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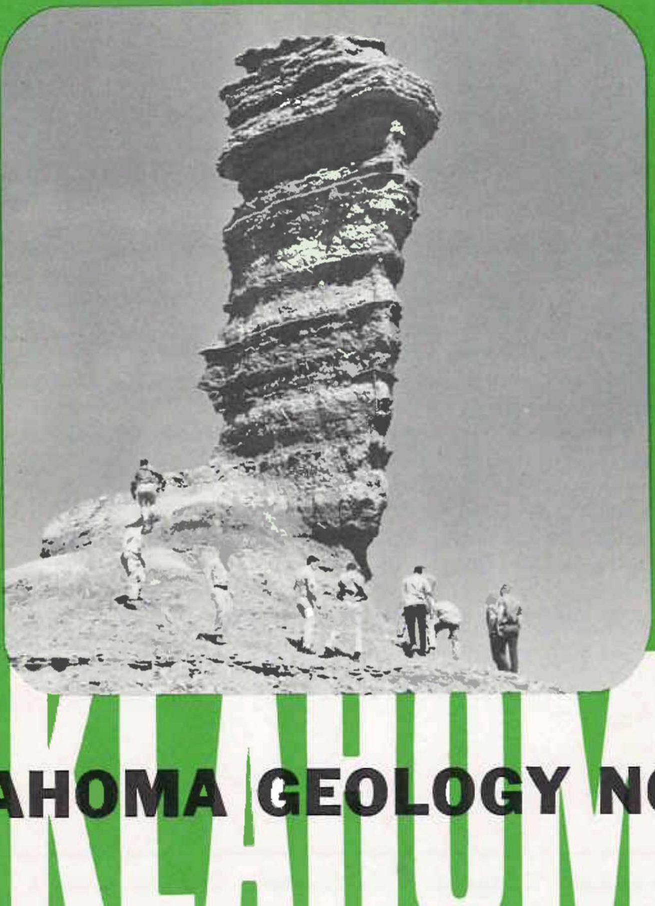

# OKLAHOMA GEOLOGY NOTES

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## *Cover Picture*

### FAREWELL TO AN OLD FRIEND

Chimney Rock is dead.

A northwestern Oklahoma landmark, Chimney Rock was on private property in the SE¼ sec. 28, T. 25 N., R. 17 W., about 8½ miles southeast of Alabaster Caverns State Park and 24 miles northeast of Woodward. It was only a few miles from the Cimarron River and during the great westward migration was used as a landmark to aid wagon-train scouts in finding a safe place to cross the treacherous river.

The rock column rose about 30 feet above a broad, cone-shaped base. The column was elongate, with its long axis in an east-west direction. As shown on the cover, erosion had undercut the north side. The chimney was formed in the Permian Flowerpot Shale, which consists of alternating layers of variegated red and gray-green shale and gypsum. The gypsum layers and cross-cutting gypsum stringers make the Flowerpot relatively resistant to erosion.

The collapse of Chimney Rock was probably brought about by a combination of events. Because of the exceptionally wet winter, the shale had softened. More rain, plus gusty winds estimated at 50 to 90 miles per hour, was too much for it. It is believed to have blown over about noon on Tuesday, March 13, 1973. Debris, including boulders that range from 1 to 4 feet in diameter, was scattered to the northeast.

Only a stump—a few feet high—remains of the once majestic landform.

—*Arthur J. Myers*

Editorial staff: William D. Rose, Rosemary Croy, Elizabeth A. Ham

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

# OKLAHOMA PALEOICHTHYOLOGY
# PART II: ELASMOBRANCHII (*Cladodus*, MINUTE ELEMENTS OF CLADOSELACHIAN DERIVATION, *Dittodus*, AND *Petrodus*)

JIRI ZIDEK[1]

## INTRODUCTION

The occurrence of shark remains in Oklahoma was probably first recorded by Cope (1894b), who mentioned 2 *Lamna* teeth collected from the Kiowa Shale (Comanchean Series), approximately 6 miles northwest of Fort Supply in Harper County.

Later, Eastman (1917) described *Cladodus aculeatus* n. sp. and commented briefly on the ichthyodorulite *Stethacanthus*. Both of these were labeled by G. H. Girty as occurring in the Caney Shale (=Delaware Creek) of middle Mississippian age. However, as already discussed (Zidek, 1972), the *Cladodus* remains actually belong to the Johns Valley Formation (Morrowan, Early Pennsylvanian), and the age of the *Stethacanthus* specimen cannot be determined with certainty because of insufficient data as to the locality from which it was obtained. The only elasmobranch remains from Oklahoma known with certainty to be of Mississippian (Chesterian) age are *Cladodus ozarkensis* Croneis and *Deltodus cingulatus* Newberry and Worthen from the Fayetteville Formation in Mayes County (Croneis, 1927) and a *Ctenacanthus*-type spine (no description published) from Craig County that came from the Hindsville or the Fayetteville Formation.

In addition to the *Cladodus* of Eastman (1917) mentioned above, Pennsylvanian formations have yielded isolated occurrences of shark teeth, spines, and fragments of calcified cartilage. *Edestus* cf. *E. vorax* Leidy (C. C. Branson, 1964) has been reported from the Deese Formation in Carter County; Cladoselachii, Xenacanthodii, and Bradyodonti Indet. (Mamay and Yochelson, 1962) from coal balls of the Secor coal in the Boggy Formation of Pittsburg County; *Cladodus, Petrodus,* and *Petalodus* (Morgan, 1924) from the McAlester, Boggy, and Francis Formations in Pontotoc County; *Petrodus* and *Petalodus* (Weaver, 1954) from the Boggy and Wewoka Formations in Hughes County; *Petrodus* (Ries, 1954) from the Wewoka Formation in Okfuskee County; *Petalodus* and *Deltodus* (Greig, 1959) from the Vamoosa, Wood Siding, Vanoss, and Oscar Formations in Pawnee County; and Xenacanthodii (Case, 1915; Wegemann, 1915; Smith, 1927; Olson, 1967) from the Oscar Formation in Jefferson and Cotton Counties.

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To the list of Oklahoma elasmobranchs of Pennsylvanian age must be added the minute, typically fragmental elements described in conodont literature. *Scolopodus, Multidentodus, Bransonella,* and *Holmesella* have been reported by Harlton (1933); *Holmesella,* by Harris and Hollingsworth (1933); *Scolopodus* and *Vesiculodus,* by Cooksey (1933); and *Holmesella* and *Idiacanthus,* by Perkinson (1934). *Holmesella* was dealt with in great detail by Ørvig (1966). *Vesiculodus* (nom invalide, cf. Zidek, 1972, p. 175), probably a single cusped tooth of a cladoselachian, cannot be discussed further due to the unavailability of the type specimen. The remaining Oklahoma elasmobranchs will be discussed, by genus, in separate sections of this report.

A number of Permian formations, including the Wellington, Garber, Hennessey, and Chickasha, have also yielded elasmobranch remains. Except for a single specimen of *Orodus,* listed by Olson (1967) but presently unaccounted for, all the specimens reported (Case, 1915; Smith, 1927; Olson, 1965, 1967) are isolated teeth, spines, and fragments of calcified cartilage belonging to a single group—the xenacanth sharks.

In addition to these reported occurrences, however, in the paleontological collection of The University of Oklahoma's Stovall Museum are a number of elasmobranch teeth that have not been reported on in the literature (*Cladodus, Orodus, Deltoptychius,* and *Deltodus*) and spines (*Ctenacanthus, Physonemus, Hybodus,* and *Anodontacanthus*) that were collected by A. A. Graffham from Morrowan, Desmoinesian, and Gearyan formations in Carter, Pontotoc, Johnston, and Jefferson Counties; by M. G. Lockwood and me from Missourian formations in Pontotoc County; and by L. C. Simpson from the Hennessey Formation (Lower Permian) of Tillman County.

Due to space limitations, only *Petrodus, Dittodus, Cladodus,* and some minute remains of cladoselachian derivation can be discussed in this paper; the remaining genera will be considered in forthcoming sections of the series.

Abbreviations used in the text are as follows: OUSM=Stovall Museum, The University of Oklahoma; USNM=U.S. National Museum; and MCZ=Museum of Comparative Zoology, Harvard University.

I would like to express sincere gratitude to Dr. Nicholas Hotton III and Dr. Robert W. Purdy of the U.S. National Museum and to Dr. John R. Boreske of the Museum of Comparative Zoology, Harvard University, for their assistance with the specimens deposited in collections under their care. Special thanks are due Dr. Carl C. Branson, geology professor emeritus at The University of Oklahoma, and Dr. Charles L. McNulty, Jr., professor of geology at The University of Texas at Arlington, for reviewing the manuscript.

## *Cladodus*

The specimens listed in the literature under the generic name *Cladodus* ought to be regarded as belonging to a variety of cladoselachian (pleuropterygian) and ctenacanth sharks that possess teeth of the so-called cladodont type—with a prominent central cusp, one or more pairs of accessory cusps, and a flat, lingual extending base. Unfortunately, articulated specimens of these Paleozoic sharks are exceedingly rare, so most identifications are based solely on isolated teeth, the morphology of which does not provide criteria sufficient to distinguish the two groups. Furthermore, the systematic position of the isolated teeth cannot be ascertained from the environment of deposition, because the cladoselachians and ctenacanths occupied similar marine and deltaic environments during approximately the same time span.

An attempt to distinguish between cladoselachians and ctenacanths based on tooth histology was made by Glikman (1964a; 1964b), who labeled Paleozoic cladodont teeth that consisted of orthodentine as cladoselachian and those that consisted of osteodentine surrounded by pallial dentine as belonging to the ctenacanth sharks. However, it has been repeatedly demonstrated (Radinsky, 1961; Patterson, 1966, p. 332) that using microscopic tooth structure as a basis for classification of cartilaginous fish can lead to a wide separation of forms that are otherwise similar in structure.

Some workers (Moy-Thomas, 1939; Dorr and Moser, 1964; Romer, 1966, 1968) regarded the cladoselachian and ctenacanth sharks only as families of the same order. The primary reason for this grouping was the suggestive association of *Cladodus*-type teeth with *Ctenacanthus*-type spines that, as Romer (1968, p. 43) put it, shows that "sharks with *Ctenacanthus* spines had teeth identical with the *Cladodus* type." Unfortunately, this similarity is not true of the spines, so the statement is irreversible. It is well known that of the two groups that comprise the Cladoselachii, only the Cladoselachida possessed fin spines; the Cladodontida were spineless (Zangerl, 1969, p. 166; Moy-Thomas and Miles, 1971, p. 213; Olson, 1971, p. 233). Furthermore, the spines of the Cladoselachida were short and with a surface of "unfinished look" (Zangerl, 1969); consequently, they are readily distinguishable from the long and well-ornamented spines of the ctenacanth sharks. It follows that the association of *Cladodus*-type teeth with *Ctenacanthus*-type spines provides no justification for closely relating the cladoselachians and ctenacanths (it only justifies, to a degree, assignation of such teeth to a ctenacanth rather than to a cladoselachian). On the contrary, the few known articulated specimens of the two groups exhibit such marked structural differences that the groups should be regarded as separate levels of elasmobranch organization (Schaeffer, 1967).

It has been shown by Patterson (1966), using the example of hybodont sharks, that due to a great deal of parallelism and convergence in the evolution of teeth and to the impossibility of knowing the degree of heterodonty and variability, erection of new species solely on a few isolated teeth is an extremely hazardous procedure. This difficulty in classification applies to most fossil shark teeth (except for some "modern level" elasmobranchs in Schaeffer's sense, 1967), but only if we view the taxa as natural ones. In the case of an acknowledged form genus such as *Cladodus*, however, any thought given to the question of heterodonty or variability would be irrelevant because, as Croneis (1938, p. 980) puts it, "the 'genus' contains 'species' not generically related in the ordinary taxonomic sense." Such artificial species have a certain value for future work, provided they are supported by a sufficient number of characters. Unfortunately, this cannot be said of all species of *Cladodus;* some of them are based on teeth so badly preserved that even their cladodont derivation is questionable. For cladodont teeth, the question of what dental characters ought to be described has never been raised; however, some general conclusions regarding such characters and their correlation exist for the hybodont sharks (Patterson, 1966, p. 311, 312), and most of the conclusions (not the correlation) may well be applied to the cladodont teeth.

Occurrences of *Cladodus*-type teeth have been reported in Oklahoma from deposits of Mississippian (Chesterian) and Pennsylvanian (Morrowan, Desmoinesian, and Missourian) age. Croneis (1927, p. 43, 44, pl. 7, figs. 13-16) described *Cladodus ozarkensis* n. sp. from the Fayetteville Formation (Chesterian) 4 miles southeast of Adair, Mayes County, northeastern Oklahoma. The species is based on a single incomplete tooth (MCZ 5320) that appears to have had only one pair of accessory cusps—close to the lateral margins of the tooth base. However, the surface immediately laterad of the central cusp is incomplete, and it may well be that another pair of small inner accessory cusps was in that area. In spite of the uncertainty as to the actual number of accessory cusps, the species appears to be in good standing because of the appearance of striation of the central cusp and the shape of the tooth base. The striation is unusually heavy, and, contrary to the general rule, the striae are clearly broader and of a higher relief on the labial side of the cusp, where some of them anastomose and some bifurcate proximally. The lingual striae bifurcate proximally. The distal third of the cusp is broken off, so the extent of the striation cannot be determined. Judging from its overall character, it is likely that the striae have reached quite close to the peak of the cusp. The base of the tooth is thick and unusually narrow, the length-width ratio being 3:1 (18:6 mm). Since both the original description and the illustration are clear and detailed, a complete redescription is not attempted here.

Eastman (1917, p. 255, pl. 10, fig. 4; pl. 18, fig. 1) described *Cladodus aculeatus* n. sp. on the basis of two fragmentary teeth that came from Girty's location 3987 in the SW¼ sec. 2, T. 2 S., R. 13 E., Atoka County. This outcrop was formerly believed to be the Delaware Creek, middle Mississippian, but according to R. O. Fay, Oklahoma Geological Survey (oral communication, 1972), it belongs to the Johns Valley Formation (Morrowan, Lower Pennsylvanian). The holotype (USNM 8106) is a tooth fragment, embedded in a dark gray shale (fig. 1), that shows the labial face of the central cusp and one accessory cusp (the left one in the labial view), the entire surface of which is missing. Only a negligible fragment of the right accessory cusp is preserved, and it offers no detail whatsoever. The central cusp is 9 mm high and 2 mm wide proximally, lenticular in cross section, with cutting edges, and sinusoidally curved in the

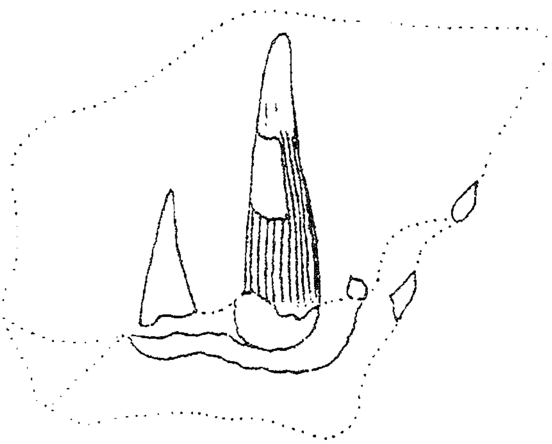

**Figure 1.** Cladodus **sp., labial face of fragmentary tooth USNM 8106 (**C. aculeatus **Eastman), from Johns Valley Formation (Morrowan, Lower Pennsylvanian) of southeastern Oklahoma;** ×5.

labio-lingual plane. Its striation is indistinct, and the striae do not quite reach the base and do not anastomose. Distally, the striae appear to reach about two-thirds of the cusp's height, but this is only an estimate because most of the surface of the middle third of the cusp is missing. The left accessory cusp is 4.5 mm high and 1 mm wide proximally, and its distance from the central cusp equals its width. The entire base of the tooth is broken. A cross section through the base may be observed at the right side of the sample, but as this is far off the center of the tooth it does not indicate the true lingual extent of the base. There can, therefore, be no certainty as to whether there was only one pair or if more pairs of accessory cusps were present. The ornament of the lingual faces of the cusps is unknown, as is the extent of the lingual curvature of the tooth base. Since Hay (1929, p. 532, 533) regarded *Styptobasis* as congeneric with *Cladodus,* the name *Cladodus aculeatus* Eastman (1917) became a younger, secondary, homonym of *Cladodus aculeatus* (Cope, 1894) [formerly *Styptobasis*] and was changed to *Cladodus eboreus* by Hay (1929).[2] But from the above account it is obvious that neither the holotype nor the still more fragmentary second specimen provides sufficient criteria for species identification, and both can—at best—be labeled only *Cladodus* sp.

Morgan (1924, p. 73, 83, 118, pl. 53, fig. 12) reported a number of Pontotoc County specimens, which he identified as *Cladodus mortifer* Newberry and Worthen, from the McAlester Formation (Desmoinesian) in C sec. 1, T. 1 N, R. 6 E., and sec. 14, T. 1 N., R. 7 E.,

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[2] Even if a future revision confirms Hay's opinion, the congenerity could not be applied to the type species, **Styptobasis knightiana** Cope (cf. Cope, 1891, pl. 28, figs. 1-4), for it clearly is an indeterminable tooth fragment.

the Boggy Formation (Desmoinesian) in C sec. 17, T. 2 N., R. 7 E., and the Francis Formation (Missourian) on the CN line of sec. 32, T. 5 N., R. 7 E. Unfortunately, due to the inaccessibility of the specimens and the poor quality of Morgan's (1924) figure, his identification cannot be confirmed. An unpublished specimen from the Francis Formation, collected in the Superior Clay Products pit near Ada, Pontotoc County, and reposited in the Stovall Museum (OUSM 00259; see fig. 2), fits the description of *C. mortifer* as given by Newberry and Worthen (1866, p. 22-23, pl. 1, fig. 5): all the cusps are lenticular in cross section, with cutting edges, and striated only in their proximal parts; the 2 pairs of accessory cusps are relatively large and differ little in size (the outer pair must have been nearly

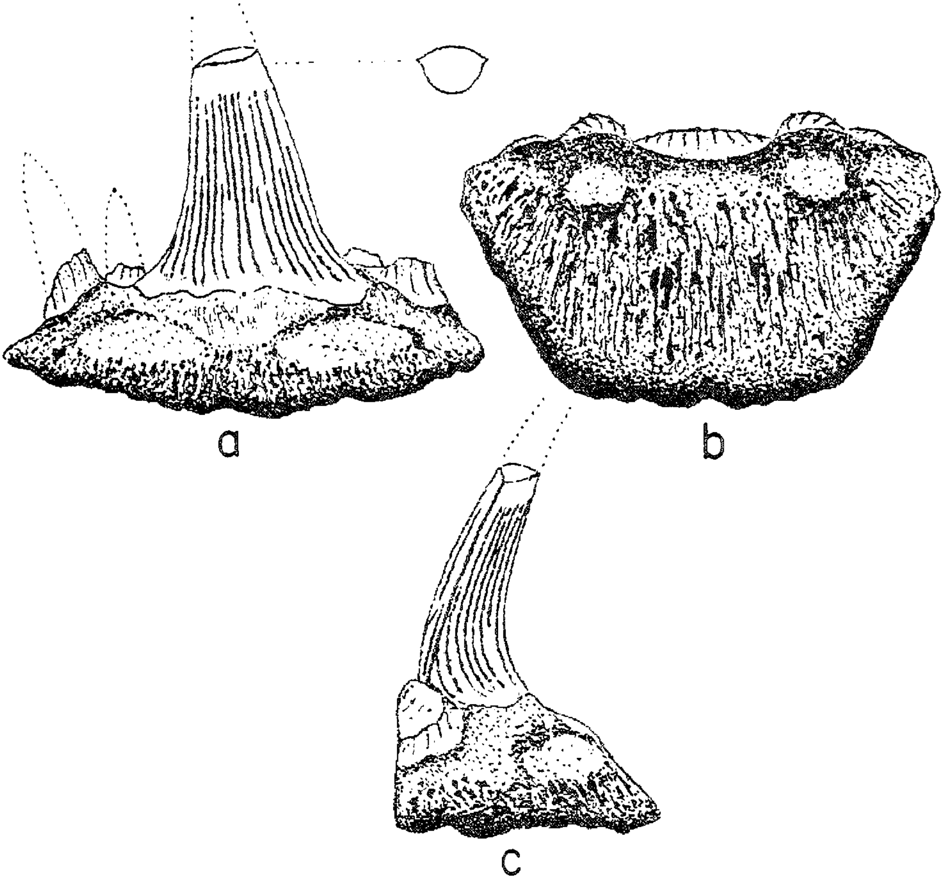

**Figure 2.** Cladodus occidentalis **Leidy, tooth OUSM 00259, from Francis Formation (Missourian, Upper Pennsylvanian) in Superior Clay Products pit near Ada, south-central Oklahoma; lingual (a), basal (b), and lateral (c) views; ×3.**

half the length of the central cusp); and the moderately thick tooth base has a width of about 2 lengths of the larger (outer) accessory cusps. However, compared with another Pennsylvanian species, *C. occidentalis* Leidy, *C. mortifer* shows no distinguishing feature that would justify its separation from the latter (cf. Leidy, 1873, p. 312, pl. 17, figs. 4-6; Woodward, 1889a, p. 24). The two species appear to be identical also in the very close spacing of the cusps, in the nature of the striation (the striae do not anastomose), and, less importantly, in size. Therefore, I concur with Leidy (1873) and Woodward (1889a) in regarding the name *C. mortifer* Newberry and Worthen, 1866, as a synonym for *C. occidentalis* Leidy, 1859.

In addition to the above specimen, the Stovall Museum possesses unpublished *Cladodus* teeth from the Pumpkin Creek Limestone Member of the Big Branch Formation (Dornick Hills Group) in sec. 32, T. 3 S., R. 4 E. (Oil Creek outcrop), Johnston County (OUSM 00257); the Boggy Formation (Desmoinesian) in the NW¼ sec. 27, T. 3 N., R. 7 E., Pontotoc County (OUSM 00256); and from Missourian (Coffeyville or Nellie Bly) formations in the NE¼ sec. 28, T. 24 N., R. 13 E., Washington County (OUSM 00258). They are all preserved as either tooth bases, with only the most proximal parts of the cusps, or as isolated and incomplete central cusps. In regard to the tooth bases, neither their appearance nor the number, cross section, and spacing of the cusps differs from *C. occidentalis*, but the isolated central cusps differ in the extent, strength, and density of their striation. None of these specimens is well enough preserved to allow positive species identification.

### MINUTE ELEMENTS OF CLADOSELACHIAN DERIVATION

In addition to the shark, acanthodian, and palaeoniscoid remains in the coal balls of the Secor coal (Mamay and Yochelson, 1962), several minute fish elements from the Oklahoma Pennsylvanian have been described in conodont literature (Harlton, 1933; Harris and Hollingsworth, 1933; Cooksey, 1933; Perkinson, 1934). The *Icthyodus gunneli* and *Scolopodus sigmoidalis* of Harris and Hollingsworth and the "cusp belonging to Distacodidae," described by Harlton, are bony fish remains; the remaining elements are elasmobranchs, and the majority of them should be regarded as being of cladoselachian derivation. A complete listing and notes on the occurrences of these minute elements have already been published (Zidek, 1972, p. 175-177), but a brief discussion of Harlton's type specimens (fig. 3) follows. These specimens are deposited in the U.S. National Museum, and their numbers may be found in a catalogue of conodonts compiled by Collier (1971). It has not been possible to study the internal structure of the specimens in this report, because they are type specimens.

*Scolopodus striatus* and *S. oklahomensis* (Harlton, 1933, p. 12, pl. 3, figs. 1, 6; see also *S. striatus* in Cooksey, 1933, p. 50, pl. 3, fig. 12) are dentition teeth similar to those named *Idiacanthus* by Gunnell (1933, *I. bellistriatus*, pl. 31, fig. 60; *I. cameratus*, pl. 32, fig. 29; *Idiacanthus* sp., pl. 33, figs. 39, 41). Wilimovsky (1954, p. 693) found the name *Idiacanthus* Gunnell preoccupied and, therefore, erected a

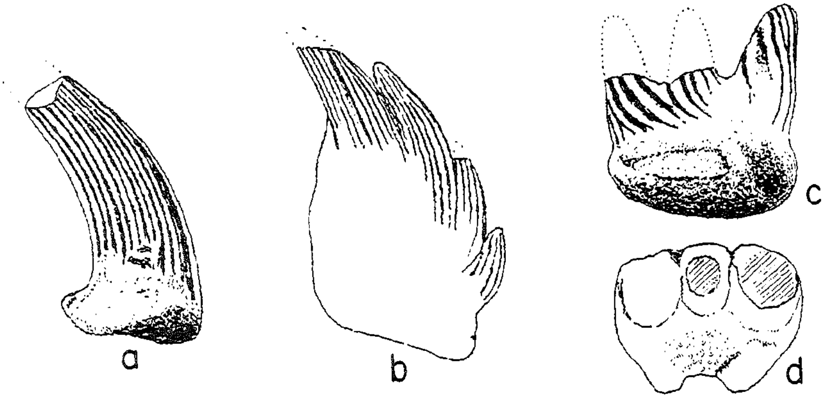

**Figure 3.**

a — Scolopodus oklahomensis **Harlton (USNM 85517A), actually a single-cusped tooth of the cladoselachian** Styptobasis aculeata **Cope; ×25.**

b — Multidentodus typicus **Harlton (USNM 85523), a mucous membrane denticle of a cladoselachian shark, possibly** Styptobasis **or** Symmorium; **×25.**

c, d — Bransonella tridentata **Harlton (USNM 85529), actually a** Dittodus**-type tooth from a xenacanthodian dentition; labial (c) and superior (d) views; ×25.**

**All from Lower Pennsylvanian (of pre-Johns Valley age) of southeastern Oklahoma. (After Harlton, 1933.)**

new name, *Gunnellodus,* for the teeth. This was unnecessary, however, because they are identifiable as the single cusped, anterior teeth of *Styptobasis aculeata* Cope (cf. Cope, 1894, pl. 20, figs. 4, 5).

Other elements, mucous membrane denticles in this case, have been named *Multidentodus wapanuckensis* and *M. typicus* by Harlton (1933, p. 13, pl. 3, figs. 2, 4). From illustrations and actual samples of mucous membrane denticles of *Styptobasis aculeata,* kindly made available to me by Gerard R. Case, Jersey City, it appears that the *Styptobasis* denticles do not differ from the above *Multidentodus.* However, for two reasons, one specific and the other general, this cannot be regarded as conclusive evidence for the systematic assignment of Harlton's species to *Styptobasis:* similar denticles are known also from *Symmorium reniforme* Cope (cf. Cope, 1894b, pl. 18, figs. 4, 5) and although the mucous membrane denticles presumably do not vary as much as the dermal denticles within a species (due to their restricted site of formation), they remain very little known and it is questionable whether they are of taxonomic value as low as on the generic level. Any attempt at generic reassignment would thus be premature. It may be of interest to note that denticles similar in appearance to those above have also been described outside Oklahoma under the names *Stemmatodus simplex* and *S. compactus* (St. John and Worthen, 1875, pl. 8, figs. 36-38). Possibly also *Mul-*

*tidentodus johnsvalleyensis* (Harlton, 1933, p. 13, pl. 3, fig. 3) belongs in this category.

Also, the remaining three *Multidentodus* species of Harlton (1933, p. 13, pl. 3, figs. 5a-b, 7, 8) may be regarded as cladoselachians. *M. brevis* and *M. irregularis* could, because of their overall appearance, be easily interpreted as belonging to the xenacanth sharks. However, the xenacanthodian mucous membrane denticles (no shagreen denticles have ever been found in this group) have funnel-shaped bases and cusps almost equal in size (cf. Fritsch, 1889, pl. 88, figs. 3-11). This is in contradistinction to the above two *Multidentodus* species that have flat bases and cusps well differentiated in size; also, although less importantly, they are considerably smaller. Furthermore, they both show striation, though indistinct, of some of the cusps. This is not what one would expect to find in the Xenacanthodii, but it is a feature common in the cladoselachians. In conclusion, the two resemble some of the cladoselachian denticles more closely than the xenacanthodian ones and are therefore regarded here as being of cladoselachian derivation. Figure 4 illustrates a suggestive resemblance of *M. brevis* Harlton (e) and *M. irregularis* Harlton (f) to a cladoselachian dermal denticle *Ohiolepis newberryi* Wells (1944; g) from the Middle Devonian of Ohio. This is only conjectural, however. In fact, there is nothing in the morphology of the elements that would prevent interpreting them as mucous membrane denticles.

*Multidentodus gracilis* Harlton (fig. 4 a-b) is a dermal denticle, the crown ornament of which has a pattern similar to such forms as the Pennsylvanian *Cladolepis ornata* (Gunnell) (cf. Wells, 1944, p. 35; *Holmesella ornata* of Gunnell, 1933, pl. 31, fig. 42) and *Holmesella* Gunnell (cf. Ørvig, 1966, fig. 1A), and the Upper Devonian *Cladodus wildungensis* Jaekel (cf. Gross, 1933, fig. 17) and *Protacrodus vetustus* Jaekel (cf. Gross, 1938, fig. 5; also Ørvig, 1966, fig. 1J). However, it differs from all these forms in (a) the extent and thickness of the basal plate, which is flat, thin, and relatively short; and (b) the shape of the crown, that proximally holds the angle of approximately 60° with the basal plate with only its distal half bent caudally into a plane parallel to that of the basal plate (fig. 4b). Such a curvature does not occur in the other forms named, where instead the entire crown lies in the plane parallel to that of the basal plate (fig. 4d). Viewed anteriorly, the crown of *M. gracilis* broadens toward the point of its caudal curvature and its maximum transversal diameter coincides with this point, whereas in *Holmesella*, *C. wildungensis*, and *P. vetustus* the crown is broadest in the anterior third of its length (fig. 4c). The crown ornament consists of concentric ridges that, very likely, correspond to the zones of growth. If so, *M. gracilis* would be a new addition to the type of dermal denticles (placoid scales) with periodic growth (those already named, plus *Cladoselache* and *Sarcoprion*—cf. Ørvig, 1966, p. 29, 30) in contrast to the more common nongrowing type. Despite this, however, nothing definite can be said about how close the relationship is between *M. gracilis* and the above-named forms, because there is not, at present, sufficient ground for treating these isolated elements as real taxa. For instance, if *P. vetustus* and *C. wildungensis* were known only from isolated denticles, they probably would be identified as belonging to the same genus (or perhaps even species), because they bear a close resemblance. Contrary to this, denticles that bear different generic names because of their distinct morphology may in the future be recognized as constituting different body parts of the same species (cf. Applegate, 1967, p. 40-44, concerning the variation). An extensive systematic study of these elements from articulated specimens of both fossil and modern elasmobranchs is needed before further definite taxonomic conclusions can be drawn.

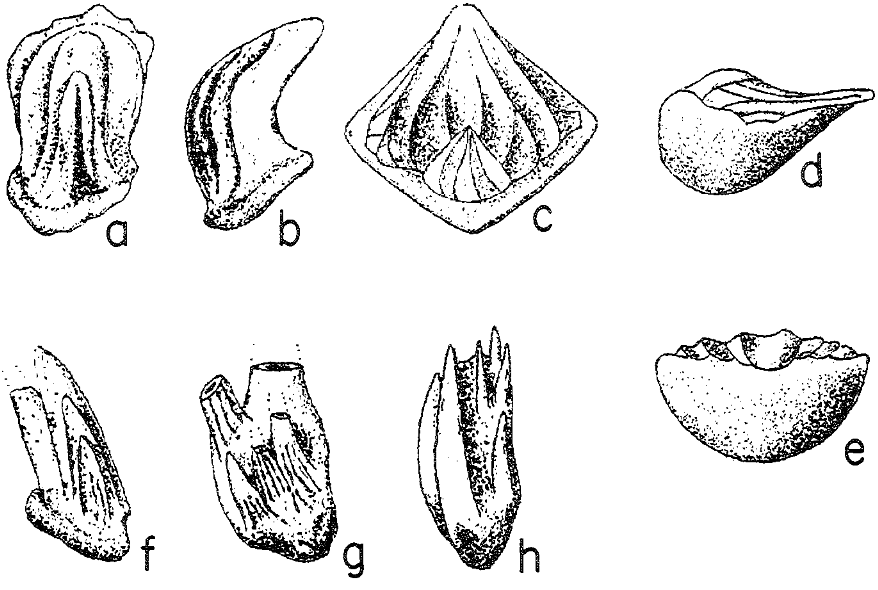

**Figure 4.**

**a, b** — Multidentodus gracilis **Harlton, a cladoselachian dermal denticle in anterior (a) and lateral (b) views; Lower Pennsylvanian (pre-Johns Valley) of southeastern Oklahoma; ×32.**

**c-e** — Protacrodus vetustus **Jaekel, a cladoselachian dermal denticle from Upper Devonian of Germany, in superior (c), lateral (d), and anterior (e) views; ×40.**

**f** — Multidentodus brevis **Harlton, a cladoselachian dermal(?) denticle; Lower Pennsylvanian (pre-Johns Valley) of southeastern Oklahoma; ×32.**

**g** — Multidentodus irregularis **Harlton, a cladoselachian dermal(?) denticle; Lower Pennsylvanian (pre-Johns Valley) of southeastern Oklahoma; ×32.**

**h** — Ohiolepis newberryi **Wells, a cladoselachian dermal denticle from Middle Devonian of Ohio; ×30.**

c-e **included for comparison with** a **and** b, h **for comparison with** f **and** g**; difference in orientation between** a **and** c **is due to curvature of crown in** M. gracilis. (a, b, f, g **after Harlton, 1933;** c-e **after Gross, 1938, from Ørvig, 1966;** h **after Wells, 1944.)**

### *Dittodus*

Finally, to make the account of the fish remains published by Harlton complete, mention should be made of the dentition teeth that he named *Bransonella tridentata* (1933, p. 14, pl. 3, fig. 9a-c)—although this is not a cladoselachian. The type specimen (fig. 3c, d) is a tooth, less than 1 mm in size, 3-cusped, with an elliptical base that has a well-defined median button on the dorsal side of its lingual extension. The cusps are circular in cross section and, as far as can be determined (only one lateral cusp is preserved in its entirety), almost equal in height. The central cusp is more slender and possibly somewhat shorter than the lateral ones. The bases of the cusps are in contact with each other, and, although not all details of the tooth morphology are available, apparently there could not be smaller accessory cusps present between the three principal ones. Striation is apparent only on the labial side of the crown, where there are relatively few coarse striae that curve mesiad toward the base. This tooth undoubtedly belongs to the genus *Dittodus* (=*Diplodus*, nom. praeocc. —cf. Hay, 1902, p. 265) and, apart from being much smaller, is remarkably similar to one of the specimens of *Dittodus priscus* (Eastman) illustrated by Hussakof and Bryant (1918, p. 145, text-fig. 51c). However, *D. priscus* is a Late Devonian fossil, so the age difference prevents any attempt to closely relate (not to mention synonymize) the two. *Dittodus* is known to range from the Upper Devonian (Eastman, 1899, 1908; Hussakof and Bryant, 1918) into the Upper Triassic (Woodward, 1889b; Seilacher, 1943, 1945). This great vertical range would seem to make it obvious that, as with *Cladodus*, we are dealing with a form genus. However, this is only partially the case, because, beginning with the Pennsylvanian, we know *Dittodus* (and *Phoebodus*) type teeth not only as detached elements, but also as *in situ* teeth of the xenacanth sharks (cf. Hussakof and Bryant, 1918, p. 147-8). (Seilacher, 1945, described a number of detached teeth from the Upper Triassic of Germany as *Phoebodus keuperinus* n. sp. However, these teeth are only three-cusped [i.e., they lack the intermediate accessory cusps characteristic of *Phoebodus*] and should be termed *Dittodus keuperinus*. Furthermore, Seilacher believed the teeth belonged to the family Cladodontidae. For the reason given above, this systematic placement must be regarded as erroneous.)

### *Petrodus*

This organ genus is known only from denticles, which are conical, broadly subcircular, or elliptical in superior view and range in diameter from 7 to 15 mm and in height from 5 to 11 mm. The bases of the denticles are somewhat broader than the crowns, usually convex on smaller specimens but concave on larger ones, and bear numerous vascular foramina. Ornamentation of the crown consists of a variable number of divergent ridges.

The denticles vary greatly in size and shape and in the regularity and extent of their ridges, and these variations have led to their being described as several different species. The majority of the American specimens have been customarily regarded as *P. occidentalis* Newberry and Worthen, 1866; however, the describing authors noted that *P. occidentalis* is so much like the type species, *P. patelliformis* M'Coy, 1848, that they hesitated to consider it distinct. The variability may be observed not only in specimens from different zones and localities but also in those from the same site and stratum. This would seem to indicate that the variations are from different body parts of only one species, *P. patelliformis,* rather than from separate species.

The first recording of *Petrodus* in Oklahoma was by Stovall (1945), and new information was added by C. C. Branson (1965), who also drew attention to the uselessness of species identifications within the genus. According to Branson, the genus ranges from the Pumpkin Creek Limestone Member of the Big Branch Formation (Dornick Hills Group, lower Desmoinesian) into the Francis Formation (lower Missourian). Outside Oklahoma, *Petrodus* denticles are known to occur in still older deposits; for example, the specimens from Derbyshire, England, on which M'Coy (1848) based the original description, are Mississippian in age.

From M'Coy's (1848) description, it is evident that he believed *Petrodus* to be true dentition teeth. More recently, Stovall (1945) also inclined to that view, claiming that the peaks of the denticles "show more wear than would be caused on dermal denticles by a fish accustomed to wallow on the bottom." However, many cases of abrasion of unquestionably shagreen denticles are known, and the wear apparent on the specimens examined by Stovall, therefore, cannot be considered evidence of their nature. At present, there are no dentition teeth known that resemble *Petrodus,* but, as shown below, there are shagreen denticles similar to this genus. The dentition teeth can be oriented by means of their more or less readily distinguishable labial and lingual faces. In the case of the shagreen denticles, however, orientation is not a quality characteristic of the category as a whole. Although in many denticles anterior and posterior faces can be recognized from the caudal curvature, in many others there is no means of determining orientation; *Petrodus* belongs to the latter category.

The paleoecology of *Petrodus* has been discussed by Zangerl and Richardson (1963) and by Ford (1964), who agree on a shallow-water, nearshore marine environment with low-energy (or perhaps even zero) currents. According to Zangerl and Richardson, the lack of currents is evidenced, among other indications, by the presence in shale samples containing *Petrodus* of such delicate structures as *Listracanthus* spines that are not oriented and appear intact. Also, Giles (1963), in his paleoecological study of the Francis Formation in Pontotoc County, Oklahoma, reported a shallow-water marine environment with fairly low-energy currents for the stratigraphic levels known to bear *Petrodus.* However, it appears that in this case the currents were relatively stronger than those reported by Zangerl and Richardson (1963), which may account for the greater scarcity of *Petrodus* in the Francis beds.

Although the genus was described more than 120 years ago, its systematic position still remains obscure. Obrutchev (1964) believed that the denticles probably belonged to cochliodonts and other Carboniferous bradyodonts, indicating that he considered *Petrodus* to be a collective genus. Bradley (1870), Demanet (1941), and Woodward (1903) found *Petrodus* in association with *Listracanthus* spines, which led the first two authors to connect the two organ genera as elements that may have belonged to the same organism. Woodward was less decisive in that matter, however, and drew attention to similarities between *Petrodus* and dermal denticles from the head of *Hybodus* (cf. also Woodward, 1889a, p. 246, pl. 8, figs. 2, 3). Finally, Moy-Thomas (1935) identified *Petrodus* as belonging to the family Hybodontidae—an assignation that was followed by Berg (1955), Ford (1964), Blot (1969), and Miles (cf. Moy-Thomas and Miles, 1971).

Of the above assignations, the one suggested by Obrutchev appears to me to be the least probable, because the features of the denticles are too consistent to justify regarding the genus as collective (artificial); also, the suggested bradyodont derivation is objectionable. As far as I know, among the bradyodonts only the denticles of the cochliodont *Helodus* could be superficially compared to those of *Petrodus,* despite the great difference in size. The *Helodus* dermal denticles are poorly preserved and their structure therefore insufficiently known (Moy-Thomas, 1936). However, it is well known that all the hitherto known bradyodont teeth lack pallial dentine (Radinsky, 1961; Patterson, 1965). If we assume its absence also in the bradyodont dermal denticles, it becomes difficult to regard *Petrodus* as a bradyodont, for in this genus the pallial dentine is present.

The *Petrodus*=*Listracanthus* assumption has received attention from Zangerl and Richardson (1963, p. 148, fig. 32), who, basing their interpretation on an analysis of the fossil content of the Mecca quarry, Indiana, concluded that despite certain similarities in occurrence, the vertical distribution of the two genera seems to rule out such a possibility.

In regard to the hybodontoid derivation, only Moy-Thomas (1935) actually examined the Leeds Museum specimen of a hybodontoid shoulder girdle and partial braincase with which the *Petrodus* denticles are associated. Objections have been raised to this assignation (Zangerl and Richardson, 1963, p. 148; Ford, 1964), because it was based on evidence from a single slab only and the assignation to the family Hybodontidae was made only on an apparent resemblance to the pectoral fin of the Jurassic *Hybodus* (Ford, 1964). Nevertheless, however tenuous this assignation may be, it remains the most likely. The *Petrodus* denticles are both externally and internally close to those of *Hybodus* and, except for the Derbyshire specimens, are roughly contemporary with the earliest known hybodontoid remains. With the Pennsylvanian hybodonts so far reported (Fritsch, 1889; Zidek, 1969; Romer, 1952; Lund, 1970) of fresh-water habitat, the paleoecology of *Petrodus* presents a certain obstacle to the hybodontoid derivation. However, the hybodont sharks as a whole are known to have occurred in both fresh and salt water throughout the Mesozoic (cf. Zidek, 1969, for further references), and there is no reason to assume a significantly different situation in the upper Paleozoic.

**Occurrences of Petrodus in the Pennsylvanian of Oklahoma:** Pumpkin Creek Ls. Mbr. of Big Branch Fm. in Johnston Co., CS½ sec. 31, T. 3 S., R. 1 E. (OUSM 00130); lower part of Deese Fm. in Carter Co., C sec. 29, T. 3 S., R. 2 E. (OUSM 00131); Boggy Fm. in Pontotoc Co., NW¼ sec. 27, T. 3 N., R. 7 E. (OUSM 00132), and in Hughes Co., C sec. 6, T. 4 N., R. 11 E. (OUSM 00133); Excello Sh. in Rogers Co. (Branson, 1965); shale of Higginsville age in Tulsa Co., CE line sec. 9, T. 21 N., R. 13 E. (OUSM 00128), and in Hughes Co., C sec. 9, T. 22 N., R. 15 E. (OUSM 00129); Wetumka Fm. in Pontotoc Co., sec. 18, T. 3 N., R. 7 E.; Wewoka Fm. in Pontotoc Co., sec. 33, T. 5 N., R. 8 E., in Hughes Co., N½ sec. 5 and S½ sec. 32, T. 6 N., R. 9 E. (OUSM 00134), in Okfuskee Co., SE¼ sec. 1, T. 10 N., R. 10 E. (OUSM 00135), and in Okmulgee Co., NE¼NE¼ sec. 2, T. 14 N., R. 12 E., and secs. 8 and 18, T. 13 N., R. 12 E. (OUSM 00136); Francis Fm. in Pontotoc Co., Superior Clay Products pit near Ada. **References:** Morgan (1924, p. 83), Stovall (1945), Ries (1954, p. 40), Weaver (1954, p. 29), Branson (1965).

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## USGS Plans Ozark Land-Use Maps

Parts of Oklahoma, Arkansas, Kansas, and Louisiana will be included in the first regional land-use mapping program conducted by the U.S. Geological Survey. A series of 9 desk-size maps, each with 5 separate overlays showing land use, State and county boundaries, river basins, and State and federal land holdings, is planned for a 56,000-square-mile area of the Ozarks. Land-use data will be monitored and updated by imagery gained from NASA's Earth Resources Technology Satellite (ERTS-1), which crosses the Ozarks once every 18 days and provides information on the region's interacting resources and environmental factors.

The rapidly accelerating rate at which rural land in the Ozarks is being converted into suburban and urban living space provided impetus for selection of this area as the first to be mapped. Hopefully, problems of urban blight and urban renewal prevalent elsewhere in our nation will be prevented. The program will be conducted by USGS personnel in cooperation with the Ozarks Regional Commission, and all data collected for the project will be computerized for inclusion in the Ozarks Regional Resources Information System. Local managers and planners will have access to reports on current land-use practices and trends.

Land-use maps will depict information, for instance, on the percentage of undeveloped land along the newly dredged channel of the Arkansas River. The foundation will be laid, then, for informed decisions on the rate and total amount of industrial development that can be allowed while still maintaining desirable amounts of space for other purposes.

The regional mapping program will also provide a test region for the standardized national land-use classification system recently proposed and outlined by the U.S. Geological Survey in Circular 671, *A Land-Use Classification System for Use with Remote-Sensor Data* (see February 1973 issue of *Oklahoma Geology Notes,* v. 33, p. 27).

## AEC Lowers Nuclear Power Forecast

Based on conservative assumptions of population growth and energy consumption, the U.S. Atomic Energy Commission predicts that there will be 132,000,000 kilowatts of nuclear power capacity in the United States by the end of 1980; 280,000,000 kilowatts by the end of 1985; and 1,200,000,000 kilowatts—over 80 times the present level—by the end of the century.

The new forecast for 1980 and 1985 is lower than the last AEC forecast, published in December 1971, because of delays in plant construction and a slight reduction in the growth rate and energy consumption. The delays are considered temporary, and AEC states that although only 4 percent of this country's electricity is provided by nuclear power at the present time, it will account for 60 percent by the end of the century.

The fast breeder reactor is expected to be commercially introduced in both the United States and foreign countries by 1986 and is expected to make up over half the nuclear capacity added after 1995. In conjunction with increased demands for nuclear power, the AEC report examines the anticipated requirements for uranium and the uranium-enriching services for the United States and other noncommunist countries. Worldwide demand is forecast at 81,000 tons of uranium oxide in 1980; 150,000 in 1985; and 337,000 in 2000.

The AEC forecast, *Nuclear Power, 1973-2000* (Wash-1139/72/), is available from the Government Printing Office, Superintendent of Documents, Washington, D.C. 20402.

# CARL A. MOORE
## 1911-1973

**Dr. Moore, holding the Honorary Professorship Diploma awarded to him (March 9, 1964) by the Bolivian Technological Institute for his work with the Peace Corps in that country.**

Dr. Carl Allphin Moore, OU professor of petroleum and geological engineering, died early Saturday morning, April 14, 1973, in Norman Municipal Hospital following a sudden heart attack. He had suffered a previous heart attack in early 1972 but had made a remarkable recovery. Memorial services were held at Bethel Baptist Church in Norman on April 17, and interment was at the IOOF Cemetery.

Carl was born May 23, 1911, in Doniphan, Missouri. He moved with his parents to Heber Springs, Arkansas, and in 1923 he accompanied them to Tulsa, Oklahoma, where they made their home for many years.

Dr. Moore earned a B.S. degree in petroleum engineering in 1936 from The University of Tulsa. In 1938 he received an M.S. in geology from The University of Iowa, where he also completed requirements for the Ph.D. degree in 1940.

He and Mary Catherine Moody were married August 27, 1937, and she and their two children, Willis H. Moore, who lives in Hawaii, and Mrs. Caroline M. Kahoe, of Norman, survive him. Carl was a devoted father and husband whose first priority in life was the welfare and happiness of his family. He was a deeply and sincerely religious person as well, being active in many capacities in the Bethel Baptist Church and the First Baptist Church of Norman and serving as faculty advisor at the Baptist Student Union.

Carl's professional career began in 1939 when he was made research geologist for Standard Oil Development Company in New York City. In 1942 he was transferred to Oklahoma, where he served as a field subsurface geologist for Carter Oil Company until 1946.

In 1946, after working approximately 6 months as a geologist with the Oklahoma Geological Survey, he joined the faculty of the School of Geology and Geological Engineering at The University of Oklahoma. He was named chairman of the School of Geological Engineering in 1946 and served in that capacity until 1962. From 1962 to 1964, he served as the University's administrator for a Peace Corps health and sanitation project involving 25 small villages in Bolivia. He returned to OU in 1964 as professor of geological engineering, a position which he held until his death.

Carl Moore was a dedicated teacher. His major interests were in petroleum and subsurface geology, and he developed and taught several popular and informative courses in these fields, including a recently instituted energy-fuels field course for petroleum and geological engineers. He introduced a course in applied oceanography for engineers. During the summer sessions between 1949 and 1962 he taught at the Oklahoma Geology Field Camp, which he had been instrumental in establishing, near Canon City, Colorado. His dedication to the teaching profession brought him well-deserved recognition. He received a $500 award for outstanding teaching in 1953, the Standard Oil of Indiana Teaching Award ($1,000) in 1970, and the Brandon Griffith Award for the outstanding engineering professor in 1972.

Dr. Moore was a member of The American Association of Petroleum Geologists, the Society of Economic Paleontologists and Mineralogists, the Oklahoma City Geological Society, and the American Scientific Affiliation. He served as faculty sponsor of the OU Society of Geological Engineers from 1946 to 1962 and was active in the Society of Petroleum and Geological Engineers from 1964 until his death.

Carl had done recent research on the origin and behavior of helium, but most of his research activity was devoted to directing graduate student research. During his busy career, however, he found time to present many papers and write scientific publications (see bibliography) including a textbook, *Handbook of Subsurface Geology*, published in 1963 by Harper and Row.

Carl Moore was well liked by his students and respected by his colleagues and members of the geological profession. He was an industrious worker, a sincere and devoted teacher, and a loyal friend. His memory is deeply engraved in the hearts and minds of those who knew him. The University of Oklahoma has lost one of its most dedicated faculty members.

*—George G. Huffman*

## Publications by Carl A. Moore

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1945 Subsurface geologist: The Link (Carter Oil Company, Tulsa, Oklahoma).

1947 The Morrow series of northeastern Oklahoma: Oklahoma Geological Survey Bulletin 66, 151 p., illus., index map, geologic maps. (Abstract in Tulsa Geological Society Digest, v. 16, p. 79-80.)

Some geological applications of the electron microscope: Oklahoma Academy of Science Proceedings, v. 27, p. 86-90, illus.

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Norman, Oklahoma, University of Oklahoma Extension Division, 115 p., illus.

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1958 Electron-microscopic analysis, chapter 8 of Haun, J. D., and LeRoy, L. W. (editors), Subsurface geology in petroleum exploration—a symposium: Golden, Colorado, Colorado School of Mines, p. 141-148, illus. (Revised from Colorado School of Mines Quarterly, v. 44, no. 3.)

1959 (editor) Proceedings of the sixth biennial geological symposium: Norman, Oklahoma, University of Oklahoma Extension Division, 175 p., illus.

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1965 (with L. L. Albano), Relation of Physical and geochemical factors to porosities in sandstones of the Bromide (Simpson) of Oklahoma, in Symposium on the Simpson: Tulsa Geological Society Digest, v. 33, p. 90-108, illus., tables.

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1968 (with P. S. Orlando), Geologic factors which affect deep drilling: World Oil, v. 167, no. 6, p. 94-98, 3 figs.

1969 The occurrence of oil in sedimentary basins: World Oil, v. 168, no. 1, p. 69-72; v. 168, no. 2, p. 46-48, illus.

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## REASONS FOR SUBMITTING MANUSCRIPTS IN GOOD CONDITION

Understanding how the condition of a manuscript affects its acceptability for publication is vital to both authors and publishers. Converting manuscripts into publications is becoming more and more costly—at a time when an overwhelming amount of scientific literature is produced. When printing budgets fail to keep pace with rising costs, publishing problems become more acute, and adjustments become necessary. One fairly evident trend is that the percentage of manuscripts accepted for publication will decrease, even though the number of manuscripts published will not.

When the number of manuscripts produced exceeds the capacity of publication resources—a "publisher's market"—editors tend to become even more selective. Competition for publication resources becomes keener; higher standards are established. Mediocre work cannot be published.

Poorly prepared copy is unacceptable, especially when it contains numerous handwritten changes. It is difficult to review and evaluate, and even more difficult to edit and print. Poor manuscript copy is the breeding ground for mistakes and the most likely means of perpetuating errors in print. Poor copy can add 30 percent to typesetting costs alone! With high page costs cutting deeply into shrinking budgets, publishers simply are not going to bear the burdens of poorly prepared copy.

Another criterion which influences acceptability of manuscripts is completeness—and for the same reasons: time and expense. Incomplete manuscripts cannot be expedited. Valid reviews cannot be consummated when figures, cutlines, maps, contents, abstracts, references, appendixes, photographs, or drawings are missing. Editors and reviewers have many responsibilities, but rounding up unfinished or unprepared items is not one of them. Any author expecting acceptance and expeditious handling must "get it all together" before submitting a manuscript. This also minimizes loss of materials, some of which may be irreplaceable. But perhaps the worst result is that incomplete manuscripts lead to delays and compromised standards.

Editors generally have a feeling for the amount of effort that has gone into preparation of a manuscript. They are also aware that carelessness on the part of the author requires time and expense to correct and that, in the end, corrections are made at the expense of other manuscripts in press.

Suppose we could disregard altogether the economic necessity for authors to submit well-prepared copy. How about other reasons, perhaps more compelling? The condition of a manuscript submitted for publication conveys something about the author's attitude and commitment, his thoroughness, his consistency, and accuracy. It reflects on his capability of documenting his work. Committing research to the printed page requires hard work; polishing drafts for publication is a wearisome task. Persons experienced in publishing, including authors, know that in the usual editorial and printing operation, GOOD COPY GETS BETTER. Authors are encouraged, as much as possible, to do their own editing. One of the long-term benefits will be better manuscripts, better writing, and better means of communicating—which, after all, is the common goal.

—*R. W. Kelley*

(**Editor's note:** Although Bob Kelley formulated these pointers for the benefit of authors submitting manuscripts to the New Mexico State Bureau of Mines and Mineral Resources, we felt they were applicable to everyone who writes for scientific publication. We expect that authors will appreciate knowing some of the reasons why editors insist on high manuscript standards.)

## Tornado Delays Environmental Information Symposium

The Southwest Environmental Information Symposium, originally planned for the first week of May, has been postponed until July. Sessions have been rescheduled for July 11-13 at East Central State College in Ada, Oklahoma, as a result of the April 20 tornado that struck Ada.

The symposium is designed to bring environmental specialists together with information and library specialists for discussion of more effective methods of categorizing, managing, and disseminating environmental information. Activities scheduled the first day include registration (1-5 p.m., July 11) and a welcoming banquet featuring Henry Kissman, associate director of the National Library of Medicine, Bethesda, Maryland, as the keynote speaker. Sessions and chairmen for the concluding two days are: Defining Environmental Information — Robert Fite, director of Programs for Professionals, Oklahoma State University, Stillwater; Identifying Users and Applications — John Wells, Office of the Governor, Information Services, Austin, Texas; Report on the Cincinnati Symposium — Sarah Thomas, chief of the library systems branch of the U.S. Environmental Protection Agency, Washington, D.C.; Information/Data Management, Control, and Dissemination — Raymond A. Jenson, manager of the Water Resources Scientific Information Center, U.S. Department of the Interior, Washington, D.C.; and System Concepts—National, Regional, State — Lee B. Zink, director of the Bureau of Business Research, Albuquerque, New Mexico. Peter House, director of the Environmental Studies Division, Washington, D.C., will chair the final session, consisting of a panel discussion intended to critique the symposium, and address a few concluding remarks. In all, approximately 35 speakers will take an active part in the program, and registrants will also have an opportunity to comment and ask questions.

The registration fee is $25. All persons interested in the generation, handling, and application of environmental information are encouraged to attend. For further information, contact Doyle L. Caton, Box D-2, East Central State College, Ada, Oklahoma 74820 (phone: 405/332-8000, ext. 3088).

# THE ARMS OF *Ulocrinus buttsi*

HARRELL L. STRIMPLE[1]

While I was stationed in Scotland with the U.S. Army Signal Corps during World War II, a paper dealing with the inadunate crinoid family Cromyocrinidae was conceived by the late James Wright and myself.

A rather delicate form from the Viséan of Scotland described as *Poteriocrinus bockschii* Geinitz, 1846, possesses morphologic cup features sufficiently similar to those of the genus *Ulocrinus* that Wright in 1927 ascribed the species to *Ulocrinus,* illustrating at the same time a series of specimens exhibiting variable cup shapes and arrangements of anal plates. The highly variable nature of *Ureocrinus bockschii* was discussed by Wright and Strimple (1945, p. 226), who noted that most of the variant specimens of this and associated crinoids were found in the Seafield Tower Limestone and had been apparently subjected to very unsettled conditions. Considering the fact that the examination of more than 542 specimens of *U. bockschii* showed the norm to be highly advanced (radianal supporting both anal *X* and *RX* above), it is doubtful that environment caused the advanced placement of anal plates. Even so, it is not possible to reject completely the possibility that a more "primitive" form survived.

*Ulocrinus buttsi* is the type species of *Ulocrinus,* and I recalled that my collection from the Wann Formation (Pennsylvanian, Missourian) of Oklahoma includes a specimen that had 10 arms and 2 anal plates; this specimen will be discussed more fully later. *U. bockshii* has 5 arms and 3 anal plates in advanced arrangement.

Yet another form, *Cromyocrinus* Trautschold, 1867, has 5 uniserial arms, but there are 3 anal plates in normal arrangement (radianal oblique on right side of *CD* [posterior] basal, supporting *RX* above and anal *X* [which also rests on *CD* basal] to the left). *C. simplex* Trautschold, type species of the genus, is from the Moscovian (Middle Pennsylvanian) of Russia and has a large bowl-shaped cup. The infrabasal circlet of *Cromyocrinus* is gently upflared or planate, whereas in *Ulocrinus* it is decidedly upflared.

The genus *Ureocrinus* Wright and Strimple, 1945, was proposed, with *Poteriocrinus bockschii* as the type species. No species of the genus is recognized in North America, but it has been reported from England, Scotland, and Germany. It is possible, therefore, that *Ureocrinus* is in the lineage leading to *Cromyocrinus,* which is typically a Russian species. A form from the Morrowan Series (Lower Pennsylvanian) of Arkansas and Oklahoma, *C. grandis* Mather, 1915, is assigned to *Cromyocrinus,* although the arms are unknown.

The previously mentioned hypotype of *U. buttsi* Miller and Gurley from the Wann Formation (Missourian), collected at the Mound on the west edge of Bartlesville in Osage County, Oklahoma, was

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[1] Research associate and curator, Geology Department, The University of Iowa, Iowa City.

photographed by a friend, Dr. Daniel J. Jones, and prints were sent to me in Scotland. I knew the proximal portions of the arms (those close to the cup) were uniserial as were those in the small portions of arms in a young specimen of *U. convexus* (Strimple, 1939, pl. 1, figs. 12, 16). The prints were poor, but Wright (with my approval) inked in sutures as though all the brachials were semiquadrate (uniserial). The result showed 13 uniserial secundibrachs in one half ray, as illustrated by Wright and Strimple (1945, pl. 19, figs. 8, 9). A new photograph is presented herein (fig. 1), in which a thin layer of

**Figure 1.** Ulocrinus buttsi **Miller and Gurley, 1890. Hypotype specimen consisting of dorsal cup and proximal portions of arms from Wann Formation of Pennsylvanian age in northeastern Oklahoma. Viewed from posterior, ×2.2. "Extra" plates in midportion of cup are radianal to right and anal X to left.**

caliche obscures some of the details. An application of glycerin was used to sharpen the sutures, after which a camera lucida drawing was prepared of one half ray. This illustration (fig. 2) shows a large secundibrach *1* followed by three quadrate secundibrachs with the third angled in distal portion for the reception of the first wedge-shaped brachial; thereafter, the brachials are biserial with equality of adjacent brachials attained by secundibrach *9*.

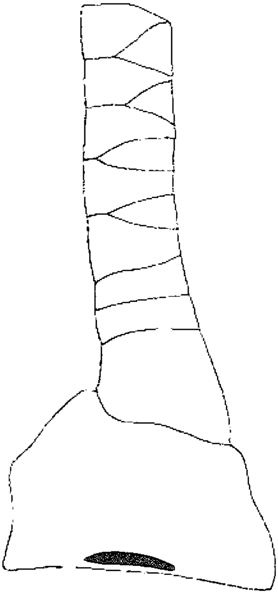

**Figure 2. Camera lucida drawing of right half ray of right posterior (C ray) arm of** Ulocrinus buttsi **showing uniserial nature of proximal brachials, changing distalward to incipiently biserial to equibiserial, ×3. Lowermost segment is axillary primibach** 1.

The hypotype of *U. buttsi,* now reposited in the National Museum of Natural History, is closely comparable to the holotype in that the radianal has lost contact with *BC* basal (right posterior); however, the radianal has not completely cut off contact between anal *X* and *CD* basal (posterior). *U. convexus* differs from these type specimens in that the radianal has broad contact with *BC* basal and anal *X* has strong contact with *CD* basal.

A hypotype of *U. convexus* from the LaSalle Limestone Member of the Bond Formation (Pennsylvanian) of Illinois has been illustrated by Strimple and Moore (1971, pl. 17, figs. 3a, b), in which the arms are biserial.

Various terminology used herein may be found in Moore and others (1952, p. 606-608) except for orientation of the cup, which is defined by Moore (1962), wherein anterior = *A,* right anterior = *B,* right posterior = *C,* left posterior = *D,* and left anterior = *E,* with combinations of appropriate letters for interrays.

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## Survey Geologist to Conduct Energy Fuels Course

Again this summer, The University of Oklahoma is conducting three 1-week courses on energy fuels of the Piceance basin. Oklahoma Geological Survey geologist Kenneth S. Johnson has been selected to instruct the course, which will be held July 29-August 18 in Grand Junction, Colorado.

The courses are sponsored by the OU School of Petroleum and Geological Engineering and are arranged as a combination field course and workshop. The first week, personnel from the Atomic Energy Commission and from private industry present information on exploration, production, and processing of uranium ores. Oil shales and nuclear stimulation are spotlighted the second week, with on-site investigations of geologic occurrences and a visit to the Rio Blanco Project area on Fawn Creek scheduled. Solid hydrocarbons provide the topic for the third week, and the stratigraphic analysis of the Piceance basin is completed.

Enrollment can be on a weekly basis or for the entire sequence, with graduate or undergraduate credit available and varying from 1 to 3 hours at the rate of 1 hour of credit per week of instruction. For additional information, contact Dr. Johnson at the Oklahoma Geological Survey, 830 Van Vleet Oval, Norman, Oklahoma 73069.

## OGS Cartographic Staff Changes

John Langford has rejoined the cartographic staff of the Oklahoma Geological Survey after a 2-year absence. He had previously worked for the OGS from March 1969 to June 1971.

John replaces Marion E. Clark, senior cartographer, who resigned after 16 years of service to take a position as sales engineer with Keuffel and Esser. She is a resource specialist for K & E's mapping division and will draw upon her experience with the Survey in conducting seminars and staffing exhibits to demonstrate new mapping techniques and supplies. Although she is primarily responsible for a six-state area (Missouri, Kansas, Oklahoma, Arkansas, Texas, and Mississippi), she is also expected to be on hand for a number of national conventions or workshops where K & E demonstrates equipment.

The Survey extends best wishes to Marion and a hearty welcome back to John.

# ENVIRONMENTAL GEOLOGY TOME RELEASED BY TULSA GEOLOGICAL SOCIETY

*Tulsa's Physical Environment* is the subject of a volume recently published by the Tulsa Geological Society. New in focus, this book is a model study in environmental geology, applying geologic principles to urban planning and development, and should prove a worthy example for future efforts in other localities. The 60 papers—by 40 authors—encompass geology, hydrology, soils, resources, drainage and engineering problems, and construction conditions.

Major efforts in preparing this 489-page symposium were put forth by the editor, A. P. Bennison, and associate editors W. V. Knight, W. B. Creath, R. H. Dott, Sr., and C. L. Hayes. Contributing authors include scientists and professionals from independent companies, major Oklahoma universities, several oil companies, the Oklahoma Geological Survey, the U.S. Geological Survey, the National Weather Service, the U.S. Soil Conservation Service, and Tulsa city and county governmental agencies.

Geologic information is absolutely essential to proper planning, and this symposium does an excellent job of presenting basic data in a form that can be understood by interested nongeologists who must make decisions based partially on geologic considerations. The editors and authors have done a fine job of showing the significance of geologic parameters in environmental problems. Planners and developers should be particularly pleased with the articles describing soil conditions, corrosion aspects, drainage and flood-plain problems, construction conditions, waste disposal, and ground-water conditions. Prospective home buyers can prevent costly mistakes by utilizing the checklist of important physical characteristics to examine before purchasing property.

Cartography for four large maps accompanying the publication was done by the Oklahoma Geological Survey under a cooperative agreement with the Tulsa Geological Society. The maps, printed in color, include an areal geologic map with Bouguer gravity contours, a general soil map, a construction map, and a map showing the locations of oil and gas wells and fields. Cartographers on the project were Marion E. Clark, Sondra Underwood, and John Langford. John F. Roberts, petroleum geologist for the Survey and a TGS member, served as liaison between the society and the Survey.

Other contributions to the volume from the Survey and the OU School of Geology and Geophysics included articles on paleontology by L. R. Wilson, Jiri Zidek, and Carl C. Branson.

*Tulsa's Physical Environment* is published as Volume 37 of the *Tulsa Geological Society Digest*. The complete volume, with maps, can be ordered from the Tulsa Geological Society, Suite 116, Midco Building, Tulsa, Oklahoma 74103. The price, which includes postage and handling, is $10.70 to TGS members and $12.70 to nonmembers.

*—Kenneth S. Johnson*

# OKLAHOMA ABSTRACTS

## GSA ANNUAL MEETING, NORTH-CENTRAL SECTION
## COLUMBIA, MISSOURI, APRIL 11-14, 1973

The following abstracts are reprinted from the North-Central Section Program of The Geological Society of America and Associated Societies, v. 5, no. 4. Page numbers are given in brackets below each abstract. Permission of the authors and of Mrs. Jo Fogelberg, managing editor of GSA, to reproduce these abstracts is gratefully acknowledged.

### Possible Diachronism of the Saukia Zone-Missisquoia Zone Boundary, a Biomere Boundary, between Oklahoma and Alberta

JAMES R. DERBY, Amoco Production Company, P.O. Box 591,
Tulsa, Oklahoma 74102

By definition, the change from one biomere to another may be diachronous; but to date, only the base of the Pterocephalid biomere has been shown to be diachronous. However, the interval containing the change from the Upper Cambrian Ptychaspid biomere to the unnamed biomere beginning with the Lower Ordovician *Missisquoia* Zone presents a unique opportunity for demonstrating diachronism because of the presence of other biostratigraphically useful groups.

In order to demonstrate diachronism, either the trilobite biomere boundary should appear to cross time lines established by other taxonomic groups, or, adjacent to the boundary, species teilzones should be missing locally, with the absence of an older zone in the younger (upper) biomere compensated by the presence of a complementary younger zone in the older (lower) biomere.

Comparison of Cambro-Ordovician boundary sections in Oklahoma and Alberta suggests the possibility of diachronism at the biomere boundary. In Oklahoma, the basal *Missisquoia* Zone is characterized by the teilzones of *Plethopeltis arbucklensis* and *Missisquoia depressa*. Slightly higher *Apoplanias rejectus, Apheoorthis ornata,* and *Fryxellodontus inornatus* simultaneously make their first appearance. At Mt. Wilson, Alberta, *A. rejectus* and the other two non-trilobite species are the basal elements of the *Missisquoia* Zone and hence of

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

the "Ordovician trilobite biomere"; apparently the teilzone of *P. arbucklensis* is missing. This means that either the change from the Ptychaspid biomere to the "Ordovician biomere" occurred slightly later in Alberta than in Oklahoma, or there is a hiatus in the Alberta section. Study of additional sections is needed to determine the answer. [311]

## Traverse in Late Cambrian Strata from the St. Francois Mountains, Missouri to Delaware County, Oklahoma[1]

VINCENT E. KURTZ, Department of Geography-Geology, Southwest Missouri State University, Springfield, Missouri 65802, JOSEPH L. THACKER and KENNETH H. ANDERSON, Missouri Division of Geological Survey and Water Resources, P.O. Box 250, Rolla, Missouri 65401, and PAUL E. GERDEMANN, St. Joe Minerals Corporation, Bonne Terre, Missouri 63628

Studies of late Cambrian strata in the subsurface of southern Missouri and adjacent areas, utilizing megascopic core examinations, insoluble residue techniques and faunal information, reveal a series of regionally persistent lithic units which may change facies abruptly.

Along the line of cross section, sediments of varying ages rest on a Precambrian terrane of high silica igneous rocks. The Cambrian section thickens to a maximum in Douglas County, Missouri, reflecting progressive increase in stromatolite content and associated reef and calcarenite buildups. West of the area of thickest Cambrian the Lamotte Sandstone pinches out against a westward rising land surface and the Bonneterre and Davis Formations change facies to a time-transgressive clastic section interpreted as the Reagan Sandstone with the Derby-Doerun Dolomite ultimately resting on the latter formation in Delaware County, Oklahoma. East of Douglas County the Lamotte Sandstone shows a regional thinning toward the St. Francois Mountains but local relief on the Precambrian strongly influences Lamotte thickness.

Bonneterre strata maintain a generally uniform thickness along the cross section from Wright County eastward. To the west the Bonneterre thins to Taney County and then all but the uppermost part of the formation changes facies to a nearshore clastic section in Carroll County, Arkansas. Lower Bonneterre strata are a sandy and shaly "zone" transitional with the Lamotte. The bulk of the Bonneterre Formation is a micrite with contiguous oolitic facies and shale facies. The upper part of the Bonneterre Formation consists of a micrite and siltstone unit, the Sullivan Siltstone Member (new), overlain by a heterogeneous shale, limestone, sandy and glauconitic unit, the Whetstone Creek Member (new).

Post-Bonneterre Cambrian sediments thicken toward Douglas County and here change character to what is interpreted as a very shallow water reef and calcarenite facies. The Derby-Doerun Dolo-

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[1] Abstract updated at authors' request.

mite maintains its lithologic character across Douglas County but expands downward as a reef and calcarenite facies of the shaly Davis Formation. The Potosi and Eminence Dolomites, characterized by "quartzose" chert (micro-druse) residues elsewhere, change character in the Douglas County holes, the Potosi to a "green clay residue facies" and the Eminence to a "spongy chert residue facies." The Gunter Sandstone contains more carbonate from Douglas County eastward. [329-330]

### A Biometrical Study of Morphology and Development of a New Species of Terpnocrinus Strimple and Moore from the Missourian of Nebraska

ROGER K. PABIAN, Conservation and Survey Division, University of Nebraska, Lincoln, Nebraska 68508, and HARRELL L. STRIMPLE, Department of Geology, The University of Iowa, Iowa City, Iowa 52240

Thirty dorsal cups of a yet to be described species of *Terpnocrinus* Strimple and Moore have been collected from the Kiewtz Shale Zone, Stoner Limestone Member, Stanton Formation, Lansing Group, Missourian Stage, Upper Pennsylvanian, exposed in four quarries along the Lower Platte River Valley in Cass and Sarpy Counties, Nebraska.

A dominant isometric growth pattern is indicated by rectilinear point distributions among nine pairs of measurements taken on dorsal cups. Changes in morphology during development include a change in outline of the dorsal cup from a medium-high cone to a medium-high truncate bowl. This is brought about by material being added interradially at a much greater rate than it is added between adjacent basals.

The new species of *Terpnocrinus* has also been collected from the upper part of the Stanton Limestone in Wilson County, Kansas, and from the Wann Formation, Ochelata Group, Missourian Stage, Upper Pennsylvanian, exposed at "The Mound," Osage County, Oklahoma. [342-343]

### Zinc, Lead and Cadmium in Reservoir Sediments

FRANK W. PITA and NORMAN J. HYNE, Department of Earth Sciences, University of Tulsa, Tulsa, Oklahoma 74104

All Oklahoma reservoirs investigated have a higher concentration of zinc and lead in their sediments than in the surrounding, subaerial soils. Reservoirs located downstream from a lead-zinc mining district have the highest concentrations of these metals in their sediments.

Zinc and lead content strongly correlates with percent organic carbon, percent clay-sized material and mean grain size of the sediments and depth of water. Zinc is considerably more abundant than lead in the sediments. Cadmium is least abundant but is concentrated in the deep areas of the reservoirs.

The sediments were physically separated into three portions on the basis of their specific gravity. These are: 1) less than 2.0 specific gravity (dominantly free organic material), 2) between 2.0 and 2.9 specific gravity (primarily clay minerals with adhered organic material) and 3) above 2.9 specific gravity (assumed to be primarily metallic sulfides). These were analyzed for zinc content. The amount of zinc in the above 2.9 specific gravity portion was relatively small and is accumulating at relatively uniform rates in all reservoirs. It is suggested that this portion is transported as airborne dust. More zinc is contained in the less than 2.0 specific gravity portion than the greater than 2.9 specific gravity portion but the largest concentration is in the 2.0 to 2.9 specific gravity portion. It is suggested that zinc is concentrated in reservoir sediments by adsorption onto clay-organic complexes accumulating in reservoirs. [343]

## Earliest Ordovician Trilobites, Wichita Mountains, Oklahoma

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A more abundant and diverse earliest Ordovician trilobite fauna has been recovered from the upper half of the Signal Mountain Formation in the Wichita Mountains than was previously reported from the same interval in the Arbuckle Mountains in Oklahoma.

The Signal Mountain-McKenzie Hill transition is not dolomitized in the Wichita Mountains as it is in the Arbuckle Mountains, and there is now faunal information for this formerly "barren" interval.

The earliest Ordovician zone, the *Missisquoia* Zone, is characterized by two species of *Missisquoia* and species of *Plethopeltis, Homagnostus, Apoplanias,* and one new unassigned species. The overlying *Symphysurina* Zone is characterized by four species of *Symphysurina* and species of *Hystricurus, Highgatella, Clelandia* and one unassigned species. The appearance in the upper 50 feet of the Signal Mountain of *Parabellefontia* (?) and *Symphysurina bulbosa* Lochman may mark the base of Zone B of Ross, usually characterized by *Bellefontia* and *Xenostegium.*

This sequence of basal Ordovician zones is widely recognizable on the North American craton, as recently documented by Derby, Lane and Norford. The fauna of the *Missisquoia* Zone can be collected wherever the interval spanning the Cambrian-Ordovician boundary consists of even moderately fossiliferous rocks. The *Symphysurina* Zone in the Wichita Mountains is correlative with Zone A of Ross and the lower part of Zone B of Hintze. [353-354]

## The Occurrence of Mooreocrinus Wright and Strimple in North America

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The genus *Mooreocrinus* Wright and Strimple has only been recognized with certainty from the Moscovian Series near Moscow, Russia, represented by *Mooreocrinus geminatus* (Trautschold), the type species, and from the Itaituba Series at Santana on the River Tapajos, State of Pará, Brazil, represented by *Mooreocrinus mendesi* (Lane). A specimen, ascribed to *Mooreocrinus mendesi,* from the Millsap Lake Formation (Desmoinesian) of Parker County, Texas, is discussed as well as an undescribed species from the upper Missourian Series of Washington County, Oklahoma. The ten rectiuniserial arms and lack of pronounced surface ornamentation serve to distinguish *Mooreocrinus* from the closely related *Dicromyocrinus* Jaekel which typically has nodose surface ornamentation and incipiently biserial arms. Comparisons are made with some closely related forms, such as *Cromyocrinus* Trautschold and *Parulocrinus* Moore and Plummer. [354]

## Biostratigraphic Potential of the Arbuckle Mountains Sequence as a Reference Standard for the Midcontinent Middle and Upper Ordovician

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Conodonts are abundant in the Middle and Upper Ordovician of the Arbuckles, Oklahoma. The Joins and Oil Creek formations (lower M. Ordovician) yield specimens of *Prioniodus, Multioistodus* and several simple cone species. McLish and Tulip Creek strata produce *Phragmodus* n. sp. and *Polyplacognathus friendsvillensis. P.* n. sp. and *Polyplacognathus sweeti* characterize the lower half, and *Phragmodus inflexus* the upper half of the Lower Bromide. The Upper Bromide yields fibrous conodonts. Viola and Sylvan samples have *Phragmodus undatus,* other Midcontinent forms, and a few North Atlantic-type conodonts.

Conodonts indicate general equivalence of the Joins-Oil Creek and the Whiterock, which is absent in most of the Midcontinent and Appalachians. The McLish and Tulip Creek, above basal sands, are probably entirely Chazyan. The lower half of the Lower Bromide, with *Phragmodus* n. sp., may be Chazyan or between type Chazy and type Black River. *Prioniodus gerdae,* in upper half of Lower Bromide, suggests that the *P.* n. sp.-*P. inflexus* boundary in mid-Lower Bromide approximates the *variabilisgerdae* boundary of North Atlantic conodont zonation (=approx. *multidens-gracilis* boundary of standard graptolite zonation). Upper Bromide fibrous conodonts are of types widespread in Black River rocks, and Viola-Sylvan conodonts indicate correlation with post-Black River Ordovician rocks elsewhere in North America.

Despite a few gaps, the Arbuckle Middle and Upper Ordovician sequence seems continuous in critical intervals. It may be a better primary reference standard than the geographically scattered sections in eastern North America with which correlations must now be made. [355]

### Geographic Distribution of Conodont Faunas in Parts of the Lower Shawnee Group (Upper Pennsylvanian) of the Mid-Continent Region, U.S.A.

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In the Shawnee Group of northeastern Kansas the *Neoprioniodus conjunctus* and *Lonchodina* conodont biofacies are restricted to and dominant in the Heebner and Plattsmouth members of the Oread Formation respectively. The distinctive lithologies of these widely distributed and stratigraphically well-defined members made it of interest to study the geographic distribution of their seemingly characteristic faunas.

Preliminary results of sampling these members in surface exposures in Oklahoma, Kansas, Missouri, Nebraska and Iowa indicate that the *N. conjunctus* biofacies characterizes the Heebner Shale throughout Kansas, Missouri and Nebraska; however, although this biofacies still characterizes the lower Heebner in western Iowa, the upper portion of the Heebner in this area is dominated by the *Gondolella* biofacies. The discovery of the *Gondolella* biofacies in the Heebner Shale is particularly significant, because in the Shawnee Group elements of this biofacies have previously been found only in the Queen Hill Shale. In northern Oklahoma, the "typical" Heebner fauna is possibly replaced by the *Cavusgnathus* biofacies. The *Lonchodina* biofacies is found throughout most of the extent of the outcrop belt of the Plattsmouth Limestone; however, in southern Kansas where the Plattsmouth consists of phylloid algal-mound complexes conodont abundances decrease sharply and the *Lonchodina* biofacies is only poorly represented.

Preliminary results of geographic studies of conodont distributions indicate that the faunas of particular members may differ in different geographic areas and that the elements of one biofacies may replace another, despite the fact that there may be little apparent change in lithology. [360-361]

## GSA ANNUAL MEETING, NORTHEASTERN SECTION
## ALLENTOWN, PENNSYLVANIA, MARCH 21-24, 1973

The following abstract is reprinted from the Northeastern Section Program of The Geological Society of America and Associated Societies, v. 5, no. 2. The page number is given in brackets below the abstract. Permission of the authors and of Mrs. Jo Fogelberg, managing editor of GSA, to reproduce the abstract is gratefully acknowledged.

### Stratigraphy of the Wreford Megacyclothem (Lower Permian) in Southernmost Kansas and Northern Oklahoma

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Extension of Wreford Megacyclothem stratigraphic units (well-known in Kansas) southward into Oklahoma, as well as concomitant clarification of their complex interrelationships, has resulted from recent detailed examination of appropriate localities during bryozoan and brachiopod paleoautecologic studies.

Wreford units recognized in southernmost Kansas (Cowley County) persist into northernmost Oklahoma. About 10 miles below the state line, the entire Speiser, middle and upper Havensville, upper Schroyer, and Wymore pass into interbedded red shale and red sandstone. A newly discovered, poorly exposed marine tongue—extending to about 40 miles below the border—consists of algal-molluscan limestone (lower Schroyer) overlain by gray-yellow mudstone (middle Schroyer). Another marine tongue, prominently exposed, consists of two algal-molluscan limestones (lower Threemile and lower Havensville) bracketing a thin brachiopod-molluscan limestone (middle and upper Threemile), and extends to about 50 miles below the border. Both tongues pass through tan quartzose sandstone and/or red clayey molluscan limestone as they grade southward into red shale and red sandstone.

Overall, the Oklahoma (unlike the Kansas) Wreford is dominated by relatively few rock types. Next to red shales interbedded with red sandstones, the most conspicuous are pelecypod-burrowed algal-molluscan limestones which southward contain progressively more molluscs, fewer lophophorates, more algally or inorganically coated grains (*"Osagia"*), and more fine quartz sand. These limestones may partly represent calcarenite shoals in the Wreford sea, immediately offshore from the coastal plain to the south. [163]

## GSA ANNUAL MEETING, SOUTH-CENTRAL SECTION
## LITTLE ROCK, ARKANSAS, APRIL 5-7, 1973

The following abstracts are reprinted from the South-Central Section Program of The Geological Society of America and Associated Societies, v. 5, no. 3. Page numbers are given in brackets below each abstract. Permission of the authors and of Mrs. Jo Fogelberg, managing editor of GSA, to reproduce these abstracts is gratefully acknowledged.

### The Generation of Explicit Parameters for Quantitative Geomorphic Investigations[1]

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A quantitative geomorphic investigation of the Mill Creek drainage basin in south-central Oklahoma indicated the need for con-

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[1] Publication authorized by the director, Bureau of Economic Geology, The University of Texas at Austin.

sistent definitions of several terms and parameters. The Mill Creek drainage basin was subdivided into 62 component basins which comprise 84 percent of its total area. Each component basin was evaluated quantitatively and compared with an analysis of the entire Mill Creek drainage basin.

Such terms as main channel, major basin, component basin, and subbasin are defined in a manner that will provide a standardization for communication between investigators and produce results that can be duplicated by different workers. Elongation ratios and relief ratios are calculated with explicit divisors. The most important divisor is the *total of average stream lengths.* This divisor is the cumulative length of the average lengths for the stream segments of each order. The elongation and relief ratios calculated by the *total of average stream lengths* provide values that are representative of the complete stream system within a drainage basin. [249-250]

## Remarks on the Age of the Everton and Smithville-Blackrock Formations of Arkansas and Correlation to Oklahoma Formations

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Since 1964 various workers at Amoco Research Center have studied aspects of the Lower and Middle Ordovician section in Arkansas and Oklahoma. This paper presents some of the results of this work.

Recently Wise and Yochelson demonstrated that the Smithville and Blackrock formations are laterally equivalent and youngest Early Ordovician in age. Trilobites and brachiopods in samples supplied me by O. A. Wise and review of older works by Ulrich and Cooper confirms their interpretation and indicates correlation with the youngest Early Ordovician beds of the West Spring Creek Formation in Oklahoma. Re-analysis of Ulrich and Cooper's work suggests that parts of the Cotter and Powell formations may be equivalent to the Smithville-Blackrock. The Smithville-Blackrock and West Spring Creek faunas appear to correlate with the Zone J faunas of the Great Basin, however this correlation needs additional study.

The Everton Formation, at ten localities in Arkansas and Missouri, is clearly of Middle Ordovician, but pre-Chazy (pre-Marmor), age. The lower Everton contains a conodont fauna which correlates with the Whiterockian uppermost West Spring Creek and lower Joins formations of Oklahoma. The upper Everton contains a fauna correlative with the upper Joins and Oil Creek of southern Oklahoma and the lower Tyner of northeast Oklahoma. The disconformity at the top of the Everton, below the St. Peter Sandstone, would appear to represent approximately the same time interval as the disconformity between the Oil Creek and McLish formations of Oklahoma. Therefore the St. Peter in Arkansas may be equivalent to the basal McLish sandstone in Oklahoma. [254-255]

## Evolution of Folds in the Blaylock Formation, Ouachita Mountains, Southeastern Oklahoma

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The Blaylock Formation is a tightly folded Silurian turbidite sequence exposed in southeastern Oklahoma around the southwestern end of the Broken Bow-Benton uplift in the Ouachita Mountains. Trends of the fold axes around the uplift are parallel to the structural trends in the central and frontal Ouachitas to the north and west. Large-scale folds in the Blaylock Formation are asymmetric and overturned southward from the craton. In these folds, ratios of the length of the long limb to the short limb and the degree of southward overturning decrease northward. Minor folds with an anomalous sense of asymmetry occur in the steep, short limbs of the large folds and are not as tightly folded as the minor folds in the upright limbs. The sense of asymmetry of the minor folds is the same in both limbs of the large folds. Slaty cleavage in the large Blaylock folds is parallel with bedding in the upright limbs and cuts bedding at a high angle in the short, steep limbs. In the steep limbs, a north-dipping cleavage is nearly parallel with the axial plane of the large folds, and a south-dipping cleavage is nearly parallel with the axial plane of the minor folds.

It is proposed that the asymmetric minor folds in the Blaylock were produced by a simple shear strain component modifying pre-existing small-scale buckle folds. A continued simple shear strain component with variations in the attitude of the shear plane must have asymmetrically folded the Ordovician through Devonian sequence, forming the large folds in the Blaylock and accentuating pre-existing minor folds in the upright limbs and partially unfolding them in the steep limb. [256-257]

## Correlation of Carboniferous Rocks of the Ouachita Geosyncline with Those of the Adjacent Shelf

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Field studies, literature review, and examination of fossil collections from the Ouachita, Arbuckle, and Ozark regions lead to the following conclusions as to contemporaneity of the trough and shelf rocks.

Early Mississippian time was marked by deposition of the upper part of the Arkansas Novaculite in the Ouachita trough and of the Boone Formation and minor pre-Boone rocks on the Ozark shelf; sediments of this age are generally absent in the Arbuckle facies. After carbonate deposition ended in early Meramecian time, brief elevation of the shelf rocks was accompanied by a period of instability

and submarine erosion in the trough. In late Meramecian time, the Moorefield Formation and equivalents were deposited on the shelf, and the basal beds of the Stanley Shale, including the Hot Springs Sandstone Member, in the trough.

During Chesterian time, deposition of most of the Stanley Shale was accompanied by that of the Ruddell Shale, Batesville Sandstone, Fayetteville Shale, Pitkin Limestone, and lower part of the Imo Shale on the Ozark shelf and the Caney Shale farther southwest. Local uplift and erosion contributed Pitkin boulders to the Chickasaw Creek Member of the Stanley. Chesterian plants occur in the basal Jackfork Sandstone.

Simultaneous deposition in early Morrowan time of most of the Jackfork Sandstone in the trough and of the Hale Formation in Arkansas and "Springer" Formation of the Ti Valley-Choctaw fault block in Oklahoma is indicated by ammonoid faunas. The "Springer," however, includes some beds of Brentwood age. In late Morrowan time, the Johns Valley Shale, Bloyd Shale, and Wapanucka Limestone were laid down contemporaneously as the trough shallowed. In Atokan time, sedimentation became more uniform over the entire region. [259]

## Relationship among Depositional Environments, Marine Benthic Communities and Sedimentary Petrology in the Wewoka Formation of Hughes Co., Oklahoma

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A petrologic study of part of the Wewoka Formation in Hughes County, Oklahoma, was undertaken to determine (1) relationship among grain size, clay mineralogy and paleosalinity, (2) source area and depositional environments and (3) relationship between these sedimentary rocks and benthic marine communities.

Lithologies in this interval are, in ascending order, (1) shale, (2) mudstone and (3) sandstone. Few differences in mean grain size were observed in the shale and lower two-thirds of the mudstone. Mean grain size increases vertically in the upper mudstone. The mean grain size decreases eastward in the shale, mudstone and sandstone. Clay mineral assemblages consist of illite, illite-montmorillonite, chlorite, mixed-layer chlorite and kaolinite with few differences in relative abundance. Paleosalinity estimates of the shale and mudstone interval range from 2.5 0/00 (freshwater) to 34.7 0/00 (normal marine). In general, paleosalinity values of the shale and upper mudstone are low, but values between are normal.

Grain size and paleosalinity data support the deltaic depositional environments and benthic marine communities proposed by West (1970). These environments are, in ascending order (1) marshy subtidal to tidal flat represented by black, fossiliferous shale, (2) shallow nearshore subtidal (delta front) represented by molluscan mudstone, (3) offshore subtidal (prodelta) represented by brachiopodal mudstone, (4) nearshore subtidal (outer delta plain) represented by silty, foraminiferal mudstone and (5) deltaic sand deposition (distributary system) represented by crossbedded sandstones containing large plant fragments.

The authors acknowledge the donors of the Petroleum Research Fund, administered by the American Chemical Society, P.R.F. Grant #2077-G3 to Ronald R. West and the Kansas State University Bureau of General Research for support of this research. [266]

## The Origin and Implications of Some Sedimentary Structures in the Jackfork Group of the Ouachita Mountains, Oklahoma

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The upper part of the Jackfork Group (Mississippian-Pennsylvanian) is composed largely of fine-grained, quartzose sandstone in thick beds, generally ranging between 6 and 40 inches. Primary sedimentary structures include small climbing ripples, flat laminations, and small scale festoon cross bedding. Coarse-grained detritus and large scale cross bedding or cut-and-fill have not been observed. Individual sedimentation units typically begin at the base with an interval of flat lamination grading upward into climbing ripples. The uppermost layers of some beds have been reworked to form small-scale festoon cross-beds.

Secondary sedimentary structures include dish structure and convolute bedding. Convolute bedding develops within the beds, penecontemporaneously with deposition, by the deformation of climbing ripples. Dish structure forms by water expulsion after deposition and development of convolute bedding. In thicker beds (greater than 18 inches), all primary structures and convolute bedding have been destroyed by the disruptive effects of dewatering.

Deposition of most of the upper Jackfork sand took place from high-energy turbidity currents, most likely near the base of a submarine slope. Deposition was rapid and the resulting deposits were quick or underconsolidated. During early stages of dewatering, convolute bedding developed concurrently with the upward movement of water through the anticlinal convolutions. Continued water expulsion in the thicker beds resulted in the formation of pervasive dish structure and eventual homogenization. [269-270]

## Conodonts from Graptolite Facies in the Ouachita Mountains, Arkansas and Oklahoma

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Conodonts have been recovered from almost one-half of the samples collected in a reconnaissance of the lower Paleozoic rocks in the

core of the Ouachita Mountains. The samples came from thin limestone units in a succession that consists predominantly of shales and sandstones. Preservation of the conodonts ranges from poor to good; most specimens can be identified at least to the generic level and many can be identified with species. Abundance of conodonts in most samples is very low. Elements from the lowest unit, the Collier Shale, represent a fauna that is widespread in North America. Age of the Collier is demonstrated to be Early Ordovician rather than Cambrian as has been assumed. Higher units in the succession (Mazarn, Womble, ?Bigfork) have yielded conodonts typical of the North Atlantic Province. Previously established ages of these units, based on graptolite occurrences, generally are confirmed.

Strata in McCurtain County, Oklahoma, believed by Pitt (1955, 1959) to underlie the Collier were identified by him as the Lukfata Sandstone. Limestones from the type section of the Lukfata contain conodonts that indicate late Early or early Middle Ordovician age. The overlying strata are correlative with the Collier of Arkansas on the basis of conodonts. An inverted stratigraphic sequence is indicated.
[277]

### Depositional Facies in the Wapanucka Formation (Lower Pennsylvanian) in the Hartshorne-Wilburton Area, Oklahoma

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The frontal ridge of the Ouachita Mountains consists of the Wapanucka Formation, which has been informally divided into an upper sandstone member, a middle shale member, a limestone member, and a lower shale and limestone member. East of Wilburton the entire Wapanucka Formation consists of sandstone and shale with a few thin limestones. A detailed outcrop and petrologic study of the lower three members resulted in an interpretation of distinctive differences in environments of deposition from deep water in the west to shallow water in the east. In the Hartshorne area the limestone member consists of siliceous, spiculiferous limestones characteristic of basin-slope or basin depositional environments. Interbedded with these rocks are sparry-calcite-cemented oolitic and skeletal grainstones consisting of material washed from the shelf and cemented in a deep-burial environment. To the east in the Wilburton area the limestone member consists of typical shelf carbonate rocks; here, thick algal mudstones and typical shelf skeletal and oolitic packstones and grainstones with thin interbeds of shale characterize the member. The lower shale and limestone member is composed chiefly of shale with interbeds of skeletal and oolitic grainstones. These grain-supported rocks were also cemented in a burial environment. Eastward this member is composed almost entirely of shale with thin beds of sandstone. The middle shale member in the Hartshorne area is replaced by limestone, whereas eastward shale and siltstone dominate.
[277-278]

## Slaty Cleavage Superimposed on Earlier Folds, Ouachita Mountains, Southeastern Oklahoma

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Slaty cleavage occurs in Lower and Middle Paleozoic strata in the Benton-Broken Bow uplift which is an arcuate structural feature trending northward and eastward from southeastern Oklahoma toward Little Rock, Arkansas. In southeastern Oklahoma, a few kilometers north of Broken Bow, folds are commonly asymmetric and have hinge surfaces which dip 0° to 50° northward. Fold axes trend due east, 30° to 40° away from the trend of the Benton-Broken Bow uplift. In most outcrop sized folds, cleavage occurs in its usual symmetrical distribution about hinge surfaces. In some folds, however, cleavage is not symmetrically distributed about hinge surfaces but cuts them at angles ranging from 30° to 40°. In these folds, cleavage is essentially parallel to bedding on the gently dipping limbs but cuts bedding at high angles on steep or overturned limbs. Large-scale folds show these latter relationships between bedding and cleavage, and cleavage evidently cuts across hinge surfaces of most of the larger folds. Both observational data and theoretical considerations indicate that cleavage is symmetrically distributed about hinge surfaces of folds when the two structures are generated together. Because cleavage is independent of hinge surfaces in a number of folds, the slaty cleavage must represent a strain field superimposed on rock with preexisting folds. These relationships between folds and cleavage may apply in general to the Benton-Broken Bow uplift, and the slaty cleavage may represent a distinct, late deformational event associated with the uplift of this arcuate structural feature. [286]

## Palynological Evidence for a Pennsylvanian Age Assignment of the Eskridge Shale[1]

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The Eskridge Shale of Kansas is a rock unit consisting of red, green, and gray shales, a minor amount of limestone and locally thin coal beds. It is generally cited as of Permian age. The palynological flora consists of species in the following genera: *Laevigatosporites, Liotriletes, Granulatisporites, Lophotriletes, Apiculatisporites, Cadiospora, Calamospora, Lycospora, Triquitrites, Ahrensisporites, Knoxisporites, Schopfipollenites, Corisaccites, Potonieisporites, Vesicaspora, Nuskoisporites, Striatites,* and *Vittatina.* These genera and the species present are abundant in various parts of the Pennsylvanian strata and a few occur as low as the Upper Mississippian. Species of the last three genera were formerly thought to be entirely Permian but

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[1] Abstract updated at author's request.

are now observed in the Middle Desmoines and Missouri Series. Some of these species range upward as high as the Blaine Formation of the Guadalupean Series. Because of the preponderance of typical Pennsylvanian species and the apparent absence of exclusively Eskridge or Permian forms, the palynological evidence indicates that the Eskridge Shale should be assigned to a Pennsylvanian age. [288]

### Palynology of the Denton Shale (Lower Cretaceous) of Oklahoma

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The Denton Shale crops out in southern Oklahoma from eastern Choctaw County westward to south-central Love County, and ranges from 50 to 70 feet in thickness. The section consists of calcareous dark gray shales with occasional sandstone and fossiliferous limestone lentils. The Denton immediately overlies the Fort Worth Limestone equivalent (Caddo Limestone in southern Oklahoma), which has been dated middle Albian on the basis of its ammonite fauna.

Samples for palynological study were collected from outcrops in Bryan and Marshall Counties and have yielded a rich assemblage of spores, pollen, and microplankton. The assemblage is characterized by numerous species of fern spores (particularly the schizaean types *Appendicisporites, Cicatricosisporites, Pilosisporites, Schizaeoisporites, Trilobosporites,* and *Lygodium*-like forms), coniferous pollen, and angiosperm pollen of the retipilate, tricolpate type, along with moderate occurrences of cycadalean, ginkgoalean, and ephedran pollen and lycopsid spores. Acritarchs and dinoflagellates are present throughout the section and make up a prominent part of the assemblage in some samples, indicating marine deposition with fluctuating distance from shoreline. Occasional recycled Upper Mississippian or Lower Pennsylvanian spores (*Densosporites, Triquitrites,* and *Cirratriradites*) indicate rocks of that age were exposed in the sediment source area. Preliminary comparison of the Denton Shale assemblage with assemblages reported from other localities in North America suggest a reasonably close correlation with the Patapsco Formation assemblage from the Atlantic Coastal Plain. [288]

## University of California

### Surface Mineralogical and Chemical Evidence for Buried Hydrocarbons, Cement Field, Oklahoma

TERRENCE JOHN DONOVAN, University of California at Los Angeles, Ph.D. dissertation, 1972

Striking mineralogical and chemical changes occur in surface outcrops of a Permian redbed sequence overlying the oil productive portions of the prolific multi-reservoir oil accumulation of the Cement anticline, Oklahoma. Gypsum beds of flank locations are altered abruptly to erosion-resistant carbonate rocks of the crestal Keechi hills. Associated sandstones, typically red and friable in the surrounding region, are altered to pink, yellow and white on the flanks of the topographically expressed structure and to hard carbonate-cemented gray sandstone at the crest. The zone of cementation, confined to sandstone intervals, extends to a depth of at least 2500 feet.

The carbonates have wide ranging isotopic compositions. At one extreme a light-carbon/heavy-oxygen carbonate was precipitated from solutions concentrated by the evaporation of pore waters into expanding vertically-migrating gases in the presence of much oxidized petroleum. At the other extreme "normal"-carbon/"normal"-oxygen cement was precipitated from pore waters whose solutes were concentrated by micropore filtration of water passing from sandstones to shales. The calcitized gypsum, exceptionally deficient in $C^{13}$, was formed by the reaction of hydrocarbons with calcium sulfate.

The distribution of these carbonates shows areal regularity with calcitized gypsum and light-carbon/heavy-oxygen cements directly overlying petroleum-productive zones near regions of superior vertical fluid-communication (faults and a shallow buried unconformity of limited extent along the crest). Away from these avenues of concentrated leakage, the influence of hydrocarbons on the isotopic composition of the carbonate cements decreases systematically. Color changes in the sandstones are related to a loss of iron due to reduction in the presence of hydrocarbons and to dissolution.

Much of the hydrocarbons leaked from Missourian reservoirs which occur beneath the crestal unconformity. Crude oil from these stratigraphically discontinuous reservoirs along the basinward flank of the structure is associated with low-salinity pore water. It was selectively depleted of gas and low-molecular-weight fractions by long-continued leakage. Paraffinicity and salinity of waters in overlying reservoirs increases systematically with decreasing depth: it is hypothesized that these salinity variations, initially effected by ingress of clay-dehydration waters from the deep basin, have played a role in the selective solubilization of low-molecular-weight paraffinic fractions. Water, vertically expelled along the crest, was desalted in passing from sandstones to shales. This resulted in cementing off large volumes of sandstone in the shallow Permian section in places over the crest; the uncemented sandstones are petroleum-productive down the flanks.

Conservative order-of-magnitude calculations indicate 7.5 million barrels of liquid petroleum and three billion cubic feet of gas may have leaked from Missourian reservoirs alone in the eastern part of the field. The total volume lost cannot be calculated but likely was large.

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## THE UNIVERSITY OF OKLAHOMA

### Geochemistry and Petrology of Some Oklahoma Redbed Copper Occurrences

RICHARD PATRICK LOCKWOOD, The University of Oklahoma, Ph.D. dissertation, 1972

Two copper-rich shales are now undergoing development or mining in southwestern Oklahoma, the Mangum deposit in Ts. 3 and 4 N., R. 22 W., and the Creta deposit in Ts. 1 and 2 S., R. 22 W. Both deposits are in the upper part of the Permian Flowerpot Formation, which consists mainly of reddish shales with interbeds of gray shale, gypsum, and dolomite. The Flowerpot Formation is in the El Reno Group and is Leonardian in age.

A total of 226 samples of ore and non-ore rock were collected or donated: 108 samples are from Mangum and 118 (including 65 pulped cores) are from Creta. Samples were analyzed for quartz, gypsum, $K_2O$, CaO, Ag, Pb, V, Co, Ni, total iron as $Fe_2O_3$, CuO, ZnO, and $MoO_3$ by x-ray methods, for illite, chlorite, and malachite (Mangum) or chalcocite (Creta) by calculation, and for organic matter by standard wet chemical methods. Two samples of bedded gypsum immediately overlying the Creta ore and 7 chalcocite concentrates were run for $\delta\,^{34}S/^{32}S$.

The patterns of correlation coefficients are very similar for shales of the same color in each deposit and for each deposit as a whole. Exceptions are correlations of U with illite, chlorite, Ag, V, Co, $Fe_2O_3$, $K_2O$, and CaO in the Mangum deposit. There are 2 sets of correlations in each deposit: positive correlations between $K_2O$ and Co, Ni, V, Ag, $Fe_2O_3$ (and ZnO, Mangum) and negative correlations between gypsum and the same metals. The negative set are interpreted to be products of illite dilution by gypsum. The positive set are interpreted as being due to the structural or interlayer position of these metals in illite in both deposits.

Sulfur isotope analyses revealed a wide range of $\delta\,^{34}S/^{32}S$ values for chalcocite samples, and higher, more uniform values for gypsum samples. This is consistent with the possible bacteriogenic origin of the sulfide. Since there are no horizontal lead and zinc zones of the Schurmann variety, the chalcocite at Creta is interpreted to be diagenetic. The copper mineral in the Mangum deposit is predominantly malachite; the overburden is thinner than at Creta, and the Mangum deposit is interpreted to be the oxidized analog of the Creta deposit.

## Texas Geological Highway Map Published

The geological highway map of Texas has recently been released as number 7 of a projected 11 such regional maps being published by The American Association of Petroleum Geologists with the cooperation of the U.S. Geological Survey. Allan P. Bennison, a consultant in Tulsa, is in charge of compilation of the maps, and the project is under the supervision of R. H. Dott, Sr.

Previously issued maps in the series cover the Mid-Continent, the Southern Rockies, the Pacific Southwest, the Mid-Atlantic Region, and the Northern Rockies. Maps of the five remaining regions will be released as completed.

Inflation has caught up with the publication of these maps, and prices have been increased to $2.00 each for folded maps and $2.50 each for rolled maps. Folded maps are available from the Oklahoma

Geological Survey; for rolled maps and for multiple orders, consult AAPG headquarters, P.O. Box 979, Tulsa, Oklahoma 74101. Special rates are in effect for orders of more than 24 copies, with a handling charge of 50 cents per order for orders of less than 24.

## 1973 Petroleum Encyclopedia Available in July

The Petroleum Publishing Company of Tulsa has announced July 1 as the publishing date for the *International Petroleum Encyclopedia 1973.*

This large (9¼ by 12¼ inches, over 400 pages long), handsome (hard cover, gold leaf, 6-color maps) volume includes a great deal of what everyone always wanted to know about the petroleum industry. Up-to-date directories include fields, refineries, plants, agencies, personnel, even offshore rigs and tanker routes. The 114-page atlas section contains 70 maps. Worldwide statistics, fiscal information, and technical data on the latest techniques for secondary recovery, petrochemical processing, offshore operation, and shipping are highlighted.

The price of the encyclopedia is $32.50, with quantity prices quoted on request. Orders and inquiries should be sent to The Petroleum Publishing Company, IPE/73, P.O. Box 1260, Tulsa, Oklahoma 74101.

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