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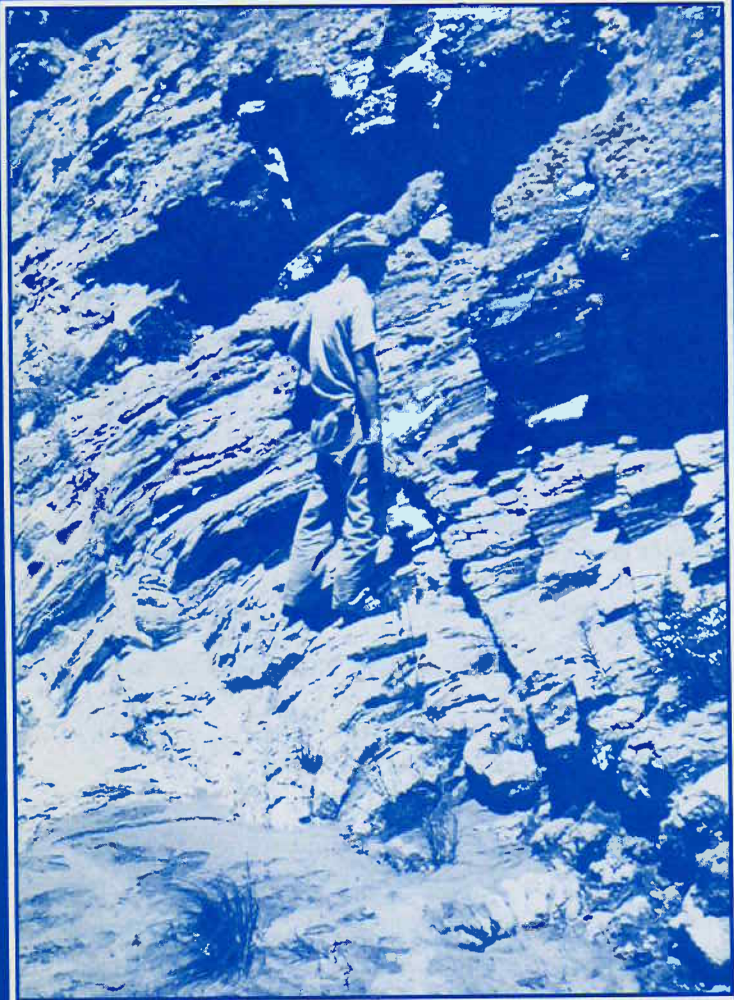

OKLAHOMA GEOLOGY NOTES

OKLAHOMA GEOLOGICAL SURVEY

Cover Picture

SHARP FLEXURE IN PERMIAN ROCKS OF SOUTHWESTERN OKLAHOMA

Shown on the cover are steeply dipping gypsum beds of the Blaine Formation (Permian), which are exposed on the north flank of the Plainview syncline in northwestern Greer County, Oklahoma. The syncline, which is 18 miles long and 1 to 4 miles wide, is bounded on both flanks by sharp, monoclinal flexures across which beds are displaced vertically as much as 150 feet. Strata dip 25° to 65° toward the fold axis, across both flexures, in narrow belts that are about 150 feet wide. Locally, the flexed beds are faulted. Just north and south of the flexures, outcropping strata are nearly horizontal. (The dip is 10 to 40 feet per mile, or less than ½°.)

The Plainview syncline is just south of the South Erick gas field, near the crest of the Wichita Mountain uplift. The north Plainview flexure shown here is the surface expression of a normal fault that apparently displaces the granitic basement about 2,000 feet below the surface. Faulting of the basement here occurred after Blaine time and attests post-Guadalupean tectonic movement in this part of the Wichita Mountain uplift.

The photograph, taken by William E. Ham in 1957, is looking west in NE¼NW¼ sec. 15, T. 7 N., R. 24 W.

—*Kenneth S. Johnson*

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.

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OKLAHOMA PALEOICHTHYOLOGY
PART V: CHONDRICHTHYES

JIRI ZIDEK[1]

INTRODUCTION

The first section of this series (Zidek, 1972) comprises an overall survey of the fossil fishes of Oklahoma, including all the members of the class Chondrichthyes known from Oklahoma up to that time. The second section (Zidek, 1973) deals more specifically with the elasmobranch chondrichthyans *Cladodus, Dittodus,* and *Petrodus* and with minute elements of cladoselachian derivation. This present section is devoted to the chondrichthyan families Stethacanthidae, Hybodontidae, Ctenacanthidae, Edestidae, Petalodontidae, and Cochliodontidae. With the exception of the spines of *Hybodus,* all specimens included are from shallow-water marine, deltaic, or lagoonal depositional environments.

There is some disagreement at present concerning whether the Edestidae, the Petalodontidae, and the Cochliodontidae should be classified as elasmobranchs or as holocephalians (cf. Patterson, 1965, 1968; Moy-Thomas, 1971; Zangerl, 1973; Bendix-Almgreen, 1968, 1971, 1975). The scope of the present study is too limited to deal with this question, and I must refer the reader to the authors cited. Of the many proposed classifications of the Chondrichthyes none can be regarded as completely satisfactory, especially in regard to the Paleozoic forms; this has led to the concept of dividing the elasmobranchs into three successive organizational levels (Schaeffer, 1967), and more recently (Zangerl, 1973) to the concept of recognizing six basic designs in the Paleozoic chondrichthyans. A formal taxonomy based on these premises, however, remains to be developed and refined. As far as the taxa dealt with in this paper are concerned, it can be said that *Stethacanthus* belongs to the anacanthous, *Hybodus* and *Ctenacanthus* to the phalacanthous, the edestids to the edestoid, and the petalodontids and cochliodontids to the bradyodont design of Zangerl.

The xenacanthodiid sharks, together with some ichthyodorulites that may be related to this group, require more lengthy consideration than is possible here and will form the content of Part VI of the study. Also, a recent discovery made by Mr. Lowell Lewis of Tulsa of shark-egg capsules *(Palaeoxyris)* in the Middle Pennsylvanian of Rogers County, northeastern Oklahoma, is the topic of a separate paper (Zidek, 1976) and requires no further mention here.

As the terms length and height could be confusing, I have, for the sake of clarification of the terminology used for orientation of the spines, re-

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tained "length" in the following descriptions to designate the proximo-distal dimension and have substituted "depth" for "height" to indicate the antero-posterior thickness.

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

I am indebted to Robert O. Fay, of the Oklahoma Geological Survey, for advice on stratigraphy; to Clair R. Ossian, of the Atlantic Richfield Company, Dallas, for species identifications of Oklahoma *Petalodus*; and to Max V. Brown and Larry C. Simpson, former graduate students of The University of Oklahoma, for photography (fig. 2 and fig. 1A, respectively).

SYSTEMATIC PALEONTOLOGY

Family STETHACANTHIDAE
Genus **Stethacanthus** Newberry, 1889
Fig. 2C

USNM 8110 (fig. 2C), a spine and the supporting basal plate of the first dorsal fin. This specimen was noted by Eastman (1917, p. 266) as coming from Girty's location 6079, but no such number exists in Girty's (1909) work. Thus, the locality can only be specified as south-central or southeastern Oklahoma (Arbuckle Mountains or western-northwestern edge of Ouachita Mountains), and the age as either the Delaware Creek Formation, middle Mississippian, or an Upper Devonian unit, possibly the Woodford Shale (cf. Zidek, 1972, p. 173).

The spine is approximately 15 mm in height, is unornamented, is laterally compressed, and has an anterior extension for the attachment of mid-dorsal musculature (Lund, 1974, p. 168, fig. 6). The apex of the spine is indistinctly preserved, and the basal plate (bpl) is incomplete antero-posteriorly. The USNM label reads "*Stethacanthus* cf. *S. humilis,*" and the Oklahoma specimen corresponds in its small size to that species (cf. Hussakof, 1913, p. 248). Lund (1974) erected a new family, Stethacanthidae, for the genus and, in addition to *S. altonensis*, recognized Hussakof's (1913) species *S. humilis* and *S. exilis* provisionally on the basis of their small size. He noted, however, that "most differences in shape between specimens representing different 'species' is attributable to postmortem distortion," and that "differences in size may be attributable to age or sexual dimorphism" (Lund, 1974, p. 165). Thus, there is no morphological basis for differentiating between *Stethacanthus* species, and the size alone obviously should not be used as a criterion.

Family HYBODONTIDAE
Genus **Hybodus** Agassiz, 1837
Fig. 1

OUSM 00515, East Manitou site, NW¼ sec. 5, T. 1 S., R. 16 W. (road cut), Tillman County, southwestern Oklahoma. Basal part of Purcell Sandstone, at base of Hennessey Group, Lower Permian.

OUSM 00522A, Northeast Frederick site of Simpson (1976), sec. 21, T. 1 S., R. 10 W., Tillman County. Upper part of Garber Formation, Lower Permian.

These specimens have already been noted and illustrated by Simpson (1974a, fig. 7; 1974b, text-fig. 1A; 1976, fig. 10); the following illustrations are presented to show more detail. The specimens are detached, incomplete fin spines that differ from one another substantially in both size and morphology.

OUSM 00515 (fig. 1A) has a depth of 13 mm and a maximum width of 6 mm at the proximal end; its length is 80 mm. The depth:width ratio is 2.2, and in the posterior two-thirds the spine's walls are vertical, i.e., parallel. The entire surface is ornamented with well-defined longitudinal ridges, one of which forms the anterior keel of the spine. Proximally there are 6, and distally 5, lateral ridges that narrow toward the distal end more gradually than does the spine itself. Consequently the sixth, most posterolateral, ridge fingers out distally, and the interspaces (grooves), which are proximally somewhat broader than the ridges (up to 1.5 times), become narrower than the ridges toward the distal end (only 0.5 of ridge width). The posterior face is denticulated throughout the length preserved. The denticles, of which 22 are preserved, are in a single series but are slightly displaced alternately to the right and to the left of the midline, in saw-blade fashion. The denticle bases cover one-half to two-thirds the width of the posterior face and are drop shaped, with their pointed distal ends bent laterad and touching their more distal neighbors posterolaterally. The few denticles preserved in their entirety have smooth surfaces and curve proximad. In hybodont spines the posterior excavation for basal support attachment constitutes 0.4-0.6 of the total spine length (Koken, 1907, plates; Stromer, 1927, pl. 2; Peyer, 1946, fig. 23; Patterson, 1966, fig. 26A, pl. 3, fig. 2). As no trace of such an excavation is preserved in the 00515 specimen, and as the tip (10-15 mm) is wanting, the total length of the spine can be estimated to have been 170-200 mm. Although probably not conspecific, the spine in question is close to *Hybodus copei (H. regularis* Cope, 1891, pl. 28, fig. 2; renamed by Hay, 1899, p. 783-784), known from the Lower Permian of Texas (cf. Romer, 1942, p. 223, and Berman, 1970, p. 19, concerning the stratigraphy), a species from which it appears to differ only in having fewer ridges and less pronounced transverse alternation of the denticles.

OUSM 00522A (fig. 1B) consists of fragments of two minute spines that are identical in size and morphology. Both are transversely complete portions of the exserted parts of the spines of the first dorsal fin. The depth:width ratio is 1.6, and the walls are ornamented with 4 longitudinal ridges separated by grooves that are 3 times as broad as the ridges. Both the grooves and the ridges are smooth and have an oblique profile. The denticles of the posterior face have smooth surfaces. They point proximad, are gently curved along their longitudinal axis, and alternate in similar fashion to the denticles of OUSM 00515 (fig. 1A), although their spacing and morphology differ. The denticle bases do not exceed the width of the lateral ridges; they are approximately 6 times longer than wide, and they have pointed distal ends. The neighboring bases are separated, with the interval between them measuring one-fourth to one-sixth the base length. The denticulation thus has the character of an interrupted and gently sinusoidally curved ridge. It appears to be identical with the denticulation in *Hybodus allegheniensis* from the Duquesne limestones (Pennsylvanian) of Pennsylvania (Lund, 1970, fig. 5A, B) but differ in spacing of the lateral longitudinal ridges. The stronger curvature and tapering of Lund's spine may be attributed to the fact that it most likely belongs to the posterior dorsal fin. The 00522A spines are not assignable to any *Hybodus* species known to me. However, as they are very incomplete, and as they most likely come from juvenile individuals, recognizing them by a new taxon would be of questionable value.

Family ?Hybodontidae
Fig. 1C

OUSM 00394, East Manitou site, NW¼ sec. 5, T. 1 S., R. 16 W. (road cut), Tillman County, southwestern Oklahoma. Basal part of Purcell Sandstone, at base of Hennessey Group, Lower Permian.
OUSM 00522B, Northeast Frederick site of Simpson (1976), sec. 21, T. 1 S., R. 10 W., Tillman County. Upper part of Garber Formation, Lower Permian.

OUSM 00394 is a spine (fig. 1C) that exhibits only a part of the left side of the exserted portion. In addition to the anterior keel, it has two well-defined, widely spaced longitudinal ridges. The grooves are 3 times as wide as the ridges, having almost flat floors and containing as many as 6 secondary longitudinal ridges that do not anastomose or bifurcate. The ornament is most closely comparable to that described in *Asteroptychius sanctiludovici* and *A. tenuis* (St. John and Worthen, 1875, pl. 16, figs. 4c, 5b).

OUSM 00522B is a fragment of a minute spine whose anterior and posterior faces are missing, making it impossible to orient the specimen. The five longitudinal ridges preserved are irregularly spaced and are triangular in profile; under higher magnification (minimum ×25) a fine crenulation becomes visible on their crests.

As these two specimens provide no information on the cross section or, more importantly, on the denticulation of the posterior face, they cannot be identified generically, and they are labeled only as fin spines of probably hybodontid derivation, although the possibility of their being ctenacanthid spines cannot be ruled out completely.

Family Ctenacanthidae
Genus **Ctenacanthus** Agassiz, 1837
Fig. 2A

USNM 14518, sec. 1, T. 25 N., R. 21 E., Craig County, northeastern Oklahoma. Hindsville or Fayetteville Formation, Chesterian, Upper Mississippian.
OUSM 00556A-B, SW¼SW¼SW¼ sec. 18, T. 4 S., R. 4 E., Wolf Creek area, Smith Ranch, Johnston County, southern Oklahoma. Pumpkin Creek Limestone Member of Big Branch Formation, Dornick Hills Group, Desmoinesian, Middle Pennsylvanian.

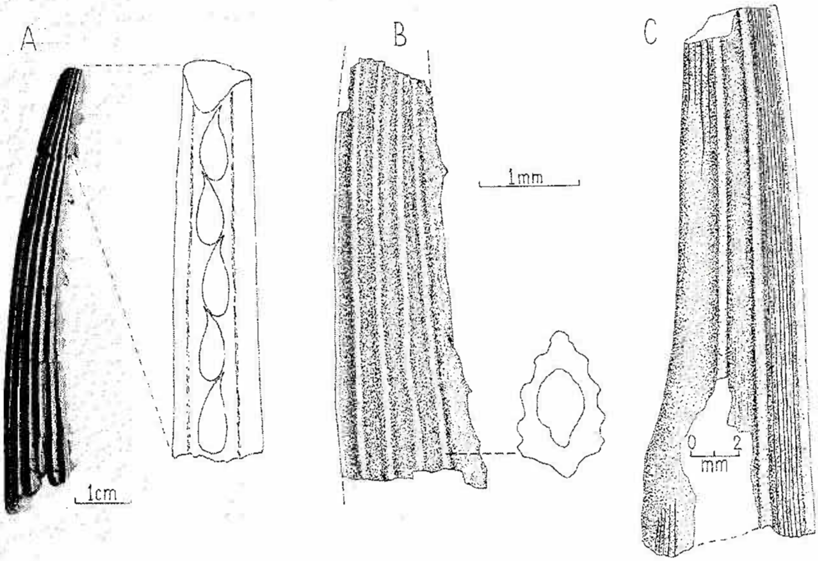

Figure 1. A—*Hybodus* sp., spine, OUSM 00515, lateral view (from Simpson, 1974a, 1974b) and detail of denticulation of posterior face. Base of Hennessey Group, Lower Permian, East Manitou site, Tillman County, Oklahoma.
B—*Hybodus* sp., spine, OUSM 00522A, lateral view and cross section of proximal end. Upper part of Garber Formation, Lower Permian, Northeast Frederick site, Tillman County, Oklahoma.
C—Hybodont(?) spine, OUSM 00394, lateral view. Base of Hennessey Group, Lower Permian, East Manitou site, Tillman County, Oklahoma.

USNM 14518 (fig. 2A) is the exserted portion of a slender and gently arched spine, evidently of the first dorsal fin. It is 16 mm deep and is up to 7 mm wide at the proximal end; its length is 175 mm. The anterior keel is 1.5 mm high, and the exposed right lateral wall is ornamented with 18 longitudinal ridges, all of equal breadth, that do not anastomose or bifurcate; in the proximal part of the specimen these ridges bear minute, irregularly spaced tubercles. The interspaces (grooves) are narrower than the ridges. The denticulation of the exposed, right side of the posterior face starts approximately 30 mm above the proximal end. The denticles are short based. They are curved proximad and are well separated, the gaps between them being equal to, or slightly larger than, the length of the denticle bases. This spine corresponds to *Ctenacanthus gracillimus* in character of individual ridges (Eastman, 1902a, fig. 12) and posterior denticulation, and also in overall shape and size (Newberry and Worthen, 1866, pl. 13, fig. 3; St. John and Worthen, 1883, pl. 24, fig. 1), but it has a somewhat higher number of ridges. The difference amounts to only 3 or 4 ridges and could be accounted for by variation. However, the illustrations of *C. gracillimus* by Newberry and Worthen (1866) and by Newberry (1889, p. 25, fig. 6) disagree with that of St. John and Worthen (1883) in that the latter authors show the ridges as decreasing in breadth progressively toward the posterior margin. The spine in question is here regarded, therefore, as *Ctenacanthus* aff. *C. gracillimus*, and, because of the element of uncertainty just noted, its definite species assignment must await comparison with the type specimen (of Newberry and Worthen, 1866, pl. 13, fig. 3).

OUSM 00556A-B consists of fragments of two large spines that may have belonged to the same species, or perhaps even to the same individual.

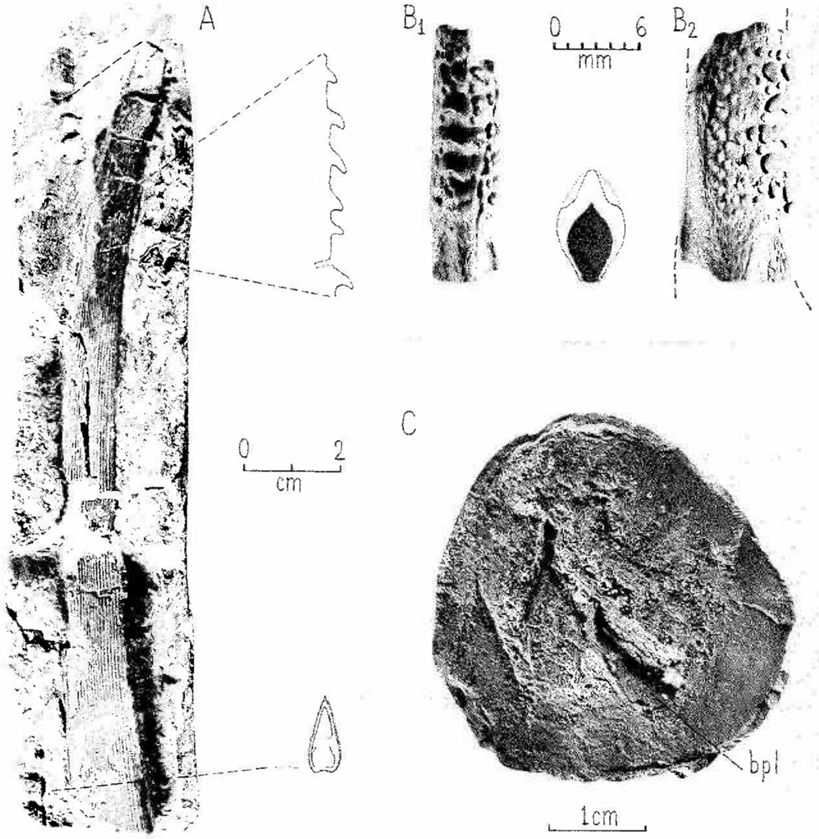

Figure 2. A—*Ctenacanthus* aff. *C.gracillimus* Newberry and Worthen, USNM 14518, spine in lateral view, cross section of proximal end and detail of denticulation of posterior face. Upper Mississippian (Chesterian) of Craig County, Oklahoma.

B—*Physonemus* aff. *P. acinaciformis* St. John and Worthen, OUSM 00398, proximal part of spine in anterior (B_1) and lateral (B_2) views, and cross section of proximal end. Cross section further distad, through ornamented part, is shown by dotted line. Coffeyville Formation, Missourian, of Pontotoc County, Oklahoma.

C—*Stethacanthus* sp., USNM 8110, spine and supporting basal plate (bpl) of first dorsal fin. Exact locality and age unknown — middle Mississippian or Upper Devonian of Oklahoma.

OUSM 00556B is a distal portion of spine, 100 mm long, with no ornamentation preserved. OUSM 00556A is up to 46 mm high and is 315 mm long. The proximal end is missing, and the complete spine may have been close to 44 cm long. The slenderness and gentle curvature of the specimen indicate its belonging to the first dorsal fin. Unfortunately, this spine has been split in the midline throughout its length, and consequently its cross section and much of the ornamentation are not available. A small fragment of the anterolateral ornamentation, preserved in negative, appears to be identical with that in *Ctenacanthus amblyxiphias* Cope (1891, pl. 28, fig. 3; cf. also Eastman, 1903, pl. 2, figs. 22, 23; Romer, 1942, pl. 1, fig. 3; Berman, 1970, p. 18-19). Cope established this species on the basis of Lower Permian specimens, and much of its record comes from the Lower Permian of Texas, but the Nebraska specimens assigned to the species by Eastman (1903) are Missourian in age. The Oklahoma spine thus is not much older than the Nebraska specimens of Eastman; it is at least twice as large as any of the *C. amblyxiphias* spines so far recorded, however, and its preservation is too poor to justify a species assignment.

Family Edestidae
Genus **Edestus** Leidy, 1856a

OUSM 00138 (old no. 4999), C sec. 29, T. 3 S., R. 2 E., Carter County, southern Oklahoma. Deese Group, Desmoinesian, Middle Pennsylvanian.
OUSM 00551, SW¼SW¼SE¼ sec. 31, T. 3 S., R. 4 E., Carter County. Deese Group.
OUSM 00400, NW¼ sec. 27, T. 3 N., R. 7 E., Pontotoc County, south-central Oklahoma. Boggy Formation, Desmoinesian.

The holotype of *E. vorax* Leidy, 1856a, does not come, as previously believed, from the Indian Territory (now part of the State of Oklahoma) but from the Carbondale Formation, Kewanee Group, Desmoinesian, of Illinois (probably from the same zone and general region as the holotype of *E. giganteus* Newberry, 1888, which is conspecific with *E. vorax;* cf. Branson, 1963, 1964a). The record of *Edestus* in Oklahoma thus consists only of the three specimens listed, all of which are exceedingly poorly preserved.

OUSM 00138 was described and illustrated by Branson (1964b, fig. 1), who identified it as the most anterior tooth (segment) in the upper symphysial series of *Edestus* aff. *E. vorax*. It is instead the second, or perhaps even more posterior, tooth in the series. OUSM 00551 is somewhat smaller, but in morphology of the crown it is similar to the 00138 specimen and may also be identified as *Edestus* aff. *E. vorax* — in this case as the most anterior symphysial tooth. OUSM 00400 is a symphysial tooth fragment too small to be identified any better than ?*Edestus* sp.

Genus **Agassizodus** St. John and Worthen, 1875
Fig. 3

OUSM 00562, W½NE¼ sec. 19, T. 3 N., R. 15 E., Pittsburg County, southeast-central Oklahoma. Wapanucka Formation, Morrowan, Lower Pennsylvanian.
OUSM 00552 and 00553, NW¼ sec. 27, T. 3 N., R. 7 E., Pontotoc County, south-central Oklahoma. Boggy Formation, Desmoinesian, Middle Pennsylvanian.

OUSM 00554, C sec. 29, T. 3 S., R. 2 E., Carter County, southern Oklahoma. Deese Group, Desmoinesian.
OUSM 00560, vicinity of Holdenville, Hughes County, southeast-central Oklahoma. Wewoka Formation, Desmoinesian.

All five of these specimens are lateral teeth, and none of them is quite complete. The 00552, 00560, and 00562 specimens can be identified without question as *A. variabilis* (cf. Newberry and Worthen, 1870, pl. 4, figs. 4, 5, 11; St. John and Worthen, 1875, pl. 8, figs. 1-22; Thomas and McClure, 1951, fig. 1), and the 00553 specimen (fig. 3A), a fragment with the longitudinal keel worn off and with denteons open on the surface of the crown, may also belong to that species. The 00554 specimen (fig. 3B) is not assignable to any *Agassizodus* species known to me. It corresponds most closely to some of the lateral teeth of *A. groenlandicus* (Nielsen, 1932, pl. 8, figs. 1-3, 17, 22), but it appears to have had an unusually prominent central summit, and, although it is not abraded, it shows no indication whatever of plicae between the transverse keels. This specimen could represent an undescribed species, but as it is only a single and incomplete tooth it is here identified only generically.

A remark is in order concerning the status of *Agassizodus*. This genus was placed in synonymy with *Campodus* Koninck, 1844, by a number of investigators, most recently by Eaton (1962), who reviewed the question in some detail. In this connection, it may be of benefit to cite Obrutchev (1953, p. 26, translated from the Russian):

> Strictly speaking, the genus *Campodus* Koninck is known from the lower Namurian of Belgium (Demanet, 1941), whereas the genus *Agassizodus*, regarded as synonymous to *Campodus* by Lohest, Eastman, Woodward, Karpinskii, and others, is met with only higher in the Carboniferous (Coal Measures) of North America and in the Lower Permian of Greenland (Nielsen, 1932). . . . The genus *Agassizodus*, as defined by Nielsen in 1932 (p. 35), is easily distinguishable by having the outer, labial side of the crown folded, whereas in *Campodus* the folds are present on both the sides.

Although the absence of folding of the lingual margin of the crown in *Agassizodus* teeth is not as total as Obrutchev states, it can nevertheless be described as only minor folding (cf. Nielsen, 1932), and in this respect I do not see the integration noted by Eaton (1962, p. 351) between the *Campodus* teeth figured by Lohest (1884) and those described and illustrated as *Agassizodus* (e.g., St. John and Worthen, 1875, pl. 8, figs. 1-22). The significance of the folding for generic distinction can of course be questioned, and the stratigraphic discrepancy noted by Obrutchev does not preclude the possibility of the European *(Campodus)* and North American *(Agassizodus)* specimens being congeneric. However, the morphological and stratigraphic evidence combined make synonymizing of the two genera unwarranted. The European *Campodus* is still known only from scattered lateral teeth, whereas in North America nearly complete skeletons of *Agassizodus* have now been recovered (cf. Zangerl, 1973, p. 9). Therefore, I find it fortunate that evidence exists in support of retaining the generic name *Agassizodus* for the North American occurrences.

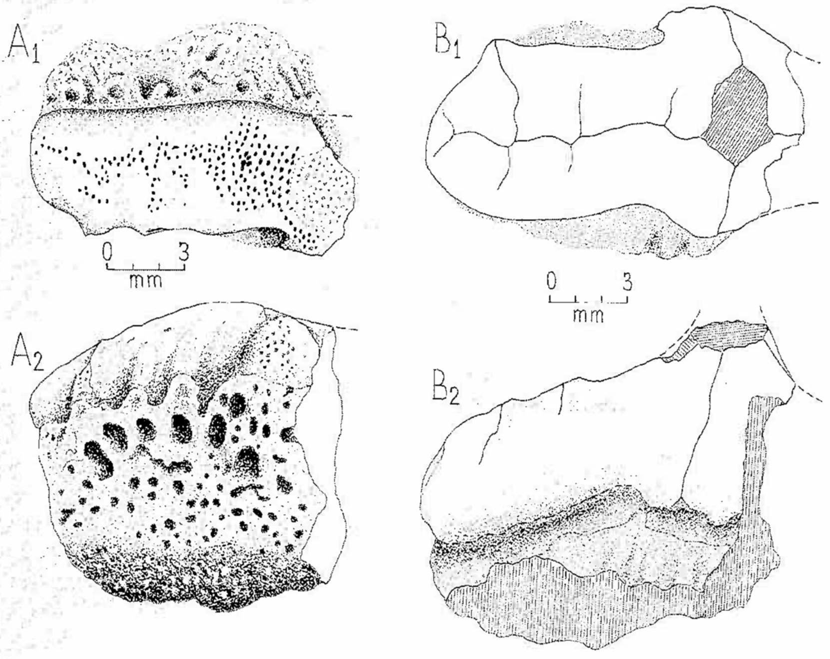

Figure 3. A—*Agassizodus* aff. *A. variabilis,* OUSM 00553, worn lateral tooth in occlusal (A_1) and labial (A_2) views. Boggy Formation, Desmoinesian, of Pontotoc County, Oklahoma.
B—*Agassizodus* sp., OUSM 00554, lateral tooth in occlusal (B_1) and lingual (B_2) views. Deese Group, Desmoinesian, of Carter County, Oklahoma.

Family ?Edestidae
Organ Genus **Physonemus** M'Coy, 1848
Fig. 2B

OUSM 00398, Superior Clay Products pit, Ada, Pontotoc County, south-central Oklahoma. Coffeyville Formation, Missourian, Upper Pennsylvanian.

The specimen (fig. 2B) is a 19-mm-long fragment of the proximal part of the spine. It is anteroposteriorly complete but lacks a substantial part of the base. The ornamentation begins 4 mm above the proximal end of the fragment and consists of a mesial row of large tubercles on the anterior margin and seven lateral, longitudinal rows of much smaller, oval-shaped tubercles that diminish in size posteriorly. The posterolateral and posterior portions of the spine are barren of ornament, probably as the result of abrasion. The most proximal anterior tubercles are transversely prolonged and trilobate, whereas more distad three separate, oval-shaped tubercles correspond to the three lobes of the transversely prolonged tubercles. All the tubercles have their blunt peaks (or undulate crests in the transversely prolonged tubercles) inclined proximad, and in the larger tubercles the proximal edges of their bases are overlapped by the peaks (crests). The margins of the tubercles are stellate, but the folding is shallow and is more extensively developed only in the smaller, lateral tubercles. The unornamented proximal end has its anterior surface drawn into a keel that increases in height proximad and is indicative of the base's having been bent anteriorly. Although the fragment is too small to show any curvature, it is clear from the anterior keel and from the location of the tubercles that the spine can be restored only as having been curved forward, i.e., with its anterior margin concave.

Physonemus was provisionally assigned to the family Edestidae by Baird (1957). The forward curvature characterizes also the ichthyodorulites *Xystracanthus* Leidy, 1859, *Drepanacanthus* Newberry and Worthen, 1866, and *Gnathacanthus* Davis, 1883, all of which were placed in synonymy with *Physonemus* (Woodward, 1891, p. 130, 132; Eastman, 1903, p. 206; Baird, 1957, p. 1013). Obrutchev (1964, p. 256), in accord with Woodward's (1891) opinion, placed *Batacanthus* St. John and Worthen, 1875, also in synonymy with *Physonemus;* from St. John and Worthen's illustrations (1875, pl. 21, figs. 1-8), however, it is apparent that in *Batacanthus* the ornamentation consists of tubercles that are either of equal size throughout or increase in size toward the convex spine's margin and that there is a double row of denticles at the opposite, concave margin. Consequently, the *Batacanthus* spines are to be oriented as curved backward, and the synonymy *Batacanthus* = *Physonemus* is thus to be rejected. In regard to *Xystracanthus, Drepanacanthus,* and *Gnathacanthus,* the transfer of some of the species of these genera to *Physonemus* (cf. Baird, 1957) appears to be justified, but it will require a revision of these genera to determine whether or not they belong in synonymy with *Physonemus* in their entirety.

The small depth (antero-posterior dimension), presumably only a gentle curvature, and the presence of the median row of transversely prolonged tubercles near the base of the anterior margin, are features that make the OUSM 00398 spine more closely comparable to *Physonemus acinaciformis* (=*Xystracanthus acinaciformis* St. John and Worthen, 1875, pl. 20, fig. 2) than to any other *Physonemus* species. The OUSM spine differs from *P. acinaciformis,* however, in being about two-thirds smaller, in having presumably only about 10 lateral tubercle rows (as compared to 15 in *P. acinaciformis),* in a more profound size difference between the anterior and lateral tubercles, and in the morphology of the transversely prolonged anterior tubercles, the trilobate shape of which resembles that of *P. (X.) mirabilis* (St. John and Worthen, 1875, pl. 20, fig. 1i) rather than the simple, oval-shaped anterior tubercles of *P. acinaciformis.* Baird (1957, p. 1014) stated that *P. acinaciformis* is closely comparable to *P. (X.) striatus* (Moore, 1929) and that, taking into account the variability expectable in shark spines, the two may be conspecific. If so, the unique specimens of *P. acinaciformis, P. striatus,* the Marietta fragment described by Baird (1957), and the OUSM 00398 fragment may all be regarded as belonging in the *P. acinaciformis* group.

Family PETALODONTIDAE
Genus **Ctenoptychius** Agassiz, 1838
Fig. 4A

OUSM 00397, west of Scenic Highway 77, Lake Murray State Park, Carter County, southern Oklahoma. Lester Limestone, Deese Group, Desmoinesian, Middle Pennsylvanian.

The 00397 specimen (fig. 4A) is an imperfectly preserved tooth, probably from the upper jaw, exposed by its labial face. The maximum height of the crown is 11 mm, and its preserved width is 14 mm (the total width probably did not exceed 16 mm). The depth of the root equals roughly the height of the crown. The labial face is strongly convex, and consequently the cutting edge of the crown is arcuate. The surface of the crown is smooth, and its cutting edge is coarsely lobate. The part preserved exhibits four lobes that increase in size toward the midline of the tooth. The lobes are apically rounded in the labio-lingual plane, and their edges are not serrated. Three, or less likely, four, lobes were present on each side (laterally) of the largest, median lobe.

Ctenoptychius is known from isolated teeth (to my knowledge, only a single specimen of a more complete fish exists; cf. Zittel, 1932, p. 89, 90; Bendix-Almgreen, 1968, p. 156) found in deposits of Mississippian, Pennsylvanian, and Early Permian age. However, of the hitherto recorded Lower Permian occurrences (Martin, 1913; Obrutchev, 1964, p. 249; Berman, 1970, p. 21), only that of Berman can be regarded as unquestionably Permian. Compared with occurrences of other bradyodont dentitions, the teeth of *Ctenoptychius* are relatively rare and are never found in large numbers. It has been repeatedly suggested, and to a degree substantiated, that in *Ctenoptychius* and some related genera there was but a single tooth in each half of the jaws (Woodward, 1889; Eastman, 1902b; David, 1944; Ossian, 1976, p. 395). If so, this could explain the scarcity of occurrences and the low number of teeth recovered from individual locations.

The Oklahoma specimen is closely comparable to *C. semicircularis* Newberry and Worthen (Newberry and Worthen, 1866, pl. 4, fig. 18; cf. also Newberry, 1875, pl. 58, fig. 14; Eastman, 1903, fig. 8, pl. 3, fig. 25; Martin, 1913, pl. 21), and on strictly morphological grounds it could be assigned to that species. However, *C. semicircularis* has been reported from the Mississippian (Chesterian) and Pennsylvanian, as well as from Lower Permian deposits, which makes its status questionable. Therefore, no species assignment is attempted here.

Genus **Petalodus** Owen, 1840-45

As a revision of *Petalodus,* including the Oklahoma material, is under way by Dr. Clair R. Ossian, I have restricted myself only to a listing of the occurrences. The species identifications were kindly provided by Dr. Ossian.

P. alleghaniensis Leidy, 1856b

OUSM 00487, SW¼NW¼ sec. 2, T. 14 N., R. 23 E., Cherokee County, eastern Oklahoma. Bloyd Formation, Morrowan.

OUSM 00253, sec. 27, T. 3 N., R. 7 E., Pontotoc County, south-central Oklahoma. Boggy Formation, Desmoinesian.

OUSM 00261, Superior Clay Products pit, Ada, Pontotoc County. Coffeyville Formation, Missourian.

OUSM 00252, SW¼ sec. 10, T. 18 N., R. 5 E., Payne County, north-central Oklahoma. Limestone in Pony Creek Shale, Vanoss Group, Virgilian.

OUSM 00245, SE¼ sec. 21, T. 18 N., R. 5 E., Payne County. Brownville Limestone, Vanoss Group, Virgilian.

OUSM 00489, NE¼ sec 1, T. 18 N., R. 5 E., Payne County. Americus Limestone, Vanoss Group, Virgilian.

Petalodus aff. *P. alleghaniensis*

OUSM 00249, Oil Creek outcrops in sec. 32, T. 3 S., R. 4 E., Johnston County, southern Oklahoma. Pumpkin Creek Limestone Member of Big Branch Formation, Dornick Hills Group, Desmoinesian.

OUSM 00246, C sec. 29, T. 3 S., R. 2 E., Carter County, southern Oklahoma, and OUSM 00254, location given only as "NE of Washita River." Both from lower part of Deese Group, Desmoinesian.

OUSM 00488, E½ sec. 23, T. 21 N., R. 7 E., Pawnee County, north-central Oklahoma. Severy-Aarde Shale, Ada Group, Virgilian.

OUSM 00247, SE¼ sec. 21, T. 18 N., R. 5 E., Payne County, north-central Oklahoma. Grayhorse Limestone, Vanoss Group, Gearyan.

P. linguifer Newberry and Worthen, 1866

OUSM 00248 and 00250, base of spillway at Greenleaf Lake, Muskogee County, eastern Oklahoma. Bloyd Formation, Morrowan.

The specimens cannot be located that are listed by Weaver (1954) from the Wewoka Formation, Desmoinesian, of Hughes County; by Morgan (1924) and Giles (1963) from the Coffeyville Formation, Missourian, of Pontotoc County; and by Greig (1959) from the Grayhorse, Red Eagle, and Neva Limestones, all Gearyan, of Pawnee County. They were identified by the authors only as *Petalodus* sp. or as *P. destructor* Newberry and Worthen, 1866, which belongs in synonymy with *P. alleghaniensis* Leidy, 1856b (St. John and Worthen, 1875, p. 396; Eastman, 1896; Woodward, 1889, p. 46; Ossian, written communication, December 1975).

Genus **Janassa** Münster, 1832

OUSM 00561, SE¼NW¼ sec. 10, T. 2 N., R. 13 E., Atoka County, southeastern Oklahoma. Uppermost part of Wapanucka Formation, upper Morrowan or lower Atokan, Lower Pennsylvanian.

A single, incomplete tooth constitutes the specimen. The linguad curved cutting portion is 5 mm high and 9 mm wide; it is asymmetrical sinistro-dextrally (laterally), indicating a lateral rather than a median tooth. The preserved length of the central portion is 7 mm and contains 13 rugae (plicae of Nielsen, 1932, p. 52; ridges of Berman, 1967) on its lingual surface. This part is narrower than the cutting part of the tooth, and also it narrows gradually toward the root. The labiad recurved basal portion of the tooth (the root) is lacking.

There is nothing in the morphology of the OUSM specimen that would distinguish it from *Janassa bituminosa* (Schlotheim). *J. bituminosa* is known, however, only from the Permian of Europe, and even disregarding the difference in age, the Oklahoma fragment is inadequate for positive species identification.

Family Cochliodontidae
Genus **Deltodus** Morris and Roberts, 1862

OUSM 00477A-C, NW¼ sec. 22, T. 25 N., R. 21 E., Craig County, northeastern Oklahoma. Hindsville Formation, Chesterian.
MCZ 5322 (plesiotype of *Deltodus cingulatus* Newberry and Worthen; cf. Croneis, 1927, p. 44, pl. 7, fig. 7), 2 miles west of Strang, Mayes County, northeastern Oklahoma. Fayetteville Formation, Chesterian.
OUSM 00490, NE¼SE¼ sec. 1, T. 14 N., R. 22 E., Cherokee County, eastern Oklahoma. Bloyd Formation, Morrowan.
OUSM 00495, Oil Creek outcrops in sec. 32, T. 3 S., R. 4 E., Johnston County, southern Oklahoma. Pumpkin Creek Limestone Member of Big Branch Formation, Dornick Hills Group, Desmoinesian.
OUSM 00494 and 00550, Superior Clay Products pit, Ada, Pontotoc County, south-central Oklahoma. Coffeyville Formation, Missourian.
OUSM 00491, SE¼ sec. 17, T. 21 N., R. 8 E., Pawnee County, north-central Oklahoma. Kanwaka Shale Member of Vamoosa Formation, Virgilian.
OUSM 00493, NE¼ sec. 25, T. 15 N., R. 5 E., Lincoln County, central Oklahoma. Grayhorse Limestone, Vanoss Group, Gearyan.
OUSM 00492, SW¼ sec. 10, T. 18 N., R. 5 E., Payne County, north-central Oklahoma. Limestone in Pony Creek Shale, Vanoss Group, Gearyan.
Greig (1959) reported *Deltodus* also from the Red Eagle Limestone (Vanoss Group, Gearyan) of Pawnee County, but his specimens cannot be located.

The name *Deltodus* refers to broad dental plates roughly triangular in outline, with the labial margin usually longer than the lingual and with grooves crossing the occlusal surface parallel to the lingual margin. From the dentition of *Deltodus mercurii* (cf. Branson, 1916), it seems more than likely that the name *Deltodus* has been applied so far only to the lateral plates, whereas the narrower median plates of the lower jaw have been described under different generic names. *Deltoptychius* (St. John and Worthen, 1875), *Deltodopsis, Stenopterodus, Taeniodus, Chitonodus* (St. John and Worthen, 1883), *Poecilodus* (M'Coy, 1855), and probably some other cochliodont genera are synonymous with *Deltodus,* but in the absence of a modern revision of the Cochliodontidae it is impossible to define the genus adequately, and no species assignments can be made.

Chondrichthyes Incertae Sedis
"**Helodus**"-Type Teeth
Fig. 4B, C

OUSM 00557, NW¼ sec. 26, T. 3 N., R. 7 E., Pontotoc County, south-central Oklahoma. Boggy Formation, Desmoinesian.
OUSM 00558, NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, northeastern Oklahoma. Coffeyville Formation, Missourian.

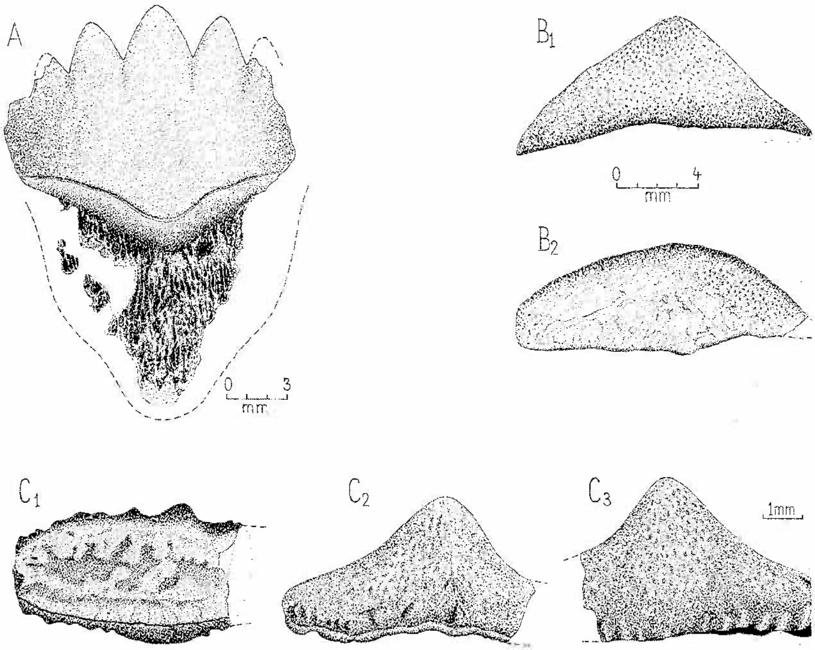

Figure 4. A—*Ctenoptychius* sp., tooth, OUSM 00397, labial view. Deese Group, Desmoinesian, of Carter County, Oklahoma.
B—*"Helodus"*-type tooth, OUSM 00557, lingual (B_1) and basal (B_2) views. Boggy Formation, Desmoinesian, of Pontotoc County, Oklahoma.
C—*"Helodus"*-type tooth, OUSM 00558, basal (C_1), labial (C_2), and lingual (C_3) views. Coffeyville Formation, Missourian, of Washington County, Oklahoma. In C_2, seemingly smaller height is due to labial inclination of summit.

The 00557 specimen (fig. 4B) is a strongly worn lateral tooth with only a negligible part of the root preserved. The crown is 3 times longer than wide and rises gradually into a blunt, labiad-inclined and nearly central summit. The lingual face is convex; the labial face is straight except for one end (right in lingual view), which is inflected labiad. There is no evidence of a longitudinal keel, nor are there any transverse keels, plicae, or folds on either of the crown faces. OUSM 00558 (fig. 4C) is a smaller lateral crown, incomplete lengthwise, that resembles 00557 in having a well-developed and somewhat labiad-inclined central (?) summit and in having no coronal keels or plicae. It differs, however, in having folds present basally on both the lingual and labial faces as well as on the short, anterior or posterior margin of the crown.

The 00557 specimen compares closely with *Helodus gibberulus* (Agassiz, 1838, pl. 12, figs. 1, 2; cf. also Newberry, 1889, p. 102), *H. (Cochliodus) nobilis* (Newberry and Worthen, 1866, pl. 6, fig. 5), *H. subtuberatus* (Lambe, 1913, pl. 2, figs. 1-3), and *H. derjawini* (Obrutchev, 1964, pl. 2, fig. 5), which are known from substantially older (Upper Devonian and Mississippian) rocks. OUSM 00558 resembles some of the *Chomatodus* teeth illustrated by Agassiz (1838), M'Coy (1855), and St. John and Worthen (1875), but no positive identification can be made. Woodward (1889, p. 218) identified *Helodus planus* and *H. laevissimus* as belonging to *Psephodus magnus* and *P. laevissimus,* respectively, and stated that all the other teeth described under the generic names *Helodus* (except *H. simplex*), *Chomatodus, Lophodus,* and perhaps *Venustodus* "are probably common to one or more genera or species" and thus ought to be recognized only as undetermined anterior teeth of the Cochliodontidae. In *Helodus simplex* the teeth of the 4th and 5th series are fused into plates (cf. Moy-Thomas, 1936, text-fig. 4), and the specimens in question could thus be assumed to come from the series either anterior or posterior to the plates. However, the situation is known to be not uniform in the cochliodontids, menaspids, helodontids, and edestids, which all possessed teeth reminiscent of those just described (cf. Bendix-Almgreen, 1975, p. 17-20).

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U.S. Board on Geographic Names Decision

The following Oklahoma place name was approved by the U.S. Board on Geographic Names and was published in the April through June 1976 issue of *Decisions on Geographic Names in the United States* (Decision List 7602).

Merkle Creek was adopted for a stream 5.6 kilometres (3.5 miles) long that heads at 35°14′20″ N., 97°27′53″ W., and flows south-southwest to the Canadian River 4.8 kilometres (3 miles) southwest of the center of Norman; sec. 2, T. 8 N., R. 3 W., Indian Meridian (35°11′53″ N., 97°29′14″ W.). The creek was named for John Merkle, who homesteaded along this stream in the 1890's.

New OGS Circular Describes Shale and Carbonate Resources of Osage County, Oklahoma

A circular entitled *Shale and Carbonate-Rock Resources of Osage County, Oklahoma* has just been published by the Oklahoma Geological Survey. The research project that culminated in this publication was funded in part by the Osage Tribal Council. The authors, William H. Bellis and T. L. Rowland, conclude that many of the shale and carbonate units are suitable for a number of commercial and industrial uses and that they constitute ample reserves for future market expansion.

The 50-page publication, released as Circular 76, includes a large, folded panel in a pocket at the back that depicts two color maps at a scale of 1:250,000 (about 1 inch = 4 miles), showing the principal shale units and the principal limestone and dolomite units of Osage County. The panel, prepared by OGS cartographer Marion Clark, also contains a stratigraphic chart for the county.

The text of the report is in three main parts. Part I is an introduction by both authors. Part II, by Bellis, is a systematic description of the shale resources of Osage County, which includes a 15-page table listing physical properties of the shales. Part III, by Rowland, is a systematic physical and chemical description of the carbonate-rock resources of the county and includes diagrams and descriptions of active and abandoned quarries; it also includes an appendix of measured stratigraphic sections. At the end are a list of cited references and an index.

Circular 76 can be ordered from the Oklahoma Geological Survey by writing to the address on the front cover. Paperbound copies are $3.50 apiece, and clothbound copies, $5.50.

Hydrologic Atlas of Clinton Quadrangle Released

The 5th in a 9-part series of cooperative water studies covering Oklahoma (exclusive of the Panhandle) on a reconnaissance basis has been released by the Oklahoma Geological Survey and the U.S. Geological Survey. Issued as Hydrologic Atlas 5, the study, by Jerry E. Carr and DeRoy L. Bergman of the USGS, is entitled *Reconnaissance of the Water Resources of the Clinton Quadrangle, West-Central Oklahoma*. The Clinton 1° × 2° quadrangle covers an area of about 7,800 square miles, extending from the vicinity of El Reno westward to the Oklahoma-Texas line.

The atlas set consists of four map sheets in color, with accompanying texts, folded in an envelope. Sheet 1 is principally an areal geologic map of the quadrangle, which includes the units deposited in the deepest part of the Anadarko basin; the basin axis is also indicated. Sheet 2 presents a map depicting the general availability of ground water as well as hydrographs showing precipitation and water levels in wells at selected sites. Sheet 3 indicates areal variations in chemical quality of ground water in the quadrangle, using chemical-analyses tables and water-quality diagrams. Sheet 4 consists of a series of small maps and graphs showing various aspects of surface-water availability and quality. The maps of sheets 1-3 are at a scale of 1:250,000; those of sheet 4 are at 1:750,000.

The principal cartographic preparation of the map was done by former OGS cartographer Sondra Underwood. OGS geologist Robert O. Fay contributed significantly to the geologic map.

The atlas can be ordered from the Oklahoma Geological Survey for $5.00 a set by writing to the address on the front cover. Other atlases in the series are available from the Survey as follows: HA-1, Fort Smith quadrangle, east-central Oklahoma, $3.00; HA-2, Tulsa quadrangle, northeastern Oklahoma, $3.00; HA-3, Ardmore-Sherman quadrangles, southern Oklahoma, $5.00; and HA-4, Oklahoma City quadrangle, central Oklahoma, $5.00. Publication of the next atlas in the series, HA-6, which covers the Lawton quadrangle, southwestern Oklahoma, is expected by early spring.

OGS Publications Reprinted

Guide Book 10

In response to continued demand, the Oklahoma Geological Survey has reprinted Guide Book 10, which had been out of print for 7 years. Written by the late William E. Ham and by Neville M. Curtis, Jr., the popular publication is entitled *Common Minerals, Rocks, and Fossils of Oklahoma.* As the introduction notes, the booklet is intended primarily for use by students in the schools of Oklahoma and was written specifically to accompany standard sets of 20 representative minerals, rocks, and fossils that are sent to schools that request them. The liberally illustrated booklet is also appropriate for use independently as a general explanation of these geologic materials and their occurrence; no collecting localities are given, however.

The 28-page booklet can be obtained for $1.00 by writing to the address on the front cover.

Mineral Reports

Several Mineral Reports (a Survey series discontinued since 1958) have been reprinted recently because of renewed interest in the mineral commodities they describe. Like Guide Book 10, they can be ordered from the Survey at the address on the front cover. The booklets and prices are listed as follows, with the original publication dates given in parentheses.

Mineral Report 3. *Glass Sands,* compiled by J. O. Beach (1939). 21 pages. $0.60.

Mineral Report 6. *Dolomite and Magnesium Limestone,* compiled by J. O. Beach and S. G. English (1940). 20 pages. $0.45.

Mineral Report 8. *Copper in the "Red Beds" of Oklahoma,* by C. A. Merritt (1940). 20 pages. $0.35.

Mineral Report 13. *Mineral Production of Oklahoma 1885-1940,* compiled by J. O. Beach (1942). 38 pages. $1.00.

Mineral Report 15. *Carbonizing Properties of McAlester Bed Coal from Dow No. 10 Mine, Dow, Pittsburg County, Okla. (Preliminary Report),* by J. D. Davis and D. A. Reynolds (1942). 12 pages plus tables. $0.50.

Mineral Report 27. *Uranium in Oklahoma, 1955,* by C. C. Branson, A. L. Burwell, and G. C. Chase (1955). 22 pages. $1.00.

Mineral Report 30. *Asphaltite in the Ouachita Mountains of Southeastern Oklahoma,* by W. E. Ham (1956). 12 pages. $0.75.

Report Issued on Rush Springs Aquifer

Ground Water Resources of the Rush Springs Sandstone of Southwestern Oklahoma is the title of a new publication by John S. Roles of the Oklahoma Water Resources Board. The Rush Springs Sandstone, Permian in age, is one of the principal aquifers in a region covering parts of Caddo, Canadian, Comanche, Custer, Grady, Stephens, and Washita Counties, in southwestern Oklahoma. The Rush Springs supplies water for household, stock, and irrigation use and for some rural water districts and municipalities.

The hydrologic investigation is detailed on three sheets. Sheet 1 contains an introduction, a water-quality chart, a geologic map, and a well-inventory map. Sheet 2 contains contour maps of the saturated thickness and total thickness of the aquifer as of 1974, bar charts of monthly and annual precipitation, and a map of water-level changes from 1956 through 1974. A discussion of the use and development of ground water from the Rush Springs is found on sheet 3, which also contains maps of 1956 and 1974 water-table measurements, a depth-to-water map, an irrigated-acreage map for the study area, and hydrographs.

The report, issued as Hydrologic Investigations Publication 72, can be obtained for $6.00 by writing the Oklahoma Water Resources Board, Jim Thorpe Building, Oklahoma City, Oklahoma 73105.

Inflation Catches *Notes* Again

Because of increased printing costs, we regretfully announce that our subscription rate for *Oklahoma Geology Notes* will have to be raised. Effective January 1, 1977, the new rate will be $4.00 a year for 6 issues. Single copies will continue to sell for 75 cents. All annual subscriptions received prior to January 1, however, will be renewed at the old rate of $3.00. Orders should be sent to the address on the front cover.

Exploration Methods and Concepts I, II
A Review

WILLIAM E. HARRISON[1]

Exploration Methods and Concepts I, II, Selected Papers Reprinted from AAPG Bulletin, compiled by J. Kaspar Arbenz. The American Association of Petroleum Geologists, 1976, 199 p., 219 p. AAPG Reprint Series Nos. 16, 17. $6 each ($5 to AAPG and SEPM members).

The latest installments in the AAPG Reprint Series, nos. 16 and 17, are important to an understanding of exploration methods and concepts. The collection contains papers dealing with four topics: risk evaluation, reservoir prediction, trap prediction, and charge evaluation.

The first volume, *Exploration Methods and Concepts I,* consists of a preface, 4 papers on methods of evaluating exploration risk (Part 1), and 11 papers on prediction of reservoir rocks (Part 2). The preface is especially useful because it lists 163 previously published papers that concern the 4 major topics.

The small number of papers on risk evaluation reflects the paucity of published studies addressed to this important aspect of petroleum geology. Lack of publications in this area does not signify lack of effort, however. Sophisticated prospect-evaluation schemes developed by industry are often the result of computer modeling, statistical analysis, and so forth, and they may provide real competitive advantages. Understandably, specific details concerning risk evaluation are not overly publicized. Thus Schwade's treatment of prospect evaluation is particularly useful. His paper contains a set of working guidelines that can be used by virtually anyone involved in petroleum exploration.

The second part of volume 1 contains papers about stratigraphic models, the use of electric-log and dipmeter surveys, and porosity-permeability relations. Individual papers by Sloss, Asquith, and Davies and Ethridge provide a good collection of depositional models for clastic environments. The overall effect of these papers might have been better if they had been arranged by subject rather than chronologically by publication date. Sloss prompts the reader to consider regional cause-and-effect relationships. Asquith's paper is somewhat more restricted, in that it concerns facies patterns associated with cyclic and deltaic sedimentation. Finally, the paper by Davies and Ethridge is directed toward methods of discriminating between subenvironments, i.e., dune sands versus lagoonal sands within a barrier-island setting. Arrangement as above might have emphasized the importance of various levels of data. Regional interpretations are possible with a given level of data; however, determination of increasingly more specific depositional settings requires considerably more and better data.

Increased demand for natural gas has been a motivating force for renewed interest in deep, hot drilling capability. The reprinting of Maxwell's

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[1]Geologist, Oklahoma Geological Survey.

paper on the influence of depth-temperature on sandstone porosity is timely. His work suggests that careful consideration of potentially detrimental effects on reservoir parameters is warranted when evaluating deep sandstone prospects.

Four papers provide examples of the use of electric-log and dipmeter data as practical exploration tools. All four of them stress application of easily obtained information to yield stratigraphic and facies interpretations as well as reservoir parameters.

The second volume, *Exploration Methods and Concepts II,* is also divided into 2 parts. Part 1 concerns trap prediction and includes papers which vary from sealing and non-sealing faults to radar geology. Levorsen's discussion of subtle traps and the need for more exploration for stratigraphic traps was a perfect build-up for the discovery of the Bell Creek field some 8 months later. Inclusion of one of the Bell Creek papers might have been appropriate in this section.

Much of the work in petroleum exploration is directed toward a better understanding of and prediction of paleogeomorphology. A working notion of how this discipline relates to prospecting for petroleum appears to be neglected in our current trend toward specialization. This makes Martin's paper on geomorphology in exploration an especially valuable asset to the collection of papers. Two in-depth presentations on unconformities round out the section on trap prediction. A general paper on geophysical exploration for traps might have complemented this section, but otherwise it is well balanced and draws together several good studies.

Part 2, entitled "Assessment of Hydrocarbon Charge," is the geochemistry section. The first paper in this section, Welte's "Relation between Petroleum and Source Rock," is an excellent summary of petroleum-generation and migration information. The paper was first reprinted in Reprint No. 1 (*Origin of Petroleum*) and is appropriately included in no. 17 because of the increasing emphasis on source-rock evaluation in exploration programs.

Price and the quality of the papers have made the AAPG Reprint Series excellent bargains. *Exploration Methods and Concepts I* and *II* are not exceptions; they are worthwhile items for anyone concerned with petroleum exploration.

Oklahoma Coverage by USGS Aeromagnetic Maps

The accompanying index map shows the locations of airborne magnetic surveys flown by the U.S. Geological Survey for which results are available to the public. A list of publications and open-file releases is keyed to the map.

Several of the publications listed are Geophysical Investigations Maps (GP) and Miscellaneous Geologic Investigations Maps (MGI). These can be purchased for the prices indicated from the Branch of Distribution, U.S.

Geological Survey, Building 41, Box 25286, Federal Center, Denver, Colorado 80225.

Maps A and B appear as illustrations in an article in *Geophysics,* a periodical available in many libraries. Photocopies of this article can be obtained from Photoduplication Service, Library of Congress, Washington, D.C. 20402, at nominal cost. Open-file releases can be examined or copied at the offices indicated.

The various maps and profiles are listed as follows.

	MAP REFERENCE
The upward continuation of anomalies in total magnetic intensity fields, by R. G. Henderson and Isidore Zietz, 1949, Geophysics, v. 14, no. 4, p. 517-535 (figs. 2-6 are aeromagnetic maps of the Elk City area)	A
(Figs. 9-13 are aeromagnetic maps of the Mangum area)	B
Aeromagnetic map of the Wichita Mountains area, southwestern Oklahoma, by U.S. Geological Survey, scale 1:62,500 (Open-File Report 75-16, 1975)	C
Copies on file at 1, 2, 3, 4. Reproductions can be ordered from 3.	
Total intensity aeromagnetic profiles over northeastern Oklahoma, by G. E. Andreasen and R. W. Bromery (open-file report, 1963)	D
Copies on file at 1, 3, 4. Reproductions can be ordered from 3.	
MGI-533-A. Magnetic map from 100° to 112° W. Longitude, by Isidore Zietz and J. R. Kirby, 1968, scale 1:1,000,000 (coverage in Oklahoma mostly from Vertical-intensity magnetic map of Oklahoma, by V. L. Jones and Paul Lyons, OGS Map GM-6, 1964), 50 cents	E
MGI-534-A. Magnetic map from 87° to 100° W. Longitude, by Isidore Zietz and J. R. Kirby, 1968, scale 1:1,000,000 (coverage in Oklahoma mostly from Vertical-intensity magnetic map of Oklahoma, by V. L. Jones and Paul Lyons, OGS Map GM-6, 1964), 50 cents	F
GP-427. Aeromagnetic map of part of the Tri-State mining district, Kansas, Missouri, and Oklahoma, by Fred Keller, Jr., and John R. Henderson, 1963, scale 1:125,000, 50 cents	427
GP-469. Aeromagnetic map of the Glencoe-Ripley area, Payne County, Oklahoma, by G. E. Andreasen, R. W. Bromery, and F. P. Gilbert, 1964, scale 1:62,500, 50 cents	469
GP-470. Aeromagnetic map of the Hominy area, Osage County, Oklahoma, by G. E. Andreasen, R. W. Bromery, and F. P. Gilbert, 1964, scale 1:62,500, 50 cents	470
GP-597. Aeromagnetic and gravity profiles of the United States along the 37th parallel, by Isidore Zietz and J. R. Kirby, 1967, scale 1:2,500,000, 50 cents	597

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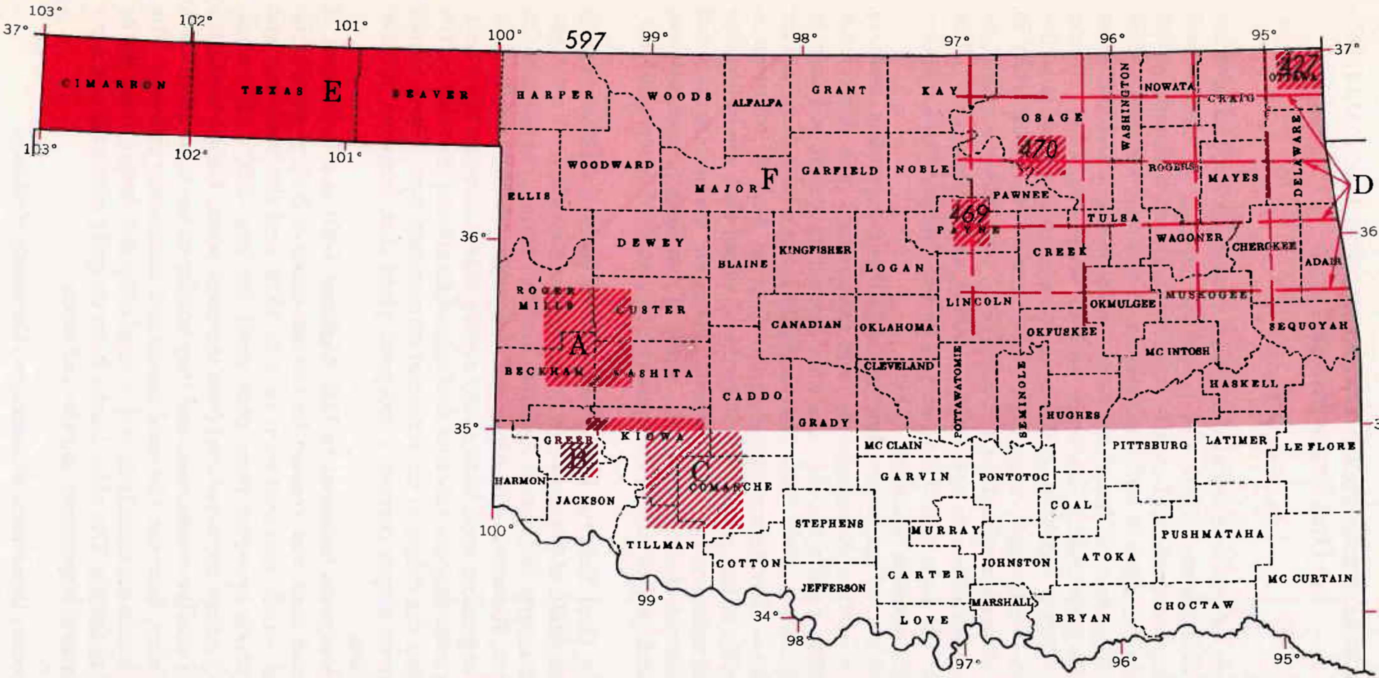
1. USGS Library, Room 4-A-100, 12201 Sunrise Valley Drive, Reston, Virginia 22070.
2. Room 1012 Federal Building, 1961 Stout Street, Denver, Colorado 80202.
3. Oklahoma Geological Survey, The University of Oklahoma, 830 Van Vleet Oval, Room 163, Norman, Oklahoma 73019.
4. Room 1C65 Federal Building, 1100 Commerce Street, Dallas, Texas 75202.



Index map of Oklahoma showing coverage by U.S. Geological Survey aeromagnetic maps and profiles. See accompanying text for explanation.

Environmental Problems Associated with Reclamation of Old Strip-Mined Land

Martin J. Haigh[1]

The pattern of environmental disruption caused through strip-mine operations is well known (USDI, 1967), and the capacity of unreclaimed strip-mine dumps to erode and create sediment-pollution problems in the surrounding environment is well documented. A national survey in 1968 indicated that 44 percent of America's surface-mined land caused pollution problems in the surrounding landscape and 40 percent suffered rill and gully erosion (USDA, 1968). In addition, it is frequently argued that the unnatural "saw-tooth-ridge" topography and patchy vegetation that is characteristic of surface-mined land (Doerr, 1961) constitutes a visual intrusion and a kind of scenic pollution (Appleton and others, 1975). The suggestion that old strip-mined land should be reclaimed is thus, usually, greeted with enthusiasm (Johnson, 1971).

Unfortunately, reclamation technology is still far from perfect, and it is possible that in certain circumstances land reclamation may cause more scenic and sediment pollution than the unreclaimed mine dumps. Recently disturbed land tends to erode more than land that has not been disturbed for several decades—other things being equal. A great deal of attention is devoted currently to the production of artificial slopes that are in equilibrium with their local erosional environment. However, the precise nature of such an equilibrium slope expressed in terms of morphology, composition, density, and surface hydraulics is a matter for conjecture (Carson and Kirkby, 1967).

Maleen, at Oral Roberts University, has recently circulated results from an investigation of the impact of strip-mine reclamation on river systems in northeastern Oklahoma (written communication, contribution to 1976 conference, Association of American Geographers). His results demonstrate that regrading spoil banks may substantially increase their sediment yield by removing the internal drainage obstructions provided by the furrows between the ridges of unreclaimed strip-mined land. Storm runoff from such barren slopes carried a sediment yield that exceeded 100,000 parts per million.

East of Henryetta (adjacent to U.S. highway I-40) is a large area of strip-mined land that was created by the activities of 2 strip mines: the Alkonak mine, which operated from 1916 to 1924, and the McGinnis and Grafe mine, which operated from 1948 until the late 1950's (Trumbull, 1957). The two mines extracted coal from the same seam, buried beneath a like amount of similar overburden, and they employed the same production techniques. Today, however, the spoil banks look completely different. The younger spoil banks are mainly devoid of vegetation and deeply dissected by rill and gully channels. The older banks have no gully channels and have substantial natural vegetation, shrubs and trees.

[1]Assistant Professor, Department of Geography, University of Chicago.

It is often assumed that the best way to reduce sediment yields from surface-mined land is to establish a vegetation cover. This is probably true. Even patchy or thin surface vegetation reduces rainfall impact on the soil surface by interception, and this restricts splash detachment, crusting, and compaction; it also provides obstacles to the development of surface wash by increasing the roughness coefficient of the soil surface; and it delays the arrival of precipitation at the soil surface, thereby granting more time for infiltration into soil opened up by channels created by the growth of roots and movements of soil organisms. In addition, root hairs in the soil bind soil particles, thus increasing resistance to creep and incision, while the ameliorating effect of the vegetative layer on soil micro-climate reduces the potential for freeze-thaw disruptions. However, recent studies of the rates of erosion affecting unvegetated, naturally vegetated, and artificially vegetated slopes on surface-mine-disturbed lands in South Wales, the United Kingdom, suggest that the reduction of erosion effected by the addition of a vegetation cover is not as great as one might expect. The results from the South Wales study indicate that slopes covered by a thin (> 80 percent) natural-vegetation cover sustained about half the soil loss of slopes that were totally devoid of vegetation, and slopes covered by a dense, seeded turf (100 percent cover) have perhaps a third the soil loss (Haigh, in press). Studies from spoil banks in Kentucky suggest that the erosion from spoil banks is a thousand times greater than that from comparable, undisturbed, forested areas (USDI, 1967).

It is unusual for land-reclamation contractors to employ seed mixtures that reflect the local vegetation communities. Usually, commercial and (or) agricultural seed mixtures are employed because they are much less expensive and more reliable than any customized mixture. The former, however, usually contain plant species that are alien to the local environment. Consequently, reclaimed lands are different floristically from their natural surroundings and thus tend to continue to be visually obtrusive. Naturally revegetated mine dumps, however, having taken their seed material from the local environment, tend to blend better into local scenery. When such areas are tree covered, surface irregularities can be disguised by the growth of vegetation. In addition, these surface irregularities may be a blessing. The rough surface, with ponds and damp hollows, may provide a wider than usual variety of habitat types and support a wide variety of wild species. It is not uncommon in western Europe for such sites to be incorporated into wild-life refuge areas.

Obviously, there are very good reasons why some of Oklahoma's old surface-mine-disturbed lands should be reclaimed. However, reclamation is still an imperfect and expensive tool, and there are circumstances when land reclamation may lead to greater sediment and scenic pollution than that caused by the abandoned mine dumps themselves. Oklahoma has many acres of old surface-mine-disturbed land that are well vegetated, which cause very little scenic intrusion, or sediment pollution, and which currently act as refuges for many wild-life species. Some of Oklahoma's surface-mine-disturbed lands are better left alone.

Acknowledgment

The author would like to thank Dr. James Goodman for his assistance in these studies.

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APGS Members in Oklahoma Hold Annual Meeting

The annual meeting of the Oklahoma Section, Association of Professional Geological Scientists (formerly American Institute of Professional Geologists), was held September 10-12 in Oklahoma City. The theme of the meeting, "An Assessment of Energy Survival," was developed by a diverse group of speakers in an all-day session September 11. The organization's annual business meeting was conducted the following day.

Robert R. Curry, a member of the geology faculty at the University of Montana, spoke from his standpoint as a research director for the Sierra Club and also as a geologist interested in geomorphology and the atmosphere. He explained that his position with the Sierra Club is a voluntary one and that he participates with the club's energy-advisory group in efforts to obtain the best possible information on energy for the membership. He said that geologists are uniquely equipped to ascertain the facts (on energy and related earth resources) and have, moreover, an obligation to present these facts to the public.

Although noting some of his differences with most industry-oriented geologists (for instance, he endorses the Sierra Club's commitment to zero energy growth and a longer range view of the energy spectrum—beyond what he termed "stockholder capitalism"), he also cited some common ground, such as energy conservation, and stated his and the club's opposition to more stringent automobile-emission controls that would lead to greater energy use.

J. R. Jackson, manager of exploration and environmental affairs for Exxon Co. U.S.A., stressed the urgency of the nation's short-term energy needs. He spoke of the necessity for greater incentives for exploration for new petroleum reserves and for increased development of coal and nuclear-energy resources in order to lessen dependency on foreign sources of supply.

Tom Noel, assistant administrator for strategic petroleum reserves with the Federal Energy Administration, outlined his agency's plan for development of sufficient storage capacity for petroleum reserves to reduce the country's vulnerability in the face of another massive petroleum embargo similar to the one imposed by the Arab nations in 1973-74. Such a strategic storage program is called for, he explained, as a part of the Energy Policy and Conservation Act, which became law last December. The act provides for an "industrial petroleum reserve" ranging from 500 million to 1 billion barrels. Mr. Noel pointed out that at the time of the last embargo the United States imported 31-33 percent of its petroleum requirements and that now these imports total about 41 percent.

The reserve plan favored by Mr. Noel's group is underground storage in salt domes in the Gulf Coast region. Eight tentative sites have been selected for this purpose. Mr. Noel cited some of the advantages of salt-dome storage:

- The geographical location of the salt domes in coastal areas is favorable because of proximity to ports, refineries, and pipelines.
- Underground storage is cheaper than storage above ground.
- Salt domes are easily minable; in fact, some have already been excavated.
- Environmental considerations favor salt-dome storage.

Mr. Noel concluded his remarks by estimating that the storage of 500 million barrels by this means would cost $8-11 billion but that this amount would more than offset the loss of the gross national product during a prolonged embargo period. He stated that completion of the storage program is required by law, and he called on groups like APGS to make meaningful input into its implementation.

John Leftwich, a market analyst with Bache, Halsey, Stuart, Inc., presented his view of the nation's economic situation. He cited inflation as a continuing menace to a healthy economy. He pointed out that mammoth federal deficits have been a principal cause of the problem and observed that the federal budget has increased by about 50 percent in only 4 years so that federal spending is now greater than $1 billion a day. Mr. Leftwich stressed that in order to halt this trend hard economic decisions would have to prevail over political expediency.

Also at the meeting, Ralph H. Espach, outgoing president of the Oklahoma Section, presented plaques in recognition of outstanding service to past section presidents John A. Taylor and Wilbur E. McMurtry. At the conclusion of the meeting Ralph Espach himself was honored in similar fashion by incoming president Henry Trattner. (See page 204 of this issue for a complete slate of section officers.)

Oklahoma's Geological Societies Install New Officers

New officers and executive committees for the 1976-77 year have been announced by the following geological and geophysical societies in Oklahoma:

Ardmore Geological Society
President, **Lawrence S. Morrison,** Westheimer-Neustadt Corp.
Vice-President, **Harry Spring,** Kingery Drilling Co.
Secretary-Treasurer, **R. P. Wilkinson,** consultant
Past-President, **Robert W. Allen,** consultant

Association of Professional Geological Scientists, Oklahoma Section
President, **Henry Trattner**, consultant
First Vice-President, **John S. Fryberger,** Engineering Enterprises, Inc.
Second Vice-President, **Wilgus B. Creath,** Environmental Sciences Corp.
Secretary-Treasurer, **John H. Gatchell,** independent
Past-President, **Ralph H. Espach, Jr.,** consultant
District Representatives: **Robert A. Northcutt,** independent; **Jerry E. Upp,** consultant; **Virgil H. Roan,** independent

Geophysical Society of Oklahoma City
President, **J. M. Collar,** Forest Oil Co.
First Vice-President, **R. R. Foster,** Dawson Geophysical Co.
Second Vice-President, **B. B. Ferrell,** Data Finders
Secretary, **M. G. Cook,** Cities Service Gas Co.
Treasurer, **R. E. Zdyb,** Phillips Petroleum Co.
Editor, **R. E. Schneider,** Continental Oil Co.
Past-President, **R. E. Schneider,** Continental Oil Co.

Geophysical Society of Tulsa
President, **R. W. Mossman,** Seismograph Service Corp.
First Vice-President, **Sheldon M. Miller,** Tesco Engineering Co.
Second Vice-President, **Harold D. Herbig,** Cities Service Oil Co.
Secretary, **Stanley S. Wedel, Jr.,** Seismograph Service Corp.
Treasurer, **Donald E. Wagner,** Amoco Production Co.
Editor, **Dale G. Stone,** Seismograph Service Corp.
Editor-Elect, **Roger M. Borcherding,** Texaco, Inc.
Past-President, **E. L. Current,** Cities Service Oil Co.

Oklahoma City Geological Society
President, **Thomas C. Cronin,** Hoover and Bracken Oil Properties, Inc.
First Vice-President, **Sherrill D. Howery,** Union Oil Co. of California
Second Vice-President, **Guy B. Kiker,** GADSCO, Inc.
Treasurer, **Don F. Weber,** independent
Secretary, **James W. Caylor,** independent
Shale Shaker Editor, **Cary L. McConnell,** Gulf Energy and Mineral Co. — U.S.
Library Director, **Philip K. Webb,** Ratliff Drilling Co.
Social Chairman, **Leonard C. Dionisio, Jr.,** Texas Oil and Gas Corp.
Public Relations Chairman, **Harold W. Hanke,** Lear Petroleum Corp.
Past-President, **William E. Jackson,** Patrick Oil Co.

Oklahoma City Geological Society executive committee for 1976-77. Front row, left to right: William E. Jackson, past-president; Sherrill D. Howery, first vice-president; Thomas C. Cronin, president; Guy B. Kiker, second vice-president. Back row, left to right: Don F. Weber, treasurer; Harold W. Hanke, public relations chairman; James W. Caylor, secretary; Cary L. McConnell, *Shale Shaker* editor; Leonard C. Dionisio, Jr., social chairman.

Tulsa Geological Society

President, **George Bole,** Amoco Production Co.
First Vice-President, **Fred Ballard,** consultant
Second Vice-President, **George W. Krumme,** Krumme Oil Co.
Secretary, **J. Glenn Cole,** Amoco Production Co.
Treasurer, **Charles D. Seiler,** Oklahoma Natural Gas Co.
Editor, **Connie Allen,** Williams Exploration Co.
Newsletter Editor, **Paul Basan,** Amoco Production Co.
Past-President, **Roderick W. Tillman,** Cities Service Oil Co.
Councilmen: **W. T. Lehman,** Cities Service Oil Co.; **Alvin A. Chinn,** Texaco, Inc.; **Edward D. Pittman,** Amoco Production Co.

USGS/USBM Bulletin Classifies Mineral Resources

U.S. Geological Survey Bulletin 1450, which is being published jointly with the U.S. Bureau of Mines, has been designed to present results of studies undertaken for the purpose of developing a standardized comprehensive system for classification of mineral resources of all kinds. One of the difficulties in evaluating these resources in the past has been the lack of a uniform method of appraisal, and this study is intended to provide a basis for coordinating varying estimates as well as a method for eliminating present discrepancies in estimates. Two sections of the bulletin have been issued to date.

The first report, Bulletin 1450-A, *Principles of the Mineral Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Sur-*

vey, offers general definitions of mineral and energy resources, the bases on which the classification system is formed, and a glossary of terms used in describing resources.

Bulletin 1450-B, *Coal Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey,* presents a glossary of the classification terms as they apply specifically to coal beds and lists criteria for identifying coal resources and reserves.

Future chapters of the bulletin will list terms for other specific commodities.

These publications can be ordered from the Branch of Distribution, U.S. Geological Survey, 1200 Eads Street, Arlington, Virginia 22202. Each is available for $0.35.

Other Recent U.S. Geological Survey Publications

U.S. Paleozoic and Mesozoic Rocks

Issued as Professional Paper 903, *The Paleozoic and Mesozoic Rocks; a Discussion to Accompany the Geologic Map of the United States,* by P. B. King and H. M. Beikman, describes and explains rock units of these eras as shown on the Geologic Map of the United States (1974). The 76-page text expands the map explanation and also gives information on the nature and origin of the rocks. Although most of the discussion covers stratified units, particularly those on which new information has become available, volcanic, plutonic, and metamorphic rocks are also included.

This publication can be ordered for $1.90 from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202.

Oklahoma Flood Measurement

Techniques for Estimating Flood Depth for Oklahoma Streams, by W. O. Thomas, Jr., a 36-page volume issued as Water Resources Investigations 76-2, is available for $4.00 ($2.50 for microfiche) from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161. The publication has been designated as NTIS PB-253 310/AS and should be ordered under this number.

Ground-Water Records, Northeastern and Southeastern Oklahoma

The first parts of two open-file reports entitled *Ground-Water Records for Northeastern Oklahoma* and *Ground-Water Records for Southeastern Oklahoma* have been issued recently by the U.S. Geological Survey. Prepared in cooperation with the Oklahoma Geological Survey and with other State, federal, and local agencies, both reports, which were compiled by John S. Havens and DeRoy L. Bergman, are essentially tabulations of data from wells, test holes, and springs in the respective areas. The northeastern report contains 100 pages and presents data from about 3,360 wells in 23 counties, and the southeastern report contains 59 pages and presents data from about 1,780 wells in 16 counties. Also given are lists of selected references to pertinent ground-water reports covering parts of the areas. The information presented in the tabulations includes location, owner, year drilled, depth, use of water, well diameter, depth to water, well yield, aquifer, altitude of land surface, and well-log data.

The second parts of the studies covering both Oklahoma areas are now being prepared and will deal with the chemical quality of these water supplies.

Single copies of the first parts of both reports are available without charge by writing the District Chief, U.S. Geological Survey, Water Resources Division, 201 NW 3d Street, Room 621, Oklahoma City, Oklahoma 73102.

Garber-Wellington Aquifer, Central Oklahoma

Another ground-water report has been issued by the U.S. Geological Survey, as Open-File Report 76-619. Compiled by Jerry E. Carr and John S. Havens, the 32-page report is entitled *Records of Wells and Water Quality for the Garber-Wellington Aquifer, Northern Oklahoma and Southern Logan Counties, Oklahoma.* The report was prepared in cooperation with the Oklahoma Geological Survey and the U.S. Bureau of Reclamation. In addition to the types of data presented as outlined in the preceding item, the report also gives data on chemical content of the water, including hardness. Single copies of this report are also available without charge from the address given in the preceding paragraph.

Potential Federal Coal-Lease Tracts Shown on BLM Maps

Recently, the Bureau of Land Management of the U.S. Department of the Interior issued a request seeking nominations of tracts of land containing potential for federal coal leasing and asking also for comments on the department's federal coal-leasing policy in the states of Alabama, Colorado, Montana, New Mexico, North Dakota, Oklahoma, Utah, and Wyoming. Nominations were received from approximately 300 sources, including both coal companies and private citizens, some of whom own land over federal coal deposits. These sources named about 1,000 areas comprising more than 3 million acres they would like to have made available for leasing; however, 75 nominations of 200 tracts covering more than 3 million acres were registered against federal leasing.

Although tabulation is not in final form, tentative results of the questionnaire have been depicted on state maps showing the areas suggested. Explanations to the maps indicate the number of tracts named, the number of nominators, and whether those responding favored leasing or considered that environmental or resource-use conflicts were sufficient to make leasing undesirable. For Oklahoma, 15 nominators favored leasing on 20 tracts totaling 44,000 acres in Haskell, Le Flore, Latimer, Pittsburg, and Coal Counties; no tracts were designated as unfavorable for leasing.

A copy of the Oklahoma map is available for inspection at the Oklahoma Geological Survey. Copies can be obtained on request from the U.S. Bureau of Mines, 168 Old Post Office Building, Oklahoma City, Oklahoma 73102. Maps of all nominated areas are also for sale by the Bureau of Land Management, Denver Service Center, Denver Federal Center, Building 50, Denver, Colorado 80255.

The survey reported and the publication of the state maps represent only the first step in the Department of the Interior's competitive coal-leasing process, known as the Energy Minerals Activity Recommendation System (EMARS). Interior estimates that it will be at least 15 to 18 months more before intervening steps leading to eventual lease sales can be completed.

Southwest Regional Energy Council Meets in Dallas

The Southwest Regional Energy Council (SWREC) convened a legislative conference on greater coal utilization August 5-7 in Dallas. The purpose of the conference was to provide greater awareness and understanding among state legislators from the five member states—Arkansas, Louisiana, New Mexico, Oklahoma, and Texas—of industry's plans to use more coal and of the constraints against coal mining and utilization.

State Senator Herschal Crow of Oklahoma, chairman of the council, stated that "with the mandatory conversion of many natural-gas-fired electric power plants to coal, we believe the western states must begin to discuss legislative and regulatory differences among the states." Several speakers indicated that increased coal production and utilization could not take place under an unreasonable set of constraints. The constraints at present concern federal and state regulations on coal mining, mined-land reclamation, air and water quality, federal leases, and the federal coal-royalty rate.

On August 5, some 200 registrants listened to representatives of coal and utility companies and of federal and state agencies speak on the conditions necessary for financial investment in coal, the increasing coal-production rate, the conversion of industrial boilers for coal use, mine-site power generation, mined-land reclamation, coal gasification, desulfurization, transportation, and labor and manpower requirements.

On August 6, the group divided into concurrent sessions on coal transportation, mining and reclamation, mine-site use of coal, water availability, coal supply and mine expansion, and taxes and impact assistance. Panel speakers presented informative summaries of their topics and then were asked questions by the other participants. It was reported that the railroad protagonists hotly debated the slurry-pipeline proponents in the transportation session.

Senator Crow, the council chairman, conducted the formal legislative meeting of the council on August 7.

Some of the speakers noted that just as increasing costs during construction delays have resulted recently in cancellations of nuclear-power-plant and coal-gasification-plant projects, so construction of proposed electricity-generating plants that would burn coal might be cancelled if costs were to rise unreasonably prior to construction. William L. Fisher, Assistant Secretary of the U.S. Department of the Interior, in a talk on western coal, stated that the greatest issue in new coal developments is uncertainty caused by increased costs as a result of delayed construction.

Charles J. Mankin, director of the Oklahoma Geological Survey, and S. A. Friedman, OGS coal geologist, served on the panel for coal supply and mine expansion. Others on this panel from Oklahoma were Ward Padgett, chief mine inspector, Oklahoma Department of Mines, and Senator Crow, the session moderator.

Dr. Mankin, in his talk, indicated that at the current rate of increasing coal production it would be impossible for the United States to achieve 1.2 billion tons of production annually by 1985. He also stressed the importance of reliable detailed information on coal resources and recoverable reserves, such as that contained in the Oklahoma Geological Survey's 1974 report to the Ozarks Regional Commission. He noted that few southwestern states have updated and published such detailed coal information or have current mapping projects to delineate their coal resources at a scale that makes the maps usable by the public. He recommended that states that lack such detailed coal information undertake similar projects.

At the close of the session on coal supply and expansion, the OGS representatives distributed extra copies of summary material on coal that had been prepared at the request of the council chairman. The handout summarized the latest figures on U.S. coal production and reserves, estimates of sulfur deficits[1] in U.S. coal production through 1990, coal resources, and production and mining highlights for four of the SWREC member states (Arkansas, New Mexico, Oklahoma, and Texas).

As a final note, the large Texas utilities are planning to use huge quantities of Texas lignite and some uranium in scheduled future power plants, and Oklahoma's utilities are planning to use subbituminous and bituminous coal from Wyoming and possibly Oklahoma, respectively, but in smaller quantities than the lignite planned for use in Texas.

This writer was impressed by the rapid exchange of ideas and facts on coal, energy, and regulations and feels that a meeting of this sort next year would bring forth additional pertinent information on these matters.

—*S. A. Friedman*

[1]A sulfur deficit, as defined by guidelines adopted by the U.S. Environmental Protection Agency and the Federal Energy Administration, is the difference between total coal requirements and the low-sulfur coal available to fill those requirements. For example, in the EPA-FEA accelerated development plan for Oklahoma and Arkansas, annual production in 1980 is estimated to be 2 million tons (a figure the writer, incidentally, believes to be much too low), but under the sulfur regulations of the EPA-approved State Implementation Plans, only 1.3 million tons is projected to be available, leaving a sulfur deficit of 700,000 tons.

OKLAHOMA ABSTRACTS

AAPG-SEPM Regional Meeting, Gulf Coast Section
Shreveport, Louisiana, October 13-15, 1976

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Geologic Evolution of Mid-Continent and Gulf Coast Areas: Plate Tectonics View

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The Gulf Coast and Mid-Continent areas of the southern United States, in the past 500 m.y., are postulated to have been the scene, first, of continental approach and collision, and later of a rifting almost at the site of the suture. Spreading apart of the newly formed continents proceeded to the present.

The approach of the two continental masses (the North American plate and the Afro-South American plate) affected sedimentation on the southern part of the North American craton. As extensions of the open ocean, epicontinental seas of Late Cambrian through Mississippian time deposited largely carbonate rocks over a vast region in what is now the Mid-Continent area. From Pennsylvanian time to the end of the Paleozoic, as the continents closed rapidly causing great instability in the area, terrigenous rocks dominated Mid-Continent sedimentation. Throughout most of Paleozoic time a shelf edge was present along an east-west line in Oklahoma and curved north-south through central Texas; in a very general way this line coincides with the northwest limits of the present Ouachita belt. Southeast of this line the water deepened rapidly and early Paleozoic sediments deposited were largely shale and deep-water carbonate rocks. By middle Paleozoic time, as collision became imminent, deep subsidence in the area of the Arkoma basin and the future Ouachita Mountains resulted in the accumulation of great thicknesses of terrigenous sediments.

Collision of the continents occurred in about early Middle Pennsylvanian time creating the Ouachita suture belt which contains the basinal rocks of the early and middle Paleozoic. In Late Pennsylvanian and Permian time relaxation of the crust occurred on the southeast flank of the Ouachita belt and rifting began. Late Pennsylvanian and Permian sedi-

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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.

ments, including red beds and some marine carbonate rocks and shales, were deposited on both sides of the Ouachitas by intermittent incursions of the sea. By Triassic time the sea had withdrawn completely from the Mid-Continent area and no further marine sedimentation occurred. South of the Ouachita belt, sedimentation of largely red beds continued into Early Triassic time as the newly formed mobile plates moved apart, creating a graben system which received the Triassic sediments.

In Late Triassic and Early Jurassic time the sea entered the area on the southeast side of the Ouachitas in a restricted, perhaps intermittent, manner so that great masses of salt were deposited. By Middle Jurassic time the newly formed Atlantic Ocean had opened sufficiently to allow normal marine sedimentation to take place on the southern margin of the North American continent. Smackover carbonate deposits, for example, are not unlike the open-sea carbonate-shelf rocks of the early and middle Paleozoic. Jurassic through Neogene carbonate and terrigenous rocks are typical deposits of epicontinental seas.

Plate-tectonic movements have affected the distribution of hydrocarbon deposits in the Mid-Continent and Gulf Coast areas. For example, the location and shifting through time of a sedimentational and tectonic hinge-line may have been controlled in part by plate movement. Structure and trap style, timing in trap development, and quality of trap also may have been affected by plate-tectonic movement, particularly in the late stages of continental approach (for the Mid-Continent) and the early stages of moving apart (for the Gulf Coast).

It is concluded that, for the sake of greater understanding, the ideas contained within the plate tectonics theory should be incorporated into any studies which involve the unraveling of the details of regional stratigraphy, sedimentation, or structural geology. In turn we may enjoy an increase in knowledge of the details of hydrocarbon accumulation and distribution. [1608]

Evaluation of Quality and Quantity Controls on Coal-Resource Assessment and Utilization

J. H. MEDLIN, S. L. COLEMAN, G. H. WOOD, JR., and K. J. ENGLUND, U.S. Geological Survey, Reston, Virginia

In the past, quality measurements such as heat value, fixed carbon, moisture, ash, sulfur, phosphorus, and coking and grindability characteristics have been the parameters used for utilization assessments. However, currently more quantitative geologic and geochemical data are necessary for a comprehensive coal-resource assessment because of (1) the development of sophisticated conversion processes, (2) environmental constraints related to coal usage, and (3) the probability that coal contains many mineral byproducts. Gathering such data involves studies on the modes of occurrence, concentration, and distribution of elements both stratigraphically and geographically within a coal bed and a coal basin. In the technologic and environmental realms, many of these elements affect coal reactivity, gaseous and liquid yields, and planned waste disposal, reclamation, and revegetation. Knowledge of various elements will aid in developing the ability to (1) predict elemental distribution, concentrations, and coal properties in localities where data are sparse; (2) incorporate these data into different classes of coal resources; and (3) categorize coal resources for metallurgical, gasification, liquefaction, petrochemical, and blending usages. Necessary determinations include ash-fusibility temperatures, mineral-matter mineralogy, petrologic characteristics, sulfur forms, pertinent washability data, and the major-, minor-, and trace-element chemistry of coal.

Measurements necessary for resource quantity and quality calculations include: (1) thickness of coal, and rank and quality parameters, (2) depth of the coal bed, and (3) the proximity of the coal resources on which the estimate will be based. Various combinations of these measurements allow the establishment of different resource classes and the estimation of tonnages within each class. The integration and aggregation of quantity and quality coal data with sedimentologic, stratigraphic, and structural data will provide a framework for determining the most efficient use of coal resources, insuring maximum-energy efficiency and conservation, and maintaining environmental integrity. [1613]

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