Oklahoma Geological Survey

OKLAHOMA GEOLOGY notes

Vol. 63, No. 4 Winter 2003

Featuring:
- *Lower Permian sharks*
- *Geonews roundup*

on the cover

Lake Frederick, Tillman County, Oklahoma

The cover photo is a view of a partial solar eclipse taken June 10, 2002, from Lake Frederick (Tillman County). Lake Frederick, located about 8 miles northeast of Frederick, Oklahoma, was created in 1974 by building a dam across Deep Red Creek. The lake and nearby facilities are owned by the City of Frederick and are used for water supply, flood control, and recreation.

This region of the State averages about 28 inches of precipitation per year, mostly in the form of rain. Permian red shales and sandstones form gently rolling hills and broad, flat plains. Short grass species, such as buffalo grass, blue grama, and side oats grama, are abundant in places (Duck and Fletcher, 1945[?]).

Several lower Permian localities in Tillman County (Fig. 1) have produced extensive vertebrate faunas (Simpson, 1979). Numerous fish, amphibians, and some reptiles were described by Cummins (1908), Olson (1967), and Simpson (1976) from the Tillman County sites. Many of these species lived in and/or near freshwater lakes and streams. Ironically, Lake Frederick is located near a Permian lake which existed about 270 million years ago.

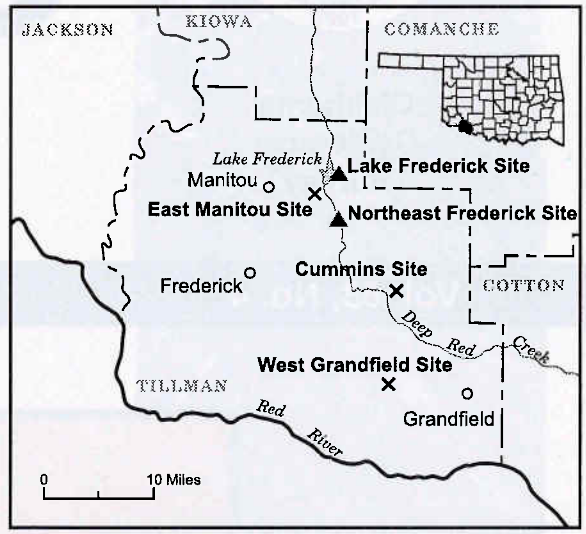

Figure 1. Tillman County sites where Permian vertebrate fossils were collected and described; × denotes sites described by Simpson (1979) and ▲ refers to the sites identified by Zidek and others (2003) for the feature article in this issue of *Oklahoma Geology Notes* (p. 136).

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Photograph taken by Gary D. Johnson
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OKLAHOMA GEOLOGY notes

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New Specimens of Xenacanth and Hybodont Sharks (Elasmobranchii: Xenacanthida and Hybodontoidea) from the Lower Permian of Southwestern Oklahoma

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ABSTRACT.—A significant portion of the skull and jaws of *Orthacanthus texensis* from the Northeast Frederick site and a palatoquadrate of *Barbclabornia luedersensis* and isolated hybodontoid teeth from the Lake Frederick site represent important additions to our knowledge of Permian sharks. Both sites are in the upper Garber Sandstone in Tillman County, southwestern Oklahoma. We identified the two xenacanth species on the basis of teeth in the specimens. Judging by the restored braincase—about 20 cm long—we believe the complete *O. texensis* specimen was from 2.0 to 2.6 m long. This is the first known occurrence of any skeletal material, including denticles, associated with the diminutive teeth of *B. luedersensis*. As the palatoquadrate, if complete, would be about 45 cm long, the shark was probably nearly 5 m long. Its teeth lack a central cusp, generally considered a xenacanth trait, and for that reason was recently assigned to a new genus. No occipital spine was associated with either specimen, although isolated *Orthacanthus* spines occur at both sites.

The hybodontoid teeth represent *Polyacrodus* (=*Lissodus*?) *zideki*, probably *Acrodus*? *sweetlacruzensis*, and *Acrodus*? cf. *A*.? *olsoni*. Although hybodontoid fin spines occur at both sites, none can be assigned to any of those species because they are known only from teeth.

Isolated remains of other vertebrates occur in one or both sites. Other fishes include the sharks *Orthacanthus platypternus*, *Helodus* sp., *Anodontacanthus belemnoideus*, and *Platyacanthus avirostratus*, the acanthodian *Acanthodes* sp., the deep-bodied chondrostean *Platysomus palmaris*, a variety of fusiform palaeoniscoids (identified by scales), and the lungfish *Sagenodus porrectus*. Amphibians include *Trimerorhachis insignis*, *Eryops megacephalus*, *Acheloma* sp., *Archeria* sp., *Diplocaulus* sp., and *Cardiocephalus sternbergi*. Reptilian remains include *Captorhinus aguti*, *Eocaptorhinus* sp., *Dimetrodon limbatus*, *Edaphosaurus pogonias*, *Ophiacodon retroversus*, and *Diadectes* sp.; they are less common, but indicate considerable diversity. The fossils occur in lacustrine facies at both sites, and at Lake Frederick also in fluvial facies characterized by coarse lithic subarkose sandstones.

INTRODUCTION

Two Lower Permian localities in Tillman County, southwestern Oklahoma, have produced remains of the xenacanthid species *Orthacanthus texensis* (Cope 1888; our Fig. 1A) and *Barbclabornia luedersensis* (Berman 1970; our Fig. 1B and Johnson, 2003). The *O. texensis* remains (collected by William May) are from the Northeast Frederick site of Simpson (1976, 1979), locality OMNH V 173, and the *B. luedersensis* specimen (collected by Alvie Claborn) and isolated hybodontoid teeth (collected by May) are from a new locality, the Lake Frederick site, OMNH V 247. The sites are only ~6.5 km (~4 mi) apart, both near Deep Red Creek (Cummins's Deep Red Run: see Olson, 1967, and Burkhalter and May, 2002); according to Havens's map (1977), both are in the Garber Sandstone, which forms the upper part of the Sumner Group. The Garber consists of 160 to 210 ft (49–64 m) of reddish-brown, fine-grain sandstones (coarse-grain at Lake Frederick), reddish-brown to grayish mudstone conglomerates, and gray claystones that were deposited in fluvial and lacustrine environments in a coastal-plain setting (Simpson, 1976). Most of the lakes were intermittent, strand-

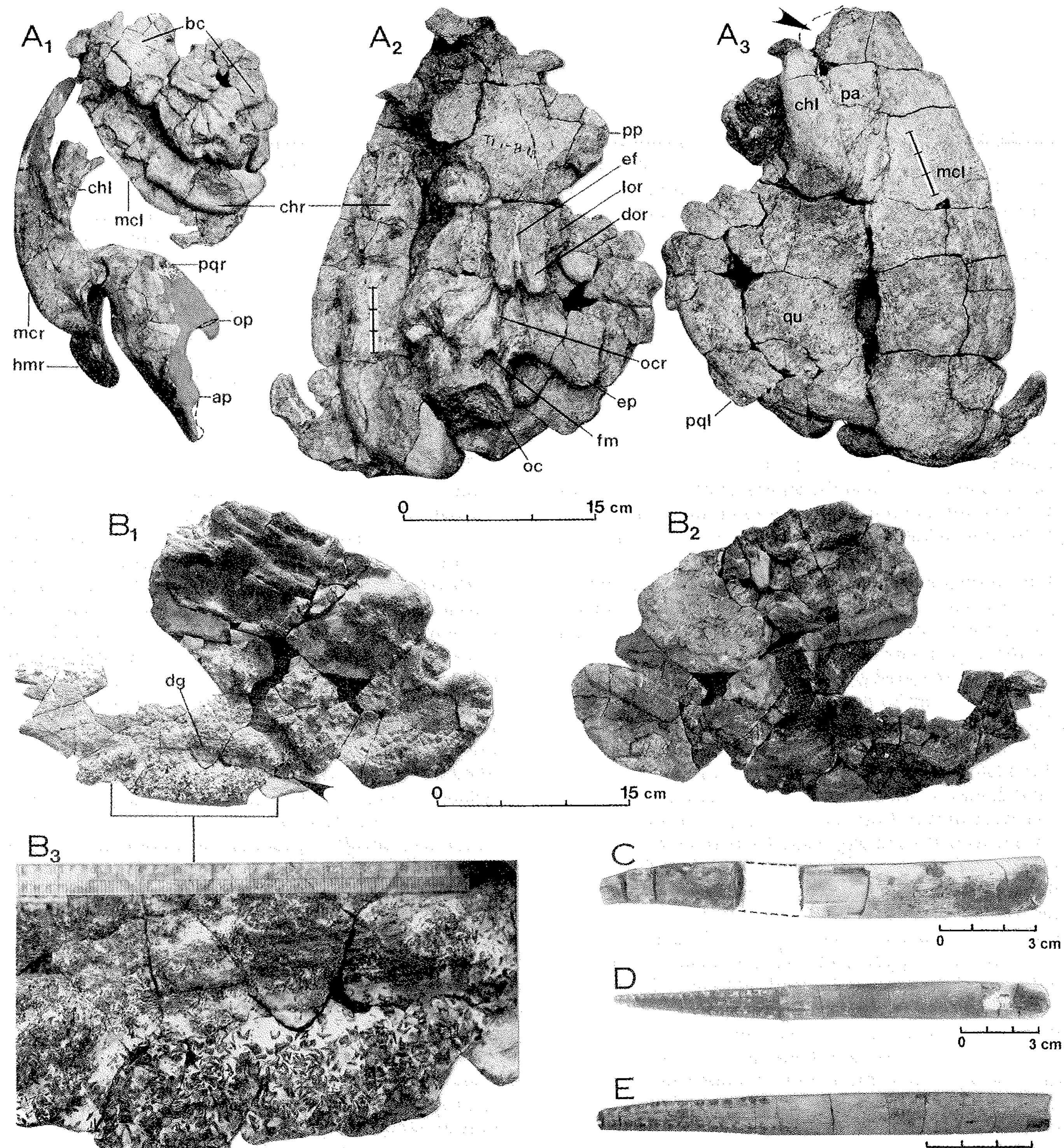

Figure 1. Xenacanthid sharks from the Garber Sandstone (Lower Permian) in Tillman County, southwestern Oklahoma. A—*Orthacanthus texensis* from the Northeast Frederick site: A_1—configuration of the remains as found at outcrop; A_2—braincase in dorsal view (see tracing in Fig. 2A); A_3—opposite side showing the left palatoquadrate and Meckel's cartilage beneath the braincase. B—Incomplete right palatoquadrate of *Barbclabornia luedersensis* from the Lake Frederick site: B_1—mesial view; B_2—lateral view; B_3—enlargement of the area bracketed in B_1 to show the number and size of teeth. C–E—Isolated occipital spines of *Orthacanthus* sp. from the Lake Frederick site. Arrows in A_3 and B_1 denote the areas from which the teeth and denticles shown in Figure 3 have been etched out.

Abbreviations: ap = antorbital (preorbital, nasal) process; bc = braincase; chl = left ceratohyal; chr = right ceratohyal; dg = dental groove; dor = dorsal otic ridge; ef = endolymphatic (parietal) fossa; ep = epiotic (lateral otic) process; fm = foramen magnum; hmr = right hyomandibular; lor = lateral otic ridge; mcl = left Meckel's (meckelian) cartilage; mcr = right Meckel's (meckelian) cartilage; oc = occipital condyle; ocr = occipital crest; op = otic process of palatoquadrate; pa = palatine region of palatoquadrate; pp = postorbital process; pql = left palatoquadrate; pqr = right palatoquadrate; qu = quadrate region of palatoquadrate. Scale in B_3 is in millimeters.

ing and killing their aquatic inhabitants in dry seasons. Simpson (1976, 1979) concluded that the Northeast Frederick site was in the upper part of the Garber Sandstone, which he (Simpson, 1979, fig. 2) correlated with the lower part of the Arroyo Formation (lower Clear Fork Group, upper Leonardian) in north-central Texas. The Lake Frederick site, too, is in the upper part of the Garber and, as far as can be discerned, belongs to the same stratigraphic interval as the Northeast Frederick site. However, correlation with the Arroyo Formation may not be correct (discussion below). Because the Lake Frederick site is new, it is described in more detail.

The Lake Frederick Site

The *Barbclabornia luedersensis* specimen was collected about 30 cm above a lower sandstone, in noncalcareous silty clay, which is dark yellowish-brown (when damp), mottled dark yellowish-orange, brownish-black and reddish-brown. The lower sandstone, near the shoreline of Lake Frederick, contains vertebrate remains, as does an upper sandstone exposed about a hundred meters to the southeast and 5.9 m above it.

Both sandstones are pebbly and granular, with fine to very coarse (mostly coarse) quartz grains, subrounded to angular (mostly angular); they contain dolomite clasts and about 10% myrmekite. Descriptions are based on thin sections and disaggregated grains. Myrmekite suggests that one source was the Cold Springs Breccia, which is exposed in the Wichita Mountains ~20 mi (~32 km) north-northwest of the Lake Frederick site (Vidrine and Fernandez, 1986). Because both sandstones are cemented with varying amounts of calcite and dolomite, treatment with 10% acetic acid helped in the recovery of vertebrate fossils. Samples from the upper sandstone were then disaggregated with dimethyl sulfoxide (DMSO), which works by disrupting kaolinite (Triplehorn, 2002)—a procedure we did not attempt on the lower sandstone. No invertebrates or plants were observed.

We found marked differences between the Lake Frederick sandstones. In the upper sandstone, rose quartz is common; K-feldspar grains were not observed, although microperthite may be present. In the lower sandstone, rose quartz is absent, though euhedral quartz grains (uncommon in the upper sandstone) are present; K-feldspar grains were common in the processed concentrate but not observed in thin section. X-ray diffraction analysis of feldspar grains from the lower sandstone showed that they consist of microcline and quartz with a moderate amount of albite, which suggests microperthite (perthite?) as well as myrmekite. Most of the grains are coated with hematite. The hematite also occurs as discrete grains (as also in the upper sandstone) and as a significant cement, especially in the upper part of the lower sandstone, and sometimes enclosing palaeoniscoid scales.

The upper sandstone is 15 to 20 cm thick and divided into upper and lower layers by 1 to 2 cm of silty clay that upon screen washing yielded fossils. The lower layer is slightly friable, and the lower surface of the upper layer is covered by a 1-cm-thick solid mat of platysomid fish remains. *Platysomus palmaris* is represented by hundreds of highly ornamented, extremely fragile scales up to 2 cm long, and by fragments of bones and tooth plates (some nearly complete). Also present in this sandstone are teeth of *Orthacanthus texensis* and *Barbclabornia luedersensis*, and a fragment of a tooth from *O. platypternus*?. Thin palaeoniscoid scales are present, but greatly outnumbered by thick "*Acrolepis*-type" scales. We obtained the hybodontoid teeth from the silty clay layer, as well as isolated remains of *Captorhinus aguti*, *Trimerorhachis* sp., and *Diplocaulus* sp. An acanthodian spine was found in an isolated piece of sandstone, and isolated acanthodian scales in processed sandstone samples.

The lower sandstone yielded many thin palaeoniscoid scales, but "*Acrolepis*-type" scales are uncommon. Also present are teeth of *Orthacanthus texensis* and *Barbclabornia luedersensis* (both uncommon) and a few isolated *Platysomus* teeth and acanthodian scales. *Trimerorhachis* is present.

Fossils at Northeast Frederick and Lake Frederick

Many of the vertebrate taxa thus far identified (Table 1) occurred as isolated elements. *Orthacanthus* sp. is represented by isolated occipital spines (Fig. 1C–E); identification of *O. texensis*, *O. platypternus*, *Barbclabornia luedersensis*, and *Helodus* sp. is based on isolated teeth. Spines of *Anodontacanthus belemnoideus* and *Platyacanthus avirostratus* are tentatively assigned to the Xenacanthida (Zidek, 1978). Fin spines and teeth represent indeterminate hybodontoids and hybodont species, respectively. *Acanthodes* sp. is represented by a fin spine and scales. Undifferentiated fusiform palaeoniscoids, including *Acrolepis* sp., are represented mostly by flank fragments and isolated scales, and the deep-bodied chondrostean *Platysomus palmaris* by scales and phyllodont tooth plates. *Sagenodus porrectus* tooth plates and opercula are present. *Diadectes* sp. is either a large tetrapod of uncertain affinity (Sumida and Lombard, 1991; Berman, Sumida, and Lombard, 1992) or possibly a reptile (Berman and Sumida, 1995).

Most of the vertebrates found are fishes and amphibians. The reptiles and *Diadectes* are few, occuring as isolated skeletal parts that may have been washed into the lakes. However, partly articulated pelycosaur skeletons have been found in the vicinity of the Northeast Frederick site (Table 1). The Northeast Frederick site, which contains abundant barite nodules, produced plant and invertebrate fossils, the latter being chiefly worm tubes of *Spirorbis* and small freshwater gastropods. The plants, although not uncommon, are poorly preserved and remain to be studied. However, excellent carbonized leaf impressions occur nearby.

The *Orthacanthus* occipital spines shown in Figure 1C–E are not determinate to species and are included here only for the record. It is rather puzzling that despite several years of systematic collecting neither site has produced occipital spines of *Barbclabornia*.

Except for *Anodontacanthus*, *Acheloma*, and *Eocaptorhinus*, the vertebrate taxa (including isolated teeth of *Orthacanthus platypternus* and *Barbclabornia luedersensis*) have been recorded by Simpson (1976, 1979); however, he identified the large, isolated *Orthacanthus* teeth as *O. compressus* and the isolated hybodontoid fin spines as *Hybodus* sp. Our identifications differ for these reasons:

TABLE 1.—VERTEBRATE FAUNAS AT THE NORTHEAST FREDERICK AND LAKE FREDERICK SITES

	Northeast Frederick	Lake Frederick
Chondrichthyes		
Elasmobranchii		
Orthacanthus sp.	X	X
O. texensis (Cope 1888)	X	X
O. platypternus (Cope 1884)	X	X
Barbclabornia luedersensis (Berman 1970)	X	
Anodontacanthus belemnoideus Zidek 1978	X	
Platyacanthus avirostratus Zidek 1978	X	
hybodontoid gen. et sp. indet.		X
Polyacrodus (=*Lissodus*?) *zideki* Johnson 1981		X
Acrodus? *sweetlacruzensis* Johnson 1981		X
Acrodus? cf. *A.*? *olsoni* Johnson 1981		X
Holocephali		
Helodus sp.	X	
Acanthodii		
Acanthodes sp.		X
Osteichthyes		
Palaeoniscida		
palaeoniscoid sp.		X
Acrolepis sp.		X
Platysomus palmaris Cope 1891		X
Dipnoi		
Sagenodus porrectus (Cope 1878)	X	
Amphibia		
Temnospondyli		
Trimerorhachis insignis Cope 1878	X	X
Eryops megacephalus Cope 1877	X	X[a]
Acheloma sp.	X	X[a]
Anthracosauria		
Archeria sp.	X	
Lepospondyli		
Diplocaulus sp.	X	X
Cardiocephalus sternbergi Broili 1904	X	X[a]
Reptilia		
Anapsida		
Captorhinus aguti (Cope 1882)	X	X
Eocaptorhinus sp.	X	
Synapsida		
Dimetrodon limbatus (Cope 1877)	X	X[a]
Edaphosaurus pogonias Cope 1882	X	
Ophiacodon retroversus (Cope 1878)	X	
Incertae sedis		
Diadectes sp.	X	

[a]Occurrences are near the Lake Frederick site.

1) *O. compressus* is not known to cross the Wolfcampian-Leonardian boundary, whereas *O. texensis* ranges well into the Leonardian—all the way to the Wichita–Clear Fork Group boundary (Johnson, 1992, fig. 2; 1999, table 1). Thus it is much more likely that only *O. texensis* occurs in the upper Garber.

2) The hybodontoid fin spines are invariably isolated, often fragmentary, and do not appear to differ in any way but size from the spine found by Simpson (1974a, fig. 7; 1974b, text-fig. 1A) higher in the section, at the base of the Hennessey Group or the so-called Garber-Hennessey transition zone at the East Manitou site (east of Manitou, in Tillman County, locality OMNH V 176). One possibly hybodontoid tooth was found at East Manitou by Olson (1967; "*Orodus*-type tooth," p. 24; however, the specimen cannot be located). Also, Johnson (1979, p. 631) recovered a *Polyacrodus* (=*Lissodus*?) *zideki* tooth (SMU 69236) as well as a hybodontoid spine fragment from East Manitou. No teeth are known from the Northeast Frederick site (doubtless for want of collecting by bulk-sampling), and, despite hybodontoid teeth at Lake Frederick, even tentative generic assignment of the spines is not possible. Of nearly 4,000 hybodontoid teeth recovered by Johnson (1979, 1981) from the Early Permian deposits of northern Texas, none are assignable to the genus *Hybodus*; moreover, despite a thorough study of the Texas fossils, Johnson was unable to assign associated hybodontoid cephalic spines and fin spines to tooth-based taxa. Thus it is obvious that the fin spines cannot be identified more closely than hybodontoid gen. et sp. indet. (Table 1).

The specimens of *Orthacanthus texensis* and *Barbclabornia luedersensis* described herein are now in the Oklahoma Museum of Natural History (OMNH) collections, cataloged as OMNH 18110 and 18111. Teeth removed from them by etching with 10% acetic acid (Fig. 3) bear the same numbers.

THE *ORTHACANTHUS TEXENSIS* SPECIMEN

Remains of *Orthacanthus texensis* were found weathered out in the configuration shown in Figure $1A_1$. They consist of the braincase, jaws, ceratohyals, the right hyomandibular, and a smaller L-shaped element (not illustrated) that probably combines the ceratobranchial and hypobranchial of the third or fourth arch. The preservation is confusing because the jaws to the left of the braincase actually are the right Meckel's cartilage exposed mesially and the right palatoquadrate turned backward and exposed laterally. The left meckelian and palatoquadrate are underneath the braincase with their mesial surfaces facing down (Fig. $1A_3$), but the meckelian is overlain by the right ceratohyal (Fig. $1A_2$), which is exposed mesially. The left ceratohyal is anteriorly incomplete and protrudes from beneath the right meckelian (Fig. $1A_1$); its anterior portion, trapped beneath the braincase during burial, can be seen to the left of the palatine region of the left palatoquadrate (Fig. $1A_3$). The right hyomandibular is associated with the right palatoquadrate but is overturned and exposed mesially (Fig. $1A_1$). The right meckelian, palatoquadrate, and hyomandibular, and the left ceratohyal are free of matrix and disassembled; thus both their surfaces can be examined. The remaining elements form a solid mass and only the right ceratohyal and the dorsal surface of the braincase reveal discrete features of their morphology.

The tip of the right meckelian and parts of the quadrate and palatine regions of the right palatoquadrate have been restored in plaster, resulting in the otic process being too beak-like, the areas anterior to the antorbital process too steep, and the tip of the palatine region too pointed; the correct outline is shown by a broken line (Fig. $1A_1$). No element differs in any aspect of morphology from those described and beautifully illustrated by Hotton (1952, pl. 58), and even the ratio of ceratohyal/meckelian length is exactly the same (0.68) for his specimens and ours. Therefore, further discussion is limited to the braincase and teeth.

The braincase is exposed in dorsal view and exhibits morphology that in no way differs from the "*Xenacanthus*" (genus uncertain) braincases described by Schaeffer (1981). The discernible parts are labeled in Figure $1A_2$, and a tracing of the photo is compared with Schaeffer's restoration in Figure 2. The preservation is fairly good in the otico-occipital region, but the orbito-nasal region is nearly absent. The length of the otico-occipital region is 13.5 cm; as this dimension in *Orthacanthus* amounts to about two-thirds of the total braincase length (Zidek, 1993b) we estimate that the braincase was 20 cm long. Measurements of articulated xenacanths show the braincase to be 10–13% of the total specimen length (Zidek, 1993b), indicating a total length of 200 to 260 cm.

Although braincases can help in recognizing xenacanth genera (Zidek, 1993a,b), the braincase in our specimen was too incomplete to indicate generic affinity. As far as known, the jaws and visceral arches are useless for this purpose, but fortunately the left palatoquadrate contains teeth (Fig. 3A) diagnostic of both genus and species. About 30 teeth were found in a small piece of palatine cartilage detached from the area marked by an arrow in Figure $1A_3$; they are near the symphysis. Their compressed and blade-like cusps are typical of *Orthacanthus* teeth; serrations, clearly visible on the posteriorly pointing cusp in the labio-oral view of Figure 3A, suggest that the tooth belongs to *O. texensis* (compare with figures 1 and 6A in Johnson, 1999).

THE *BARBCLABORNIA LUEDERSENSIS* SPECIMEN

Our specimen of *Barbclabornia luederensis* is a right palatoquadrate containing numerous minute teeth (Fig. 1B). Although incomplete, it is 37.5 cm long, and its total length must have been about 45 cm. Assuming that the fish was 10 to 11 times as long as its jaws (ratios based on articulated specimens of other xenacanthid species), we conclude that it is by far the largest xenacanth shark ever found—4.5 to 5 m (14 to 15 ft) long. This palatoquadrate is thinner than that of *Orthacanthus texensis*, the lighter build apparently reflecting the character of the dentition and the mode of feeding.

Of hundreds of teeth in the specimen (Fig. $1B_3$), about 20 were etched with acid from the small piece of calcified cartilage marked by the arrow in Figure $1B_1$. The freed teeth (Fig. $3B_1$) are lateral and differ from the anterior teeth in having obliquely quadrangular bases; whereas the anterior teeth have obliquely triangular bases, the posterolateral teeth do

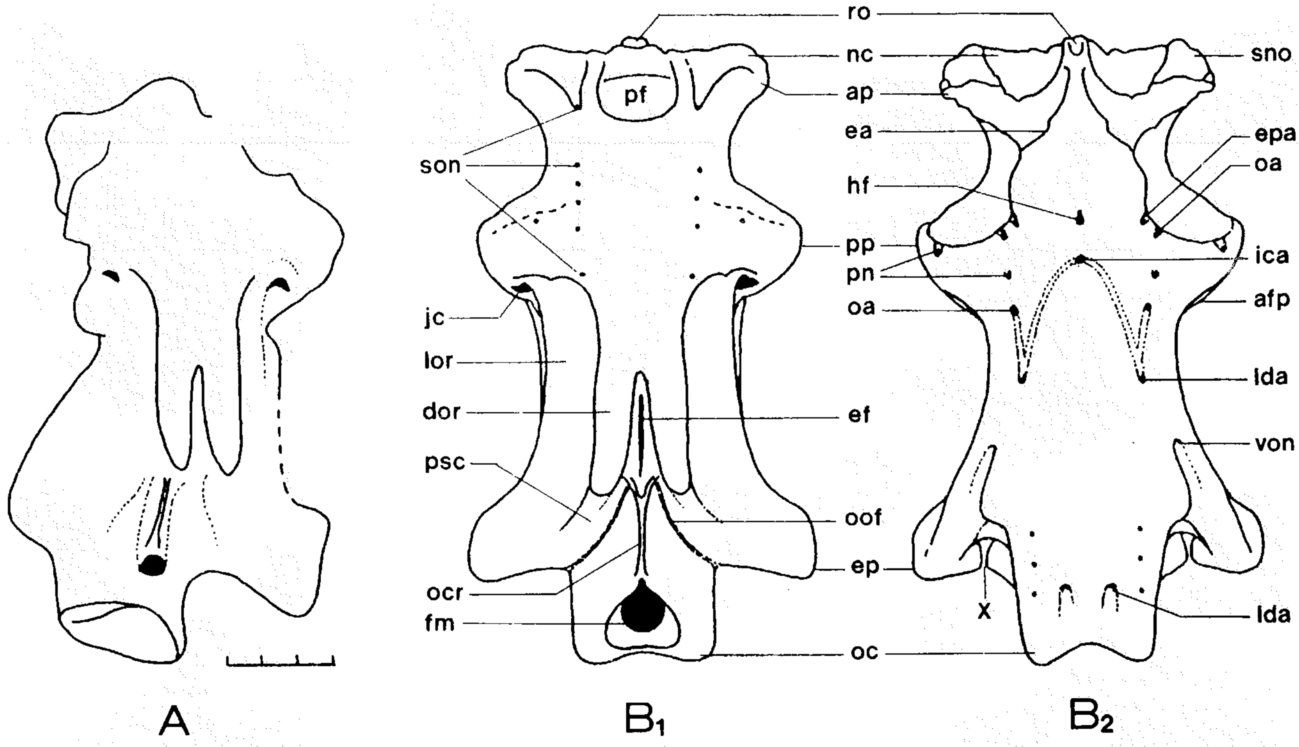

Figure 2. A—Tracing of the photo in Figure $1A_2$ compared to Schaeffer's restoration (1981, fig. 6) of xenacanthid ["*Xenacanthus*" sp. (genus uncertain)] braincase in B_1—dorsal and B_2—ventral views.

Abbreviations: afp = articular facet for palatoquadrate; ap = antorbital (preorbital, nasal) process; dor = dorsal otic ridge; ea = ethmoid articulation; ef = endolymphatic (parietal) fossa; ep = epiotic (lateral otic) process; epa = foramen for efferent pseudobranchial artery; fm = foramen magnum; hf = hypophysial fenestra or fossa; ica = foramen for internal carotid artery; jc = canal or groove for jugular vein (lateral head vein); lda = foramen or canal for lateral dorsal aorta; lor = lateral otic ridge; nc = nasal capsule; oa = foramen or groove for orbital artery; oc = occipital condyle; ocr = occipital crest; oof = otico-occipital fissure; pf = precerebral (epiphysial) fontanelle or fossa; pn = foramen or canal for branch of palatine nerve or branch of orbital artery; pp = postorbital process; psc = posterior vertical semicircular canal; ro = rostrum; sno = separate nasal ossification; son = foramina for superficial ophthalmic nerves; von = ventral otic notch; X = foramen or canal for vagus nerve.

not differ from the laterals. In all teeth, the labio-lingual dimension (2.5–3.0 mm) exceeds the anteromesial-posterolateral dimension (2.0–2.5 mm). In contrast to other xenacanth species, this one has no central cusp, and so Johnson (2003) has suggested a new genus. The lateral cusps curve lingually, are mildly divergent or rarely parallel, their cross section is proximally oval and distally circular, and the angle between the major transverse axis of the cusp base and the labial margin of the tooth is 60–65° (Fig. 4). The distal parts of the cusps are cristated, the cristae being longer, more pronounced, and more numerous (~10) on the labial face; the cristae of the lingual face are sparse (4–5) and very faint, and some of them anastomose toward the tip. The base is thick, amounting to at least 30% of the tooth height. The basal tubercle is concave, with a prominent, horseshoe-shaped labial rim (Fig. 4). The apical button is large, extending from the lingual margin to between the lateral cusps and nearly touching their bases. Vascular foramina are concentrated in the central position of the aboral surface and at the lingual termination and lateral walls of the apical button. In addition, the apical button is frequently split by a labio-lingual fissure that may be continuous or discontinuous and is almost never centered. High magnification reveals that the fissure consists of a set of unevenly spaced, minute foramina that terminate in a larger foramen at the labial base of the button. One of the etched-out teeth is broken longitudinally (i.e., in the anteromesial-posterolateral direction), revealing that the base is essentially hollow: it consists of two large pulp cavities separated by a narrow septum underneath the apical button. The septum is riddled with vascular canals descending from the fissure and lateral walls of the button.

Monocuspid denticles (Fig. $3B_2$) are scattered among the teeth and occur in the etched sample as well. Their greatest concentration is immediately above and below the palatine dental groove (the dental furrow of Hotton, 1952), particularly in its posterior half (right half of Fig. $1B_3$). The largest denticles barely exceed 2 mm in height, of which about 40% is the base. The cusp is sharply pointed, gently arcuate, round to circular at the base, and lenticular (i.e., carinated) in the distal half to two-thirds. Some cusps have lateral cristae that diverge toward the tip and merge with the carinae, and sparse short, vertical cristae may be present in the distal third. The base is bulbous in its upper (oral) third to half and narrows downward to a blunt aboral tip. As a result most of the denticles appear remarkably claw-like, although some are shorter and stubby (Fig. $3B_2$, left). The mesial wall of the dental groove has collapsed against its lateral wall due to post-mortem compression, reducing the originally deep and

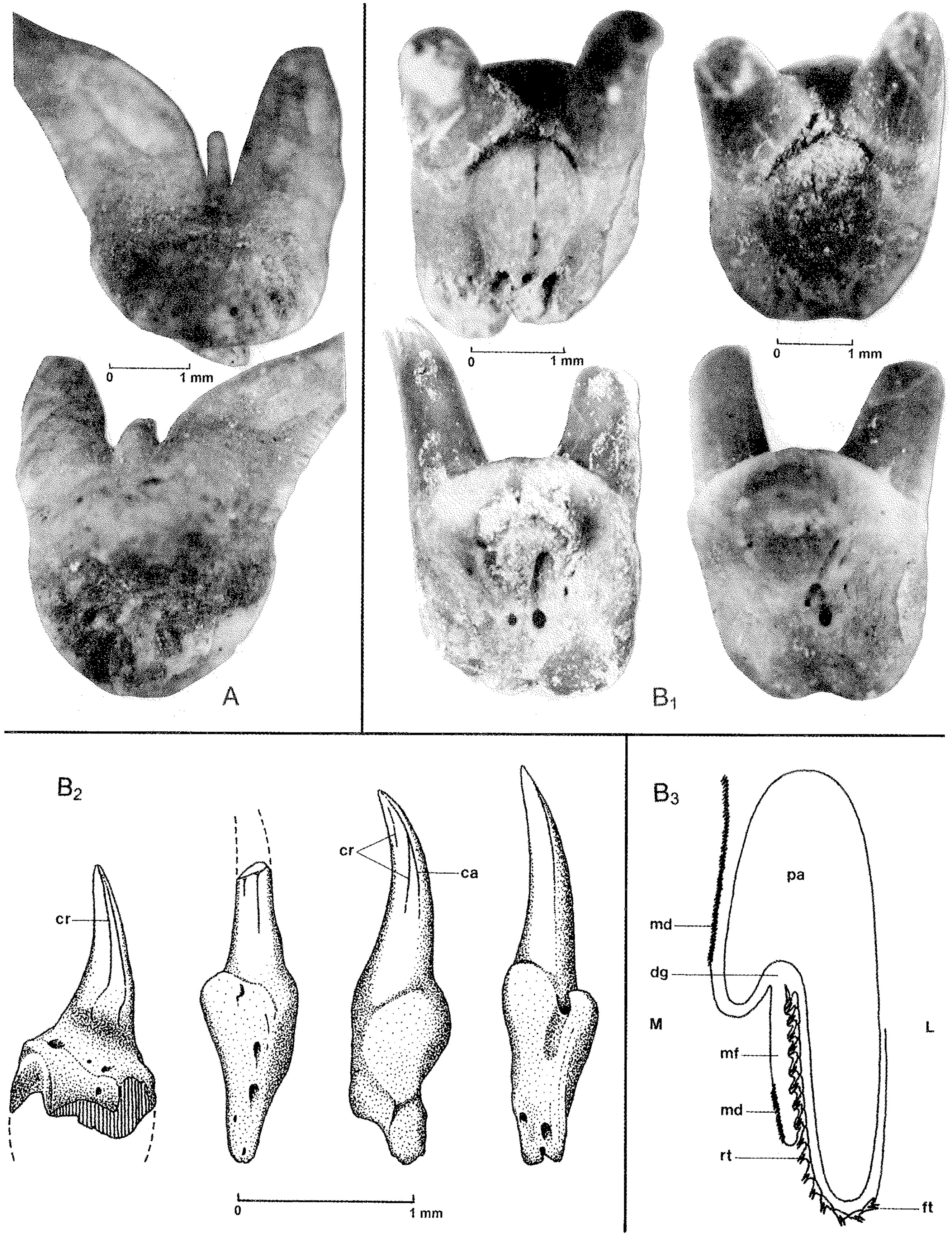

Figure 3. Teeth and mucous-membrane denticles from the xenacanthid specimens in Figure 1. A—*Orthacanthus texensis*, anterior tooth, OMNH 18110, in lingual (top) and labio-aboral views (lateral teeth are typically twice this size; Johnson, 1999). B—*Barbclabornia luedersensis*: B_1—two lateral teeth, OMNH 18111, in oral (top row) and labio-aboral views. B_2—four mucous-membrane denticles in lateral views. B_3—schematic cross section of the palatine to show the presumed location of mucous-membrane denticles.

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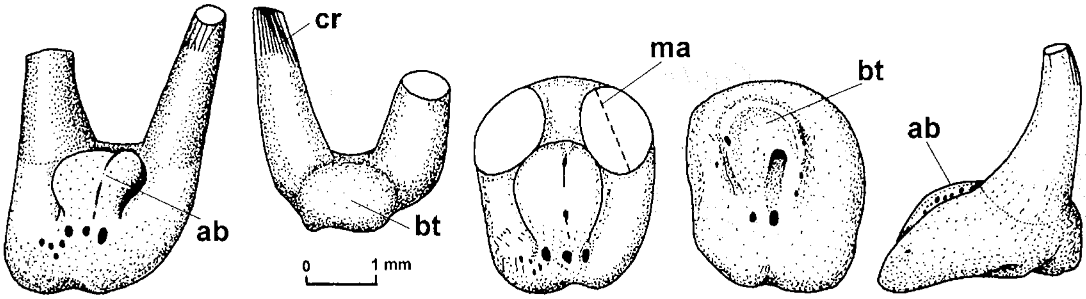

Figure 4. Sketch of the left tooth shown in Figure $3B_1$ in (left to right) lingual, labial, oral, aboral, and lateral (anteromesio-posterolateral) views. (Compare with fig. 1 in Johnson, 1999.)
Abbreviations: ab = apical button; bt = basal tubercle; cr = crista; ma = major transverse axis.

upward-invaginated structure (cf. Hotton, 1952, pl. 58, fig. 1C) to a shallow trough. In life, the groove housed replacement teeth that were covered by a mucous-membrane fold. In modern sharks (cf. Peyer, 1968, pl. 1b) the free, mesial side of the fold is covered with denticles, so we assume a similar condition for the xenacanths and conclude that the monocuspid denticles are from the protective mucous-membrane fold and the mesial face of the palatine above the dental groove (Fig. $3B_3$).

Teeth of *Barbclabornia luedersensis* have been discussed in considerable detail by Johnson (1979, p. 96–122, pls. 17–20; 2003), whose account leaves no doubt that the teeth in our specimen belong to that species. The only feature not recorded by Johnson is the fissure on the apical button, which, however, is not present in all teeth and certainly falls within limits of intraspecific variability. Thus the Lake Frederick palatoquadrate demonstrates that *B. luedersensis* was a very large shark with exceedingly small and numerous teeth—a late Paleozoic analog of the extant basking shark (*Cetorhinus maximus*, teeth only 6 mm long in a 9-m shark; Bass and others, 1975, p. 31) or the whale shark (*Rhiniodon typus*, 4.5-mm teeth in an 8-m shark; Bass and others, 1975, p. 51, fig. 24B). The claw-like mucous-membrane denticles are a new morphotype.

Johnson (2003) reassigned this species to a new genus, although except for a single character it might have been assigned to the genus *Triodus* Jordan 1849. *Triodus* was an enigmatic genus before the recent discovery of nearly complete specimens in the Saar-Nahe Basin of southwestern Germany; those specimens are being studied at the Johannes Gutenberg Universität, Mainz (cf. Schneider and Zajíc, 1990, p. 27), and data on cranial and postcranial anatomy are not yet available. However, the tooth morphology and histology are well known (Hampe, 1989, 1991, 1993), and comparison of characters reveals that *Barbclabornia luedersensis* teeth differ from those of *Triodus* (namely *T. lauterensis* and *T. palatinus*) only in base thickness, cristation pattern, and absence of the central cusp, which except for the last are species rather than generic characters.

(caption for Figure 3, continued from facing page)

(Normally there would be dermal denticles on the lateral face of the palatine, but xenacanths are not known to possess any.)

Abbreviations: ca = carina; cr = crista; dg = dental groove; ft = functional teeth; md = mucous-membrane denticles; mf = mucous-membrane fold; pa = palatine; rt = replacement teeth; L = lateral; M = mesial.

HYBODONTOID TEETH

We recovered 15 hybodontoid teeth at the Lake Frederick locality and compared them directly with teeth from the Lower Permian of Texas (Johnson, 1981). All the Oklahoma teeth possess specialized foramina (Fig. 5). None have secondary cusps, but all have single longitudinal and transverse occlusal crests.

Five of the teeth (OMNH 52220) are *Polyacrodus zideki* (Johnson, 1981). The species may belong to *Lissodus* (Duffin, 1985). All are similar to teeth from the Texas Permian (Waggoner Ranch Collection, Shuler Museum of Paleontology, Southern Methodist University; Fig. 6), and are typically small, with a restored crown length of less than 2 mm (four are incomplete). In occlusal view, the crowns are symmetrical in the longitudinal direction; in some, the presumed labial side is slightly greater than the lingual side, but otherwise they are symmetrical in the transverse direction. Because the base is either missing or covered by matrix in four of the teeth, the labial and lingual sides cannot be determined. All but one of the crowns are straight in lateral and occlusal views. The principal cusps are mostly prominent, with well-developed labial and lingual processes. Crenula-

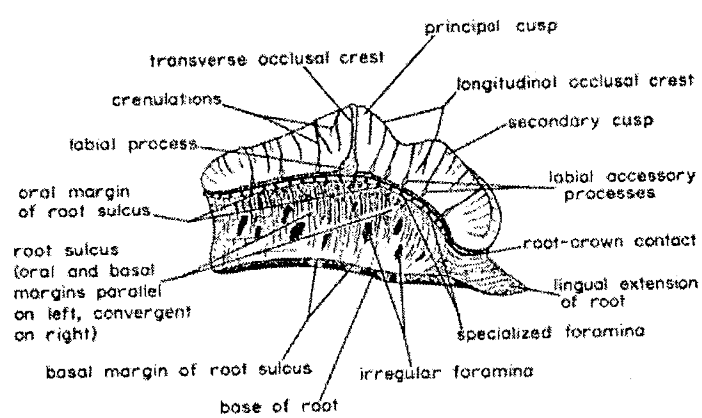

Figure 5. Sketch of a hypothetical hybodontoid tooth in labial view showing morphological characters. (From Johnson, 1981, fig. 1.)

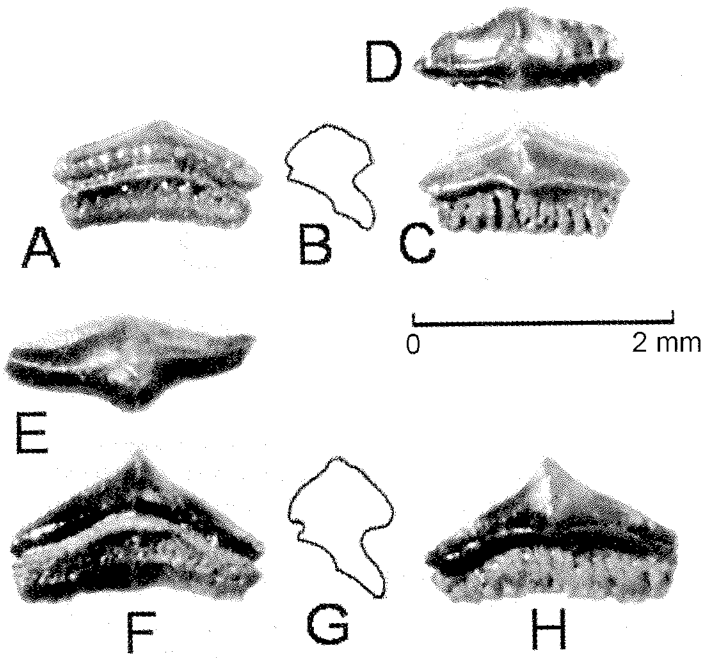

Figure 6. A–D—Probable anterior, and E–H—probable lateral, teeth of *Polyacrodus* (=*Lissodus*?) *zideki* from the Lower Permian of north-central Texas (modified from Johnson, 1979, pl. 53). A—lingual, B—transverse outline, C—labial, and D—occlusal (labial side at bottom) views of SMU 64437 from the Rattlesnake Canyon local fauna, upper Admiral Formation (upper Nocona Formation); E—occlusal (labial side at top), F—lingual, G—transverse outline, and H—labial views of SMU 64456 from the West Franklin Bend C/ac local fauna, upper middle Clyde Formation (lower middle Waggoner Ranch Formation). Formation names in parentheses are from Hentz and Brown, 1987.

tions are absent except for slight development in one tooth. The base-crown contact is straight where it can be determined.

Seven teeth (OMNH 52221, 52225, 52226; Fig. 7A–F) are tentatively assigned to *Acrodus*? *sweetlacruzensis* (Johnson, 1981) with reservations (the questioned generic assignment is discussed by Johnson, 1981). All are complete, or nearly so, and of intermediate size compared to all the *Acrodus*? species from the Lower Permian of Texas (Johnson, 1981). Crown length ranges from 2.95 to 3.36 mm, well within the range of the Texas teeth. The crowns are symmetrical in the longitudinal direction as seen in occlusal view, but the ends of the crowns are variously curved or flexed in a labial direction (Fig. 7C) in all but one tooth. The labial part of the crown is often more than twice as wide as the lingual side. The crowns are mostly straight in occlusal view as are the teeth from the Texas Permian, except for the flexed ends, which are not common and not as pronounced in the Texas teeth. The principal cusp is absent, or weakly developed. Crenulations are absent or poorly developed; they are usually present on the labial side of the crown in the Texas teeth. A labial process is generally well developed on each crown (Fig. 7B,C), and secondary processes are usually present, as in the Texas teeth. A lingual process is absent or poorly developed. The contact between the crown and base is arcuate. The sulcus on the base is short, centrally placed, and closed (oral and aboral or basal margins meet at each end; see Fig. 5; it is in shadow at the bottom of Fig. 7E).

Except for *Acrodus*? *sweetlacruzensis*, no described teeth from the Texas Permian (Johnson, 1981) have a typically short, closed sulcus on the base. Because the bases of hybodont teeth tend to be more morphologically conservative than the crowns, we assign these Lake Frederick teeth to *A.*? *sweetlacruzensis* despite their unusually curved ends of the crown and general lack of crenulations.

The remaining three teeth do not particularly resemble any of the species described by Johnson (1981), but compare most closely to *Acrodus*? *olsoni*. The first, OMNH 52222, is nearly complete, but damaged just enough to make determination difficult. The crown length is 4.85 mm. In occlusal view, its ends are slightly curved lingually; the principal cusp is poorly developed. This first tooth differs from those described above, and from *A.*? *sweetlacruzensis* in general, in possessing a sulcus that has convergent margins and is open at one end; the other end is damaged. The open end corresponds to a crown that is narrower (in occlusal view) than the remaining crown half, thus showing some longitudinal asymmetry. The sulcus extends along the length of the base, as opposed to being short as in *A.*? *sweetlacruzensis*.

The crown of the second tooth (OMNH 52223, Fig. 7G–I) is 5.4 mm long and symmetrical longitudinally and transversely. The principal cusp is central in position but poorly developed, and the ends of the crown are curved lingually (Fig. 7G). Crenulations occur on the labial side (Fig. 7I), and the labial process is moderately developed with a prominent, slightly concave, articulating surface; the lingual process is poorly developed as a blunt extension of the crown. The base-crown contact is arcuate. The sulcus is open at both ends with slightly convergent margins (Fig. 7I). It is unlike any of the other teeth, but could be conspecific with OMNH 52222 and 52224 if we accept the variability in the individual *Acrodus*? species described by Johnson (1981).

The third tooth, OMNH 52224, lacks one tip of the crown. The crown is about 5.2 mm long as restored (the base is complete) and is probably symmetrical longitudinally. The lingual half is slightly wider than the labial half in occlusal view. The preserved crown tip is curved lingually, and the other end was probably similarly curved, giving the crown an arcuate shape in occlusal view. Crenulations and the principal cusp are weakly developed. Development of the labial process is moderate and of the lingual process poor; both processes are similar to OMNH 52223. The base-crown contact is considerably more arcuate than in OMNH 52223; the sulcus is damaged, but was probably open at least at one end. This tooth is similar to OMNH 52223 except that the latter has a transversely symmetrical crown and is not as arcuate in labial view.

All three teeth are more like *Acrodus*? *olsoni* than any of the other described hybodont teeth from Texas (Johnson, 1981). The three probably belong to the same species. Because OMNH 52223 is the most complete (Fig. 7G–I), we compared it with the teeth of *Acrodus*? *sweetlacruzensis* and *A.*? *olsoni*. Only a few teeth in the SMU collection assigned to *A.*? *olsoni* closely approach the features exhibited by both crown and base of OMNH 52223. The teeth of *A.*? *olsoni* are large, and the sulcus on the base is open with generally con-

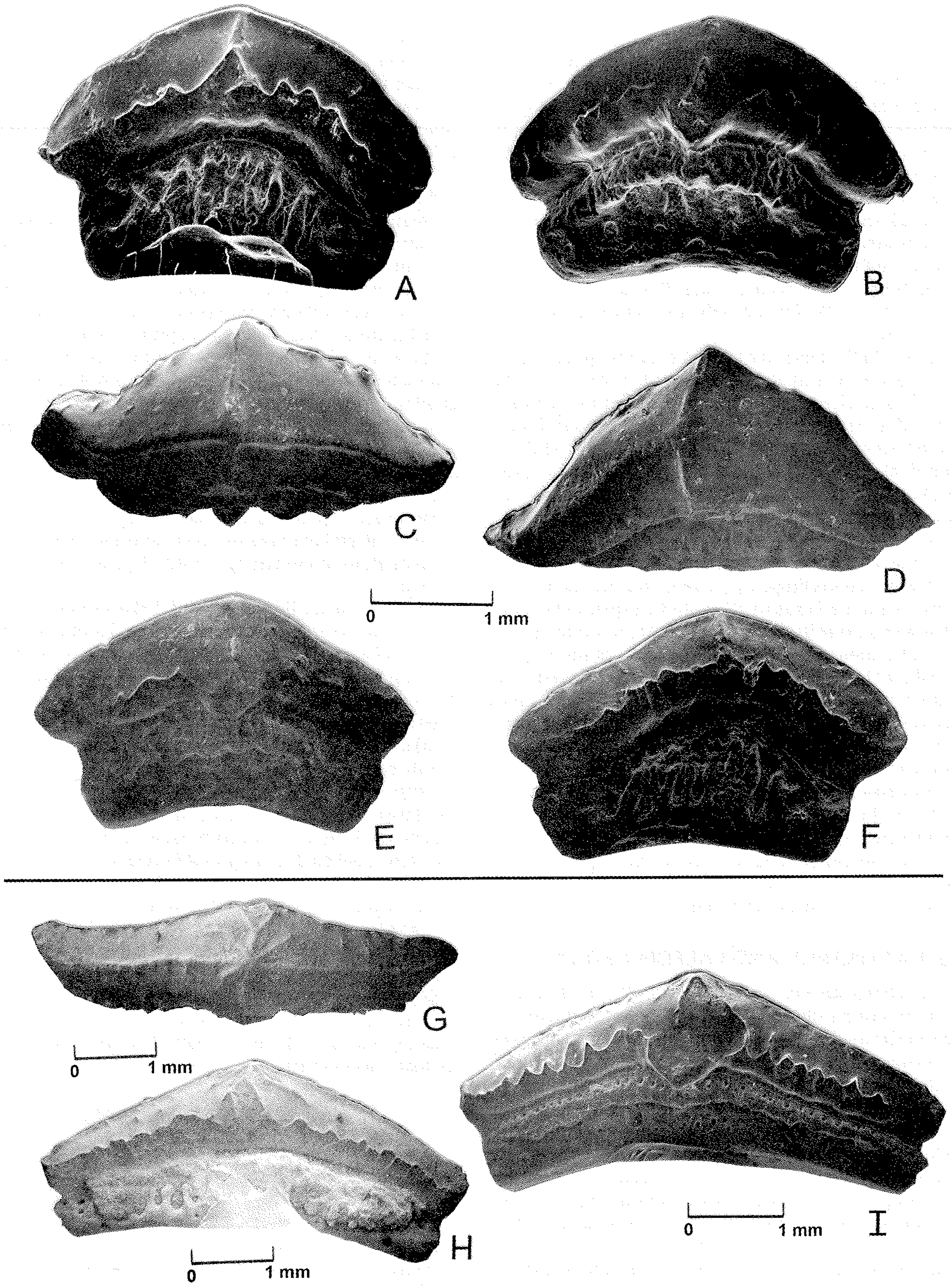

Figure 7. A–I—Hybodontoid teeth from the Lake Frederick site; A–F—*Acrodus*? *sweetlacruzensis*; A—lingual (base partly covered by mounting medium), B—labial, and C—occlusal (labial side at top) views of OMNH 52225; D—lingual-occlusal, E—labial, and F—lingual views of OMNH 52226; G–I—*Acrodus*? cf. *A.*? *olsoni*; G—occlusal (labial side at bottom), H—lingual (base obscured by matrix and mounting medium), and I—labial views of OMNH 52223.

vergent margins. However, the margins are nearly parallel in the holotype (Johnson, 1981, fig. 6). They are slightly convergent in OMNH 52223. The crowns of the holotype and OMNH 52223 are generally similar, with a poorly developed principal cusp, lack of a distinct lingual process, and a similarly developed labial process in each. A longitudinal occlusal crest is present in both teeth (Fig. 7G), giving the appearance of a better developed principal cusp. In contrast to OMNH 52223, the principal cusp in the holotype is slightly offset longitudinally. Only one end of the crown is lingually curved in the holotype; the other end is straight. Teeth of *A.*? *olsoni* with both ends curved are rare. The holotype is considerably more like OMNH 52223 than are most of the other *A.*? *olsoni* teeth.

The three OMNH teeth are lateral; they are quite unlike the probable medial and posterior teeth of *Acrodus*? *olsoni* (Johnson, 1981). The lateral teeth of *A.*? *olsoni* vary more than those of *A.*? *sweetlacruzensis*, which lacks heterodonty. None of the *A.*? *olsoni* teeth is exactly like the three OMNH teeth, but if taken as a population this species encompasses the morphological features of the three teeth. Therefore we provisionally assign OMNH 52222, 52223, and 52224 to *Acrodus*? cf. *A.*? *olsoni*.

Nine of the ten OMNH teeth assigned to *Acrodus*? possess crowns with both ends lingually curved. This discrepancy in comparison with the Texas teeth might be explained in part by differing positions in the dental arcade, but that seems beyond the bounds of coincidence. Recovery of more teeth may reveal that both *Acrodus*? taxa from the Lake Frederick locality are new species that rarely occur in the Texas faunas (thereby restricting the variation envisioned by Johnson, 1981, for *Acrodus*? species).

All three OMNH species extend throughout the section sampled in Texas by Johnson (1981), from the upper Admiral Formation to the middle Lueders Formation (Leonardian age). To use current stratigraphic terminology (Hentz and Brown, 1987), the range is equivalent to the upper Nocona Formation through the lower part of the upper Waggoner Ranch Formation (Johnson, 1999, table 1).

STRATIGRAPHY AND PALEOECOLOGY

Because *Orthacanthus texensis* is found as high as the Lueders Formation (Albany Group, equivalent to the top of the Wichita Group; Johnson, 1996) but not in the overlying Arroyo Formation (at the base of the Clear Fork Group) in Texas (Murry and Johnson, 1987; Johnson, 1992, 1996), it appears that Simpson's correlation (1979) of the upper Garber Sandstone with the Arroyo is not correct and that instead of the Arroyo the underlying Lueders Formation is the southern equivalent of the upper Garber; this seems further supported by the last occurrences of hybodontoid sharks in the Texas Permian, with none of the species occurring above the Lueders Formation (Johnson, 1992, fig. 2). Also implied is that if the upper Garber equals the Arroyo, it should have no hybodontoid fin spines or teeth. However, correlation is complicated by paleoenvironmental considerations because these hybodonts, as well as *O. texensis* (Johnson, 1999, p. 253), may have preferred coastal water or estuaries during part of their life cycle and not the persistently freshwater conditions in which Arroyo sediments were deposited (Johnson, 1996, p. 380). Furthermore, the presence of *Acanthodes* at Lake Frederick suggests that the upper Garber may be equivalent to strata no higher than the Lueders Formation where spines and scales are uncommon or absent (Johnson, 1979, p. 404). No evidence of acanthodians has been found in the Clear Fork Group (Murry and Johnson, 1987), contrary to Simpson's listing (1979, fig. 3) of *Acanthodes* in the Arroyo Formation. Also, *Barbclabornia luedersensis* teeth at Lake Frederick are similar to those in the Wichita Group, and quite unlike the much more robust teeth near the base of the Clear Fork Group (Murry and Johnson, 1987; Johnson, 2003). The presence of *Polyacrodus* (= *Lissodus*?) *zideki*, a hybodontoid fin spine, *Acanthodes* fin spines, and *B. luedersensis* at the East Manitou site (bulk sample collected with E. C. Olson; Johnson, 1979, p. 631) further complicates biostratigraphic correlation between Oklahoma and Texas if that site is as high in the section as Simpson (1979) states. Although equivalency of the upper Garber and the Lueders certainly is an option, the points noted above may not negate Simpson's correlation (1979) as he has satisfactorily explained on paleoenvironmental grounds the greater longevity of many taxa in the Early Permian of southern Oklahoma. Therefore, at the present state of knowledge, neither possibility can be excluded.

The Northeast Frederick and Lake Frederick sites are fluvial and lacustrine deposits, each extending over about a quarter of a square-mile section. Thus the two Permian lakes (excluding the fluvial facies in parts of the Lake Frederick site) covered ~160 acres each, enough to sustain several large predatory fish but not a breeding population. The xenacanth sharks could be considered potamodromous, i.e., permanently freshwater and migrating from lake to lake through the stream system if enough lakes were perennial. If most of the lakes were intermittent, as maintained by Simpson (1979), then the xenacanths must have been euryhaline diadromous fishes that migrated between marine and freshwater environments (as suggested by Schneider and Zajíc, 1994; Schneider, 1996; and possibly applicable to *Orthacanthus texensis*, according to Johnson, 1999), and may have occasionally wandered into lakes higher up on the coastal plain. *O. texensis* may have existed in Europe (Johnson, 1999), then a part of Pangaea; but so far *O. platypternus* is known only from North America, as is *Barbclabornia luedersensis* (Johnson and others, 2002). The apparent differences in distribution must have been governed by habitat.

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geonews roundup

State agency investigates OU's water

Environmental officials recently learned previously high-arsenic wells are in operation.

By Ty McMahan

NORMAN—The state Department of Environmental Quality is investigating the University of Oklahoma to determine whether some of its water wells are producing arsenic levels that exceed safe water standards.

Environmental officials were on campus Friday [April 9] to gather information for an audit they believe will take three weeks.

Officials learned recently that the wells that had high arsenic levels were back in operation, said Monty Elder, spokeswoman for the DEQ.

The high levels of arsenic originally were discovered in 1995, Elder said.

In a Feb. 13, 1996, response to environmental officials' concerns about the arsenic levels, the university said it stopped using the three wells that did not meet water quality standards. OU Physical Plant workers planned to continue testing two others that were close to having unacceptably high arsenic levels.

Also in that response, OU stated that water tested from distribution points, such as faucets and spigots, was within allowable criteria.

Burr Millsap, associate vice president of administrative affairs and director of Physical Plant, said three of the wells OU voluntarily took out of use in 1996 are now operational.

"There were five wells in question. One was actually not operational at the time the 1995 compliance tests were taken. Another was taken out of service in 2000. They continue to be tested periodically. The remaining three are still operational," Millsap said.

Elder said agency officials were under the impression that the wells were not being used because they were known to produce water that did not meet quality standards.

Millsap said no current university employees were working with the water system at the time OU agreed not to use the wells. He said because of that, he and other officials are relying on documentation to provide answers to the water quality investigation. He said he can not speculate why the wells were put back into service.

Elder said there is no stipulated penalty that the university would face for operating the wells. She said the only violation would be failure to provide public notice that the wells were in use.

"Nothing says they can't use water above the standard," Elder said. "They just have to let people know. We didn't require them to tell people before because we thought the wells were not being used."

Millsap said he does not know why the public was not informed the wells were operational.

Elder said the last three test samples from the wells show they have been in compliance with arsenic standards. The last time the wells had arsenic levels that tested above the allowable limit was in 2002.

Water samples are submitted to the DEQ under two different classifications. Owners of public water systems must submit compliance water samples to determine whether water meets standards established by the Environmental Protection Agency. A courtesy sample is for information only and not used for rule enforcement.

Millsap said a misunderstanding in the type of water samples OU submitted could be a factor in the reason the wells in question were operational.

Millsap said OU officials have invited the environmental workers to retest the water from the wells to establish their formal compliance status. He said OU and the state officials are cooperatively completing an audit of the university's records pertaining to water samples taken from the wells.

Elder said the agency will examine compliance test results, monthly operational reports and annual usage.

Water in the future

Elder said because of Oklahoma's geological composition, it is not uncommon for water wells to exceed arsenic levels. She said about 10 water systems in Oklahoma have at least one well over the 50 parts-per-billion standard.

Acceptable arsenic levels will lower to 10 parts per billion in 2006. University officials are working to establish a system to buy water from a municipal water supply to meet the new standards. No well water will be used for public consumption once the new standards take effect.

For more information on OU's water quality, visit its Environmental Health and Safety website at **http://www.ou.edu/ehso**. Click on "University of Oklahoma Annual Drinking Water Report."

Deep knowledge

➤ New arsenic testing method could save Norman water and money

By Melissa Koontz

A machine built by Norman resident James Greer, a U.S. Geological Survey hydraulic technician, could save cities affected by the lowered arsenic standard thousands of dollars in water-well testing.

Known as the IZ-Machine, this device sits atop a 16-foot trailer and could prove to be a more efficient and cost effective way to sample ground water arsenic levels at various depths in a well.

Greer along with Jerrod Smith, USGS hydrologist, demonstrated the machine Thursday [April 15] in Oklahoma City as part of a one-day forum where USGS scientists briefed more than 80 federal, state and local natural resource officials on several new and existing studies.

"This is one of only two that exist," Smith said. He said the other is in California where it originally was designed to test wells for salt water intrusion. "We're here today to show our colleagues in the science industry our capabilities in testing water quality," Smith said.

Smith, who is heading a two-year project in Norman to determine the machine's viability, said if the device works efficiently at finding where arsenic is

Deep knowledge *(continued)*

concentrated, cities could save nearly $40,000 per well in testing costs.

What sparked the idea for the project was the EPA's lowered arsenic standard that passed in 2000. The EPA has estimated that by 2006 the new standard of 10 micrograms of arsenic per liter of water will affect about 3,000 communities.

The reason for the scientists' focus on Norman is indicated by a USGS study on the Garber-Wellington aquifer, which found the Norman area to have the highest concentrations of arsenic. Smith said he hopes the study using the IZ-Machine will provide more data on the specific distribution of arsenic in the aquifer's water, which is needed to determine whether existing wells can be isolated and, therefore, saved.

"The question is can we fix the well so that it's still usable?" asked Scott Christenson, a hydrologist for the USGS, who watched the demonstration Thursday.

He said currently the cheapest way to test a well's arsenic level is to take a sample from the top of the well.

"All we know is the mixture at the top is not compliant," he said. "We don't know if the bad water is universal."

He said the new method "will allow us to determine zone-specific water quality."

Kim Winton, USGS Oklahoma City district chief, said the only method available now for testing water quality at different levels is expensive and involves removing the pump and injecting balloons into the well to isolate certain levels for testing.

"Ideally what we want to be able to do is know where the good water and the bad water is" and to be able to find that out while the well is operational. That way the testing results are based on real and actual conditions, she said.

Bryan Mitchell, capital projects engineer for the City of Norman, said Norman has contributed two of its wells to the research effort, both of which have already been shut down. He said city officials, in turn, get to find out if the water quality is better at some levels and worse at others, which "has always been a question."

"I'm just happy that Norman has been able to participate in this manner," he said. "If it were to be shown that it works then, in concept, we have a good number (of wells) that we're hoping to be able to use in the future."

Mitchell said if the new testing method proves effective, Norman would save thousands of dollars in terms of testing its wells that are marginally close to meeting the lower arsenic standard to determine which levels of intake should be plugged.

"They are half way through the two-year project," he said. "The results are very promising for municipalities all over the nation at this point."

Reprinted with permission as published in *The Norman Transcript* April 16, 2004.

States to monitor river pollution

Oklahoma and Arkansas planners meeting for 2 days in Tahlequah to decide just how they can do it.

By Jack Money

TAHLEQUAH—The Arkansas River Compact Commission wants to monitor the impact of phosphorus and other pollutants on the Arkansas River and its tributaries in Oklahoma and Arkansas.

Representatives of Oklahoma and Arkansas environmental agencies will be working here on a monitoring plan today and Friday [April 29–30].

"The whole idea is to discuss how it will be done," said Earl Smith, chief of the water management division of the Arkansas Soil and Water Conservation Commission. "We need to talk about where we want to locate our monitoring sites, and how many of those there should be.

"We also need to discuss how often samples should be taken, what we will sample for, and when we want to take samples. I would hope answers to all these questions would be incorporated into our plans.

"We want to know . . . how much progress we are making toward meeting the required water quality standards."

The chief standard Smith and other compact commission officials are concerned about is that of 0.037 milligrams per liter phosphorus pollution within Oklahoma's six scenic rivers and streams.

Five of the six—the Illinois River, Flint Creek, Lee Creek, Little Lee Creek and the Baron Fork River—are within the Arkansas River basin and flow into the river. The sixth—the Upper Mountain Fork River—flows across state lines and could be monitored as well.

The Oklahoma Water Resources Board set its phosphorus standard for scenic rivers more than a year ago. Oklahoma officials subsequently threatened to sue Arkansas to force changes in its rules and regulations for cleaning up water on its side of the state line.

Since then, the two states have agreed to work together, choosing the Arkansas River Compact Commission as the organization.

Phosphorus, a nutrient, is a byproduct of sewage treatment plants and decomposing chicken litter spread as fertilizer on fields. In excessive amounts, it causes explosive algae growth, turning water green.

Generally, increased sewage discharges from fast-growing northwest Arkansas communities and waste from a growing number of chicken farms are believed the culprits behind the pollution problems.

Both states want the monitoring program ready to go by August.

"One of the reasons the meeting is important is because it is time we get past focusing on things we disagree about and focusing on what we can agree upon," said Derek Smithee, water quality programs manager for Oklahoma's Water Resources Board.

"We need to reduce the nutrients in the river, and we need to agree on how to make that happen," Smithee said.

Oklahoma monitors water pollution on the Illinois River near Watts in Adair County and near Tahlequah in Cherokee County. Average phosphorus contamination amounts observed during 2002 and 2003 were 0.225 milligrams a liter at Watts and 0.119 milligrams a liter at Tahlequah. Oklahoma's standard for maximum levels of phosphorus in the Illinois and other scenic rivers is 0.037 milligrams a liter.

Reprinted with permission as published in *The Oklahoman* April 29, 2004.

For more information, visit the Oklahoma Water Resources Board's website at **http://www.owrb.state.ok.us/**.

Aquifer's guardians rally to protect its level, their futures

By Tom Lindley

TISHOMINGO—One-quarter-mile of fourlane highway is all there is in Johnston County, but that may be all that is needed in a place paved with clear, pure spring water that flows over a bed of pink granite and creamy white limestone.

It's a unique mode of transportation that is easy on the shocks, gentle on the mind and possibly at the end of its road.

The fear of losing even one drop of water brought out the people Monday night [March 22] the way the trout lured the fly rods and those who cast them to Blue River last weekend. More than 100 members of the Citizens for the Protection of the Arbuckle-Simpson Aquifer crowded into the Tishomingo Community Center intent on eating tasty barbecue and doing whatever it takes to preserve their piece of utopia, where the rhythm of the water can carry the imagination anywhere it wants to go.

"Our streams separate us from a lot of other counties in the state," said Ray Lokey, publisher of the Tishomingo Johnston County Capital-Democrat. "That's what this whole issue is about. There is only one Blue River and there is only one Pennington Creek.

"Having this aquifer is like having a 401(k) or a savings account. It gives you a sense of security and the belief that it will be there in the future."

Still, there is the concern that unless permanent steps are taken to control how much water can be safely pumped out of the aquifer, the only carefree water ride left in the state will be along the Bricktown Canal.

To illustrate the point, Earl Brewer, the group's founder, held up a full bottle of water and pointed to the waterline just below the cap, which he said represented the spot in the aquifer where water discharges to the surface.

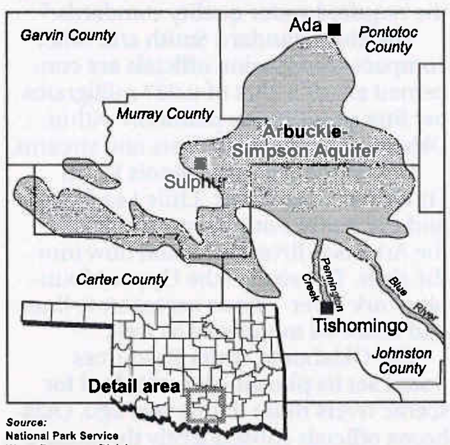
"It's the water near the top of the cap that matters to us," he said. "None of the water is viable if the aquifer falls below the spring level, and if that happens, the springs will dry up."

To prevent that from occurring, Duane Dahlgren of Oklahoma City forked over a $100 bill for a walking stick that was being auctioned to raise funds. The money is needed for legal fees so the group can get involved in a court action involving the constitutionality of a state moratorium on the sale of water by a group of ranchers to municipalities in central Oklahoma.

While some dug into their pockets to support the cause, others have dug even deeper.

A prayer group leader was presented with a plaque in acknowledgment that some form of divine intervention must have been at work last year when the state Senate, by a one-vote margin, voted to implement the moratorium until a comprehensive study could determine how depletion of the aquifer would affect downstream users. The key vote was cast by a senator who, when he re-entered the chamber, thought he was voting for a different bill.

Monday night, the prayer group was reminded that its services might be needed again because another bill that could pave the way for the sale of water has passed the state House and is headed to a Senate committee.



Source: National Park Service Water Resources Division

"It's like an old movie trailer from 'Jaws 2'—just when you thought it was safe to get back in the water," aquifer advocate John Bruno said, referring to the legislation that is intended to protect Panhandle farmers but could also affect the sale of water in the aquifer.

Bruno said the bill potentially would allow previously issued temporary groundwater permits to automatically convert into permanent permits.

"This essentially creates a privileged class of groundwater rights holders to the detriment of all other groundwater rights owners," he said.

Conversely, some ranchers near Sulphur believe their property rights have been unfairly usurped by the moratorium, which could remain in place for as long as five years.

It's estimated that the sale of water could be worth millions of dollars to the ranchers and could end the desperate search for water in Yukon and other growing communities. Opponents argue that the sale poses recreational and environmental concerns and could jeopardize the water supply of towns in the area that now rely exclusively on the aquifer.

"That water is our future, too," Lokey said. "It seems like we have to fight for every single thing we get in this part of the state, and now we have to fight to keep what we have."

No one realizes how important the stakes are more than Bruno, who since he was a child dreamed of one day owning a piece of Pennington Creek.

He got his wish more than 10 years ago when he bought the 80-acre Rainbow Falls Ranch. Later, he purchased 400 acres along the creek, including the celebrated collection of granite rocks known as Devil's Den.

Orange lichen clings to the giant boulders, which stand guard as the water swirls and babbles below. In another week, the sedum plants will be producing yellow blooms on the granite floor of the bluff. About the same time, the white oaks, dogwoods and seaside alder also will make their spring splash.

Along Pennington Creek, granite and water are as one, exhibiting both nature's firm hand and soft touch.

"I know critters and plants don't take priority over man, but if there ever was a place where you should be allowed to have both, this is it," Bruno said.

Reprinted with permission as published in *The Oklahoman* March 25, 2004.

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For more information, visit the website of the Citizens for the Protection of the Arbuckle-Simpson Aquifer at **http://www.arbsimaquifer.net/**. Click on "OWRB Study of Arbuckle Simpson."

Drilling helps rural economies

Times are good as rig count rises in oil patch

By Adam Wilmoth

Rodney Wilson's job as an oil and natural gas rig hand has pulled him to projects as far away from home as Montana and Florida.

Working one week on the job and the next week off, he was able to spend time with his family, but he had to make long trips—at his own expense—between them and the job site every week.

Increased drilling in western Oklahoma over the past two years, however, has allowed the Marlow resident to work much closer to home.

"I still work seven days on and seven days off, but I had to drive further before," said Wilson, a tool pusher for Nabors Industries Ltd. "I'm closer so if something was to happen, I could get home to my family sooner."

Wilson went to work in the oil patch while still a high school student during the oil boom in 1979. Since then, the industry has collapsed and rebuilt itself a few times, making it sometimes difficult for Wilson and thousands of other rig operators like him to keep a steady job in the industry.

But times are good now, with the state's rig count climbing near levels unseen in more than a decade. More than 150 rigs are actively drilling for oil and natural gas in the state this week, up from 111 one year ago and 72 in March 2002.

The uptick in drilling activity has provided thousands of jobs for rural Oklahomans and has given a boost to dozens of rural communities.

"It has a big affect on our economy," said Guy Hylton, city manager of Elk City. "The natural gas exploration companies and companies that support them all buy items here, and we appreciate it. It helps our sales tax."

Each of the state's active rigs employs an average of 50 to 75 people, both directly and indirectly, including rig hands, drilling supervisors, geologists and support.

Most of the rig operators and support personnel either work at or visit the drilling sites, which often are in rural areas. Those visits lead to other benefits for the local communities.

"There's a lot more heavy truck traffic in town, and that type of clientele has benefited our restaurants, hotels and gas stations," Marlow City Manager Janice Cain said.

Communities also have gained from an influx of royalty payments to mineral owners.

Oil and natural gas companies paid about $1 billion in 2003 for drilling activity in the state, said Richard H. Chapman, chief executive of the National Association of Royalty Owners. The association estimates that about 55 percent of the payment—or $550 million—went to royalty owners who live in Oklahoma.

"Without a doubt, prices holding where they are have paid off a lot of mortgages and have bought new equipment and new trucks," Chapman said. "Most of this money is supplemental income for farm equipment, for sending the kids to college and for giving to churches and giving back to the communities."

Besides the economic benefit to employees in rural communities, the spike in drilling activity over the past two years also has funneled millions of dollars directly to state coffers. The industry paid about $540 million in severance taxes on oil and natural gas production in 2003.

Drilling activity is up statewide, but the increase is most prominent at Oklahoma City–based Chesapeake Energy Corp., which accounted for about 27 percent of the active rigs in the state as of Feb. 27. Chesapeake had 40 active rigs out of 148 active statewide.

Chesapeake has said it plans to spend about $600 million on drilling in Oklahoma this year with an estimated return of about $2.5 billion in revenue. The production would lead to royalty payments of about $500 million, with about half of that amount staying in the state, Chief Executive Aubrey McClendon said.

For more information, read "2003 Report on Crude Oil and Natural Gas Activity within the State of Oklahoma" by Larry Claxton. It's available online from the Oklahoma Corporation Commission's website at **http://www.occ.state.ok.us/**. Click on "Oil and Gas Information," then click on "Oil and Gas Annual Reports," then click on "2003 Annual Report."

Energy companies digging deep

Technology leading way for drilling

By Adam Wilmoth

Rising natural gas prices and the depletion of shallow, lower-risk fields have driven oil and natural gas producers to increasingly turn their sights as far as five or six miles below the state.

Deep wells have potential for great finds, but also for great disappointment.

To better manage the risk, energy companies are turning to new technologies that help them more accurately pinpoint where profitable reserves may be found.

A typical well of up to 12,000 feet may cost between $1.2 million and $1.8 million and take just a few weeks to drill.

Deeper wells, however, can be much more costly, with a typical 20,000 foot well totaling more than $6 million and more than six months in drilling time.

"You can't afford not to be successful when you drill at that depth," said Tom Price Jr., senior vice president of investor and government relations for Oklahoma City-based Chesapeake Energy Corp.

With the state's first wells tapped before statehood, Oklahoma is considered to be one of the more mature oil and natural gas states in the country.

Newer technologies, however, promise to help energy companies continue to extract resources from under the state for years to come.

Most of the state's large, shallow reserves already have been recovered, but deep reserves—some as far down as five

Energy companies *(continued)*

or six miles—still could hold huge profits.

About 12 trillion cubic feet of gas equivalent has already been extracted from the Anadarko Basin in southwestern Oklahoma, according to the Potential Gas Agency at the Colorado School of Mines.

The agency, however, also estimates an additional 16 trillion cubic feet remains in the basin, mostly more than 15,000 feet below the surface.

Three-dimensional imaging has been used statewide for about 15 years, but companies are now adapting technology to better fit the particular demands of Oklahoma's geology.

Three-dimensional imaging uses dynamite or seismic trucks to vibrate the ground. Seismic waves bounce off formations and return to sensors on the surface, allowing geologists to see ancient river beds or other buried features where natural gas is likely to be hiding. Two-dimensional imaging technology—similar to the one used in the opening scene of Jurassic Park—has been used in the oil patch since the early days of drilling. Three-dimensional imaging, however, gives geologists a much better view, as they can see the image in full color and move in and out of layers on a computer screen.

Three-dimensional imaging has been especially popular in the Gulf Coast region of Texas and Louisiana, where the geologic structures produce an easily recognizable signature when they contain oil and gas reserves.

The geology in Oklahoma and other onshore locations is less revealing, only showing where there is a potential for reserves.

Despite the more stubborn nature of Oklahoma rocks, energy companies continue to enhance their technology to get a better read of what really lies underground.

Geologists and engineers at Chesapeake have taken 3-D imaging one step further by constructing a $2 million to $3 million viewing room, which uses sophisticated computers, a large screen and dual projectors to shine a true 3-D image on the screen. Using special glasses, the images appear to reach out of the screen like a hologram.

The viewing room allows the image to be projected as a true 3-D image, rather than as a 3-D slide on a 2-D computer screen, Chesapeake Chief Executive Aubrey McClendon said.

"Today, while it's still called 3-D seismic, it's very different than what we had five or 10 years ago," McClendon said. "Just the computer power is so much higher today than it was even a couple of years ago. What we're using today gives us a much clearer sense of what's down there."

Houston-based Apache Corp. is using a different innovation to enhance the 3-D images.

The company is using more sophisticated sensors to record three-channel, three-dimensional images, known as 3C3D. Apache's sensors measure horizontal, or sheer, waves along with the vertical, or primary, seismic waves.

"The sheer waves measure a slightly different component in the rock," said Rob Johnson, vice president of exploration and development of Apache's central region in Tulsa. "There have been a few 3C3D surveys shot in Oklahoma, and they appear to be superior at shooting deep into the rock."

As technology continues to improve, energy companies are likely to adapt the latest advance for use in the oil patch.

"I think any time, whether it's in the 1970s or 2000s, you're going to use every means available to you to try to explore and exploit the process to the best of your ability," Johnson said. "We aren't to the point that we just have the magic bullet, but we do try to use everything at our disposal."

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DID YOU KNOW ?

The drilling process

- The drilling process begins months or years before the rig crew arrives on a property. Engineers and seismic technicians first map out the land and use seismic imaging to get a picture of what lies below the surface. Geologists then analyze the data to determine the best places to set up the rigs and how deep they should drill.
- After a site is selected, drilling rights are obtained and all the paperwork has been filed, the energy producers hire a drilling company to set up a rig and begin the drilling process. About 15 people work in three shifts a day for about a week to move a rig from one location to another and set it up for drilling in the new spot.
- Once the rig is in place, another crew of about 15 people work in three shifts to operate the rig. Shallow wells can take as little as five days to drill, and deeper wells can take longer than six months to complete.
- Most Oklahoma wells require directional drilling, which uses a motor on the end of the drill to steer the bit to the desired location. Directional drilling typically requires one person to operate the directional motor and another to measure and analyst the data to determine whether the bit is on course.
- Once drilling is completed, a service company sends a crew of about 15 to 20 people to pump treated water or another liquid into the hole to make the natural gas flow stronger. When the stimulation is complete, a different crew of about six people is sent to complete the well by tying the hole into a natural gas pipeline and cleaning up the surface facility.

Shifting focus

Oil taking back seat to natural gas

FOR YEARS, Oklahoma's identity as an oil-producing state was reinforced by the large drilling rig on the state Capitol grounds. The Lincoln Terrace No. was among many rigs drilled in the 1930s and '40s in the Oklahoma City Field, which at one time produced more oil than any field in the world.

That was then. The rig is no longer there—it was dismantled three years ago to become part of the Oklahoma History Center—and now it's natural gas that is making Oklahoma a major player in the energy industry.

Dan Boyd, geologist with the Oklahoma Geological Survey, touched on the shift during a talk in Tulsa. Boyd said natural gas makes up about 80 percent of the oil and gas production

Shifting focus *(continued)*

in our state, and producers are adding healthy reserves of natural gas.

Oklahoma gas wells on average produce 175 thousand cubic feet per day, the equivalent of 29 barrels of oil (most Oklahoma oil wells average a little over 2 barrels per day, Boyd said). State gas reserves stood at 18.3 trillion cubic feet 40 years ago. But since then, thanks in part to advances in drilling technology, Oklahoma has produced 72.5 trillion cubic feet and plenty remains.

The rise in natural gas prices has been good news for Oklahoma producers and the state. Unlike a year ago, Oklahoma will be able to put a little money in the Rainy Day Fund when this fiscal year ends, thanks to consistently solid revenue collections that are tied in part to the energy sector. A recent survey by Creighton University indicated an expanding economy for our state in the next several months, and pointed to high energy prices as one reason.

Boyd noted that low demand made Oklahoma's biggest gas fields an afterthought for many years. Not anymore. Demand for natural gas has increased greatly and shows no sign of abating, and Oklahoma appears well positioned to take advantage.

From macaroni and beer to petroleum exploration

By Ed Montgomery

Something funny happened to Everette Lee DeGolyer on his way to earning a geology degree. He took a summer job that enabled him to help find a big oil field and point him toward one of the most successful careers in the early days of scientific petroleum exploration.

But first, said the oil historian Ruth Sheldon Knowles, he had to learn to cook.

DeGolyer entered the University of Oklahoma in 1906. After his freshman year, he applied for a United States Geological Survey trip but the only spot open was for a cook, Mrs. Knowles wrote in her book, "The Greatest Gamblers" (meaning the greatest oil wildcatters).

She wrote DeGolyer enjoyed attributing his success to macaroni and beer.

"His mother taught him to make macaroni and cheese," Mrs. Knowles said. "The art of producing a cold bottle of beer on a field trip first brought him to the attention of Dr. C. Willard Hays, chief of the survey, when he visited the camp on a hot day."

The next summer, Hays agreed to supervise a search for oil in Mexico for Sir Weetman Pearson's Mexican Eagle Oil Co. and took DeGolyer along. The student jumped at the chance, although his expert advice was against it.

"DeGolyer's geology professor tried to discourage him and his classmates," the book says. The prof thought they had been born too late for oil geology.

"All the big oil fields have been discovered," he said.

Two days after Christmas in 1910, an Eagle Oil wildcat blew in what, in 1959 when this book was written, was still the biggest producer in history with 130 million barrels of oil. Soon after that, DeGolyer announced he was going back to Oklahoma to finish his education.

Everette Lee DeGolyer (1886–1956), the father of modern exploration geophysics.

When Pearson could not talk him out of it, he offered to pay for his young undergraduate's schooling if he would come back to his company.

"Diploma in hand," the author wrote, "DeGolyer became Mexican Eagle's chief geologist. He soon discovered another spectacular field . . . whose first well gushed 50,000 barrels a day."

In 1918, DeGolyer founded Amerada, an exploration company to operate in both the United States and Canada. He hired a young OU physics graduate, J. C. Karcher, and gave him $300,000 (a crew might use $18,000 worth of dynamite in a few days) to further the research in geophysical research he had started in his spare time. The result was the reflection seismograph technique that revolutionized oil exploration.

By 1932, DeGolyer had made Amerada the biggest company in the country entirely devoted to oil exploration.

He resigned as Amerada chairman at the age of 46 and, in partnership with Karcher, found six major fields.

Before his death in 1956, DeGolyer presented thousands of books on the history of science to OU. His interest in books was legendary. He once bought a rare one in Chicago and asked that it be mailed to him in Texas.

"I'm going by plane," he said, "and I don't want anything happening to the book."

Quake shakes up state's residents

By Chad Previch

An earthquake knocked pictures from walls and dishes from sinks Monday night [April 19] in Love and Carter counties, according to the Oklahoma Geological Survey Observatory.

The 2.7-magnitude earthquake originated at 7:09 p.m. between Ardmore and Lone Grove, chief geophysicist Jim Lawson said.

"Dishes were pitched out of shelves in Ardmore," Lawson said.

Lawson didn't expect any injuries from the tremors.

The last Oklahoma earthquake shook Grady County on April 22. It registered a 2.9 magnitude, Lawson said.

There have been 22 earthquakes this year, although only Monday's and the one in Grady County were felt.

Lawson said officials received about 100 reports within a few hours of Monday's earthquake.

Anyone who felt the quake is asked to report it at www.okgeosurvey1.gov.

Earthquake shakes Lindsay residents

LINDSAY—The largest earthquake to hit Oklahoma this year shook the community of Lindsay early Thursday [April 22], knocking knickknacks off the walls of businesses and homes.

The magnitude 2.9 earthquake occurred at 11:13 a.m., the Oklahoma Geological Survey Observatory in Leonard reported. It was the largest earthquake in Oklahoma since an Oct. 20, 2002, magnitude 3.3 earthquake in Atoka County.

Sandra Burns, Lindsay police dispatcher, said there were no reports of injuries or structural damage.

Lawson said the quake was centered about four miles west of Erin Springs and about five miles southwest of Lindsay. Lindsay is in Garvin County, about 60 miles south of Oklahoma City.

Reprinted with permission as published in *The Oklahoman* April 23, 2004.

Quake rocks parts of state

By Jack Money

WAURIKA—Some southern Oklahomans may not realize it, but they experienced an earthquake Thursday morning [June 10].

The quake, which measured 2.7 on the Richter scale, appears to have been centered in an area under the Red River 14.5 miles southeast of Waurika. Monitoring stations show the quake occurred at 7:30 a.m., geological survey officials said.

Thursday's event, they said, likely was not on the same fault line as another earthquake Monday evening [June 7] that nearly 150 Oklahomans in the Ardmore area felt.

Jim Lawson, chief geophysicist at the Oklahoma Geological Survey Observatory, said Thursday's quake was so minor that his office didn't even receive any notifications from residents that it had happened.

Lawson also said he didn't believe the earthquake was an aftershock of Monday's bigger, 3.7-magnitude event, which knocked dishes off shelves and clocks from walls.

One key showing whether a quake is an aftershock of another is the way it looks on a seismographic monitor. If the quake is an aftershock, its recorded motions mirror those taken during the earlier event—even if they are less intense.

"The two earthquakes' characteristics look different," Lawson said.

The geophysicist said numerous, other smaller earthquakes have struck Oklahoma between the two larger events.

Lawson said the quakes hitting Oklahoma this week are a little unusual, but residents shouldn't worry too much.

"I think it is very unlikely we will see one as large as the June 7 event for quite some time," he said.

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For more information about earthquakes in Oklahoma, visit the Oklahoma Geological Survey website at **http://www.ogs.ou.edu/**; click on "Earthquakes," then click on "OGS Earthquake Observatory."

Texas County worker finds prehistoric tusk

By Dawn Marks

GOODWELL—The sharp eyes of a county worker have provided Oklahoma Panhandle State University with a tusk possibly preserved from the Ice Age.

During the weekend, professors and students excavated the tusk from an undisclosed location in Texas County near the Beaver County line and now will start to determine more about it, Amy Sheldon, a paleontologist and professor of biology at the university, said Tuesday [May 4].

A Texas County employee was removing gravel at a quarry April 27 when he saw the five-foot tusk and stopped digging.

Sheldon said when she arrived at the scene that afternoon, she knew the find was an important one that must be preserved.

"Tusks are especially fragile because of the way they grow," Sheldon said. "I was just really pleased that the gentleman knew that it was not a normal part of the gravel he was working with and they called us."

Sheldon said the tusk appears to be from a Pleistocene-era Columbian elephant and could be up to 1.6 million years old.

Sheldon, students and Jonena Hearst, a paleontologist from Colorado Springs, Colo., whose expertise is the Pleistocene era, encased the tusk in plaster Saturday and transported it to the university in Goodwell.

Sheldon said she and students soon will remove the plaster cast protecting the tusk, clean it and preserve it for display.

Reprinted with permission as published in *The Oklahoman* May 5, 2004.

A career built solid on rocks

An Ardmore man earns a medal for his prized fossil collection.

By David Zizzo

ARDMORE—For half a century, Allen Graffham searched for remnants of a long-lost world. He also has bought and sold them, but he's not worried the modern world will run out.

"Who cares? There's millions of them," Graffham said.

Over the years, the Ardmore geologist/paleontologist has handled more than his share of fossils, maybe more than anyone's, according to the Association of Applied Paleontological Sciences, a trade organization of fossil-sellers.

"He has been an inspiration, a motivator, a pioneer . . . and one of the greatest fossil collectors there has ever been," the association said in awarding him its 2004 Sternberg Medal.

Fossils of bugs, plants and animals can be found almost everywhere, if you know where to look, Graffham, 85, said. Buyers for them—like museums, researchers, collectors and people who just want to make paperweights or coffee tables—can also be found.

Finding a namesake

In the 1950s, while analyzing microscopic fossils in drilling core samples for oil companies, Graffham realized there could be a living made in long-dead things. A demand existed, and he could find a supply.

A career built solid on rocks *(continued)*

So Graffham advertised in scientific magazines and started hearing from interested buyers, like paleontology instructors from around the world.

The wish lists included fossilized corals, wood, ferns, insects, dinosaur bones, brachiopods—"everything imaginable."

One trilobite led to another, and Graffham, in 1955, launched Geological Enterprises Inc. Since then, *Graffhamicrinus matheri* and more than a dozen other fossils bear his name.

A team effort

Sixteen years ago, Graffham married Fran, widow of a fossil-hunting companion. Together, the Graffhams continued uncovering fossils, many of them dinosaurs, including an ankylousaur, an edmontosaur and a mother and baby triceratops.

However, the most notable fossil the Graffhams have handled was a 40-foot-long *Acrocanthosaurus*, which two amateur rockhounds discovered in 1983 in southeastern Oklahoma. The fossil was the only known essentially complete skeleton of the *Tyrannosaurus*-like predator, and one of the most complete dinosaur skeletons ever found.

The Graffhams bought the fossil in 1989 and named it Fran, yes, after Mrs. Graffham. They had it completely restored and sold it for $3 million to North Carolina State University. They still offer casts of the skeleton for $120,000.

The couple get their fossils from many places, including a generous layer of fossils in a 160-acre limestone quarry they own in Coal County. They've spent summers fossil-hunting on land they leased in Wyoming.

"There's no shortage," Graffham said.

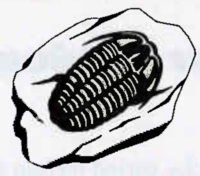
All about business

From a nondescript metal building near an Ardmore cemetery, "out here with the other old bones," Graffham and his wife deal in almost anything fossilized.

The Graffhams will sell anyone dinosaur eggs from China, amber-encased insects from South America and Camasaur teeth from Canada. In their 65-page catalog, they also offer meteorites and ancient artifacts, from axeheads to pendants of a "bat god."

"The secret of keeping business going is coming up with new things," Graffham said. "New things do turn up every year."

Reprinted with permission as published in *The Oklahoman* April 4, 2004.



COLLECTOR OPENS HIS OWN REGISTERED MUSEUM

By Ginger Shepherd

CUSHING—For the last 60 years Richard Dodrill has been collecting things like rocks and fossils.

Many years after he began collecting, it became an issue of what he was going to do with his vast collection. He wanted to be able to keep it together, he said, even if he died.

Dodrill and his wife decided the best way to do this was to open a museum, which they did at 123 S. Cleveland.

The museum is registered with the State of Oklahoma and the federal government, an action the Dodrills took so they could accept donations and donors could receive a tax credit. Registering also allows them to feature exhibits from different museums.

"We have fun with it," Dodrill said. "And that is what you get out of life."

While the museum serves as a legal means to keep his collection together, he said, it also provides a unique opportunity to work with children. He likes to host children's groups at the museum, he said as it provides the children a chance to learn something they don't know.

Children can walk through and look at a variety of different rocks, mineral and gemstones. Some of the rocks have fossils.

A display case shows different fish fossils that Dodrill has found over the years. Some of the fish fossils and coral displays raise questions from children, especially when the fossil or coral is from Oklahoma or Kentucky, Dodrill said, adding that he explains to the children that earth used to be one big ocean.

His mineral collection also sparks a lot of questions from children, he said. One purple-white mineral in the display case is fluorite. Many of the children don't recognize it as the same mineral used in toothpaste, he said.

Fluorite, Dodrill said, is ground up into a white powder called fluoride and is commonly found in toothpaste and some municipal water systems.

If a child has a question that he can't answer, Dodrill said, he quickly looks up the answer. He has a small library of books and videos in the museum's conference room.

Dodrill's rock lessons are more than questions and answers and looking at examples in glass cases.

He has also set up a hands-on area for the children. The section allows the children to touch rocks, crystals and minerals and feel their weight and texture.

One rock, Dodrill said, has a fossil in it. Children can examine the rock closely to find the small set of jaws lodged in it.

The hands-on area also features a pan filled with dirt and different rock types, which allows the children to get the basic feel of digging for a rock, Dodrill said.

While different rocks and fossils fill the main exhibit area, Dodrill's Museum has three other rooms. One focuses on minerals and gemstones and the other two on local, state and tribal histories.

One room is simply designated the Indian Artifact Room. Everything in the room, except for one shelf, is an American Indian artifact, Dodrill said. They range from arrowheads to peace pipes to even photographs of local tribes like the Sac and Fox.

Dodrill said one piece of jewelry was made by a Cherokee woman in the 1920s. One of her family members donated it to the museum so it would be taken care of and be in one place.

Collector opens museum *(continued)*

After he opened his museum, Dodrill said, many older Cushing residents approached him about dedicating one room to Cushing history. He said he didn't have a problem doing that.

The room's contents include pictures of Cushing and the sign from the old Hudson refinery. He even has old curling irons, hair pins and doctors' kits. They fit into the local history because they were donated by local people, Dodrill said.

The room's focus has been expanded beyond just Cushing. Many of the materials in the room relate to Oklahoma history like pictures of Frank "Pistol Pete" Eaton and equipment from old oil rigs and pumps. An old pump sitting in the corner, Dodrill said, created the familiar "putt-putt-putt" sound so many heard in the boom days.

Recently an individual donated several old tools, Dodrill said, including a hand drill dating back to the 1600s and a drill press from the mid-1800s.

Reprinted with permission as published in *The Norman Transcript* May 23, 2004.

Dodrill Museum
123 S. Cleveland
Cushing, Oklahoma
(918) 225-0662
Open 10 a.m. to 4 p.m.
Monday through Saturday
There is no charge to visit the museum, but donations are welcome.

For outdoor lovers, Oklahoma rocks

By Keli Clark

WITH the varied terrain in Oklahoma, there is always one constant. From the highest point of the molten lava-formed Black Mesa in the far northwest to the vast range of the Kiamichi Mountains in the southeastern region of the state, Oklahoma rocks.

There are many ways to enjoy the many geological and mineral formations in the state. Starting small and working up, rock hounds can find ample varieties of stones, gems and fossils on exhibit in the **Midgley Museum** in Enid. Housed in the former home of Enid residents Dan and Libbie Midgley, the walls of the museum are built from petrified wood, rock and fossils found in Oklahoma and surrounding states, making the structure a rocky showpiece in itself.

Oklahoma's state rock is displayed in single forms and clusters at the **Timberlake Rose Rock Museum** in Noble. The barite formed in a flowery shape and colored by the red soil are found only in a few places around the world, including central Oklahoma.

As a child, taking a spoon to the back yard and digging up stones to collect for keepsakes was always fun. At **Salt Plains National Wildlife Refuge** near Cherokee, visitors can spend hours re-creating those childhood memories by digging in the sand and salt for the elusive selenite crystal.

The crystals, also known as "stone of the moon," are unusually shaped crystals of gypsum found only in the northern part of the state. Digging for them is a dirty but fun job, and shovels or hand spades, not spoons, are highly recommended when searching for the crystal treasures. After a hard day on the salt plains, crystal buffs can relax in the comfort of a cabin or campsite in nearby **Great Salt Plains State Park**.

Red Rock Canyon State Park in western Oklahoma near Hinton is home to a different type of rock. Although you can't dig them up, you can dig your hooks into them. The towering walls of the canyons are a preferred destination for hikers, rock climbers and rappellers. The rugged sandstone canyons and cliffs were formed more than 200 million years ago by wind, water and natural erosion. Specific walls within the canyon are designated for climbing and rappelling, however guests must bring their own safety-certified equipment. After a long day of scaling the heights, guests can cool off in the swimming pool in the park. Sites for recreational vehicles and tents are offered in the park, as well as a group camp with cabins to accommodate larger parties.

Extreme rockers flock to **Baldy Point** in the **Quartz Mountain** range in southwestern Oklahoma near Altus. The tall, granite, dome-shape formation rises high above the prairie. A variety of high and low angle faces offer a challenge to wall climbers who enjoy going vertical. Lodging accommodations are available in the beautiful **Quartz Mountain Lodge** or at a campsite at **Quartz Mountain Resort Park**.

The **Wichita Mountains** in southwestern Oklahoma near Lawton offer a wide array of areas for visitors. Climbers, hikers and bikers converge on the mountains to test their skills on the wide-ranging terrain.

Mount Scott, the best known peak in the **Wichita Mountain Wildlife Refuge**, is one of the more popular areas for climbing and hiking. Visitors can explore the mountain by driving to

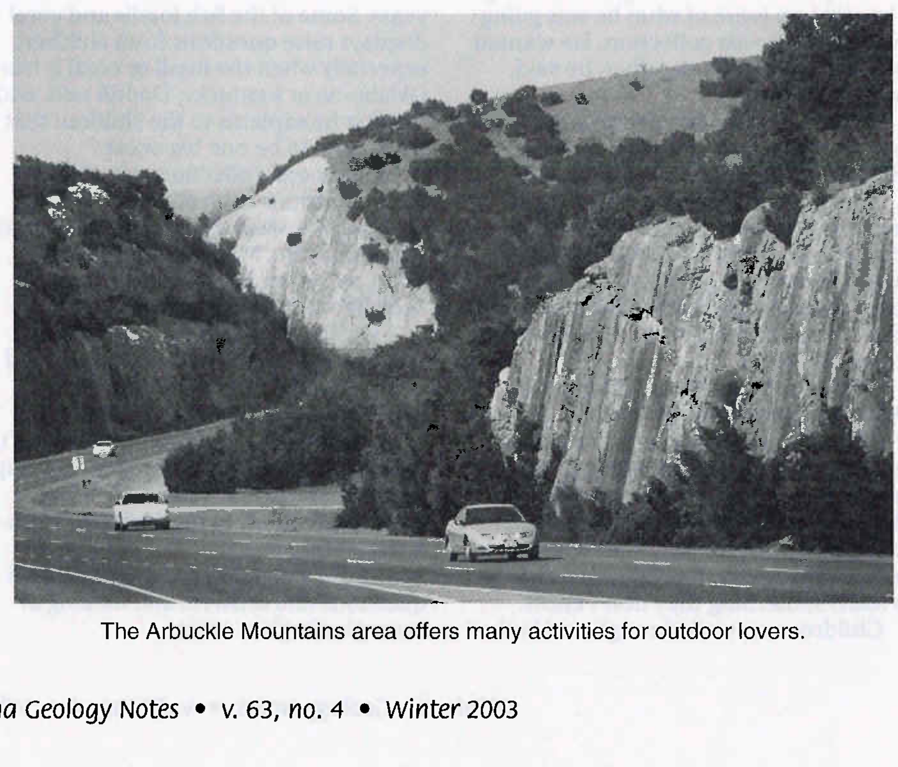


Photo courtesy Oklahoma Parks, Resorts and Golf

The Arbuckle Mountains area offers many activities for outdoor lovers.

Oklahoma rocks *(continued)*

the top and taking in the incredible view, or starting at the bottom and trekking your way up the mountain.

The refuge holds an assortment of wildlife including buffalo, longhorn cattle, elk and deer. Wildflowers in bloom are a spectacular sight beginning in spring and continuing through summer.

Nearby **Lake Lawtonka** and **Lake Elmer Thomas** are ideal destinations for water lovers to enjoy swimming, fishing and water sports activities, or to park a recreational vehicle or pitch a tent and relax around a campfire.

In central Oklahoma from Sulphur to near Ardmore, the **Arbuckle Mountains** are overflowing with activities for outdoor lovers. The range of smaller mountains spills over into a large area, allowing hikers the chance to explore the ancient terrain.

The **Chickasaw National Recreation Area** in Sulphur is a haven for families who enjoy camping, hiking, nature trails and fishing. The **Travertine Nature Center** in the park is an educational center where guests can learn more about the ecosystem and history of the region.

The cool, clear water of nearby **Lake of the Arbuckles** is a great getaway for fishing, water enthusiasts and campers. A popular recreation area in the Arbuckle range is **Turner Falls Park**, just outside Davis, where the main attraction is the 77-foot waterfall and natural swimming pool. Tent and recreational vehicle sites as well as cabins are available for guests who want to stay and check out the various rock formations, natural caves, hiking and equestrian trails included in the park area.

One of the most picturesque areas in the state is the **Kiamichi Mountain** range in southeastern Oklahoma. The tall pines that sprout from the hills of the **Ouachita National Forest** reach skyward, sometimes seeming to touch the low, feathery clouds that float over the mountains. During spring and summer, the lush greenery of the landscape is inviting. But the spectacular hues of the leaves in fall attract visitors from all over. Campers can find amenities including cabins and campgrounds at **Lake Wister State Park**, at the northern end of the mountain range.

At the southern end of the Kiamichis, guests can enjoy hiking, camping, fishing and an assortment of other outdoor activities at **Beavers Bend Resort Park** near Broken Bow. The park's 40-room lodge, historic cabins and riverfront cabins are tucked away in the forest and offer visitors a relaxing hideaway. There are plenty of ways to see the sights throughout the area, on foot or on horseback, in this hiking and equestrian paradise. Miles of trails accommodate two-footed and four-legged enthusiasts visiting the area year-round.

Reprinted with permission as published in *The Oklahoman* June 6, 2004.

For more information on Oklahoma's rocky destinations, visit the official Oklahoma Tourism website at **http://www.travelok.com** or call (800) 652-6552.

STATE HAS JUST BEGUN TO HARNESS WIND

By Tom Lindley

WOODWARD — A ballet on stilts that could have been choreographed for the stage is playing out on high, windy ground in western Oklahoma.

Mounted on steel and concrete cylinders nearly 17 stories high, rows of blades as long and majestic as the wings of a 757 airliner silently dip out of the sky in perfect unison and circle effortlessly back into the heavens.

"Look at the way they turn—breathtaking," LaVern Phillips of the Woodward Industrial Foundation said Thursday [April 29]. "All that's missing is a little Beethoven playing in the background."

> ***"With wind generation of electricity, we can cleanly power our homes and businesses while at the same time putting money in the pockets of Oklahoma landowners instead of Wyoming coal miners. It seems like a pretty obvious choice."***
>
> *Miles Tolbert, Oklahoma's environment secretary*

Not far from where the giant turbines turn wind into kilowatts, the blades of a rickety old windmill spin furiously and water trickles from the ground, slowly filling a rusty cattle trough.

The past has met its future in a place that until recently would not have been called cutting edge.

"This type of power has come of age and has put Woodward on the map," Phillips said as he led a tour of the 12,000-acre Oklahoma Wind Energy Center. These days, tourists and schoolchildren by the busload can't kick up the caliche fast enough to travel 10 miles north of town to stare in amazement at the 68 turbines.


Photo courtesy Oklahoma Wind Power Initiative

This wind farm near Woodward harnesses wind power using million-dollar turbines.

Back in the city, utility customers in Oklahoma City, Edmond and elsewhere are lining up to buy electricity from the wind farm, one of two built in the state last year.

Gov. Brad Henry has singled out wind power as one of the state's brightest economic development opportunities, predicting it's one way for Oklahoma to remain an energy state indefinitely.

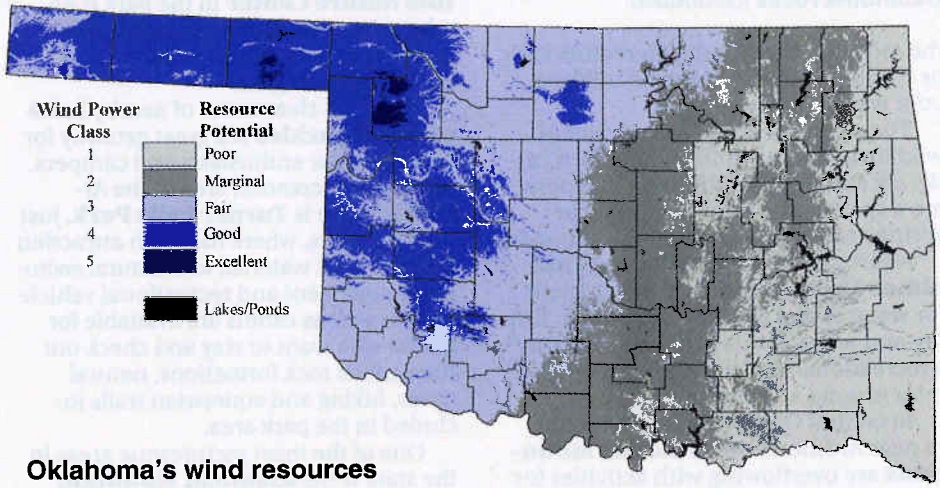
State harnesses wind *(continued)*

All that bluster does not necessarily mean Oklahoma will quickly ride the wind sweeping down the prairie into a state of environmental bliss and prosperity. Oklahoma ranks eighth nationally in wind potential, but it remains to be seen whether we have the will to harness it.

"I think we are likely to meander along for a while, although the public seems willing to pay extra for clean energy," long-time wind power entrepreneur Mike Bergey of Norman said last week.

A series of factors, some beyond the state's control, has conspired to throw up a temporary windbreak in the path of Oklahoma, which last year increased its wind capacity to 176 megawatts.

First, unlike several other key energy-producing states, Oklahoma has not taken legislative steps to force public utilities to add wind power to their portfolios, and it has not formulated a long-term energy plan.



Oklahoma's wind resources

Note: Results of this wind study have not been thoroughly verified, but researchers said this map likely underestimates the potential for wind energy in many areas, especially eastern Oklahoma.

Source: Oklahoma Wind Power Initiative

Without a contract to sell power, wind speculators can't find the financing for turbines that cost $1 million each. And without a full-scale commitment to wind power, Oklahoma's attempts to recruit foreign turbine manufacturers and their 600 to 800 jobs to the Tulsa area may fall several hundred megawatts short.

Secondly, Oklahoma remains virtually dependent on the largesse of the federal government to provide incentives for wind farms and on the whims of investors to take an interest in Oklahoma. The energy bill that would extend the life of the tax credits is stalled in Congress.

Finally, the nation's inadequate, outdated electrical grid could stymie the development of wind farms in Oklahoma's windiest but most remote locales.

Miles Tolbert, Oklahoma's secretary of the environment, said those obstacles shouldn't be enough to undermine what he claims is inevitable.

"With wind generation of electricity, we can cleanly power our homes and businesses while at the same time putting money in the pockets of Oklahoma landowners instead of Wyoming coal miners," he said. "It seems like a pretty obvious choice."

No standard

For the time being, the state's major utilities have won the battle to determine the parameters of common sense, having successfully shot down attempts in the Legislature to establish a renewable portfolio standard, which would have forced renewable energy on a state not known for its environmental activism.

Texas and New Mexico, which like Oklahoma are flush with wind and have deep ties to fossil fuels, have created energy portfolios that call for an increasing reliance on renewable energy.

Oklahoma Gas and Electric Co. helped lead the way in staving off the threat of more regulation by voluntarily contracting to buy 50 megawatts of power from Florida Power and Light, which built and operates the Woodward wind farm.

Proponents of renewable energy question whether OG&E joined the more than 500 utilities nationwide that offer "green pricing" simply to avoid being told what to do. The utility calls its actions an aggressive step that was taken over the objections of some of its larger customers, who feared that it would spark rate increases.

Although OG&E ranks second in the nation for low-priced renewable power, it remains cautious.

"Our position is let's let demand drive the supply," OG&E spokesman Brian Alford said.

The "windies" remain undaunted in their belief that the economic winds ultimately will blow favorably for wind.

"Forget about the treehugging stuff and all the environmental issues if you want to. Wind power is now about the same price (as fossil fuels) but is trending in the direction of being cheaper in the long run," said Scott Greene, director of the Environmental Verification and Analysis Center.

That's true in Woodward County, where the $307,000 in additional tax revenue that the carefully sculpted turbines produce isn't the only thing that looks good to Phillips.

"It also makes you feel good, when you look up at them and think how this is helping solve the nation's energy problem," Phillips said.

Reprinted with permission as published in *The Oklahoman* May 2, 2004.

For more information, visit the Oklahoma Wind Power Initiative's website at **http://www.seic.okstate.edu/owpi/**.

For more information on OG&E's Wind Power Program, visit the website at **http://www.oge.com/**. Click on "OG&E Wind Power."

PSO announces wind-farm plan

Deal depends on credit's future

By Adam Wilmoth

Public Service Co. of Oklahoma on Monday [June 28] announced its plan to build the state's largest wind farm near Weatherford, ending months of speculation about the project.

The plan—which is contingent on Congress extending a federal tax-credit program—calls for construction of 71 wind turbines each producing 1.5 megawatts that would generate a total of nearly 107 megawatts of electricity, enough to power more than 31,000 homes.

"We're always looking to support the state in economic development, and this was an opportunity to obtain some wind-generated power in Oklahoma at a very competitive price," PSO spokesman Jeff Rennie said.

"We think it's good for our customers and for the state. It's a good economic development project for the Weatherford area, and it's a good long-term supply of energy for us at a very competitive price."

The move would bring PSO in line with the state's three other major electric utilities, which all built wind farms last year totaling about 176 megawatts.

The project will be developed, owned and operated by Florida-based FPL Energy, the same company that built the two 51-megawatt wind farms near Weatherford that serve Oklahoma Gas and Electric Co. and the Oklahoma Municipal Power Authority.

Western Farmers Electric Cooperative buys power from a 74.3-megawatt wind farm near Lawton operated by Texas-based Zilka Renewable Resources.

FPL Energy spokesman Steve Stengel said in April that the company was looking to construct a wind farm near Weatherford, although he would not disclose at the time who the project would serve or how much power it would produce.

While PSO and FPL on Monday announced their intention to build the new wind farm, the contract is binding only if Congress extends the federal wind energy production tax credit.

The tax credit program was originally included in the controversial energy bill, which has been stalled out repeatedly in Congress over the past two years.

The credits have now been moved to the corporate tax bill. Different versions of the legislation have been passed by both the House and the Senate, and the bill is now in a conference committee.

Industry leaders are hopeful the bill will be approved this fall, but they acknowledge the tax credit program's fate is still uncertain.

"As with any such large bill with a lot of interests in it, there are a lot of items that will have to be negotiated," said Christine Real De Azua, communications director for the American Wind Energy Association.

"Just about everybody in the industry has put projects on hold and is waiting for the credit to be extended before going ahead."

The association had expected about 2,000 megawatts in wind projects to come online this year, but nearly all development has stalled or been canceled, Real De Azua said.

Despite the uncertainty caused by the tax credit bill, community and state leaders Monday praised PSO and FPL for their wind farm pledge.

"It will benefit the land owners and put some money in circulation and hopefully be a benefit to our whole town and especially to our school system," Custer County Commissioner Raymond Ford said.

Several hundred contractors would work to install the 300-foot-tall wind turbines, and about eight to 10 full-time employees would manage the site once it becomes operational.

Corporation Commission Chairman Denise Bode has been a strong proponent of wind energy, encouraging the state's utilities to adopt renewable energy programs.

"Our utilities recognize the importance of having reliable energy and having it from a variety of sources," Bode said.

"I'm looking forward to having more wind power developed in the state, and I'm pleased PSO is looking at it."

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Tar Creek proposal clears House panel

By Carmel Perez Snyder

A House committee Wednesday [March 24] advanced the Tar Creek relocation plan proposed by Gov. Brad Henry.

The House Appropriations Subcommittee on Natural Resources and Regulatory Services voted "do pass" on Senate Bill 1490, which now will be heard by the full House Appropriations Committee before heading to the House floor.

Henry said the Tar Creek relocation plan is "a critical issue."

"I will continue to push for speedy, final legislative approval of this initiative so we can deliver much-needed and long-awaited assistance to families in the Tar Creek Superfund site," Henry said. "I believe, as do many lawmakers and citizens, that we have a moral responsibility to help the vulnerable children there. The families in Picher and Cardin have waited long enough."

The governor outlined the plan in February to use $5 million to buy the homes of families with young children in the areas of Picher and Cardin in northeastern Oklahoma.

Money for the Tar Creek plan was not included in the $5.3 billion budget bill signed Monday by Henry.

The governor said he had reached agreements with legislative leaders addressing items, such as the Tar Creek plan, left out of the budget bill.

Reprinted with permission as published in *The Oklahoman* March 25, 2004.

For more information on Tar Creek, visit the Oklahoma Department of Environmental Quality's website at **http://www.deq.state.ok.us/**. Click on "Tar Creek Information."

Inhofe discusses Tar Creek

Cleanup site residents say they are encouraged.

By Sheila K. Stogsdill

MIAMI, OK—Both sides expressed optimism about future dialogue after U.S. Sen. Jim Inhofe and residents of the Tar Creek Superfund Site met privately earlier this week.

Some of the residents have been among Inhofe's harshest critics. After Monday's meeting [April 5], there were encouraging comments about working with the senator to resolve the decades-old environmental and health problems of the area.

Inhofe, R-Tulsa, visited with members of the Tar Creek Basin Steering Committee on Monday at a private business office near Miami Municipal Airport.

"We didn't see the old Inhofe we expected," said Ed Keheley, technical adviser to the committee. "We expected to be read the riot act, but he really surprised us."

Keheley said issues discussed in the private meeting included a relocation plan, Inhofe's $45-million cleanup plan, and the levels of lead in children in the Tar Creek area.

"There will be sincere follow-up on all the topics mentioned in the meeting," said Danny Finnerty, a spokesman for Inhofe. "It was a positive, productive meeting, and Senator Inhofe was pleased with the meeting."

John Sparkman, executive director of the Picher Housing Authority and spokesman for the steering committee, said Inhofe appears very sincere in his concern for the Tar Creek area.

"More meetings are planned in the future," Sparkman said.

During a March 25 meeting in Miami, Sparkman accused Inhofe of lying to him about agreeing to meet in public with Picher and Cardin residents. Inhofe missed the meeting, which included discussion among state, federal, tribal and citizens groups about cleaning up lead and zinc pollution in the Tar Creek Superfund Site, but a spokesman said his absence was because of senatorial duties. Tar Creek, a 40-square-mile area including Picher, Cardin, Quapaw, Commerce and North Miami, was a lead and zinc mining area throughout much of the 20th century. The mines were shut down in the 1960s. Sparkman supports Gov. Brad Henry's proposed $5 million voluntary relocation plan. Henry's voluntary relocation plan would give families the option of selling their property to the state for the average county market value for comparable properties. After Monday's meeting, Sparkman and Inhofe toured the Tar Creek area.

Reprinted with permission as published in *The Oklahoman* April 7, 2004.
Contributing: The Associate Press

Tar Creek relocation may take less money

A state senator thinks the project can be done for less than $3 million.

By Sheila K. Stogsdill

PICHER—The governor's office expects only $3 million will be appropriated this session for a Tar Creek buyout plan, and a state senator said that may be more than enough.

Gov. Brad Henry asked the Legislature for $5 million to fund a voluntary relocation and buyout plan that focuses on families with children 6 years old and younger.

About 100 families could qualify for the voluntary relocation from the Tar Creek area and its environmental problems.

Only $3 million will be available next fiscal year, said Paul Sund, Henry's communications director. Another $2 million could be appropriated in the next session and could be available as early as February 2005, he said.

State Sen. Rick Littlefield, D-Grove, said Tuesday [April 13] that relocating Tar Creek residents might take less than $3 million.

"I want to do the very best we can and still take care of the problem, but we are not going to waste money," Littlefield said.

The senator said he is worried about where families will be relocated and who controls the money in the trust authority that oversees payouts.

More than $100 million has been spent on Tar Creek, a 40-square-mile area of Picher, Cardin, Quapaw, Commerce and North Miami.

The area was once a lead and zinc mining capital throughout much of the 20th century. After the mines closed in the 1960s, mining companies left behind numerous environmental problems.

Studies indicate children in the Tar Creek area have higher lead levels in their blood than normal. County health officials believe the high levels may have caused increased learning disabilities among students in the Tar Creek area.

John Sparkman, executive director of the Picher Housing Authority and spokesman for Tar Creek Basin Steering Committee supports Henry's proposed voluntary relocation.

"The people in Picher and Cardin have complete faith and trust in Governor Henry," Sparkman said. "We are confident we can work out any problems that may rise."

Reprinted with permission as published in *The Oklahoman* April 14, 2004.

Survey reveals health conditions in Tar Creek area

By Sheila K. Stogsdill

QUAPAW—Preliminary results from a survey conducted by a Tar Creek citizens' group shows a high percentage of residents have tested for hypertension problems and heart disease.

Earl Hatley, president of Local Environmental Action Demanded, said Tuesday [June 1] the agency has tested 562 households in the 40-square-mile area known as Tar Creek.

"This study is designed to be a lay effort to identify illness," he said. "We are not medical doctors."

Since Tar Creek was placed on the Superfund National Priorities List in 1983, there has not been a door-to-door survey conducted by a state or federal agency to determine whether any illnesses are evident and if they are related to metals found in the area, Hatley said.

The area includes Picher, Cardin, Quapaw, Commerce and North Miami, and was a lead and zinc mining range throughout much of the 20th century. Mining companies left numerous environmental problems, including sinkholes, acid mine drainage and moun-

Health conditions *(continued)*

tains of chat when they closed in the 1960s.

Gov. Brad Henry is expected to sign the Tar Creek voluntary relocation bill into law today.

The $3 million voluntary relocation plan, approved by the Legislature last week, will provide financial assistance for families with children ages 6 and younger to relocate to a safer area.

Hatley said about 1,400 people were interviewed between August and September. The studies indicate 58 percent of the 1,400 interviewed tested positive for hypertension, 43 percent for diabetes and 40 percent for heart disease.

The surveyed population appears to be sicker than the general population of Oklahoma, he said. However, whether specific medical problems are associated with Tar Creek will be determined by additional information, Hatley said.

County health officials have said they believe high blood lead levels have caused a high incidence of learning disabilities among students in the Tar Creek area.

Reprinted with permission as published in *The Oklahoman* June 2, 2004.

Tar Creek relocation due Henry's signature

By Ryan McNeill

A bill creating a fund to pay for voluntary relocation of children from the Tar Creek Superfund Site passed the House without debate Tuesday [May 25].

Senate Bill 1490 goes to the governor, who said he would sign the legislation. It passed the Senate 35-9 on Friday [May 21].

"This marks a historic opportunity for Oklahoma to provide some desperately needed and long-overdue help for families of Tar Creek," Gov. Brad Henry said.

The $5 million plan will be split into two years, with $3 million being appropriated this year, said Paul Sund, a spokesman for Henry. An agreement between the governor and legislative leaders calls for an appropriation next year of the final $2 million.

Families with children ages 6 and younger will receive state assistance to relocate to another area. The site, located near Picher and Cardin, is plagued with lead exposure.

TAR CREEK

- **What is it?** 40 square miles in Ottawa County.
- **Why is it contaminated?** Mining for lead and zinc from 1891 until the 1970s.
- **Contaminants:** Lead, iron, sulfate, zinc and cadmium.
- **What's the problem?** Children have elevated blood lead levels, which can cause learning disabilities and reduced growth.

Officials estimate 100 families could qualify for the program.

"The children there deserve the chance to lead a healthy and happy life," Henry said. "Senate Bill 1490 goes a long way toward ensuring that possibility for children growing up amid the high lead concentration of Tar Creek."

Reprinted with permission as published in *The Oklahoman* May 26, 2004.

Tar Creek relocation bill signed in Picher ceremony

Governor says the law will help families protect "our youngest citizens."

By Sheila K. Stogsdill

PICHER—As children played on chat piles, Gov. Brad Henry told a group of Tar Creek residents Wednesday [June 2] it's time to help and protect "our youngest citizens."

Henry then signed the Tar Creek voluntary relocation bill.

He touted the measure, approved by the Legislature last week, as "historical legislation." The bill is designed to assist young children who live in the Tar Creek Superfund site, he said.

"We have a moral obligation as a state to take care of our youngest citizens," Henry said.

About 100 families could qualify for the $3 million voluntary relocation plan. Under the bill, families with children 6 years old and younger, living in the most affected area, can receive state assistance to relocate.

Picher resident Teresa Dixon attended the bill signing. She said she wants to move from Picher with her 6-year-old son Jason.

Jason, who wears a brace on his left ankle, had six vertebrae removed from his spine because of a tumor when he was 3, Dixon said.

Photo courtesy *Miami News-Record*/Gary Crow

Jason Dixon, 6, and Emily Aldinger, 3, watch as Gov. Brad Henry signs a voluntary relocation bill.

"It could have been environmentally caused is what the doctor told us," Dixon said.

Henry asked the Legislature for $5 million to fund a voluntary relocation and buyout plan, but only $3 million was appropriated. Another $2 million is expected to be appropriated in the next session.

Tar Creek relocation bill signed *(continued)*

Paul Sund, Henry's communications director, has said the funds should be available as early as February.

Henry told the crowd he first visited Tar Creek in 2002.

"Until you are here, you can't appreciate the magnitude of the problem," he said.

The northeastern Oklahoma Superfund site was the lead and zinc mining capital of the country throughout much of the 20th century. The abandoned mines have created numerous environmental and health problems for residents living in a 40-square-mile area encompassing Picher, Cardin, Quapaw, Commerce and North Miami.

The bill does not absolve the government or the mining companies of their responsibility to clean up the area and take care of the health needs, Henry said. But it will give families the option to sell their property to the state for the average county market value for comparable property.

Rep. Larry Roberts, D-Miami, said the bill was the highlight of his 21-year legislative career.

John Sparkman, executive director of the Picher Housing Authority and spokesman for the Tar Creek Basin Steering Committee, said, "It's a great day and it's been a long time coming."

More than $100 million has been spent on Tar Creek cleanup efforts.

Ottawa County health officials believe high blood lead levels have caused a high incidence of learning disabilities among students living in the Tar Creek area.

Susan Karnes, a Picher grandmother who has lived in the Tar Creek area for 40 years, attended the bill-signing ceremony with her 4-month-old granddaughter, Savannah.

"We're just thankful our grandchildren don't live here," she said.

Karnes said her children were raised in Tar Creek and they suffered from medical problems ranging from bad headaches and allergies to a son who was diagnosed with cancer as an adult.

Henry told the crowd he has spoken with health care providers about the problems of lead in children younger than 6 years old.

Under the plan, the bill also will help renters find and finance new rental property or comparable housing elsewhere in Ottawa County for 12 months.

Eligible people will receive a $1,000 stipend for moving expenses and recipients must agree they will not again reside within one-half mile of the most affected area of the site until the secretary of health formally determines the area is safe for children.

Families can expect to begin the filing process by Sept. 1, with checks issued in the fall, Henry said.

In addition to helping families, the plan provides assistance to local government agencies such as the school district and utility authority, to help minimize the affects of the relocation.

Tar Creek's future held by dreams

By Tom Lindley

PICHER—Some still dare to dream at the foot of the infamous chat mountains.

Rebecca Jim, a soft-spoken former high school counselor whose determination gave rise to one of the most powerful environmental movements in state history, dreams about a brighter future for the children and the land within the Tar Creek Superfund site. "I can see it clean, and I can see it looking like the original prairie did," she said. "I have a lot of hope."

Billie Joe Crawford, who shoveled lead and zinc in the bottom of a shaft 60 years ago, dreams about the past and the men who split rock wielding 10-pound hammer heads and then hoisted it from a deep, dark hole one giant cast-iron can at a time.

"I dream now about the guys I worked with and the places I worked in down under and on top," Crawford, 80, said Thursday [June 10] as he thought about making preparations for this weekend's annual miners' parade and reunion.

"I don't know that I'd change anything about this place or my life. I got a paycheck every Saturday night. It wasn't much, but it kept me and my family going."

Governor approves funds

The only problem with staking your dream to a place with a bull's-eye painted on its back is that it makes it difficult for the past and the future to escape the present, which has been described as a nightmare for those who are either determined to stay or can't afford to leave.

"This whole thing is just a monster, and there's no end to it," one-time miner and outdoors enthusiast John Mott said of the questionable attempts to address long-standing health and environmental concerns.

Gov. Brad Henry last week signed a bill that will pay up to $5 million to voluntarily relocate about 100 families with young children, who, research shows, run a high risk of lead exposure in the Tar Creek Mining District.

To Jim, it was an important step signaling the state will no longer wait for someone else to clean up a mess that came out of Oklahoma's own back yard.

"I'm proud of Governor Henry for doing it, and I believe those families who will take the opportunity to leave will be safer for it," she said.

Values of hard work

Long-time residents, such as Orval Ray, think it's the kind of help the town doesn't need.

"A bunch of college professors who never lived here and never talked to anyone here have determined this place is unsafe to live," said Ray, who operates a mining museum and pool hall in the heart of Picher. "This is all just a political football."

Crawford, who in his prime was part of a two-man crew that shoveled seven tons of lead in seven minutes, said the best way to improve the town would be for younger folks to learn a little more about hard work.

"Not one time in 50 years did I call my

Tar Creek's future *(continued)*

boss and lie to him about why I couldn't come to work," he said. "There were a lot of days when I didn't feel like going, but I did, except if I had a broken leg or something like that."

Crawford still lives in the house he and his wife bought near the center of Cardin for $500 in 1948. They came up with $480 of their own and borrowed the last $20 from the bank by using Crawford's bicycle as collateral.

It is no wonder then that there is no shortage of advice when it comes to Tar Creek.

In fact, there's almost more of it to sift through than there is chat, the nickname given to the gray, gravel-like mining residue that has been stored in huge volumes in the middle of a cluster of old Ottawa County mining towns.

Tar Creek water flows orange

For all their differences, everyone here seems to share the same sense of disbelief that federal and state officials have spent 20 years and more than $100 million to accomplish very little.

"The chat is still there, the polluted creek is still there and the sinkholes are still there," Jim said. "It'd be nice to take people on a tour some day and show them what's gone."

Her decision to question more than a decade ago why Tar Creek was flowing a toxic shade of orange almost got her buried in one of those sinkholes.

Motivated by students in the Cherokee Volunteers Society at Miami High School, Jim ignored the threats and put into motion a grassroots effort that brought public awareness to one of the nation's most serious and complex environmental blights.

Jim's cause goes back farther than that, to 1982 when she attended a task force meeting on Tar Creek in Tulsa.

"They showed some graphs and maps of the county and put a big red spot on Ottawa County, which represented that it had the highest lung cancer rate in the country," she said. "The scariest thing of all was when they showed a photograph of the chat piles, where you could see children's footprints."

After a tribal health study in the mid-'90s revealed abnormally high blood lead levels among children of Picher, Cardin and Quapaw, the Environmental Protection Agency decided to go the miners one better. The EPA said the answer was to haul off the lead-contaminated topsoil that had spread to the front yards of most residences with dump trucks that were bigger than the "cans" miners had used to raise the ore to the surface.

Opponents of the plan call it a scam and a waste. In some cases, Ottawa County dirt became more valuable than beachfront sand.

"They spent $70,000 on my yard," Ray said. "All it did was kill four of my trees and cause my floor to fall in because of the moisture." Jim stops short of calling the yard remediation program a failure. "I don't care how much it costs if it helps protect these kids at the most vulnerable point in their lives," she said. As far as Henry's new buyout plan, Ray predicts "nothing will come from it." But he's not going to sit around and wait to find out. "I'm working an idea—wind generators," he said. "If we can get wind generators up and running, we can produce more money than the mines ever did." Even a troubled, old mining town can still dream.

Reprinted with permission as published in *The Oklahoman* June 13, 2004.

Getting the lead out

➤ Tar Creek site cleanup proceeding with efforts of government, OU

By James S. Tyree

The University of Oklahoma is a major player in the Oklahoma Plan for Tar Creek, the U.S. Senate's $45 million, three-year comprehensive plan to improve an environmental mess in northeastern Oklahoma.

OU's College of Engineering will conduct three of the plan's seven parts while the Oklahoma Department of Environmental Quality spearheads the other four projects.

The effort will try to reduce heavy metal contamination from old mine shafts in the air, water and land and to eliminate open mine-shaft hazards. It will be a collaborative effort involving OU, the State of Oklahoma, U.S. Senate and the Quapaw Tribe of Oklahoma.

Sen. James Inhofe, R-Oklahoma, chaired the Committee on Environment and Public Works and is the main senator behind the project. In the Plan's narrative, "Sen. Inhofe has committed to obtain the necessary funding from the federal government to support this work."

According to the plan, OU will:

➤ Develop a passive treatment system within one year to clean water of metals, mineral acidity and sulfates. Passive treatment relies on natural biogeochemical and microbiological functions to lessen the damage caused by mine drainage. The Senate expects to appropriate $5.2 million over three years for the project, including $2.84 million in its first year.

➤ Pave a section of road with a mix of chat (mining remnants) and asphalt in the Commerce–North Miami area, and then monitor the area's air and water quality to be sure the mix is environmentally safe. The plan explanation said, "This work will provide valuable insight for further large-scale chat-asphalt pavement."

The test section will be paved in the first year. The Senate expects to spend $100,000 in each of the three years.

➤ Continually monitor the surface water, ground water, air and land quality to evaluate how the clean-up projects are working. Monitoring will begin in the Commerce–North Miami area and grow from there. About $2.63 million will be needed to monitor all seven Plan projects throughout the three years.

Tom Landers, associate dean at the College of Engineering, said OU is already laying the groundwork for its projects.

The environmental sampling and monitoring is under way through a contract with the U.S. Geological Survey. Terms for the other projects are close to completion and actual work on the passive water treatment and chat road projects should begin in late summer or early fall.

Mary Jane Calvey, Tar Creek environmental program manager at the DEQ, said OU's and her agency's projects are independent of each other but "work very well to complement each other.

"For example," she said, "they have money to do some monitoring in the area, and that data will feed into some of the things that we want to do."

Getting the lead out *(continued)*

Calvey said the Oklahoma Plan is only a step toward cleaning a region that was extensively mined for lead and zinc through much of the 20th century.

The Tar Creek area affects about 30,000 people who live in Cardin, Picher, Commerce, North Miami and Quapaw. Huge piles of chat with lead and other minerals stand like mini-mountains throughout the area, especially in Picher and Cardin, but chat from much smaller locations is a greater health hazard because it blows in the air.

"The Oklahoma Plan was never meant to be comprehensive; it's supposed to be part of the overall bigger plan which is to deal with the entire site in a holistic way," Calvey said, "What we're trying to do with these projects is to have success stories early on."

The DEQ will be in charge of finding healthy uses for chat, restoring streams clogged by mine waste, restoring land quality and plugging dangerous open mine shafts.

But residents, especially children, cannot wait years for the area to be cleaned. Testing conducted in 1995 showed high levels of lead in 35 percent of American Indian children living in the area. A follow-up test of all Ottawa County children revealed elevated blood lead levels of more than 30 percent.

Some of that was due to lead-laden chat used in driveways, playgrounds, yards and other surfaces. So on June 2 of this year, Gov. Brad Henry signed a bill that established a $5 million fund to help families with children ages 6 and under—the ones most vulnerable to lead poisoning—pay for moving outside the immediate area.

The Oklahoma Plan is part of the federal government's effort to clean a tri-state area that also affects southeastern Kansas and southwestern Missouri. The difference, Calvey said, is there's more work to do in this state.

"We're falling behind in getting some of those projects done simply because there are more projects to do in Oklahoma, and it's more complex because of issues like land ownership, Indian lands, those types of things," she said. "So in identifying the projects in the Oklahoma plan, our hope was to get things moving . . . to show there are actual things being done."

Indeed, federal officials believe this $45 million plan will do more than the $100 million spent over the previous 20-plus years because this time there will be more cooperation and few legal or technical obstacles.

Calvey pointed to smaller successes that have lead up to this point, one like ridding a 54-acre site near Picher of 70,000 cubic yards of chat debris and topping it with fertile soil that can sustain plant life. A joint effort of state agencies spearheaded those and other projects, and federal officials believe they can do the same.

"This is different from any other effort at Tar Creek," the Senate document said, "as this is the first time that the highest levels of federal, state and tribal governments have been assembled to form a team that cooperatively addresses the Tar Creek Superfund Site."

Despite the new optimism, Calvey said it will take years for the cleanup to be complete. The state can do things in the short term like plugging open shafts and capping hazardous ponds with land and grass. But the key to completely clean the area, she said, will be removing the tons of chat.

"If we have rail and a conveyor system, I think they can be moved relatively—in three to five years," she said. "If we don't have that, trucking and all that stuff will take longer."

Heather Bragg, an OU student in the Research Experience for Undergraduates program, understands what her school and the DEQ are up against. While visiting Commerce recently for a summer project involving water quality, she was amazed by the sheer size of the research subject.

"The acid mine drainage and chat buildup affects everyone here," she said. "When you're actually here seeing the huge chat pile as you're driving off and seeing the (drainage) bubbling up from the ground, it's much different (than) seeing it in a magazine."

Reprinted with permission as published in *The Norman Transcript* July 4, 2004.

Gypsum example of opportunity

By Jack Carson

When the Harrison cattle ranch near Lindsay needed to apply gypsum to some heavy clay soil, its owners decided to buy property with a good quantity of the mineral and mine it themselves.

Before long they were supplying the soil-enhancing native rock to neighbors and watching their business grow. Gypsum, they found, has a variety of uses. Aside from wallboard and cement, gypsum is used in pharmaceuticals, plaster, certain cement products, and foods. E. R. "Tracy" Shirley III, chief financial officer for the company, said gypsum shipped from Harrison's mines now finds its way to nearly every continent.

"By far our largest market is the plaster market," said Shirley. "But our product is very high quality and we have a tremendous share of the market from breweries and the companies who supply the baking industry.

"Brewing and baking yeast," he said, works best with a little gypsum added. "Every time anyone in America eats bread, there is a good chance they are eating a little bit of Oklahoma rock. Two of the largest companies in the world, ADM and Fleishman's, are customers of ours."

Oklahoma Secretary of Agriculture, Terry Peach, said he believes the Harrison story is an example from which other agricultural producers and communities can learn.

"This business grew from a ranching operation and the Harrison family is still strongly involved in the cattle industry today," Peach said. "There are more opportunities out there waiting for us to tie the agriculture production and natural resources we already have to enterprises that will create even more jobs and growth."

Shirley will be a featured speaker at the Governor's Conference on Agriculture and Economic Growth in Oklahoma City April 13–14 [2004] to share the Harrison story with community leaders and agriculturists from across the state.

"Next month's conference is going to bring even more of these success stories into the spotlight," Peach said. "I think we will all come away with some real inspiration."

He said the key to building rural Oklahoma's economy is to find profitable ways to use natural resources.

"The message I want to get across is

Gypsum *(continued)*

that we have the diversity of natural resources, the infrastructure and the work ethic to realize great economic opportunities," he said. "We need to focus on developing a large number of smaller companies that employ 10 to 20 people rather than spending so much of our resources trying to attract larger corporations."

Advantages of smaller companies tied to particular natural resources are two-fold, he said. Companies are less likely to relocate and, if they do, fewer jobs are at stake.

"If a community loses a company that employs several hundred people, it can devastate their economy," Shirley said. "If they lose a business that employs 10 or 20 it still hurts but not nearly as much."

He said success for new businesses depends on their ability to find an area where they can be competitive and have access to startup capital.

Experts in both these areas will be featured at the conference.

Reprinted with permission as published in *The Oklahoman* March 21, 2004.

Allied Gypsum chief keeps family business growing

By Paul Monies

The amount of food-grade gypsum needed to keep a brewery running is relatively small.

But that didn't stop frazzled Anheuser-Busch managers in Houston from panicking one night a few years ago when mishandled inventory caused the brewery to come to a standstill.

A brewery manager wanted Lindsay-based Allied Custom Gypsum Co. to charter a plane and fly some gypsum down to Texas. A few phone calls later, the company had rounded up a supplier in Houston who managed to send a pallet of gypsum—about 500 pounds worth—over to the brewery.

"It's one of those things that's not a major ingredient, but they need it," said Charles W. "Russ" Harrison, president and chief executive officer of Allied Custom Gypsum. "You want to be able to service your customer with no red tape so you can bail them out."

Oklahoma has an abundant supply of high-grade gypsum, a naturally occurring salt used in everything from wallboard and cement to beer and pharmaceuticals.

The family-owned company last month opened a plaster plant in Mooreland, a venture Harrison, 47, first started researching more than 20 years ago. Along the way, that research led to the company's expansion from agricultural gypsum into the food and pharmaceutical industries.

Harrison's father and grandfather started the company in 1955. He joined in 1982 and has since bought out his father and other family members. Allied Custom Gypsum now has four mines in western Oklahoma, a mill and packaging plant in Bessie and the new plaster facility in Mooreland. The company, which has about 100 employees, estimates its total gypsum reserves at more than 250 million tons.

Harrison, who still has a house outside Lindsay, lives in Alexandria, Va., with his wife, Natalie Shirley. The couple moved there in 1991 after she became president of an insurance company. They have two children, Charlotte, 10, and Chase, 5. The following are excerpts from a recent conversation with *The Oklahoman.*

Q: It sounds like you get excited by the science behind the business.
A: Oh yeah, the science and engineering. It's just fascinating that you can take something out of the ground and do so many things with it.

Q: Your competitors are huge conglomerates. What kinds of challenges does that cause for your business?
A: All my competitors are multibillion dollar outfits in sales. They have the ability to access capital in the markets. What we have to do as a company is concentrate on being able to move fast and service the heck out of our customers from top to bottom.

Q: What are your niche markets?
A: The cement industry. The food industry. These are not big markets. I can produce in less than half a day all of Anheuser-Busch's needs. With the plaster, we're working with companies to provide them the joint compounds. We are a component of their mix to produce a product. I look for opportunities to find large companies where I can meet a small need. If you can meet that and keep them out of trouble, you become a preferred supplier.

Q: What are you most proud of in the business?
A: The people that I have somehow been lucky enough to hire. It's my people, the organization and the culture. The quality of the people I have—I don't deserve them.

Q: What's your biggest regret or mistake?
A: I don't believe in regrets. I've made mistakes. I spent a lot of money banging my head against the wall with synthetic gypsum. But I still learned a lot. We had sales but it wasn't going anywhere.

Q: Do you see yourself as a better manager or entrepreneur?
A: Probably an entrepreneur, because I constantly look for opportunity and planning for a different direction. Because of my ADD (attention deficit disorder), I think my people are much better at implementing the opportunities that I find.

Q: Talk a little about how your ADD affects the business.
A: It does because you're constantly going from one thing to the next. I was at a seminar recently and they were talking about the highest concentration of ADD people were presidents of companies. It's a different skill set, but it doesn't make you a very good follower.

Q: Was there any pressure to go into the family business?
A: Yes, from my aunt and my mom. We were expanding, and Dad was working himself crazy, and my aunt and my mom came to me. I actually was afraid of it because of my friends' experiences (in family businesses). Since I've joined the company, we've doubled our sales every five years for the last 20 years. This company was very small, it was really a side business because the family's primary business was farming. But the groundwork was there because my dad was taking care of the customer.

Q: Would you like to see your son or daughter in the company?
A: Absolutely. My daughter can remember the name of every person she's ever met, so she can do sales. And my son, I can already tell he's the engineer in the family; he's a math whiz and very exacting. I'd like them to. I hope it's an environment they'd want to be in.

Reprinted with permission as published in *The Oklahoman* June 20, 2004.

For more information on Allied Custom Gypsum Co., visit the website at **http://www.harrisongypsum.com/ACGHome.htm**.

Base of Treatable Water Maps Available

A new series of maps showing the base of treatable water in 34 counties of Oklahoma is now available as Open-File Reports (OF 12-2004 through OF 45-2004) from the Oklahoma Geological Survey. Prepared by Geologist Dennis Niskern of the Oklahoma Corporation Commission (OCC), these maps characterize the base of treatable water with subsurface datums obtained from the analysis of electric logs.

In Oklahoma, ground water containing less than 10,000 parts per million total dissolved solids (<10,000 ppm TDS) is considered treatable and must be protected for use by future generations. To comply with OCC rules in this regard, drillers are required to set surface casing in wells to prescribed depths as determined by the agency from current versions of these maps. The maps, one county per sheet, are drawn at a scale of 1 inch equals 2 miles (~1:126,720). They contain handwritten depth values, contoured at 100-foot intervals. Figure 1 shows an area in T. 11–13 N., R. 5–7 W. in Canadian County just west of Lake Overholser. To use the maps, given depth values must be subtracted from elevation to obtain subsea depths for the base of treatable water.

The Corporation Commission began developing these maps in 1997, working first on those counties where the most drilling was occurring. To date, maps of the following counties have been completed: Blaine, Canadian, Carter, Creek, Custer, Dewey, Ellis, Garvin, Grady, Haskell, Hughes, Kingfisher, Latimer, Le Flore, Lincoln, McClain, McIntosh, Muskogee, Nowata, Okfuskee, Okmulgee, Payne, Pittsburg, Pontotoc, Pottawatomie, Roger Mills, Rogers, Seminole, Sequoyah, Stephens, Tulsa, Wagoner, Washington, and Woodward. As additional data points become known, Niskern adds them to his set of master maps. When a user contacts him for "official updated information," as suggested on each map sheet, Niskern will advise the user where to plot the new data points on the map.

Although the maps were designed for use by the oil and gas industry, the information they present should be of value to others interested in learning about and/or protecting the State's treatable ground-water resources.

Black and white xerox copies of the maps can be purchased over the counter or postpaid from the OGS Publication Sales Office, 2020 Industrial Blvd., Norman, OK 73069; phone (405) 360-2886; fax (405) 366-2882; e-mail: ogssales@ou.edu. The maps should be requested by county name. The price is $3.00 per county (folded sheet), plus 20% for postage and handling, with a minimum postage charge of $2.00 per order.

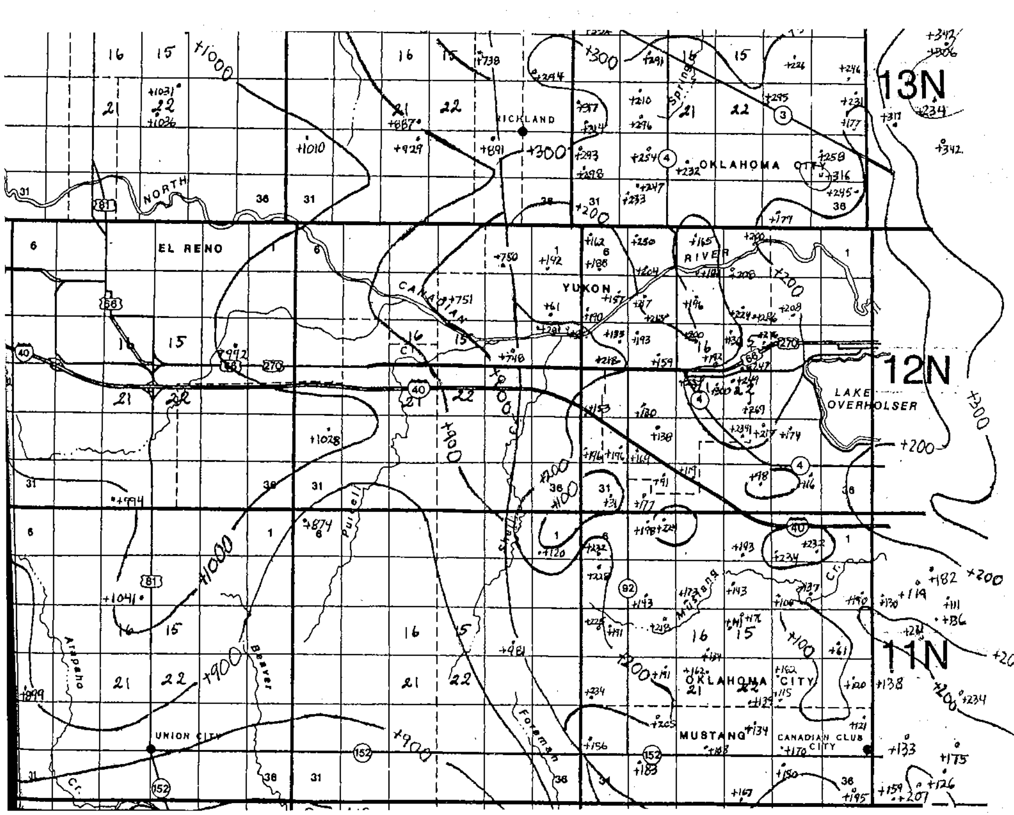

Figure 1. A part of the Base of Treatable Water Map for Canadian County, Oklahoma (Oklahoma Corporation Commission, circa 2002). Shown are parts of T. 11–13 N., R. 5–7 W. (reduced ~50%).

upcoming meetings

OCTOBER

American Association of Petroleum Geologists, Gulf Coast Association of Geological Societies, Annual Meeting, "Geologists on a Mission," October 10–12, 2004, San Antonio, Texas. Information: AAPG Convention Dept., P.O. Box 979, Tulsa, OK 74101; (888) 945-2274, ext. 617 (USA and Canada only) *or* (918) 560-2679; 918-560-2684; e-mail: convene@aapg.org. Web: http://www.aapg.org/meetings/.

Society of Exploration Geophysicists, International Exposition and Annual Meeting, "Reaching New Summits," October 10–15, 2004, Denver, Colorado. Information: SEG, P.O. Box 702740, Tulsa, OK 74170; (918) 497-5500; fax 918-497-5557; e-mail: meetings@seg.org. Web: http://www.seg.org/meetings/.

International Petroleum Environmental Conference, October 12–15, 2004, Albuquerque, New Mexico. Information: Kerry L. Sublette, Dept. of Chemical Engineering, University of Tulsa, 600 S. College Ave., Tulsa, OK 74104; (918) 631-3085; fax 918-631-2154; e-mail: ipecenrollment@utulsa.edu. Web: http://ipec.utulsa.edu/.

Interstate Oil and Gas Compact Commission, October 17–19, 2004, Oklahoma City, Oklahoma. Information: IOGCC, P.O. Box 53127, Oklahoma City, OK 73152; (405) 525-3556; fax 405-525-3592; e-mail: iogcc@iogcc.state.ok.us. Web: http://www.iogcc.state.ok.us.

Geological Society of America, Penrose Conference, "Secular Variation in Tectonic and Allied Fields," October 22–28, 2004, St. George, Utah. Information: Dwight Bradley, U.S. Geological Survey, 4200 University Dr., Anchorage, AK 99508; (907) 7434; fax 907-786-7401; e-mail: dbradley@usgs.gov. Web: http://www.geosociety.org/penrose/.

American Association of Petroleum Geologists, International Conference and Exposition, October 24–27, 2004, Cancun, Mexico. Information: AAPG Convention Dept., P.O. Box 979, Tulsa, OK 74101; (888) 945-2274, ext. 617 (USA and Canada only) *or* (918) 560-2617; fax 800-281-2283 (USA and Canada only) *or* 918-560-2684; e-mail: convene2@aapg.org. Web: http://www.aapg.org/meetings/can04/.

DECEMBER

24th Annual Gulf Coast Section SEPM Foundation Bob F. Perkins Research Conference, "Salt-Sediment Interactions and Hydrocarbon Prospectivity: Concepts, Applications, and Case Studies for the 21st Century," December 5–8, 2004, Houston, Texas. Information: Paul J. Post, Minerals Management Service, 1201 Elmwood Park Blvd., New Orleans, LA 70123; (504) 736-2954; fax 504-736-2905; e-mail: paul.post@mms.gov. Web site: http://www.gcssepm.org.

A Field Symposium

Stratigraphic and Structural Evolution of the Ouachita Mountains and Arkoma Basin: Applications to Petroleum Exploration

October 21-23, 2004

Robert S. Kerr Conference Center
Poteau, Oklahoma

Sponsored by the Oklahoma Geological Survey, University of Oklahoma, and Oklahoma State University, this field symposium will consist of two morning sessions of presentations and posters. Field trips are planned for two afternoons and a full third day.

Those interested in presenting a paper and/or poster may submit a 250-word abstract to Roger Slatt (e-mail: rslatt@ou.edu) by *August 1, 2004.* Of particular interest are papers on stratigraphy, structure, sedimentology, paleontology, and subsurface geology of the Arkoma Basin and Ouachita Mountains as applied to the search for and development of petroleum resources. Symposium papers will be published by the Oklahoma Geological Survey as a proceedings volume.

For more information, contact:

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Oklahoma Geological Survey
100 E. Boyd, Room N-131
Norman, OK 73019
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Fax: (405) 325-7069
E-mail: nsuneson@ou.edu

GSA Annual Meeting & Exposition

November 7–10, 2004 • Denver, Colorado

GEOSCIENCE in a Changing World

The 2004 Annual Meeting in Denver is shaping up to be an outstanding overview of hot research in both new and traditional areas of the earth sciences. With eight Pardee Keynote Symposia, more than 140 Topical Sessions, and a wide range of open discipline sessions, the meeting will have something for every interest in the earth sciences.

In addition, the Annual Meeting is the principal forum for presentation and discussion of the latest ideas in geoscience education, and this year will feature more than 25 sessions on education-related topics. Downtown Denver is a vibrant location for a meeting. And of course, the Rocky Mountains beckon with many field trip and recreational opportunities.

I would like to issue a challenge to every professional geoscientist reading this: **to encourage at least one student or junior colleague to attend the meeting.** The Annual Meeting continues to be one of the preeminent venues for presenting and hearing about new directions in our science, and for interacting with a wide spectrum of geoscientists and educators. As you make your own plans for November, urge your colleagues to do likewise.

See you in Denver!

— Jane Selverstone
Technical Program Chair

GSA Annual Meeting Agenda

PARDEE KEYNOTE SYMPOSIA

Early Paleoproterozoic (2.5–2.0 Ga) Events and Rates: Bridging Field Studies and Models
Geoinformatics and the Role of Cyberinfrastructure in Geosciences Research
Geoscientific Aspects of Human and Ecosystem Vulnerability
Medical Geology
Adversity, Advantages, Opportunities: Phanerozoic Stromatolites as "Survivor" vs. "Disaster" Taxa
Pre-Mesozoic Impacts: Their Effect on Ocean Geochemistry, Magnetic Polarity, Climate Change, and Organic Evolution
Seeing Mars with New Eyes: Active Missions, Science Results, and Geoscience Education
Weathering, Slopes, Climate, and Late-Quaternary Geomorphic Change in Arid and Semi-Arid Landscapes

TOPICAL SESSIONS

The Future of Hydrogeology
Upcoming Revolutions in Observing Systems: Implications for Hydrogeology
History of Hydrogeology in the United States: Celebrating the Contributions of O. E. Meinzer, Stan Lohman, and John Ferris
Over 40 Years of Influence in Environmental Hydrogeology: In Honor of Dick Parizek
Groundwater Depletion and Overexploitation in the Denver Basin Bedrock Aquifers
Hydrologic Impacts of Urbanization and Suburbanization on Water Resources
The Occurrence, Storage, and Flow of Groundwater in Mountainous Terrain
Mountain Watershed Pollutant Transport and Water Quality Issues, Including Groundwater—Surface-Water Interplay in Pollutant Transfer
Sustainable Management of Water Resources
Comprehensive Monitoring Approaches at Regional and Statewide Levels—Advantages and Limitations
Hydraulic and Geochemical Behavior of Man-Made Aquifers
Fluid Flow and Solute Transport in Fractured Rocks
Modeling Flow and Transport in Chemically and Physically Heterogeneous Media
Applications of Geophysics to Groundwater Resource Management
How Effectively Are We Using Advanced Groundwater Modeling Tools in Practice?
Linking Groundwater Models and Watershed Models
Aquitard Studies: Understanding Geologic Constraints on Flow and Transport in Groundwater Flow Systems
Characterization, Attenuation, and Remediation of Contaminants in Runoff
Innovative Tracer Applications in Hydrogeology: New Techniques, Design and Interpretation Methods, and Case Studies
Dissolved Gases as Indicators of Geochemical and Hydrogeologic Processes GSA Hydrogeology Division
Vadose Zone Nitrogen: Sources, Fate, and Transport
Assessing the Importance of Colloids in Natural Waters
Sources, Transport, Fate, and Toxicology of Trace Elements in the Environment
Organic Compounds in Near-Surface Environments as Drivers on the Redox-Reaction Highway: A Tribute to the Career of Mary Jo Baedecker
Stable Isotope Tracers of Water Balance and Biogeochemical Cycling in Large River Basins
Seasonal and Long-Term Groundwater Quality Changes in Alluvial Aquifer Systems
Characterization and Representation of Flow through Karst Aquifers
New Perspectives in Karst Geomicrobiology and Redox Geochemistry
From Subterranean Crawlways to Scientific Hallways: Research on Our Public Cave and Karst Lands
New and Multidisciplinary Approaches to Dating Cave Deposits
Impacts of Water Storage and Consumption on Watershed Processes
Geologic Disposal of Radioactive Waste: Rising to the Challenge of Regulatory Requirements and Environmental Protection at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, and the Yucca Mountain Site, Southern Nevada
Monitoring to Confirm Performance Assessment of Nuclear Waste and Decommissioning Sites: Geoscience Input to Monitoring System Design through Identification and Measurement of Critical Features, Events, and Processes
Assessment and Characterization of Geologic Formations for Long-Term CO_2 Storage (Sequestration)
Geophysical Solutions for Characterizing and Locating Geological Sites for Carbon Dioxide Sequestration
GIS, GPS, and Remote Sensing in Geologic Hazard Assessment
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Terrane Translation, Orogenesis, and Plate Interactions in the Late Mesozoic to Early Cenozoic North American Cordillera, and Implications for Paleogeographic Reconstructions
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STEMS: Science Teaching Enhanced with Museums and Surveys
Integration of Geoscience into Programs of Integrated Science and Math
Innovative and Unique Advanced Geology/Geoscience Courses at the K–12 Level
Authentic Research Collaborations: Bringing Scientific Researchers, K–12 Schools, and Other Community Groups Together in the Scientific Endeavor
Online Geoscience Education at Two-Year Colleges: Hybrid or Strictly Distance Learning Instruction for Nontraditional Students
Why Earth Science Curriculum: National Science Foundation-Funded Projects for Improving Earth Science Education
Current Research on Situated Teaching and Learning in Geoscience: Field-Based, Case-Based, Problem-Based, Place-Based
We Can Do Better: Alternatives to the Same Old Lab-Lecture Format in the College Classroom
Improving Delivery in Geoscience Education (IDIG): A Session Celebrating Dorothy LaLonde Stout
Electronic Student Response Technology in the Geoscience Classroom: Is It a Valuable Teaching and Learning Tool?
Minorities, Women, and Persons with Disabilities in the Geosciences: Continuing Issues and Innovative Solutions
New Methods and Technologies in Teaching Geology to Nontraditional and Disabled Students—The Aspects of Change to Incorporate Technology and Hands-On Methods
Geoscience Education Strategies and Methods that Encourage ALL Students (Especially Students with Disabilities) to Participate in the Geosciences
Beyond Video Games—Promoting Active Learning for All Students
Building a Digital Library that Supports Diversity: Goals, Lessons Learned, and Future Directions
Building Strong Geoscience Departments: Opportunities, Successes, and Challenges

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Evaporites: A Practical Approach, *Nov. 5–6*
Introduction to Geographic Information Systems (GIS), Using ArcGIS9 for Geological Applications, *Nov. 5–6*
Multi-Temporal Stereo Aerial Photography, *Nov. 5–6*
Calibrated Peer Review Training for Faculty and Teaching Assistants: Writing Exercises for Large and Small Classes without the Pile of Papers to Grade, *Nov. 6*
Characterization and Toxicity Assessment of Mine-Waste Sites, *Nov. 6*
Estimating Rates of Groundwater Recharge, *Nov. 6*
Hydrogeologic Field Methods, *Nov. 6*
Management and Leadership Skills for Academic Administrators in the Geosciences, *Nov. 6*
Practical Geoscience Ethics: Elements and Examples, *Nov. 6*
Sequence Stratigraphy for Graduate Students, *Nov. 5–6*
Biological Revolutions in the Neoproterozoic and Cambrian, *Nov. 6*
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Earth Science Inquiry-Based Student-Centered Curriculum Developed by the American Geological Institute with support from the NSF: EarthComm, IES, CUES, and HSES, *Nov. 6*
Using the Internet in the Earth Science Classroom to Develop Data Driven Lessons, Activities, and Lab, *Nov. 6*
Geoscience Classroom to Workforce: Skills and Partnerships for the Real World, *Nov. 6*
How to Establish and Sustain an Undergraduate Research Program, *Nov. 6*
Toward a Sustainable Future: Connecting the Dots, *Nov. 6*
Using Conceptests to Improve Teaching and Learning in Large Classes, *Nov. 6*
Using the "Our Dynamic Planet" and "Global Ocean Data Viewer" to Implement Effective Science Writing Activities, *Nov. 6*
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Inquiry-Based Digital Laboratory Materials for Introductory Geology Courses, *Nov. 7*
Creating an Online Learning Environment with Visionlearning, *Nov. 7*

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Strike-Slip Tectonics and Thermochronology of Northern New Mexico, *Nov. 4–6*
Geology of the Silver Cliff–Rosita Hills Mining District and Spanish Peaks Area, *Nov. 5–6*
Hyperpycnal Wave-Modified Turbidites of the Pennsylvanian Minturn Formation, North-Central Colorado, *Nov. 5–6*
Structural Implications of Underground Coal Mining in the Mesaverde Group, Somerset Coal Field, Delta and Gunnison Counties, Colorado, *Nov. 5–6*
A New K-T Boundary in the Denver Basin, *Nov. 6*
Buried Paleo-Indian Landscapes and Sites in the High Plains of Northwestern Kansas and Eastern Colorado, *Nov. 6*
Colorado Front Range—Anatomy of a Laramide Uplift, *Nov. 6*
Continental Accretion, Colorado Style: Proterozoic Island Arcs and Back Arcs of the Central Front Range, *Nov. 6*
Eco-Geo–Hike along the Dakota Hogback North of Boulder, Colorado, *Nov. 6*
Geological Reconnaissance of Dinosaur Ridge, Red Rocks, and the Front Range of the Rocky Mountains near Morrison, Colorado, *Nov. 6*
Glenwood Springs, Colorado Coal Fire—Observations, Discussion, and Field Data Collection Techniques, *Nov. 6*
Overview of Laramide Structures along the Northeastern Flank of the Front Range, *Nov. 6*
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Paleontology and Volcanic Setting of the Florissant Fossil Beds, *Nov. 6*
Stratigraphy and Paleobiology of Mammoth Sites in the Denver Area, *Nov. 6*
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Underground Tour of Henderson Molybdenum Mine, *Nov. 11*
Walking with Dinosaurs along Colorado's Front Range, *Nov. 11*

For more information, contact Geological Society of America, P.O. Box 9140, Boulder, CO 80301 • (303) 447-2020 • Fax: 303-357-1071 • e-mail: meetings@geosociety.org • http://www.geosociety.org. *The preregistration deadline is September 30.*

Oklahoma abstracts

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

The Status of Geologic Mapping in Oklahoma

THOMAS M. STANLEY, GALEN W. MILLER, and *NEIL H. SUNESON,* Oklahoma Geological Survey, 100 E. Boyd St., Room N-131, Norman, OK 73019

As part of the STATEMAP component of the USGS's National Cooperative Geologic Mapping Program, the Oklahoma Geological Survey has been undertaking a 2-part mapping program consisting of: (1) a series of 1:100,000-scale reconnaissance geologic maps of the entire State that will become the foundation for a new 1:500,000-scale geologic map of Oklahoma; and (2) detailed 1:24,000-scale geologic maps of metropolitan areas, which helps identify potential engineering and environmental hazards in rapidly growing urban areas. Detailed mapping of 25 7.5′ quadrangles in the Oklahoma City Metro Area (OCMA) has just been completed and made available to the public. This project has led to significant changes in the distribution and extent of Quaternary alluvial deposits, particularly those associated with the North Canadian River drainage system, as well as led to a better understanding of the geometry of the Garber-Wellington aquifer. For the most part, terrace deposits are smaller in areal extent than what was previously mapped; this will have considerable impact on potential sand and gravel operations as well as on the potential use of alluvium-based aquifers for agricultural enterprises. The distribution of these terrace deposits also allows for better understanding of Quaternary base-level changes that have occurred along the North Canadian River. Detailed mapping of the Garber and Wellington Formations in the OCMA has led to better delineation of the surface and subsurface occurrences of these important water-bearing units. This will aid in more effective land-use for municipal and residential development, and allow for better cost-effective measures in setting depth of casing of oil and gas drill holes. Currently ten 1:100,000-scale reconnaissance maps in western Oklahoma have been completed. This project also has led to better delineation of different types of Quaternary deposits compared to previous 1:250,000-scale maps, particularly by differentiating between vegetated dune and wind-blown sheet sand deposits, and between high and low fluvial terrace deposits. Greater accuracy in locating the eastern extent of the Ogallala aquifer has also been achieved.

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Brine Impact on Water Quality in Seminole County, Oklahoma

LAURIE A. WHITESELL, University of Tulsa, 600 S. College Ave., Tulsa, OK 74104

Seminole County, Oklahoma, has been the site of extensive oil and gas production dating from the first decades of the last century. The impact of the produced formation waters has been reported to have adversely affected the water quality in the county. It is the goal of this project to determine the degree of current brine contamination, and its source. In this vain 318 surface and ground water samples have been analyzed for major ionic components. Stream samples have associated parameters such as velocity, dissolved oxygen, conductivity, pH, and salinity, while the ground water samples have additional variables such as static water depth, and height of casing.

All data has been entered into (Geographic Information System) GIS for spatial analysis. The current data as well as historical data supplied by the (United States Geological Survey) USGS where examined for any possible trends relating to legal legislation, proximity to wells, depth of wells, age of wells, proximity of wells to streams, and slope analysis.

In Oklahoma all Indian property falls under the jurisdiction of the (Bureau of Indian Affairs) BIA and non-Indian land is regulated by the Oklahoma Corporation Commission. This division complicates any clean up efforts and preventative measures that might be enacted. In an effort to establish regulatory domain, a property map of the county was draped over the data. This allows regulatory ownership to be determined and may bring about faster and greater prevention and clean up of existing or future contamination.

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Subsurface Well-Log Correlation of Arsenic-Bearing Lithofacies in the Permian Garber Sandstone and Wellington Formation, Central Oklahoma Aquifer (COA), Cleveland County, Oklahoma

BEN N. ABBOTT and *STANLEY T. PAXTON,* School of Geology, Oklahoma State University, 105 Noble Research Center, Stillwater, OK 74078; *ROBERT W. PULS,* National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Ada, OK 74821; and *JAMIE L. SCHLOTTMANN,* Consultant, 1708 Remington Road, Edmond, OK 73034

The Garber-Wellington aquifer is an important source of drinking water in central Oklahoma. The formations making up the aquifer, the Garber Sandstone and the underlying Wellington Formation, consist of amalgamated fluvial sandstones interbedded with mudstones, siltstones, and some conglomerates (Breit et al., 1990). Water from some of the wells contains naturally occurring arsenic levels that exceed federal standards (EPA, 2001). Past work suggests that the arsenic is concentrated in water produced from sandstones isolated by finer-grained rocks. This is because the low permeability of the finer-grained intervals inhibits the flushing-out of soluble trace substances by freshwater (Schlottmann et al., 1998). Therefore, one strategy for remediation is to selectively produce water from low-arsenic zones and to limit or avoid completion and development of sandstones isolated by finer-grained lithofacies. This strategy requires the development of an improved stratigraphic model that defines the lateral and vertical distribution of arsenic-prone lithofacies. To accomplish this, geophysical logs from oil and water wells, subsurface core, and outcrops are being used to produce stratigraphic cross-sections and maps (such as net-to-gross and sandstone-shale ratio maps). To date, our work suggests that sand-prone and mud-prone packages within these formations can be correlated but that correlation of individual sandstone bodies is problematic. Through integration of on-going companion studies, the projection of outcrop gamma-ray profiles and paleodepositional environment to the subsurface should help to further constrain the habitat of arsenic and better define regional permeability fairways. (This is an abstract of a proposed presentation and does not necessarily reflect EPA policy.)

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Outcrop-Based High Resolution Gamma-Ray Characterization of Arsenic-Bearing Lithofacies in the Permian Garber Sandstone and Wellington Formation, Central Oklahoma Aquifer (COA), Cleveland County, Oklahoma

GREGORY A. GROMADZKI and *STANLEY T. PAXTON*, School of Geology, Oklahoma State University, 105 Noble Research Center, Stillwater, OK 74078; *ROBERT W. PULS*, National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Ada, OK 74821; and *JAMIE L. SCHLOTTMANN*, Consultant, 1708 Remington Road, Edmond, OK 73034

The COA supplies drinking water to a number of municipalities in central Oklahoma. Two major stratigraphic units in the COA, the Garber Sandstone and Wellington Formation, contain naturally occurring arsenic that exceeds government mandated drinking-water standards (EPA, 2001). Previous work in the COA (Schlottmann et al., 1998) has shown that arsenic concentrations in the aquifer vary with lithofacies. Isolated sandstones (encased by thick shale intervals where flow is reduced) tend to yield water with elevated arsenic levels. In order to better constrain the distribution of arsenic with lithofacies, we have constructed numerous high-resolution spectral gamma-ray profiles of the outcrops using a portable gamma-ray scintillometer. In addition, rock samples associated with each gamma ray reading taken from outcrops were returned to the laboratory for textural analysis. We find that many of the arsenic-bearing lithofacies are characterized by high total gamma-ray counts (associated with K, U and Th). This result is because arsenic in the rocks is associated with iron oxide that appears to be enriched in the finer-grained, clay-rich lithofacies. Calculated permeability profiles mimic fining-upward grain-size profiles characteristic of fluvial depositional settings. Data from previous USGS studies (cores, geochemistry, petrography, and x-ray diffraction) are being incorporated into the evaluation of the gamma-ray responses as well. Results of this work are being integrated with other on-going companion studies to constrain subsurface well log correlation and the reconstruction of paleodepositional environments in the Garber-Wellington interval of the COA. (This is an abstract of a proposed presentation and does not necessarily reflect EPA policy.)

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Outcrop-Based Lithofacies and Depositional Setting of Arsenic-Bearing Permian Red Beds in the Central Oklahoma Aquifer (COA), Cleveland County, Oklahoma

KATHLEEN M. KENNEY and *STANLEY T. PAXTON*, School of Geology, Oklahoma State University, 105 Noble Research Center, Stillwater, OK 74078; *ROBERT W. PULS*, National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Ada, OK 74821; and *JAMIE L. SCHLOTTMANN*, Consultant, 1708 Remington Road, Edmond, OK 73034

In January 2001, the Environmental Protection Agency established the new safe drinking water standard for arsenic at a maximum concentration of 10 mg/L. Water-quality assessments for parts of the COA, however, document arsenic concentrations above this standard. Based on the work of Schlottmann et al. (1998), concentrations of arsenic tend to occur in sandstone layers that are isolated between thick layers of mudstone. As a means to evaluate various approaches to arsenic remediation during well construction, we are developing a lithofacies and stratigraphic conceptual model for the Permian (Leonardian) Garber Sandstone. Detailed study of outcrops in Cleveland County and surrounding area has resulted in identification of nine lithofacies. The sandstone lithofacies include (1) massive, (2) ripple-laminated, (3) sandstone with horizontal to low angle planar laminations, and (4) tabular and trough cross-bedded sandstone, some with mud rip-up clasts. Other lithofacies include (5) carbonate clast conglomerate, (6) mud clast conglomerate, (7) iron stone, (8) shale/siltstones, and (9) blocky mudstones. These lithofacies and lithofacies associations provide the foundation for construction of lithofacies maps, vertical stratigraphic profiles, and paleoenvironmental reconstructions. A fluvial depositional setting for the Garber Sandstone is supported by the presence of lenticular-shaped sandstone bodies, erosional truncation of underlying units, fining upward grain-size profiles, and rapid lateral changes in the proportion of sandstone and shale. These findings are being used to constrain the habitat of arsenic in the aquifer system and as input to regional flow modeling. (This is an abstract of a proposed presentation and does not necessarily reflect EPA policy.)

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Indicators of Biogeochemical Cycling at Centimeter-Scale Water-Sediment, Sediment-Aquifer Interfaces in a Wetland System

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A fundamental issue in chemical fate and transport is correlating linked hydrogeologic, microbiologic, and geochemical processes and determining their role on the redox state of a system. In subsurface environments, redox reactions are mediated by the metabolic activities of microorganisms through terminal electron accepting processes (TEAPs), which are in turn controlled by the delivery of electron acceptors and donors. Understanding the variable redox conditions of these environments is crucial to evaluating the fate and transport of nutrients and contaminants and thus in protecting human and ecosystem health.

The research site is a riparian wetland that runs parallel to a closed landfill in Norman, OK. A leachate plume extends from the landfill flowing underneath the wetland system. Our study focuses on the in-situ measurement of redox conditions and TEAPs in the groundwater/surface water mixing interfaces at cm-scale spatial resolution. In-situ characterization of redox chemistry has been limited by the volume of porewater necessary to perform chemical analyses. This study overcomes this limitation by using an emerging technology, capillary electrophoresis (CE), for the analysis of anions, cations, and organic acids. CE requires sample volumes as low as 5 microliters per chemical suite. A vertical profile of porewater, surface water and groundwater samples was collected using a passive-diffusion membrane (peeper) with half-centimeter resolution. These samples were analyzed in the field for alkalinity, Fe(II) and S2-, and in the laboratory for NH4, Ca, Na, K, Cl, SO4, and organic acids such as, acetate, butarate and propionate. Results show significant TEAP variability at cm-scale suggesting new boundaries of variable microbial processes occurring at the sediment/water, sediment/aquifer interface.

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Correlating Biogeochemical Processes at Small-Scale Mixing Interfaces in a Contaminated Wetland System

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A fundamental goal in determining chemical fate and transport is to correlate linked hydrogeologic, microbiologic, and geochemical processes and their role in the redox state of a system. In subsurface environments, redox reactions are mediated by the metabolic activities of microorganisms through terminal electron accepting processes (TEAPs), which are in turn controlled by the delivery of electron acceptors and donors. Understanding the variable redox conditions in these environments is crucial to evaluating the fate and transport of nutrients and contaminants and thus in protecting human and ecosystem health.

This study was conducted in a riparian wetland that parallels a closed landfill in Norman, OK. A leachate plume from the landfill underlies the wetland system. Our study focuses on the in-situ measurement of redox conditions and TEAPs in the groundwater/surface water mixing interfaces at small-scale spatial resolution. Observed small-scale changes in porewater redox conditions were correlated with the stable C, N and S isotopes in sedimentary organic matter to delineate microbial processes within the sediments such as sulfate reduction and methanogenesis.

In-situ characterization of redox chemistry has been limited by the volume of porewater necessary to perform chemical analyses. This study overcomes this constraint by using an emerging technology, capillary electrophoresis (CE), for the analysis of anions, cations, and organic acids. CE requires sample volumes as low as 5 microliters per chemical suite. A vertical profile of porewater, surface water and groundwater samples was collected using a passive-diffusion membrane (peeper) with half-centimeter resolution. These samples were analyzed in the field for alkalinity, Fe(II) and sulfide. Sediment cores collected near the peepers were sectioned at high (mm scale) resolution and analyzed for bulk organic constituents. Stable sulfur isotopes will be determined in order to discern sulfate reduction boundaries. Isotopic ratios will be used to determine the source of the organic matter in the sediments (i.e., groundwater inputs or overlying wetland material). Results indicate significant TEAP variability at the cm-scale suggesting new boundaries of variable microbial processes occurring at the sediment/water interface.

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The Relationship of Microbial Diversity to Plume Geochemistry in an Anoxic Landfill Leachate Plume, Norman, Oklahoma

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The variability of electron acceptors and microbial populations was studied in a landfill-leachate plume at the Norman Landfill, a closed municipal landfill on Canadian River alluvium and the site of long-term biogeochemical investigations of plume evolution. Temporal variability in plume geochemistry after 5 years shows electron acceptors (i.e., sulfate) and degradation products (i.e., methane) change significantly at the water table and plume fringes where recharge and advective flux of less-contaminated groundwater provide sources of electron acceptors. Sulfate concentrations are variable, ranging from >950 mg/L near the water table to <1 mg/L only 2 m deeper in the center of the anoxic plume. Near the lower boundary of the plume, where upgradient groundwater mixes with the sulfate-depleted plume, sulfate ranges from 10 to 60 mg/L. Since 1997, the 2-D area of sulfate-depletion has more than doubled and methane concentrations have reached 30 mg/L in the center of the plume. To determine if changes in plume geochemistry are correlated with presence or dominance of different microbial groups, terminal restriction length polymorphism analysis (T-RFLP) was used to obtain DNA fingerprints of bacteria and methanogens present in water and sediment from the same plume section. Microbial populations are affected by factors such as proximity to the water table or groundwater mixing fronts, driven largely by variability of electron acceptors, nutrients, and the quality of electron donors. Bacterial abundances in water are highest near plume fringes, where electron acceptors such as sulfate are available; however, the greatest diversity is observed within the plume. In contrast, the greatest diversity of bacteria in the sediment is outside the plume. In general, the distribution of methanogens is less variable than bacteria. At all sites, non-acetoclastic methanogens are found in both sediment and water fractions, whereas acetoclastic methanogens are present only in water samples within the plume. These patterns of methanogens indicate the availability of electron donors, such as organic acids, may be controlling their distribution. We are conducting further studies to examine how availability of electron donors and acceptors influences microbial structure and function in this dynamic hydrogeochemical system.

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Basin Topographic Influence on Delta Progradation in the Modern Lacustrine Red River Delta, Lake Texoma, Texas/Oklahoma

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Lake Texoma is a man-made lake impounded in 1944 which flooded the Red River valley approximately 45 km upstream of the dam. The lake shape is "meandering" and the banks have gradients between 0.01 and 0.2. Knowledge of pre-deltaic basin topography and observation from air photos and satellite imagery show delta progradation rates of approximately 250 m/year over a 60 years period and indicate a high control of topography on delta progradation direction. The Red River inflow is hyperpycnal most of the time because total dissolved solids and suspended sediment concentrations are higher in the river water than in the lake water. When the inertial-hyperpycnal delta started to fill the lake, it prograded straight. When reaching the first original channel meander, the delta followed the main valley, bypassing some parts of the lake, despite the relatively narrow lake width. This phenomenon can be explained by the tendency of the river effluent to follow the steepest gradient, which in this case is the talweg of the previous river. During high discharge periods, the hyperpycnal delta prograded straight and the influence of slope gradient is minimal. During low discharge periods, inertial flows are redirected toward the steeper slopes. These observations, although commonly made in theoretical experiments, are difficult to observe in natural system because the predeltaic topography is usually unknown and long time observations are necessary. The results show that delta progradation direction is a result of the interplay between the inertial and gravitational forces which act on sediment load.

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Morphology of a Modern Lacustrine Delta Changes with River Discharge: Red River Delta, Lake Texoma, Texas–Oklahoma

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The modern Red River delta has prograded more than 15 km into Lake Texoma since it was impounded in 1944. Because the river water is salty, there has been no other major engineering construction upstream of Lake Texoma. The Red River delta is an excellent place to examine the morphometric evolution of a modern, unconstrained lacustrine delta in a temperate setting.

Aerial and satellite images from 1952 to 2002 show the evolution of the delta. In the earliest images, the delta is not distinguished as it is largely subaqueous. The 1976 image shows that the delta has grown more than 8.7 km into lake. This represents an average progradation rate of 270 m/year. The 1976 image shows a lobate delta containing 4 active terminal distributary channels. The 1982 image shows that most of the discharge was captured by a single channel. Since 1982, the delta has developed a more elongate shape built by a single distributary channel. Despite the change in the number of active distributary channels, the progradation rate for 1976 to the present is similar to the lobate phase, about 270 m/year.

Delta morphology is interpreted to relate to river discharge. At low discharge, the delta develops numerous active terminal distributary channels due to increased friction. At high discharge the delta develops an elongate shape, with a single main distributary channel. This may be a consequence of the increase in inertial forces during large magnitude floods.

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An Elemental and Isotopic Investigation in Water Column of Lake Texoma

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Lake Texoma, a large impoundment on the Texas-Oklahoma border formed by the confluence of the Red River (Total Dissolved Solids, TDS >1000 mg/l) and the Washita River (TDS <500 mg/l), provides an opportunity to study saline and fresh water mixing processes, element budgets and metal cycling. Water column samples, collected at 20 locations throughout the lake in summer and fall 2003 and analyzed for elemental and stable isotope (sulfur and carbon) compositions show distinct spatial and seasonal variations related to inflow mixing, biogenic consumption and summer anoxia. Ca, K, Mg, Li, Na and Sr exhibit conservative behavior in both the main lake and two river arms with lake concentrations in good agreement with inflow cation budgets. Main lake Zn concentration is higher than both the Red and the Washita river arms, which indicates an extra source. In contrast, lower Si concentration in the main lake compared with two river arms suggests biogenic consumption. During summer, dissolved oxygen decreases with depth (from 7 to 0.1 mg/l) while Fe, Mn and HS^- show complementary increases. Thus, summer anoxia apparently leads to reduction of Fe and Mn oxyhydroxides in sulfide-rich bottom waters.

Lake Texoma and two river arms show relatively small variations in $\delta^{34}S$ (from 11.5 to 13.4‰ CTD), similar to Permian/Cretaceous marine gypsum and anhydrite ($\delta^{34}S$ 10–15‰) in headwater regions. Increasing $\delta^{34}S$ with depth (>16 m) in the main lake suggests fractionation associated with sulfate reduction in anoxic bottom waters. $\delta^{13}C_{DIC}$ values become more negative (from –2.5 to –8.2‰ PDB) with depth in summer, suggesting bacterial oxidation of organic matter linked to sulfate reduction.

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Hierarchical, Self-Affine Fluvial Sand Body Shapes from Ancient and Modern Settings

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Stratigraphic studies of ancient (Jurassic, Salt Wash Fm., Green River, Utah) and modern (Red River, Randlett, Oklahoma) fluvial bar complexes reveal multiple orders of nested body shapes which are self-affine and have consistent internal grain size and sedimentary structure distributions. Sand body shape is defined as the 3-D surface bounding all genetically related sedimentary particles. Stratigraphic data were derived from measured sections, ground penetrating radar and aerial photos. Grain size and sorting information came from visual estimates from outcrops and laser particle size analysis of vibracored samples. Studied sand bodies range in scale from the crossbed set to the bar complex, but they all exhibit the same fundamental form. In plan form they originate from an upstream apex and expand laterally downstream in a lobate pattern. Thickness trends are characterized by a rapid increase downstream from the apex followed by a prolonged taper to the down flow and lateral edges. Thickness changes are related to basal erosion and depositional mounding. At all scales there is downstream and interior to margin exponential grain-size fining which mirrors the thickness changes. Coarse lags at the apices of sand bodies deviate from this trend. The similarities of sand body shape and internal property distribution across several size classes of the hierarchy suggest that there are scale invariant processes at work. Elements of the shape hierarchy are interpreted to have been deposited by downstream expanding, decelerating flows operating over a wide range of time and length scales.

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Enigmatic Organic-Walled Microfossils from the Pennsylvanian (Missourian and Virgilian) of Iowa, Missouri, Kansas, and Oklahoma

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Enigmatic dark-black organic-walled microfossils have been recovered from Pennsylvanian (Missourian and Virgilian) shales in Iowa, Missouri, Kansas, and Oklahoma. The microfossils are less than 2.5 millimeters in length and 0.5 millimeters in diameter. They are cylindrical in shape and usually inflated on one side. Shoulders on each end slope to a narrow neck that connects one cylinder to the next one in a chain-like configuration. Most connections are marked by a simple enlargement of the necks. A small short tube is located on one end of the cylinder on the inflated part of the cylinder shoulder, but sometimes occurs on the neck. Exceptionally well-preserved specimens exhibit a wide flange arranged around the top of the small tube. The outer surface is very smooth, shiny, and without ornamentation. The wall thickness is usually less than 20 microns. These fossils are often associated with annelid worm (Polychaeta) jaw elements (scoleconodonts) and conodonts, but the relationship between the two and the unknown microfossils is not known at this time. Most specimens are found in the gray shale facies of the core shale of cyclothems (as defined by Heckel) in abundances of up to several thousand per kilogram, but can also rarely be found in the more offshore parts of the transgressive and regressive limestones.

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Transgressive Ravinement on an Epeiric Shelf as Recorded by a Limestone Conglomerate in the Upper Pennsylvanian Leavenworth-Heebner-Plattsmouth-Heumader Depositional Sequence, SE Kansas and NE Oklahoma

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The TST of the Leavenworth-Heebner-Plattsmouth-Heumader sequence overlies multi-story calcareous paleosols and consists of basal Gleysol and carbonaceous shale (10s cm), middle limestone conglomerate (5–25 cm), and upper fossiliferous shale and Leavenworth Limestone (1–2 m). The conglomerate was observed in 15 outcrop sections covering 100 km, and interpreted in 14 wireline logs and cores in SE Kansas and NE Oklahoma. It is a single bed with conformable lower and upper contacts, composed of blackened clasts (80–95%), bedding-plane-parallel brachiopods, crinoids, and encrusting forams (5–20%), and rare coal fragments. Clasts are rounded, equant to elongate, coarse-sand-to-granule in size, and moderately sorted. They include micritic and radial-fibrous calcite grains, and pisoids. Micritic grains contain quartz silt, radiating and/or concentric spar-filled cracks, and rounded central molds filled with micrite or spars. Pisoids have micritic-clast cores and concentric micritic cortexes. Petrographically, the clasts have the same texture and composition as pebble-sized calcitic nodules, rhizoliths, and clasts of a channel-fill conglomerate in underlying calcareous paleosols and, thus, were probably derived from soil nodules.

The calcareous paleosol-Gleysol transition indicates a semiarid to subhumid climatic change, and an elevated groundwater table associated with shoreline transgression. Gleysols developed in coastal-marginal-marine environment. The limestone conglomerate is the first transgressive marine deposit. Its persistent thickness and composition suggest significant regional excavation of underlying calcareous paleosols and landward transport and deposition of soil-nodule clasts. Transgressive seas caused peneplanation on the vast epeiric Kansas shelf where homogeneous transgressive Leavenworth Limestone was deposited. An extensive ravinement surface may be present basinward of the study area.

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Environmental Impacts of Oil Production on Soil, Bedrock, and Vegetation at the U.S. Geological Survey OSPER Study Site A, Osage County, Oklahoma

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The lease at the Osage-Skiatook Petroleum Environmental Research (OSPER) site A in Osage County, Oklahoma, produced about 100,000 barrels of oil between 1913 and 1981. Prominent production features include a tank battery, an oil-filled trench, pipelines, storage pits for both produced water and hydrocarbon sludge, and an old power unit. Site activities and historic releases have left open areas in the local oak forest adjacent to these features and a deeply eroded salt scar downslope from the pits which extends to nearby Skiatook Lake. The site is underlain by surficial sediments comprised of very fine grained eolian sand and colluvium as much as 1.3 m thick which, in turn, overlay flat-lying, fractured bedrock comprised of sandstone, clayey sandstone, mudstone, and shale. A geophysical survey of ground conductance and concentration measurements of aqueous extracts (1:1 by weight) of core samples taken in the salt scar indicate that unusual concentrations of Na-Cl-rich salt are present at depths to at least 8 m in the bedrock however, little salt occurs in the eolian sand. Historic aerial photographs, anecdotal reports from oil-lease operators, and tree-ring records indicate that the surrounding oak forest was largely established after 1935 and thus postdates the majority of surface damage at the site. Blackjack oaks adjacent to the salt scar have anomalously elevated chloride (>400 ppm) in their leaves and record the presence of Na-Cl-rich salt or salty water in the shallow subsurface. The geophysical measurements also indicate moderately elevated conductance beneath the oak forest adjoining the salt scar.

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Impacts of Petroleum Production on Ground and Surface Waters: Results from OSPER "A" Site, Osage County, OK

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We are involved in a multidisciplinary investigation to study the transport, fate, natural attenuation and impacts of released petroleum compounds and inorganic salts in produced water at the Osage-Skiatook Petroleum Environmental Research (OSPER) "A" and "B" sites in Oklahoma. At the OSPER "A" site, about 1.5 hectare of land has been impacted by oil operations that started in 1913 and were largely terminated by 1937. Impacts include salt scarring, tree kills, soil salinization and brine and petroleum contamination due to the leakage of produced water and associated hydrocarbons from brine pits and accidental releases from pipes and tank batteries. Groundwater impacts are being investigated by repeated sampling of 35 wells (1–36 m deep) completed with slotted PVC tubing.

Results indicate a 3-D plume of high salinity water (5,000–30,000 mg/L TDS) with chemical and isotopic characteristics similar to those of the source produced water. The plume intersects Skiatook Lake, which provides drinking water to the local communities and is a recreational fishery, but the plume's depth and horizontal boundaries are not currently defined. One well penetrates a deeper aquifer with lower salinity (~2,000 mg/L TDS), but high Fe, Mn and dissolved organics, and all wells deeper than 2 m at the site encounter the plume. A "background" well, located 0.6 km from the site has freshwater (450 mg/L TDS) and other characteristics of local groundwater, but also has high dissolved organics, including BTEX. Results show that large amounts of salts and organics remain in the local rocks and groundwater after more than 65 years of natural attenuation.

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Models of Eperic Seaway Connections: Middle Cretaceous of the U.S. Western Interior

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Mid Cretaceous (Upper Albian–Lower Cenomanian) strata in the U.S. Western Interior between Wyoming and Texas reveal that rocks generally attributed to transgression during the early part of the Greenhorn third-order cycle record three thin sequences of unusually large, regional extent deposited during three lower-order marine cycles. Outcrop and core sections in southeastern Colorado, northeastern New Mexico, and the Oklahoma panhandle show that each sequence records biofacies shifts of over 200 km within vertical sections of less than 20 m that mark ephemeral connections between Boreal and Tethyan realms across eastern Colorado. In each sequence, basal fluvial-estuarine sandstone with nonmarine fossil assemblages passes vertically into a section of marine-influenced shale and sandstone. Biofacies in marine-influenced units show a progressive loss of marine influence up dip. Marine palynomorphs and a diverse *Skolithos* ichnofacies occur in coastal plain strata up dip of marine shoreface and shelf deposits. Marine fossils become progressively depauperate up dip until only brackish-tolerant ichnofauna, foraminifera, dinoflagellate cysts, acritarchs, and nonmarine palynomorphs remain. The depauperate fauna record intervals when ephemeral biotic connections allowed limited and selective exchange of Tethyan and Boreal fauna. The occurrences of a low diversity agglutinated foraminiferal biota (e.g., Tethyan *Ammobaculites* and boreal *Miliammina*), nearshore dinoflagellate cysts, such as *Cyclonephelium, Palaeoperidinium* and *Cribroperidinium,* and the acritarch genus *Pterospermella* in these sediments suggest that the ephemeral connections were so brief that brackish conditions were established instead of fully marine conditions. This observation is supported by isotopic carbon signals and palynofacies analyses. The sequence boundaries separating these thin sequences are unique mappable surfaces over the length of this transition.

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Cyclicity in Paralic Deposits, Mid-Cretaceous, United States Western Interior

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Cretaceous tectono-eustatic cycles in the U.S. Western Interior range from second- and third-order transgressive-regressive cycles of 4 to 8 m.y. duration to fourth- and fifth-order climatic cycles expressed as offshore marine, chalk-marl couplets. However, short-term cycles in paralic siliciclastic facies are poorly understood.

Shale-sandstone, coarsening-up, meter-scale cycles in the Dakota Group in New Mexico, Oklahoma, Colorado, and Kansas comprise transgressive systems tracts of two alloformations. The Cucharas Canyon Alloformation consists of the Upper Albian Mesa Rica and Dry Creek Canyon formations and is bounded below by sequence boundary SB3 that overlies the lower Upper Albian Kiowa–Skull Creek Cycle. The Huerfano Canyon Alloformation bounded by SB 4 consists of the Romeroville Formation.

Thirteen meter-scale, coarsening-up and fining-up cycles in the Cucharas Canyon Alloformation in Kansas become progressively non-marine as indicated by the upward decrease in trace fossils and dinoflagellates. By graphic correlation analysis average cycle duration is estimated to be 169,000 yrs. In southeastern Colorado and New Mexico this alloformation consists of fluvial sandstone deposited in active-fill channels and bars.

Meter-scale coarsening up mudstone-sandstone cycles comprise the upper part of the Huerfano Canyon Alloformation in New Mexico, Oklahoma, and Colorado. The cycles become progressively marine up section by the inclusion of trace fossils, the Ammobaculites-dominated agglutinated foraminiferal biofacies, and nearshore marine dinoflagellates. These cycles are overlain by dark gray, restricted marine Graneros Shale. By graphic correlation analysis the estimated average cycle duration was 98,000 years so these cycles could represent allocyclic climatic processes, although variation in sediment input cannot be discounted.

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Tropical Latitudinal Climatic Gradients in the Pennsylvanian of North America: Evidence from Swamp Communities and Leaf Morphology

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Plants are sensitive to their habitat and, as a result, are excellent environmental indicators. Using macrofloral and microfloral assemblages, coal macerals, coal abundance, and pyrite abundance, a community gradient spanning deeply flooded to drained peat substrates has been established for the Pennsylvanian. Lycopsids flourished in flooded peat swamps; although some appear adapted to drained peat. Tree ferns possibly required exposed substrates for reproduction. Tree ferns, seed ferns, and sphenopsids flourished in areas with high siliciclastic influx. Cordaites may have been adapted to peat swamps that experienced seasonal saltwater influx linked to seasonally dry climates. The habitat preferences of these Pennsylvanian plants has been used to reconstruct environments within a single coal bench or seam, and to trace paleoclimatic change in the Pennsylvanian. They can also be used to reconstruct latitudinal climatic gradients during the Pennsylvanian. During the Late Atokan, tree ferns and lycopsids predominated in the paleoequatorial Illinois Basin. Cordaites predominated in both the Western Interior Basin to the north and in the Appalachian Basin to the south, suggesting seasonal rainfall in both locations.

Paleobotanists have long sought to use leaf morphology to determine Paleozoic paleoclimates. *Alethopteris* leaves, derived from medullosan seed ferns occur in most Pennsylvanian coals with permineralized peat. The ratio of laminar thickness to surface area and the relative abundance of fibers in *Alethopteris* leaves may correlate with paleoclimate. *Alethopteris* species from the early Desmoinesian of the Western Interior Basin, interpreted as a relatively dry interval, have thicker lamina, smaller surface areas, and more fibers than *Alethopteris* species from the wet middle to late Desmoinesian. *Alethopteris* from the early Desmoinesian of the Western Interior Basin appear to be xeromorphic. However, seasonal saltwater influx into the swamp rather than aridity may account for xeromorphy in these leaves.

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Was Tropical Climate Constant in the Pennsylvanian?

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Paleotropical climate change associated with Pennsylvanian Milankovitch cyclicity is controversial. Paleoclimatic interpretations of glacial-eustatic sedimentary cycles (cyclothems) using sedimentological data suggest seasonally dry conditions before, and ever-wet conditions during coal accumulation. The constancy of plant communities within Pennsylvanian coal swamps from cycle to cycle, particularly in the mid-to-late Desmoinesian, has led paleoecologists to stress the climatic constancy of the Pennsylvanian tropics. A better understanding of Pennsylvanian swamp ecology may help to resolve this question. In the late Atokan–early Desmoinesian, a cordaite–seed fern–tree fern community flourished in the peat swamps of the Western Interior Basin. Cordaites have been interpreted both as marine swamp trees (mangroves) based on root morphology and pyrite distributions, and as freshwater plants adapted to drained peat substrates. Mangrove peat rarely occurs in siliciclastic depositional settings. However, most paralic peat swamps experience salt water influx during the dry season. Growth in predominantly freshwater swamps that experienced seasonal saltwater influx may account for the paleogeographic distribution of cordaite-dominated swamps. In the late Atokan–early Desmoinesian coals of Iowa, the succession of plant communities indicates changing rainfall conditions during peat accumulation. In the late Atokan Blackoak coal, the presence of a cordaite–tree fern–seed fern community at the base of the seam suggests seasonally dry climates at the onset of peat accumulation. Conditions became gradually wetter during peat accumulation, culminating in a *Lepidophloios* community, adapted to growth on deeply flooded peat substrates. A similar community progression occurs in the early Desmoinesian Cliffland coal. The amount of rainfall varied consistently during coal accumulation in late Atokan–early Desmoinesian glacial-eustatic cycles.

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Pilot Tests in the Illinois and Western Interior Basins to Determine Commercial Productivity from Pennsylvanian Aged Coals

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Coalbed methane production is viewed as an attractive source for the growing U.S. natural gas demand. Undeveloped resources of coalbed methane in the United States have been estimated at 60 Tcf. A majority of the coal in the USA is accessible at shallow depths, making well drilling and completion inexpensive. Finding costs are also low since methane occurs in coal deposits, and the location of the Nation's coal resources are well known.

Millions of acres of potential coalbed methane gas production identified in the Illinois and Western Interior Basins and depths vary from 300 to 2,800 feet in depth, vary from 0.3 to 2 meters, are High Volatile C to Medium Volatile in rank and are of Middle to Upper Pennsylvanian in age. The coal seams have gas contents varying from 5 to 325 scf per ton. Permeability measurements range from >0.1 mD to as high as 250 mD.

The primary purpose of a pilot test program is to determine gas deliverability potential and initial water production. Well spacing, time to dewater, and ultimately time to reach maximum gas production is crucial to overall project development economics. Secondarily, the pilot programs are designed to confirm gas contents and permeability estimates obtained from initial data wells.

The pilot wells are placed in such a way to maximize well-to-well interference during a reasonably short production test period (4 to 6 months). This paper presents the initial results of several ongoing pilot projects in both basins. Parameters such as full-field well spacing, water disposal requirements and facilities, artificial lift, gas deliverability, and ultimate recoveries can be estimated and asset development economics determined.

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Regional Gas Content and Permeability Trends for the Coals in the Interior Basin, USA

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The Interior Basin is a term used for the extensive deltaic deposition and subsequent development of widespread coal deposits during Middle and Upper Pennsylvanian times and that would eventually become the Arkoma, Forest City, Cherokee and Illinois Basins of present day. The coal seams are generally high volatile bituminous C through A, 0.3 to 2 meters thick, and have large lateral extent. Coal bed methane activity continues at a frantic pace in the Arkoma and Cherokee Basins but has slowed or stalled considerably in the Forest City and Illinois Basins. A number of test wells, pilot projects and development drilling by industry and state organizations over the past two years have begun to characterize the coals and shales of the Interior Basin. The present four basins comprising the Interior Basin have undergone different tectonic history which has inherently controlled gas contents and permeability of the coals. Episodic periods of degassing, influx of meteoric waters and migration of low temperature hydrothermal fluids has further either enhanced or reduced permeability and gas content of the coal seams. Within the four basins only some of the coals seem to contain recoverable whereas others do not. In addition, there is in most of the Interior Basin fully saturated or over saturated black shales that have not seem to been as readily degassed as the coals. Shale gas represents a potentially overlooked resource. By integrating the various data sets a more definitive set of models can be constructed upon where to explore for coal bed methane and shale gas in the Interior Basin.

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The Critical Element in Coal Bed Methane: Permeability

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The majority of literature and exploration programs focus on gas content and thickness of coals as a prerequisite to determine the viability of any basin for coal bed methane. Many of the coal basins developed in the 1980s and 1990s had a combination of permeability and gas contents that allowed them to overcome in general any reservoir limitations and thus be successful. In recent years basins that were considered less perspective in the past, such as Arkoma, Alberta, Cherokee, Piceance, Forest City and Illinois have become increasing the focus of exploration and development. While the gas contents in these basins have varied, the greatest stumbling block for their development has been finding completion and drilling methods that enhance or connect what is generally considered low permeability reservoirs. The use of horizontal drilling has overcome to some degree the low permeability reservoir characteristics of coals in the Arkoma and parts of the Appalachian basins. However, in other basins low gas contents prohibit the use of these directional methods. Therefore, measuring permeability in these basins is critical to determine the potential area of drainage for a wellbore and ultimate resource recovery. Permeability can be measured during the exploration phase of any program via injection fall off tests. This type of test allows for a measure of relative permeability and reservoir boundaries. This paper will present several examples how permeability is measured and what it implies for the viability of various coal seams as an economic resource in certain basins.

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