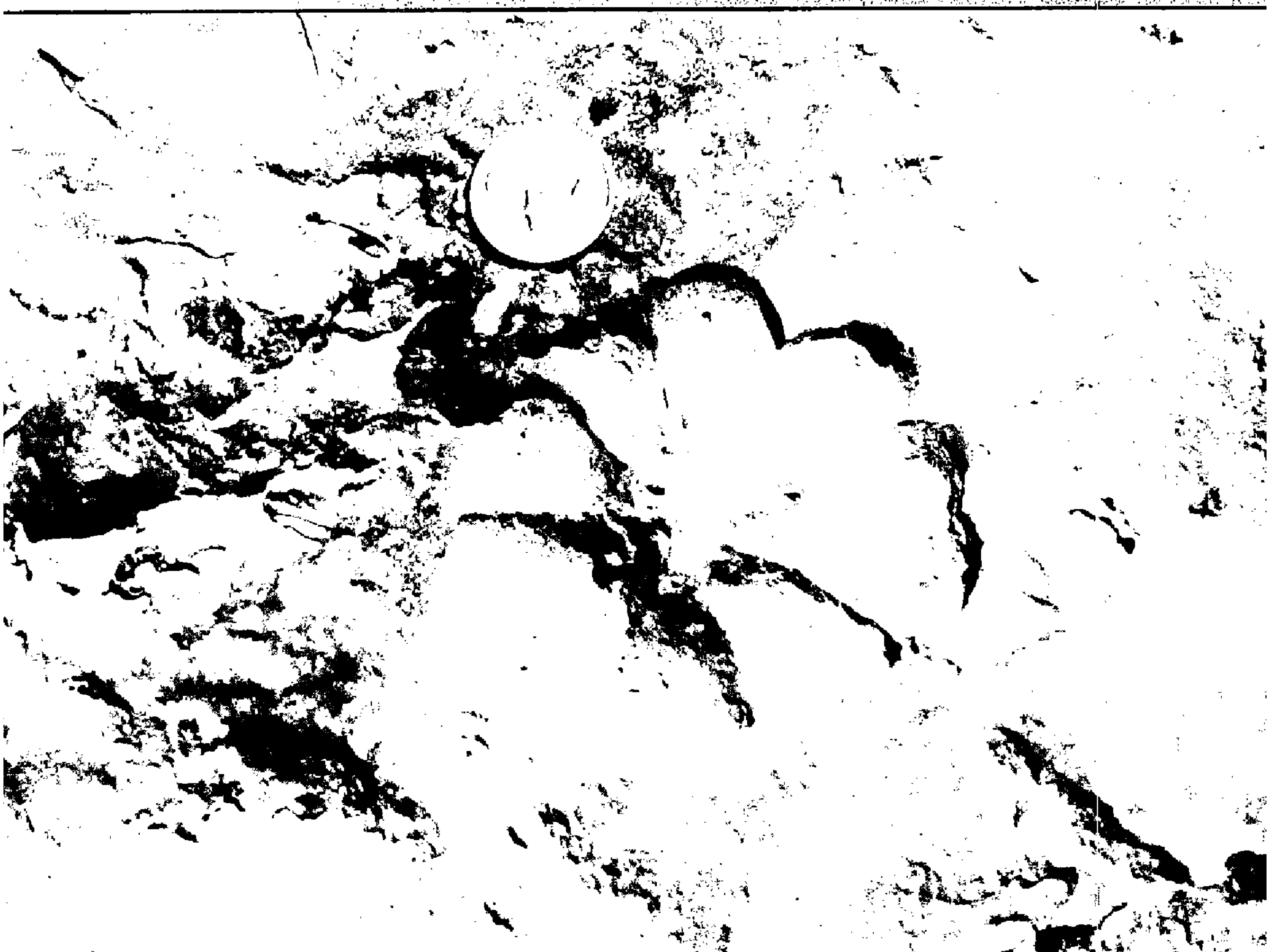
OKLAHOMA GEOLOGY



February 1998

Vol. 58, No. 1

On The Cover —

Jellyfish Body Fossil or Trace Fossil?

The cover photograph shows a flowerlike fossil found as an impression on the surface of an unnamed sandstone bed in the Denton Formation (Lower Cretaceous), Marshall County, Oklahoma (quarter for scale). The fossil is identified tentatively as *Kirklandia texana* Caster, 1945. Caster (1945, p. 175) was the first scientist to study specimens of this unusual fossil, which had been discovered earlier in Texas, in the Pawpaw Formation (Washita Series) of the Comanchian, Lower Cretaceous. He referred to *Kirklandia* as a "new medusa" and coined the new family name Kirklandiidae Caster for it because of its distinctiveness. Medusae are jellyfish that are unattached and commonly have an umbrellalike form with eight-lobe symmetry. Caster (1945, fig. 1, p. 10) interpreted the prominent lobes of *Kirklandia* as gastrogenital sacs (stomach pouches). Such lobes are well preserved as molds in the specimen shown on the cover.

In the system of classification of animals, *Kirklandia texana* was originally placed in the phylum Coelenterata; the order Trachylinida Haeckel, 1877; the suborder Trachymedusina Haeckel, 1866; and the family Kirklandiidae Caster, 1945. The term "coelenterata" has fallen into disuse, and the jellyfish, corals, and hydrozoans are now placed in the phylum Cnidaria. The major divisions of the Cnidaria are the classes Anthozoa, Hydrozoa, and Scyphozoa. The class Scyphozoa includes the cnidarians, which are aquatic invertebrates that almost all inhabit the sea. They have highly varied forms and are the most simply organized of the animals that have well-developed body

(continued on p. 39)

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OKLAHOMA GEOLOGY

Notes

CONTENTS

February 1998

VOL. 58, NO. 1

Review of the Geology and Stratigraphy of the Oklahoma City Metro Area—STATEMAP Progress Report

Neil H. Suneson[1] *and LeRoy A. Hemish*[1]

Introduction

COGEOMAP AND STATEMAP Programs

The Oklahoma City Metro Area (OCMA) geologic mapping project is the latest part of a continuing effort by the Oklahoma Geological Survey (OGS) to produce detailed geologic maps of the State. Recently, this effort has been partly funded by the U.S. Geological Survey (USGS) which, in 1984, requested proposals from state geological surveys to complete new geologic mapping of areas that were of high-priority interest to federal and state agencies. The request for proposals was part of a new federal program called COGEOMAP, which stands for Cooperative Geologic Mapping. States were allowed to request as much as 50% federal matching funds to complete the mapping. The Oklahoma Geological Survey (OGS) recognized the program as an opportunity to begin new, detailed geologic mapping of parts of the Ouachita Mountains in southeastern Oklahoma (Johnson and Suneson, 1996).

In response to the request for proposals, the Arkansas Geological Commission, which recognized a need for new mapping in the Ouachita Mountains of west-central Arkansas, and the OGS applied for and received COGEOMAP funding. The OGS Ouachita mapping project continued to receive USGS support under the COGEOMAP program for the next seven years (eight years total), ending in FY92 (contract ending June 30, 1993). Beginning in 1993, in response to the National Geologic Mapping Act signed by President George Bush, the OGS continued its Ouachita mapping under the STATEMAP program, which replaced COGEOMAP. This work in southeastern Oklahoma continued through FY96 (June 30, 1997), by which time the OGS had completed and released 22 detailed geologic maps of the northern part of the Ouachita Mountains fold-and-thrust belt and the southern part of the Arkoma basin.

Oklahoma Geologic Mapping Advisory Committee

In 1993, the Oklahoma Geologic Mapping Advisory Committee (OGMAC) was formed from representatives of State agencies, State planning associations, State industrial associations, and other organizations that have a Statewide perspective of geologic mapping needs in Oklahoma. In addition, OGMAC maintains correspondence with major universities, city governments, sub-State planning groups, Native American tribes, industry associations, and some major companies.

On September 4, 1996, OGMAC met to discuss the continued need for detailed geologic mapping in Oklahoma and concluded that mapping of the OCMA was the highest priority. This assessment was based on the following factors: the OCMA is

[1]Oklahoma Geological Survey.

the most populous area in the State; it is an area of rapid development; it has major waste-disposal problems; there are increasing demands for local geological resources; there are hazardous-waste cleanup problems at Tinker Air Force Base; city and eastern suburbs overlie a major aquifer that provides municipal drinking water. The committee noted that there are no recent, detailed geologic maps of OCMA and recommended a multi-year project of the geologic mapping of 7.5-minute quadrangles. The OGS recommended to OGMAC that mapping begin in the northern suburbs, where outcrops are extensive, and progress to the south, where much of the bedrock geology is covered by Pleistocene terrace deposits and Recent alluvium. OGMAC unanimously accepted this recommendation.

STATEMAP Program for Oklahoma City Metro Area

Based on OGMAC's acceptance of its recommendation, the OGS included in its FY97 STATEMAP proposal to the USGS the geologic mapping of the Piedmont, Bethany NE, Edmond, and Arcadia 7.5-minute quadrangles (Fig. 1). This proposal, which was funded by the USGS, is to be the first part of a three-year project that would include an additional eight 7.5-minute quadrangles that would cover Oklahoma City and surrounding suburbs and communities to the east, north, and west. These 12 quadrangles constitute OCMA (Fig. 1). Field work in the FY97 project area started in September 1997, and detailed geologic mapping will be completed by June 30, 1999, if federal funding is received as planned for FY98 and FY99. Future plans are to continue detailed geologic mapping to the south to include the OCMA communities of Newcastle, Blanchard, Moore, Norman, Goldsby, and Noble.

As part of the OGS geologic mapping effort, previous surface geologic maps and stratigraphic studies have been examined. This report is a review of previous efforts to describe the geology of the OCMA.

History of Geological Studies in OCMA

Geologic Maps of the OCMA

Early Work

Gould (1905) published the first geologic map of the OCMA and first widely distributed study describing the rocks of central Oklahoma. His map is at a scale of approximately 1:1,250,000 and obviously is very generalized. He mapped the western three-fourths of the area as the Enid Formation (Permian) and the eastern one-fourth as the Chandler Formation (Pennsylvanian) (Fig. 2A) and showed the contact between the Enid and Chandler Formations striking north-northeast through Moore and Arcadia. He stated that the Enid Formation is part of the Permian "red beds" sequence that occupies much of Oklahoma; in particular, the Enid Formation is composed "chiefly of brick-red clay shales, with some interbedded ledges of red and whitish sandstone" (Gould, 1905, p. 41). Sandstone ledges are "few" and "inconspicuous" in the eastern part of the Enid outcrop area and "mostly wanting" in the western part (Gould, 1905, p. 41). Gould (1905), like many geologists after him, attempted to correlate the strata in the OCMA with formations mapped in Kansas (see discussion below).

Gould published two papers in 1926 (Gould, 1926; Gould and Lewis, 1926) that also contained maps and descriptions of the stratigraphic units in the OCMA. Of the two maps, the one by Gould and Lewis (1926) is more detailed and at a larger

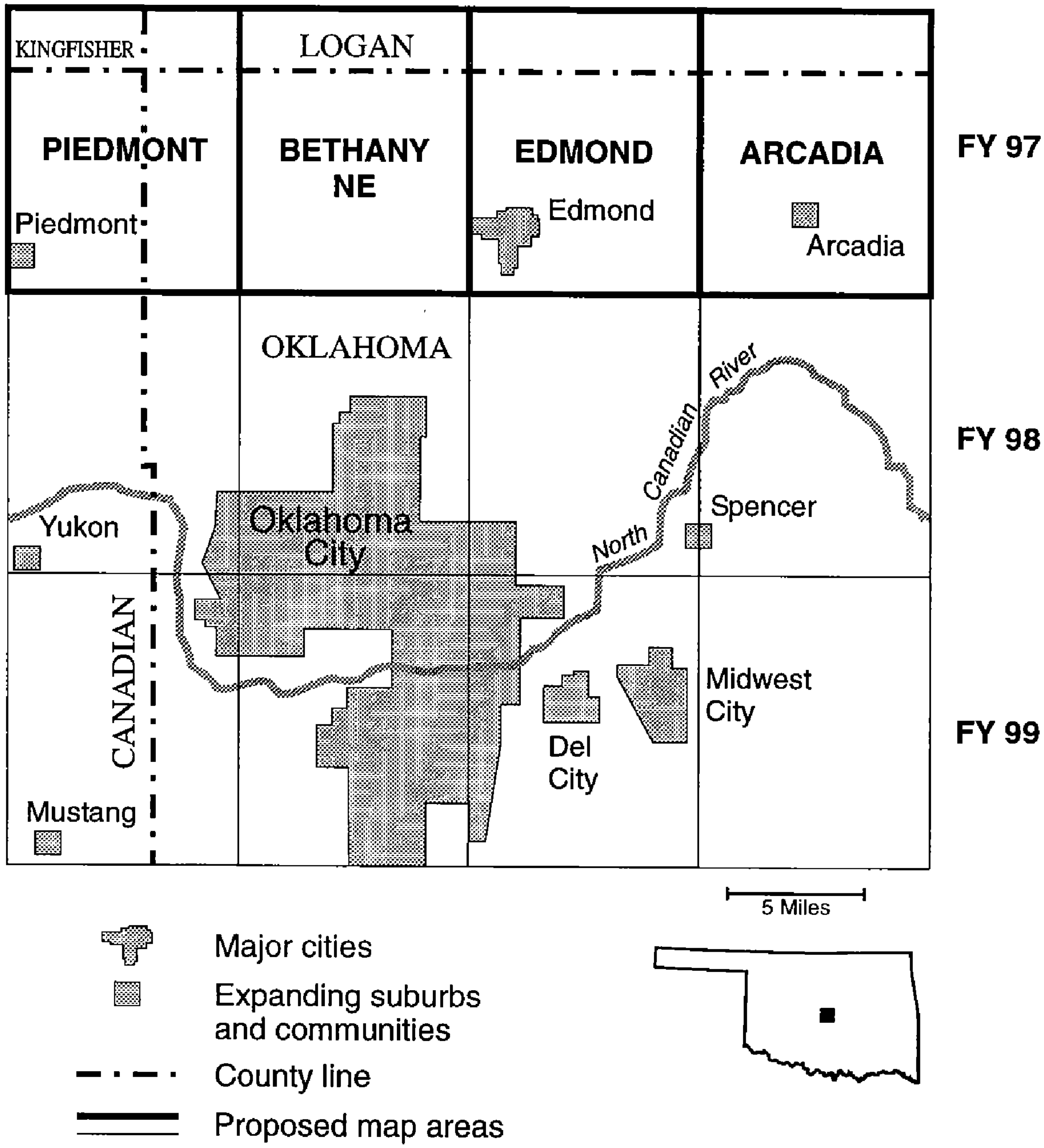


Figure 1. Map of the Oklahoma City Metro Area (OCMA) showing 7.5-minute quadrangles to be mapped in FY97 and areas to be mapped in subsequent years.

scale (approximately 1:870,000). However, the surface geology of the OCMA is essentially identical on both maps. It consists of an outcrop belt of Duncan Sandstone in the extreme southwest corner of the area, Chickasha Formation to the west (outside the OCMA), and pre-Duncan (red Permian) formations to the east (Fig. 2A). Gould named these formations (discussed below) in 1924. Gould (1926) and Gould and Lewis (1926) included all the strata in the OCMA in the Enid Group (Fig. 2A).

Miser (1926), on his geologic map of Oklahoma (scale 1:500,000), appears to have lowered the rank of the Enid Group (Fig. 2A) and shows the southwest corner of the OCMA to be within the upper part of the Enid Formation, which he correlated with the Duncan Sandstone and Chickasha Formation. To the east, Miser (1926) mapped most of the OCMA as the lower part of the Enid Formation. He mapped the easternmost part of the area as Permian and Pennsylvanian (correlates with Sumner, Chase, and Council Grove Groups of Kansas). Miser (1954) subsequently mapped that part of the "Permian and Pennsylvanian" in the OCMA as Permian, which currently is accepted as proper by the OGS.

One of the most important publications on the geology of central Oklahoma is by Aurin and others (1926). (Gould is a coauthor of this paper.) They published a geologic map including all of the OCMA at a scale of about 1:2,300,000 and, for the first time, subdivided the Enid Group into formations (Fig. 2A) that are still recognized widely. (Although Aurin and others [1926] gave formation status to the Enid in the title of their paper, they clearly considered it to be a group name [for example, see their table I].) The Enid Group includes (from bottom to top) the Stillwater Formation, Wellington Formation, Garber Sandstone, Hennessey Shale, Duncan Sandstone, and Chickasha Formation. (The origin of the stratigraphic nomenclature used in the OCMA is described below.) The Garber was further subdivided into the Lucien Shale (lower) and Hayward Sandstone (upper) Members; and the Hennessey was subdivided into the Fairmont Shale (lower) and Bison Banded (upper) Members, although these members were not shown on the map (Aurin and others, 1926, fig. 1). All the formations except the Stillwater and Chickasha crop out within the OCMA. Like most previous geologists, Aurin and others (1926) suggested that the strata in the OCMA could be correlated with named units in Kansas.

Travis (1930) published the first relatively large-scale map of Oklahoma County, which constitutes most of the OCMA, at a scale of about 1:125,000 (Fig. 3). He accepted the stratigraphy established by Aurin and others (1926) (Fig. 2A). However, his map was different in several important aspects, the most important of which is that he recognized the Garber Sandstone exposed in the crest of a very broad anticline on the southeast side of Oklahoma City. (This structure, which extends to the north, apparently was mapped between 1917 and 1927 by several geologists working for different oil companies [Travis, 1930, p. 6–7]. This anticline later became famous as the "Oklahoma City structure" and was the site of extensive oil exploration and development.) Travis (1930) also mapped the Garber-Hennessey contact farther east than did Aurin and others (1926).

Travis (1930) did not map the members of the Hennessey Shale or Garber Sandstone in Oklahoma County (Fig. 2A). He did, however, describe in great detail the units immediately above and below the Garber-Hennessey contact and admitted that "the difficulty of remaining on the same sandstone member (at the top of the Garber) has caused a great deal of uncertainty in the surface work in the county" (Travis, 1930, p. 11).

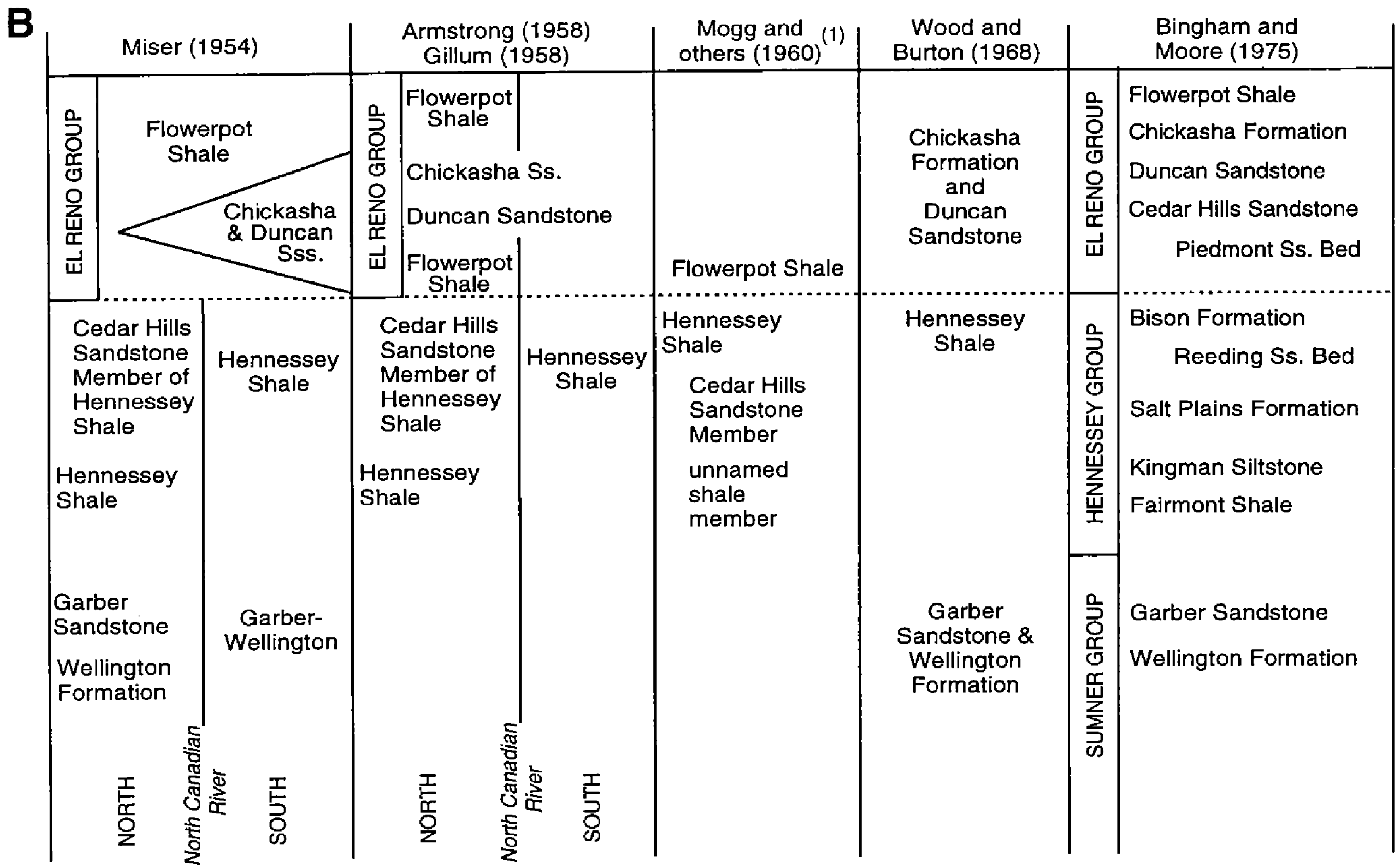
Becker (1930) focused his studies on the area southwest of Oklahoma City and did not publish any maps of the OCMA. However, he did recognize that certain formations graded laterally into others; in particular, he recognized that the Chickasha-Duncan Sandstone graded into the Flowerpot Shale, the Blaine Formation, and the Dog Creek Shale (Fig. 2A). He also included all the units above the Hennessey in the El Reno Group and made no mention of the Enid Group.

Patterson (1933) mapped the surface geology of Logan County at a scale of about 1:850,000; this area includes the northernmost part of the OCMA (Fig. 3). For that part of the section exposed in the OCMA, he retained the stratigraphic nomenclature proposed by Aurin and others (1926) but subdivided the Wellington Forma-

A

Gould (1905)	Gould (1926), Gould and Lewis (1926)	Miser (1926)	Aurin and others (1926)	Travis (1930)	Becker [(2)] (1930)	Patterson (1933)	Green [(2)] (1936)
Enid Formation	ENID GROUP: [Chickasha Formation] Duncan Sandstone	Upper Part of Enid Formation	ENID GROUP: [Chickasha Formation] Duncan Sandstone	ENID GROUP: [Chickasha Formation] Duncan Sandstone	EL RENO GROUP: Chickasha-Duncan Sandstone; Dog Cr. Shale Blaine Fm. Flower-pot Shale		Flowerpot Shale Duncan Ss. Cedar Hills Ss.
	pre-Duncan "red Permian"	Lower Part of Enid Formation	Hennessey Shale Bison Banded Member Fairmont Shale Member Garber Sandstone Hayward Ss. Member Lucien Shale Member Wellington Formation	Hennessey Shale Garber Sandstone Wellington Formation	Hennessey Shale	ENID GROUP: Hennessey Shale Fairmont Shale Member Garber Sandstone Wellington Formation Iconium Shale Mbr. Evansville Ss. [Lowrie Ss.] [Fallis Ss. Mbr.]	Hennessey Shale Garber-Wellington
Chandler Formation		Permian and Pennsylvanian (probably Permian Sumner Gp.)[(1)]	[Stillwater Formation]	[Stillwater Formation]		[Stillwater Formation]	

(1) See text for discussion. (2) Stratigraphic study only. No map.



(1) Stratigraphic study only. No map.

Figure 2. A—History of nomenclature of Permian strata in the OCMA based on pre-1940 mapping and stratigraphic studies. Names in brackets ([ ]) are entirely outside the OCMA as used in this report. Dotted line is reference line at top of Hennessey Shale. B—History of nomenclature of Permian strata in the OCMA based on post-1940 mapping and stratigraphic studies. Note that some studies recognized different stratigraphic sections on either side of the North Canadian River. Dotted line is reference line at top of Hennessey Shale.

tion into the lower Fallis Sandstone Member and the upper Iconium Shale Member (Fig. 2A). Patterson (1933) also mapped two sandstone beds (Evansville, Lowrie) within the Iconium; the Evansville sandstone is shown in the extreme northeast corner of the OCMA.

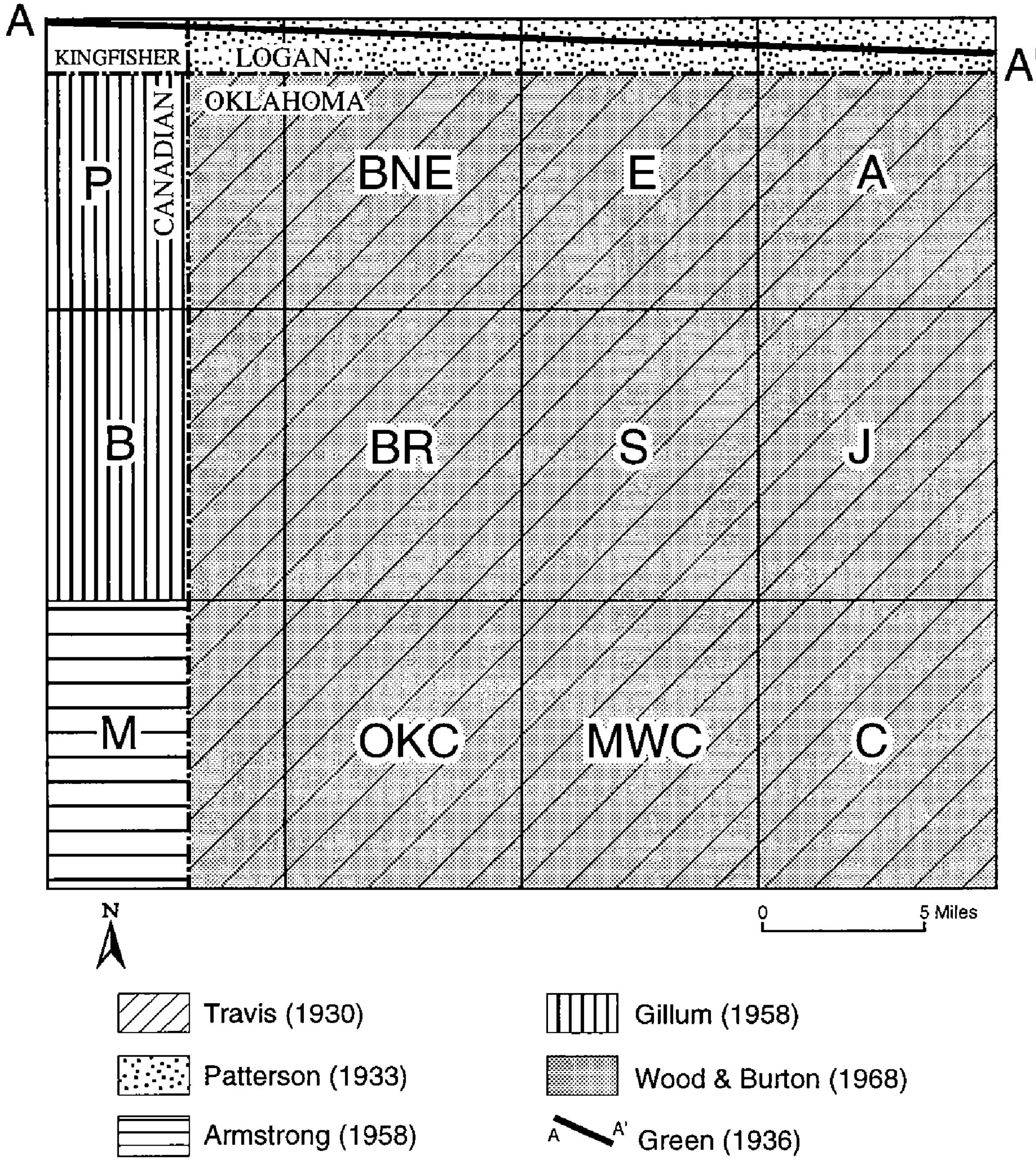


Figure 3. Index map of geologic maps and sections in the OCMA. Geologic maps that include all of the OCMA have been published by Gould (1905, 1926), Gould and Lewis (1926), Miser (1926), Aurin and others (1926), Miser (1954), and Bingham and Moore (1975). The geology of parts of the OCMA have been mapped by Travis (1930), Patterson (1933), Armstrong (1958), Gillum (1958), and Wood and Burton (1968). (See text for scales.) Also shown is part of a cross section by Green (1936) that is within the OCMA. Quadrangle abbreviations: P = Piedmont; BNE = Bethany Northeast; E = Edmond; A = Arcadia; B = Bethany; BR = Britton; S = Spencer; J = Jones; M = Mustang; OKC = Oklahoma City; MWC = Midwest City; C = Choctaw.

Patterson (1933) was not able to distinguish the Lucien and Hayward Members of the Garber in Logan County, and he admitted that he was not able to trace the base of the Lucien (base of Garber) south from its type locality in Noble County (Fig. 2A). He agreed that the top of the Garber as recognized by Travis (1930) in Oklahoma County is correct, and Patterson showed it in the same stratigraphic position on his map.

Green (1936) prepared a stratigraphic column of a large part of the Permian section along an approximately east-west line immediately north of Oklahoma County, probably within the OCMA (Fig. 3). He recognized the following stratigraphy (oldest to youngest): Garber-Wellington, Hennessey Shale, Duncan Sandstone, Cedar Hills Sandstone (local), Flowerpot Shale (Fig. 2A). Green (1936, p. 1463) maintained that the Iconium Shale Member described by Patterson (1933) at the top of the Wellington becomes sandy south of Logan County and that the Wellington, therefore, cannot be distinguished from the Garber. He said little about the Hennessey, except to note that "in central Oklahoma, formation boundaries must necessarily follow lithologic contacts which are gradational both vertically and laterally. These formation contacts transgress lines of time" (Green, 1936, p. 1465). Green (1936) mapped the Duncan Sandstone as an irregular wedge within the Flower Pot [*sic*] Shale.

Later Work

After the intial flurry of papers in the 1920s and 1930s, few studies of the surface geology of the OCMA were published for about 20 years. In 1954, Miser published a new geologic map of Oklahoma at a scale of 1:500,000 (Miser, 1954). He recognized different stratigraphic sections north and south of the North Canadian River (Fig. 2B). On Miser's (1954) map, the Garber Sandstone and Wellington Formation are combined into a single unit south of the river; north of the river, they are mapped separately. North of the river, the map shows the upper part of the Hennessey Shale as the Cedar Hills Sandstone Member; south of the river, the Cedar Hills is absent. Miser (1954) included northward-thinning beds equivalent to the Chickasha Formation and Duncan Sandstone in the middle part of the Flowerpot Shale and, following Becker (1930), included all the units above the Hennessey in the El Reno Group.

Armstrong (1958) and Gillum (1958) each produced a detailed geologic map of a part of Canadian County at a scale of about 1:40,000. The eastern parts of both maps are within the OCMA (Fig. 3). As in Miser (1954), there are significant differences in the stratigraphy north and south of the North Canadian River (Fig. 2B). South of the river, Armstrong (1958) mapped a relatively straightforward sequence of (from oldest to youngest): Hennessey Shale, Duncan Sandstone, and Chickasha Formation. North of the river, Gillum (1958) mapped more complex relations (from oldest to youngest): Hennessey Shale, Cedar Hills Member of the Hennessey Shale (thins to south), and Flowerpot Shale, which includes a northward-thinning wedge of Duncan Sandstone and Chickasha Formation. Gillum (1958) included all units above the Hennessey in the El Reno Group. Only the Hennessey, Cedar Hills, and Duncan of Gillum (1958) and the Hennessey, Duncan, and Chickasha of Armstrong (1958) are present in the OCMA.

Mogg and others (1960) published a brief description of the stratigraphy of Canadian County in the western part of the OCMA, but they did not publish a map. They recognized (from oldest to youngest) the Hennessey Shale with the Cedar Hills Sandstone Member at the top, overlain by the Flowerpot Shale (Fig. 2B).

They did not recognize any of the stratigraphic complexities described by earlier workers.

Wood and Burton (1968) published the most recent detailed geologic map of Oklahoma County at a scale of about 1:95,000 (Fig. 3). Although their map is at a relatively large scale, they combined a number of units. For example, they maintained that the Garber Sandstone and Wellington Formation are not distinguishable in the area and that the contact is conformable and gradational. In addition, Wood and Burton (1968) mapped the Duncan Sandstone and Chickasha Formation together (Fig. 2B). The contact between the Garber-Wellington and Hennessey as mapped by Wood and Burton (1968) is essentially identical to that mapped by Miser (1954).

Perhaps the most controversial geologic map of the OCMA is that published by Bingham and Moore (1975) at a scale of 1:250,000. They appear to have resurrected, in part, the subdivisions of the Hennessey Shale originally proposed by Aurin and others (1926), but they also recognized two additional units (Fig. 2B). In subdividing the Hennessey into four formations, they elevated the Hennessey to group status. In addition, Bingham and Moore (1975) considered the Garber and Wellington to be part of the Sumner Group. Bingham and Moore (1975) recognized the following stratigraphy in the OCMA (from oldest to youngest): Wellington Formation; Garber Sandstone; Hennessey Group, including Fairmont Shale, Kingman Siltstone, Salt Plains Formation, and Bison Formation (with Reeding Sandstone Bed at base); Duncan Sandstone (Fig. 2B). The authors gave no explanation for their subdivision of the Hennessey.

The most recent reports that refer to the geology of OCMA are Carr and Marcher (1977) and Parkhurst and others (1996). These authors accepted the terminology used by Bingham and Moore (1975) and did not attempt to evaluate critically the stratigraphy.

Stratigraphic Studies of the OCMA

The following discussion reviews the history of the stratigraphic nomenclature of the Permian geologic units in the OCMA. Figures 4A and 4B show the type localities of these units.

Wellington Formation

Nomenclator: F. W. Cragin, 1896.

Type Locality: The town of Wellington, Sumner County, Kansas (Fig. 4A).

Character: At type locality, bluish-gray, greenish, and reddish shales, and thin beds of sandstones, including beds of impure limestone, calcareous shales, and rare beds of dolomite and gypsum.

Thickness: 255 ft at type locality.

Cragin (1885, p. 86) casually alluded to "Wellington shales" but did not determine an age for the strata. Subsequent discovery of plant and vertebrate fossils enabled Cragin to determine that the Wellington Formation is Permian, and he formalized the name at that time (Cragin, 1896, p. 3, 16). Aurin and others (1926, p. 793–794) applied the term "Wellington" to rocks in central Oklahoma and considered them a subdivision of the Enid Group; they described the formation as follows: "The Wellington is made up of alternating beds of red shales and red sandstones....The top of the Wellington is the base of the lowest heavy sandstone of the Garber formation." Southward from Kansas, the characteristics of the Wellington change; the shale becomes red and sandstones become more abundant. South of the Cimarron River, the Wellington Formation consists of red sandstone alternating with beds of red shale, which is very different from its character at its type locality (Aurin and others, 1926, p. 791–792).

Patterson (1933, p. 248–249) proposed that the Wellington Formation be divided into a lower member (Fallis Sandstone) and an upper member (Iconium Shale) (Fig. 2A). The Fallis Sandstone Member was named for the town of Fallis, sec. 29, T. 15 N., R. 2 E., Lincoln County, Oklahoma (Fig. 4B), where it is ~240 ft thick. In this area, the Fallis "is at least 90 per cent sandstone ... [with] dolomitic conglomerates [and] shales lenses" (Patterson, 1933, p. 249), but northward it contains increasingly more shale, interbedded with the sandstones. The Iconium Shale Member is ~470 ft thick and was named for the small town of Iconium, sec. 10, T. 16 N., R. 1 E., Logan County, Oklahoma (Fig. 4B). The Iconium "is about 65 per cent shale" in its lower part and "contains more sandstone beds with the shale beds" in its upper part (Patterson, 1933, p. 249). "The shales of the Iconium are red, blocky, non-laminated, and contain calcareous or dolomitic material in the form of septarian concretions and veined geodes. The sandstones are friable, reddish brown to gray, micaceous, and cross-bedded" (Patterson, 1933, p. 250). Patterson (1933, p. 251) included the Evansville and Lowrie Sandstone beds within the Iconium and noted that they are "massive, cross-bedded, friable, and reddish-brown in color," that is, that they are similar to all the other sandstone beds in the Iconium. The change from Wellington to the overlying Garber Formation is gradational and both units are thought to be delta deposits (Patterson, 1933).

Garber Formation

Nomenclators: F. L. Aurin, H. G. Officer, and C. N. Gould, 1926.

Type Locality: The town of Garber, in eastern Garfield County, Oklahoma (Fig. 4B).

Character: Cross-bedded, more or less lenticular, commonly conglomeratic, massive, red sandstone, interstratified with beds of red fissile shale and sandy shale.

Thickness: 600 ft in type area.

Aurin and others (1926, p. 795) proposed that the Garber Formation "include a series of red clay shales, red sandy shales, and red sandstones lying above the Wellington." They also divided the Garber into two members—the lower Lucien Shale Member, named for the village of Lucien, secs. 19 and 30, T. 21 N., R. 2 W., in western Noble County, Oklahoma (Fig. 4B), and the upper Hayward Sandstone Member, named for the village of Hayward, sec. 22, T. 21 N., R. 3 W., in southeastern Garfield County, Oklahoma (Fig. 4B). The Lucien Member is 250 ft thick and "is composed largely of red, more or less fissile or laminated clay shales with several ledges of red sandstone" (Aurin and others, 1926, p. 794). The Hayward Member is 350 ft thick and "consists for the most part of heavy ledges of massive red sandstone, more or less lenticular, generally cross-bedded and not uncommonly conglomeratic, interstratified with beds of fissile shale and sandy shale" (Aurin and others, 1926, p. 795).

Patterson (1933, p. 252) stated that there is no basis for distinguishing the Lucien Shale and Hayward Sandstone Members of the Garber in Logan County (which is south of their type localities). He described the Garber in Logan County as follows:

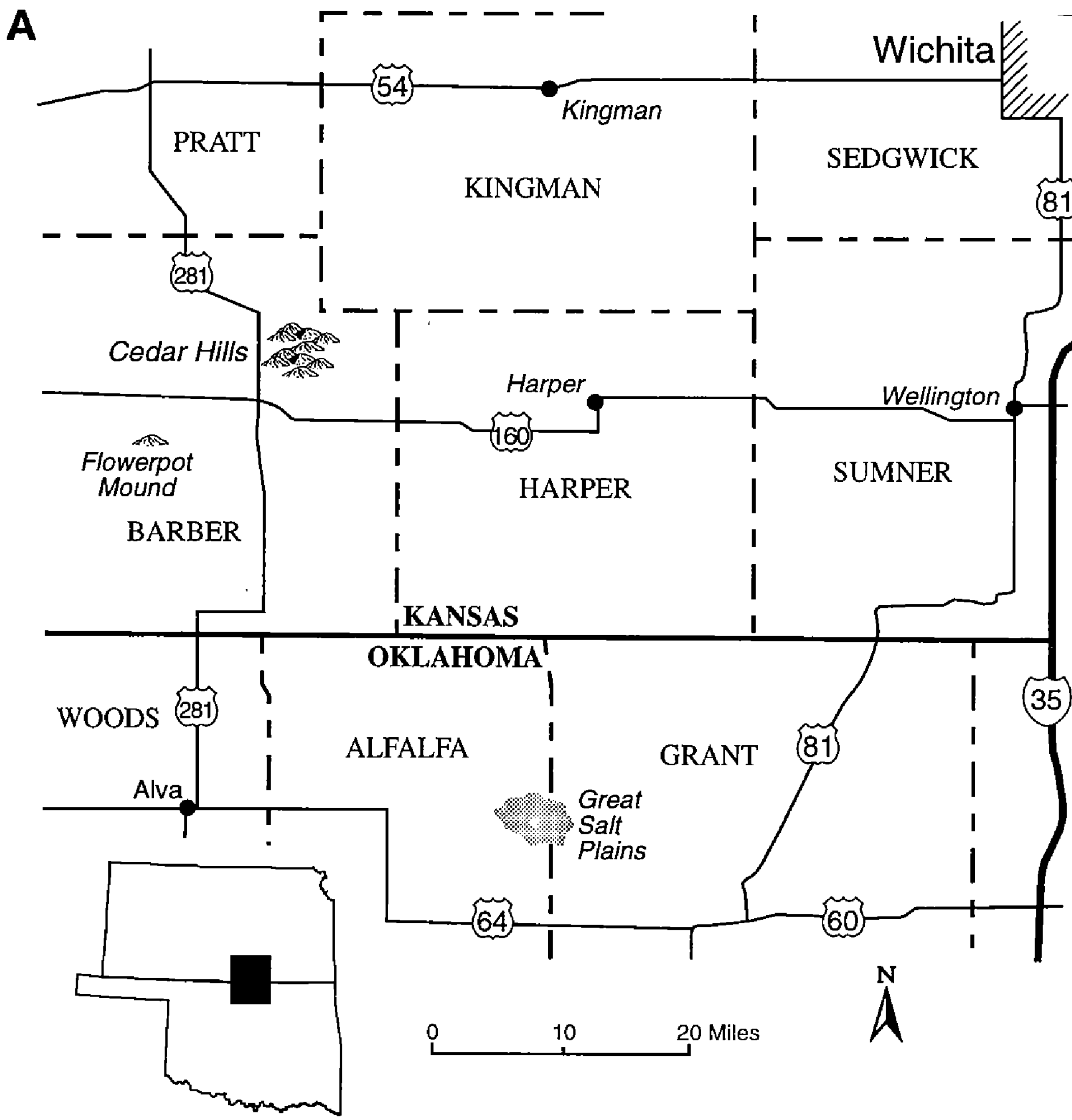
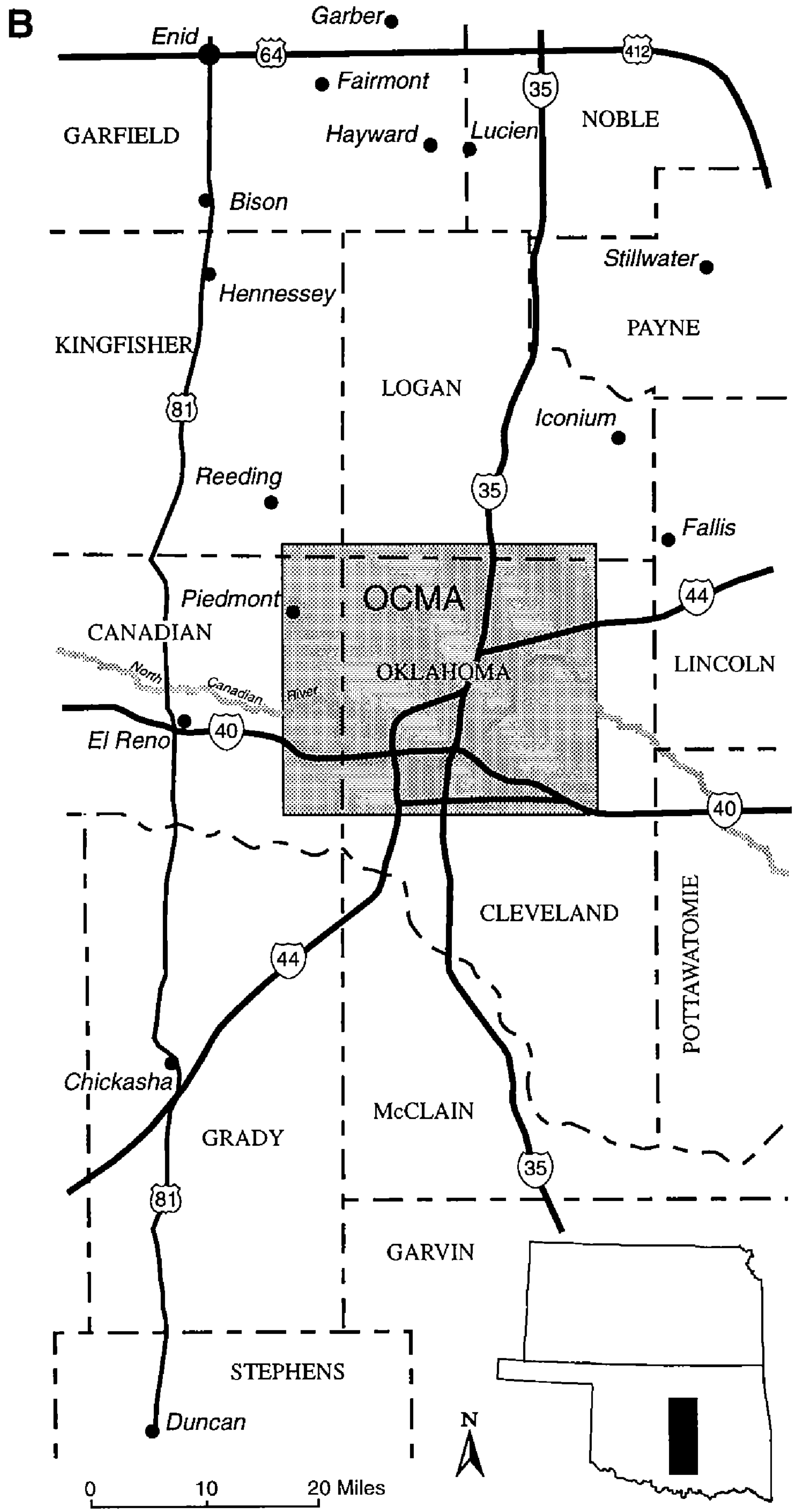


Figure 4. A—Map showing the type localities (mostly from south-central Kansas) of Permian units previously mapped or correlated with units in the OCMA. B*(opposite page)*—Map showing the type localities of various Permian units previously mapped in central Oklahoma (that may or may not be mappable in the OCMA). Type localities are in italics.

"The sandstones of the Garber are gray to reddish brown....The sandstones are friable and cross-bedded. They contain concretionary iron and barite rosettes....The shales of the Garber of Logan County are red, non-laminated, and sandy.... Dolomitic conglomerates are generally intermittently exposed at the bases of the sandstones" (Patterson, 1933, p. 253).

Placement of the top of the Garber has caused considerable controversy in the past (Graham, 1933, p. 562–563). The problem arises because sandstone beds resembling the Garber are interbedded with red shales in the basal 50 ft of the overlying Hennessey Formation (Patterson, 1933, p. 254). However, these sandstone


B
Garber
Enid
64
412
Fairmont
35
NOBLE
GARFIELD
Hayward
Lucien
Bison
Stillwater
Hennessey
PAYNE
KINGFISHER
LOGAN
81
Iconium
Reeding
35
Fallis
OCMA
Piedmont
44
CANADIAN
OKLAHOMA
LINCOLN
North Canadian River
El Reno
40
40
CLEVELAND
44
POTTAWATOMIE
Chickasha
McCLAIN
GRADY
35
81
GARVIN
STEPHENS
N
Duncan
0
10
20 Miles

beds are lenticular, rarely more than 5 ft thick, and are usually very fine grained (finer grained than any of the sandstones in the Garber Formation).

Hennessey Formation

Nomenclator: F. L. Aurin, H. G. Officer, and C. N. Gould, 1926.

Type Locality: The town of Hennessey in northern Kingfisher County, Oklahoma (Fig. 4B).

Character: Predominantly rusty-red, blocky, rarely fissile shales and siltstones that are marked by white or light green bands, streaks, and spots and commonly break with a conchoidal fracture.

Thickness: 400 ft in type locality.

Aurin and others (1926, p. 797) proposed that the lower 250 ft of the Hennessey Formation be named the Fairmont Shale Member for the town of Fairmont, sec. 26, T. 22 N., R. 5 W., in Garfield County, Oklahoma (Fig. 4B). The interval "has scattered thin white or greenish bands or streaks [and] is composed of alternating hard and soft layers, which weather into characteristic benches and shoulders, forming minor topographic features" (Aurin and others, 1926, p. 796). Aurin and others (1926, p. 797) also proposed that the upper 150 ft of the Hennessey be named the Bison Banded Member for the town of Bison, sec. 19, T. 20 N., R. 6 W. and sec. 24, T. 20 N., R. 7 W., in southern Garfield County, Oklahoma (Fig. 4B). The Bison is composed of rusty-red, blocky clay-shales that "contain a considerable number of white or greenish bands or streaks of shale, here sandy, there calcareous. These bands or streaks are thicker and more numerous than those of the Fairmont member...[and] may be very persistent" (Aurin and others, 1926, p. 796–797). Aurin and others (1926, p. 797) placed the top of the Bison Banded Member (and the top of the Hennessey) at the base of the overlying Duncan Sandstone.

The Fairmont Member of the Hennessey Shale is the only part of the Hennessey recognized by Patterson (1933) in Logan County. He described it as "at least 90 per cent shale" with thin beds of fine sandstone. "The shales are red, blocky, non-laminated, sandy, and contain dolomitic concretions....Lenses of sandstone resembling the Garber sandstone immediately below, are found associated with the red shales of the basal 50 feet of the Fairmont. In certain areas, sand lenses of this zone cause confusion in correlating the top of the Garber, especially where they are exceptionally developed" (Patterson, 1933, p. 254).

Duncan Sandstone

Nomenclator: C. N. Gould, 1924.

Type Locality: Just north of the town of Duncan, Stephens County, Oklahoma (Fig. 4B).

Character: Ledge-forming white or buff sandstone, sometimes dolomitic, separated by shales (at the type locality).

Thickness: 75 to 250 ft.

"As exposed in northern Oklahoma, the Duncan consists of rather soft, friable, or shaly, red sandstone. It is commonly cross-bedded, locally conglomeratic, and not uncommonly interstratified with red shales" (Aurin and others, 1926, p. 798). The Duncan is equivalent to the uppermost of the Harper sandstones named in 1896 by F. W. Cragin in Harper County, Kansas (Fig. 4A). Aurin and others (1926, p.

797) carried the Harper sandstones southward into Oklahoma, where they constitute the Garber Formation, the Hennessey Formation, and the Duncan Sandstone. The uppermost sandstone was traced south through Grant, Garfield, Kingfisher, Canadian, and McClain Counties, where it correlates with the Duncan Sandstone in the area where the Duncan was named.

Chickasha Formation

Nomenclator: C. N. Gould, 1924.
Type Locality: The city of Chickasha, Grady County, Oklahoma (Fig. 4B).
Character: A series of variegated sandstones and shales that vary in lithologic character from place to place, known by the local name "purple sandstone."
Thickness: 175 ft.

Gould (1924, p. 329–330) traced the Chickasha Formation northward from its type locality and noted that it changed to brick-red gypsiferous shales with splotches and bands of white and green shale. Aurin and others (1926, p. 799) believed that the Chickasha included most of the Flowerpot Shale and probably the Cedar Hills Sandstone and "Salt Plain measures" of Cragin (1896). Cragin (1896) named the Flowerpot Shale for rocks exposed at Flowerpot Mound, Barber County, Kansas (Fig. 4A). He also named the Cedar Hills Sandstone (which underlies the Flowerpot Shale) for Cedar Hills in Harper County, Kansas (Fig. 4A). The shale underlying the Cedar Hills Sandstone was named the "Salt Plain measures" by Cragin (1896) (Fig. 4A). He stated that "the stratigraphic position of this salt zone may be seen in Kansas on the east slope of the Cedar Hills of Harper County and on the south side of the Salt Fork...below the bright red Cedar Hills sandstones" (Cragin, 1896, p. 22) (Fig. 4A). The upper limit of the Chickasha Formation is the Blaine Formation.

Summary of Geological Mapping and Stratigraphic Studies in the OCMA

Despite the greatly different scales and somewhat different stratigraphic sections used by geologists mapping in central Oklahoma, some general observations can be made, based on the authors' reading of the existing literature.

1) The Wellington Formation and Garber Sandstone are generally similar and, in places, difficult to distinguish. The members of the Wellington recognized by Patterson (1933) in Logan County (Fallis Sandstone, Iconium Shale) have not been recognized in the OCMA.

2) Most workers have not been able to recognize the two members of the Garber Sandstone (Lucien Shale, Hayward Sandstone) identified by Aurin and others (1926).

3) The Garber-Hennessey contact is mapped very differently by different workers. Most authors (e.g., Travis, 1930; Miser, 1954; Wood and Burton, 1968) show it striking approximately north-south through Edmond. Other authors (e.g., Aurin and others, 1926; Bingham and Moore, 1975) map the contact farther to the west.

4) The Garber-Hennessey contact is imprecisely defined because (a) it is gradational, (b) there are shales similar to the Hennessey in the upper part of the Garber, and (c) there are sandstones similar to the Garber in the lower part of the Hennessey.

5) There is no agreement on possible subdivisions of the Hennessey Shale.

6) The top of the Hennessey is shown in the southwest corner of the OCMA on all the geologic maps of the area.

7) Most of the geologic maps show the Duncan Sandstone overlying the Hennessey. Miser (1954) shows Flowerpot but states that the Flowerpot is equivalent, in part, to the Duncan and Chickasha.

Mapping and Stratigraphic Problems

Since the various stratigraphic units discussed above were named, numerous correlation problems have arisen. To solve some of these problems, some geologists have subdivided named geologic units and, in doing so, have changed their ranks. For example, Bingham and Moore (1975, pl. 1) elevated the rank of the Hennessey from formation to group and thus gave formation status to the existing Fairmont and Bison Members (Fig 2B). They introduced the term "Kingman Siltstone"—probably derived from the Kingman Sandstone Member of the Harper Formation (named in Kansas for the town of Kingman [Norton, 1937, p. 1557]) (Fig. 4A)—as well as the term "Salt Plain[s]" Formation, also a Kansas name. None of these changes followed procedures recommended in the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983), nor was any evidence presented indicating how these names were carried southward into north-central Oklahoma.

Another problem is that certain members of a particular formation may be similar. Aurin and others (1926) admitted that the distinction between their Fairmont Shale (lower) and Bison Banded (upper) Members is not always easy to recognize.

The use of informal terms, such as the "Reeding Sandstone" and the "Piedmont Sandstone," has created confusion (Fig. 2B). On a "projected cross section," Schweer (in Brown, 1937, fig. 9) showed the Reeding at the base of the Cedar Hills Member of the Hennessey Formation and the Piedmont at the top. Although Schweer (in Brown, 1937, fig. 9) shows them extending from northwestern Oklahoma to Canadian County (in the OCMA), Gillum (1958, p. 14) maintained that they "were used in a very local sense and have not been adopted in the literature." Bingham and Moore (1975) resurrected the names but named the upper member of the Hennessey the Bison Formation, and put the Piedmont at the base of the overlying Cedar Hills Sandstone (Fig. 2B).

Although the lack of consistency in descriptions of the various stratigraphic units in the OCMA map area (particularly in definitions of boundaries) is the main problem, other problems exist. Relationships of various units are difficult to interpret in the field because of extensive cover. In addition, the units may contain no continuous mappable beds or formation contacts. Correlation of stratigraphic units is hampered by numerous wide flood plains and terrace deposits that are present in the area.

Specific OCMA Mapping Objectives

A major objective of the OCMA geologic mapping project is to clarify the relationships of the various rock units within the map area. The specific objectives listed here will help achieve that goal.

1) To identify, if possible, the named members of the Wellington Formation in the map area. If this is possible, the Iconium Shale Member of the Wellington may be distinguishable from the base of the Garber.

2) To distinguish, if possible, the Garber Formation from the Wellington Formation in the map area. If this is possible, establish the criteria for identifying the contact.

3) To identify, if possible, the named members of the Garber Formation in the map area.

4) To determine if the most recently published formations (members?) in the Hennessey Group (Formation?) (see Bingham and Moore, 1975, pl. 1) can be recognized in the map area. Can the Kingman Siltstone and the Salt Plain[s] Formation be correlated with the stratigraphic units of the same names where they were named in Kansas, or, should the Fairmont and Bison Banded Members of the Hennessey, as originally proposed by Aurin and others (1926), be applied in the OCMA (if they can be recognized)?

5) To determine how the term Cedar Hills should be applied. Is it a member of the Hennessey Formation (e.g., as shown in Miser [1954]), or is it the basal formation of the El Reno Group, which is stratigraphically higher (Bingham and Moore, 1975)? Schweer (in Brown, 1937, also 1939) proposed the names "Piedmont Sandstone" and "Reeding Sandstone" for the light-colored units at the top and bottom of the Cedar Hills Formation, respectively. However, Bingham and Moore (1975, pl. 1) indicate that the Piedmont Sandstone is the basal bed of the Cedar Hills Formation, the easternmost outcrop of which is ~11 mi northwest of the town of Piedmont. They show the area around Piedmont as being within the Bison Formation, which suggests that the sandstone that crops out around Piedmont is at the base of the Bison and, therefore, is Reeding Sandstone.

We believe that detailed field investigations and new geologic mapping at a 1:24,000 scale will contribute significantly towards clarifying the Permian stratigraphy in the OCMA map area.

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Oklahoma City Couple Donates Fossils to OGS for Use in Schools

Granville and Minnie Lee Morgan donated to the OGS thousands of fossils that will be used in kits for teachers to use in their classrooms.

The Oklahoma Geological Survey recently received a very generous donation of fossil specimens from Mr. Granville Morgan of Oklahoma City. The fossils include both vertebrates and invertebrates and number in the thousands.

Granville Morgan and his wife, Minnie Lee, are lifetime members of the Oklahoma Mineral and Gem Society, which they joined in 1959. Self-taught amateur collectors, the Morgans have been sharing both their knowledge as well as sharing the many mineral, rock, gem, and fossil specimens they have collected over the past 38 years. Granville collects fossils, Minnie Lee collects mineral crystals, and they both collect Indian artifacts.

Though they had no formal training in fossils or minerals, the Morgans had a strong desire to learn. In their pursuit of knowledge, they amassed books and field guides on the subjects of collecting, cleaning, and identifying minerals and fossils. During their working years they planned vacations to sites where they could add to their collections. They have gathered specimens in nearly all of the states except for Florida and the New England area. In addition, they have taken field trips in Mexico and Alaska.

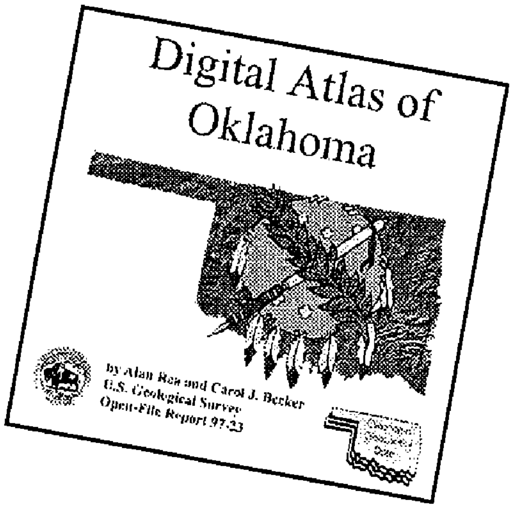
The Morgans have attended numerous gem and mineral shows, often displaying some of their specimens in competition. Perhaps the most gratifying experience of Granville's life occurred in 1959 when he was invited to present a "show and tell" program about his hobby of collecting minerals and fossils to elementary students at Sequoyah School in Oklahoma City. According to Granville, the students were enthusiastic and eager to learn. The following week he was rewarded for his visit when he received a packet of 27 letters from the students and one from the teacher, Mrs. E. Railey. This experience launched Granville's life onward, not only toward his continued quest for knowledge regarding the collecting and identifying of fossils and minerals, but more importantly, toward his continued desire and willingness to share with others. At 91, Granville finds life's challenges worthwhile.

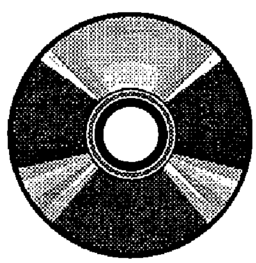
Through the generosity of the Morgans' fossil donations, schoolchildren throughout the State of Oklahoma will benefit well into the future. The specimens will be used to prepare fossil kits for Oklahoma earth science teachers to use with students in grades 1–12. Teachers will be able to use the fossils to make earth science learning fun in the classroom and laboratory. Again, many thanks, Granville and Minnie Lee, for your very thoughtful educational gift to Oklahoma's public schools.

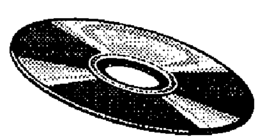
—James R. Chaplin

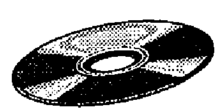
Digital Atlas of Oklahoma Offered by OGS

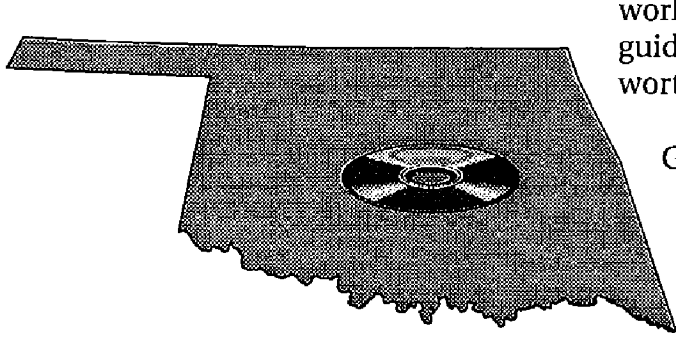
New viewer supports Windows 95 and Windows NT









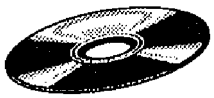


A new viewer for the *Digital Atlas of Oklahoma* CD-ROM, designed especially for Windows 95 and Windows NT users, is now available. ArcExplorer is data-viewing software created by Environmental Systems Research Institute, Inc. (ESRI) that can be used to view the data sets on the *Digital Atlas of Oklahoma* CD. It can also be used as a stand-alone viewer to display and query other GIS (geographical information system) data, but it will not function as a development application. ArcExplorer runs only on personal computers using Windows 95 or Windows NT (with Service Pack 3) operating systems, neither of which can use the ArcView Version 1.0 contained on the Oklahoma CD.

There are two ways to obtain ArcExplorer. If you have Internet access, ArcExplorer may be downloaded free from ESRI's homepage at: www.esri.com. In addition, ArcExplorer has been packaged on four 3.5-in. diskettes available for sale only through the Oklahoma Geological Survey.

ESRI has also provided the Oklahoma Geological Survey with a CD-ROM containing ArcExplorer, non-Oklahoma map data, and information about GIS, and other ESRI products. This is a free CD that will be shipped with the *Digital Atlas of Oklahoma.* It has been found that this version of ArcExplorer does not work on all computers, but the GIS guided tour and other data are well worth viewing.

With the new viewer, the Oklahoma Geological Survey will continue to offer for sale the *Digital Atlas of Oklahoma* CD-ROM by Alan Rea and Carol J. Baker of the U.S. Geological Survey. The



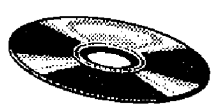
Oklahoma CD contains 25 digital-map data sets, providing basic Statewide geographic data for use with GIS software. Most of the data sets were developed from 1:100,000-scale maps (1 in. = ~1.6 mi) and provide a level of spatial detail convenient for users interested in geographic areas ranging from a few square miles to watersheds, a county, or the entire State. Compilation of the data sets contained on the Oklahoma CD was funded under a cooperative Joint Funding Agreement between the Oklahoma State GIS Council and the U.S. Geological Survey.

ArcExplorer may be downloaded free from ESRI's World Wide Web site at: ***www.esri.com***

Users of the Oklahoma CD have access to a wide range of information about Oklahoma. Numerous data sets are included under the main directory, DATA_ARC. DATA_ARC contains the subdirectories A_SHDRLF, A_STATE, and one for each county. A_SHDRLF represents a shaded relief map of Oklahoma. A_STATE contains subdirectories including administrative boundaries; county boundaries; latitude lines; longitude lines; Oklahoma names; indexes of the USGS 1:100,000- and 1:250,000-scale topographic quadrangles; State and federal legislative district boundaries; watershed district boundaries; and locations of weather stations. Each county subdirectory includes data sets for elevation contours and point data; roads; school district boundaries; streams; names; sections, townships and ranges; census data; and an index to the USGS 1:24,000-topographic quadrangles.

The *Digital Atlas of Oklahoma* CD-ROM is intended to benefit both new and experienced GIS users. Alan Rea, USGS hydrologist and principal author, said, "The real power of the GIS comes into play when people use the GIS to analyze their own information in a geographic context. Realtors might bring in their multiple listings, a marketer might use GIS to analyze the competition's service areas, a traffic engineer might display accident reports, or an environmental scientist might want to provide a digital framework upon which people can build applications to suit their information needs."

The *Digital Atlas of Oklahoma* CD-ROM is available in two formats. The first includes the ArcView, Version 1.0 viewing program for Windows 3.1 computer operating systems. This also is the format to order if you have Windows 95 or NT, but you will need to obtain a copy of the ArcExplorer viewing program. The second format is a transfer version that requires separate GIS viewing software. The Oklahoma CD is designed for IBM-compatible PCs, but Macintosh users can view the information if they have appropriate Mac-compatible GIS software.



Copies of the *Digital Atlas of Oklahoma* and ArcExplorer viewing software can be ordered from the Oklahoma Geological Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031 or (800) 330-3996; fax (405) 325-7069, or purchased over the counter at the OGS Publications Sales Office at 1218-B W. Rock Creek Road, Norman; phone (405) 360-2886; fax (405) 366-2882. The *Digital Atlas of Oklahoma* CD-ROM and the ArcExplorer viewing software on four 3.5-in. diskettes cost $5.00 each. For mail orders, add 20% per order.

—T. Wayne Furr

NEW OGS *Publications*

SPECIAL PUBLICATIONS: ***Fluvial-Dominated Deltaic (FDD) Oil Reservoirs in Oklahoma*** workshop volumes:

- **97-3.** ***The Tonkawa Play,*** by Jock A. Campbell and others, 74 pages, 5 plates.
- **97-5.** ***The Cleveland and Peru Plays,*** by Jock A. Campbell, Robert A. Northcutt, and others, 105 pages, 10 plates.
- **97-6.** ***The Bartlesville Play,*** by Robert A. Northcutt and others, 98 pages, 4 plates.

Price: $6 per volume. *The Tonkawa Play* also is sold as part of a set for $10 (see paragraph at top of next page).

These three volumes complete a series of eight publications addressing fluvial-dominated deltaic (FDD) light-oil reservoirs in Oklahoma, a project jointly funded by the Bartlesville Project Office of the U.S. Department of Energy and by the State of Oklahoma. The publications contain the material covered in workshops on the Cleveland and Peru plays (held October 1996); the Tonkawa play (July 1997); and the Bartlesville play (October and November 1997).

The scope of the FDD project and the significant features of FDD reservoirs is described by Richard D. Andrews and others in Part I of each publication. Depositional environments are related to reservoir properties in order to provide a better understanding of the individual FDD reservoirs identified in the project.

The Tonkawa Play **(SP 97-3).**— Jock A. Campbell presents an overview of Tonkawa FDD areas in Oklahoma. Kurt Rottmann describes a study of the Tonkawa sand reservoir in the Blackwell oil field in Kay County, Oklahoma. The results of a simulation of a Tonkawa sand reservoir in the Blackwell oil field are presented by R. M. Knapp, Z. Samad, and C. Xie.

The Cleveland and Peru Plays **(SP 97-5).** — Jock Campbell provides an overview of Cleveland FDD areas in this report, and Kurt Rottman presents the field study of the Pleasant Mound oil field, a Cleveland reservoir. The results of a simulation of Pleasant Mound field are explained by R. M. Knapp and X. H. Yang. Robert A. Northcutt discusses Peru play geology and presents a field study of the Hogshooter field, a Peru reservoir, with contributions by Bruce Carpenter.

The Bartlesville Play **(SP 97-6).** — Robert A. Northcutt provides an overview of Bartlesville FDD areas. Richard D. Andrews presents the field studies of the Paradise field, NW Russell field, and is coauthor of the study on the Ohio-Osage field. R. M. Knapp, C. Xie, and Z. Samad describe a simulation of the Bartlesville reservoir in Paradise field.

All three publications contain core descriptions and well logs. Digital images of select rock intervals also are included for the Tonkawa play and the Bartlesville play volumes.

The three lead geologists on the FDD team are OGS geologists Richard D. Andrews and Jock A. Campbell, and consultant geologist Robert A. Northcutt, Oklahoma City. Kurt Rottmann and Bruce Carpenter are consultant geologists.

R. M. Knapp is the petroleum engineer for the FDD project and is a professor in the OU School of Petroleum and Geological Engineering. Z. Samad, C. Xie, and X. H. Yang are graduate students or former graduate students in petroleum engineering.

The Tonkawa Play (SP 97-3) also can be purchased as a set with **OGS Open-File Report 3-97, *The Marine Tonkawa Sands: Natural Gas and Associated Liquids Production in the Anadarko Basin*.** Material from this 57-page report was presented at the workshop also. Part 1 of OF 3-97, "Regional Synthesis of Marine Tonkawa Sand in the Anadarko Basin," is by Carlyle Hinshaw, petroleum geologist with the University of Oklahoma's Geo Information Systems research unit. Part 2, "Waynoka NE Field Tonkawa Sand Reservoir Study," is by Kurt Rottmann. Purchased as a set SP 97-3 and OF 3-97 cost $10; OF 3-97 purchased alone costs $6.

SPECIAL PUBLICATION 97-4. ***Oklahoma Oil and Gas Production by Field, 1993–96.*** 441 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 1993 through 1996 by type of product: oil, condensate, total liquids, associated gas, natural gas, and total gas;
- Cumulative production from 1979 through 1996 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 424,700 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.

CIRCULAR 100. ***Ames Structure in Northwest Oklahoma and Similar Features: Origin and Petroleum Production (1995 Symposium),*** edited by Kenneth S. Johnson and Jock A. Campbell. 396 pages, 41 contributions. Price: Hardcover, $15.

From the editors' preface:

The transfer of technical information will aid in the search for, and production of, our oil and gas resources. To facilitate this technology transfer, the Oklahoma Geological Survey (OGS) and the Bartlesville Project Office of the U.S. Department of Energy (BPO-DOE) cosponsored a symposium dealing with the search for, and production of, oil and gas resources from meteorite-impact craters. The focus of the symposium was on the Ames structure, an Early Ordovician circular structure formed in northwestern Oklahoma by meteorite impact, volcanic activity, or dissolution and collapse. The structure is 6–10 mi across, is buried by 9,000 ft of younger sedimentary units, and is a prolific source of oil and gas. Information also was presented on similar features elsewhere in the world. The symposium was held on March 28–29, 1995, at the Oklahoma Center for Continuing Education, The University of Oklahoma, Norman. This volume contains the proceedings of that symposium.

Research reported upon at the symposium focused on meteorite-impact craters, exploration, hydrocarbon occurrences, reservoir characterization, geochemistry, remote sensing, recognition criteria, and alternative interpretations for the origin of the Ames structure. In describing the Ames structure and similar features, and their related petroleum reservoirs, the researchers have increased our understanding of how the geologic history of an area can affect reservoir heterogeneity and our ability to efficiently recover the hydrocarbons they contain. We hope that the symposium and these proceedings will bring such research to the attention of the geoscience and energy-research community and will help foster exchange of information and increased research interest by industry, university, and government workers.

Twenty-four papers were presented orally at the symposium, and they are presented in this volume as full papers or abstracts. An additional 17 reports were given as posters, and they are presented as short reports or abstracts. In each of the two parts of this volume, papers are arranged as follows: (1) general papers on impact craters, (2) the Ames structure, and (3) similar features elsewhere in North America. About 225 persons attended the symposium. Stratigraphic nomenclature and age determinations used by the various authors in this volume do not necessarily agree with those of the OGS.

This is the eighth symposium in as many years dealing with topics of major interest to geologists and others involved in petroleum-resource development in Oklahoma and adjacent states. These symposia are intended to foster the exchange of information that will improve our ability to find and recover our nation's oil and gas resources. Earlier symposia covered the Anadarko basin (published as OGS Circular 90), Late Cambrian–Ordovician geology of the southern Midcontinent (OGS Circular 92), source rocks in the southern Midcontinent (OGS Circular 93), petroleum-reservoir geology in the southern Midcontinent (OGS Circular 95), structural styles in the southern Midcontinent (OGS Circular 97), deltaic reservoirs in the southern Midcontinent (OGS Circular 98), and Simpson and Viola Groups in the southern Midcontinent (OGS Circular 99).

OGS SP 97-3, SP 97-4, SP 97-5, SP 97-6, OF 3-97, and Circular 100 can be purchased by mail from the Survey at 100 E. Boyd, Room N-131, Norman, OK 73019; 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.

GSA South-Central Section Annual Meeting
Norman, Oklahoma March 22–24, 1998

The School of Geology and Geophysics at the University of Oklahoma and the Oklahoma Geological Survey will host the annual meeting of the South-Central Section of the Geological Society of America. The meeting will be held on the OU campus.

The following agenda is planned:

Symposia

Innovative Ideas for College-Level Field Trips and Labs
Application of Trace Elements and Isotopes to Igneous and Sedimentary Systems
Geologic Mapping (STATEMAP)
Climatic Signals in Paleozoic Strata of the Mid-Continent
Basinal Fluids
Near-Surface Geophysics
Rock Deformation and Structure Style
Mid-Continent Basement Character
Taphonomy: New Looks at Fossilization
Geoscience Information
Geology and Travel: Historical Perspective
Pennsylvanian/Permian Boundary—New Biostratigraphic and Sequence Stratigraphic Data
Geophysics at the Norman, Oklahoma, Landfill

Workshop

Learning from the Fossil Record, *March 22*

Field Trips

Premeeting

Basement Rocks of the Southern Oklahoma Aulacogen, *March 20–22*
Biostratigraphy and Sequence Stratigraphy of the Pennsylvanian/Permian Boundary in Kansas and Oklahoma, *March 20–22*
Sequence Stratigraphy of the Middle Carboniferous of the Southwestern Ozark Mountains, *March 20–22*

Postmeeting

Stratigraphy and Depositional Environments of the Lower Permian, Oklahoma City Metro Area, Oklahoma, *March 25*

For further information about the meeting, contact Sara Moody, School of Geology and Geophysics, University of Oklahoma, 100 E. Boyd, Suite 810, Norman, OK 73019; (405) 325-3253, fax 405-325-3140.

Pennsylvanian and Permian Geology— A Workshop ✯ Norman, Oklahoma, April 4–5, 1998

"Pennsylvanian and Permian Geology in the Southern Midcontinent" is the theme of a two-day workshop cosponsored by the Oklahoma Geological Survey and the Bartlesville Project Office of the U.S. Department of Energy. The workshop will be held at the Postal Service National Center for Employee Development (formerly the Postal Service Technical Training Center) in the southeastern part of Norman.

This workshop will transfer technical information to aid in the search for, and production of, oil and gas resources. It will focus on rocks, events, and resources of the Pennsylvanian and Permian Periods. Clastics and carbonates of this age are major sources of oil and gas in the southern Midcontinent, and they have great potential for additional recovery using advanced technologies. This is the 11th workshop in as many years; each program has covered a special topic on exploration for, and development of, petroleum resources in Oklahoma and adjacent states.

The preliminary program for talks and posters is listed below:

Oral Presentations

Tectonic Overview of the U.S. Southern Midcontinent During the Pennsylvanian-Permian—Thomas L. Thompson, Thompson's Geo-Discovery, Inc., Boulder, CO; and Jim R. Howe, Boulder, CO

Geology and Petroleum Reservoirs in Pennsylvanian and Permian Rocks of Oklahoma—Kenneth S. Johnson, OGS; Robert A. Northcutt, Independent Geologist, Oklahoma City; and G. Carlyle Hinshaw, Geo Information Systems, Norman

Sequence Stratigraphy and Stratigraphic Framework of the Upper Morrow, Anadarko Basin—Zuhair Al-Shaieb and Jim Puckette, Oklahoma State University

Major Pennsylvanian Deltaic Systems in Oklahoma—Robert A. Northcutt; Rick Andrews and Jock Campbell, OGS; and G. Carlyle Hinshaw

Analysis of Morrow Incised-Valley Producion, State Line Trend, Northern Anadarko Basin—Roderick W. Tillman, Consulting Geologist/Stratigrapher, Tulsa

Enhancing "Limited" Log Suites Using Neural Networks: Lower Pennsylvanian Morrow Sandstones, Beaver County, Oklahoma—Jeff S. Arbogast, Applied Neural Networks, LLC, Denver; and Mark Franklin, Rocky Mountain Petrophysics, Aurora, CO

Hydrocarbon Prospecting Using "Quick Look" Bulk-Volume Water: Example from Morrowan Sandstone, Anadarko Basin, Oklahoma—Mark Franklin

Sequence Stratigraphy of the Red Fork Sandstone—Richard D. Fritz and Larry D. Gerkan, MASERA, Tulsa

The Impact of Drilling and Completion Practices on Red Fork Recovery in the Anadarko Basin—Robert F. Shelley, Halliburton Energy Services, Oklahoma City; and Paul W. Smith, Petroleum Information/Dwight's, Oklahoma City

Geochemical Characteristics of Selected Pennsylvanian Oils and Rocks—R. Paul Philp, University of Oklahoma; and H. Wang, ARCO, Plano, TX

Interpretation of Red Fork Incised Valleys Using 3-D Seismic, Watonga-Chickasha Trend, Anadarko Basin, Oklahoma—Richard J. Bottjer, Coal Creek Resources, Louisville, CO; S. Lynn Peyton, Texaco, Denver; and Al Warner, Consulting Geologist, Oklahoma City

Oklahoma Coalbed-Methane Completions—Brian J. Cardott, OGS

Structural Geometry and Evolution of Thrust Faulting in the Wilburton Triangle Zone and its Eastern Continuation, The Frontal Ouachitas-Arkoma Basin Transition Zone, Southeastern Oklahoma—Ibrahim Cemen, Zuhair Al-Shaieb, Jeff Ronck, Justin Evans, and Syed Mehdi, Oklahoma State University

Permian Sedimentation and Diagenesis in the Northern Margin of the Wichita Uplift—R. Nowell Donovan, Texas Christian University

Reservoir Characterization of the Giant Hugoton Gas Field, Kansas—Jack A. Babcock, T. M.

Olson, K. V. K. Prasad, S. D. Boughton, P. D. Wagner, M. H. Franklin, and K. A. Thompson, Amoco Production Co.

Depositional and Diagenetic Origins of Sandstone Reservoirs in the Queen Formation, Permian Basin of Texas—Jim Mazzullo, Texas A&M University

Facies and Sequence Stratigraphy of the Late Permian Yates Formation on the Western Margin of the Central Basin Platform of the Permian Basin—Ron Johnson and Jim Mazzullo, Texas A&M University

Rejuvenation of Underdeveloped Oil Fields in Permo-Penn Carbonates of New Mexico Yields Major Reserves—Ronald F. Broadhead, New Mexico Bureau of Mines and Mineral Resources

Trace and Rare-Earth Elemental Variation in a Midcontinent Carbonate Sequence—Recognition of Exposure Surfaces and Influence of Detritus—Peer Hoth, Michael Bau, and Peter Dulski, GeoForschungsZentrum Potsdam, Germany; and Timothy R. Carr, Kansas Geological Survey

Poster Presentations

Regional Stratigraphy and Reservoir Characteristics of the Red Fork, from the Shelf Through the Basin and into the Mountain-Front Washes—Walter J. Hendrickson and Paul W. Smith, Petroleum Information/Dwight's, Oklahoma City

Low Resistivity–Low Contrast Permian Red Cave Reservoirs in Southeastern Colorado—William T. Goff, Cholla Production, LLC, Denver

Geochemical Study of Oils Produced from Bartlesville, Red Fork, and Skinner Formations, Prairie Gem Field, Central Oklahoma—Elli Chouparova, University of Oklahoma; Kurt Rottmann, Independent Geologist, Oklahoma City; and R. Paul Philp

The Clear Fork Group (Leonardian, Lower Permian) of North-Central Texas—W. John Nelson, Illinois State Geological Survey; Robert W. Hook, University of Texas at Austin; and Neil Tabor, University of California at Davis

The Impact of Drilling and Completion Practices on Red Fork Recovery in the Anadarko Basin—Robert F. Shelley and Paul W. Smith

Overpressure and Hydrocarbon Generation in the Anadarko Basin, Southwestern Oklahoma—Youngmin Lee and David Deming, University of Oklahoma

Major Pennsylvanian Deltaic Systems in Oklahoma—Robert A. Northcutt, Rick Andrews, Jock Campbell, and G. Carlyle Hinshaw

Geology and Petroleum Reservoirs in Pennsylvanian and Permian Rocks of Oklahoma—Kenneth S. Johnson, Robert A. Northcutt, and G. Carlyle Hinshaw

The Evolution of the Meers Valley—R. Nowell Donovan

Depositional Facies of the Lower Permian Section, Northeastern New Mexico: Preliminary Observations and Paleoclimatic Implications—Jennifer Kessler and Gerilyn Soreghan, University of Oklahoma

Progress Report on Pennsylvanian-Permian Mapping in Oklahoma: The STATEMAP Project—Neil H. Suneson, LeRoy A. Hemish, and T. Wayne Furr, OGS; and Mark S. Gregory, Oklahoma State University

Integration of Lithofacies and Petrophysics: A Midcontinent Rock Catalog—Alan P. Byrnes, Kansas Geological Survey

Tectonic Overview of the U.S. Southern Midcontinent During the Pennsylvanian-Permian—Thomas L. Thompson and Jim R. Howe

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Registration Information

The fee for advance registration (prior to March 20) is $50, and includes two lunches and a copy of the proceedings. Late and on-site registration will be $70 per person. Lodging will be available at the Postal Service NCED and local hotels/motels. **For more information,** contact Kenneth S. Johnson, General Chair, or LeRoy Hemish, Poster Chair, Oklahoma Geological Survey, University of Oklahoma, 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031 *or* (800) 330-3996; fax 405-325-7069. To request registration forms, contact Tammie Creel or Jan Coleman at the same location and numbers.

UPCOMING *Meetings*

Lunar and Planetary Science Conference, March 16–20, 1998, Houston, Texas. Information: LeBecca Simmons, LPI Publications and Program Services Dept., 3600 Bay Area Blvd., Houston, TX 77058; (281) 486-2158; e-mail: simmons@lpi.jsc.nasa.gov.

Society of Petroleum Engineers Roundtable, April 15–16, 1998, Houston, Texas. Information: Society of Petroleum Engineers, P.O. Box 833836, Richardson, TX 75083; (972) 952-9306; e-mail: dlipsher@spelink.spe.org.

National Earth Science Teachers Association, Annual Meeting, April 16–19, 1998, Las Vegas, NV. Information: NESTA, 2000 Florida Ave. N.W., Washington, DC 20009; (202) 462-6910, fax 202-328-0566.

Mid-America Paleontology Society National Fossil Exposition, April 17–19, 1998, Macomb, Illinois. Information: Tom Witherspoon, 6611 Miller Road, Dearborn, MI 48126.

Geographic Information Systems (GIS) Day at the Capitol, May 13, 1998, 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.

Petroleum Industry Trade Fair, May 14, 1998, Ardmore, Oklahoma. Information: Linda Nero, Marginal Wells Commission, 1218-B W. Rock Creek Road, Norman, OK 73069; (405) 366-8688 or (800) 390-0460, fax 405-366-2882.

American Association of Petroleum Geologists, Annual Meeting, May 17–20, 1998, Salt Lake City, Utah. Information: AAPG Conventions Dept., P.O. Box 979, Tulsa, OK 74101; (918) 560-2679, fax 918-560-2684.

Society for Sedimentary Geology, Annual Meeting, May 17–20, 1998, Salt Lake City, Utah. Information: SEPM, 1731 E. 71st St., Tulsa, OK 74136; (918) 493-3361.

Waterflood Workshop, June 10–11, 1998, Oklahoma City, Oklahoma. Information: Michelle Summers, Oklahoma Geological Survey, 100 E. Boyd, Room N-131, Norman, OK 73019; (405) 325-3031 or (800) 330-3996, fax 405-325-7069.

Major Forum on Industrial Minerals, May 2–6

The Oklahoma Geological Survey (OGS) has invited the prestigious Forum on the Geology of Industrial Minerals to come to Norman, Oklahoma, for their 34th annual meeting on May 2–6. The Program will focus on the geology, economics, production, and marketing of nonfuel, nonmetallic minerals in Oklahoma and surrounding states. Talks, posters, and field trips will provide a good overview of important local resources such as limestone, dolomite, silica sand, gypsum, salt, iodine, clays, and sand and gravel. The technical program, to be held in Norman on May 3–4, will be preceded by a one-day field trip to the Arbuckle Mountains on May 2, and will be followed by a two-day trip to northwest Oklahoma on May 5–6.

For further information and registration forms, contact the OGS at 100 E. Boyd, Room N-131, Norman, OK 73019; phone (405) 325-3031, fax 405-325-7069; e-mail <jlcoleman @ou.edu>.

The following are abstracts from theses prepared by graduates of the University of Oklahoma. Permission of the authors to reproduce the abstracts is gratefully acknowledged.

Basal Aquifers and Their Role as Conduits for Orogenic Fluids: A Paleomagnetic Case Study of the Colbert Rhyolite and Reagan Sandstone in the Arbuckle Mountains, Southern Oklahoma

TEREE CRISTI CAMPBELL, University of Oklahoma, Norman, M.S. thesis, 1995

Basal aquifers in the sedimentary section have received a great deal of attention in the recent geologic and geophysical literature as conduits for migration of orogenic/basinal fluids. Although numerous paleomagnetic studies have inferred that fluids have caused alteration and remagnetization in the rock record, few have directly studied the likely fluid conduits. Paleomagnetic and geochemical results from the Reagan Sandstone, the basal aquifer in the Paleozoic section, and the underlying Middle Cambrian Colbert Rhyolite Porphyry in the Arbuckle Mountains provide information on the pathways and the timing of fluid migration.

Samples of the lower, relatively unaltered Colbert Porphyry contain two components of magnetization: an easterly and shallow-to-moderate component interpreted to be a thermal remanent magnetization (TRM) residing in magnetite and a southeasterly and shallow component interpreted to be a chemical remanent magnetization (CRM) residing in hematite. A fold test suggests that the easterly and shallow-to-moderate magnetization could be primary and the paleopole position for this magnetization corresponds closely with other paleopoles of similar age. The upper Reagan Sandstone and Honey Creek limestone contain an easterly and shallow component of magnetization that resides in hematite and could be primary in origin. The pole positions (after tilt) for both the upper Reagan and Honey Creek also coincide with other Cambrian poles.

In contrast, the uppermost Colbert Porphyry and lower and middle Reagan Sandstone are completely remagnetized by the southeasterly and shallow CRM residing in hematite. This CRM is apparently synfolding and the paleopole position suggests remanence acquisition in the late Paleozoic.

Geochemical studies (XRF) indicate differences in major and trace elements with depth in the Colbert that are suggestive of alteration by weathering fluids during the Cambrian or basinal fluids in the late Paleozoic. Petrographic studies reveal abundant calcite-filled veins within the uppermost rhyolite porphyry which indicate the movement of fluids through fractures. These fluids may be responsible for the late Paleozoic remagnetization.

The results of this study indicate that most of the basal aquifer and the top of the underlying igneous rocks in the Arbuckle Mountains are remagnetized. The CRM residing in hematite and the petrographic/geochemical results suggest that fluids, perhaps basinal in origin, moved through this conduit during the late Paleozoic period of orogenic activity and created a remagnetization "halo" in the Reagan Sandstone and Colbert Rhyolite. The rocks outside of the "halo" retain an apparent primary magnetization.

Geologic Study of the Karsted Arbuckle Brown Zone and Its Relation to Petroleum Production in the Healdton Field, Carter County, Oklahoma

ROBERT TODD WADDELL, University of Oklahoma, Norman, M.S. thesis, 1996

The Arbuckle Group has a gross thickness in excess of 10,000 feet in the southern Oklahoma aulacogen. The Healdton field, located within the southern Oklahoma aulacogen, has produced over 12 million barrels of oil from the upper Arbuckle. Cumulative production records attribute approximately 95% of all Arbuckle production within the Healdton field to the Brown zone. The thesis problem is to determine why the Brown zone is the most prolific hydrocarbon producer within an 8,000 to 10,000 foot carbonate section and how to explore for areas with similar reservoir development.

The Brown zone in the Healdton field underwent extensive replacement dolomitization, while the overlying Wade and Bray zones retained their original limestone depositional fabric. A stratigraphic variation exists between the Healdton field and the Shell Chase #1-28 well, approximately 2 miles to the north. The stratigraphic equivalent of the Brown zone in the Chase well is a black carbonate mud, indicating it was deposited in a deeper and quieter water environment than that of the Healdton field. An isopach thinning was found over the Healdton field between the top of the Bray and the top of the Brown zone, indicating paleotopography played an important role in the development of the initial facies, and subsequent dolomitization.

The Brown zone has major karst development, but the Wade and Bray do not. No karst was observed in the stratigraphic equivalent of the Brown zone in the Shell Chase well either. Karst development is closely tied to dolomitization. The Brown zone had opportunities for both meteoric and deep burial karst development. Some studies cite lack of faunal evidence in support of a pre-Simpson shallow burial karst, however geochemical studies cite evidence of higher temperatures indicating deep burial karst. Baroque dolomite, usually an indicator of hydrothermal fluids, was found throughout the Brown zone core examined in this study. Combined evidence suggest that the majority of the karst development in the Brown zone occurred during deep burial and exposure to basinal fluids.

The sequence of events for the development of the Brown zone dolomite are proposed as follows: (1) replacement dolomitization soon after deposition, (2) subsidence and exposure to basinal fluids, (3) deep burial karst development, (4) uplift of the Healdton field structure in the Morrowan, (5) collapse of dolomitic karsted reservoir, (6) subsequent deposition of pore rimming baroque dolomite, and (7) hydrocarbon migration.

Dolomitization is the key to Arbuckle reservoir development. It served as the conduit for all subsequent diagenetic fluids. Dolomitization also serves to significantly increase the fracture potential, thereby increasing the fracture network during tectonic movement.

Ground Penetrating Radar Data Processing and Analysis

JINGSHENG SUN, University of Oklahoma, Norman, M.S. thesis, 1994

GPR (ground penetrating radar) data consists of a mixture of events from different origins. Recognition and selective removal of certain events is an essential step in GPR data interpretation. Due to much more rapid attenuation of radar wave in the ground than in the air and small dielectric contrast between air and ground, the GPR data is usually contaminated by surface scattered events. Failure to recognize these features may result in an erroneous geological interpretation. Radar waves travel three times faster in the air than in the ground. Several criteria are proposed in this thesis for identification of surface scattered events based on this velocity difference. These criteria include animated migration at both ground wave velocity and air wave velocity, horizontally condensed display scale, forward modeling, antenna orientation testing, and CMP (Common Mid Point) data analysis.

The surface scattered events and other coherent noise modes can be selectively attenuated by domain filtering. The domain filter is a filter defined both in the T-X domain and in transform the F-K domain. It distinguishes signal and noise in both domains thereby minimizing the overlap between signal and noise. Consequently, it provides a more effective method for event removal.

GPR data were collected in Oklahoma at Byrds Mill Spring near Ada and at the South Canadian River near Norman. GPR data processing includes: time zero correction, spherical and exponential compensation, spectral balancing, bandpass filtering, domain filtering, reverse time migration and topographic correction. Spectral balancing is used to shrink the wavelet and broaden the spectrum. Domain filtering is designed to remove coherent events such as the direct arrival, system ringing, surface scattering, and ground water table reflection. Animated reverse time migration collapses the subsurface diffractions and helps data interpretation. In both case studies, processed GPR data demonstrated an ability to image subsurface structure to a depth of 6 m with vertical resolution less than 0.3 m. In the South Canadian River case, processed GPR section reveals an abandoned migrating channel which is confirmed by a local topographic map afterwards.

Reservoir Development Scale Modeling Based on Integration of High Resolution 3-D Seismic Data, Well Logs and Core Data: Gypsy Site, Pawnee County, Oklahoma, USA

DIRK SEIFERT, University of Oklahoma, Norman, M.S. thesis, 1994

Three-dimensional seismic is used to improve the detail and accuracy of a geological model for studying fluvial flow within a reservoir. A high-resolution survey consisting of 52 in-lines and 52 cross-lines with a frequency spectrum from 20 to 180 Hz covering approximately 40 acres was acquired and processed by Western Geophysical using 25′ by 25′ bins to provide information on the distribution and continuity of sandstone channels within the Pennsylvanian Gypsy interval. The composite thickness of up to 5 channels varies from 28 to 61 feet within the survey area. Cores and logs from six wells penetrating the interval within the study area are used to constrain and calibrate the seismic interpretation.

Eight major lithologic sequences were mapped based on seismic interpretation that proceeded in three phases, each with increasing resolution. After locating the Gypsy interval in time on the seismic sections (phase 1), two major sand-zones were identified as being the major flow units (phase 2). However, the lower sand-zone could be further subdivided into two channels, the lower one being present only within part of this dataset (phase 3). The seismic interpretation was followed by geological modeling, performed by integration of depth converted seismic horizons, well log and petrophysical core data. The resulting detailed three-dimensional geological model consists of more than 150,000 grid-cells, each approximately 25×25×2 feet in size. Simple deterministic interpolation algorithms were used to distribute permeability and porosity within the reservoir. Evaluation of the permeability distribution defines the major flow-zones, which were used in four reservoir simulation cases, consisting of two inverted five-spot and two line-drive well patterns. The simulations are based on simplified physics to permit rapid computation of differing scenarios using the full geological detail provided by the integrated model. The difference between the models used in the two simulations of a given well pattern is crossflow versus no crossflow at sequence boundaries. However, in the four simulations it was found, that no substantial differences in flow performance occured for the two simulations of the same well pattern.

This study is part of a comprehensive reservoir characterization program using the Gypsy data set to develop and evaluate technology for improving petroleum recovery through better reservoir management based on the simulation of fluid flow in detailed geological models.

Characterization in Three Dimensions of a Low-Velocity Layer Using Crosswell Seismic Travel Times

FUZHEN WANG, University of Oklahoma, M.S. thesis, 1994

Three crosswell surveys conducted in a five-spot at the Gypsy Test Site in NE Oklahoma give a three-dimensional picture of the top and bottom boundaries of the Pennsylvanian Gypsy formation. The seismic expression of the channel sand sequence comprising the Gypsy formation is that of a low-velocity unit encased by higher velocity sands and sandy shales. The existence of reflections and headwaves due to these large velocity contrasts at the boundaries of the Gypsy formation is confirmed by raytracing in a velocity model using a hybrid approach based on the method of Andersen and Kak. This one dimensional model is established using the horizontal path log. Multiple stages of median filtering greatly enhance reflection amplitudes. Clearcut reflections from within the Gypsy formation suggest that a horizontal stacking scheme would successfully image individual channel sands.

The origin depths of the reflections from selected common shot and common receiver gathers establish formation boundary depths. A simple analysis of the extent of headwave and reflection events produces a boundary map in the vicinity of the receiver wells. Depths derived using the crosswell data alone agree well with density logs.

Continuity mapping using headwaves is feasible and presents an inexpensive alternative to full aperture crosswell surveying for structural objectives.

Depositional and Diagenetic History of the Mississippian Chat, North Central Oklahoma

SUZANNE MAYO ROGERS, University of Oklahoma, Norman, M.S. thesis, 1996

The Mississippian Chat, a tripolitic to dense chert, in Northern Oklahoma is present at the unconformity between the Pennsylvanian and Mississippian. Well logs and completion records from over 6600 wells within Townships 22 North through 29 North and Ranges 3 West through 5 East indicate the occurrence of the Chat is widespread but not continuous. Because of uplift and subsequent erosion the Mississippian in this area represents only the Osagean and locally the Kinderhookian stages. The Chat is found as a weathered and/or detrital, siliceous interval of tripolitic chat or more dense chert at the top of the Osagean.

The depositional environment of the Chat reflects uplift and both erosion and weathering in-place of Osagean Mississippian cherty limestone. From the size and variety of the unsorted clasts, 0.5 in. to 3 in. across, the eroded fossiliferous clasts must have been in a high energy environment such as that found above wave base in the shallow seas believed to have been present in northern Oklahoma during Mississippian time. These eroded clasts were transported by a "debris flow" into a lower energy environment and deposited with less fossiliferous material. Subsequently, either a siliceous cap or Pennsylvanian shales were deposited on top of the rubble.

The Osagean throughout northern Oklahoma is known to contain chert. Early diagenesis probably replaced some of the eroded limestone material with silica likely derived from siliceous sponge spicules. Examination of thin sections indicates during later diagenesis silica partially replaced calcite shells and cement subsequent to the debris flow and then meteoric water dissolved the remaining calcite to create secondary porosity. Well preserved original fossil structures indicate that "force of crystallization" was the method of molecule by molecule calcite replacement by silica.

Analysis of producing fields indicates production from structural highs, pinchouts and diagenetically formed stratigraphic traps. Trend analysis of selected fields suggests a relationship between positive structural residual values or a negative to positive change in stratigraphic residual values and production from the Chat. Seismic reflections indicate the presence of the Chat which can be clearly seen as a double peak with a separation between these two peaks of a few milliseconds as compared to the strong reflector, frequently a doublet, produced by the Mississippi Lime where it is not overlain by Chat.

The Chat can be a prolific reservoir rock that typically after a rapid decline in the production rate has a long economic life. Production occurs on structures or where the Chat pinches out on the flanks of structures. The Chat appears on well logs as a low resistivity zone with low density and high porosity that by normal interpretation methods would calculate to have a high water saturation. Oil and gas produced from such zones are almost always accompanied by saltwater. Ultimate recovery from unitized fields ranges from 1 to 4 million barrels of oil. Individual wells in good quality Chat reservoirs have produced over 150,000 barrels of oil.

Completion techniques in the Chat should be designed for a siliceous zone containing detrital clays and no carbonate. A careful examination of samples should indicate whether the zone is tripolitic or cherty, with the former being preferable for a good quality reservoir.

Methodology for Constructing High Resolution Three Dimensional Reservoir Characterization Models for Petroleum and Environmental Applications

TIMOTHY MICHAEL COLLINS, University of Oklahoma, Norman,
M.S. thesis, 1996

By using a systematic methodology including geologic interpretation to supplement the available data when constructing high resolution geologic models, pitfalls resulting in inadequate models can be avoided. A sensitivity analysis is performed comparing differences in flow characteristics for models built with varying degrees of complexity. A goal of this study is to determine if the individual stacked channels that comprise the Gypsy formation have a significant effect on fluid flow.

A highly characterized outcrop site in Oklahoma (The Gypsy Field Laboratory) was chosen as the main study site because of the extensive data available. Data was obtained from 22 core holes located behind a road cut at the outcrop site. Permeability, porosity and lithologic data were measured for each foot of core or each significant change, whichever was smaller. Four models of the Gypsy outcrop site were constructed, two of which isolated channels within the formation. The models differed in both degree of detail (number of cells, ranging from 4536 to 374,976) and degree of geological interpretation. The first model, termed the "simple model," consists of one layer bounded by the top and bottom of the formation. The second model, termed the "single layer per channel sequence model," has each of channels as a distinct sequence with one layer per sequence. The third model is the "fifty layer model" which has no channels defined, and the formation divided vertically into fifly layers of equal thickness proportional to the thickness of the formation. The fourth model, termed the "detailed model," has all of the channels modeled as in the second model, and has each channel sequence divided into one foot layers filled from the base upwards. A simulated well model consisting of nine wells, three by three, was used to conduct simulated fluid flow experiments on all four of the models. This was accomplished by first simulating contamination of the study site, by injecting 365,000 barrels of fluid into the central well, with all of the surrounding wells shut in, and the perimeter of the model at constant pressure. Although the sizes and shapes of the resulting contaminant plumes were significantly different for each model, it was discovered that each model contained only one flowbody. A flowbody is a section of a reservoir that is connected with respect to fluid flow. Each separate compartment of a reservoir represents a flowbody. All of the channels cut into one another at various places. The higher the resolution of the model, the more heterogeneous the permeability distribution, and the larger the initial plume is in areal extent. The fifty layer model best approximated the highly detailed model. This is due in part to the lack of separate flowbodies within this reservoir. A lack of continuous flow barriers reduces the effect channeling within a reservoir has on fluid flow.

The second phase of the experiment was to simulate a clean-up for each model. The location of the injector wells was designed to clean up the plume for the simple model. Twice the contaminant volume (730,000 barrels) was injected into the eight surrounding wells, while an equal volume was extracted from the central well. It was concluded that the degree of contaminant stranding is directly related to the heterogeneity of the model. Two hundred fifty-six percent more contaminant volume was left unrecovered with the detailed model as compared to the simple model. The aerial extent of the highly detailed model's plume was approximately 10 times the simple model's. Again, the one foot resolution model without individual channels most closely approximated the highly detailed model. In models that do not have separate flowbodies or large internal flow barriers, vertical resolution is much more important than degree of channel modeling, in constructing representative models. This is not to say that in a reservoir with compartmentalized channels, the same would be true.

The Application of Ground Penetrating Radar for Geological Characterization in Three Dimensions at Gypsy Outcrop Site, Northeastern Oklahoma, USA

ZHENGHAN DENG, University of Oklahoma, Norman, M.S. thesis, 1996

Ground Penetrating Radar (GPR) has been widely applied to high-resolution mapping of soil and rock stratigraphy, and fracture detection. GPR is successful in defining stratigraphic boundaries and fractures in three dimensions at the Gypsy Outcrop Site, near Tulsa, Oklahoma. The dielectric contrasts between lithofacies and within a lithology both cause radar reflections at the Gypsy Outcrop Site. The boundary reflection is caused by the difference in clay content and/or porosity of the lithofacies across the boundary. The reflection within a facies is caused by the change of grain size and/or the change of porosity. Fractures can be detected at the Gypsy Outcrop Site because the place where fracture intersects with dielectric contrasts can cause radar diffractions. These diffractions are different from the diffractions caused by subsurface heterogeneity because they form regular patterns.

Some GPR data processing techniques have been used in order to increase the S/N ratio and to attenuate air wave reflections. Techniques for 2-D data processing include: time-zero shift, bandpass filtering, amplitude recovery, spectral balancing, domain filtering and migration. Since 3-D radar data require much higher S/N ratio, the following special processing techniques have been applied after applying 2-D data processing techniques mentioned above: 3-D dip filtering and 3-D coherence.

GPR 2-D data were interpreted with the help of borehole information at the ends of radar lines forming a grid. The interpreted radar boundaries were digitized and isopach maps of the upper two channels were then made based on the digitized data. Isopach maps with and without adding radar information between boreholes show that the composite map adds detail to the shape of the channel and its horizontal extent. The pinchout of the channel is seen to be more abrupt after adding GPR information.

3-D coherence processing is a new technique applied to seismic reflection data. This is the first time for this method to be applied to radar data. The 3-D coherence processing at the Gypsy Outcrop Site has shown a much clearer view of the stratigraphic boundaries and fractures. The fractures detected by radar data have a 90° dip, N/S strike and regular spacing.

Geothermics of the Gypsy Site, Northcentral Oklahoma

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Equilibrium temperatures were measured in 6 closely-spaced boreholes ~380 m deep at a location (Gypsy site) in Northcentral Oklahoma (36.36°N, 96.70°W) in both May and October, 1993. The average geothermal gradient in the boreholes from surface to total depth was 34.5°C/km. Several hundred laboratory measurements of thermal conductivity were made on cores collected at the study site; 65 heat capacity measurements were also made. Rock matrix density was measured, and used to estimate in situ porosity from density logs. Background heat flow at the Gypsy site was estimated to be 72±7 mW/m^2 after making a small correction (+3 mW/m^2) for Holocene warming. The effects of topography, heat refraction, and local groundwater flow on the thermal regime were considered but judged to be negligible. Three regional groundwater flow systems are present in the southcentral US, and likely converge within a few hundred kilometers of the Gypsy Site. However, an examination of hydrogeologic and geochemical evidence indicated that background heat flow at the Gypsy site is likely not significantly perturbed by regional groundwater flow. Radioactive heat production measurements made on two cores of basement rocks from nearby wells yielded values of 2.4 and 1.9 μW/m^3. These data do not indicate abnormally high heat production, but by themselves are inconclusive due to the possibility of crustal heterogeneity in radioactive isotope enrichment.

Temperatures in the upper 150 m of the boreholes appeared to be anomalously warm when the average thermal gradient was extrapolated from below 150 m depth. The average thermal gradient below 150 m depth was 37.5°C/km; the average thermal gradient from 20–150 m depth was 27.4°C/km. Average thermal diffusivity of the upper 110 m of the stratigraphic section was estimated to be 20.3±2.0 m^2/yr. Heat flow was estimated to be 52±6 mW/m^2 from 20–110 m depth and 69±7 mW/m^2 (before corrections for Holocene warming were applied) from 277–305 m depth. The observed energy imbalance and anomalously warm temperatures in the upper 150 m of the boreholes could not be explained solely by hypotheses related to topographic gradients, vegetation, heat refraction, groundwater flow, or land use changes. The only hypothesis which satisfactorily explained all of the observations was an apparent increase (1.25–1.50± 0.5°C) in ground surface temperature (GST) related to a climatic warming starting in the middle to early 19th century or before (1835, +50, –150 yr). When constraints from surface air temperatures (SATs) were used to interpret borehole temperatures, a better match to observations was obtained, suggesting that changes in SATs at the study site were tracked by changes in GSTs.

Structure of the Wichita Mountains Frontal Zone and Subsequent Deformation of Permian Sediments—Southwestern Oklahoma

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The Wichita Mountains Frontal Zone in Okahoma is the boundary between the Wichita Mountains Uplift and the Anadarko Basin. The Frontal Zone may be tracked by large scale geophysical surveys from Okahoma to the Texas Panhandle and beyond. However, the geometry of this boundary is obscured by a blanket of Permian stratigraphic units. Although the last major movement along the Frontal Zone was a period of uplift in the Pennsylvanian, minor readjustments, such as the Meers Fault of Holocene age, have continued to affect the area. These adjustments have left subtle folds at the surface as well as extensions of subsurface faults that give a sense of the complex thrusting and folding geometries of the Frontal Zone below.

The Permian cover has heretofore appeared to be devoid of information concerning the Frontal Zone beneath. Passive folds, zones of erosional susceptibility, joint/fracture patterns, as well as fracture offset all provide clues to the geometry of the Frontal Zone. These observations, found in surface, seismic, and well-log data, are combined into an interpretation of the complex nature of the Wichita Mountains Frontal Zone and an understanding of the interplay between preexistent structures and overlying sedimetary units.

Jellyfish Body Fossil or Trace Fossil? *(continued from p. 2)*

tissues. The medusae are the most conspicuous cnidarians (Stearn and Carroll, 1989, p. 94–95). Most medusae have diameters of 10–50 mm, lack hard parts, and are not readily fossilized (Moore and others, 1952, p. 99).

For comparison, a photograph of a rubber cast taken from the natural mold of the holotype (type specimen) of *Kirklandia texana* is shown ×1 in the inset photo (back cover) (Caster, 1945, pl. 1, fig. 1, p. 212). About 40 specimens of this curious fossil were initially made available to Caster for study. Forrest Kirkland, an amateur fossil hunter, had collected the specimens in the early 1940s in Denton County, Texas, ~50 mi south of the site where the specimen on the cover was found in Marshall County, Oklahoma. A comparison of descriptions of strata from the type locality in Texas and of strata in Marshall County, Oklahoma, suggests that the Oklahoma fossil material comes from a stratigraphic horizon similar to the one in Texas—a thin, cross-bedded, calcium-carbonate-cemented, sandy zone in the midst of shale or clay beds (see Huffman and others, 1987, fig. 4).

Concerning the depositional environment in Texas, Caster (1945, p. 186) said that "everything about the specimens at hand suggests alignment with the neritic zone, and probably an inter-co-tidal setting." In his discussion of the preservation of *Kirklandia texana*, Caster (1945, p. 186–187) noted the similarity between the Cretaceous fossils and imprints made by jellyfish stranded on sand beaches in modern coastal environments: "When washed ashore and left stranded at low tide..., medusae quickly dry on the surface and become crisply crusted above.... While the upper surface is hardened, thus inhibiting dehydration, the surface in contact with the beach remains soft and often turgid as in life.... The incoming tide often picks up the partially embedded jellies and carries them further ashore, and occasionally turns them over to embed them again.... In the case of the Cretaceous fossils we deal exclusively with buried medusae, many of which were apparently interred oral side up."

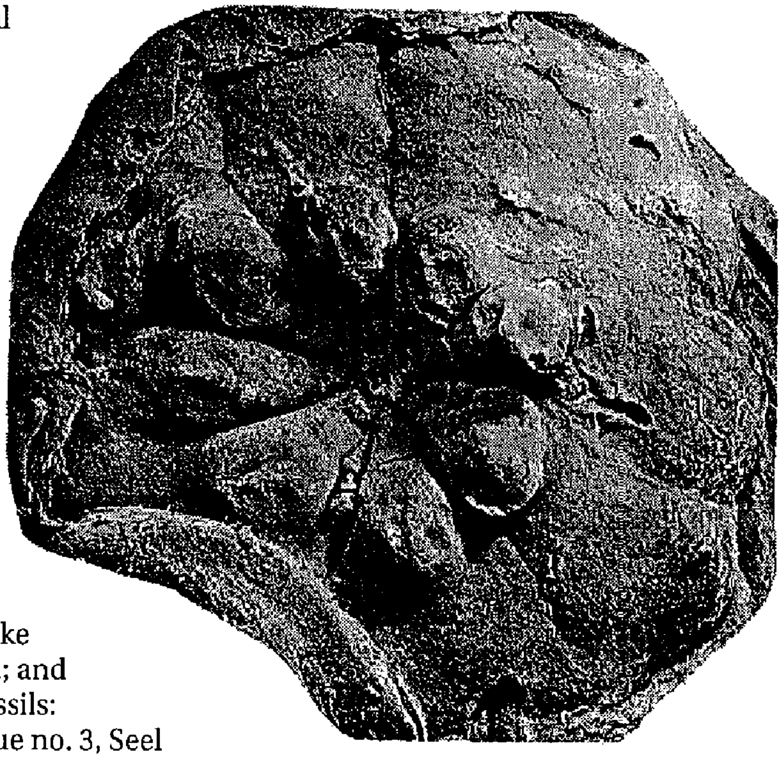
Caster (1945, p. 186) said that the molds of Cretaceous medusae indicate quick burial and that the crusted and shriveled surfaces of the molds (especially of the side uppermost in the bed) resemble the surfaces of stranded, "mummified" jellyfish found on the present-day seacoast. Rapid hardening of the matrix material, which would ensure preservation of the "mummy," is suggested by calcium-carbonate cementing of the sandstone.

Subsequent to publication of Harrington and Moore's (1956, p. F70) detailed description of the medusae, *Kirklandia texana*, Häntzchel (1975, p. W144, W147–W148) said that the affinities of many starlike (flowerlike) fossils reminiscent of medusae are uncertain. Häntzchel (1975, p. W144) described most as "medusoid" and placed them in medusae *incertae sedis* Häntzchel. Interpretation of some of these forms as medusae is uncertain and very controversial. Probably some of the controversial forms are body fossils and may represent genuine medusae. However, Häntzchel (1975, p. W144) said that "the suspicion exists that in other cases we are dealing with trace fossils." It was his opinion that *Kirklandia texana* should be treated as a problematic fossil. Earlier, Häntzchel (1970, p. 206–208) had discussed the possibility that some of the problematic starlike fossils, such as *Kirklandia texana*, could be interpreted as feeding and dwelling burrows. Some workers have suggested that the starlike features reflect systematic probing and

(continued on back cover)

Jellyfish Body Fossil or Trace Fossil? *(continued from p. 39)*

backfilling around the vertical dwelling tubes of wormlike sediment feeders (J. R. Chaplin, personal communication, 1998). More investigations of problematic medusoids are needed in order to clarify their true nature.



Holotype of *Kirklandia texana*, ×1 (Caster, 1945, pl. 1, fig. 1, p. 212).

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