from a violent electrical storm struck a number of storage tanks and they burst into flames (Franks, 1980). Intense rainfall apparently did little to suppress the fire; instead, the runoff carried flaming rivers of oil and spread the fire to storage tanks—all full—in other parts of the field.

The discovery of the Healdton field occurred early in the "black gold era" (1908–1928) of Oklahoma oil development (Northcutt, 1985), and its oil contributed significantly to U.S. World War I efforts. The Healdton field reached its maximum annual oil production of 36.5 million bbls in 1916. However, by 1927, when Oklahoma's annual oil production reached its all-time high of 278 million bbls (Northcutt, 1985), annual production in the Healdton field had declined to 4.76 million bbls (see Terry, fig. 3, this issue). The field's reserves were exceptional, nevertheless, and it has continued to produce for more than 80 years. For a history of development in the Healdton field, see the feature article in this issue (p. 4).

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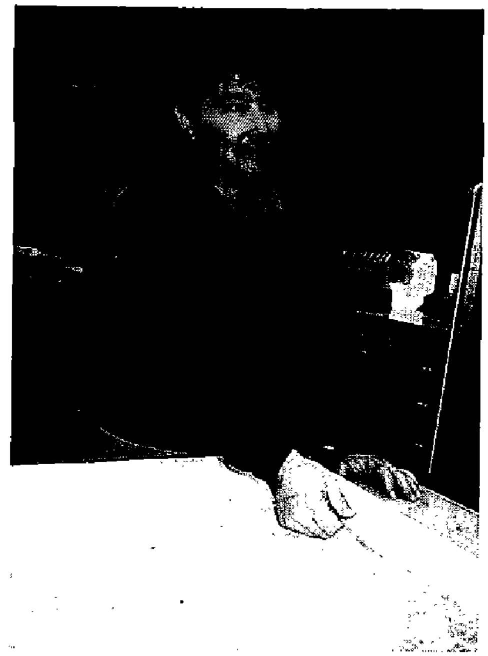
Jock A. Campbell

Photograph from the McGalliard Historical Collection, Ardmore Public Library, Oklahoma

Tom Stanley—Newest Member of the OGS Team



Tom Stanley joined the Oklahoma Geological Survey staff last November, and went almost directly into the field to help with the popular Hartshorne field trips that were sponsored by the OGS. He is now hard at work on field mapping with OGS colleague Neil Suneson in the Oklahoma City area.

Tom comes to the OGS from the Kansas Geological Survey, where he was a research assistant. He still has Kansas ties, however—he is finishing his doctoral degree in geology from the University of Kansas.

Tom feels his experience in Kansas will be very valuable in his mapping work in Oklahoma. "I'm very familiar with Kansas geology, and parts of Oklahoma are similar. Based on my dissertation research, I'm especially interested in working with Pennsylvanian and Permian strata, and I'll have lots of opportunities to do that in Oklahoma."

Tom enjoys field work and believes that it is an important part of geology. "Good scientific investigations start in the field. That's something that is unique about geology—you always have to go back to the field."

Tom received a bachelor of science degree in geology from Southern Illinois University and a master's degree in geology from Kent State.

He served as an assistant curator of invertebrate paleontology at the Cleveland Museum of Natural History in Ohio in the '80s, then worked for nine years as an exploration geologist for Bond Gold and Atlas Precious Metals in Denver. There, he analyzed Precambrian-, sedimentary-, and volcanic-hosted gold deposits in Nevada, South Dakota, Colorado, and Oregon. He designed and implemented more than 20 exploration and delineation drill programs.

Tom enjoyed the work, and remembers the 3-million-oz. gold body he helped develop from the exploration phase to the actual mining phase. During the two years that it took, Tom says he had one day off.

After that exhausting schedule, Tom spent 1996 teaching part-time at Park College, Parkville, Missouri, while he worked on his doctorate degree at the University of Kansas. He then joined the KGS, where he evaluated the paleontology and stratigraphy of Pennsylvanian and Permian cyclothemic units of Kansas, Oklahoma, and Missouri through field mapping and subsurface correlations from core and drill logs. He also mapped and described more than 200 outcrops in eastern Kansas as part of his dissertation, and did work with the general public that included leading field trips and judging student science projects.

Tom is enthusiastic about coming to the Oklahoma Geological Survey and mapping in the Oklahoma City area, as well as being involved in the many public-service opportunities that arise at the OGS. If you happen to see him in the field or in the office, stop to meet him and welcome him to Oklahoma.

—*Connie Smith*

NEW OGS *Publications*

SPECIAL PUBLICATION 98-5. ***Oklahoma Oil and Gas Production by Field, 1994–97.*** 439 pages. Price: $12.

This annual publication provides data on reported oil and gas production and related information for each formally recognized field in the State. The volume contains the following types of field data:

- Field name;
- County or counties in which the field is located;
- Total acreage of the field;
- Date the Oklahoma Nomenclature Committee named the field and date of the last revision of field boundaries;
- Annual production from 1994 through 1997 by type of product: oil, condensate, total liquids, associated gas, natural gas, and total gas;
- Cumulative production from 1979 through 1997 by type of product.

Part 1 of this publication includes oil and gas production by county; Part 2 is a summary of production within each county that is not assigned to any formally recognized field. Part 3 is an alphabetical list of all fields, districts, and gas areas that have been formally recognized by the Oklahoma Nomenclature Committee. Part 4 is a listing of discontinued field names.

This publication has been developed from data contained in the Natural Resources Information System (NRIS), a computerized data base of oil and gas information for the State of Oklahoma. NRIS currently contains data files of monthly oil and gas production by lease that can be aggregated by such categories as field, producing interval, geologic play, petroleum province, and political area (e.g., county). NRIS also contains digitized records for 430,258 well completions and recompletions dating from statehood (1907) to present. The well records include latitude/longitude coordinates that permit plotting and use in a GIS system.

The NRIS data base can be used by the public at the OGS NRIS facility, 1218-B W. Rock Creek Road, Norman, Oklahoma. It is open by appointment only; for information call Jane Weber at (405) 360-2886, (405) 325-3031, or (800) 330-3996.

OGS SP 98-5 can be purchased by mail from the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 360-2886, fax 405-325-7069. To mail order, add 20% to the cost for postage, with a minimum of $1 per order.

All OGS publications can be purchased over the counter at the OGS Publication Sales Office at 1218-B W. Rock Creek Road, Norman; phone (405) 360-2886, fax 405-366-2882.

Notes on New Publications

Geologic Controls of Deep Natural Gas Resources in the United States

The 14 papers in this 239-page USGS bulletin summarize major geologic research on deep natural gas resources. Edited by T. S. Dyman, D. D. Rice, and P. A. Westcott, this volume defines the areal extent of deep drilling and known resources in the U.S., and summarizes geologic controls of deep natural gas resources by basin and region. A plate-tectonic framework for deep natural-gas resources is presented, as well as a sequence of Laramide deformation for the Rocky Mountain region with respect to the emplacement of deep natural gas accumulations. Reservoir rocks are discussed, including a summary of reservoir pressures in deep sedimentary basins, microporosity trends in reservoirs using mercury-injection porosimetry, and porosity in clastic reservoirs in relation to thermal maturity for Rocky Mountain basins and the Anadarko basin. Also described are geochemical and source-rock studies on Precambrian source-rock potential, source and controls of deep-basin natural gas, and migration of hydrocarbon and nonhydrocarbon gases. The potential of deep natural gas resources in the Gulf Coast basin is discussed in terms of both source and reservoir rocks. Assessment methodologies are evaluated, an assessment is presented for a hypothetical deep natural gas play, and play input parameters are modeled in order to show the range of results under different play conditions. The papers in this volume introduce the petroleum community to a set of geologic tools that may be used to conduct future exploration and production studies.

Order Bulletin 2146 from: U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225; phone (303) 202-4210. Cost is $26, plus $3.50 per order for handling.

Assessment of Deep Conventional and Continuous-Type (Unconventional) Natural Gas Plays in the United States

T. S. Dyman, J. W. Schmoker, and D. H. Root wrote this 30-page USGS open-file report.

Order OF 96-0529 from: U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225; phone (303) 202-4210. Cost is $4.50 for a paper copy or $4 for microfiche, plus $3.50 per order for handling.

Effects of Produced Waters at Oilfield Production Sites on the Osage Indian Reservation, Northeastern Oklahoma

J. K. Otton, Sigrid Asher-Bolinder, D. E. Owen, and Laurel Hall wrote this 48-page USGS open-file report.

Order OF 97-0028 from: U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225; phone (303) 202-4210. Cost is $7.50 for a paper copy or $4 for microfiche, plus $3.50 per order for handling.

Hydrocarbon Production from Low Contrast, Low Resistivity Reservoirs—Rocky Mountain and Mid-Continent Regions—Log Examples of Subtle Pays

This volume contains a set of well log examples showing hydrocarbon production from reservoirs that exhibit subtle resistivity expression of the hydrocarbon-bearing fluid-rock system. These examples, along with specifically selected topical papers that discuss the importance of carefully quantifying the rock and fluid properties involved in estimating hydrocarbon saturation in a potential reservoir, could lead to increased production from this class of reservoirs. Examples are included to use as analogs for finding and producing additional hydrocarbons. Most examples include a characterization of the reservoir in the form of log curves and core or sample rock data, the associated production, a map putting the example into perspective, and a short commentary discussing the characteristics of the particular reservoir. The 290-page volume, edited by Edward D. Dolly and James C. Mullarkey, includes 77 clastic examples, 21 carbonates, 3 chert reservoirs, and one volcanic reservoir. There are examples from the Williston, Powder River, Denver-Julesburg, Illinois, and Anadarko basins, as well as the Hugoton embayment and the Las Animas arch.

Order from: The Rocky Mountain Association of Geologists, 820 16th Street, Suite 505, Denver, CO 80202; phone (303) 573-8621. Cost is $45, plus $5 per order for handling.

Ranking of the World's Oil and Gas Provinces by Known Petroleum Volumes

This USGS open-file report, by T. R. Klett, T. S. Ahlbrandt, J. W. Schmoker, and G. L. Dolton, ranks the oil and gas provinces of the world by known petroleum volumes. Released as a CD-ROM, the report presents maps of the world showing (1) geologic provinces and (2) priority provinces outside the United States chosen to be assessed in an ongoing program by the U.S. Geological Survey. It also includes a series of graphs that show the distribution of petroleum fields by size for each priority province. The CD-ROM contains Portable Document Format (PDF) files and viewing software, Adobe Acrobat Reader, for a variety of computer systems. The various parts of the text, maps, and graphs are linked, and views can be planned and zoomed.

Minimum system requirements to use the data with the software provided on the CD-ROM are as follows:

• *Macintosh computers:* 68020 (Macintosh II series) or greater processor (including all Power Macintosh computers). MacOS 7.0 or later, 4 megabytes (MB) application RAM, 13 MB hard disk space.

• *Intel-based ×86-based personal computers:* (386 minimum; 486, Pentium, or Pentium Pro recommended) Microsoft Windows for Workgroups, Microsoft Windows 95, Microsoft Windows NT 3.51 or 4.0, 4 MB application RAM, 12 MB hard disk space.

Order OF 97-0463 from: U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225; phone (303) 202-4210. Cost is $32, plus $3.50 per order for handling.

Seventh Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, by the U.S. EPA and others, April 10–14, 1999, Harrisburg, Pennsylvania. Information: Gayle Herring, P.E. LaMoreaux and Associates, 106 Administration Road, Oak Ridge, TN 37830; (423) 483-7483, fax 423-483-7639; e-mail: pelaor@usit.net; World Wide Web: http://www.uakron.edu/geology/karstwaters/7th.html.

Geographic Information Systems (GIS) Day at the Capitol, April 14, 1999, Oklahoma City, Oklahoma. Information: Bob Springer, Oklahoma Conservation Commission, 2800 N. Lincoln Blvd., Suite 160, Oklahoma City, OK 73105; (405) 521-4831, fax 405-521-6686.

In Situ and On-Site Bioremediation, International Symposium, April 19–22, 1999, San Diego, California. Information: Bioremediation Symposium Registrar at The Conference Group, 1989 W. Fifth Ave., Suite 5, Columbus, OH 43212; (800) 783-6338, fax 614-488-5747; e-mail: conferencegroup@compuserve.com.

Two Popular OGS Programs to Run Again in Spring

• OGS geologists Neil Suneson and Richard Andrews will lead another two-day field trip to view Hartshorne Formation outcrops in southeastern Oklahoma on **March 31 and April 1.** This field trip ran twice last fall, attracting 38 participants the first time and 49 on the second outing.

The field trip acquaints participants with a variety of sandstone and coal exposures illustrating floodplain, fluvial-dominated deltaic (FDD), and marine depositional facies representative of the Hartshorne Formation, a major Arkoma basin gas reservoir. The leaders relate the surface exposures to subsurface well logs.

The trip begins and ends in McAlester. The cost is $75 before March 19 ($95 after that date). The price includes transportation, coffee breaks, lunch, and the field-trip publication (OGS Guidebook 31). For information, contact Michelle Summers, Oklahoma Geological Survey, 100 E. Boyd, Room N-31, Norman, OK 73019; (405) 325-3031 or (800) 330-3996, fax 405-325-7069. Participants must make their own lodging arrangements; a block of rooms has been reserved at the Days Inn in McAlester, phone (918) 426-5050.

• In cooperation with the Oklahoma City Geological Society, the OGS will sponsor "Fluvial-Dominated Deltaic Oil Reservoirs in Oklahoma: The Cleveland and Peru Play," on **May 6** from 1 p.m. to 5 p.m. This half-day workshop is based on material presented at a full-day OGS workshop held in October 1996. It will be held in Oklahoma City. OGS geologist Jock Campbell and independent geologist Bob Northcutt are the primary presenters. The cost is $30 for members of the OCGS, $35 for nonmembers. To register, please contact the OCGS reservation lines at (405) 236-8086 or (405) 235-3648, ext. 40. If you have questions regarding the workshop, call Carol Jones at (405) 236-8086, ext. 11.

Oklahoma Academy of Science to Hold Spring Field Meeting in April

The Oklahoma Academy of Science will hold its 1999 spring field meeting at Robbers Cave State Park (in Latimer County, just north of Wilburton) April 23–25, 1999. The meeting will be held at campsite no.1. Cabins and tent sites are available.

For further information contact Larry Magrath, Dept. of Biology, USAO, Chickasha, OK 73018, phone 405-224-3140.

Industrial Wastes Technical Conference, April 25–28, 1999, Milwaukee, Wisconsin. Information: WEF/Purdue University, e-mail: phayden@wef.org.

Seismological Society of America, Annual Meeting, May 3–5, 1999, Seattle, Washington. Information: World Wide Web: www.seismosoc.org/htdocs/meetings.html.

Petroleum Industry Trade Fair, May 13, 1999, Ponca City, Oklahoma. Information: Marginal Wells Commission, 1218-B W. Rock Creek Road, Norman, OK 73069; (405) 366-8688 or (800) 390-0460, fax 405-366-2882.

From Image to Information: Annual Conference, May 17–21, 1999, Portland, Oregon. Information: American Society for Photogrammetry and Remote Sensing. World Wide Web: http://www.asprs.org/asprs *or* http://www.asprs-portland99.com.

The Mineralogy of Gems and Precious Metals, Symposium, May 21–23, 1999, State College, Pennsylvania. Information: Penn State Mineral Symposium, c/o Mineral Museum, 122 Steidle Building, University Park, PA 16802; (814) 865-5427; e-mail: sicree@geosc.psu.edu.

Interstate Oil and Gas Compact Commission, Midyear Meeting, June 6–8, 1999, Jackson Hole, Wyoming. Information: IOGCC, P.O. Box 53127, Oklahoma City, OK 73152; (405) 525-3556, fax 405-525-3592; e-mail: iogcc@oklaosf.state.ok.us.

Vail Rock '99 Symposium, by American Rock Mechanics Association, June 6–9, 1999, Vail, Colorado. Information: Expomasters, (303) 771-2000, fax 303-843-6212; e-mail: mcramer@expomasters.com.

International Airborne Remote Sensing Conference, June 21–24, 1999, Ottawa, Ontario. Information: World Wide Web: www.erim-int.com/CONF/conf.html.

National Speleological Society Convention, July 12–16, 1998, Filer, Idaho. Information: David W. Kesner, Box 1334, Boise, ID 83701; (208) 939-0979; e-mail: drdave@micron.net.

American Association of Petroleum Geologists, Mid-Continent Section Annual Meeting, August 29–31, 1999, Wichita, Kansas. Information: Alan L. DeGood, (316) 263-5785; e-mail: degood@feist.com.

Bartlesville Play Workshop, cosponsored by Oklahoma City Geological Society and Oklahoma Geological Survey, September 9, 1999, Oklahoma City, Oklahoma. Information: Carol Jones, OCGS, (405) 236-8086, ext. 11.

AAPG Annual Convention
San Antonio, Texas
April 11–14, 1999

¡Bienvenidos a San Antonio!

It is my pleasure to welcome you on behalf of your host, the South Texas Geological Society, to the 1999 convention of the American Association of Petroleum Geologists, its divisions—the Energy Minerals Division, the Division of Professional Affairs, the Division of Environmental Geosciences—and the SEPM (Society for Sedimentary Geology). Our theme, **"Reflections–Projections: Revisiting the Rocks—Applying New Technologies,"** will be the thread that connects the oral and poster presentations, the field trips and short courses, the vast array of exhibits, and many other events.

The focus of the convention will be to show how important concepts that were developed in the past have been enhanced by the creativity of geoscientists and the use of technology. The potential of a growing demand for oil and gas in a global economy is real. Developing countries will require energy to improve the standard of living for their citizens, while developed nations will need reliable sources of energy to maintain their economies. This global search for new sources of oil and gas will require sufficient numbers of well-educated geoscientists and state-of-the-art technology.

The convention committees will provide outstanding opportunities for you to continue your education and improve your skills. You will have ample opportunity to tour the exhibit hall, to learn new technologies, and to visit with friends. The International Pavilion continues to grow, and it will add a truly multinational flavor to the meeting. As always, field trips and short courses are important activities at the annual convention, and this year will be no exception.

Your visit to San Antonio will be an opportunity to enjoy the bicultural nature of this wonderful city. The entertainment committee is planning numerous events for your enjoyment, including the famous "Night in Old San Antonio." You can have a memorable dinner at Club Giraud or an evening of Western music, dancing, and great barbecue at the Leon Springs Dance Hall.

Please join us in San Antonio for a wonderful time. The technical program will be of high quality, and the setting will be perfect. Our city will welcome you in a fiesta spirit.

Edward C. Roy, Jr.
General Chairman

Convention Agenda

Technical Program

Monday, April 12

Depositional Systems from Reservoirs to Basins: Overview
Recent North American Exploration Plays and Development
Salt and Subsalt Exploration: Tectonics and Sedimentation
Paleobiological, Geochemical, and Other Proxies of Sea-Level Change
Gas Hydrate Exploration and Development
Selected Academic Research Topics
Remote Sensing, GIS, and Geoscience Information Systems
Depositional Systems from Reservoirs to Basins: Alluvial Systems
Exploration of Mature Basins
Salt Dynamics and Sedimentation
Student Session
Unconventional Reservoirs
Geochronology in Carbonate Stratigraphy
Origin of Massive Sandstones in Terrestrial Sequences
Applications of Near-Surface Hydrocarbon Expressions in Petroleum Exploration

Tuesday, April 13

Depositional Systems from Reservoirs to Basins: Deltaic Systems
Interpretation of Compressional and Strike-Slip Structures and Traps
Petroleum Generation, Migration, and Fluid Flow
Latin American Exploration Plays and Development
Energy Economics
Seafloor Alteration of Marine Carbonates
Enviromental Considerations in Exploration, Production, and the Aftermath
Electric Deregulation and Power Fundamentals
Depositional Systems from Reservoirs to Basins: Shore-Zone and Shelf
CO_2 Sequestration, Environmental Management Systems, and Other Environmental Topics
Depositional Systems from Reservoirs to Basins: Carbonate Platform Systems
Applications of Formation Water Chemistry to Exploration and Production
Distributed Power in the Oil and Gas Patch

Wednesday, April 14

Depositional Systems from Reservoirs to Basins: Clastic and Carbonate Slope and Basin Systems
Exploration and Exploitation of Fractured Reservoirs
European and Asian Exploration Plays and Development
Basin Modeling
Late Quaternary Stratigraphic Record of the Northern Gulf of Mexico
Role of Fluid Flux in Diagenesis

New Developments in Formation Evaluation
Creativity in Petroleum Exploration
Interpretation of Extensional and Diapiric Structures and Traps
Formation and Development of Reservoir Compartments
Eurasian-African Exploration Plays and Development
Applications of Sequence Stratigraphy in Nonmarine Strata
Mesozoic Carbonate Exploration on the Gulf of Mexico Rim
Upper Paleozoic Carbonate Mound Reservoirs
Bacterially Mediated Mineral Crystallization
Depositional Facies and Surfaces of Falling-Stage Systems Tracts
Applications and Attributes of 3-D Seismic

Short Courses

Pre-Convention

Introduction to Workstation Interpretation of Seismic Data, *April 10–11*
Use of Standard Wireline Logs in Estimation of Ground-Water Quality, *April 10*
Reservoir Analysis for Geologists and Engineers, *April 10–11*
Surface Exploration for Oil and Gas—Assumptions, Applications, and Recent Advances, *April 10*
Pitfalls of the Seismic Method Via 3-D Case Histories, *April 11*
Petroleum Geology of Deep-Water Clastic Depositional Systems, *April 9–11*
Practical Salt Tectonics, *April 10–11*
Application of Sequence Stratigraphy to Hydrocarbon Systems, *April 10–11*
Culture and Business Interactions, *April 11*
Environmental Management Systems (International Standards Organization [ISO] 14,000) for Geotechnical Decision-Makers and Managers, *April 10*
Raising Corporate Equity Capital: Is a Public Offering Appropriate for My Company? *April 11*
Basement Structures, Their Detection and Relationship to Hydrocarbon Plays, *April 11*
Gas Hydrates—A Primer on the Largest Gas Resource, *April 11*
Sequence Stratigraphy and Characterization of Carbonate Reservoirs, *April 9–11*
3-D Seismic Interpretation: A Primer for Geologists, *April 10–11*
Tectonics of Sedimentary Basins, *April 10–11*
Late Quaternary Depositional Systems of the Northern Gulf of Mexico Shelf: A Core Workshop, *April 11*
Geology and Development of a Lower Cretaceous Natural Gas Field, Lavaca County, Texas (restricted to students and faculty advisors), *April 11*

Post-Convention

Current Technology and Processes, *April 15–17*
The Interpretation Problem, *April 15–16*

Field Trips

Pre-Convention

Reefal Development in a Terrigenous Province—Veracruz/Anton Lizardo Reefs, Mexico, *April 7–10*

Architecture of Slope and Basinal Sandstones, Delaware Mountain Group, West Texas, *April 9–11*

The Edwards Aquifer—From Sinkholes to Springs, *April 10–11*

Classic Outcrops of the Trinity Group (Lower Cretaceous) of South-Central Texas: Sequence Stratigraphic Units of Marine and Non-Marine Sedimentary Packages, *April 10–11*

The Dam Geology of Bexar County, *April 11*

The San Antonio River—History, Hydraulics, and Urban Geology, *April 11*

Rocks, Landscapes and Man: Geology in the San Antonio Area, *April 11*

Lower Cretaceous Sedimentary Geology of the Edwards Plateau, San Antonio Area, *April 10*

Shore Zone/Deltaic to Slope/Basin Depositional Systems in the Arkoma Basin, Oklahoma and Arkansas, *April 7–10*

Post-Convention

Tectonics and Sedimentation of Trans-Pecos Texas, *April 14–18*

Upper Paleozoic Algal Mound Complexes of the Orogrande Basin, *April 14–16*

Stratigraphy and Structure of Jurassic and Cretaceous Rocks of the Sierra Madre Oriental, Northeastern Mexico, *April 14–17*

Geology, Frontier History, and Wineries, Texas Hill Country, *April 15*

The San Antonio River—History, Hydraulics, and Urban Geology, *April 15*

Tertiary Coals in South Texas: Anomalous Cannel-Like Coals of Webb County (Claiborne Group, Eocene) and Lignites of Atascosa County (Jackson Group, Eocene), *April 14–15*

Sequence Framework and Facies Architecture of a Cretaceous Carbonate Ramp: Late Albian of the Pecos River, West Texas, *April 14–18*

Depositional Systems of the East Texas Coastal Plain and Continental Shelf, *April 15–16*

Beach Processes and Patterns of Shoreline Change along the Upper Texas Coast, Galveston Bay Area (student trip), *April 14–16*

For more information about the annual meeting, contact AAPG Annual Convention, P.O. Box 979, Tulsa, OK 74101-0979, phone (918) 560-2617, fax 918-560-2684 or 800-281-2283; World Wide Web: www.geobyte.com/meetings.html.

Oklahoma ABSTRACTS

The Oklahoma Geological Survey thanks the American Association of Petroleum Geologists and the Geological Society of America for permission to reprint the following abstracts of interest to Oklahoma geologists.

Origin of Oil and Its Primary Migration from Shale Source Rocks

MARIE D. COMMISSO, MATTHEW FULLER, and *NEAL O'BRIEN,*
Dept. of Geology, State University of New York, College at Potsdam,
Potsdam, NY 13676

The early stages of oil formation and migration in known shale source rocks of the Woodford Shale, Oklahoma, New Albany Shale, Indiana, and Green River Shale, Wyoming, were studied. Liquid hydrocarbon was produced in the lab by using the hydrous pyrolysis technique and then viewed with the Scanning Electron Microscope (SEM). Hydrous pyrolysis, thin-section analysis, and SEM techniques were used in studying the processes of these potential source rocks.

The samples were heated in the lab using temperatures ranging from 100°C to 350°C at 25°C to 50°C increments for time periods of 1, 2, 3, 4, and 5 days. This was done to allow for oservation at various stages in the production and migration of the liquid hydrocarbons. Unheated and heated samples of the Woodford, New Albany, and Green River shales were prepared to be studied using the SEM and thin-section analysis to determine the pathways of oil migration.

Results from the study show that the microfractures are produced simultaneously with the initial production of liquid hydrocarbon and provide pathways for the hydrocarbon to travel through the shale. The gas pressure that was built up in the sample from the water being heated and from the conversion of kerogen to liquid hydrocarbon produced the microfractures. Once the microfractures are present, the oil droplets drip into them from the matrix. Once in the microfractures, the oil droplets travel through them and coalesce to form sheetlike, taffylike, or sausagelike structures. The form which the oil droplets take after coalescing depends upon the morphology of oil produced from each of the individual shales. The liquid hydrocarbons consequently move through the microfractures from an area of higher pressure to an area of lower pressure and eventually are forced out of the source rock.

The photomicrographs will be displayed to show each of the stages in the oil formation and migration processes in the shale source rocks.

Reprinted as published in the Geologica Society of America *1998 Abstracts with Programs*, v. 30, no. 1, p. 12.

Bromine Analysis in Petroleum Geology

SALEH M. BILLO, Dept. of Geology, King Saud University, Riyadh, Saudi Arabia

Bromine analyses are of great importance in the solution of many problems related to the origin and development of source and reservoir rocks. In the Apache oil field, Oklahoma, an oil pool occurs in the Bromide sand (Ordovician) throughout this area. The Ordovician faulting does not carry above the interregional basal Pennsylvanian

unconformity resulting in baldheaded overturned anticlinal traps. The reservoirs are sandstones belonging to the Bromide, McLish, and Oil Creek formations of the Simpson Group of Ordovician age. These reservoirs have yielded large volumes of oil and gas, and have a great potential for producing additional hydrocarbons by the use of advanced-recovery technologies.

Bromine is a reactive deadly halogen with properties fitting the periodic law. It is recovered mainly from seawater, salt brines, and evaporite and potash minerals. Bromine in halite has been used as a paleosalinity indicator and stratigraphic marker. Many ancient evaporite deposits include basal sapropelic units which may be enriched in bromine. Halite may be of marine or nonmarine origin. Bromine analyses may be used to distinguish between the different petrographic types of halite in various parts of the evaporite basin.

Reprinted as published in Geological Society of America *1998 Abstracts with Programs*, v. 30, no. 3, p. 2.

Geological-Engineering Teamwork: Key to Successful Development of Two Stratigraphic Traps

CHARLES E. MEAR, Consulting Geologist, Austin, TX

Geologist-engineer teams, using only subsurface data, developed and extended two oil and gas fields that produce from stratigraphic traps. The geologists mapped realistic reservoir models, and the engineers used basic reservoir engineering to determine the likelihood of undeveloped reserves being present in the accumulation.

A large stratigraphically trapped gas deposit present in an unconventional 30-foot-thick Hunton dolomite reservoir in Major County, Oklahoma, was developed after a joint geological-engineering study showed that the water level indicated by electrical logs was irreducible water contained in microporosity and illite clay; and that the producing zone extended 300 feet downdip from its upper limit. The zone was artificially fractured to obtain commercial production. The fracture fluid contained as little water as possible to avoid reservoir permeability degradation in the micropores by water and by movement of the illite. Care was taken to avoid fracturing into water-bearing zones.

The Herrin Burson sand (upper) oil field in the Knox-Baylor Trough of Haskell County, Texas, has been redrilled after a joint subsurface study indicated that the field wells had been drilled along the flank of a Strawn sandstone bar, and that most of the wells had communicated with an underlying water-bearing sandstone that caused premature abandonment of most of the field wells. Significant new oil reserves have been developed in extensions and in wells along the crest of the bar.

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3-D Seismic Exploration in the Ames Hole

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The Ames Crater of Major County, Oklahoma, has been one of the more controversial drilling projects to emerge in the Mid-Continent province in this decade. Within the crater, dolomitic and granodiorite breccias produce substantial quantities of oil and gas within structurally controlled accumulations. To understand the structural complexities of the crater, Continental Resources, in partnership with other Ames operators, acquired 3-D seismic data in four separate acquisition projects across various exploratory and development projects across the crater.

Integrated seismic and subsurface control revealed four separate features within the principal crater floor oil and gas accumulation. Using the 3-D data as a lead tool, these companies identified and developed a significant number of commercial tests within the limits of the seismic surveys.

Although the tool generally proved to be successful, reservoir variability, velocity variations, and interpretational errors resulted in some non-commercial and dry tests.

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Gravity and Magnetic Modeling of the Ames Structure, North Central Oklahoma

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The Ames Structure in Oklahoma has been attributed to meteorite impact, volcanic activity, dissolution collapse, etc. Analysis and modelling of the gravity and magnetic field over the Ames Structure places constraints on possible models for its origin.

The residual Bouguer gravity anomaly reveals a highly circular negative anomaly of about 1 mgal that coincides with the central structural depression defined by Sylvan Shale structure contours. This low is surrounded by an annular high with a radius of 6 km and an amplitude of about 0.5 mgal; this positive anomaly ring coincides with the structural high comprising the rim of the Ames Structure.

The gravity signature of impact craters is relatively distinctive and the relationship between impact effects and density is somewhat straightforward. The amplitude, shape and character of gravity over the Ames Structure are consistent with observations of other structures believed to be caused by meteorite impact.

A magnetic low over the Ames structure is also consistent with magnetic field observations over other impact craters, although the magnetic field associated with impact craters is less distinctive than their gravity field.

A 2½-D gravity and magnetic model and a 3-D gravity model have been constructed with the impact model in mind. The density and magnetization structure derived from modeling, like the fields themselves, is similar to that found from geophysical modeling of known meteorite impact craters.

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Ames Hole, Oklahoma: Impact-Formed Petroleum Reservoirs

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Ames Hole is a 16 km wide circular subsurface structure centered at 36°15′ north, 098°12′ west in Major County, northern Oklahoma. An impact origin is confirmed by the presence of shock metamorphosed mineral grains and impact melt rocks recovered from drill cores and by a negative Bouger gravity anomaly over its center. Buried about three km deep, the structure is composed of shattered, central zone of uplifted Precambrian granite and Cambrian-Ordovician Arbuckle dolomite surrounded by two concentric rims of fractured and brecciated Arbuckle dolomite. The crater is filled with, and covered by, marine sediments of the middle Ordovician Oil Creek shale. The crater was formed during Ordovician time in a shallow sea on the northern shelf of the Anadarko Basin. Restricted water circulation and anoxic conditions within the deep crater promoted precipitation of plankton-rich sediments. This Oil Creek shale became both the source and the sealing rocks for hydrocarbons which migrated into underlying porous target rocks fractured during the impact event. About one hundred wells within the area underlain by the Ames Hole astrobleme presently produce nearly half of Oklahoma's oil and gas.

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Remote Sensing and Subsurface Structure of the Ames Crater, Oklahoma

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The Ames Crater, or "Ames Hole", in southeast Major County, Oklahoma, is the site of many prolific new oil and gas wells that produce from brecciated Precambrian to Ordovician rocks. Brecciation was caused by the impact of a large meteorite shortly after deposition of Arbuckle Group rocks. The impact pulverized the carbonate, clastic, and igneous rocks, thus forming thick, porous reservoirs that are difficult to map.

The "Ames Hole" was once thought to be a deep Precambrian graben because Lower Paleozoic rocks are much thicker than elsewhere in the region. Because it was "low" and the Arbuckle was believed to have poor porosity, little exploration effort was expended until recently. After good production was established on local seismic highs, reinterpretation of the structure showed that the graben was part of the central rebound structure of an astrobleme.

Subtle geomorphic keys, interpreted from Landsat TM and MSS imagery, help locate the astrobleme. Several of the local, now prolific outer rim and central floor structures are clearly represented on the imagery as small, oval tonal patterns. Because of the stratigraphic chaos caused by the impact, these structures are difficult to map even with detailed 3D seismic surveys. When properly processed and interpreted, inexpensive landsat imagery can offer leads for more detailed and expensive exploration techniques.

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Recognition and Regional Correlation of Impact-Related "Ames Crater" Arbuckle and Simpson Reservoir Lithofacies

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The concentric structural feature known as the "Ames Hole," or "Ames Crater," located on the northern shelf of the Anadarko Basin, contains several heterogeneous and uniquely associated hydrocarbon reservoirs, as well as a locally thick (craterfilling) Middle Ordovician (Simpson shale) source rock. Critical diagnostic structural and morphological features, along with petrographic and shock metamorphism evidence, strongly support an impact origin of the structure. Principle crater reservoirs include extremely brecciated, fractured, and faulted, Cambro-Ordovician Arbuckle Group dolomites, Pre-Cambrian granodiorites, devitrified pseudopyroclastic (impact melt) rocks, and a rather homogenous, dolomitic ejecta-fallout breccia, which is present along the rim and flanks of the crater.

Stratigraphic trapping of hydrocarbons associated with the presence of reservoir-quality ejecta-fallout lithologies unconformably present in the upper portion of the Arbuckle Group, and in reworked, arkosic/dolomitic impact-related lithofacies within the overlying basal Simpson Group, may exist both locally and regionally relative to the "Ames Crater." Recognition and regional correlation of Arbuckle ejecta-fallout breccias, and arkosic/dolomitic (reworked) Simpson clastics, requires a thorough understanding of the genesis, distribution, structural complexities, and petrographic/petrophysical properties associated with various "Ames Crater" lithofacics. Calibration of log-rock characteristics of ejecta-fallout reservoir lithofacies from key crater rim wells provides the basis for field-wide and regional inferences about lithologies, reservoir quality, and related production characteristics. An awareness and understanding of impact-related "Ames Crater" Arbuckle and Simpson lithofacies should lead to refinement of regional Lower and Middle Ordovician stratigraphy, and create renewed exploration strategies for potential stratigraphic traps.

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New Impact Craters Discovered Using Landsat Imagery

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A debris filled basin, 12 kilometers in diameter, exists on the south margin of the Chukotskiy Poluostrov, 50 kilometers east of Zaliv Kresta, in Eastern Siberia. This feature is drained by the Limgytynot River and is herein designated as the Limgytynot Impact Structure. It is similar in size and structure to the Ames, Oklahoma, impact structure.

A sharply defined basin, 1,300 meters in diameter, 35 meters deep, and with internal drainage, is located 35 miles south of Dodge city, Kansas. This feature is named Big Basin on topographic maps of the region. Remote sensing data indicate prominent radial fracture sets and a polygonal shape that reflects the regional fractures. Subsequent field work revealed that the strata on the rim of the feature dip radially away from the center of the feature. The rim and wall materials are intensely fractured.

Primary impact structures can range in size from pits a few meters across to multiring basins 800+ kilometers in diameter. Close examination of the geometry of primary impact features reveals that they often exhibit a polygonal shape related to the preexisting regional structure. The forces of impact superimpose radial and concentric fractures onto the preexisting regional structure. Associated fractures and size related features, such as central uplift zones, interior rings, and slump blocks, are good diagnostic characteristic of primary impact structures.

The above physical features can be located on remote sensing data that specifically enhances such characteristics regardless of their subtleness. The bands of Landsat imagery, both MSS and TM, acquire in the near-IR at low angles of illumination are excellent tools to use in a search for primary impact structures.

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