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Cover Picture

SAND AND GRAVEL PROCESSING PLANT CANADIAN RIVER, NEAR NOBLE

A large increase in commercial and residential construction in the Oklahoma City metropolitan area has stimulated the need for additional supplies of sand, gravel, and aggregate resources. Some of these needs are being fulfilled by new operations developed at locations once previously thought to be too far away from the Oklahoma City market to be competitive because of additional transportation costs.

One such operation is located south of Noble, Oklahoma, on the north bank of the Canadian River, approximately 27 miles from downtown Oklahoma City. A 100-ton/hour plant (cover photograph) was built by E. C. Nelson, owner of Big 8 Construction Co., and went into production in July 1978. The resource material consists mainly of Pleistocene terrace deposits composed of lenticular beds of sand and gravel with minor amounts of silt and clay. The water table is sufficiently high in this area to permit the use of a hydraulic dredge as the principal method for sand and gravel removal. An 8-inch pump, barge, and suction-pipe system are used to remove the loose material beneath the water table. This material is transported by pipe (*A*) to the processing plant (*B*) for screening, washing, and separation. The material is first separated into two fractions, plus $\frac{5}{16}$ inch and minus $\frac{5}{16}$ inch. The minus $\frac{5}{16}$-inch material is washed, screened, and classified into the following three end-use categories: masonry sand, concrete sand, and washed fill sand. These materials are transported away from the washing and screening plant by conveyors (*C*) to stacking piles. The coarser material, plus $\frac{5}{16}$ inch, is sized into three categories and is primarily used as decorative rock in flower gardens and exposed aggregate in concrete work.

—*Kenneth V. Luza*

Editorial staff: William D. Rose, Elizabeth A. Ham, Judy A. Russell

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

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UPPER GEARYAN AND LOWER LEONARDIAN TERRESTRIAL VERTEBRATE FAUNAS OF OKLAHOMA

Larry C. Simpson[1]

Abstract—Recent investigations of the Permian-Pennsylvanian boundary in southern Oklahoma and remapping of the Oklahoma Permian formations have made it possible to assign more valid stratigraphic positions to the State's vertebrate fossil sites. Vertebrate faunas range from the upper Oscar Group (Pennsylvanian, Gearyan) to the lower part of the Hennessey Group (Permian, Leonardian), correlating with Admiral through Vale in the Texas section. Paleoecologic conditions reflected by the changing faunas indicate a progression from pond and marsh to temporary pond to stream environment, a severe increase in aridity having eliminated many genera in northern and central Oklahoma before the beginning of Hennessey deposition. The investigation determined the importance of the Wichita Mountains in allowing many elements of the late Gearyan vertebrate faunas to survive into the late Leonardian.

The opening of three new sites, rediscovery of Oklahoma's first Permian vertebrate site, and recovery of new material from old sites add significantly to the faunal record.

Introduction

From the time the Permian red beds of Oklahoma were first described, their stratigraphic divisions and correlations with other states have been a controversy over which many authors have argued (Moore, 1940; Simpson, 1973a). Years of mapping by individuals and companies culminated in the *Geologic Map of Oklahoma* (Miser, 1954). The boundaries of the Permian formations had not been precisely determined, however, and for this reason R. O. Fay of the Oklahoma Geological Survey proceeded to redefine and map the Oklahoma Permian (Fay, 1967, 1968, 1972). Before Fay completed his remapping, the Oklahoma Geological Survey published a report by E. C. Olson on *Early Permian Vertebrates of Oklahoma* (Olson, 1967), in which Olson described each collecting locality meticulously, listing each fauna and stating what he believed to be the locality's stratigraphic position. He also attempted to correlate each locality with the north Texas section by means of lithology and faunas. Other papers (Daly, 1969, 1973; Olson and Daly, 1972) that described Permian vertebrate material from Oklahoma used Miser's (1954) map and were out of date in their age assignments.

Now that the Permian of Oklahoma has been accurately mapped, the vertebrate sites described by Olson and others can be put into their proper stratigraphic context (fig. 1). I have attempted to do this in this paper by referring to four recent geologic maps accompanying hydrologic atlases (Bingham and Bergman, in preparation; Bingham and Moore, 1975; Hart, 1974; Havens, 1977).

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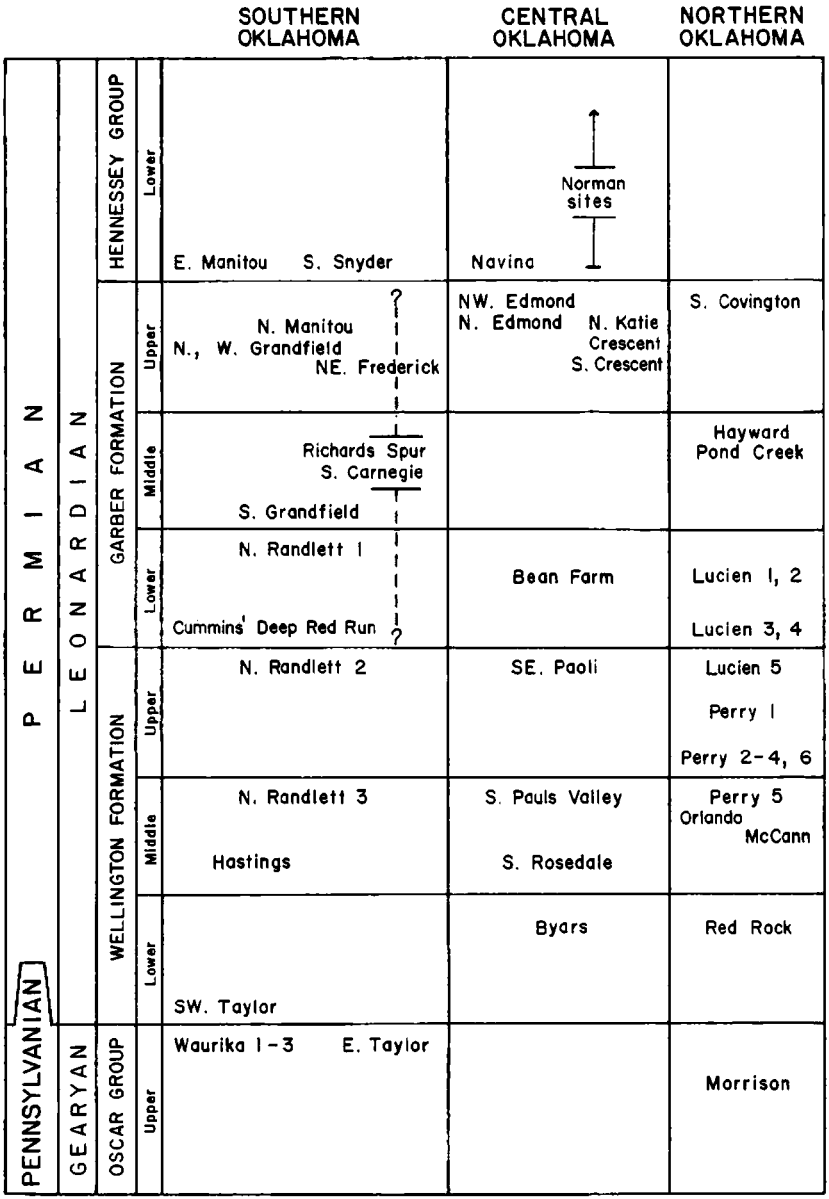

Figure 1. Stratigraphic positions of Oklahoma's Upper Pennsylvanian and Lower Permian terrestrial vertebrate sites.

In 1973 I prepared a preliminary correlation between the Upper Pennsylvanian and Lower Permian formations of Texas and Oklahoma (Simpson, 1973a), but an extended study of the Pennsylvanian-Permian boundary in southern Oklahoma by Fay has required a revision of the correlation of some of the formations (fig. 2).

It is still uncertain where two of Olson's sites should be placed stratigraphically (table 1). The Richards Spur and South Carnegie sites (Olson, 1967, p. 34, 36) are both Dolese Brothers quarries along the north flank of the Wichita Mountains, where an upland fauna of amphibians and reptiles has been preserved in clay-filled cracks in the Lower Ordovician limestones of the Arbuckle Group. The Richards Spur fauna is highly diverse and may represent a long period of accumulation. However, the large number of specimens of *Captorhinus aguti* found at the site suggests that the age is probably Arroyo, corresponding to the upper Garber Formation of Permian age (Fox and Bowman, 1966). The similar Carnegie site is probably of the same age.

Faunal lists incorporated in this paper (tables 1–5) have been compiled from various authors who have written on Oklahoma's Lower Permian vertebrates (Olson, 1967, 1970, 1971; Carlson, 1968; Carroll, 1968; Bolt, 1969, 1974b, 1974c; Daly, 1969, 1973; Olson and Daly, 1972; Zidek, 1972, 1976, 1978; Simpson, 1973a, 1973b, 1974a, 1974b, 1976; Haglund, 1977). Field investigations for this paper resulted in the discovery of three new sites; the rediscovery of Oklahoma's first Permian vertebrate site, Cummins' Deep Red Run site; and enlargement of the faunas known from some of the previously described sites (tables 1–5). The previously unrecorded sites and new material are also discussed. Specimens housed in the Stovall Museum of Science and History of The University of Oklahoma are designated OUSM.

Oklahoma sites that were unnamed, incorrectly located, or loosely referred to by Olson (1967) are named herein as follows:

Olson (1967)	This paper
A. Deep Red Run sites, Cotton County	
1. Sec. 21, T. 4 S., R. 12 W.	North Randlett 1 site
2. Sec. 16, T. 4 S., R. 12 W.	North Randlett 2 site
3. Sec. 13, T. 4 S., R. 12 W.	North Randlett 3 site
B. NE¼ NW¼ sec. 8, T. 4 S., R. 9 W. (Wegemann, 1915), Cotton County	Hastings site
C. Hayward site, Garfield County, sec. 13, T. 20 N., R. 2 W.	Hayward site, Garfield County, sec. 13, T. 20 N., R. 4 W. (typographical error in Olson, 1967, p. 64, placed this site in R. 2 W.)

New Sites

North Grandfield

(NW¼ NW¼ sec. 28, T. 3 S., R. 15 W., Tillman County, Oklahoma)

This site is associated with two other previously known localities, the West Grandfield site (Olson, 1967; Simpson, 1976) and the South Grandfield site (Daly, 1969, 1973; Olson and Daly, 1972). The section consists of uniform red

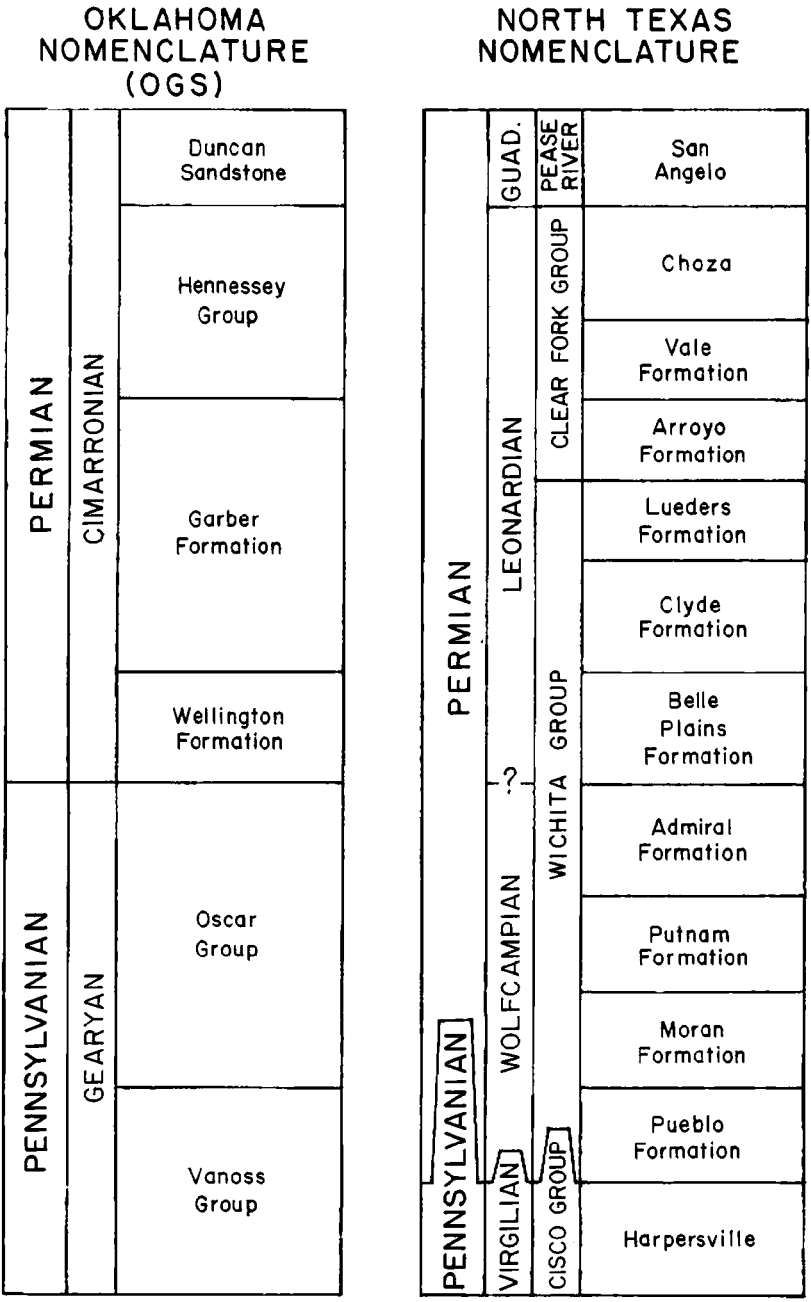

Figure 2. Correlation of Upper Pennsylvanian and Lower Permian stratigraphic units of Oklahoma and north Texas.

TABLE 1.—VERTEBRATE FAUNAS FROM OKLAHOMA SITES OF UNCERTAIN AGE

		Richards Spur	South Carnegie
REPTILIA	*Basicranodon fortsilensis*	x	x
	Captorhinus aguti	x	
	Colobomycter pholeter	x	
	Delorhynchus priscus	x	
	Labidosaurus hamatus	x	
	Thrausmosaurus serratidens	x	
AMPHIBIA	*Cacops* sp.	z	
	Cardiocephalus sternbergi	x	
	C. peabodyi	z	
	Dissorophidae indet.	x	
	Doleserpeton annectens	x	
	Eryopidae indet.	z	
	Euryodus primus	x	
	Llistrofus pricei	z	
	Phlegethontia sp.	x	
	Tersomius sp.	x	
	Trematops sp.	z	
PISCES	Undifferentiated xenacanths	x	

x = previously known
z = newly discovered

TABLE 2.—VERTEBRATE FAUNAS FROM UPPER OSCAR GROUP, OKLAHOMA

		Morrison	Waurika 1	Waurika 2	Waurika 3	East Taylor
REPTILIA	*Captorhinus aguti*		z			
	Dimetrodon sp.	x			x	x
	D. limbatus		x			
	D. incisivus	?				
	D. dollovianus	?				
	Edaphosaurus sp.					x
	E. boanerges		x			
	Ophiacodon retroversus		x			
	Pantylus sp.		z			
AMPHIBIA	*Archeria* sp.	?	x			
	Diadectes sp.		x			
	Diplocaulus magnicornis		x			
	Eryops sp.					x
	E. megacephalus		x			
	Trimerorhachis insignis		x			
PISCES	*Anodontacanthus belemnoideus*		z			
	Ectosteorhachis sp.		y			
	Gnathorhiza sp.		z			
	Orthacanthus compressus		y			
	Undifferentiated palaeoniscoids		x			
	Sagenodus porrectus		z			
	Undifferentiated xenacanths					x
	Xenacanthus luederensis		y			
	X. platypternus		y			

x = previously known
y = recently differentiated
z = newly discovered

TABLE 3.—VERTEBRATE FAUNAS FROM WELLINGTON FORMATION, OKLAHOMA

		North Randlett 2	Lucien 5	Southeast Paoli	Perry 1	Perry 2	Perry 3	Perry 4	Perry 6	Perry 5	South Pauls Valley	Orlando	McCann	Hastings	South Rosedale	Byars	Red Rock	North Randlett 3	Southwest Taylor
REPTILIA	Captorhinomorpha indet.										z								
	Captorhinus aguti								y			x							
	Dimetrodon sp.	x			x			x			z			x	x		x		
	D. limbatus								x			x	x						x
	Edaphosaurus boanerges		x									x	x						
	E. cruciger																		x
	Dictyobolus tener								x										
	Eocaptorhinus laticeps				y								y						
	Pleuristion brachycoelus											x							
	Ophiacodon uniformis								x										
AMPHIBIA	*Archeria* sp.											x							
	A. victor												x						
	Broiliellus sp.										?								
	Cricotillus brachydens											x							
	Crossotelos annulatus				?							x							
	Diadectes sp.															x		x	
	Diplocaulus sp.	x																	
	D. magnicornis								x			x	x						
	Eryops sp.						x				x								x
	E. megacephalus	x							x			x	x		x				
	Lysorophus tricarinatus											x							
	Seymouria baylorensis											?							
	Trimerorhachis sp.									z									x
	T. insignis				x		x		x			x	x						
	Zatrachys serratus															x			
PISCES	Crossopterygii indet.								?										
	Gnathorhiza sp.				x	x		x		x									
	G. serrata								x			x							
	Orthocanthus compressus						y	y	y	z		y							x
	Undifferentiated palaeoniscoids							x	x				x						
	Platysomus parvus								x										
	Sphaerolepis arctata								x			x	x						
	Sagenodus sp.									z									
	Undifferentiated xenacanths												x						
	Xenacanthus platypternus		y																
	X. luederensis							z											

x = previously known
y = recently differentiated
z = newly discovered

TABLE 4.—VERTEBRATE FAUNAS FROM GARBER FORMATION, OKLAHOMA

	North Katie	Northwest Edmond	North Edmond	Crescent	South Conyington	South Crescent	West Grandfield	North Grandfield	Northeast Frederick	North Manitou	Pond Creek	Hayward	South Grandfield	Lucien 1	Lucien 2	Lucien 3	Lucien 4	North Randlett 1	Bean Farm	Deep Red Run (Cummins)
REPTILIA																				
Acleistorhinus pteroticus													x							
Araeoscelis gracilis							z													
Captorhinus aguti									z		x		x							
Dimetrodon sp.	x		x					z				x		x		x				
Dimetrodon dollovianus																				x
D. giganhomogenes		x		x	x		x				x						x			
D. grandis											x									x
D. limbatus									z											
D. loomisi													x							
D. macrospondylus																				x
Edaphosaurus sp.											x		x				y			
E. pogonias									z											
Labidosaurus sp.													x							
L. hamatus											x									
Labidosaurikos meachami				x	x	x														
Ophiacodon retroversus									z											
Ophiacodon major																				x
AMPHIBIA																				
Archeria sp.									z		?									x
Cardiocephalis sternbergi													x							
Diadectes sp.									z		x					z	x			
Diplocaulus sp.		x		x			x		z			x					x			
D. magnicornis											x		x	x				x	x	
Eryops sp.											x	x		x		x	x			

mudrock, and the site yielded plant-leaf impressions and bone scraps of *Dimetrodon*. The site is late Garber in age, and the fossils are probably preserved in the same sequence of flood-plain sediments that yielded fossils in the nearby West Grandfield site.

Northeast Frederick

(NW¼ sec. 21, T. 1 S., R. 16 W., Tillman County, Oklahoma)

This site is late Garber in age and belongs to approximately the same zone as the North and West Grandfield sites. The rock is a lenticular bed of gray claystone and conglomerate contained in the red mudstone that is typical of the Garber Formation south of the Wichita Mountains. The gray claystones were

AMPHIBIA	*Eryops megacephalus*			x	z								x		
	Euryodus dalyae							y							
	Hapsidopareion lepton							x							
	Lysorophus tricarinatus							x							
	Micraroter erythrogeios							x							
	Peronedon primus							y							
	Tersomius texensis							x							
	Trimerorhachis sp.		z	x			x				x		x		z
	T. insignis				z			x				x			
PISCES	*Platyacanthus avirostratus*				z										
	Ectosteorhachis sp.						x								
	E. nitidus							x							
	Gnathorhiza serrata						x								
	G. noblensis							x							
	Grandfieldia callilepidota							x							
	Hybodus sp.				z										
	Orthacanthus compressus	y			z		y								
	Undifferentiated palaeoniscoids				z			x			z				
	Platysomus sp.						x								
	Platysomus palmaris														x
	Sagenodus sp.				z								z		
	S. porrectus				z										
	Sphaerolepis arctata						x								
	Undifferentiated xenacanths									x		x		x	
	Xenacanthus platypternus	y		z	z	y	y	y	y		y				
	X. luederensis				z										

x = previously known
y = recently differentiated
z = newly discovered

laid down in a temporary pond that covered a quarter section. The site is one of the most productive in the State, containing an extensive flora, invertebrates, and vertebrates (OUSM 00510–548, 10081–133, 15100–140) (table 4).

The fauna contains not only the sole occurrence of *Platyacanthus*, *Hybodus*, *Sagenodus*, *Archeria*, and *Ophiacodon* from the Garber Formation but also the stratigraphically youngest occurrences of *Platyacanthus* and *Archeria* (Simpson, 1976, p. 50–54, 118, 119; Zidek, 1978).

Red Rock

(Center W½ sec. 26, T. 23 N., R. 1 E., Noble County, Oklahoma)

This site lies northeast of Perry, Oklahoma. The rock sequence consists of a

TABLE 5.—VERTEBRATE FAUNAS FROM HENNESSEY GROUP, OKLAHOMA

		East Manitou	South Snyder	Navina	Norman (sec. 13)	Other Norman sites
REPTILIA	*Captorhinikos chozaensis*				x	x
	C. parvus				x	
	Cotylorhynchus romeri			x	x	x
	Dimetrodon sp.	x			?	
	Ophiacodon major	x				
AMPHIBIA	*Eryops* sp.	x				
	Goniorhynchus stovalli				x	
	Lysorophus tricarinatus				x	
	Peronedon primus				x	
	Trimerorhachis sp.	x				
	Tersomius mosesi				x	
	Trematops milleri		x			
PISCES	*Acanthodes* sp.	x				
	Undifferentiated crossopterigians	z				
	Gnathorhiza sp.				x	x
	Hybodus sp.	x				
	Orthacanthus compressus	x				
	Undifferentiated palaeoniscoids	x			x	
	Platysomus sp.	x				
	Sagenodus porrectus	x				
	Xenacanthus platypternus	x				

x = previously known
z = newly discovered

basal sandstone overlain by 20 feet of gray to red shales containing silty and conglomeratic stringers. In the middle of the sequence is a shaly limestone 3–7 inches thick that contains roughly cylindrical tubes 1–4 inches in diameter. These tubes resemble *Gnathorhiza* burrows, which are common at sites to the south, near Perry (Olson, 1967, p. 39; Carlson, 1968). None of the cylindrical structures, however, have yielded any skeletal remains. If they are burrows, the animals were not trapped in them as they were in ponds to the south. The shales and conglomerates have produced bone and wood scraps. The only recognizable remains are those of *Dimetrodon*.

Rediscovered Site

Deep Red Run (Cummins, 1908)

(W½ sec. 21, T. 2 S., R. 15 W., Tillman County, Oklahoma)

Cummins' Deep Red Run site (Olson, 1967, p. 22) was originally discovered in the early 1880's by W. T. Cummins along a stage road between Fort Sill and Fort Augur in Indian Territory. Fort Augur was used sporadically until the 1890's during times of Indian hostilities and local arguments over grazing rights (Maxwell, 1978). By the early 1900's the road was abandoned, and the exact location of the fossil site was lost. There have been no reports of collecting since Cummins (1908, p. 741) described the site some 25 years after its discovery. Olson (1967, p. 22) apparently postulated that the old road went directly from Fort Augur to Fort Sill and believed the site to be east of Fort Augur in Cotton County. However, three maps of Oklahoma and Indian Territory, dated 1875, 1885, and 1906 (Maxwell, 1976, 1978), show the stage road to go due north from Fort Augur, crossing Deep Red Run Creek near its intersection with Horse Creek in Tillman County.

Examination of this area resulted in the discovery of a highly eroded terrain exposing 40 feet of typical lower Garber reddish-brown mudstone. Some of the mudstone is mottled, and isolated 1–12-inch-thick white-shale beds are present. The fine sediments contain coarser units of 3–40-inch-thick gray, cross-bedded siltstones and mudball conglomerates. Numerous bone scraps and a partial *Trimerorhachis* sp. skull were found.

The vertebrate material originally discovered by Cummins at this site has been very important. Cummins' collection contained the type specimens of a palaeoniscoid fish, *Platysomus palmaris* (Cope, 1891, p. 460) and two pelycosaurian reptiles, *Dimetrodon dollovianus* (Cope, 1888, p. 287) and *Dimetrodon platycentrus* (Case, 1907, p. 54, 75, 134), a synonymous form to *D. macrospondylus* (Romer and Price, 1940, p. 355).

New Material from Previously Known Sites

West Grandfield

(SE¼ sec. 32, T. 3 S., R. 15 W., Tillman County, Oklahoma)

Olson (1967, p. 24) first discussed this site, and it has been restudied (Simpson, 1976). The fauna was enlarged by the discovery of *Eryops megacephalus*

and remains of *Araeoscelis gracilis*. *Eryops* is represented by three fragmentary skeletons (OUSM 10135–145). A large number of *Araeoscelis* (OUSM 15142–161) bones were discovered, with hundreds of axial, appendicular, cranial, and girdle elements representing a minimum of 27 individuals. This is one of the largest concentrations of *Araeoscelis* known and the only known occurrence outside of north Texas. The remains were concentrated in a bone bed adjacent to one of the small channels that traversed the area. The *Araeoscelis* bones were found associated with immature *Eryops* and *Dimetrodon* skeletons, and the concentration is interpreted as an accumulation of carcasses in a backwash.

East Manitou

(NW¼ sec. 5, T. 1 S., R. 16 W., Tillman County, Oklahoma)

The fauna described by Olson (1967, p. 24) and Simpson (1973a, 1974a, 1974b) has been enlarged by the discovery of a number of cranial elements that appear to be from a crossopterygian (Rainer Zangerl, Field Museum of Natural History, Chicago, and Jiri Zidek, The University of Oklahoma, oral communication, 1974), possibly *Ectosteorhachis*. This fish, along with *Acanthodes*, *Sagenodus*, and *Ophiacodon*, is represented in the Wichita faunas of Texas, which became absent in the middle Clear Fork of Texas but continued to survive into the upper Leonardian along the southern flank of the Wichita Mountains of Oklahoma (Simpson, 1974b).

Olson (1967, p. 24) mentioned the presence of a marine *Orodus*-type shark tooth from these characteristically terrestrial channel–flood-plain deposits. His specimen has been lost, and the identification cannot be verified, but it appears quite possible that this tooth was actually that of a fresh-water *Hybodus*, the spines of which are known from the site (Simpson, 1974a, 1974b; Zidek, 1976).

North Randlett 1

(W½ sec. 21, T. 4 S., R. 12 W., Cotton County, Oklahoma)

Vertebrate remains from this section were originally described by Olson (1967, p. 23), who collected his specimens from the southwest quarter of the section. Olson identified *Eryops* cf. *E. megacephalus*, *Diplocaulus* cf. *D. magnicornis*, *Dimetrodon* sp., and three spine fragments of *Xenacanth* sp. (OUSM 1–35–S5) from the locality. The spine fragments, however, are *Edaphosaurus* neural spine segments, not remains of a shark. Newly discovered remains of *Sagenodus* roofing-bone elements were recovered in a reddish-brown channel-fill conglomerate in an extension of Olson's site into the northwest quarter of the section. Although not determinable as to species, it should be noted that the only *Sagenodus* species known from Oklahoma is *Sagenodus porrectus*.

Waurika 1

(SW¼ NW¼ sec. 36, T. 4 S., R. 9 W., Jefferson County, Oklahoma)

Although collections have been made from this Upper Pennsylvanian site for 60 years (Wegemann, 1915; Olson, 1967, p. 17), new material is still being recovered. This area has produced the largest amount of material from the upper

Oscar Group (Pennsylvanian, Gearyan) known from Oklahoma.

Various collectors have recovered many fish-skull fragments and large scales from this site. They resemble remains of *Ectosteorhachis* sp. (Zidek, oral communication, 1976), which is known from equivalent beds in Texas, and this genus is therefore added tentatively to the Waurika 1 faunal list.

A large number of xenacanth remains have been collected here, along with a variety of large and small *Anodontacanthus belemnoideus* spines (Zidek, 1978). *Anodontacanthus*-like spines are known from only a few Pennsylvanian and Permian sites in Bohemia, England, and America (Davis, 1881; Fritsch, 1889; Hussakof, 1911; Simpson, 1976).

Recently some dipnoian material was recovered from this site. It includes splenial and pterygoid tooth plates (OUSM 00401), opercular fragments, and roofing-bone elements. The tooth plates are from *Sagenodus porrectus* (Romer and Smith, 1934, figs. 5, 7), and, as the other fragments resemble *S. porrectus* remains from a pond deposit in the Garber Formation (Simpson, 1976, p. 67), all the *Sagenodus* remains are here assigned tentatively to *S. porrectus*.

Another dipnoian tooth fragment appears to be the posterior portion of the right splenial of *Gnathorhiza* (Olson and Day, 1972; Berman, 1976; Berman, oral communication, 1976). This represents only the second occurrence of this genus in southern Oklahoma, although it is common at sites in northern Oklahoma.

According to Malcolm Heaton (Evindale College, University of Toronto, written communication, 1974), remains of *Pantylus* have been discovered at this site by E. C. Olson. Such a find not only increases the already diversified amphibian population from this site but represents the only occurrence of this genus in Oklahoma.

The only reptile that has not been previously recorded from Waurika 1 is *Captorhinus aguti*. The species is known from two prefrontals and a partial dentary (John Bolt, Field Museum of Natural History, Chicago, oral communication, 1974; Fox and Bowman, 1966, figs. 2, 3). *Captorhinus* was not previously known from the Oscar Group, but it is known from the Texas equivalent, the Admiral Formation (Seltin, 1959).

North Edmond

(SE¼SE¼ sec. 1, T. 14 N., R. 4 W., Oklahoma County, Oklahoma)

This upper Garber Formation site has previously produced *Diplocaulus* and *Dimetrodon* remains (Olson, 1967, p. 77). More recently the proximal half of a *Trimerorhachis* femur was recovered.

Lucien 3

(NW¼SW¼ sec. 18, T. 21 N., R. 2 W., Noble County, Oklahoma)

Continued collecting from a "fine-grained green conglomerate" (Olson, 1967, p. 60–61) produced a large fauna in these lower Garber fluvial deposits. A cluster of isolated palaeoniscoid scales was found in the western part of the site together with teeth of *Xenacanthus platypternus*. The eastern part of the site produced a well-preserved *Diadectes* vertebra. Such additions make Lucien 3's

fauna more similar to that of Lucien 4, which is 1 mile to the south. The fossils are from the same zone in both sites and appear to have been deposited in the same flood plain.

Perry 5

(SE¼NE¼ sec. 32, T. 22 N., R. 1 W., Noble County, Oklahoma)

Three more genera were recovered from the top of the road-cut exposure at this predominantly *Gnathorhiza*-bearing site (Olson, 1967; Carlson, 1968). A large *Orthacanthus compressus* tooth (Simpson, 1974b, table 3), a fragmentary interclavicle that resembles that of the common temnospondyle *Trimerorhachis*, and a well-preserved *Sagenodus* frontal (Watson and Gill, 1923, figs. 1, 2; D. S. Berman, Carnegie Museum of Natural History, Pittsburgh, oral communication, 1976) were identified.

At the time these marginal Perry-site ponds were formed, the climate appears to have been arid with erratic precipitation, as is shown by the predominance of estivating animals in the local fauna. Such a climate would not be ideal for xenacanths, *Sagenodus*, or *Trimerorhachis*; but these genera are not directly associated with the *Gnathorhiza* burrows, and the remains are scrappy and restricted to a small gray lens. They could have been washed from a nearby area and do not necessarily represent an abrupt change in environmental conditions with the directly underlying *Gnathorhiza* beds at the site.

South Pauls Valley

(SW¼ sec. 19, T. 3 N., R. 1 E., Garvin County, Oklahoma)

The beds at this site have previously produced only scraps, some of which were identifiable as belonging to *Eryops* (Olson, 1967, p. 32). However, John Bolt of the Chicago Field Museum of Natural History collected a captorhinomorph skull, a dissorhophid skull (cf. *Broilelis*), and *Dimetrodon* material (Bolt, oral communication, 1976). This is a substantial discovery for the central Oklahoma area, which generally has produced scanty remains from the Wellington Formation.

Richards Spur (Fort Sill)

(SW¼ sec. 31, T. 4 N., R. 11 W., Comanche County, Oklahoma)

This site, which was named by Olson (1967), is widely known for its large quantities of *Captorhinus aguti* material (Price, 1935, 1940; Olson and Miller, 1951; Peabody, 1951, 1961; Warren, 1961; Fox and Bowman, 1966; Olson, 1967; Bolt and DeMar, 1975). It has also produced a variety of other reptiles and amphibians (Vaughn, 1958; Fox, 1962; Olson, 1967; McGinnis, 1967; Carroll, 1968; Bolt, 1969, 1974b, 1974c, 1977; Carroll and Gaskill, 1978). Bolt (oral communication, 1975) has identified remains of the amphibian *Trematops* and an eryopsid, which were previously unknown from Richards Spur.

Discussion

The vertebrate faunas characteristic of the "Permian" of Texas occur in

Oklahoma from the upper Oscar Group (Pennsylvanian, Gearyan) to the lower part of the Hennessey Group (Permian, Leonardian). This correlates with Admiral through Vale in the Texas section (fig. 2).

The sites of the Oscar Group include the Waurika 1, 2, and 3 and the East Taylor sites in far south-central Oklahoma and a solitary locality, the Morrison site, in north-central Oklahoma. The Morrison site produced the oldest remains noted in this paper. The largest and most widespread occurrences of Leonardian vertebrate sites are in the upper Garber Formation. These upper Garber sites contain large faunas and are present across the breadth of Oklahoma. However, the transition into the Hennessey Group appears to be a severe one in central and northern Oklahoma. Here, only near Norman and at a single site near Navina in the central part of the State, vertebrates survived into the Hennessey. The central Oklahoma Garber faunas are composed entirely of xenacanths, *Diplocaulus*, *Trimerorhachis*, *Labidosaurikos*, and *Dimetrodon*. None of these vertebrates, which are also characteristic of the earlier populations in these areas, are found in central or northern Oklahoma in the basal Hennessey. Above the Garber Formation, the fauna consists of estivating genera (*Gnathorhiza* and *Lysorophus*), terrestrial (*Tersomius*) and aquatic (*Goniorhynchus*, *Peronedon*) amphibians, and small (*Captorhinikos*) and large (*Cotylorhynchus*) reptiles (Olson, 1970, 1971; Bolt and Wassersug, 1975). These genera are characteristic of the fauna of the upper Leonardian and lower Guadalupian Vale, Choza, and San Angelo Formations of Texas (Olson, 1958). The upper Garber vertebrates, which did not continue into the Hennessey of central Oklahoma, characterize the faunas of the lower half of the Leonardian of Texas.

The destruction of the early Leonardian chronofauna in north and central Oklahoma coincides with environmental changes in north Texas that temporarily disrupted these vertebrate assemblages (Olson, 1958, p. 440). However, between these two coastal lowland areas were the topographically high Wichita Mountains, and the environment around these mountains appears to have been more stable than that along the marginal-marine areas to the south in Texas and to the north in central and northern Oklahoma.

Increasing aridity occurred in the Midcontinent from Wichita into Clear Fork time (Olson and Vaughn, 1970). This change from pond and marsh to temporary pond to stream environment eliminated many genera of fish, amphibians, and reptiles from the geologic record. By the end of Wichita time and into early Clear Fork time, prominent Wichita vertebrates, such as *Acanthodes*, *Hybodus*, *Sagenodus*, crossopterygians, *Archeria*, and *Ophiacodon*, had become extinct in Texas as well as in northern and central Oklahoma. However, the environmental conditions that sustained these genera continued around the Wichita Mountains, as is shown by a succession of these genera at southern Oklahoma sites from late Gearyan to late Leonardian times (Simpson, 1973b, 1974a, 1974b, 1976) (fig. 3).

Sediments and faunas indicate that drier conditions existed in northern and central Oklahoma even before they became pronounced in Texas. A prominent number of estivating genera are found in these marginal Anadarko Basin deposits, while estivating forms are virtually unknown throughout the Leonardian

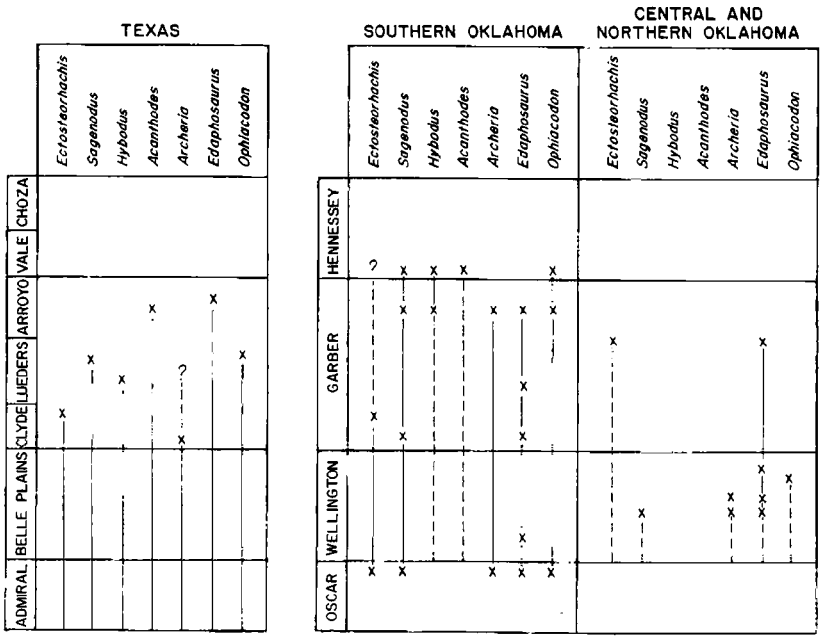

Figure 3. Stratigraphic occurrence in Texas and Oklahoma of seven vertebrate genera characteristic of chronofaunas of Wichita age.

in southern Oklahoma. The southern Oklahoma faunas were more closely associated with the north Texas vertebrate population than with those to the north of the Wichita-Arbuckle-Mountain positive area (Olson and Vaughn, 1970). This is due in part to the orientation of the Lower Permian fluvial systems in Oklahoma and north Texas. The north Texas streams headed in the Wichita-Arbuckle positive belt. The central and northern Oklahoma waters flowed from the east and northeast in the Ozarks and Ouachitas. When severe climatic conditions occurred, the vertebrates of central and northern Oklahoma were eliminated, while it appears that the faunas of southern Oklahoma were less affected. This topographically positive area of the Wichitas could have harbored certain genera during harsh climatic cycles.

Only a small part of the Lower Permian chronofauna could traverse far from the fluvial-lacustrine boundaries. Thus, movement was limited to fluvial valleys or delta systems, and the dry interfluvial or deltaic areas were traversed only by a few advanced reptiles. So the north Texas faunas could move upstream to the Wichitas to escape climatic fluctuations along the coast; the central and northern Oklahoma vertebrates had no nearby upstream haven, and, being unable to escape across the interdeltaic zones, they were trapped and destroyed during severe climatic conditions like those of upper Garber time.

Southern Oklahoma faunas could return to the north Texas marginal-marine environment when suitable climatic conditions returned. Such a situation could explain the more consistent north Texas chronofauna, which experienced only temporary disruptions, versus faunas in northern and central Oklahoma, which experienced complete destruction in late Garber time and again in early to middle Hennessey time.

Acknowledgments

I would like to thank John Bolt and Roger Burkhalter for supplying information on recent vertebrate discoveries in the State. Deep appreciation is also conveyed to D. S. Berman, Rainer Zangerl, and Jiri Zidek for identifying various fossils and to Zidek for reviewing this manuscript. Robert O. Fay of the Oklahoma Geological Survey and James H. Irwin of the U.S. Geological Survey supplied maps and information without which the stratigraphic context of this paper could not have been completed. This study was partially supported by grants from The American Association of Petroleum Geologists, the Society of the Sigma Xi, and the Chicago Field Museum of Natural History.

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OGS Releases Circular on Industrial Minerals

A new publication containing 14 papers and two abstracts covering various aspects of nonfuel industrial minerals has been released by the Oklahoma Geological Survey.

The 107-page illustrated volume, *Thirteenth Annual Forum on the Geology of Industrial Minerals*, issued as Circular 79, was edited by Kenneth S. Johnson, associate director of the Survey, and Judy A. Russell, OGS associate editor. The papers incorporated were presented at a mineral-industries conference held in

Norman May 12–14, 1977, when 116 representatives of industry, government, and academia met to discuss problems involved in exploration, evaluation, and development of deposits of such nonmetallic resources as gypsum, sand, and salt. The first such forum was held in 1965 at The Ohio State University, Columbus.

Johnson, who is well known for his work on gypsum and other evaporites, contributed a paper on "Major Gypsum Districts of Western Oklahoma," in which he describes three major districts with estimated reserves of 48 billion tons of high-purity gypsum.

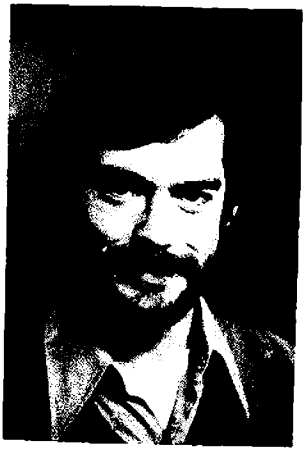
Other articles on gypsum include a discussion of prospecting for deposits prepared by Duane Jorgensen of United States Gypsum Co., Saltville, Virginia; "Energy Usage in the Gypsum Industry," by E. Robert Kiehl of Celotex Corp., Tampa, Florida; and a description of land reclamation and production at Southard, Oklahoma, by Edward B. Westphal, United States Gypsum Co., which quarries the deposits in that area.

Five papers on silica-rich sediments offer information on economics, environmental considerations, tripoli deposits in Missouri and Oklahoma, Arkansas Novaculite beds, and feldspathic sands refined from the Arkansas River. Authors of these papers are Thomas E. Shufflebarger, Jr., of Pennsylvania Glass Sand Corp., Berkeley Springs, West Virginia; Richard A. Hunnisett and George H. Didawick, of the same firm; W. F. Quirk and A. K. Bates, of Electro Minerals Division, Carborundum Co., Niagara Falls, New York, and American Tripoli Division, Carborundum Co., Seneca, Missouri, respectively; Drew F. Holbrook and Charles G. Stone, both of the Arkansas Geological Commission; and Frank W. Bowdish, of the Nevada Mining Analytical Laboratory, Mackay School of Mines, Reno. An abstract of a paper by William A. Kneller and Karinlee Kneller deals with determinations of characteristics of chert that affect performance in concrete.

Five papers cover natural brines: "Origin and Chemical Evolution of Brines in Sedimentary Basins," by Alden B. Carpenter, University of Missouri, Columbia; "Geochemistry of Bromide-Rich Brines of the Dead Sea and Southern Arkansas," by Carpenter and Michael L. Trout of Phillips Petroleum Co., Bartlesville, Oklahoma; "Iodine in Northwestern Oklahoma," by Howard M. Cotten, Amoco Production Co., Tulsa, Oklahoma; "Geochemistry of Anomalous Lithium in Oil-Field Brines," by A. Gene Collins, U.S. Energy Research and Development Administration, Bartlesville Energy Research Center; and "Preliminary Design and Analysis of Recovery of Lithium from Brine with the Use of a Selective Extractant," by Vi-Duong Dang and Meyer Steinberg, both with the Process Technology Division of Brookhaven National Laboratory, Upton, New York.

Circular 79 can be obtained from the address on the front cover. The price is $5.00 for paperback and $7.00 for hardback copies.

Jim Myers Joins OGS Staff



Charles J. Mankin, director, has announced the addition of James J. Myers to the staff of the Oklahoma Geological Survey as a minerals geologist. Myers is on a 14-months continuous appointment under a grant project administered by Bendix Field Engineering Corporation for the U.S. Department of Energy's NURE (National Uranium Resource Evaluation) program. He will assist Salman Bloch, OGS uranium geologist, in a survey of known uranium occurrences in the Clinton and Enid Quadrangles of west-central and north-central Oklahoma, an area covering approximately one-fifth of the State.

This project is under the direction of Kenneth S. Johnson, economic and environmental geologist and associate director of the OGS. Other staff members participating are Robert O. Fay, Arthur J. Myers, and William E. Harrison, geologists; and Stephen J. Weber, analytical chemist. The survey involves evaluation of the surface geology, collection and analysis of 300 water samples, and radiometric testing by use of a scintillometer. (See *Oklahoma Geology Notes*, April 1978, v. 38, p. 65.)

Jim Myers comes to the OGS well equipped and well recommended to fill this apointment. He has worked on uranium and base metals for Anschutz Minerals in Asunción, Paraguay, and for Homestake Mining Co. in Colorado. He held previous summer positions with International Minerals Corp. of Soda Springs, Idaho, evaluating phosphorite deposits. He has served as a survey assistant with a private surveying firm, and while at the University of Idaho he was laboratory assistant in the geochemical lab and a chemistry tutor. He is a member of the American Institute of Mining Engineers (AIME), the Northwest Mining Association, and Phi Theta Kappa, national junior college honor society.

The son of a U.S. Air Force colonel, Jim was born in Sacramento, California. He received his secondary education in Anchorage, Alaska, and in Coeur d'Alene, Idaho. He attended North Idaho College in Coeur d'Alene and

then earned a B.S. degree in geology from the University of Idaho, Moscow.

He is an expert skier and is a member of the Pacific Northwest Ski Association. He was a ski-racing coach for Schweitzer Basin, Inc., of Sand Point in far northern Idaho.

Jim's wife, Ana, is a native of Peru and taught English in Lima. A linguist, she speaks Japanese and French in addition to English and her native Spanish.

We are happy to have the Myers' with us.

OGS Receives Grant for Survey of Mines

The Oklahoma Geological Survey has received a grant of $24,995 from the U.S. Bureau of Mines (USBM) to conduct a survey of all active and inactive mines and mineral-processing plants in the western half of Oklahoma. Kenneth S. Johnson, OGS economic geologist and associate director, has been named principal investigator for the grant program; he is being assisted by Arthur J. Myers, geologist with the Survey.

Data obtained will be used by USBM in its nationwide survey of mineral-producing areas under the Mineral Industry Location System (MILS) program. When completed, the data base will provide ready access to information on each mine and processing plant in the country, including the precise location, type of operation, commodity produced, name of producer, and current status.

In Oklahoma, this project represents a continuation of the Oklahoma Geological Survey's ongoing investigations into the distribution of important mineral resources in the State. Johnson estimates that the survey will show approximately 5,000 separate past and present mineral operations in the 40 counties under examination in western Oklahoma. This is exclusive of the great number of oil and gas wells in the region. Minerals that have been or are being produced in this area include sand and gravel, limestone, dolomite, granite, gypsum, copper, salt, shale, uranium, and asphalt.

The current national program is expected to extend over a period of 3 to 5 years. Plans call for an extension of the program in Oklahoma at a later date to provide for a similar survey to be conducted over the eastern half of the State.

Coming Meetings of Interest

AAPG-SEPM Annual Meeting

The idea that petroleum is discovered through creative thinking and with the use of inventive technology will be the central theme of the 1979 annual convention of The American Association of Petroleum Geologists and the Society of Economic Paleontologists and Mineralogists, which will be held in Houston April 1–4. "Our Ideas Find Oil" is the theme of the meeting, which is being hosted by the Houston Geological Society.

Several members of the Oklahoma Geological Survey and The University

of Oklahoma's School of Geology and Geophysics will participate in the convention's activities, most of which will be held in the Albert Thomas Convention and Exhibit Center.

Kenneth S. Johnson, OGS associate director, will present a paper entitled "Potential for Subsurface Disposal of Industrial Wastes in Oklahoma." The late John F. Roberts, OGS geologist, coauthored the paper.

Survey geologist Thomas W. Amsden will give a paper entitled "Late Ordovician–Early Silurian Strata in the Midcontinent Area."

Faculty member Bernie Bernard will speak on "Isotopic Compositions of Biogenic Carbonate Cements," a paper that was coauthored with his colleague Burr Silver. Bernard will present a second paper, "A Model for Interstitial Sulfate Reduction and Methane Production."

The registration fee, due by March 15, is $50 per person; the fee will be $60 at the convention site. The deadline for sending in housing-request forms is March 20.

Registration for any of the four short courses is required by March 15, and a March 9 deadline has been set for payment of fees for the eight field trips available to convention participants. Additional information can be obtained from AAPG, P.O. Box 979, Tulsa, Oklahoma 74101.

Great Plains Water Conference

This conference, scheduled for April 1–4 in Tulsa at Williams Plaza, is sponsored by The University of Tulsa and the Association of Professional Geological Scientists, Oklahoma Section. Sessions include discussion of ground water, surface water, and legal, regulatory, and political aspects of water. The principal objective of the conference is to provide participants with an understanding of the fundamental subjects required to deal effectively with impending crises in the allocation, use, and conservation of water resources.

The registration fee is $75 for governmental agencies, universities, and other nonprofit organizations and $150 for industry and business organizations. Two or more attendees from the same organization will receive a 20-percent discount. For additional information, contact Pat Hall, College of Engineering and Physical Sciences, Division of Continuing Education, The University of Tulsa, 1133 North Lewis, Tulsa, Oklahoma 74110 (phone, 918—939–6351, ext. 347).

GSA South-Central Section Meeting

The South-Central Section of The Geological Society of America will hold its 13th annual meeting April 9–10 in Mountain View, Arkansas.

The meeting, which includes two days of technical sessions and three field trips, is being sponsored by the Arkansas Geological Commission. The advance registration fee is $18; after March 28 the fee will be $24.

Additional information can be obtained from Norman F. Williams, Arkansas Geological Commission, 3815 West Roosevelt Road, Little Rock, Arkansas 72204 (phone, 501—371–1488).

Grants Uranium Symposium

The Grants symposium, sponsored by the Energy Minerals Division of AAPG in cooperation with the Central New Mexico Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers and the New Mexico Bureau of Mines and Mineral Resources, will be held in Albuquerque May 13–16.

Topics of papers include geology of specific ore bodies, depositional environments of the Morrison Formation, the role of organic materials in the formation of uranium deposits, geochemistry, regional ground water, geochronology, and sources of the uranium.

The conference registration fee is $75; the fee for the field trip to the Grants Uranium Region on May 14 is $20. For more information contact Sondra Biggs, AAPG, P.O. Box 979, Tulsa, Oklahoma 74101 (phone, 918—584–2555).

IX-ICC

The Ninth International Congress of Carboniferous Stratigraphy and Geology (IX-ICC) will be held May 21–26 in Urbana, Illinois, with seven pre-meeting field trips to the Appalachian Mountains (May 10–21) and eight post-meeting field trips to the Midwest and Far West (May 26–June 2). In addition to the field trips and technical sessions, subcommission meetings will be held in Washington (May 17–20) as well as the opening plenary session, also in Washington (May 19). April 15 is an important date to remember, because this is the last day to be assured housing in Urbana and the last day to qualify for the special rates in Washington, D.C.

This is the first time that the United States has hosted this meeting. The congresses are held every four years; the first was in 1927 in The Netherlands, and the 1975 meeting was in Moscow. Expected attendance is 1,000–1,500 scientists.

One general purpose of the meeting is the discussion of all aspects of the geology of Mississippian and Pennsylvanian and equivalent strata throughout the world. The various field trips will examine rocks of these ages.

Sponsors of the meeting include seven national associations and societies. Co-hosts for the technical sessions are the Illinois State Geological Survey and the University of Illinois; co-sponsors in Illinois are the Field Museum of Natural History, the Illinois State Museum, and Southern Illinois University. IX-ICC is an official event of the centennial celebration of the U.S. Geological Survey.

National officers are Mackenzie Gordon, Jr., president, and Ellis L. Yochelson, secretary-general. Both are with the U.S. Geological Survey in Washington, D.C. Charles J. Mankin, director of the Oklahoma Geological Survey, is serving on the national organizing committee for the Congress, and William D. Rose, geologist/editor with OGS, is serving on the publications subcommittee.

The guidebook for field trip 11 (May 27–June 1), entitled *Mississippian-Pennsylvanian Shelf-to-Basin Transition, Ozark and Ouachita Regions, Oklahoma and Arkansas*, will be published by OGS as Guidebook 19. Editors for the guidebook are Patrick K. Sutherland, The University of Oklahoma, and Walter

L. Manger, University of Arkansas. Sutherland and Manger are also the organizers of symposium IV, *Mississippian-Pennsylvanian Boundary in North America*, and will give papers during the symposium.

Inquiries concerning the congress should be addressed to Mackenzie Gordon, Jr., or Ellis L. Yochelson at IX-ICC, 1979, Museum of Natural History, Washington, D.C. 20560.

Three Oklahoma Place Names Approved

Three Oklahoma place names have been approved recently by the U.S. Board on Geographic Names. The place names were published in the July through September 1978 issue of *Decisions on Geographic Names in the United States* (Decision List 7803).

New Tulsa (not: Oak Grove) has been adopted to identify a community 27 km (17 miles) east-southeast of Tulsa, Wagoner County; secs. 1 and 2, T. 18 N., R. 15 E., and secs. 35 and 36, T. 19 N., R. 15 E.; Indian Meridian (36°04′30″ N., 95°40′21″ W.).

Stonebluff (not: Stone Bluff) has been adopted to identify a community 11 km (7 miles) southwest of Coweta, Wagoner County; secs. 5 and 8, T. 16 N., R. 15 E.; Indian Meridian (35°53′08″ N., 95°44′15″ W.).

Yashau Creek (not: Yashoo Creek) has been adopted to identify a stream 28 km (17.5 miles) long that heads at 34°09′58″ N., 94°45′02″ W., and flows south to Little River, 8.9 km (5.5 miles) south of Broken Bow, McCurtain County; sec. 18, T. 7 S., R. 25 E.; Indian Meridian (33°56′54″ N., 94°44′03″ W.).

GSA Committee Issues Report on Floods

The relationships between hydrology, physiography of flood plains, and man's use of flood-prone lands are the subject of *Floods and People: A Geological Perspective*, a report prepared by the Committee on Geology and Public Policy of The Geological Society of America.

The publication, which is free to GSA members, includes definitions of floods, natural factors controlling flood magnitudes, effects of changes in land use, the timing of floods, and means of coping with flood hazards.

The report, written for the general public, stresses the "inevitability" of flooding in nearly any region and emphasizes the need for understanding the concepts of probability used in describing the frequency of floods, the brevity of the hydrologic record, and the close association of natural river processes with the landscape of the river valley. The study contends that only informed citizens, planners, and elected officials can, in the long run, avoid the mistakes of the past.

The GSA address is 3300 Penrose Place, Boulder, Colorado 80301.

JOHN FREDRICK ROBERTS
(1911–1978)

The Oklahoma Geological Survey lost one of its most faithful and valued staff members when John F. Roberts died last November 17 in Norman.

John came to the Survey in 1965 as petroleum geologist under director Carl C. Branson, becoming senior petroleum geologist following the death of Louise Jordan in November 1966. His contributions to the OGS have been immeasurable. He conducted virtually single-handedly the massive, exacting task of compiling an annual statistical report of Oklahoma's petroleum industry. The data he assembled on petroleum and natural gas have been published each year in *Oklahoma Geology Notes* and also incorporated into the Oklahoma reports issued by the U.S. Bureau of Mines in the *Minerals Yearbook* series.

This work requires both detailed and broad awareness of every phase of the industry: exploration and development, drilling, production, reserves, reservoirs, fields, significant wells, economics, and technology. It involves knowing the geology, particularly in subsurface, and also the geography, of the entire State. It was the knowledge John had in his head and at his fingertips that made him such an asset to the Survey and in such demand for consultation by industry representatives and private citizens with an interest in petroleum and natural gas. He was always ready to offer assistance.

John's helpfulness extended beyond the realm of the professional. He might grumble a bit if anyone made over anything he did, but he was always there to pitch in wherever his help was needed, even lending a hand in the main office when it was short-staffed or especially busy, waiting on customers, manning the phone, always, always answering questions. He knew where everything was, whether current or archival. If it happened to be apocryphal, nonscientific

material, he might look as if he thought the seeker was pretty stupid not to know the location of what he sought, but then he would point the way, or find what was wanted—if it was to be found. He organized and staffed exhibits for numerous scientific meetings.

There is no one in the Survey organization, co-professionals or support staff, whose appreciation of John Roberts did not deepen upon longer acquaintance. He was a surrogate father to some, a respected source of information to others, a willing co-worker, a friend. On another level, both he and his wife, Latane, were always the ones to be at hand at a time of illness or bereavement, helping without being asked, just being there.

He is missed.

John was born March 11, 1911, in Windsor, Missouri. He earned an A.B. degree in geology from the University of Missouri at Columbia in 1932 and received his M.A. in geology two years later from the same university. His master's thesis was on the "Ostracoda of the Sundance Formation of Wyoming."

Completion of his graduate degree came during a low period for geological employment, and he was needed to run the family business, so for the following 9 years he managed a family-owned department store in Windsor. He was called into military service during World War II and served with the U.S. Army from August 1943 until November 1946, with much of his tour of duty having been spent in the European theater of operations in England, France, and Germany. Following discharge from the army, he went to work for Carter Oil Co. (later Humble Oil and Refining Co., now Exxon). He served the company in various capacities.

First assigned to wellsite and surface geology, he became production liaison geologist for the Purcell and Seminole areas in Oklahoma, filling in from time to time during this period as district geologist, processing development recommendations, reviewing farm-out and support deals, and writing reports for Oklahoma, Kansas, and Texas. He was transferred to the position of assistant to the district geologist for the Arkoma Basin, supervising all drilling wells and wellsite geologists and initiating the first subsurface mapping on a regional basis in the area. He was promoted to district production geologist for the Ardmore area, again supervising drilling wells and wellsite geologists. He also worked in liaison with the production department in workovers, deepening of wells, and all phases of secondary recovery.

He remained with the company until 1965, when he joined the staff of the Oklahoma Geological Survey.

At the time of his death, in addition to keeping his statistical records, John was serving as principal investigator for Oklahoma on a 3-year cooperative program with the geological surveys of Kansas and Missouri designed to study the "heavy" oils in this Tri-State area. The project has been funded by the U.S. Department of Energy. Results have been assembled from examination of hundreds of well logs and from 18 wells drilled specifically for the Oklahoma portion of the investigation in Craig and Nowata Counties. This project is now being completed under the direction of OGS petroleum geologist William E. Harrison.

John Roberts was also supervising collection of data for updating the Oklahoma Geological Survey *Index to Geologic Mapping in Oklahoma* series to show surface mapping from 1901 to 1976 and subsurface mapping in 3-year increments between 1967 and 1976. He also was working with Survey geologists Kenneth S. Johnson and Kenneth V. Luza on a study of the general suitability of various parts of the State for subsurface disposal of industrial wastes. Results of this investigation will be issued as an open-file report shortly and will be published later as an OGS circular.

John was a member of The American Association of Petroleum Geologists, the Association of Professional Geological Scientists, the Oklahoma City Geological Society, the Tulsa Geological Society, and the Ardmore Geological Society. He chaired several committees for these organizations. He was elected to Epsilon chapter of Sigma Gamma Epsilon (honorary geological fraternity) at the University of Missouri. He retained his membership in the First Christian Church of Windsor and was also a member of the Windsor Masonic Lodge.

He is survived by his wife, Latane; twin daughters, Mrs. Molly Pappan of Norman and Mrs. Polly Lackey of Plainview, Texas; a brother, Frank L. Roberts of Windsor; and one granddaughter, Juliet Pappan.

A memorial fund has been established in his name under the Oklahoma Geological Survey Foundation. Friends and associates who would like to honor John Roberts through the Foundation should contact the Oklahoma Geological Survey at 830 Van Vleet Oval, Norman, Oklahoma 73019 (phone 405—325–3031).

It would have been good to write this tribute upon the occasion of his retirement, but John suffered a bad fall at his home and was unable to overcome the complications that resulted from his injuries. Services were held November 20, 1978, at Mayes Chapel of Remembrance in Norman, with Dr. Lavonn Brown of the First Baptist Church and Dr. Robert Chesnut of the First Presbyterian Church, both of Norman, officiating. Services were also conducted at the Mangum Funeral Home in Center, Texas, prior to interment in the family plot at Neuville Cemetery near Center.

—Elizabeth A. Ham

USGS Issues Reports on Oklahoma

The U.S. Geological Survey has issued the following reports that might be of interest to Oklahoma geologists:

Open-File Reports

78–414—*Application of Hydraulic and Hydrologic Data in Urban Stormwater Management*, by Thomas L. Huntzinger, 33 p., 24 figs., 4 tables. The report discusses the types of hydrologic data collected in a flood-insurance study

and presents some techniques for applying the data to stormwater management; Oklahoma is used as an example in the report.

78–766—*Geohydrology of the Antlers Aquifer, Southeastern Oklahoma*, by D. L. Hart, Jr., and R. E. Davis, 39 p., 12 figs., 3 tables. OGS plans to release this as a circular later this year.

78–1038—*Hydrologic Data for the Antlers Aquifer, Southeastern Oklahoma*, by R. E. Davis and D. L. Hart, Jr., 24 p., 5 tables. Tables are computer printouts of hydrologic data, which include concentrations of common constituents and trace elements, physical properties of water, and low-flow-discharge measurements for selected streams.

78–721—*Selected Water-Level Records for Oklahoma, 1975–1977*, by R. L. Goemaat and D. E. Spiser, 58 p., 1 fig., 1 table.

78–781—*Geohydrology of the Vamoosa Aquifer, East-Central Oklahoma*, by J. J. D'Lugosz and R. G. McClaflin, 63 p., 9 plates, 10 figs., 5 tables. OGS also plans to release this as a circular.

78–857—*Reconnaissance of Ground Water in the Vicinity of the Wichita Mountains, Southwestern Oklahoma*, by J. S. Havens, 27 p., 7 figs., 1 table. This will also be released by OGS as a circular.

Open-file reports are available for inspection at the Oklahoma Geological Survey and at the Office of the District Chief, U.S. Geological Survey, Water Resources Division, 201 Northwest 3d Street, Room 621, Oklahoma City, Oklahoma 73102 (phone, 405—231–4256). A limited number of single copies of Reports 78–1038 and 78–721 can be obtained on request to the district chief.

An additional open-file report, 78–927, *Isotopic and Chemical Data from Carbonate Cements in Surface Rocks over and near Four Oklahoma Oil Fields*, by M. E. Henry and T. J. Donovan, 20 p., 10 figs., is available from Open-File Services Section, Branch of Distribution, U.S. Geological Survey, Box 25425, Federal Center, Denver, Colorado 80225. The cost is $3.50 for microfiche and $3.00 for paper copy.

Water-Data Reports

OK–77–1—*Water Resources Data for Oklahoma Water Year 1977, volume 1, Arkansas River Basin*, 543 p., 8 figs. OK–77–2—*Water Resources Data for Oklahoma Water Year 1977, volume 2, Red River Basin*, 235 p., 8 figs. These reports are available for inspection at OGS and the Water Resources Division in Oklahoma City. Single copies can be obtained on request to the district chief at the address given previously.

Water-Resources Investigations

78–70 (NTIS number PB-284 668)—*Plan of Study for the High Plains Regional Aquifer—System Analysis in Parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming*, by J. B. Weeks, 32 p. The report is available from National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161. The cost is $4.50; use NTIS number when ordering.

The American Association of Stratigraphic Palynologists, Inc., 11th Annual Meeting Phoenix, Arizona, October 24-28, 1978

The following abstracts are reprinted from the *Abstracts with Program*, 11th Annual Meeting. Page number is given in brackets below the abstract. Permission of the author and of Vaughn Bryant, editor of AASP, to reproduce this abstract is gratefully acknowledged.

Comparison of the Litho- and Biostratigraphy at the Pennsylvanian-Permian Boundary in Oklahoma and Kansas

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Where sedimentation is continuous from one time unit into another, there generally occurs a transition of environmental conditions which results in gradual changes of sedimentary and biologic types. When stratigraphic boundaries are drawn in these areas, they are largely determined by the phylogenetic groups used and often are supported by local unconformities. An understanding of litho- and biofacies is necessary to establish a well-founded boundary, and it is obvious that no absolute agreement will be reached without thoroughly exploring all of these conditions. The Pennsylvanian-Permian boundary in Oklahoma and Kansas is an excellent example of a controversy that has long continued because stress has been placed on too few criteria.

In 1963 the Gearyan Series was established by stratigraphers from Kansas and Oklahoma to distinguish the transitory portion of the Upper Pennsylvanian and Lower Permian, which in northern Oklahoma and eastern Kansas was generally known as the Wolfcamp Series. The group divisions of the Gearyan are, in ascending order, the Admire, Council Grove and Chase. The reason for the designation is the indefinite relationship with the Wolfcamp Series of New Mexico and Texas. A lithofacies study of the Virgilian Series (Upper Pennsylvanian), the Gearyan Series (here considered to be Pennsylvanian), and the Wellington Formation (Cimarronian Series, Lower Permian) show the following changes: shales, Virgilian (black to gray), Gearyan (gray to brownish red, upward), Wellington (gray to bright red); coals, Virgilian (few and thin), Gearyan (rare), Wellington (none); gypsum and salt, Virgilian (none), Gearyan (none?), Wellington (abundant).

OKLAHOMA ABSTRACTS is intended to present abstracts of recent unpublished papers relating to the geology of Oklahoma and adjacent areas of interest. The editors are therefore interested in obtaining abstracts of formally presented or approved documents, such as dissertations, theses, and papers presented at professional meetings, that have not yet been published.

The Pennsylvanian-Permian boundary established on invertebrate criteria (according to several authors) has varied greatly, from the Brownville Limestone at the base of the Gearyan to the Ft. Riley Limestone in the Chase Group of the Gearyan. Other boundaries have been the Americus Limestone, Neva Limestone, and Cottonwood Limestone, all of the Council Grove Group, as well as the Wreford Limestone of the Chase Group. Vertebrate criteria has placed the boundary as high as the Carlton Limestone in the Cimarronian Series (Lower Permian). Plant megafossils indicate a boundary at the Neva Limestone in the Council Grove Group. Evidence from palynology places the boundary below the Nolans Limestone in the Odell Shale of the Chase Group. This boundary is approximately 30 feet below the Herington Limestone Member of the Nolans Limestone, which is the Pennsylvanian-Permian boundary suggested by lithology. [40]

Oklahoma State University

Physical Stratigraphy of the Avant Limestone Member of the Iola Formation, Southern Osage County and Parts of Nearby Counties, Oklahoma

JOE DWAIN DAVIDSON, Oklahoma State University, M.S. thesis, 1978, 3215 Riverside Drive, Apt. 129, Tulsa, Oklahoma 74105

Scope and Method of Study: The depositional trend of the mound facies of the Avant Limestone Member of the Iola Formation was established in southern Osage County and parts of nearby counties, Oklahoma, chiefly from an isopach map of net limestone, a log map, and correlation sections. An isopach map of the interval between the base of the Hogshooter Limestone and the base of the Avant Member was used to estimate the influence of variation in thickness of this interval on thickness of the Avant. Correlation sections extending outside the area of primary mapping were used to determine the western and southern identifiable extents of the Avant in the subsurface and to determine its stratigraphic relation to the Perry gas sand of Noble County. Characteristics of the Avant were compared to those of typical late Paleozoic phylloid-algal mounds of the Midcontinent and to those of typical "upper" or "regressive" limestone members within cylothems of the Midcontinent.

Findings and Conclusions: The mound facies of the Avant Member trends southwestward from R. 12 E. to R. 3 E. along T. 23 N. through T. 20 N. Local thickening of the Avant-Hogshooter interval along the eastern and southern portions of the area of primary mapping corresponds well with thickening of the overlying Avant mound facies. This suggests that submarine paleotopography might have initiated development of a mound along this trend. The Avant can be correlated southward and westward in the subsurface, along R. 8 E. from T. 23 N. through T. 18 N. and from T. 23 N., R. 12 E., to T. 20 N., R. 2 E., respectively. The stratigraphic position of the Perry gas sand is between that of the Wildhorse Dolomite Lentil, Barnsdall Formation, above and the Avant Limestone Member below.

Petrography and Geochemistry of the Butterly Dolomite, and Associated Sphalerite Mineralization, Turner Prospect, Arbuckle Mountains, Oklahoma

PETER VAL KRANAK, Oklahoma State University, M.S. thesis, 1978, 922 Red Poll Circle, Corpus Christi, Texas 78418

Scope and Method of Study: The Butterly Dolomite was studied in Murray County of Oklahoma, by petrographic and geochemical means. The geochemical study is one of the most extensive ever attempted on a dolomite. Samples were collected on outcrops and from a core. Dolomite samples were analyzed for Ca, Mg, Fe, Mn, Sr, Na, K, Cu, Pb, Zn, Cd, Cr, Ni, and Li. Sphalerite samples were analyzed for Cd, Mn, Fe, Cu, and Pb. Both dolomite and sphalerite samples were analyzed by means of atomic absorption. The data were analyzed by non-parametric statistics.

Findings and Conclusions: The Butterly Dolomite is a medium crystalline replacement dolomite, with about 5 percent of the sand as quartz and feldspar. Overgrowths of quartz and feldspar suggest that the sea was hypersaline and saturated in SiO_2. Detrital clay minerals include illite, kaolinite, and Fe-chlorite. Chemical elements of the dolomite do not have normal distributions, even after transformations. This is best explained by several diagenetic alterations changing the distribution of the elements of the original limestone. Comparison of the dolomites and original limestone suggest that dolomitization increased grain size, and Mg, Na, Zn, Cr; decreased Ca, Sr, K, Cd, Ni, and residual; and did not affect Fe, Mn, Cu, Pb, Li. Fabric of the dolomites indicate that there were two dolomitizational events separated by a corrosional event. The first dolomitization occurred inches below the sea-sediment interface. The second dolomitization was periodic, filled the pore space created by previous dolomitization, and probably was associated with zinc mineralization. Zinc mineralization concentrated in the brecciated host fragments and was localized by replacement of remnant limestone beds.

Relationship of the Carbonate Shelf and Basinal Clastic Deposits of the Missourian and Virgilian Series of the Pennsylvanian System in Central Beaver County, Oklahoma

STEVEN DALE LANE, Oklahoma State University, M.S. thesis, 1978, 2016 E. Willow Creek Terrace, Mustang, Oklahoma 73064

Scope and Method of Study: This study was concerned with the stratigraphic relationships of the basinal clastics and shelf carbonates of the Virgilian Douglas Group and the Missourian Lansing and Kansas City Groups in T. 1–6 N., R. 23–25 W., ECM, Beaver County, Oklahoma. Materials involved in interpretation and solution of the specific problem are a structural contour map of the base of the Heebner Shale Member, Oread Limestone, and isopachous map of strata between the Heebner and the uppermost limestone bed in the Lansing Group, a set of cross sections, a sand-distribution map, and log maps of the upper portion

of the combined Lansing and Kansas City Groups. Correlations in the section were based chiefly on electric-log characters and on commercial sample logs. The available core in the study area was photographed and inspected for fusulinids. Various core samples were stained with Alizarin Red-S and acetate peels made of them were studied with a binocular microscope and photographed.

Findings and Conclusions: The submarine paleotopography of the upper Lansing Group can be determined by an isopachous map of the overlay clastic wedge. Delineated on the isopachous map are areal extent of major carbonate depositional environments; shelf, shelf margin, and basin. "Time-marker" within the Lansing-Kansas City section was judged mostly to be correlative shale "breaks." Relative thicknesses between shale "breaks" can be used to infer major carbonate depositional environments and log maps show trends as well as areal extent of the environments. The Tonkawa sandstone is contained in the foreset-slope sediments deposited with the Virgilian Douglas Group and therefore not equivalent to the Missourian Lansing Group.

The Economic Potential of the Lower Hartshorne Coal on Pine Mountain, Heavener, Oklahoma

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Scope and Methods of Study: The geology of the Lower Hartshorne coal on Pine Mountain was mapped by using drill logs, coal core logs, aerial photographs and field mapping. Maps showing the structural contour, coal thickness, overburden thickness and sandstone thickness were developed. The coal reserves were calculated based on information from maps. Coal analyses, petrographic information, and washability tests were used to determine the quality of the coal.

Findings and Conclusions: The rocks studied were of the Atoka Formation, Atoka Series and the Hartshorne and McAlester Formations, Krebs Group, Desmoinesian Series, all of which are Pennsylvanian rocks. The Lower Hartshorne coal occurs in the Hartshorne Formation. The structure of the Lower Hartshorne coal on Pine Mountain is an eastward plunging syncline. The formations are composed of sandstone, siltstone, shale, and coal deposited in a deltaic environment.

The Lower Hartshorne coal averages 28.4 inches thick in the study area. There are 5.37 million block tons with an average of 53 feet of overburden to a 100-foot-high wall. The overburden is 52 percent sandstone. The coal is ranked low- to medium-volatile bituminous and has an average Btu of 13,700 (dry basis). The quality is variable and averages 2 percent sulfur and 14 percent ash. Concentration of sulfur in the upper portion of the seam suggests that the coal can be upgraded by selective mining. The ash content can be reduced significantly through coal preparation but the sulfur cannot. The coal is suitable as steam coal using conventional mining techniques or as both steam and metallurgical coal by selective mining.

The University of Oklahoma

Feldspar Dispersal Patterns in Mudrocks of the Vanoss Group South-Central Oklahoma

JOHN ROBERT CAPRARA, The University of Oklahoma, M.S. thesis, 1978, 909 Merrill Street, Houston, Texas 77009

Sixty samples of the Pennsylvanian Vanoss Group of south-central Oklahoma were collected for the purpose of evaluating feldspar dispersal from a known granitic source. The solid silica (quartz and chert) plus feldspar fraction was isolated from mudrocks and sandstones by chemical techniques. This material was then analyzed by atomic absorption spectrophotometry for normative percentages of orthoclase, albite, and anorthite. Furthermore, because the plagioclase in the source rocks is approximately 12.5 percent normative anorthite, the amount of normative albite that should be attributed to plagioclase can be calculated using the normative anorthite data. The remaining normative albite is attributed to pure albite lamellae in perthitic grains.

Although the lower part of the Vanoss Group is composed mostly of limestone conglomerates, the interbedded mudrocks reveal a gradual increase in feldspar in this part of the formation, resulting from the removal of the Paleozoic cover from the Troy and Tishomingo granites. The detrital carbonate part of the Vanoss was succeeded by feldspathic conglomerates and sandstones as the igneous core of the Arbuckle Mountains became the predominant source for the sediments of the Vanoss Formation. A study of the feldspar plus solid silica fraction of the 3.5–4.0 ϕ size fraction of mudrocks associated with these conglomerates and sandstones showed a progressive decrease of feldspar away from the granitic source. Because the normative orthoclase plus the normative albite from perthites did show a progressive decrease away from source, failure of the normative albite plot to reveal its source was probably due to loss of oligoclase during diagenesis.

To evaluate the relative degree of diagenesis between the sandstones and mudrocks of the Vanoss Group, the feldspar plus solid silica fraction of the 3.5–4.0 ϕ size fraction from 12 depositionally associated sandstones and mudrocks was studied. In modern sand-mud pairs the ratio of feldspar to feldspar plus solid silica of a single size fraction has been shown to be nearly identical. However, in the sediments of the Vanoss Group this ratio is considerably higher in the sandstones. The ratio is also higher in the sandstones for normative orthoclase and albite considered separately. Petrographic studies indicated that an increase of feldspar in the 3.5–4.0 ϕ size fraction of the sandstones resulted from diagenetic size reduction of feldspar grains larger than 3.5 ϕ.

Through the use of chemical techniques accurate data can be obtained concerning the feldspar concentrations of mudrocks. Furthermore, by using the normative percentages of feldspar in the feldspar plus solid silica fraction of a single size fraction of mudrocks a progressive decrease in feldspar away from source can be demonstrated. Some information, however, may be lost from mudrocks during diagenesis.

Distribution, Structure, Origin, and Resources of the Hartshorne Coals in the Panama Quadrangle, Le Flore County, Oklahoma

DANA LEON CRANEY, The University of Oklahoma, M.S. thesis, 1978, El Paso Natural Gas Co., P.O. Box 990, Farmington, New Mexico 87401

The Hartshorne coals were studied in the Panama 7.5 minute topographic-quadrangle map area in Le Flore County, Oklahoma, to determine their distribution, structure, origin, and resources. The area is in the Arkoma Basin which was on the continental margin north of the theoretical Ouachita geosyncline during Paleozoic time. The Hartshorne sandstone deltaic system (Desmoinesian) prograded southwestward into the basin and provided an environment on which a forested peat-forming swamp flourished. Brackish conditions added sulfide minerals to the peat. An isochore map of the clastic interval between the Upper and Lower Hartshorne coals suggests that possible Desmoinesian slippage along an Atokan growth fault caused a small split-forming transgression. The interruption in the deposition of the Hartshorne peat formed the Upper and Lower Hartshorne coals and the laterally equivalent upper and lower benches of the Hartshorne coal to the north.

Isocarb maps of the Hartshorne coals and a study of the fixed carbon content of the coals in the Arkoma Basin showed that the rank of the coals is the result of: 1) the original depth of burial to provide a sufficient geothermal temperature to continue the coalification process, 2) igneous Mesozoic and Cenozoic intrusions in the eastern Ouachita Mountains in Arkansas imparting a strong eastward increase to the coal rank, 3) degasification due to fracturing of the strata from the deformation of the Arkoma Basin, and 4) an extremely long coalification time.

All contacts in the Savanna, McAlester, Hartshorne, and Atoka Formations in the Panama Quadrangle are conformable as shown by 9 cross sections. The Hartshorne Formation is 130 to 250 feet thick. The Hartshorne coals are 1.7 to 6.9 feet thick and contain 0.6 to 2.7 percent sulfur. Remaining resources of 13,711,000 short tons (strippable) and 230,696,000 short tons (nonstrippable) are present in 42 square miles of the Panama Quadrangle.

The Geology of the Hartshorne Coals in the Spiro and Hackett Quadrangles Le Flore County, Oklahoma

VICTOR FUNMILOLA AGBE-DAVIES, The University of Oklahoma, M.S. thesis, 1978, 2809 South Dewey #115, Norman, Oklahoma 73069

A study of the Hartshorne coals (Desmoinesian) was conducted in Spiro and Hackett 7.5 minute quadrangles consisting of approximately 90 square miles. Previous studies in the area have been regional in scope without major concentration on the Hartshorne coals.

The study area is in the Arkoma Basin which received sediments from the Ouachita uplift and the Ozark uplift during the Pennsylvanian Period. Structures in the area include narrow anticlines and shallow synclinal troughs.

The Hartshorne Formation was deposited in part by a prograding delta. Peats, progenitors of the Hartshorne coals, were deposited in the deltaic and

deltaic-related environments. The Hartshorne coal splits into the Upper and Lower Hartshorne coal beds that are 40 feet (12.2 m) to 110 feet (33.5 m) apart stratigraphically in the study area.

The Lower Hartshorne coal is medium-volatile bituminous in rank, 1 foot (0.3 m) to 5.0 feet (1.5 m) thick containing 0.7% to 1.4% sulfur. The calorific value of the Lower Hartshorne coal averages 13,836 Btu (dry basis). The Upper Hartshorne coal and the Hartshorne coal (undivided) are 1 foot (0.3 m) to 6.0 feet (1.8 m) thick. The sulfur content is 0.8% to 2.7%. The calorific value ranges from 12,474 Btu to 14,751 Btu, with a free swelling index value averaging 6.

The rank of the Upper Hartshorne coal increases locally due to a geothermal anomally. Detailed stratigraphic and chemical analyses of the area show that the Hartshorne coals were formed by forest peat. The stratigraphy of the Hartshorne Formation shows two depositional cycles. Underclays beneath the Hartshorne coals and upright fossil tree trunks support an autochthonous (in place) origin for the Hartshorne coals.

Resource calculations for the Hartshorne coals in the study area show a grand total of 341,917,000 short tons in the remaining category. The grand total for the mined and lost-in-mining category is 11,509,000 short tons. The unmined area, underlain by identical coal resources, consists of 48,054 acres.

The Geology of the Hartshorne Coals (Desmoinesian) in Parts of the Heavener 15′ Quadrangle, Le Flore County, Oklahoma

DAVID RICHARD DONICA, The University of Oklahoma, M.S. thesis, 1978, P.O. Box 900, Dallas, Texas 75221

An 119-square-mile area within the Heavener 15′ quadrangle, Le Flore County, in the eastern part of the Arkoma Basin, Oklahoma, was investigated to determine the geology of the coals in the Hartshorne Formation (Desmoinesian). The Lower Hartshorne coal lies about 60 feet above the base of the Hartshorne Formation, and is low- to medium-volatile bituminous in rank (70–84% fixed-carbon, mmf). It is low in sulfur (0.5–3.0%) and ash (8.6–14.2%), is 1.5 to 6 feet thick, and has a calorific value of about 14,000 Btu. A free-swelling index of 9 indicates that the coal makes a strong blast-furnace coke. Approximately 13,356,000 short tons of coal has been mined and lost-in-mining, leaving an estimated 313,478,000 tons in the remaining-resources category.

The northeastward increase in rank of the Lower Hartshorne coal was probably caused by a deep-seated heat source in eastern Arkansas. In the Arkoma Basin, folding induced by the Ouachita orogeny apparently did not affect the rank of the coal.

The Upper Hartshorne coal lies between 60 and 120 feet stratigraphically above the Lower Hartshorne coal. The coal is low- to medium-volatile bituminous in rank, is 1½ to 3 feet thick, contains 0.8–2.6% sulfur, and it contains 126,161,000 tons of coal in the remaining-resources category.

Hundreds of fossil tree trunks, stems, and leaves are evidence for deposition within a crevasse splay and overbank environment. A southwestward flowing distributary stream was active during the deposition of the upper Hartshorne

Formation. The Upper Hartshorne coal is thin where it overlies a channel-fill sandstone in the distributary; the coal is thicker in areas adjacent to the channel because of greater subsidence. It is proposed that the sediments which formed the Hartshorne Formation were deposited within a prograding deltaic-plain environment.

A Study of Teleseismic P Wave Travel Time Residuals at Oklahoma Seismograph Stations

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Teleseismic P wave residuals study for Oklahoma seismograph stations reveals that the majority of the stations record delays relative to reference station TUL. Residuals derived from teleseismic events of epicentral location in distance range of 15° to 100° and different azimuthal orientation were used.

Wave forms of P arrivals were visually correlated between stations, and two common points such as first peak and first zero crossing were timed.

Larger values of delays were observed at the southernmost station, WLO, where a relative delay of up to +0.74 sec. is recorded. In the northwest and southeast, delays appear to be smaller, whereas in the northeast, relative residuals very close to zero are observed.

It is assumed that the relative variations of station residuals are caused by the geological environment of each station, where the crust has suffered either thickening or thinning in accordance with isostatic adjustments.

The Areal Geology and Cretaceous Stratigraphy of Northwest Marshall County, Oklahoma

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Marshall County, in south-central Oklahoma, comprises part of the Dissected Coastal Plain, a subdivision of the Gulf Coastal Plain of the southern United States.

Exposed sedimentary strata range in age from Ordovician through Early Cretaceous. Paleozoic rocks, which include the Viola Limestone (Ordovician), Woodford Chert (Devonian), and Sycamore Limestone (Mississippian), are partially exposed on Turkey Creek in northern Marshall County along the axis of the Mannsville Anticline. Lower Cretaceous beds rest unconformably on folded and faulted strata of the underlying Paleozoics. Paleozoic structural features are reflected at the surface as small, gentle folds in Cretaceous strata in Marshall and adjacent counties.

Cretaceous strata exposed at the surface in northwest Marshall County include, in ascending order: Antlers Sandstone and Baum Limestone (Trinity Group); Goodland Limestone and Kiamichi Formation (Fredericksburg Group); Caddo Formation and Bokchito Formation (Washita Group).

The Antlers Sandstone forms a hilly topography with a sandy soil which

supports substantial tree growth. The limestones and shales of the Goodland, Kiamichi, and Caddo Formations form a gently rolling prairie topography covered with shrubs and grasses. The Bokchito Formation grades upward from clays to sands and forms rolling hills with sandy soils supporting trees and grasses.

Oil and gas comprise the principal mineral resources which contribute to the economy of the county. Production is from various zones within the Paleozoic and from the Cretaceous Antlers Sandstone. Other mineral production includes quarrying of the Goodland Limestone and use of terrace sands and gravels.

Subsurface Stratigraphic and Structural Analysis Cherokee Group, Pottawatomie County, Oklahoma

DAVID MICHAEL PULLING, The University of Oklahoma, M.S. thesis, 1978, The University of Oklahoma, Norman, Oklahoma 73019

The Cherokee Group is an alternating cyclic succession of transgressive and regressive lithologic units of early and middle Desmoinesian age. The group can be divided into several sand-shale sequences which are separated by thin limestone marker beds. Sands, shales, and limestones of the group are generally of a shallow-marine and fluvial-deltaic origin.

This sequence of sedimentary rocks is well suited for detailed subsurface structural study. Throughout much of Oklahoma and Kansas, it has been extensively drilled because it is a prime objective of hydrocarbon exploration. This has provided excellent well control in many areas, including the area of this investigation. Also, the stratigraphic nature of the Cherokee Group allows for accurate stratigraphic and structural correlations to be made.

Deep Structure of the Southern Oklahoma Aulacogen

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Long period seismograms of deep focus earthquakes from the South American region recorded at the stations situated in and around the Southern Oklahoma Aulacogen were used. These stations are TUL, LUB, DAL, WMSO, AZTX, SKTX, DUOK, and APOK. The crustal transfer function ratios of these data were compared to the Fernandez's master curves. Most of the observed curves do not match well. The best match is obtained at DAL. The crustal thickness beneath DAL is approximately 37 km. Poorly matched data suggested that the crustal thickness beneath WMSO is approximately 34 or 45 km. The data suggest a dipping boundary between the crust and mantle beneath the Southern Oklahoma Aulacogen. Therefore, this crustal structure may not be satisfactorily modelled by assuming a simple horizontally layered medium.

A Vertical Intensity Magnetic Study of the Western Part of the Arbuckle Mountains

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A series of detailed magnetic profiles was made in the Arbuckle Mountains of Oklahoma, primarily in the area known as the Arbuckle Anticline. The profiles were surveyed so as to cross major tectonic features such as faults, folds, and exposed igneous bodies, and to traverse major magnetic anomalies as they became apparent during the survey. In the course of the field work, a large magnetic anomaly with 2,182 gammas positive recorded relief was observed.

The crestal area of the anomaly is located in the western part of the Arbuckle Anticline. The Washita Valley fault zone, which is the main through-going tectonic rupture in the area, has a strong magnetic expression and appears to be the NNE limit of the regional anomaly. The majority of the local anomalies, which are superimposed on the large regional anomaly correspond to the position of structural features, especially faults. The cause of the local anomalies is thought to be due to mineralization within the fault zones.

Analytical model studies suggest that a large percentage of the regional anomaly can be produced by a tabular body of high susceptibility (15,000–20,000 $\times$ 10^{-6} cgs) inclined to the south with an abrupt north end which corresponds to the Washita Valley fault zone. It is quite likely that part of the magnetic anomaly is due to a near surface (1,000–3,000 feet) source which is possibly the result of mineralization in the highly fractured West Timbered Hills—Washita Valley fault area.

Mineralogic and Textural Dispersal Patterns within the Permian Post Oak Formation of Southwestern Oklahoma

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The Early Permian (Upper Leonardian) Post Oak Formation south of the Wichita Mountains in southwestern Oklahoma was sampled at 123 stations for purposes of determining mineralogic and grain size dispersal patterns. The purpose of this work is to reconstruct the paleogeography for this period. Only the coarse sand fraction was sampled to insure that the hydraulic regime was approximately constant for each sample. Consequently, any observed variations in mineralogy can be interpreted in terms of distance of transport and selective weathering.

The three principal source lithologies contributing to the Post Oak Formation are granite, rhyolite, and limestone of the Arbuckle Group. Granite rock fragments are found throughout the basin having their greatest concentration in the western one-third of the study area. Rhyolite and limestone occur only in the eastern half of the study area because those source lithologies are restricted to the eastern half around T. 2 and 3 N., R. 12 W.

Variations in mineralogic and lithologic parameters have been mapped. By

comparing the mineralogic and lithologic distributions of the total sediment to that of the selected size fraction, the mapped distribution of the size fraction was much more restricted laterally than that for total sediment indicating rapid breakdown of rock fragments to more stable monocrystalline material with little distance from source (e.g. 10 kilometers).

From the grain size and mineralogic data, an interpretation based on a best fit approach is given locating the main avenues of sediment transport. Sedimentary structures, textures, and facies geometry indicate that four depositional environments are represented: (1) alluvial fan, (2) fluvial (those having an origin on the fan complex and streams originating off the fan complex), (3) floodplain, (4) lacustrine. Textures, structures, and authigenic minerals suggest a semiarid Early Permian climate in this part of southwestern Oklahoma.

In future studies of clastic sedimentary rocks where source material is not exposed for comparison, recognition of changes in mineralogic and textural patterns will make possible the recognition of strandline positions as well as nearness to source.

Breccias and Megabreccias of the Arbuckle Mountains, Southern Oklahoma Aulacogen, Oklahoma

JAMES BRYAN TAPP, The University of Oklahoma, M.S. thesis, 1978, University of Oklahoma, Norman, Oklahoma 73019

The existence of breccias and megabreccias in the Arbuckle Mountains has been acknowledged for many years. These breccias have been interpreted as tectonic breccias but have not been described or studied in detail. This study attempts to develop methods which can be used to recognize megabreccia outcrops and to develop tests which can be used to determine mechanisms of origin for the megabreccias and breccias seen in the Arbuckle Mountains.

Map areas were defined on the basis of notations used by William E. Ham on his original aerial photograph maps of the Arbuckle Mountains which were done on a scale of 1 inch = 660 feet. Approximately 36 areas of interest were identified on the aerial photographs. These areas were located on 7½-minute topographic sheets and were studied in the field.

The megabreccia exposed along Interstate I-35 was studied in detail. The study of the I-35 megabreccia involved testing for any preferred orientation of the limestone boulders contained in the megabreccia and comparison of the clay assemblages in the megabreccia clay matrix material and in the limestone boulders with the clay mineral assemblages found in clays in the Kindblade Formation and some clay-filled sinks in the area.

The lack of any preferred orientation of the limestone boulders in the megabreccia and the clay mineralogy comparisons were evaluated using mechanisms proposed for megabreccia formation. The regional geology of the area and the evidence collected suggest that the I-35 megabreccia is a solution feature.

The surface characteristics seen in study of the I-35 megabreccia were used to investigate areas noted by Ham as complex, crumpled and bouldery limestone. Most of the areas investigated showed none of the characteristics considered to

be exhibited by megabreccias. These areas were faulted and folded or were simply weathering phenomena along joint systems. Only one other area on the Arbuckle Anticline showed the surface features exhibited by a megabreccia but the field evidence was inconclusive.

Four areas of crush breccia were studied and found to be part of a bedded breccia horizon in the Cool Creek Formation. This breccia horizon was mapped. Samples of the bedded breccia were studied in thin section. The bedded breccia exhibits sedimentary textures and is interpreted as a sedimentary breccia resulting from debris flow from a fault escarpment. This implies that the Southern Oklahoma Aulacogen was tectonically active during Ordovician deposition.

This study documents for the first time that there are at least two genetically different breccia types in the Arbuckle Mountains in addition to the mineralized breccias which have been studied previously.

Depositional Environment of the Basal Atoka Formation in Northeastern Oklahoma, Based on Biogenic Structure and Faunal Evidence

JAMES HUGH TREXLER, JR., The University of Oklahoma, M.S. thesis, 1978, The University of Oklahoma, Norman, Oklahoma 73019

Ichnofossils were used as the primary source of information for a paleoenvironmental interpretation of the basal Atoka Formation where it outcrops on the southwest flank of the Ozark Uplift. Eight distinct, shallow marine, clastic facies were established, each having a typical ichnofossil assemblage and energy level. These facies were subjected to cluster analysis, and it was shown that their ordering by energy level has a 98 percent confidence level.

The paleoenvironment of the basal Atoka Formation, based on facies data, is interpreted as being a complex of small deltas prograding into a transgressing sea. The distribution of high energy facies implies that the source area for the clastic material was toward the northwest. The regional unconformity below the Atoka is thought to end along a strand line running approximately northeast-southwest through Cookson, Oklahoma. The deltaic sequence gives way above to laterally consistent, moderate energy, shallow clastic marine environments.

A Study of Local Earthquakes in Oklahoma Recorded on 1-3 Hertz Seismographs

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In the years previous to 1972, all the short period seismographs operating in Oklahoma were of the teleseismic type, operating on a band pass of about 1–3 hertz. Local earthquakes occurring in Oklahoma, typically having frequencies in the 2–10 hertz range, do not always appear clearly on the seismograms recorded on such seismographs. The effect of the filtering is such that local earthquakes cannot always be distinguished from other high frequency events such as quarry blasts.

In May 1972, a high-pass vertical seismograph, HPZ, began operation at TUL, the seismic station of the University of Oklahoma Earth Sciences Ob-

servatory at 35.90°N., 95.79°W. near Leonard, Oklahoma. Early work with HPZ indicated that local earthquakes could easily be identified. Later work using a narrow band-pass very short period vertical seismograph, VSPZ, corroborates the earlier work, allowing reasonable identification of local earthquakes. Determination of local earthquakes in recent years is thus very dependable and allows work to be done to develop a method of detection of earlier earthquakes by studying the short period records of recent years.

Investigation of Surficial Structural Geology of Portions of Beckham, Custer, Roger Mills, and Washita Counties, Oklahoma

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Detailed surface mapping in portions of Beckham, Custer, Roger Mills, and Washita Counties demonstrates that surface faulting and deformation previously ascribed to solution collapse is related to the subsurface faults in this portion of the Anadarko Basin. This conclusion is strengthened by Landsat (ERTS satellite imagery interpretations) studies which suggest that major lineaments are related to basement weakness zones which, by reactivation, are responsible for fracturing in overlying sedimentary rocks.

The surface faulting appears to have been active at least from the Permian (Cloud Chief time) to the early Pleistocene. Evidences for movement in early Pleistocene include a downtown block of Tertiary strata west of Elk City and fractures that were contemporaneously filled with material of probable early Pleistocene age. Evidence for Permian movement includes fractures filled with Cloud Chief formation material.

The faulting appears to be related to the Wichita megashear fault system, the northwest trending faults being parallel to it, and the northeast trending faults, generally unrecognized, being oblique to it.

Clastic dikes are associated with the surface trace of the master subsurface faults. In the area where the Yelton Salt is known to be present in the subsurface, clastic dikes occur only along the fault traces. Collapse features due to the solution of the salt appear to have a spatial relationship to Cretaceous outliers, and may have a complex relationship with zones of weakness associated with the subsurface faults.

Deep Coal Mine Under Way in Le Flore County

A multimillion-dollar experimental deep coal mine is being excavated near Poteau in Le Flore County by Armco Material Resources. The mine will operate in the upper and lower Hartshorne coal beds, each of which contains 46 to 52 inches of low-volatile metallurgical coal.

W. B. Browning, president of the Armco division, has stated that no production estimate will be made until the mine nears completion but that these

beds are expected to hold 42 million recoverable tons of coal. Armco Steel operates coke ovens and steel mills in Houston, Texas, and the coal recovered in the new deep mine would be shipped to that destination. According to Browning, this coal will be blended with high-volatile coals to make satisfactory metallurgical coal.

This test is of special interest, because for the past 5 years all Oklahoma coal has been mined by surface methods.

Oklahomans Active in APGS Affairs

John S. Fryberger has recently begun serving a term as secretary-treasurer on the national executive committee of the Association of Professional Geological Scientists. John, who is senior vice-president of Engineering Enterprises, Inc., in Norman, Oklahoma, was a member of last year's executive committee as a delegate from the APGS advisory board. In addition, he is the immediate past president of the association's Oklahoma section.

Other national APGS officers for 1979 are Edward E. Rue, Mount Vernon, Illinois, president; James R. Dunn, New Orleans, president-elect; Frederick L. Stead, Dallas, vice-president; and Russell R. Dutcher, Carbondale, Illinois, editor. The remainder of the executive committee is made up of the chairman of the association's policy board, four delegates from the advisory board, and the president and vice-president of the American Geological Institute. Last year Charles J. Mankin, director of the Oklahoma Geological Survey, served on the executive committee as AGI president.

At the association's annual meeting in December, Dr. Mankin was appointed chairman of a special committee to find a replacement for Arthur F. Brunton, who had resigned as APGS executive director after having served in that capacity for more than a decade. Also appointed to this search committee were Suzanne Takken, Oklahoma City consultant and retiring national secretary-treasurer; John S. Fryberger; and Frederick L. Stead.

New Mapping Chief Named by USGS

Rupert B. Southard, an employee of the U.S. Geological Survey since 1949, has been named chief of the survey's Topographic Division, one of the major divisions of the USGS and the largest civilian mapping operation in the nation. Southard had been acting chief of the division since Robert H. Lyddan retired as head in June 1977 after 44 years of service with the USGS.

The Topographic Division, with headquarters in Reston, Virginia, employs about 2,000 persons and operates on a yearly budget of more than $70 million. In addition to the National Cartographic Information Center, the division operates regional mapping centers in Reston and in Rolla, Missouri, Denver,

Colorado, and Menlo Park, California, and conducts cooperative mapping agreements with more than 40 states and many local governments.

Southard, who received his bachelor of science degree in civil engineering from Syracuse University in 1949, has been active in mapping activities in the nation and overseas. From 1965 to 1970, he was assistant chief topographic engineer for plans and program development and as such was responsible for planning, programming, and budgeting for the National Topographic Program, international activities, and conduct of the Map Information Office of the USGS. In 1970 he was named associate chief of the Topographic Division.

In 1972 Southard served as the Department of the Interior's representative on the Federal Mapping Task Force, an interagency group that conducted a 1-year study of all federal mapping, charting, and geodetic surveying and which made a number of far-reaching recommendations for national programs.

Hydrogeochemical Report of Oklahoma City Quadrangle Issued

A report on the results of stream-sediment and ground-water reconnaissance in the Oklahoma City 1:250,000-scale, 2° quadrangle has been recently placed on open file by the U.S. Department of Energy. The report, *Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Oklahoma City NTMS Quadrangle, Oklahoma*, was prepared by the staff of the Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, as part of the National Uranium Resource Evaluation (NURE) program.

Stream-sediment samples were collected from 847 sites, and ground-water samples, from 812 sites. The data include results of uranium analyses in ground-water samples by fluorometric and mass-spectrometry–isotope-dilution methods. Uranium in stream sediments was analyzed by fluorometry and neutron-activation–delayed-neutron counting. The uranium concentrations in ground-water samples range from 0.02 to 176.7 ppb, and in sediments, from 0.55 to 38.2 ppm.

Atomic absorption, plasma-source emission spectrometry, and spectrophotometric methods were used for analyses of 27 other elements in sediments and 24 other elements and ions in stream-water samples.

The tables, diagrams, maps, and statistical plots in the report contain the analytical data and field measurements. Also included are a geologic map and a summary of the geology of the area.

The 87-page report, plus seven oversize plates, three appendixes, and microfiche, is on open file at several locations in the nation, including the Oklahoma Geological Survey. The report, GJBX-109(78), is available on microfiche from the Grand Junction office of DOE for $6.50. Checks should be made payable to Bendix Field Engineering Corp., the operating contractor.

A computer-readable, magnetic tape containing measurement, analysis, and location data is available for $80 from Frank D. Hammerling, GJOIS Project, UCC-ND Computer Application Department, 4500 North Building, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tennessee 37830.

AAPG Issues Publication on Geologic Time

A new volume in The American Association of Petroleum Geologists' Studies in Geology series (no. 6) contains a collection of 30 papers on stratigraphic time correlations. Edited by George V. Cohee, Martin F. Glaessner, and Hollis D. Hedberg, *Contributions to the Geologic Time Scale* includes up-to-date information on geochronologic scales, various types of age dating from biochronology to isotopic to radiometric methods, and continental and global correlations. Some systemic boundaries are discussed, and each system is covered by one or more specialists. The papers incorporated were presented at the 25th International Geological Congress in Sydney, Australia, in 1976.

Contributions to the Geologic Time Scale can be ordered from AAPG, P.O. Box 979, Tulsa, Oklahoma 74101. The price is $16.00 for AAPG/SEPM members, $19.00 for others.

New Theses Added to OU Geology Library

The following M.S. theses have been added to The University of Oklahoma Geology and Geophysics Library:

Paleomagnetic Evidence for Structural Rotation in the Pacific Northwest, by William Lassiter Basham.

Distribution, Structure, Origin, and Resources of the Hartshorne Coals in the Panama Quadrangle, Le Flore County, Oklahoma, by Dana Leon Craney.

A Study of Teleseismic P Wave Travel Time Residuals at Oklahoma Seismograph Stations, by Adelso Vera Gonzalez.

An Analysis of Some Secondary Magnetizations of Baked Clays, by Julie Martin Grisso.

Numerical Models of Faulting, by Ronald John Stein.

Some Thermal Magnetic Properties of Baked Clays, by Jen Haur Yu.

Monumental Kentucky Mapping Project Completed

The most ambitious cooperative federal-state geologic-mapping program undertaken to date has been brought to a successful conclusion. Conceived by Wallace W. Hagan, former state geologist of Kentucky and director of the Kentucky Geological Survey, this project of mapping the areal geology of Kentucky was initiated in 1960. The program has taken more than 18 years to complete and has resulted in the publication of 707 geologic-quadrangle maps at a scale of 1:24,000 (1 inch = 2,000 feet). These detailed maps, published as part of the U.S. Geological Survey's 7.5-minute Geologic Quadrangle Map series, provide complete coverage of Kentucky's geology.

From its inception, the joint KGS-USGS mapping program was designed to utilize the ample scientific-manpower resources of the federal survey in carrying out most of the geologic mapping in the field. These USGS geologists worked closely with personnel of the KGS in setting up and carrying out the program. During the course of the project a total of 260 USGS employees were assigned at various times, with as many as 61 persons assigned during any one year.

The joint venture is estimated to have returned to the state more than $1 billion in benefits already, or 50 times the $21 million cost to the state and federal governments, through discovery of new deposits of coal, oil, gas, and other resources. Auxiliary benefits have been the creation of new jobs and improved environmental planning.

Among the first to point out these effects of the project was Preston McGrain, assistant state geologist of Kentucky, who documented such direct economic benefits as more accurate soil maps for use in agriculture, better land-use planning in various types of construction and environmental considerations, and the delineation both directly and indirectly of valuable mineral deposits. More specifically, information gained during the program is credited for the discovery of a major coal field, a fluorspar deposit, an oil and gas field, and an estimated saving of $3-4 million in the construction and routing of the Purchase Parkway in extreme western Kentucky.

Indexes to the geologic maps are available free from the Kentucky Geological Survey, University of Kentucky, Lexington, Kentucky 40506. Individual geologic maps can be obtained for $1.75 each from the KGS or from the USGS Branch of Distribution, 1200 South Eads Street, Arlington, Virginia 22202.

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