

OKLAHOMA GEOLOGICAL SURVEY

CARL C. BRANSON, *Director*

CIRCULAR 70

NEW PERMIAN VERTEBRATES  
FROM THE CHICKASHA FORMATION  
IN OKLAHOMA

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# CONTENTS

ABSTRACT	5
INTRODUCTION	6
GEOLOGY AND COLLECTING SITES	7
Chickasha Formation	7
Collecting Sites	12
Blaine County	12
Kingfisher County	22
Canadian County	24
Grady County and northern Stephens County	26
McClain County	28
SYSTEMATICS	29
Class Chondrichthyes	29
Subclass Elasmobranchii	29
Order Xenacanthodii	29
<i>Xenacanthus</i> sp.	29
Class Osteichthyes	30
Subclass Actinopterygii	30
Order Palaeoniscoidea	30
Family uncertain	30
Class Amphibia	30
Subclass Lepospondyli	30
Order Microsauria	30
Family Gymnarthridae	30
<i>Cymatorhiza kittsi</i>	30
Subclass Apsidospondyli	30
Superorder Labyrinthodontia	30
Order Temnospondyli	31
Suborder Eryopoidea	31
Family Trimerorhachidae	31
<i>Nannospondylus</i> , new genus	31
<i>Nannospondylus stewarti</i> , new species	31
Family Dissorophidae	34
<i>Fayella</i> , new genus	34
<i>Fayella chickashaensis</i> , new species	34
Family uncertain	37
New genus, not named	37
Incertae sedis	37
Genus not determined	37
Class Reptilia	38
Subclass Anapsida	38
Order Captorhinomorpha	38
Family Captorhinidae	38
<i>Rothia</i>	38
<i>Rothia robusta</i> , new species	38

Subclass Synapsida	48
Order Pelycosauria	48
Suborder Sphenacodontia	48
Family Varanopsidae	48
<i>Varanodon</i> , new genus	49
<i>Varanodon agilis</i> , new species	57
Suborder Caseasauria	57
Family Caseidae	57
<i>Cotylorhynchus bransoni</i>	58
<i>Angelosaurus romeri</i>	59
Unassigned caseids	60
Family Tappenosauridae?	60
New genus, not named	63
Incertae sedis	66
ASSESSMENT OF THE FAUNA	69
REFERENCES	

## ILLUSTRATIONS

### PLATES

I. Fossil site BC-7	15
II. Fossil sites BC-7 and BC-8	17
III. Fossil site BC-9	19
IV. Fossil sites BC-10 and BC-6	21
V. Chickasha exposures in Grady County	25
VI. Chickasha exposures in Grady County	27
VII. <i>Rothia robusta</i> , <i>Fayella chickashaensis</i> , and <i>Nannospondylus stewarti</i>	33
VIII. <i>Varanodon agilis</i> and <i>Xenacanthus</i> sp.	55

## FIGURES

1. Map showing locations of fossil-collecting sites in relation to Chickasha-El Reno facies change	8
2. <i>Fayella chickashaensis</i> , <i>Cacops aspidephorus</i> , <i>Nanospondylus stewarti</i> , <i>Xenacanthus</i> sp., and an unnamed labyrinthodont	35
3. <i>Rothia robusta</i>	45
4. <i>Varanodon agilis</i> and <i>Varanops</i>	51
5. <i>Dimetrodon gigashomogenes</i> , <i>Cotylorhynchus bransoni</i> , and an unnamed taptenosaurid (?)	61

## TABLES

1. Measurements of Oklahoma specimens of <i>Rothia robusta</i> and Texas specimens of <i>Rothia multidonta</i>	41
2. Measurements of <i>Varanodon agilis</i>	48

## NEW PERMIAN VERTEBRATES FROM THE CHICKASHA FORMATION IN OKLAHOMA

EVERETT C. OLSON\*

## ABSTRACT

Field exploration has increased the known number of vertebrate-bearing sites in the Chickasha Formation from two, known in 1962, to twenty. The sites occur along the western margin of the Chickasha Tongue close to the zone of interfingering with the formations of the El Reno Group. They are grouped along an irregular line which passes from Blaine County on the northwest to Grady County on the southeast. Facies shifts occur along the trace. The dominant shales of the north give way to sandstones and conglomerates to the south. This change marks a closer approach to the southeasterly source of the sediments and an increase in the marine character of the beds. Vertebrate fossils become increasingly sparse from north to south.

The vertebrates include xenacanth and paleoniscoid fishes, gym-narthrid, trimerorhachid, and dissorophid amphibians, and captorhinomorph and pelycosaurian reptiles. Caseid reptiles outnumber all other constituents of the fauna, with captorhinomorphs in second position. Two new genera of amphibians, a trimerorhachid and a dissorophid, a new species of the captorhinomorph *Rothia*, and a new genus of the pelycosaurian family Varanopsidae are named and described.

The vertebrate fauna preserved in the Chickasha deposits lived on a delta marginal to the sea in which the deposits of the El Reno Group were formed. The ancestral sources of the fauna appear to be represented in part by an assemblage much like that found in the late Arroyo or early Vale *Cacops* bone bed in Baylor County, Texas. The fauna bears some resemblance to that of the San Angelo Formation of Texas and the earlier Hennessey Formation of Oklahoma.

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## INTRODUCTION

The first paper of a projected series, based upon a program of study of vertebrates in the Permian of Oklahoma by the writer and his associates, was published in 1962 (Olson and Barghusen, 1962). Since completion of the work reported at that time, three seasons have been devoted to field studies and much new material has been obtained.

The first phase of the continuing work involved completion of excavation of a quarry in Kingfisher County, now called the Omega quarry after a small town nearby. This site is designated as KF-1 and is in NW¼ NW¼ NW¼ NW¼ sec. 19, T. 17 N., R. 9 W., Kingfisher County. Many new specimens were obtained. They are mainly caseids, *Cotylorhynchus bransoni* Olson and Barghusen and *Angelosaurus romeri* Olson and Barghusen. Detailed treatment of these particular specimens will be presented in a comprehensive study of the family Caseidae now in preparation.

During completion of the quarry and afterwards, attention was directed to searches for other sites. The work was made easier and more effective by the aid of Robert O. Fay of the Oklahoma Geological Survey. He accompanied our parties in the field on several occasions and directed our attention to various sites that had possibilities of producing vertebrate fossils. As noted in the paper cited above, he discovered the Omega quarry. Two of his recent publications (Fay, 1962, 1964) have immensely facilitated the stratigraphic aspects of the project. The hunt for new sites is continuing. Of the 21 fossil-bearing sites located to date, 19 have yielded identifiable specimens of vertebrates.

I have been assisted in field work by Matthew Nitecki, Curator of Walker Museum, Ted Cavender, now at the University of Michigan, and George Olson of Beloit College. David B. Kitts of The University of Oklahoma has aided in the work in many ways. The continuing cooperation of the Oklahoma Geological Survey, through its director, Carl C. Branson, is an indispensable part of the program. Space and equipment for our studies during the summer of 1964 were provided by Charles J. Mankin, Director of the School of Geology at The University of Oklahoma.

Field work, laboratory preparation and study of materials, and the preparation of this manuscript have been supported by National Science Foundation grants B19093 and B2453.

## GEOLOGY AND COLLECTING SITES

### CHICKASHA FORMATION

All of the collecting sites reported in this paper, with one exception (MC-1, Duncan Formation), are in the Chickasha Formation. In a recent publication, Fay (1964) considered the history, interpretations, and distribution of this formation in some detail. The account included here is brief and confined to the points pertinent to the vertebrate remains found in the formation.

The Chickasha Formation, along with the underlying Duncan Formation from which it is lithologically indistinguishable in many places, comprises an array of clastic sediments ranging through all gradations from shales to coarse conglomerates. The beds appear to have been deposited by waters of a major stream system which terminated in a large delta, the Tussey delta of Green (1937), marginal to a persistent evaporite basin. The source of sediment was to the southeast of the areas of deposition.

The formation is distributed along a rather narrow band from Blaine County on the northwest to Stephens County on the southeast, passing through Kingfisher, Canadian, and Grady Counties. The general trend of the outcrops is shown by the dashed line indicating the facies change in figure 1. Along its western margin the Chickasha Formation sends tongues of shale, sandstone, and mudstone into the evaporite sequences of the typical El Reno formations, Flowerpot, Blaine, and Dog Creek (fig. 1). It is principally in these tongues, intercalated with the "marine" deposits, that vertebrates have been found. To the east, in the thick, back-delta areas few remains have been located.

As the western margin of the delta is traced southward and southeastward, through Kingfisher, Canadian, and Grady Counties into northeastern Stephens County, the Chickasha Formation interfingers with successively younger formations of the El Reno Group. In Blaine County and adjacent southern west-central Kingfisher County, the Chickasha penetrates into the middle part of the Flowerpot Formation (Fay, 1962; Olson and Barghusen, 1962). In Canadian County it interfingers with the upper part of the Flowerpot and with the Blaine Formation. In Grady County the upper part of the Chickasha is a Dog Creek equivalent, and in southern

Grady County and northern Stephens County it passes with a gradual transition into the Marlow sandstones. The normal Marlow beds then come to overlies the Chickasha.

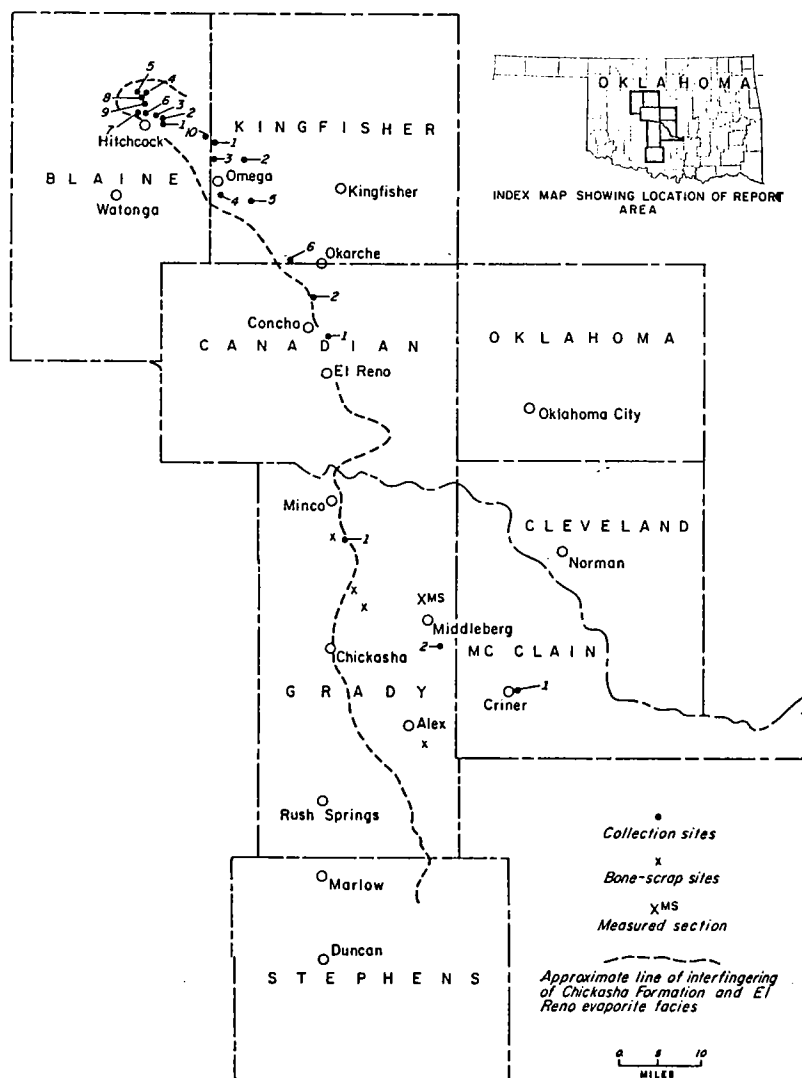


Figure 1. Map of the area which has been studied in the course of the search for vertebrate remains. The line portraying the position of interfingering of the Chickasha Formation and the evaporite facies of the El Reno Group is approximate and depicts in general the highest horizon of interfingering at each site upon which it is based. The numerals are the identification numbers for the fossil sites in each of the counties.

The types of sediments differ along this traverse as well. To the north they are predominantly red shales, with thinner layers of green sandstones and sandy shales. The regularity of the stratigraphy is broken by deposits formed in stream channels and by layers of moderately coarse clastics formed laterally to the channels under conditions of flood. These deposits represent terrestrial beds laid down on flood plains and in channels close to the margin of the evaporite seas. A typical section is that shown at site BC-8, as follows:

MEASURED SECTION AT SITE BC-8\*  
(see pl. IIB)

Bed	Description	Thickness (feet)
6	Weathered red shale and soil	2- 5
5	Sandy shale, hard, light-colored; passing laterally into coarse sandstone and fine mudstone in places; some cross-bedding and channeling	3- 5
4	Red shale; grading laterally into siltstone	15-20
3	Cross-bedded siltstones, green to gray	1- 2
2	Red shale, clean to sandy; salt-crystal casts and molds, with clay gall-and-pebble conglomerates in places	5- 7
1	Light-red shales and siltstones with lenses of gypsum	3+ to base

Southward the relative amount of sandstone increases, and thick lenses of interfingering sandstone and conglomerate are commonly in evidence. The amount of shale is much reduced. The bright orange red of the beds of the northern area is replaced by deeper red brown in the more southerly deposits. Bedding, although irregular, is such that major units can be traced laterally for considerable distances. Clearly recognizable stream-channel deposits become fewer. The lenticular sand and conglomerate masses in many cases appear to have been formed by subaqueous currents. The transition to such conditions is gradual. A typical section in central Grady County, given below, illustrates a circumstance in which they are rather fully developed. This section does not represent the full thickness of the Chickasha, in contrast to the section at site BC-8.

\* In this and other sections given herein the range of thickness is reported, based upon measurements made within 0.5 mile of the central measured section. The ranges give a more realistic picture than do single figures for thickness.

MEASURED SECTION IN GRADY COUNTY  
(SE $\frac{1}{2}$  sec. 29, T. 8 N., R. 5 W.)  
(see pl. VA)

<i>Bed</i>	<i>Description</i>	<i>Thickness (feet)</i>
8	Sandy shale to shale; with rapid lateral variation; deep red to brown	4 - 5
7	Fine mudstone conglomerate, red and green	1.5- 2
6	Red-brown shale	5
5	Green sandstone; grading to green, sandy shale laterally	3.5
4	Sandy, brown shale	1.5
3	Fine red-brown mudstone	0.25
2	Sandstone, massive, brown; with some cross-bedding; many dikes and nodules, with green shale "inclusions" in many places (cutting into bed 1 irregularly)	5 -15
1	Sandy shale and sandstone, brown, irregular; cut 10+ to base by overlying bed; lenses of conglomerate	

In central Grady County (Davis, 1955; Fay, 1964) the maximum thickness of the Chickasha Formation is encountered. The Chickasha and Duncan combined (and for the most part they cannot be separated) reach almost 700 feet in thickness. To the south, in northern Stephens County, the thickness decreases rapidly, to be as little as 200 feet.

In southern Grady County and northern Stephens County the red-brown color gives way to the highly colored shales and sandstones termed the "purple" Chickasha. The sediments, except for their color, resemble those of the red-brown beds of central Grady County and consist of massive sandstones, with mudstone stringers and lenses, conglomerates, and small amounts of shale. Individual beds are irregular in composition and thickness but can be traced as more or less coherent units for considerable distances.

A full interpretation of the conditions of deposition of the different parts of the Chickasha Formation and the paleogeography of the area of deposition and sources of the sediment is beyond the scope of this report. A number of persons have given attention to it, most recently Fay (1964). He follows the concepts of Schweer (1937) in an interpretation that the changes in thickness of the southern Chickasha are the result of deposition accompanied by recession of the Marlow sea, rather than the result of erosion of the Chickasha prior to initiation of deposition of the Marlow sand-

stones. This accords with observations of the relationships of the uppermost Chickasha and the Marlow made in the course of this study. The transition between the two is gradual and an erosional unconformity is not evident.

Differing conditions along the zone of contact of the Chickasha and the El Reno evaporite beds are important to an understanding of the vertebrate distributions. The northern deposits, in Blaine and Kingfisher Counties, appear to have been formed under terrestrial conditions, rather far from the source of sediments. The typical flood-plain and stream-channel patterns attest to the former, and the types of sediments and their distributions to the latter (pls. I-IV). Coarse sediments, above sand sizes, are predominantly mudstone conglomerates, locally derived. Sandstones contribute less than 10 percent of the total. Little change occurs in sediment sizes from terrestrial to marginal basin deposits. The principal differences relate to the presence of gypsum and absence of stream-channel deposits in the basin sediments.

Southward and southeastward, as coarseness increases, beds become more persistent and numbers of stream channels decrease (pls. V, VI). The source of sediments is successively closer, and deposition along the zone of contact of the Chickasha Formation and evaporite-bearing beds evidently was taking place more basinward with respect to the nonmarine-marine interface of the delta. The absence of extensive evaporites in the Chickasha appears to be the result of the great amount of clastic sediment carried in from the relatively closer sediment sources. The phases seen to the north, in Blaine and Kingfisher Counties, did not exist in the more southerly delta-basin complex. Locally deposits that appear to have been formed in terrestrial streams are encountered, but these are not common and admittedly are difficult to differentiate from deposits formed by current action under subaqueous circumstances.

The distribution of known vertebrate remains follows this general pattern. Although not abundant, they are encountered with reasonable frequency in the more northerly parts of the Chickasha Formation. Conditions were rather like those recorded in parts of the San Angelo and Flowerpot Formations of Texas (Olson, 1962). This situation persists into northern Canadian County. But accompanying the initiation of the increase in coarseness of the sediments, the change in color from red to red brown, and the diminution of

the number of mudstone conglomerates formed in stream channels is a decrease in the occurrence of vertebrate remains. By the time the traverse reaches northern Grady County, remains are extremely scarce, although some have been found. Scraps have been discovered as far south as the south-central part of the county; beyond that point none has yet been encountered.

The decline in occurrence of vertebrate remains is unfortunate from the standpoint of obtaining materials from the higher part of the Permian section. Middle Flowerpot equivalents have yielded good remains, upper Flowerpot some, but finds in Blaine and Dog Creek equivalents are few. Perhaps this circumstance will be altered, but at present this seems unlikely.

The pattern of occurrence is only partly the result of conditions of deposition. A second factor also seems to be involved. The northern deposits, predominantly shales, are poor aquifers. To the south, however, with the greater amount of sandstone in the deposits, the contrary is the case. The physical features of the rocks themselves and the reported yields of water (Davis, 1955) give much evidence of ground-water-circulation. Such conditions, of course, are unfavorable for preservation of fossils. In a few places, "ghosts" of bones have been found, showing where they had been prior to their removal by solution. It appears that whatever may have been present was in large part removed. Possibly there exist pockets which for one reason or another were sealed off from water circulation. If so, they may yield some vertebrate fossils. The absence of vertebrate remains in the thicker parts of the deltaic deposits, away from the zone of interfingering of the Chickasha and evaporite facies, probably is in part to be explained in the same way. Near to the margins where there may be an overlying and underlying shale seal inhibiting water circulation, preservation is much more likely than in the back regions where there is no such block.

#### COLLECTING SITES

##### 1. BLAINE COUNTY

Ten vertebrate sites, designated by the letters BC and a number, have been found in Blaine County. Some are extensive and others small, but all have yielded identifiable remains of vertebrates. All

except BC-10 are near Hitchcock, to the east, northeast, and northwest of this small town (fig. 1).

All the deposits are in that part of the Chickasha Formation delineated by Fay as the Chickasha Tongue within the Flowerpot Formation (1962, pl. 1). The tongue contains four mapped beds, numbered consecutively from 1 (lowest) to 4 (highest), and these numerical designations are used in the following descriptions of the Blaine County sites.

Vertebrate fossils have come from a variety of sediments at these sites, from shales, sandy shales, sandstones, and mudstone conglomerates. The identities of the vertebrates from the various sites are given in the systematic section of this paper. No recognizable correspondence exists between the genera and species and the sites or types of sediments in which they have been found. Perhaps, if more adequate collections can be obtained, some correlations will appear. For the present, the kinds of sediments that have yielded fossils at the different sites will be mentioned without reference to what they contained from a taxonomic standpoint because no importance can be attached to this.

##### Site BC-1

SW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 6, T. 17 N., R. 10 W., Blaine County. This is a small outcrop of mudstone conglomerate and sandstone in a road cut. It appears to represent a portion of a complex stream-channel system. Many scraps of bone have come from the mudstone. The deposit lies between beds 2 and 3 of the Chickasha Tongue.

##### Site BC-2

SW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 31, T. 18 N., R. 10 W., Blaine County. Limited outcrops of hard, red-brown siltstone and fine, red conglomerate occur. Some bone scraps are in both. The deposits are part of a channel and off-channel series. The horizon lies between beds 2 and 3 of the Chickasha Tongue.

##### Site BC-3

NE $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 36, T. 18 N., R. 11 W., Blaine County. Scattered exposures of mudstone conglomerates occur along the slopes of gullies. Scraps of bone are scattered through them. The beds appear fairly rich, but exposures are poor. These small channel deposits lie between beds 1 and 2 of the Chickasha Tongue.

## Site BC-4

SW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 15, T. 18 N., R. 11 W., Blaine County. A small set of exposures lies north and south of the east-west section-line road, with fossils found to date only on the north side. The site is formed by a cap of hard, brown siltstone, with some conglomerates and siltstones below. Bone occurs in both siltstone and conglomerate. The beds lie at about the level of bed 2 of the Chickasha Tongue.

## Site BC-5

Secs. 16, 17, T. 18 N., R. 11 W., Blaine County. On both sides of the east-west section-line road are rather extensive exposures. They show fairly evenly bedded red shales, sandstones, siltstones, and mudstones. There is a transition from flood-plain to channel deposits, passing from north and northwest to southeast. Fossils have been found only in the channel deposits. The deposits lie between beds 1 and 2 of the Chickasha Tongue.

## Site BC-6

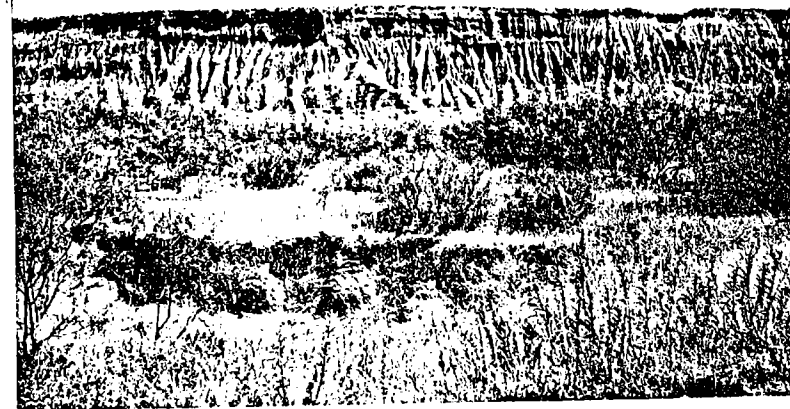
This is an extensive site in NW $\frac{1}{4}$  sec. 35, sec. 34 (except for a small area in SW $\frac{1}{4}$  NW $\frac{1}{4}$ , see BC-7), S $\frac{1}{2}$  sec. 27, T. 18 N., R. 11 W., Blaine County (pl. IVB). The exposures reveal varied sediments, including shales, siltstones, sandstones, and conglomerates. In the northern part are thin-bedded layers of gypsum, indicating interfingering with evaporite facies. Exposures in section 35 and in the southern part of section 34 reveal excellent channel deposits. Most of the vertebrates have come from the rather limited exposures in section 35. They were in siltstone and green sandstone marginal to channel deposits. The beds lie mainly between beds 2 and 3 of the Chickasha Tongue.

## Explanation of Plate I

## Fossil Site BC-7

- A. Flood-plain deposits of the Chickasha Formation exposed along the south side of site BC-7, Blaine County. The beds lie just east of evaporite deposits of the middle part of the Flowerpot Formation and interfinger with these deposits at the base of the exposed section along its western margin. The section consists mostly of rather evenly bedded red and green shales, with some siltstone and sandstone. Some evidence of channel deposits is seen in the central part of the photograph.
- B. In the foreground are exposures of the evenly bedded red shales of site BC-7, seen primarily in low mounds away from the south-facing northern exposures of this site. The mounds are capped by remnants of a hard, green sandstone, seen in place near the base of the bank in the extreme right of the picture.

## PLATE I



A



B



## Site BC-7

SW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 34, NE $\frac{1}{4}$  sec. 33, S $\frac{1}{2}$  sec. 28, T. 18 N., R. 11 W., Blaine County (pls. I, IIa). The exposures consist mainly of evenly bedded red shales and sandstones with channel deposits at several places made up of sandstones, mudstone conglomerates, and some shale.

In section 34 is a complex of green sandstone and conglomerate which carries large nodules with bones and plants. In one was a skeleton of *Rothia* which was complete prior to weathering. The nodules appear to have formed in the clastics, probably from the chemical effects of the included organic materials. This layer continues westward into section 33 and is seen from place to place along the northern flank of the exposures. Below it are red shales of flood-plain origin, and above it are persistent, cross-bedded siltstones and shales. A typical section, measured (with lateral variations entered) along the northern exposures (facing southwest) is as follows:

Bed	Description	Thickness (feet)
5	Pleistocene sand and gravel	0- 5
4	Hard, green sandstone, grading laterally into fine conglomerate; nodular in places	1- 5
3	Siltstone; with layers of shale; cross-bedded; with some sandstone lenses	18-25
2	Hard, green sandstone; nodular in places; grading laterally into conglomerate	1- 3
1	Dark-red shale, evenly bedded; with some gypsum in lower part	7+ to base

Along the southern exposures bedding is more even than it is to the north, and the coarse layers are less well developed (pl. I). Shales and siltstones predominate and channel beds are not well developed. The beds are mainly beds 2 and 3 of the Chickasha Tongue.

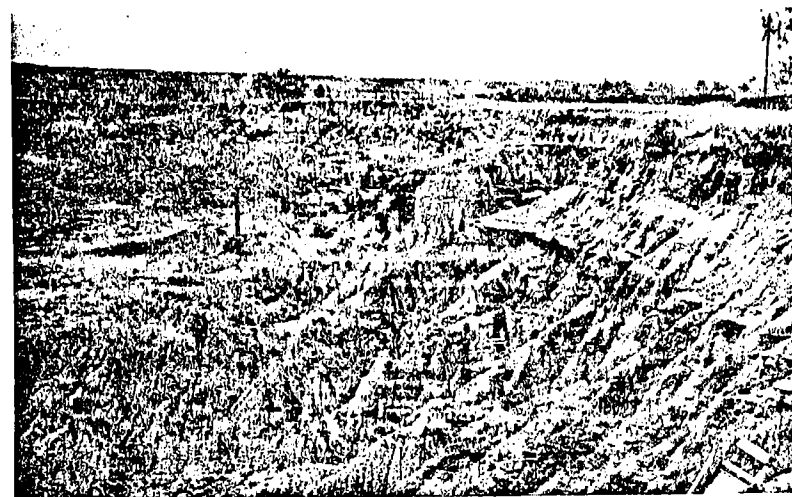
## Site BC-8

W $\frac{1}{2}$  sec. 22, SE $\frac{1}{4}$  SE $\frac{1}{4}$  sec. 21, NW $\frac{1}{4}$  SE $\frac{1}{4}$  sec. 21, T. 18 N., R. 11 W., Blaine County (pl. IIb). Evenly bedded red shales and siltstones predominate. Some channel deposits are present and are best developed at the southwest margin of the exposures in section 21. The general section given for this site on page 9 is typical for the area. Vertebrates have come from the red shale of bed 2, associated with small lenses of clay gall conglomerate.

## PLATE II



A



B

## Fossil Sites BC-7 and BC-8

- A. Nodules forming in the upper, massive, hard, green sandstone at site BC-7. The nodules form in relationship to plant and animal remains.
- B. The section at site BC-8, showing green, sandy layers standing out as somewhat resistant beds, with intervening red shales and sandy shales. Fossils have come from below the lower resistant layer. The section is described in the text (p. 9).

No other beds have yielded vertebrates. In the eastern part, in section 22, beds are even and are largely shale. The level is bed 2 of the Chickasha Tongue.

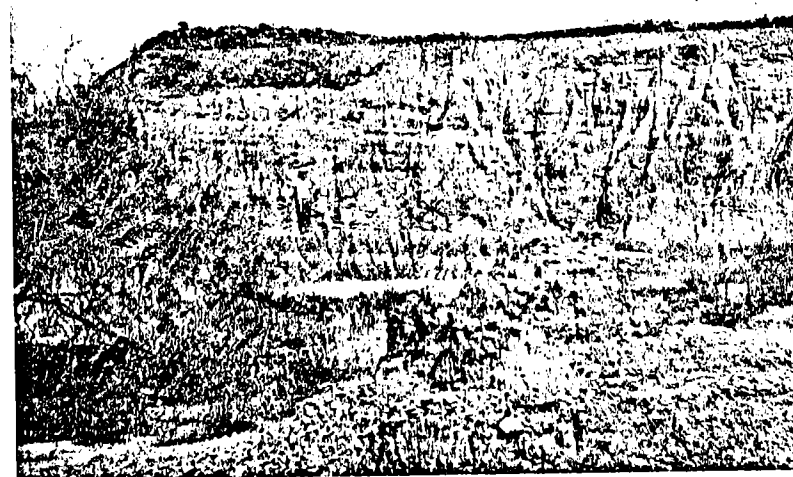
#### Site BC-9

S $\frac{1}{2}$  sec. 27, T. 18 N., R. 11 W., Blaine County (pl. III). Most of the exposures are in the southwest quarter of the section. Some variation occurs over the area, but, except for interfingering of terrestrial and evaporite deposits to the north, conditions were reasonably uniform. The deposits include beds 2 and 3 of the Chickasha Tongue. A typical section, taken in the south-central part of the site is as follows:

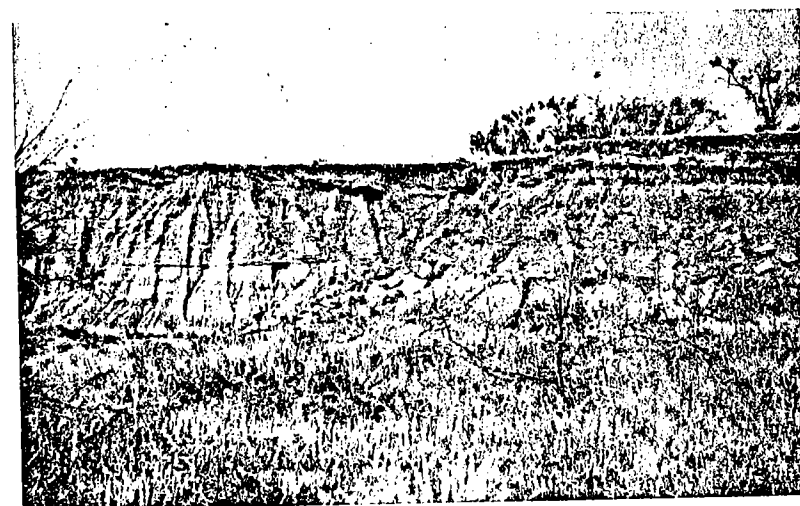
<i>Bed</i>	<i>Description</i>	<i>Thickness (feet)</i>
6	Pleistocene sand and gravel, cutting deeply into underlying beds in places and sloping into a predepositional valley	1 -15
5	Weathered red shale of uncertain age (Permian and/or Pliocene-Pleistocene)	2 - 5
4	Green sandstone, soft and friable; grading to hard, massive, lenticular, cross-bedded sandstone in places	0.3- 3
3	Red, brown, cross-bedded shale	5 -12
2	Predominantly green, hard sandstone, varied. Cross-bedded in places and lenticular	0.5- 6
1	Uniform red shale; interbedded with gypsum in northern part of site	5+ to base

#### Site BC-10

NW $\frac{1}{4}$  sec. 13, T. 17 N., R. 10 W., Blaine County (pl. IV<sub>A</sub>). This site is about 0.75 mile northwest of the Omega quarry site, KF-1, and probably in the same channel system. It includes evenly



A



B

#### Explanation of Plate III

##### Fossil Site BC-9

- A. Exposure at approximate position of measured section of site BC-9 (see above). Lower green sandstone at level of feet of figure thickens to several feet about 100 yards beyond right side of photograph. Upper green sandstone, above figure, is main fossil-bearing horizon. Note the truncation of the Permian strata by Pleistocene deposits along the upper part of the exposure.
- B. Site BC-9, about 0.25 mile northeast of above view. The upper green layer, seen near the top of the cut, is thicker and composed of hard, cross-bedded sandstone with rather sharp dips. The rubble down the slope is derived from this bed. Pleistocene deposits are almost immediately above the sandstone bed.

bedded, red and green shales and sandy shales and a remarkably well-exposed channel deposit. It is the latter that has yielded some bone fragments. The principal characteristics of this type of stream-channel deposit are better revealed in this exposure than in any other known in the area. The exposures lie between beds 2 and 3 of the Chickasha Tongue.

*Comment on Blaine County sites.*—This is an area of deposition of flood-plain and channel deposits formed immediately adjacent to the margin of an evaporite basin. To the west are typical mid-Flowerpot shales, with dolomite and gypsum. The thin wedges of Chickasha can be traced into them, and the transition studied in detail. The Chickasha deposits are fairly similar over the whole area. Sections differ in detail, but the pattern does not change materially. A relatively short time interval is represented by these deposits, confined to the time of deposition of a limited section of middle Flowerpot shales. No evidence of any changes is present in the vertebrate fauna either laterally or vertically.

Vertebrate remains are scattered and no concentrations have been found. Bones occur in all types of sediments. In shales and sandstones, fragments, single bones, and partially articulated skeletons are present. Only fragments have been found in the mudstones. Plant remains occur at various places, mostly highly macerated. Wood is preserved in the nodules at the east end of BC-7.

#### Explanation of Plate IV

Channel Deposits of the Chickasha Tongue in the Middle Part of the Flowerpot Formation, Fossil Sites BC-10 and BC-6

- A. Well-exposed major channel deposit at site BC-10, cutting sharply into evenly bedded red shales and green, sandy shales of the flood plain. This deposit is probably a continuation of the channel system from which came the specimens of site KF-1 (Omega quarry).
- B. A channel deposit near the east end of site BC-6, on the east side of the north-south section-line road. This exposure is in an area of well-developed channels and lateral beds in the southern part of the site. Several vertebrates, all single bones, have come from flood-plain and younger beds near the channel shown in the photograph.

#### PLATE IV



A



B

## 2. KINGFISHER COUNTY

Two sites were described earlier (Olson and Barghusen, 1962). Four additional sites now have been opened, although not thoroughly investigated. Additional field work can be expected to add to the number of sites now known. The older sites, KF-1 and KF-2, are described only briefly. The more recent ones are designated by successive numbers 3 through 6, in order of discovery.

## Site KF-1

NW $\frac{1}{4}$  NW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 19, T. 17 N., R. 9 W., Kingfisher County. This is the site, now termed the Omega quarry, described earlier by Olson and Barghusen (1962). Since the time of first description, work has continued and has virtually exhausted the site. All fossils have come from sandstones, mudstones, and hard, siliceous conglomerates, disposed in lenses. Altogether about 100 blocks containing vertebrate fossils were removed. Remains are predominantly caseids, *Cozylorhynchus* and *Angelosaurus*, comprising partially articulated skeletons, small parts of skeletons, individual bones, and fragments. In addition to the caseids, *Rothia*, palaeoniscoids, and sharks were found. Plant remains were abundant.

Accumulation was clearly in channel deposits, probably made by a relatively small stream system.

## Site KF-2

NW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 34, T. 17 N., R. 9 W., Kingfisher County. The extent of this site has been enlarged by further exploration since the original description (Olson and Barghusen, 1962) was given. For the most part exposed beds consist of rather evenly bedded shales and sandstones. There is, however, a persistent layer of coarser material, ranging from coarse sandstone to mudstone conglomerate. This bed, from 1 to 5 feet thick, is strongly cross-bedded and dips sharply over short distances. It appears to have been formed by rapid deposition lateral to a major channel system.

All fossils have come from the coarse bed or from immediately beneath it. The deposits of KF-1 and KF-2 do not differ appreciably in age.

## Site KF-3

NW $\frac{1}{4}$  SW $\frac{1}{4}$  sec. 31, T. 17 N., R. 9 W., Kingfisher County. This is a small site with limited exposures of the Chickasha Formation. The section, in a stream cut, is as follows:

Bed	Description	Thickness (feet)
6	Soil, deeply weathered	4
5	Badly weathered, red shale	2
4	Green sandstone with shale lenses interfingering	2
3	Carbonaceous shale; sandy in places; some cross-bedding and wavy bedding; some plants and bones	0.5
2	Green sandstone, cross-bedded; with some plants	1
1	Red shale and green sandy shale	3 to base

Only a few specimens have been found. It seems probable that additional material could be obtained by cutting back the top beds, down to bed 3, which appears quite persistent. The level is about the same as that of KF-1, which lies about 2.5 miles to the north.

## Site KF-4

T. 16 N., R. 9 W., mostly in sec. 20, just to the north of section-line road, Kingfisher County. The site may be reached by proceeding 2 miles south of State Highway 33, along the Omega road, and 0.5 mile to the east on the section-line road. It lies on Kingfisher Creek. The section comprises soft sandstones and two layers of mudstone conglomerate, separated by an interval of about 10 feet of the sandstone. The exposures are quite limited.

Bones occur in the conglomeratic layers. The level appears to be somewhat higher in the column than the level of KF-1, but its precise position in the section has not been determined.

## Site KF-5

Secs. 34, 35, T. 16 N., R. 9 W.; sec. 2, T. 15 N., R. 9 W., Kingfisher County. This site includes a large series of exposures along a tributary of Kingfisher Creek. They consist of large sandstone lenses, thick conglomerates, and some shales. Colors are red, brown, and green, with the reds somewhat less orange than in the Hitchcock area. Much of the sandstone is cross-bedded. Stream channels filled with later sediments are also present. This part of the section has yielded no fossil remains, but prospects seem good. It has been searched briefly.

In section 2 exposures are limited. Brown sandstone is predominant, but shale and conglomerate are present. Fossil vertebrates have come from a hard, brown sandstone near the top of the

exposures. The stratigraphic level is about the same as that of KF-4.

#### Site KF-6

Sec. 33, T. 15 N., R. 8 W., Kingfisher County, about 4.5 miles west of Okarche. This site includes a rather restricted set of exposures which show predominantly red shales, with lenses of dipping siltstones and sandstones. Some conglomerate lenses are present. Near the base is a coarse, purple conglomerate that contains impressions of plant stems (*Equisetales*) and fragments of bones.

The stratigraphic level is above that of the other Kingfisher sites, probably about equal to Flowerpot Unit I of Fay (1964).

### 3. CANADIAN COUNTY

A considerable amount of exploration has been carried out in Canadian County, but as yet returns have been scant. Studies will be continued in coming years. Two sites have been found, both through the aid of Robert Fay of the Oklahoma Geological Survey.

#### Site C-1

Sec. 16, T. 13 N., R. 7 W., east of Concho School, Canadian County. The site consists of somewhat scattered small outcrops of cross-bedded sandstone and siltstone with patches of mudstone conglomerate. These appear to represent facies of the upper part of the Flowerpot, perhaps about 40 feet below the contact with the Blaine. Scraps of bone have been found in the mudstone conglomerates.

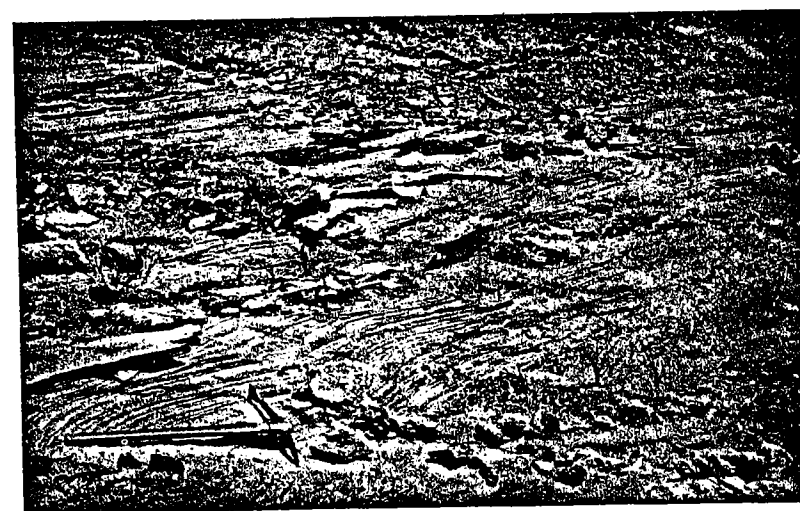
#### Site C-2

Sec. 19, T. 14 N., R. 7 W., Canadian County. A small exposure is present on both sides of a cut formed by a creek, just west of U. S. Highway 81 and about 4 miles south of Okarche. The strati-

### PLATE V



A



B

### Explanation of Plate V

#### Chickasha Exposures in Grady County

- A. The exposure at which the upper part of the measured section given on page 10 was taken. The lower part was taken from exposures across the road from which the picture was taken, to the west. Note the thinness and even character of the beds. The location is SE $\frac{1}{2}$  sec. 29, T. 8 N., R. 5 W., Grady County.
- B. A typical example of the thick sandstone beds containing siliceous veins and concretions found throughout the Chickasha Formation in the southern part of the area considered in this report (fig. 1). The resistant siliceous structures are shown lying on the surface. The location is SE $\frac{1}{4}$  sec. 21, T. 8 N., R. 6 W., Grady County.

graphic level is somewhat problematical. Probably the beds lie about 100 feet below the Flowerpot-Blaine contact. Sandstone, cross-bedded in places, and mudstone conglomerate are present. From the latter have come some small pieces of bone and one identifiable specimen. Recent road work has in large part destroyed the outcrops.

#### 4. GRADY COUNTY AND NORTHERN STEPHENS COUNTY

Grady and Stephens Counties have been treated together in a report by Davis (1955) and form a coherent geological unit. Extensive explorations of the Chickasha deposits have been carried out during the last three seasons. They are not completed, but enough has been done to give a good picture of vertebrate prospects. In general they appear poor.

The Chickasha over this area is equivalent in age to the Blaine, Dog Creek, and the basal part of the Marlow. The Marlow overlies the Chickasha in places, but it also grades laterally into Chickasha facies through a narrow zone in which assignment of the rocks to one or the other is not possible.

Explorations to date have yielded almost no identifiable vertebrate remains. Scraps have come from a few places and plant remains are somewhat more widespread. All of the minor finds have been in Grady County. Two sites, with possible identifiable remains, have been designated in Grady County (fig. 1).

#### Site GR-1

Eastern margin sec. 24, T. 9 N., R. 7 W., about 6 miles southeast of Minco, Grady County. The site is a small exposure of red, conglomeratic mudstone and sandstone. The conglomerate yielded

#### PLATE VI



A



B

#### Explanation of Plate VI

##### Chickasha Exposures in Grady County

- A. Exposure showing the fairly evenly bedded Chickasha Formation at SE $\frac{1}{4}$  sec. 21, T. 8 N., R. 6 W., Grady County (same locality as in pl. Vii). Units show much lateral variation in thickness and composition (for example, the amount of mudstone interbedded in predominantly sandstone beds) but are traceable as entities over distances of a mile or more. The total section of the Chickasha Formation consists of repeated sequences of the type seen in the photograph (for examples see measured sections in Fay, 1964).
- B. The Chickasha Formation in a common role as a ridge and hill former near Chickasha. The exposure is about 1.5 miles northeast of Tabler, on the south side of U. S. Highway 62.

part of a small jaw. The deposit represents a thin wedge of the Chickasha Formation which is equivalent to the uppermost part of the Blaine in age.

#### Site GR-2

SW¼ sec. 26, T. 7 N., R. 5 W., Grady County. Exposed is a series of red to purple sandstones and mudstone conglomerates. The lens in which a specimen was found is part of the purple conglomerate. The age is somewhat uncertain. Apparently the beds are equivalent to the Dog Creek. The site is rather far from the zone of interfingering, so that precise relationships are difficult to determine.

In addition to these two sites, a few other exposures have yielded fragments of bone, totally indeterminate (fig. 1). The fragments have all been in conglomerate except for the one from the exposures south of Alex. This was in a sandstone which formed part of a series of typical purple Chickasha beds exposed in a road cut. It is the only specimen that has been found in the distinctly purple Chickasha beds.

#### 5. MC CLAIN COUNTY

In large part exposures in this county reveal beds older than the Chickasha. Little exploration has been carried out. At one place, however, just east of Criner, some fragmentary skull plates and other remains were found in a road cut. This is the site MC-1 designated on the map (fig. 1).

#### Site MC-1

Sec. 19, T. 6 N., R. 3 W., 0.5 mile east of Criner, McClain County. The exposure in which a specimen was found is in a road cut. Bones were found in a very fine-grained sandstone. The beds lie only a few feet above the contact of the Hennessey and are Duncan rather than Chickasha.

## SYSTEMATICS

### CLASS CHONDRICHTHYES

#### Subclass ELASMOBRANCHII

#### Order XENACANTHODII

#### *Xenacanthus* sp.

Plate VIIIb; figures 2i, j

Two specimens of the shark *Xenacanthus* have been found in the Chickasha Formation. Both are of middle Flowerpot age. One is a tooth, from the Omega quarry, site KF-1, CNHM UF 974; the other is a spine, from BC-9, CNHM UF 978.

The tooth (figs. 2i, j) is small, the distance from the base to the top of the longer spinelike cusp being only 6 mm. A small central cusp is present and the elliptical base of the tooth is lightly built, with a distinct, but small, articular "button." The cusps are quite straight and do not have serrated edges.

The spine (pl. VIIIb) is similarly small. The preserved part, which includes almost the full length, measures less than 10 cm. The spine has been flattened by compaction. Its maximum width, prior to deformation, could not have been more than 5 mm. The distal three-fifths of the spine carries strongly recurved, toothlike denticles on its lateroposterior flanks.

Both tooth and spine are typically xenacanth. The generic name, however, undoubtedly includes a wide variety of fresh-water sharks which have somewhat similar dentitions, chondrocrania, and spines. It clearly is a form genus, including as it does in its most useful sense sharks ranging from the Devonian well into the Permian. Probably the tooth and the spine came from the same species within this genus complex, but no real basis exists for such an assignment other than size and contemporaneity. The small size may be merely coincidental.

The characters of the tooth given above are most suggestive of *Xenacanthus platypternus* as defined and described by Hotton (1952). Although specific assignment cannot be justified, the Chickasha specimen conforms in general to what is expected in view

of the trends of development from the late Carboniferous through the Clear Fork, Permian.

## CLASS OSTEICHTHYES

### Subclass ACTINOPTERYGII

#### Order PALAEONISCOIDEA

#### Family Uncertain

A small patch of scales representing part of the body of a paleoniscoid provides the only evidence of Osteichthyes in the Chickasha deposits. This specimen came from the Omega quarry, KF-1. It was found in a red sandstone in one of the small channel deposits. This specimen was studied by Ted Cavender, but he has reached no conclusions about its identity. Eventually, analysis of the details of the scale histology may give clues to the relationships, but at present a familial assignment is impractical.

## CLASS AMPHIBIA

### Subclass LEPOSPONDYLI

#### Order MICROSAURIA

#### Family GYMNARTHRIIDAE

#### *Cymatorhiza kittsi* Olson and Barghusen

A fragment of jaw, CNHM UR 855, provided the basis for this genus and species described in the first paper of this series (Olson and Barghusen, 1962). It was found at site KF-2, Kingfisher County, in a rather coarse conglomerate in the Chickasha Formation. The age is middle Flowerpot.

No new specimens definitely assignable to this genus and species have been found. One small vertebra, CNHM UR 922, from site BC-2, is of the general type that might be expected for the genus, having a spool-shaped centrum and rather low, elongate arch and spine. It may pertain to *Cymatorhiza*, but this cannot be determined at present.

### Subclass APSIDOSPONDYLI

#### Superorder LABYRINTHODONTIA

## Order TEMNOSPONDYLI

### Suborder ERYOPOIDEA

#### Family TRIMERORHACHIDAE

#### *Nannospondylus*, new genus

*Diagnosis*.—A small rhachitinous amphibian. Intercentra with flat bases carrying strong processes for tubercula of the ribs. Outline of intercentra in ventral aspect subrectangular. Pleurocentra wedge-shaped, high, narrow, and well ossified. Neural arches and spines strongly ossified and zygapophyses strong; spines sloping sharply posteriorly. Ribs heavy and long, one at least, highly modified with tripartite head and spatulate distal portion.

#### *Nannospondylus stewarti*, new species\*

Plate VII; figures 2E, F, G

*Holotype*.—CNHM UR 1002. Four well-preserved vertebrae, parts of several more, and a number of ribs, plus one problematical bone, identified as a highly specialized rib.

*Horizon and locality*.—From the Chickasha Formation equivalent to the middle Flowerpot, Upper Permian. Site BC-6, north of Hitchcock, Blaine County.

*Diagnosis*.—As for genus.

*Description and discussion*.—Only a single specimen of this new genus and species has been found. This consists of vertebrae and ribs. In the shape of the intercentra and an odd bone (pl. VII, figs. 2E, F, G), tentatively identified as a rib, the specimen differs rather sharply from other rhachitinous labyrinthodonts. Although it is small, it is unmistakably mature. Of somewhat similar size is *Slaughenhopia* of the San Angelo of Texas (Olson, 1962). The vertebrae of *Slaughenhopia* are less well ossified and lack the flat ventral surface of the intercentra. In general *Slaughenhopia* is much closer to *Trimerorhachis* of the earlier Permian than is *Nannospondylus*.

The vertebrae of *Nannospondylus* resemble those of *Dvinosaurus* (Bystrow 1938, fig. 26; Amalitsky, 1921, pl. 2, fig. 2) more closely

\* The specific name is given for Orvil Stewart of Omega, Oklahoma. He has been a great aid to our field studies both in technical matters and as a sincere friend.



than those of any other rhachitome. *Dvinosaurus*, quite properly, was called neotonic by Bystrow, but the vertebrae, although considerably pitted, are well formed. The bases of the centra are considerably more rounded than are those in *Nannospondylus*, and the rib facets, the parapophyses, are somewhat more dorsal and lateral and are less distinctly developed.

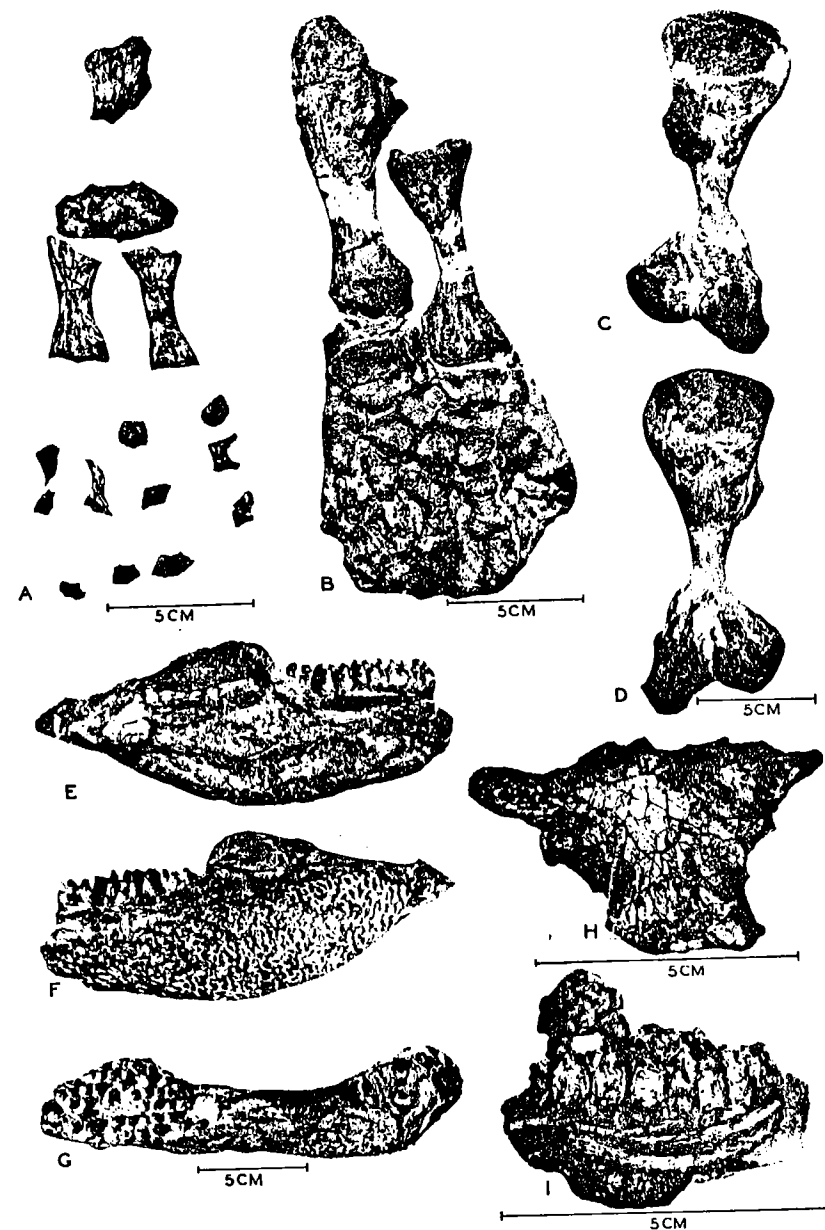
The ribs in *Nannospondylus* are distinctive, being disproportionately large in comparison to the size of the vertebrae. Presumably they were double-headed, although no heads are well enough preserved to show this conclusively.

The most peculiar bone present is that illustrated in figure 2E. It has been tentatively identified as a rib, although a most unusual one. If the three-pronged structure is the head, as it seems it must be, then this rib is oriented oppositely to the ribs on the other side of the column. If the bone were not a rib, it could only be a humerus with an odd structure. This seems untenable, and hence the determination as a rib has been made.

The base of the shoulder girdle is preserved, and the rib in question occurs in its vicinity. It probably lay under the shoulder girdle, and in this case the expanded, flat distal end duplicates the sort of expansion found in various other tetrapods. The odd shape, irrespective of its meaning and function, is further evidence of the distinctiveness of this genus.

The bed from which the specimen came contained no other remains in the outcrop. The column was encased in a red nodule, which in turn was covered by sandy, red shale. It was found along the southern exposures in BC-6, in flood-plain deposits not far from

## PLATE VII



## Explanation of Plate VII

*Rothia robusta*, *Fayella chickashaensis*, and *Nannospondylus stewarti*

- A. Forelimb of an immature specimen of *Rothia robusta*, new species, CNHM UR 989.
- B. Radius, ulna, and foot of *Rothia robusta*, new species, CNHM UR 967.
- C, D. Femur of *Rothia robusta*, new species, CNHM UR 967. C. Ventral aspect. D. Dorsal aspect.
- E, F, G. The jaw (lacking anterior portion) of *Rothia robusta*, new species, holotype CNHM UR 966. E. Median aspect. F. Lateral aspect. G. Dorsal aspect.
- H. Ventral aspect of occiput of *Fayella chickashaensis*, new genus, new species, holotype CNHM UR 1004.
- I. Vertebrae of *Nannospondylus stewarti*, new genus, new species, holotype CNHM UR 1002. Ventral aspect showing characteristic intercentra.

a heavily channeled area in which the presence of conglomerates and cross-bedded sandstones suggests rather vigorous water action.

Assignment of the genus to the family Trimerorhachidae is, of course, open to some question, since the information available for any assignment is slight. The vertebrae, however, are of the trimerorhachid pattern. Although they are somewhat similar to those of *Dvinosaurus*, both the Late Permian age of that genus and the geographic separation argue for caution in any suggestion of closer relationships. Romer (1947) discussed the trimerorhachid aspects of *Dvinosaurus*, concluding, with some reservation, that *Trimerorhachis* and *Dvinosaurus* have many features that suggest a relationship. The presence of *Nannospondylus*, and also of *Slaughenhopia*, temporally and morphologically more or less intermediate between the two, lends some support, even if rather tenuous, to this general thesis.

#### Family DISSOROPHIDAE

#### *Fayella*, new genus\*

**Diagnosis.**—Basioccipital with only partially double occipital condyle, flat ventrally, and with a deep, notochordal pit. Basioccipital tubera strong. Basipterygoid processes inflected sharply ventrally and passing into pterygoid without evident suture. Teeth labyrinthine only at the bases. Skull rather deep in proportion to length and approximately twice the size of the largest dissorophid known heretofore.

#### *Fayella chickashaensis*, new species

Plate VIIH; figures 2A, B, C

**Holotype.**—CNHM UR 1004. Brain case with part of basicranium, basipterygoid processes, and part of otic complex.

**Horizon and locality.**—Chickasha Formation at level of middle Flowerpot, Upper Permian. From BC-7, in hard, green sandstone of bed 2 (see measured section, p. 16), northwest of Hitchcock, Blaine County.

**Diagnosis.**—Same as for genus.

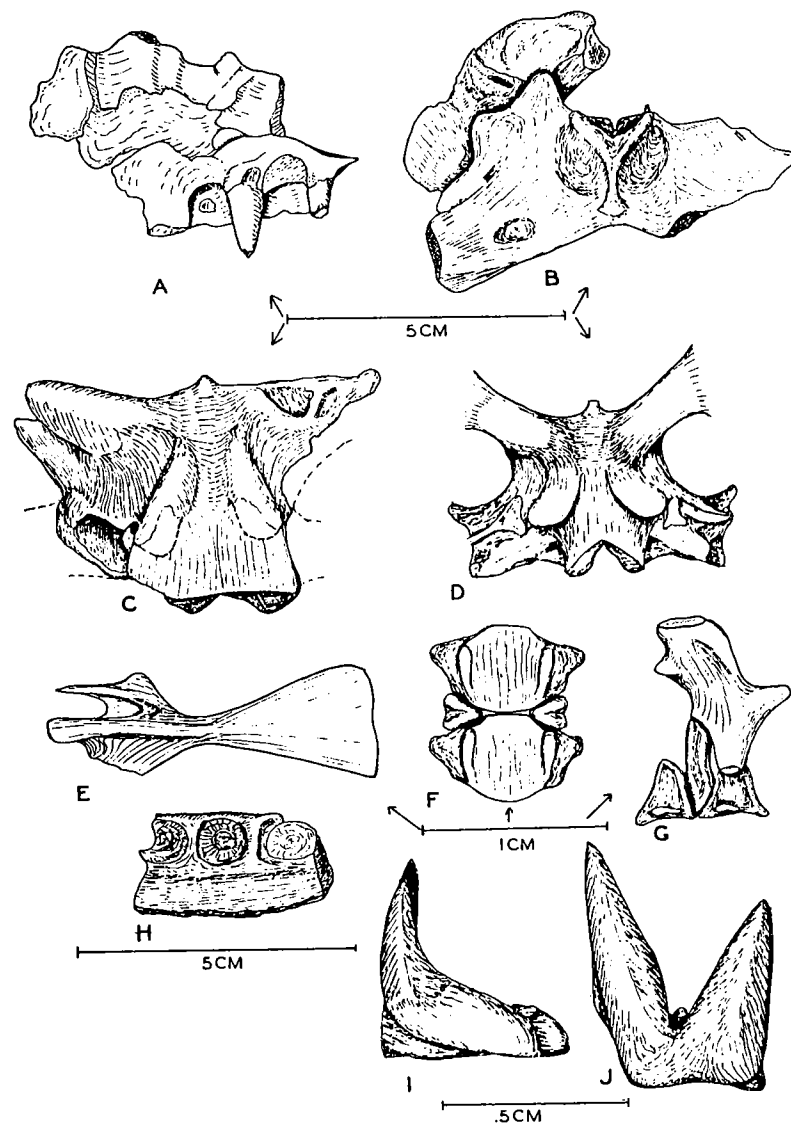


Figure 2.

- A. Medial aspect of a fragment of the skull of *Fayella chickashaensis*, new genus, new species, drawn from referred specimen CNHM UR 1003.
- B, C. Basicranium and brain case of *Fayella chickashaensis*, new genus, new species, holotype CNHM UR 1004. B. Anterior aspect. C. Ventral aspect.
- D. Basal aspect of brain case of *Cacops aspidephorus* Williston; drawn from CNHM UR 649. Compare with B and C.
- E, F, G. *Nannospondylus stewarti*, new genus, new species, holotype CNHM UR 1002. E. Element identified as a rib. F. Ventral aspect of vertebrae. G. Lateral aspect of vertebrae.
- H. Fragment of jaw of unnamed labyrinthodont, CNHM UR 999.
- I, J. Tooth of *Xenacanthus* sp., CNHM UR 974.

\* This name is given in recognition of the invaluable aid to this project provided by Robert O. Fay of the Oklahoma Geological Survey.

*Referred specimen.*—CNHM UR 1003. This specimen consists of fragments of a skull, including part of the marginal tooth row; a small part of the palate, including the socket and impression of a large palatal tooth; and various pieces of skull roof. It is from the same bed as is the holotype at site BC-7. About 20 feet separated the two, so that there is no assurance that they did or did not come from the same individual.

*Description and discussion.*—The brain case is fairly well preserved. The basioccipital is flat ventrally and carries a partially double occipital condyle. This bone has a rather well-developed, notochordal pit and, continuing forward from the pit, a deep groove in the dorsal surface. The basioccipital tubera were strong. The posterior flanges are broken off. It appears that much of the basioccipital, including the tubera, was covered ventrally by the parasphenoid, but precise limits of neither bone can be determined.

Basipterygoid processes are strong and directed ventrolaterally. They appear to have passed into the pterygoids without sutural interruption. The otic bones are only partially ossified, so that little detail can be made out. The paroccipital process is partially missing on both sides. A strongly ossified dorsum sellae is present, and the ossification passes into a robust laterosphenoid. This serves to isolate the trigeminal foramen almost completely.

The brain case is clearly that of an amphibian and within the amphibians resembles the brain case of dissorophids closely. It is rather different from any others that might be expected at this time in the geological record. Reference to the family thus seems reasonably certain.

The brain case is more than twice the size of that of any known dissorophid, including the relatively large *Zygosauros* from the Russian Kazanian.

The reference of specimen UR 1003 to this genus is based primarily upon the tooth structure. It is without question an amphibian and belongs among the labyrinthodonts. Tooth emplacement is much like that found among various eryopoids, with the lateral and palatal teeth set in shallow depressions or partial sockets. The teeth, however, are but slightly labyrinthine, with this feature best

expressed at the base and seemingly reflected in the radial pattern of the bone surrounding the bases of some of the teeth. The pattern is much like that in *Cacops*.

In addition to this feature, it appears that the skull was rather deep, as in some dissorophids. The sculpture of the skull surface, the large palatal tooth, and a fragmentary piece of skull roof with part of the otic notch are suggestive but not definitive.

The size of the referred specimen fits with that of the brain case, suggesting that skull length would be about 10 to 12 inches.

#### Family Uncertain

#### New Genus, Not Named

#### Figure 211

From site C-1, probably of late Flowerpot age, has come a fragment of a portion of amphibian jaw with the bases of three teeth, CNHM UR 999. These bases show that the teeth were strongly labyrinthine and set in extremely shallow "sockets." Beyond this, little is definitive.

No genus is known from the Chickasha Formation to which this specimen could be referred. Thus it probably is an otherwise unknown genus. Little purpose would be served at the present time by giving it a name.

The specimen came from a red mudstone conglomerate and is of special interest as one of the few vertebrates known from higher than the middle part of the Flowerpot. No other specimens were found in association, although fragments of a rib were found about 30 feet distant, in another small lens.

#### INCERTAE SEDIS

#### Genus Not Determined

A badly damaged specimen from the Duncan Formation, site MC-1, appears to consist of fragments of skull of a small amphibian. It may be possible at a later time to make assignment. The specimen is CNHM UR 1007.

## CLASS REPTILIA

## Subclass ANAPSIDA

## Order CAPTORHINOMORPHA

## Family CAPTORHINIDAE

*Rothia* Olson and Beerbower*Rothia robusta*, new species

Plate VIIA-G; figure 3

*Holotype*.—CNHM UR 966. A left lower jaw lacking the anterior portion, but with a well-preserved dental plate showing the significant features of this part of the animal.

*Horizon and locality*.—From the Chickasha Formation, middle Flowerpot age, approximately bed 2 of the Chickasha Tongue, Upper Permian, locality BC-7, about 1¾ miles northwest of Hitchcock, Blaine County.

*Referred specimens:*

CNHM Number	Part	Site
UR 829	vertebra	KF-1
UR 830	partial vertebra	KF-1
UR 831	partial vertebra	KF-1
UR 832	partial vertebra	KF-1
UR 833	partial pelvis	KF-1
UR 834	rib	KF-1
UR 922	partial tooth plate	KF-2
UR 934	astragalus	KF-1
UR 950	jaw fragment	KF-2
UR 951	skull plate	KF-3
UR 952	jaw	KF-3
UR 953	limb bone	KF-3
UR 954	part of skull roof	KF-5
UR 955	tooth plate	BC-1
UR 956	jaw fragment	BC-1
UR 957	jaw fragment, rib	BC-1
UR 958	jaw fragment	BC-1
UR 959	jaw fragment	BC-1
UR 960	jaw fragment	BC-1
UR 961	partial jaw	BC-6
UR 962	jaw fragments	BC-6
UR 963	vertebra	BC-7
UR 964	two sacral vertebrae	BC-7
UR 965	vertebra	BC-7
UR 966	partial jaw, holotype	BC-7

UR 967	much of skeleton and skull	BC-7
UR 989	immature limb, scrap	BC-7
UR 991	humerus	C-2
UR 994	front part of jaw	BC-1
UR 996	part of scapulocoracoid, part of vertebra	BC-8
UR 1008	fragment of jaw	BC-9
UR 1009	part of jaw	KF-5
UR 1010	part of tooth plate	KF-2

*Diagnosis*.—A large species of *Rothia* with linear measurements of adults about 20 percent greater on the average than those of comparable measurements of *R. multidonta*. Lower jaw with tooth plate carrying up to seven rows of teeth. Limbs large and robust, proportionately larger and heavier than those of *R. multidonta*.

*Discussion*.—In an earlier publication (Olson and Barghusen, 1962) some material now referred to this species was described and illustrated, but was referred to *Rothia multidonta*. *R. multidonta* had been described earlier (Olson and Beerbower, 1953) from the San Angelo Formation of Texas, and additional specimens from the San Angelo and Flowerpot Formations of Texas had given supplemental information (Olson, 1962). Upon the basis of vertebral comparisons, it was decided that assignment of the Oklahoma materials to *Rothia multidonta* was the best procedure. The specimens all came from the Omega quarry site, KF-1, and only the vertebrae provided good comparative material.

Now that additional materials have been discovered, in particular specimens with well-preserved dentitions, it is clear that the Chickasha specimens of *Rothia* must be referred to a new species. The clearest diagnostic feature of the new species, *Rothia robusta*, is the presence of a large number of rows of teeth in the dental plate. Seven rows are present in the holotype. The lower jaw in the holotype of *R. multidonta* (CNHM UR 87) seems to have only four, or possibly five, rows. This specimen, like the holotype of *R. robusta*, represents a large, mature individual. A skull (CNHM UR 713), from the Kahn quarry of Knox County, Texas (Olson, 1962), shows four rows of teeth in the upper tooth plate. This, too, seems to be a fully matured individual. As a rule, within this family, the number of lower rows of teeth is either the same as or less than the number of uppers.

As is well known, a problem in diagnoses based upon the

number of rows of teeth relates to the fact that the number of rows increases during growth. Only the dental plates of adults should be used. In this instance, the skulls and jaws are unmistakably adult so that the growth aspect does not enter in.

Other comparisons between the species are made in the descriptions of *Rothia robusta* that follow. *Rothia* is the most common genus from the Chickasha Formation and occurs at more sites than does any other genus. It is rivaled in total numbers only by the caseids, *Cotylorhynchus* and *Angelosaurus*, and most specimens of these two come from the one rich site, KF-1.

The wide size range among the individuals of *Rothia* has prompted a study of the possibility of the existence of two genera, as is the case with a smaller captorhinid, *Kahneria*, in the San Angelo and Flowerpot Formations of Texas, where it is fairly abundant. Without many fairly complete specimens, of course, it is impossible to reach firm conclusions on this matter. Several bits of evidence, however, suggest that only one genus is present. One relates to measurements of the teeth. A simple measurement of basal length of the crown has been used to provide some estimate of general tooth dimension. A considerable size range occurs within individuals, but this is much less than the range that comes from sampling different parts of the growth series. In table 1 the mean and range for a series of specimens are shown. Although these depend in part upon the section of the dental plate measured and upon how many teeth were involved, they do give some idea of the spread and do show a fairly continuous distribution rather than a grouping that might be expected if two genera were represented more or less equally. These data are suggestive but, of course, far from conclusive.

A second line of evidence is provided by other parts of the skeleton. No small mature bones have been found. Those that are small show features indicating that they were from young individuals. The limb bones of specimen CNHM UR 989 give a good example. As shown in plate VIIA, the humerus, radius, and ulna are poorly ossified and carpal elements are for the most part absent, even though teeth, present in scraps of the skull, suggest a moderate-sized animal. Various single bones show this feature as well. Among the rather fragmentary remains of postcranial elements only a single genus is indicated.

TABLE 1.—MEASUREMENTS OF OKLAHOMA SPECIMENS OF *Rothia robusta* AND TEXAS SPECIMENS OF *Rothia multidonta*  
(Measurements in millimeters)

	MEASUREMENTS OF LIMB BONES			
	Length	Length to Notch	Proximal Width	Distal Width
<i>R. robusta</i> (CNHM UR 967)				
Forelimb				
Ulna	114	82	43	34
Radius	85			
Hind limb				
Femur	146		58	61
Tibia			42	38
Fibula				58
<i>R. multidonta</i> (CNHM UR 263)				
Hind limb				
Femur	106			

WIDTHS OF POSTZYGAPOPHYSES OF DORSAL VERTEBRAE  
(Columnal positions approximately the same,  
but not precisely determinable)

<i>R. robusta</i>			<i>R. multidonta</i>	
CNHM UR 829	CNHM UR 831	CNHM UR 967	CNHM UR 263	CNHM UR 502
53	50	53	41	38
		54	39	
		47	43	
		52	42	
		53		
		51		
		48		
		49		

LENGTHS OF BASES OF TEETH IN DENTAL PLATES OF *Rothia robusta*

CNHM Specimen	Locality	Number Measured	Range	Mean
UR 960	BC-1	2	4.4-4.8	4.6
UR 961	BC-6	11	3.1-4.2	3.7
UR 957	BC-1	9	2.6-4.1	3.4
UR 959	BC-1	8	1.1-2.2	1.8
UR 922	KF-2	7	4.8-5.8	5.2
UR 966	BC-7	15	3.2-5.8	4.1
UR 1010	KF-2	4	3.2-4.2	3.7
UR 955	BC-1	10	2.4-4.1	3.3
UR 967	BC-7	5	3.4-4.4	3.8
UR 952	KF-3	17	3.2-5.2	4.1

The reference of all the known materials to a single species is justified solely by the supposition that it is more probable that one rather than two or more species lived within the relatively restricted geographic and temporal limits represented by the collections. Except for the well-preserved specimens, morphological reference to species is, of course, impossible. This restriction applies both to the Chickasha specimens and to those from the San Angelo and the Flowerpot of Texas. *Rothia robusta* has been found in a variety of types of sediments. At BC-1 it occurs in a fine-grained mudstone conglomerate. A similar occurrence is at KF-1, but there specimens have been found in fine sandstone and in an extremely hard, quartzitic conglomerate as well. At KF-5 specimens have come from an evenly bedded, hard, brown sandstone, and at BC-7 some specimens were preserved in clean red shale and others in conglomerate. Also at BC-7 excellent remains have come from a hard, green, locally conglomeratic sandstone. For the most part remains have been disarticulated. The red-shale specimen from BC-7 and one of the specimens from the hard, green sandstone of this site, however, were deposited as complete skeletons. When found, they had suffered considerably from the effects of diagenesis and weathering.

As far as can be determined, the species was ubiquitous with regard to the terrestrial environments extant in areas of deposition of the Chickasha Formation during middle and late Flowerpot times.

*Description and comparisons.*—Many details of the morphology of *Rothia robusta* can be made out from the new specimens. These give a good knowledge of this species and add materially to what is known of the genus. Most of the information comes from a partial skeleton, CNHM UR 967. This individual had been preserved in nodular materials formed in the hard, green sandstone of locality BC-7. Once it had been a complete skeleton, but long before its discovery, weathering had begun to take its toll. Thus what was recovered, although excellent in many respects, was on the whole fragmentary. This material suggests that the total length of the animal was about 5 feet. The tail was fairly long and the skull was large. Limbs and girdles were heavy. About 50 feet from this specimen was found the holotype, CNHM UR 966, which gives excellent data on the lower jaw and dentition.

*Skull.*—No complete skull is preserved. Many fragments accompany the skeleton, UR 967, but enough parts are missing to make reconstruction impossible. The preserved parts of the skull, as well as some impressions of the skull on the nodular matrix, show no major differences between the skulls of *R. multidonta* and *R. robusta*. Comparisons have been made primarily with specimen CNHM UR 87, the holotype of *R. multidonta*, and with specimen CNHM UR 713, from the Kahn quarry. The reticulate patterns of the temporal regions appear to differ, but how variable this character is within species is not known. One specimen from the San Angelo quarry, CNHM UR 627, has a pattern that is quite similar to that of *R. robusta*.

*Lower jaw.*—The principal features of the lower jaw are shown in figures 3b, and plate VIIe-g. The jaw is heavy and deep, somewhat reminiscent of the jaw of *Diadectes* as far as the posterior portions are concerned. Although structurally similar to the jaw of *R. multidonta*, the jaw of *R. robusta* is deeper and thicker in proportion to length. The dentary flares medially to form a well-defined dental plate. The articular is a heavy bone with a massive articular surface.

*Dentition.*—The most commonly preserved parts of *Rothia* are pieces of the dental plate. Ease of recognition undoubtedly contributes to the number of identified specimens. The pattern of dentition of the lower jaw, based largely upon the holotype, shows both longitudinal and transverse rows of teeth. The large number of longitudinal rows is characteristic of the species, differentiating it from *R. multidonta*. The teeth differ somewhat in size, with a tendency for the larger ones to be concentrated more or less in the center of the plate. The less worn teeth occur in the marginal rows, both on the inner and outer sides, indicating that addition of new rows took place both laterally and medially. The teeth anterior to the tooth plate are somewhat larger and more elliptical in cross section than are those of the plate. In none is there a marked departure from the simple, bulbous, conical shape.

Upper teeth are preserved in the collections mainly on fragmentary maxillary plates. In the partial skull of CNHM UR 967, the bases of teeth are present, although rather badly preserved. They show that the maxillary plate was quite broad. There appear to have been at least six rows (longitudinal), but the number cannot be determined with any certainty. Clearly there are more rows than in

CNHM UR 87 and 713, the best preserved specimens of *R. multidonta*. From what little is known, it appears that both upper and lower tooth plates in the two species were generally comparable in size and shape. Both are covered with rows of teeth. The teeth of *R. multidonta* seem to have been larger than those of *R. robusta*, the differences in number being such that the area of the plates remained about the same. As in other features, however, this judgment is based upon so few specimens that the effect of intraspecific variation cannot be estimated.

*Vertebrae*.—No complete series of vertebrae is present; consequently the numbers in the various parts of the column have not been determined. As far as the general morphology is concerned, the vertebrae of *R. multidonta* and *R. robusta* seem to be entirely similar. The difference between them is merely one of size. Even this is a difficult matter to pinpoint, not only because of the few specimens but also because of the difficulty of locating individual vertebrae accurately within the column. The best that can be done is what is shown in table 1. Upon the basis of the width of the posterior zygapophyses, the Chickasha specimens are distinctly larger than the largest known specimen of *R. multidonta*. Alone this cannot be considered of any great significance. Now that other features which show these two to be different have been discovered, the size difference may take on added meaning.

*Rothia robusta* has a sacral complex that is somewhat specialized. It has one large sacral rib and a second more posterior one which also provided strong support of the pelvis. The principal sacral rib has a broadly expanded head, which must have made contact over much of the inner surface of the ilium. Specimen CHNM UR 130 from the San Angelo, the only representative of *R. multidonta*

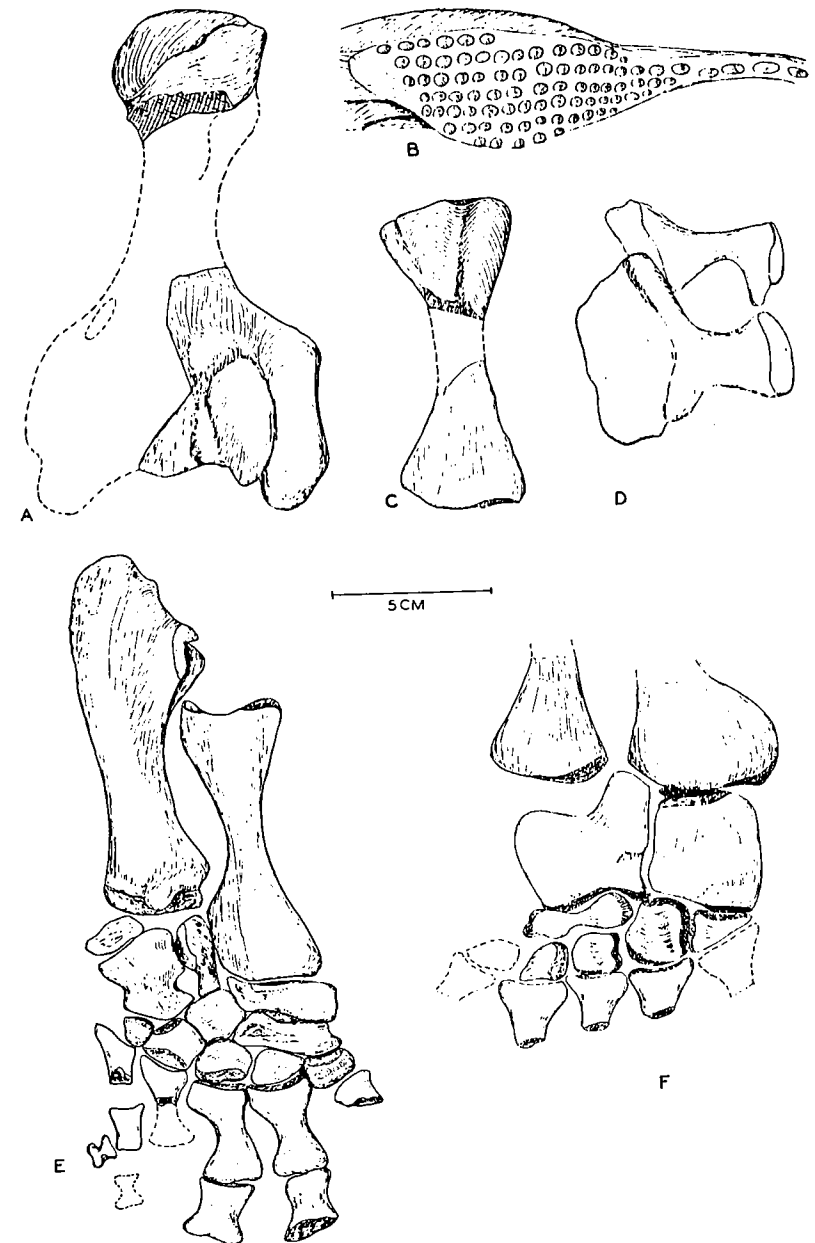


Figure 3. *Rothia robusta*, new species

(All drawings, except B, are based upon specimen CNHM UR 967)

- A. Humerus, restored.
- B. Dorsal view of jaw showing tooth pattern, somewhat diagrammatic and based upon holotype CNHM UR 966 and partial jaw of specimen CNHM UR 961.
- C. Tibia, shaft reconstructed.
- D. Two sacral ribs in proper relationship.
- E. Radius, ulna, and part of front foot (see photograph, pl. VIIb).
- F. Part of hind foot, with elements restored to appropriate positions from displaced positions in specimen.

showing the sacral ribs\*, reveals a much lighter complex. This appears to have come from a mature individual, so that the differences between it and *R. robusta* probably reflect more than mere age differences.

*Appendages.*—It was pointed out in discussions of *R. multidonta* that the limbs and girdles were quite lightly built and that there seemed to be a tendency toward reduction of massiveness and length of limbs in captorhinid evolution (Olson and Beerbower, 1952; Olson, 1962). *R. robusta* seems to offer a case which is quite the opposite.

The pelvis, now assigned to *R. robusta*, was discussed in an earlier paper (Olson and Barghusen, 1962). A partial pelvis is with the skeleton, CNHM UR 967, but it adds nothing new, merely confirming the size and massiveness of this complex. No detail is available for the shoulder girdle.

1. Forelimb.—CNHM UR 967 includes an excellently preserved radius, ulna, and carpus. The metacarpals are present along with some proximal phalanges, but the rest of the foot is missing. The details of structure are shown in figure 3E and measurements are given in table 1. Both the radius and ulna are fully ossified and sturdy. In fundamental structure they are typically captorhinid. Fragments of the humeri are preserved in this specimen, showing a strong radial condyle and a generally heavy construction (fig. 3A). A partial humerus has been found higher in the section, CNHM UR 991 from site C-2, but it adds little detail to what is already known.

Little is known of the forelimb of *R. multidonta*, but what information there is, mainly from CNHM UR 263, indicates that both the girdle and limb were lightly constructed and small in proportion to other skeletal elements.

The elements of the carpus of *R. robusta* are well ossified and arranged as shown in figure 3E. Distal to the radius is a broad bone that appears to have resulted from fusion of the radiale and centrale 4. The intermedium is narrow and elongate, and the ulnare is a large element. Centralia 1 and 2 appear to be coossified, although there is some evidence of the line of junction. The third centrale

is separate and is larger than the others. All of the distals are strong, well ossified, and well articulated with adjacent bones. The fifth centrale is notably smaller than the other four. The preserved metacarpals are short and heavy. From the metacarpals and phalanges as preserved it appears that the front foot was little specialized, retaining the generalized primitive structure characteristic of captorhinids.

2. Hind limb.—A well-preserved femur, the proximal and distal ends of the tibia and fibula, the tarsus, and three metatarsals are present in CNHM UR 967. All elements indicate that the hind limb was large in proportion to other parts of the animal, well ossified, and strong. Both ends of the femur are present. The shaft was missing but a mold for the whole bone was present so that the form and dimensions could be restored. The bone is shown in plate VIIc, D, and its dimensions are given in table 1. It is a considerably larger femur than that of CNHM UR 263 from the Texas Flowerpot. The latter is badly crushed, so that it is difficult to compare the two with respect to robustness. What evidence is present suggests that the Oklahoma species had a much more massive femur. The structure of the ends of the tibia and fibula, a restored tibia, and hind foot are shown in figures 3C, F. The tibiale and fibulare (astragalus and calcaneum) are large and well ossified. The three elements that enter into the formation of the astragalus, sometimes separated in captorhinids (Peabody, 1951; Vaughn, 1958; Olson and Barghusen, 1962), are fully ossified in *R. robusta*. The centrale is elongate in typical captorhinid fashion and the distals similarly conform to the general pattern. Only the proximal ends of the middle three metatarsals are present so that little can be said about the structure of the foot proper.

In the same beds in which the skeleton was found were other elements of the hind limb. Of particular interest is an astragalus which is even larger than the one with the skeleton. In the Omega quarry collections are similarly large foot elements that appear to belong to *R. robusta* (e. g., CNHM UR 934). Although fully adult and considerably larger and more robust than any known specimens of *R. multidonta*, the skeleton, CNHM UR 967, does not appear to represent the maximum size to be found in *R. robusta*.

\* They were identified as lumbar earlier (Olson, 1962); present information shows them to be sacral.



## Subclass SYNAPSIDA

## Order PELYCOSAURIA

## Suborder SPHENACODONTIA

## Family VARANOPSIDAE

*Varanodon*, new genus

**Diagnosis.**—The largest known genus of the family Varanopsidae, with skull measuring about 175 mm along the lateral, ventral margin. Facial region proportionately rather long in comparison to that of *Varanops*. Suspensorium far posterior, lying well back of occipital condyle. Thirty-eight to forty slender recurved teeth on maxilla and premaxilla, essentially isodont except for decrease in size of posterior few. Well-developed antorbital fenestra. Lower jaw long and extremely slender.

Scapular blade high and narrow and little expanded dorsally. Fourth toe of forefoot elongate and heavy, dominating structure of the manus. Measurements as in table 2.

TABLE 2.—MEASUREMENTS OF *Varanodon agilis* (CNHM UR 986)  
(Measurements in millimeters)

LEFT LIMB BONES				
	Length	Length to Notch	Proximal Width	Distal Width
Humerus	81		35	31
Radius	55		10*	11*
Ulna	67	55	20*	15*

LENGTHS OF FRONT FOOT BONES					
(Composite, based upon measurements of bones of right and left feet)					
	I	II	III	IV	V
Metacarpals	5	19	19	37	25
Phalanges					
1	5	7	9	18	10
2	14†	6	13	12	5
3		15†	6	9	—†
4			14†	6	
5				15†	

\* Measurement somewhat greater than that in life because of crushing; an increase of perhaps 10 percent.

† Terminal or ungual element.

*Varanodon agilis*, new species

Plate VIIIA-C; figures 4A-D

**Holotype.**—CNHM UR 986, skull, lower jaws, skeleton including vertebra (27 presacral, 2 sacral, 10 caudal) and ribs, shoulder girdles and forelimbs and feet, lacking pelvis and hind limb. Abdominal ribs present.

**Horizon and locality.**—Chickasha Formation, equivalent to middle Flowerpot, Upper Permian. From lower red shale at locality BC-8 (see measured section, p. 9), approximately 3 miles north of Hitchcock, Blaine County.

**Diagnosis.**—Same as for genus.

**Description.**—The specimen that is the basis for this new genus and species is one of the finest yet found in the Chickasha Formation of Oklahoma. It was in three slightly disarticulated parts as found. A segment of posterior presacral vertebrae was displaced with reference to the sacrum and more anterior part of the column. The specimen lay mostly in a red shale, but it passed from this into a sandy, green shale in places. At the contact of the two types of sediment there had been considerable differential movement, and bones, where they passed this zone, were ground to small fragments. Fortunately only a minor part of the skeleton was so affected. Considerable crushing, mostly lateral, occurred, but it is not sufficiently severe to obscure many critical characters. The dorsal surface of the skull in the preorbital region lay in the interbedded zone and was badly damaged. Other parts suffered some similar damage, but for the most part it has been possible to distinguish individual bones and related structures and to reconstruct the skull with confidence.

The matrix is soft, but the bone is extremely friable. Complete preparation will be a long and painstaking process. For this reason some parts of the skull are not taken up in the present description. The palate has not been revealed, although this will be possible, and only a small part of the occiput has been exposed. Eventually, if it is considered sufficiently important, parts of the interior of the skull can be cleared as well.

**Skull and lower jaws.**—The general features of the skull and lower jaws are illustrated in figures 4A, B and plate VIIIA. Lateral crushing has exaggerated to some extent the posterior position of the suspensorium and the relative narrowness of the skull. In the

drawings the width has been increased somewhat over the preserved condition, but no attempt at restoration of longitudinal proportions has been attempted. At the most, the relative extension of the suspensorium does not seem to be more than about 5 to 10 percent.

The over-all resemblance of the skull of *Varanodon* to that of *Varanops* is striking. In large part the skull of *Varanodon* merely shows a stronger expression of the features that distinguish *Varanops* from other related pelycosaurs, such as *Ophiacodon*. A striking feature is the presence of a well-developed antorbital fenestra, displayed on both sides of the skull, although on neither is the full outline completely clear. The fenestra occupies much of the lateral surface of the skull between the orbit and naris. The bone in this area is thin in most carnivorous pelycosaurs. This feature has not, as far as I am aware, been described elsewhere among the pelycosaurs. Preliminary preparation of an undescribed skull of *Varanops*, recently undertaken, has revealed the probable existence of an antorbital fenestra in that genus.

Back of the antorbital fenestra is a strong osseous pillar, lying anteroventral to the orbit. Behind it, mostly under and just in front of the orbit is an area of thin bone which is somewhat depressed in the specimen. Whether the depression is "natural" or was induced by compression after death cannot be determined. The pillar and depressed area are similar to the structures found in this area in *Varanops*.

The orbit in *Varanodon* is large and incised rather deeply into the dorsal surface of the skull. The temporal fenestra is long and low, just as in *Varanops*. It is underlain by a thin spur of the jugal and the quadratojugal. Although the shape and position in the temporal region are reminiscent of *Varanops*, the whole region is far posterior, an accentuation of the odd situation in *Varanops*. At least one-half of the temporal fenestra lies back of the occipital condyle.

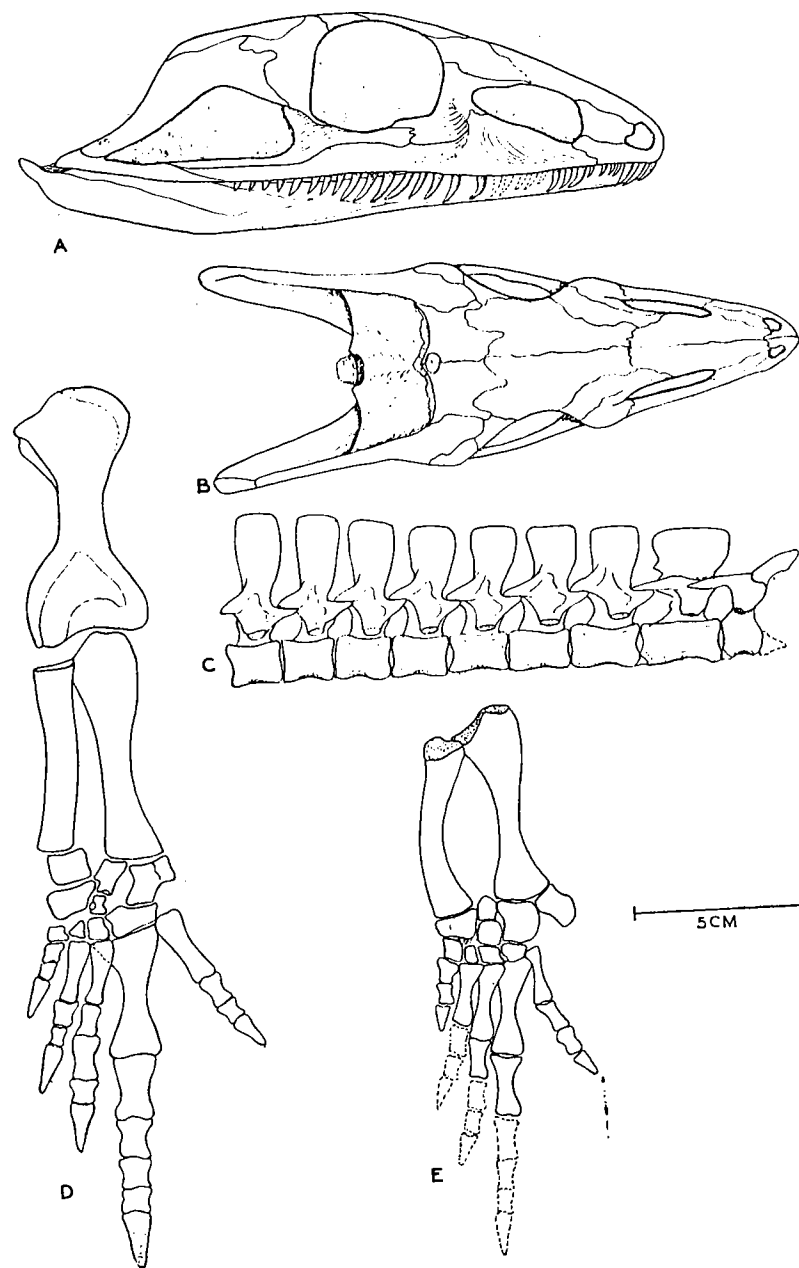


Figure 4.

A-D. *Varanodon agilis*, new genus, new species, holotype CNHM UR 986. A. Skull in lateral aspect. B. Skull in dorsal aspect. C. Vertebrae from atlas to anterior dorsal region. D. Left front foot, somewhat restored.

E. *Varanops brevirostris* (Williston) (after Williston, 1911).

The dermal pattern of the skull roof is shown in reconstruction in figure 4b. Most of it is known from readily visible sutures, but the area in front of the orbit has been restored as the bone is poorly preserved. Some traces of the sutures are present, but they cannot be followed in full detail. The skull may well have been somewhat broader than is shown in this restoration.

The most striking feature in dorsal aspect is the relative shortness of the preoccipital area. Back of it, just posterior to the rather large pineal foramen, the occiput breaks off rather sharply, but then is continued as a rather gently sloping shelf to the foramen magnum. The lateral margins of the skull, including the suspensory apparatus, then continue far posteriorly. Only about two-thirds of the total skull length is occupied by the dorsal surface of the skull anterior to the occiput.

In lateral aspect the extremely long maxilla and tooth row are shown. The tooth row, including the teeth on the premaxilla, extends for about two-thirds of the total length of the skull, as measured along the lateral margin. Teeth are sharp, simple, and strongly recurved. They have a slightly expanded waist, but otherwise are more or less needlelike. Little differentiation occurs along the tooth row. The posterior several teeth are slightly shorter, but outside of this the dentition is essentially isodont.

The lower jaw, like the upper, is long and extremely slender. It has not been fully exposed and the lower dentition is not visible. The greatest depth of the jaw is found below the posterior margin of the temporal fenestra. Even here the jaw measures only about 17 mm from base to upper margin, about 10 percent of the total length of the jaw. The articular extends well back of the articulation with the quadrate and there appears to have been an effective depressor system. The articular surface seems to have departed little from the horizontal.

More details of the lower jaw will become available as preparation is continued. What can be seen at present generally resembles the jaw structures in *Varanops* and also *Ophiacodon*.

*Vertebrae and ribs.*—The anterior part of the vertebral column is fairly well preserved and articulated. The detached presacral are severely crushed. The posterior segment, including three presacral, two sacral, and ten caudal vertebrae, is well preserved. The principal

features of the vertebrae are as shown in figure 4c. Vertebrae are similar to those of *Varanops*, differing principally in size, being larger, and in proportions. As in *Varanops*, the lengths of the centra increase along the column from the anterior dorsal vertebrae to the axis. In *Varanodon*, the increase is marked, with the axial centrum almost twice the length of that of the eighth vertebrae posterior to it. The change is reflected to a lesser degree in the increased broadening of the neural spines. Crushing has accentuated the condition somewhat. The neural spines, which are rather broad in the middorsal region, become narrow just anterior to the sacrum. This condition persists into the tail. The spines remain quite high to at least the sixth caudal. Beyond that their condition is obscure. Haemal arches, on the sixth and seventh caudals are long, measuring about 10 cm. The tail was a narrow, deep organ, well adapted for swimming.

Ribs are present on all vertebrae, including the axis. They are double-headed, long, and slender. The ribs in the vicinity of the shoulder girdle are not specialized. Two sacral ribs are present. The first is enlarged, with a broad platelike shelf. The second is much smaller and abuts distally against the first. Anterior caudal ribs are large and strongly reversed posteriorly. Back of the girdle and ventral to the ribs, in the preserved specimen, are well-ossified, slender gastralia.

*Forelimb and girdle.*—The scapulocoracoid is preserved on both sides of the specimen, but it is so flattened and damaged that not much detail can be obtained from it. The scapula was high and relatively slender, in some contrast to that in *Varanops*. The coracoids were ossified, but their form has not been preserved. Clavicles were strong, and the interclavicle appears to have been robust. General features are shown in plate VIIIA. As far as can be determined, the girdle has no particularly distinctive features.

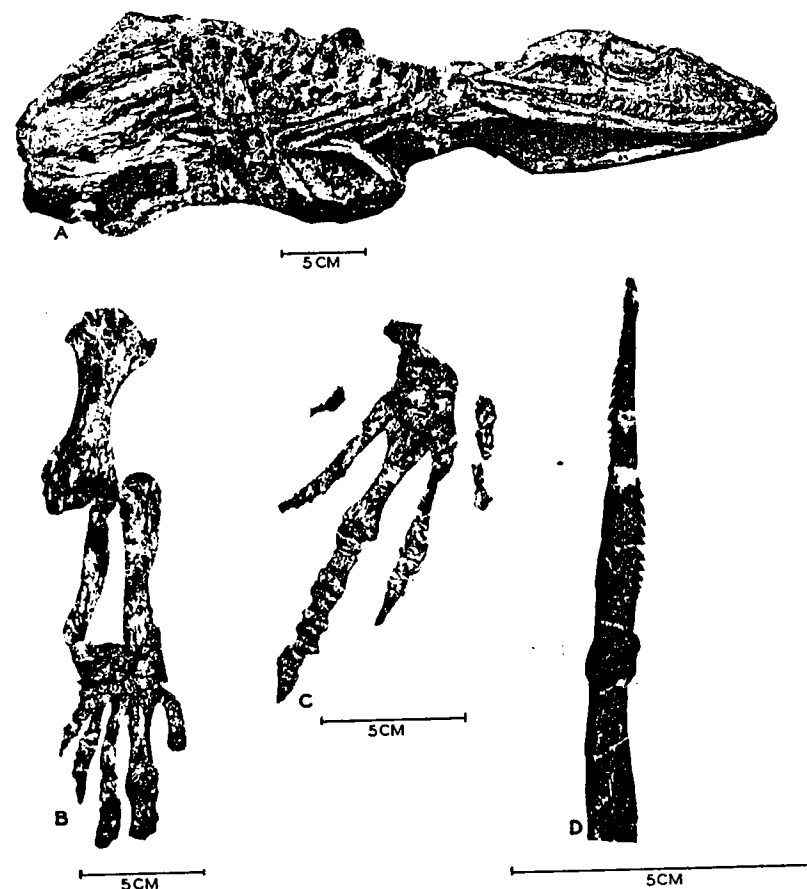
Both the right and left forelimbs are preserved in fairly good condition. In the course of preparation they were removed from the specimen. Although neither was in articulation with the girdle, each had maintained articulation of its constituent elements. Figure 4b shows a restoration based mostly upon the left forelimb with some details of the foot supplied from the right. Both the left and right humeri were rather badly crushed, as were the radius and ulna. The feet, however, particularly the left, are well preserved.

The radius was a slender bone. The ulna was slightly heavier and had a well-ossified olecranon process. The carpals are as shown in the drawing. Except for details they compare closely with those of *Varanops*, redrawn in outline for comparison (fig. 4E). The long pisiform element shown by Williston (1911) has not been found in *Varanodon*. As shown in the figure, the ulnare appears to be a somewhat double bone, with the two parts only partially joined. This partial separation may be a suture or it may be a break. The lateral element could be the pisiform, smaller and less well formed than in *Varanops*.

An apparent difference between *Varanodon* and *Varanops* is the presence of a large, lateral centrale in the former. The absence of this bone in *Varanops* quite surely is the result of poor ossification, for a space is present in which the cartilage element presumably lay. This has been restored in outline by Romer and Price (1940, fig. 40E). If the space is any guide to the dimension of this element, then the bone was much larger in *Varanodon* than was its cartilaginous counterpart in *Varanops*. The distal carpal 5 is not present in *Varanodon* and presumably, as is supposed to be the case in *Varanops*, its absence is due to lack of ossification. The medial centrale is small in *Varanodon* as exposed in dorsal view. This condition may be somewhat misleading, for it looks as if this bone might flare considerably at a more ventral level, beneath adjacent elements. Finally, the fourth distal in *Varanodon* seems to indicate an accentuation of a characteristic feature of *Varanops*. An odd feature of the third toe, seen to some extent in the second as well, is the relatively massive construction of the more distal bones as compared to the proximal ones of the same toe.

**Discussion.**—Romer and Price (1940) considered the phylogenetic position of the family Varanopsidae in considerable detail. Since that time the only specimen to be added to what was known is the one described in this paper. As they noted, *Varanops* is known but from a single locality, the *Cacops* bone bed which lies near the Arroyo-Vale boundary of the Clear Fork, probably in the basal Vale (Olson, 1954a, 1954b). Romer and Price tentatively referred two rather poorly known genera from New Mexico, *Aerosaurus* and *Scoliomus*, to the family. *Elliotsmithia* and *Anningia* (Broom, 1937) from the Karroo Series, and *Mesenosaurus* from the Russian Permian were also suggested as members. The evidence

## PLATE VIII



*Varanodon agilis* and *Xenacanthus* sp.

- A. Partial skeleton with skull and jaws of *Varanodon agilis*, new genus, new species, holotype CNHM UR 986.  
 B, C. Forelimbs and feet of *Varanodon agilis*, new genus, new species, holotype CNHM UR 986. B. Right. C. Left.  
 D. Spine of *Xenacanthus* sp., CNHM UF 978.

for inclusion of all of these forms is at best slight, as Romer and Price noted. *Mesenosaurus* is generally now not referred to the pelycosaurs at all, but to the eosuchians, following Watson (1942). Little can be added to what has been said about the other genera. The only one for which a convincing case can be made, in my opinion, is *Elliotsmithia*.

*Varanodon* lies somewhat intermediate in time between *Varanops* and *Elliotsmithia*. If the assignment of the last is proper, then the varanopsid line is extremely long lived and at the same time conservative in the exploitation of its basic characteristics. This is the suggestion that Romer and Price have made and the present find certainly is in accord with it. Romer and Price stressed the primitive nature of the family, with considerable justification. They mention the skull as basically ophiacodont and the postcranium as basically spheonacodont. Much can be said for this point of view, and the postcranium of *Varanodon* fits it as well as does that of *Varanops*. The skull, however, as modified to some extent in *Varanops* and to a great degree in *Varanodon*, although retaining a primitive cast, actually has rather marked specializations. It is certainly nonsphenacodont, but also it is not particularly ophiacodont. The elongate jaw and somewhat isodont teeth result in a resemblance to *Ophiacodon*, but the facial lengths show marked contrast. Elongation of the tooth row is attained in a quite different way, by elongation of the posterior part of the skull in varanopsids and the anterior part in ophiacodonts. The dentition of *Varanops* is somewhat like that of some of the eothyridids, with emphasis of a few teeth in the "canine" region. No such emphasis is found in *Varanodon*.

The structure of the temporal region and suspensorium is unique among pelycosaurs. The long, low temporal fenestra with its flat base, formed by an extremely slender bar, is not found elsewhere in the group. Each of the details of the skull, in particular of the temporal region, the facial area, and the suspensorium, when examined separately suggests that the varanopsids have departed rather far from the other main lines of pelycosaur evolution. Oddly, the appearance, when the skull is looked at as a whole, is that of a fairly primitive pelycosaur, and ophiacodont, or an eothyridid, as Romer and Price (1940) indicated. The specializations, which presumably are adaptations, have not resulted in a striking modification of appearance. Some of the modifications, even though actually quite

different from those of the ophiacodonts, increase the apparent resemblances between the two groups.

With the few forms known at present, statements about trend within the varanopsid group are hardly justifiable. At present we have only *Varanops* of the lowest Vale, *Varanodon* from the Chickasha, from a lens interfingering with the middle Flowerpot, and *Elliotsmithia* from somewhat later in the Karroo. The last, of course, is by no means certainly related to the other two. Development certainly did not take place in the areas of the Permian where evolution of vertebrates is well known.

The geographic locations and associations of *Varanops* and *Varanodon* immediately suggest some paleoecological interpretations. There seems to be emerging a picture of two systems, ecologically and to a large extent geographically separate, evolving in a somewhat parallel manner and contributing to a joint assemblage in at least one instance, in the fauna found in the San Angelo Formation.

#### Suborder CASEASURIA

##### Family CASEIDAE

##### *Cotylorhynchus bransoni* Olson and Barghusen

This species was named upon the basis of several specimens from the Omega quarry (site KF-1) described earlier (Olson and Barghusen, 1962). Additional specimens have now been obtained, largely but not exclusively, from the quarry. Additional morphological data will be presented in the monograph on the caseids now being prepared. Here, assigned specimens will merely be listed, with their localities.

Some parts of the skeletons of *Cotylorhynchus* and *Angelosaurus* are difficult to distinguish. This is particularly true for some vertebrae, but also applies in the case of some of the lower limb bones, foot bones, and so forth. Where no reasonable distinction can be made, specimens have been assigned to neither. Almost all of these are either *Cotylorhynchus* or *Angelosaurus*, but a few caseids possibly may not belong in either genus. Unassignable specimens are listed following the consideration of *Angelosaurus*.

Specimens assigned to *C. bransoni* are listed below; numbers UR 835 through UR 843 have been previously assigned (Olson and Barghusen, 1962).

<i>CNHM</i>		
<i>Number</i>	<i>Part</i>	<i>Site</i>
UR 835	pelvis, femur, partial sacral rib, holotype	KF-1
UR 836	foot	KF-1
UR 837	part of forelimb	KF-1
UR 838	astragalus	KF-1
UR 839	tibia (immature)	KF-1
UR 840	fibula	KF-1
UR 841	maxilla, 2 teeth	KF-1
UR 842	ungual	KF-1
UR 843	ungual	KF-1
UR 905	part of foot	KF-1
UR 910	cervical ribs	KF-1
UR 912	clavicle	KF-1
UR 913	chevron	KF-1
UR 915	series of vertebrae	KF-1
UR 918	scapulocoracoid	KF-1
UR 919	scapulocoracoid, humerus	KF-1
UR 923	sacral vertebra	KF-1
UR 937	caudal vertebra	KF-1
UR 972	caudal vertebra	BC-6
UR 983	dorsal vertebra	BC-2
UR 984	part of humerus	BC-7
UR 988	base of pelvis	BC-7

*Angelosaurus romeri* Olson and Barghusen

As in the case of *Cotylorhynchus*, most of the material has come from the Omega quarry (site KF-1). Many new specimens, including parts of skulls and jaws, have been found. It is now possible to give a description of most of the skeleton and part of the skull and jaws. This is to be presented in the work on caseids mentioned above. One point to be noted here is that the new specimens show a much greater size range than was apparent in the original material. Specimens now assigned are listed below. Numbers UR 827 through 854 were assigned earlier (Olson and Barghusen, 1962).

<i>CNHM</i>		
<i>Number</i>	<i>Part</i>	<i>Site</i>
UR 827	part of skeleton, holotype	KF-1
UR 844	pelvis	KF-1
UR 845	pubis	KF-1
UR 846	interclavicle	KF-1
UR 847	dorsal rib	KF-1
UR 848	dorsal rib	KF-1

UR 849	dorsal rib	KF-1
UR 850	dorsal rib	KF-1
UR 851	cervical rib	KF-1
UR 853	4 caudal vertebrae	KF-1
UR 854	snout, 3 teeth	KF-1
UR 904	part of skeleton	KF-1
UR 906	part of scapulocoracoid	KF-1
UR 907	scapulocoracoid	KF-1
UR 908	about 20 vertebrae	KF-1
UR 909	scapulocoracoid	KF-1
UR 911	tibia	KF-1
UR 914	toe bones	KF-1
UR 916	lumbar, sacral vertebrae, ribs	KF-1
UR 917	femur	KF-1
UR 926	maxilla, 2 teeth	KF-1
UR 927	base of skull, occiput	KF-1
UR 928	dorsal rib	KF-1
UR 932	dorsal rib	KF-1
UR 933	clavicle	KF-1
UR 940	dorsal rib	KF-1
UR 941	dorsal rib	KF-1
UR 944	2 dorsal ribs	KF-1
UR 971	series of 20 caudal vertebrae, ribs	BC-6
UR 977	femur	KF-1
UR 978	pubis	KF-1
UR 979	pelvis	KF-1
UR 980	pelvis	KF-1

Unassigned Caseids

The following materials have not been assigned to a genus. In large part they pertain either to *Cotylorhynchus* or *Angelosaurus*.

<i>CNHM</i>		
<i>Number</i>	<i>Part</i>	<i>Site</i>
UR 852*	cervical rib	KF-1
UR 930	cervical rib	KF-1
UR 936	large rib	KF-1
UR 968	caudal vertebra	KF-1
UR 969	caudal vertebra	KF-1
UR 970	fibula	KF-1
UR 985	large humerus	BC-7
UR 1000	vertebra	GR-2
UR 1001	vertebra (caseid)	GR-2
UR 1005	scapulocoracoid, toe bone	BC-9

\* Previously assigned by Olson and Barghusen (1962) to *A. romeri*, now considered indeterminate.

## Family TAPPENOSAURIDAE?

## New Genus, Not Named

Figures 5A-C, F-II

From five places in site BC-7 have come scraps of badly weathered bones of a large, otherwise unknown genus of reptile. The known specimens are:

- CNHM UR 973 From about 30 feet to the north of UR 976 (below) in red shale at about the same level, have come parts of limb bones or girdle along with scrap.
- CNHM UR 974 A centrum and a broad flat rib segment (fig. 5F). From the red shale just below the high, capping sandstone in the section for BC-7.
- CNHM UR 975 A large piece of bone, with associated scrap, from a nodule in the low green-sandstone section of BC-7, at the east end of the site in direct association with the skeleton of *Rothia robusta*, new species. The identity of this bone has not been established. It is part of a girdle or a limb bone.
- CNHM UR 976 Head and distal end of a femur, two vertebral centra, one dorsal and one sacral, two parts of vertebral arches and spines, and various indeterminate pieces of scrap. These specimens came from the lower green sandstone of the section given under BC-7. They are in part illustrated in figures 5A-C,G,H.
- CNHM UR 987 A partial head of a large femur. Bone surface poor. From siltstone in BC-7.

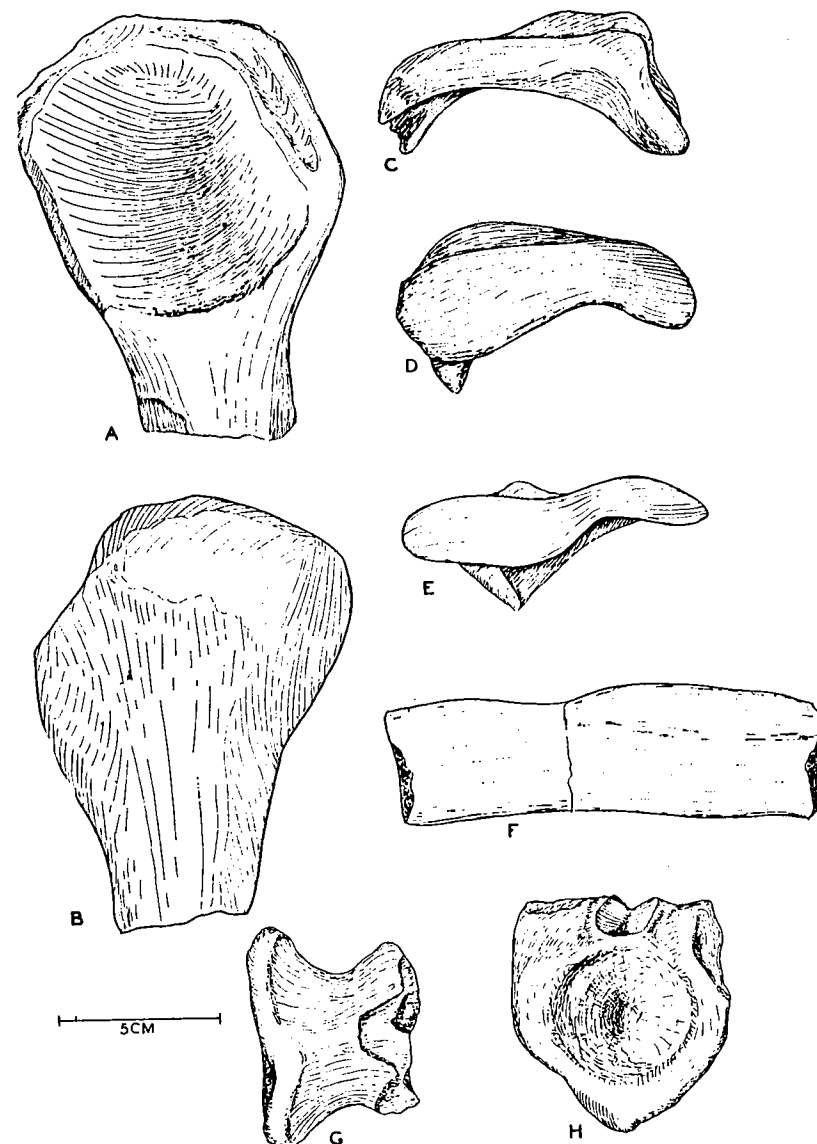


Figure 5.

- A, B, C. Head of femur of unnamed tappenosaurid (?), based upon CNHM UR 976. A. Ventral aspect. B. Dorsal aspect. C. Proximal aspect, not precisely to scale.
- D. Proximal aspect of head of femur of *Dimetrodon gigashomogenes* Case, CNHM UR 209, not precisely to scale.
- E. Proximal aspect of head of femur of *Cotylorhynchus bransoni* Olson and Barghusen, holotype CNHM UR 835, not precisely to scale.
- F. Rib of unnamed tappenosaurid (?), based upon CNHM UR 974.
- G, H. Vertebral centrum of unnamed tappenosaurid (?), based upon CNHM UR 976. G. Ventral aspect. H. Anterior aspect.

The only possible diagnostic elements are those of UR 976. The others are associated with this specimen largely upon the basis of size and upon the assumption that two or more extremely large genera are less likely than one in a small area over a restricted time span.

Except for some poorly known large reptiles from the San Angelo Formation of Texas, *Driveria* and *Mastersonia*, the only synapsid reptiles of comparable size from the North American Permian are *Tappenosaurus* and the two caseids, *Cotylorhynchus* and *Angelosaurus*. Even the little that is known shows quite conclusively that these new materials do not pertain to either *Driveria* or *Mastersonia*. If they can be referred to any known groups, these must be spenacodontids, assuming considerable size increase over any known heretofore, tappenosaurids, or caseids. Neither the vertebrae nor the femur, as described below, can be considered as caseid, and hence the choice lies between the other two.

The proximal end of the femur (figs. 5A,B,C) shows a rather close resemblance to that of *Dimetrodon*. The size and placement of the trochanters and adductor ridge, as far as they can be made out, are unlike those of caseids, and are more spenacodontlike. The femur lacks an anterior shelf, such as that in *Cotylorhynchus* (Olson, 1962). The head, however, is somewhat lighter and thinner than that of *Dimetrodon* and in this more like that of *Cotylorhynchus*. As far as can be told, however, the greatest similarity is with the head of the femur of *Tappenosaurus* (Olson, 1962). The resemblance is found in particular in the distribution of weight, or thickness, of the head. The heaviest portion is anterior, as in *Tappenosaurus* but not as in *Dimetrodon*, *Angelosaurus*, or *Cotylorhynchus* (figs. 5C,D,E).

The distal end of the femur is only partially preserved. The dorsal intercondylar area is quite broad, not deep and narrow as in *Dimetrodon*. The resemblance is to *Cotylorhynchus* and *Tappenosaurus*, but unlike the former, there is no evidence of the modification of the distal end for accomodation of an enlarged tibial head. Closest resemblance is to the condition of *Tappenosaurus*.

The vertebral centra are deeply amphicoelous and distinctly keeled. They are rather elongate and without the strongly reflexed lips of a caseid type. They are clearly spenacodontid or tappenosaurid, and not caseid. The vertebral spine and postzygapophysis that

it carries are similar to their counterparts in the type of *Tappenosaurus*. This is perhaps not a sound diagnostic feature, however, for there undoubtedly was much variation along the column.

Unquestionably these materials represent a genus that is not otherwise known. As the descriptions indicate, however, insufficient diagnostic material makes it inadvisable to give a name to this genus. It appears to belong either to the tappenosaurids or spenacodontids, with closer association to the former. It shows the presence of an extremely large reptile in the Chickasha deposits, presumably a member of the mid-Flowerpot fauna, but it gives little detail beyond this.

#### INCERTAE SEDIS

Usually when exploratory studies of hitherto unworked deposits are made, collections include indeterminate specimens, mostly fragmentary, that are of some interest in one way or another. This is true of the Chickasha. The specimens listed below, determined merely to be reptiles, fall in this category.

CNHM UR 920 This specimen consists of a partially preserved, very large rib. It could be from a large caseid, such as *Cotylorhynchus*, or it could pertain to the large tappenosaurid(?) described and figured earlier in this report. If it is *Cotylorhynchus*, it must have come from an individual of the size of *C. hancocki* Olson, known at present only from the San Angelo Formation of Texas. It is, of course, quite possible that it does not pertain to any of the genera known otherwise.

The interest, beyond the large size and possible relationships, lies in fact that this is the only specimen that has been found in the purple Chickasha. It was discovered in a road cut, in a reddish-brown sandstone, about 4 miles southeast of Alex, Grady County (fig. 1). It lies well away from the zone of interfingering of the deltaic and evaporite facies and hence the age is difficult to determine.



- CNHM UR 921 This specimen consists of a fragment of the front part of a jaw with two sharp teeth. It measures less than 2 cm long. It appears to be part of a reptilian jaw, probably from some small carnivore. Possibly it is an immature specimen of *Rothia*, although the sharp, simple cones of the teeth argue to the contrary. The specimen comes from site BC-10, from sandstones of the channel deposit there. It is one of the few specimens known from this site.
- CNHM UR 993 A fragment of a jaw that appears to be part of a small, predaceous reptile form from site BC-1. It measures just under 5 mm in length and has, it appears, a single row of teeth, of which only fragments are preserved.
- CNHM UR 1006 This specimen is in some ways the most puzzling that has been found. It consists of part of the ramus of a lower jaw, with two teeth in place and others represented by "alveoli." The teeth have a clear-cut, acrodont insertion on the crest of the jaw. The ramus is about 3 cm long, which probably represents about half of the total length of the jaw. The specimen does not fit at all with any other known Permian genus.

The stratigraphic position of the specimen also poses a problem. It came from about 2 feet above the upper green sandstone of site BC-9, some 4 feet below the identifiable Pleistocene that cuts into the Permian (pl. IIIA). *Xenacanthus* and *Rothia*, with obvious Permian affinities, have come from the green sandstone. The red shales above it seem to be Permian. In plate IIIA, the position of the find lies above and to the right of the figure, below the lower break-point of the clearly shown Pleistocene. It is possible that the redbeds, although appearing

to be Permian, are in fact reworked and possibly Late Tertiary in age. This situation obtains elsewhere, at the top of the Cloud Chief and the Elk City. Generally once the situation is recognized, the reworked sediments can be differentiated from the originals. In this instance this has not been done yet. The visible surface characters have proven nondefinitive so far.

In site BC-8, from well down in the Permian, remains of a turtle were found. The shell features suggest that it was a Tertiary chelonian. The fragments were on the surface with only a slight cover, so it may be assumed that they washed down from above, although preservation is not different from that of Permian specimens. The specimen indicates that there have been or are Tertiary deposits in this area.

The jaw and teeth are lizardlike, or rhynchocephalian. It has not been possible, however, to associate them with any known lizard. This specimen remains an enigma, both as to age and identification. If the age is actually Permian, as the stratigraphy suggests, then the specimen shows the presence of a rhynchocephalianlike creature early in the Upper Permian.

## ASSESSMENT OF THE FAUNA

Information is far from adequate for anything beyond tentative interpretations of the nature and meaning of the vertebrate fauna that has come thus far from the Chickasha Formation. Only one phase of it, that from Blaine and adjacent Kingfisher Counties, provides a basis for any sort of meaningful discussion. This phase of the formation is approximately middle Flowerpot in age. Although no broad synthesis can be made, several points of interest have arisen and are worth noting. Each is, of course, subject to modification as the data become more complete.

A first point of some general significance is that the assemblage from the Chickasha Tongue within the middle Flowerpot does not appear to be closely related to faunas from the San Angelo and Flowerpot Formations of Texas. Of these, however, only the upper San Angelo array is well enough known that comparisons can be meaningful. The Oklahoma fauna probably is slightly more recent in time than is the San Angelo assemblage, although this is not clearly established. The differences do not, in general, appear to be a function of time, but more of geographic and ecological separation.

As far as specific determinations can be carried, no species is common between the two. *Cotylorhynchus*, *Angelosaurus*, and *Rothia* are the common genera to which this applies. Although marked morphological differences occur in each instance, they do not reveal any sort of antecedent-descendant relationships.

The carnivores of the San Angelo are *Dimetrodon* and some phthinosuchidlike and titanosuchidlike creatures. They are advanced relative to the Early Permian carnivores, especially the last two. The only reptilian carnivore found thus far in the Chickasha Formation is *Varanodon*, which clearly is descended from *Varanops* of the Early Permian *Cacops* bone bed. Perhaps more advanced genera will be found, but as yet there is no sign of them.

Amphibians, although represented mainly by scrappy remains which are difficult to identify, are much more diversified than are those known from the San Angelo. Only two specimens representing one genus, the trimerorhachid *Slaughenhopia*, have been found in the San Angelo. In the Chickasha are four known genera, three rhachitomes and one gymnarthrid lepospondyl. With the possible

exception of the unnamed genus (CNHM UR 1007), none of these represents the typical large, *Eryops*-like amphibians so abundant in the Early Permian or their descendants well known in the later Russian Permian.

The large reptile known from a few bones and tentatively assigned to the tappenosaurids may be an indication of some relationship between the Chickasha and the San Angelo. Three such creatures, *Tappenosaurus*, *Driveria*, and *Mastersonia*, are known from the San Angelo. Of these, Chickasha remains most closely resemble those of *Tappenosaurus*. How much weight this should be given in comparisons of the faunas cannot be judged.

A second point, related to the first, arises in the association of *Varanodon*, caseids, and the dissorophid *Fayella* in the Chickasha. These all occur in the same beds and quite certainly were biological associates. In one pocket, and in no other place, in the Texas Permian has such an assemblage been found. This is the well-known *Cacops* bone bed described in several publications by Williston (1911, 1916). *Varanops*, *Casea*, and *Cacops* were found intimately intermingled. None of these genera has been identified elsewhere in rocks of comparable or earlier age. *Casea* has been found in two isolated occurrences in the higher Clear Fork (Olson, 1954a, 1962). Dissorophids do occur elsewhere, in many places in association with *Seymouria* and *Trematops* in the Arroyo as well as older beds. *Cacops* was tentatively identified from the Choza by the writer (Olson, 1956), but the humeri upon which the record was based could well belong to another dissorophid.

The only other varanopsid found in North America, except for some tentatively assigned genera of the Early Permian (Romer and Price, 1940), is *Varanodon* of the Chickasha.

It was suggested (Olson, 1962) that the *Cacops* bone bed may have tapped representatives of an ecology not otherwise represented in the Texas Permian. The isolated specimens of *Casea* from the Vale and Choza were similarly interpreted. Now, it may be argued, we come once again upon the *Cacops* bone bed type of assemblage in the Chickasha Formation of Oklahoma. *Varanodon* quite likely was derived directly from *Varanops*. *Casea* itself is not known, but *Cotylorhynchus* and *Angelosaurus* are present. The dissorophid, *Fayella*, could have been derived from *Cacops*; it could also have been derived equally from *Dissorophus*.

It may be that what we see in the Chickasha is a sample of a persistent chronofauna that developed in total or partial isolation

from the Clear Fork chronofauna of Texas (Olson, 1952, 1958). Under this interpretation the San Angelo is somewhat puzzling. Clearly some of its elements, *Dimetrodon* in particular, could have been derived from the Clear Fork chronofauna. Others, such as *Caseoides*, *Caseopsis*, *Cotylorhynchus*, and *Angelosaurus*, could have come from some early phase of the suggested Chickasha chronofauna. In addition, however, are elements that find no ancestors in either, the very large animals such as *Driveria* and *Master-sonia*, the phthinosuchids, and the titanosuchids. These "advanced" types must have had a source elsewhere, among unknown antecedents.

The presence of *Cotylorhynchus* in the Hennessey Formation suggests that the fauna preserved in this formation might have led to the Chickasha fauna. But three species, the only others known, seem to have Texas counterparts from the contemporary Clear Fork. These are *Labidosaurikos meachami* (Seltin, 1959), *Captorhinikos chozaensis* (Vaughn, 1958; Olson and Barghusen, 1962), and *Lysorophus tricarinatus* (Olson, 1962). Also, *Cotylorhynchus romeri* of the Hennessey appears to be close to *Cotylorhynchus hancocki* of the San Angelo, closer than it is to *Cotylorhynchus bransoni* of the Chickasha.

Extensive collecting and stratigraphic analysis are necessary to clarify these matters. In this instance, in contrast to many, it would appear that the opportunity to do the necessary work is provided by the exposures over the areas of Texas and Oklahoma.

The third point that emerges is that the fauna found in the Chickasha is strictly "North American," that is, it does not contain any elements that have commonly been associated with European Permian faunas as represented in the Russian Kazanian. In this it contrasts sharply with the upper part of the San Angelo and the early Flowerpot of Texas. As in all points, negative evidence provides part of the basis for this conclusion, and additional work may show the contrary to be the case.

This is how it looks at the present. Work is continuing in both Oklahoma and Texas. It will be extended to include certain selected parts of the earlier Permian sections of Texas and the Hennessey of Oklahoma. Further exploration of the San Angelo deposits in Texas is anticipated. This work should aid in testing the validity of some of the tentative conclusions put forth in this report.

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