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EARLY PERMIAN VERTEBRATES OF OKLAHOMA

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ABSTRACT

Remains of terrestrial Early Permian vertebrates were discovered in Oklahoma prior to 1900. Occasional finds have been made since that time and the Hennessey Formation was carefully explored by J. Willis Stovall. No other systematic collecting has been done and no comprehensive report on the vertebrates has been made. The study reported here represents an attempt to establish a sound base from which future work can proceed.

All sites discovered earlier have been revisited and, as possible, recollected. A large number of new sites have been discovered. The general geology of the Lower Permian beds of Oklahoma is reviewed and revised to establish a context in which the vertebrate sites may be related. For each site a list of vertebrate genera and species, conditions of occurrence of the fossils, geological age, and, as far as possible, a measured section are given. A summary of the vertebrate fossils in each of the three producing areas, southwestern, south-central, and central and north-central Oklahoma, is given.

The pre-Hennessey Permian faunas have a close relationship to those of north-central Texas. The Hennessey vertebrates have affinities with those of the later Chickasha beds of Oklahoma and the San Angelo beds of Texas.

INTRODUCTION

The term "Lower Permian," as used in this report, includes the formations generally considered as Wolfcampian and Leonardian in age. These are the formations included in the Wichita and Clear Fork Groups in Texas, from which most of the well-known Permian faunas of that state have come. In Oklahoma they are above the Vanoss Formation or its time equivalents and below the Duncan Sandstone. The Duncan Sandstone and younger Permian beds are considered to be Late Permian (Guadalupean and Ochoan) in age. The vertebrates from these higher beds, specifically those of the El Reno Group, have been treated in two recent reports (Olson and Barghusen, 1962; Olson, 1965b).

Early Permian vertebrate remains were known from the State of Oklahoma prior to the present century. Specimens from Deep Red

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Run in Cotton County, collected by W. F. Cummins, and from the McCann quarry in Kay County were among the earlier finds. E. C. Case did the principal work on these materials. It was not until J. W. Stovall came to The University of Oklahoma that extensive or systematic efforts to collect from the Oklahoma Permian were undertaken. During the 1930's he concentrated on collecting in the vicinity of Norman, but accumulated some materials from other parts of the State. Earlier, in 1927, G. M. Smith attempted a collation of the Permian vertebrates of Oklahoma and presented his results as a Master of Science thesis at The University of Oklahoma (Smith, 1927). In the course of this work he did additional collecting.

Stovall and L. I. Price made extensive collections of Early Permian vertebrates from fissures in the Arbuckle limestone at Richards Spur, north of Ft. Sill. This is the one site, away from the Norman area, to which considerable attention has been paid. A number of persons have collected from it, and collections have become widely scattered. It has become difficult to conduct any comprehensive study of these materials because of this scattering, and this is also true, in large part, for all of the collections from Oklahoma. Fairly substantial collections are present in the Stovall Museum of The University of Oklahoma, the University of Kansas, the Field Museum, the University of California at Berkeley, the University of Michigan, the American Museum of Natural History in New York, the Museum of Comparative Zoology at Harvard University, and the U. S. National Museum in Washington, D. C. Other institutions have small amounts of material.

Studies and collecting have been sporadic and documentation of materials has in general been poor. Except for the summaries of Case (1902, 1915) and the thesis of Smith (1927), most mentions of Oklahoma vertebrates in the literature have been casual or related to a small suite of specimens, in most cases of some genus or species. This is in sharp contrast to the systematic and intensive work that has been carried on in the Permian of Texas since the early 1870's. The reasons are several, but the most important is the less favorable condition of the Oklahoma exposures as compared to those in Texas. Much of the area of the Lower Permian is covered either by grass or woodland. Exposures tend to be widely separated, making both collecting and stratigraphic studies difficult.

This report is the result of initial efforts to remedy this situation. It cannot, of course, hope to match the work of nearly one hundred years in Texas. With the knowledge of the Texas faunas as a basis, a useful introductory account of the vertebrate sites, their faunal contents, and their stratigraphy can now be produced. Most of the field work was conducted during a four-month period in 1965. The party making the study was under the direction of the writer. John Bolt, Keith J. Carlson, and Brent Kilbourne were members of the group for part of the season. George Olson, employed for this purpose by the Oklahoma Geological Survey, supervised the work for the full period, providing continuity of effort and ensuring as complete coverage as possible in the time available. As in all of our recent studies, Carl C. Branson, then director of the Oklahoma Geological Survey, and members of his staff were of invaluable assistance. The work has been supported by National Science Foundation grant B 2453.

Many new specimens have been collected and parts of old collections have been restudied. It has not as yet been possible to see all the Oklahoma specimens, because of their wide dispersal. A number of undescribed genera and species are in the materials at hand. These are being studied, but a comprehensive taxonomic analysis of the faunas from the Lower Permian of Oklahoma will not be possible for some time to come. The stratigraphy of much of the Lower Permian has been treated only briefly and somewhat superficially in the literature. An immense amount of detailed study is necessary to bring it to the state in which it would serve the needs completely. However, in the course of our studies it was possible to make reasonably accurate stratigraphic assignments for the majority of sites. Some awkwardness in description arises from the lack of a stable frame of stratigraphic reference for the State as a whole. Although information on both the fossils and stratigraphy is less than would be the case ideally, the present report can provide a firm base from which later studies can be conducted, and that is its principal aim.

GENERAL GEOLOGY OF THE LOWER PERMIAN

The areal extent of the Lower Permian in Oklahoma is shown in figure 1. The Permian of the southwestern part of the State is partially isolated from the rest by the Wichita and Arbuckle Mountains. Difficult problems of correlation between the different areas result from lack of continuous, or even generally contiguous, exposures. The southwestern portion ties more closely to the Texas Permian south of the Red River than it does to the Permian in more northern parts in Oklahoma. From south-central Oklahoma to the northern border of the State occur scattered outcrops of rocks of Early Permian age. In general, the lower part, from the base to the top of the Garber Formation, is only locally exposed. The Hennessey Formation, on the other hand, has extensive and more nearly continuous exposures, although, in this case as well, some outcrops are separated by broad covered areas.

Figure 2 is a general stratigraphic chart to show the groups and formations that make up the Lower Permian. Vertebrate sites are scattered throughout the areas shown in figure 1. In the southern part of the State are good exposures of the Wichita Formation, following the usage of Miser's geological map (1954). The section from east to west includes successively younger beds, which have been considered to contain both Wellington and Garber equivalents. The presumed Garber of this area, that overlying the dark sands called the Asphaltum and Ryan, does not, however, appear to be the time equivalent of the Garber to the north, as indicated by correlations based upon faunas. Overlying the lower beds, which are predominantly gray and maroon shales and gray to black sandstones, are redbeds, present in Tillman and Jackson Counties. These have been called Hennessey and they do bear considerable lithological resemblance to the Hennessey beds in the central and northern parts of the State. They are, however, early Clear Fork in age, based upon their faunal and stratigraphic relationships to the Texas section, whereas the Hennessey beds to the north appear to be largely late Clear Fork.

North of the Arbuckles a broad band of pre-Hennessey beds stretches to the northern border of the State, changing radically in stratigraphic relations along the trace. South of the Canadian River these beds are not well differentiated into Garber and pre-Garber units, although a succession of sandstones mapped in Garvin County by Dott (1927) provides a basis for subdivision into a number of units. Northward from the Canadian River the eastern part of this

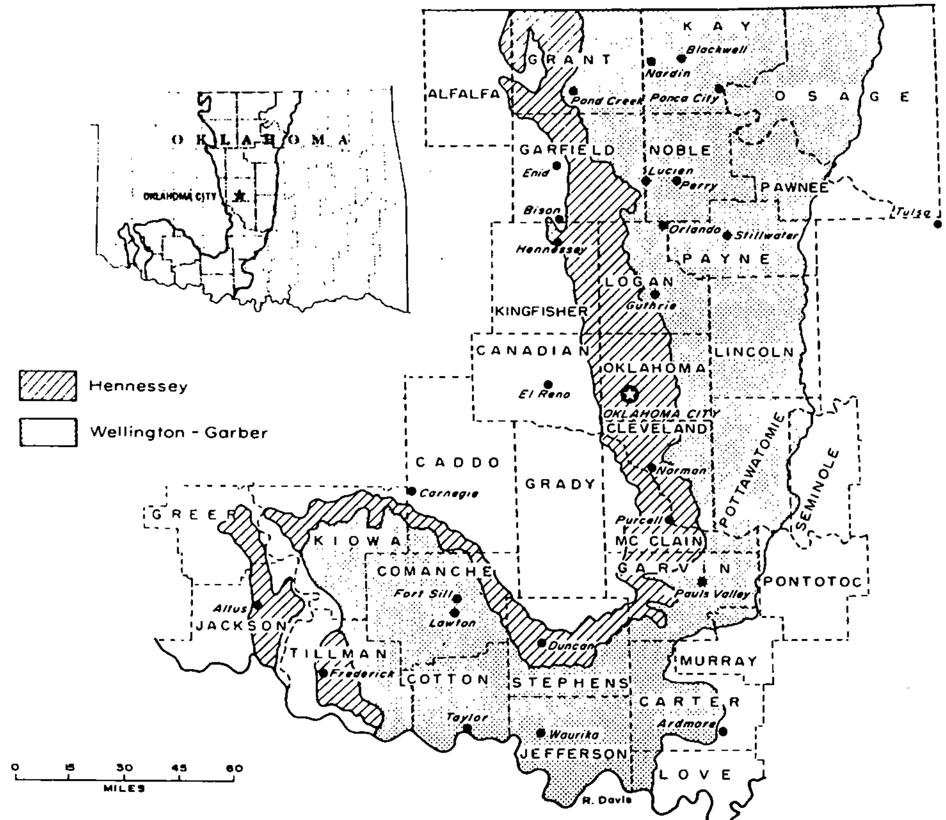


Figure 1. Map of central and western Oklahoma, showing general distribution of strata of Early Permian age.

band is marked by eastward-facing escarpments formed by the complex of sandstones and shales called the Fallis Sandstone (Patterson, 1933). West of this area are more or less undifferentiated Wellington and Garber sandstones and shales. This condition persists to approximately the latitude of Oklahoma City, where the basal Garber Sandstone becomes more clearly defined and the Wellington and Garber are partially separable.

To the west of the Wellington-Garber complex throughout this part of the area, is the Hennessey Shale, composed predominantly of highly colored red shales, with some sandstone. The Hennessey, which is overlain by the basal member of the El Reno Group, the Duncan Sandstone, is a complex unit, both in distribution and in physical characteristics. It is partly terrestrial and partly marine in origin.

North of the Cimarron River, Wellington shales are well developed. To the east the Fallis Sandstone persists, thinning westward with thin wedges extending into the lower four-fifths of the Wellington Shale. In Noble County, Patterson (1933) recognized the Fallis Sandstone as a lower member of the Wellington, and a shale, which he termed "Iconium," as an upper member. Subsequent workers have made more detailed subdivisions, but these have been in large part unpublished (Raasch, 1946a, 1946b). For the purposes of the present report, the subdivision into a shale and lower sandstone, with the western wedges of sandstone providing markers in the shales, gives a sufficient breakdown with respect to the vertebrate fossil sites.*

*Tanner (1959) used the terms for the Wellington proposed by Raasch (1946a), but these were published only in a thesis summary, without description (Raasch, 1946b).

Series	Group	SOUTHWESTERN OKLAHOMA	SOUTH-CENTRAL OKLAHOMA	CENTRAL, NORTH-CENTRAL, AND NORTHERN OKLAHOMA
UPPER	EL RENO		Duncan Sandstone	Duncan Sandstone and Flowerpot Shale
LOWER	CLEAR FORK		Hennessey Formation	Hennessey Formation: Cedar Hills Member; Bison Banded Member; Fairmont Member
LOWER	CLEAR FORK	"Hennessey Shale" (Clear Fork)	Garber Formation	Garber Formation: Hayward Member; Lucien Member
LOWER	WICHITA	"Garber" and Wellington equivalents equal "Wichita" Formation	Wellington Formation	Wellington Formation: Iconium Member; Fallis Member
LOWER	WICHITA	Upper part of Pontotoc Group	"Stillwater Formation" equals upper part of Pontotoc Group	Chase Group; Council Grove Group; Admire Group
		Vanoss Formation (Lower part of Pontotoc Group)	Vanoss Formation (Lower part of Pontotoc Group)	Vanoss Formation (Lower part of Pontotoc Group)

Figure 2. Generalized stratigraphic chart of the Lower Permian beds in the areas of Oklahoma treated separately in this report. The names used are mostly adapted from the *Geologic Map of Oklahoma* (Miser, 1954), with subdivisions and modifications from appropriate published sources.

Northeastward from about the latitude of Perry the Wellington shales pass from predominantly red to predominantly gray (Aurin, Officer, and Gould, 1926; Anderson, 1941). They become much more evenly bedded, and thin gray dolomites form an important element of the sections. These predominantly gray beds contain the thin red wedges of the Fallis Sandstone, which lose their identity westward. This general condition continues to about the Kansas border, the sandstones becoming less prominent and then disappearing and the general cast of the beds becoming more and more marine. The Wellington, as part of the Sumner Group, has been classified as Leonardian in the Kansas section, and this assignment has been carried over into Oklahoma. The Belle Plains Formation of Texas has also been called Leonardian (Dunbar and others, 1960; Tanner, 1959). Vertebrate paleontologists, recognizing the sharp break in faunas between the Belle Plains and Clear Fork, have tended to consider the former to be Wolfcampian rather than Leonardian. Some invertebrate evidence, however, suggests Leonardian age for the Belle Plains. This problem cannot be solved in this report. Here the Wichita and Clear Fork Groups will be the large units used. The Belle Plains is considered as the highest formation of the Wichita Group, and the Clyde as the lowest formation of the Clear Fork Group. Correlations developed in this paper fall within this framework.

To the west of the Wellington Formation, the Garber Formation is well exposed in the area north of the Cimarron River. The lower portion, the Lucien Member, is composed predominantly of red shale and sandstone; the upper part, the Hayward Member, is largely sandstone. The Hayward forms a prominent scarp in the southern part of this region. In the more northern parts, beginning somewhat north of Perry, shale is dominant. The red color is maintained, in contrast to the color of the Wellington.

Overlying the Garber, here as to the south, is the Hennessey Shale. The most prominent member is the Fairmont, which is largely red shale, but which also includes sandstone and green sandy shale in its lower and more eastern portions. The Hennessey-Garber contact is a series of transition beds about 50 feet thick. In Blaine and Kingfisher Counties the Cedar Hills Sandstone interfingers with the upper part of a red shale in the Hennessey Formation (Fay, 1962); this red shale is part of the Fairmont Member. In the northern and western parts of its outcrop area the Hennessey is represented by the Bison Banded Member, a distinctly marine facies.

DISTRIBUTION OF VERTEBRATE FOSSILS

The absence of extensive and continuous exposures of Lower Permian beds presents difficulties in relating the fossiliferous sites throughout the State. Except for work in the Norman area, little systematic study of the sites had been made prior to that done for this report. Much additional study is needed and much more profitable work is possible. The three most fossiliferous regions are in the southwestern part of the State in the "Wichita" beds, around Norman in the Hennessey Formation, and in the areas near Lucien and Perry in the Garber and Wellington Formations. In addition, of course, there are the rich local sites, such as the fissure deposits at Richards Spur, and the Orlando, Pond Creek, and McCann quarry occurrences.

The beds in Jefferson and Cotton Counties to the southwest and Logan County to the north are by far the most promising for additional collecting. Fossils from the former undoubtedly will prove to be much like those of adjacent sections in Texas and will extend these faunas well to the north. The less fossiliferous deposits of McClain and Garvin Counties may provide an even greater northward extension.

The northern sites, beginning at about the latitude of Orlando, will undoubtedly produce a wealth of information concerning the Wellington. The known localities have yielded many genera and some species identical to those of the Texas Permian, but the collections include some species and genera that are different. Also, among the genera and species common to both areas, there are striking differences in relative proportions. The redbeds around Orlando and north to Perry show depositional resemblances to beds in Texas, but to those of the Arroyo rather than to those of the Admiral and Belle Plains, which are closer age equivalents. Some of the common fossils suggest that this apparent similarity is, in fact, a reflection of similar conditions of life and deposition between the Arroyo and the earlier beds in north-central Oklahoma. The shales and thin beds of dolomite of the Wellington and, to an extent, the sands which represent the upper portions of the Fallis Sandstone are not matched in the Texas section. They represent types of deposition and presumably life conditions different from those encountered either in contemporary or noncontemporary deposits of the classic Texas region. The faunas seem to bear out these differences.

Fossils are not abundant in the Garber, but a number of productive sites are known in the Lucien Member, and additional study will probably reveal others. In general, conditions of deposition at the fossiliferous sites appear to have been similar to those of the Arroyo Formation in Texas, and the same genera and species are for the most part present. The Hayward Member of the Garber has yielded few fossils, and what few are available are in the form of badly broken scrap.

The transition beds between the Garber and the Hennessey are more fossiliferous. In this complex, which averages about 50 feet in thickness, conditions were such that preservation is excellent, and a number of good sites have been found. Others probably can be opened up by additional work.

The Hennessey, although widespread, has yielded identifiable fossils only in the vicinity of Norman and about 40 miles to the northwest near Navina. The paucity of fossils may be partly due to rapid weathering of the surface of the Hennessey beds, which tends to destroy organic remains. Only large, dense bones reach the surface in recognizable form. Although weathering undoubtedly is a factor, study to date, which has covered most of the exposures in at least reconnaissance style, suggests that for the most part the Hennessey is barren of organic remains. It is reasonable to believe that new pockets will turn up, but there is little promise that continued hunting would be immediately successful. The Hennessey in the Norman area, which is the most fossiliferous locality known, has been so thoroughly collected that little material is now available, except at one site just south of Norman.

FOSSIL-PRODUCING AREAS AND SITES

Division of Oklahoma into large areas produces a convenient framework for discussion of the vertebrate sites. Accordingly, the sites are assigned herein to the following geographic areas: southwestern Oklahoma; south-central Oklahoma; fissure sites (Caddo and Comanche Counties); and central, north-central, and northern Oklahoma. Although this procedure has the disadvantage of masking the stratigraphic continuity and relationships of the areas, it permits analysis of questionable temporal relationships separate from the descriptions and discussions of particular sites. The final section of this paper is a collation of the faunal and stratigraphic information.

Southwestern Oklahoma

Vertebrate remains have come from a number of scattered sites in Jefferson, Cotton, Tillman, and Jackson Counties (figure 3). The fossils have been found in sediments of the middle and upper parts of the beds called Wichita and from the overlying beds called Hennessey. Some of the sites were discovered in the last century, when work on Permian vertebrates in North America was in its infancy.

Little systematic geologic work has been carried out. The most explicit work is Wegemann's (1915) structural study of part of this area.

The present study brings together, as far as possible, all available earlier knowledge and adds some new information. Collections made by parties from the Stovall Museum include specimens from this area, but documentation is insufficient for stratigraphic or faunal analysis. The Wegemann collections, now in the U. S. National Museum, are the most useful for these purposes, but they comprise scrappy specimens, except for two skeletons of *Diadectes*. The best that can be done, in lieu of much more extensive field work, is to establish a basis for general comparisons with other sections and provide a foundation for future studies.

Lower Permian beds of Wichita age are exposed in Jefferson and Cotton Counties, and also in adjacent parts of Stephens, Carter, Comanche, and Love Counties. Each of these has at least some potential as a producer of vertebrate remains. The best known sites, however, lie in a strip just north of the Red River in southwestern Jefferson and south-central Cotton Counties. Of these the Waurika site 1 (6 miles west of Waurika) and the Southwest Taylor site (2 miles southwest of Taylor) are best known. W. F. Cummins' Deep Red Run site, northwest of Randlett in Cotton County, has been noted in a number of publications (e.g., Romer and Price, 1940, p. 27).

A traverse from eastern Jefferson County westward, north of the Red River, passes through bench-forming sandstones and gray and maroon shales. This sort of lithology persists, with some slight increase in the red cast of the sediments, to about the middle of Tillman County, where the grays and maroons give way to bright-red shales. The gray and maroon beds roughly correspond to the Wichita Group of Texas, but the upper portions include what appear to be Clyde equivalents, which places them in the base of the Clear Fork Group. The redbeds are indicated as Hennessey on the *Geologic Map of Oklahoma* (Miser, 1954). They extend into Jackson County as red shales and rather thick red and white sandstones and conglomerates. In large part, these beds appear to be equivalent to the Arroyo Formation of Texas.

The stratigraphy along this traverse has not been fully worked out. Wegemann (1915) gave a number of sections at various sites and these show the general nature of the beds. Bunn (1930) published a geologic map and section for Jefferson County, on which he applied the name Asphaltum Sandstone and Ryan Sandstone to the prominent capping sandstones a short distance north of the Red River. He considered these units to be equivalent. About 125 feet below the top of the Ryan he recognized the Oscar Sandstone, and between the two are shales which carry irregularly disposed lenses of sandstone. The color is predominantly gray to yellow.

Robinson (1921) presented a more detailed but still general description, emphasizing the lenticular nature of the sandstones. It is from the shale between the Ryan-Asphaltum Sandstone and the Oscar Sandstone that the fossil vertebrates have come. Careful stratigraphic analysis will be needed before they can be placed accurately in the section.

Wichita sites described below are roughly all of the same age, but at present they cannot be precisely related. The upper sandstone of the area north of the Red River, the Ryan-Asphaltum, has been used as a marker, but, owing to structural complications, identification of this sandstone is not certain at all places. The presence of lenses and discontinuous beds, as shown by Bunn, complicates correlations. The Clear Fork beds, in the western part of the area, have been little studied; they have been called Hennessey or merely Clear Fork.

In the course of various studies of the geology of this region,

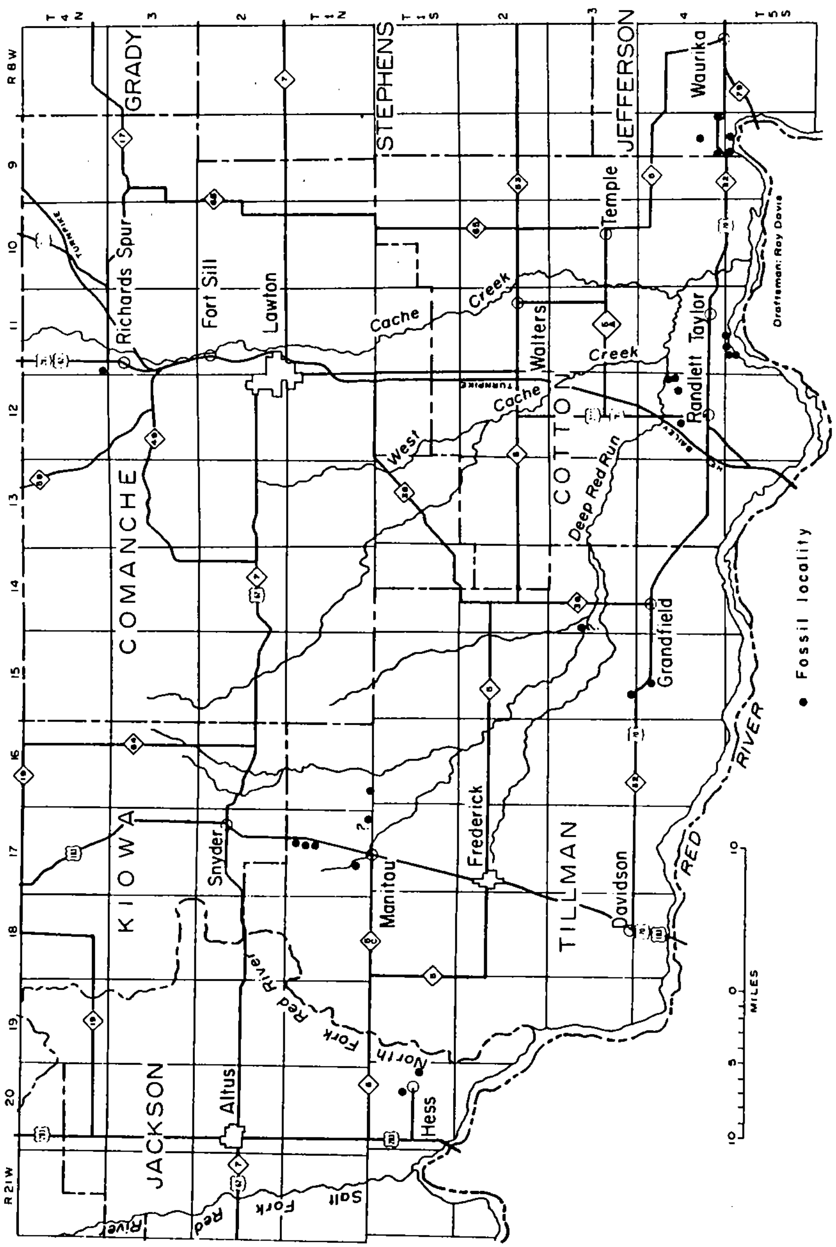


Figure 3. Map of southwestern Oklahoma, showing known collecting sites for vertebrate fossils, including the one at Richards Spur. Sites in the eastern part of the area are in rocks of Wichita age; those in the western part Clear Fork (equivalent to the Arroyo Formation of Texas).

vertebrate fossils have been found in a number of places. In addition, casual finds have been reported to The University of Oklahoma. Wegemann's list includes sites found in the course of his work in parts of Jefferson and Cotton Counties (Wegemann, 1915). He gave precise quarter-quarter section locations and indicated the genera present, the kind of sediments in which they were found, and the condition of the fossils. C. W. Gilmore identified the specimens, and E. C. Case examined them and gave his opinions on them. In 1915, Case published a faunal list based upon these materials. In a footnote, however, he indicated that they came from 2 miles southwest of Taylor. His list, except for an addition of some species names, is the same as that of Wegemann from a site discussed below as Waurika site 1. Wegemann did have some scrappy material from the site southwest of Taylor, but this could not have been the source of Case's faunal list.

In the discussions that follow, the locations of particular finds are taken as the basis for definition of a site. In the northern part of the State, where outcrops are isolated, this practice is particularly appropriate, for intervening finds are unlikely. In the southwestern part, however, this practice is to some extent a formality, and the sites are based more upon accidents of discovery than upon discontinuities of fossil-bearing beds. In time to come, when the stratigraphy is better known and more thorough collecting has been carried out, it probably will be possible to group sites into meaningful locations of considerable areal extent.

WAURIKA SITE 1

Waurika site 1 has long been known and often spoken of as the "Waurika locality." It was one of the sites given by Wegemann (1915), the one from which most of the fossils that he described were obtained. Collections are now present in a large number of museums. The location is about 6 miles west of Waurika in SW¼ NW¼ sec. 36, T. 4 S., R. 9 W., Jefferson County. The total section at the site is about 50 feet. Vertebrates are abundant in a gray shale which lies about 40 feet below the base of the capping sandstone, interpreted as the Ryan-Asphaltum Sandstone. The bone-bearing shale is dark, but it weathers to a light gray.

The shale contains a high concentration of extremely fragmentary remains of vertebrates. Individual lenses exhibit restriction of content to particular types. One lens, for example, is rich in sharks' teeth but carries little else. Along the southern margin of the deposit are shales that carry moderately complete limb bones and vertebrae of *Edaphosaurus*. One partly articulated skeleton has come from this site, but it was collected by amateurs and apparently has been lost. The shale bed ranges from about 2 to 3 feet in thickness. Adjacent beds comprise sandstones, mudstones, and conglomerates, which are somewhat more maroon in tone than the highly fossiliferous shale. Although these carry fossils, the fossils are thinly distributed.

Case's faunal list for this site (Case, 1915, listed in his table 1 as T) is as follows:

Chondrichthyes
  Diacranodus texensis Cope
Amphibia
  Diplocaulus salamandroides Cope
  Eryops megacephalus Cope
  Aspidosaurus crucifer Case
  Cricotus hypantricus Cope
Reptilia
  Diadectes phaseolinus Cope
  Dimetrodon incisivus Cope
  Edaphosaurus claviger Cope

Wegemann (1915) listed in addition only *Platysomus*, based upon scales. Emendation of Case's list to bring it into correspondence with present-day usage, taking into account modifications of names and synonymies, yields the following:

Chondrichthyes
  Xenacanthus texensis (Cope)
Amphibia
  Diplocaulus cf. *D. magnicornis* Cope
  Eryops megacephalus Cope
  Aspidosaurus crucifer Case
  Archeria sp.
  Diadectes sideropelicus Cope
Reptilia
  Dimetrodon limbatus (Cope)
  Edaphosaurus cf. *E. cruciger* (Cope)

Additional collecting and study have resulted in a list that represents our present knowledge of the faunal assemblage of this site. Some expansion and some better definition of species probably will be possible when more collecting has been carried out. The up-to-date list is as follows:

Chondrichthyes
  Xenacanthus sp.

Osteichthyes
  Ganoid scales
  Paleoniscoids
Amphibia
  Archeria sp.
  Trimerorhachis cf. *T. insignis* Cope
  Eryops cf. *E. megacephalus* Cope
  Diplocaulus cf. *D. magnicornis* Cope
  Diadectes sp.
Reptilia
  Ophiacodon retroversus (Cope)
  Dimetrodon limbatus (Cope)
  Edaphosaurus boanerges Romer and Price

Some comment upon the changes from list to list will help to clarify the usages and will also serve for clarification of other faunal lists. It is important to recognize that most of the early students of Permian vertebrates were much more prone to make specific assignments upon the basis of fragments than have been later students. Thus, as a rule, generic names are followed by a specific name. The consequence of the philosophy that species could be determined from the rather poor materials normally available was that a rather large number of species was named. It has become apparent, as better collections have been made and the concept of variation has become more adequate, that many assignments were made without adequate basis and that many of the described species were either synonyms of ones named earlier or indeterminate from the type of materials. Thus newer lists are more conservative in assignment of specimens to species and the number of specific names in individual lists and in lists taken together is smaller.

A second item of importance is the wide variation in the more or less generally accepted concepts of species assignment among different genera. This is something that has historical origin, depending, for example, upon the amount of detailed work on a group and upon who did the work. Species such as *Eryops megacephalus* are broadly conceived, with acceptance of a wide range of morphological variation. Thus, almost all materials of *Eryops* can be assigned to this species, or at least compared to it, for it is in effect a "form species." The species of *Diadectes*, of which two are now generally recognized from the Wichita-Clear Fork sequences of Texas and Oklahoma, are nearly or completely indistinguishable morphologically. For better or worse, the two species are distinguished primarily upon their stratigraphic position, whether they are Wichita or Clear Fork. This genus shows immense variation, and no real sense has ever been made of its systematics.

Some species are treated as if they were long-lived. They are based on animals that have lasted over long periods of time without evident change in morphology, as far as preserved parts are concerned. *Diadectes* could be one of these, but it has not been treated this way. In this category are such species as *Lysorophus tricarinatus* Cope and *Trimerorhachis insignis* Cope. The former was named from Pennsylvanian beds in Vermillion County, Illinois, and ranges all the way into the middle Choza. The type of *L. tricarinatus* was based on vertebrae, and during this long period of time the vertebrae did not develop distinguishing features. *T. insignis* spans much of the Wichita and Clear Fork and, even though excellent skulls are known, morphological differences have not been detected.

Xenacanthus is a good example of a form genus. Teeth and cartilage of the chondrocranium, jaws, and visceral arches of the xenacanth shark occur from the Devonian well into the Permian. In addition, there are various associated spines. If only teeth and fragments of cartilage are available, all that can be ascertained is that the shark is a xenacanth, which is then called *Xenacanthus*. Excellent chondrocrania undoubtedly form a good basis for both generic and specific differentiation, but at present this has not been worked out to a usable stage.

Finally there are genera, like those of the pelycosaurs studied in detail by Romer and Price (1940), for which the species have been reasonably worked out and drawn at practical operational levels. *Dimetrodon* is a good example of this kind of genus. Assignment is in many instances not possible from scrappy material, but reliable criteria are available for assignment of reasonably good specimens.

All of the faunal lists must be viewed in the light of the above considerations. The differences among the foregoing lists are intelligible in those terms. *Diacranodus texensis*, a xenacanth, has been referred to *Xenacanthus* sp. *Diplocaulus salamandroides* is a species based on material from the Pennsylvanian of Illinois. This Illinois site was considered to be Permian for some time after its discovery (Cope, 1878; Case, 1900), and many Texas and Oklahoma genera were considered to include species from that fauna. The tendency was to put all small specimens of *Diplocaulus* into *D. salamandroides*, but it has been shown (Olson, 1951) that at least most of the small specimens are the young of *D. magnicornis*. As Romer has shown (Romer, 1957), the Wichita embolomerous amphibian is

Archeria Case, not *Cricotus* Cope, which was also named from Vermillion County, Illinois. The specific name, carried over, clearly is not applicable on morphological grounds.

The material of *Eryops* from Waurika, even with the breadth of *E. megacephalus*, is inadequate for specific assignment. Romer (1964) suggested that the genus *Diadectes* should be placed with the amphibians, and this change has been made. Species assignment for *Diadectes*, being stratigraphic, poses an impossible problem, for, as of now, correlation must be made by means of the faunas. Hence it is not assigned. *Ophiacodon retroversus* (Cope), in our list, is a genus and species not reported by Case or Wegemann. *Edaphosaurus boanerges* has been given this name on the basis of better materials, replacing the name used by Case.

The faunal assemblage at this site is quite clearly aquatic and semiaquatic and probably was deposited in a shallow lake or pond, a conclusion supported by the sedimentation. The pelycosaurian species, for which specific assignments have been possible, indicate an age range that places these beds as equivalent to those of either the Admiral or Belle Plains Formations of the Texas section. From what is now known, more precise determination is not possible.

WAURIKA SITE 2

Waurika site 2, previously undescribed, is in NW¼ NW¼ sec. 26, T. 4 S., R. 9 W., about 1.5 miles northwest of Waurika site 1. It was found by A. Allen Graffham of Ardmore, Oklahoma. He obtained an excellent specimen of *Diadectes* from it. Various other scraps have been found, but nothing else is identifiable.

WAURIKA SITE 3

Waurika site 3 is one discovered and described by Wegemann (1915). It is in SW¼ SW¼ sec. 34, T. 4 S., R. 9 W., Jefferson County. Fragments of *Dimetrodon* sp. came from the surface of a red shale, but the source of the bones is uncertain. Nearby were deposits of sandstone and conglomerate.

EAST TAYLOR SITE

East of Taylor and just east of the west boundary of Jefferson County, along the bluffs of the Red River, is an area of breaks in NW¼ NW¼ sec. 3, T. 5 S., R. 9 W. Good exposures of sandstones and shales are found here. Bone occurs about 20 feet below the capping sandstone, which is possibly the Ryan-Asphaltum, and appears to be coming from either sandstone lenses or from the shale.

Eryops sp., *Dimetrodon* sp., and *Edaphosaurus* sp. have been identified.

SOUTHWEST TAYLOR SITE

More or less continuous with the exposures of the East Taylor site, but farther west, are extensive exposures in Cotton County that lie south and southwest of Taylor. Wegemann (1915) listed some fragmentary specimens from this site. The best exposures are in secs. 3, 4, T. 5 S., R. 11 W. Notes in the Stovall Museum indicate that some of the Cotton County specimens came from this site. Considerable collecting may have been done, but it is not possible to make accurate identifications of the materials and sites at which collections were made.

The section along the north bluffs of the Red River include shales and sandstones, both bedded and lenticular. They range from gray to maroon and are disposed irregularly through a section of about 75 feet.

DEEP RED RUN SITES

Deep Red Run, or Deep Red Creek, which cuts Permian beds for a major part of its course across Cotton and Tillman Counties, has excellent exposures at many places. Undoubtedly careful hunting would produce good assemblages of vertebrates. Cummins, Williston, Case, and Stovall all made collections from this area. During 1965 we also obtained small amounts of material from several places. By far the best collections to date are those of Cummins, from his Indian Territory site, which are now at the American Museum of Natural History.

Cummins' Deep Red Run Site

This site is in Cotton County near where the old road from Ft. Sill to Ft. Auger (north of the Red River opposite Electra, Texas) crossed Deep Red Run. The site is several miles northwest of Randlett, but we were not able to locate it more precisely. Case noted these materials in his studies (1915) and the most recent mention is by Romer and Price (1940). Present, according to these students, are the following:

Amphibia
Cricotus sp. (= *Archeria* sp.)
Reptilia
Ophiacodon major Romer and Price
Dimetrodon dollovianus (Cope)
Dimetrodon grandis (Case)
Dimetrodon macrospondylus (Cope)

Romer and Price (1940) suggested the age to be that of the Clyde, based in large part upon the presence of *Ophiacodon major*, known only from the Clyde in the Texas section. *Dimetrodon grandis* is known only from the Arroyo, but this assignment is only problematical in the Deep Red Run materials. *D. macrospondylus* is a Belle Plains and Clyde species. The presence of *Archeria* does not preclude Clyde equivalence, for the genus does occur this high in the Texas section. The range of this genus in Oklahoma is uncertain, for it may occur in higher beds, as indicated in the discussion of the Pond Creek locality.

Secs. 16, 21, T. 4 S., R. 12 W.

Exposures to the west of U. S. Highway 277-281 on the south side of Deep Red Run in Cotton County have yielded a considerable amount of scrap and a partial skull of *Eryops*. These were taken from sandstones and shales that make up a section of about 30 feet of gray and yellow beds. From the SW¼ sec. 21, T. 4 S., R. 12 W., the following have been identified:

Amphibia
Eryops sp.
Trimerorhachis sp.
Diplocaulus sp.
Dimetrodon sp.

From NE¼ NW¼ sec. 16, T. 4 S., R. 12 W., has come a partial skull of *Eryops megacephalus* Cope.

Sec. 13, T. 4 S., R. 12 W.

Wegemann (1915) described this site, in N½ NE¼ sec. 13, T. 4 S., R. 12 W., Cotton County. From it came two skeletons of *Diadectes* deeply encased in a calcareous coating. The details of the skeletons are concealed by this material, but they are excellent specimens. The two were found weathered out of their shale matrix, resting upon sandstone.

Other Sites

Case (1915) reported *Eryops* and *Dimetrodon* from beds near Randlett and *Edaphosaurus* from near Emerson (an old townsite approximately 6 miles west of Walters). He also noted that Williston had found scraps of vertebrates, *Diplocaulus* and others, farther to the south. Also, Wegemann (1915) noted scraps of *Dimetrodon* in NE¼ NW¼ sec. 8, T. 4 S., R. 9 W., Cotton County, about 5 miles southeast of Temple.

WEST GRANDFIELD SITE

Fragments of vertebrates have been found in two places in the area of the West Grandfield site, SE¼ sec. 4, T. 4 S., R. 15 W., and SE¼ sec. 32, T. 3 S., R. 15 W., Tillman County. These localities are just to the west of the zone of moderately rapid change from the gray, maroon, and yellow beds that make up the eastern part of this region to the bright reds that are found in the western part. This change appears to coincide with the transition from the Wichita to the Clear Fork deposits. The redbeds have been called Hennessey in Oklahoma, although they are apparently equivalent to the Arroyo beds of Texas and thus older than the Hennessey proper that occurs farther north in Oklahoma.

The vertebrates identified from these deposits, based on fragmentary specimens, are:

Chondrichthyes
  Xenacanthus sp.
Amphibia
  Diplocaulus magnicornis Cope
  Trimerorhachis? sp.
  Dimetrodon cf. *D. giganhomogenes* Case

The known genera and species are not clearly diagnostic of Clear Fork. The presence of *Dimetrodon*, which, from the scrap at hand, appears to be *D. giganhomogenes*, is suggestive of the Clear Fork.

EAST MANITOU SITE

The East Manitou site is 4.5 miles east of U. S. Highway 183, on a secondary road that passes through the center of Manitou, Tillman County. It is a road cut with exposures that contain a considerable amount of bone scrap and trunks of large trees. A small collection was made in SW¼ sec. 32, T. 1 N., R. 16 W., but there are similar deposits with some scraps across the road.

The section consists of a basal red shale, overlain by yellow to black shale, which includes thick lenses of heavy, coarse sandstone and conglomerate. This mottled coarse rock, which is as much as 6 feet thick in places, carries a variety of bone scraps, most of which are too badly damaged for identification. Elements suggestive of *Eryops*, *Dimetrodon*, and *Trimerorhachis* are present. Of particular

interest is the presence of *Orodus*-type shark teeth. These suggest a marine origin.

About 0.5 mile east of this site are outcrops of dark-gray shales with three, or possibly more, thin beds of dolomite. About 1.2 miles to the west are exposures of rubbly red shale and gray shales that contain dolomite nodules. Near Manitou the beds are predominantly red shales, typical of the terrestrial Clear Fork.

This sequence suggests nearshore marine deposition for the beds at the bone site and to the east and west of it. Current action must have been strong, sweeping in not only the conglomerates that form the lenses, but the large logs, up to 1 foot in diameter, and the bone fragments that were buried in the gravels. This sequence, including the overlying red shales at Manitou, suggests the general Lueders-Arroyo sequence as it occurs in the vicinity of Lake Kemp, Baylor County, Texas.

NORTH MANITOU SITE

One and one-half miles northwest of Manitou, in SW¼ SW¼ sec. 28, T. 1 N., R. 17 W., Tillman County, are open exposures of redbeds. Scraps of bone, teeth of *Xenacanthus*, and coprolites have been found in this site.

SOUTH SNYDER SITE

Mehl (1926) described a partial skull of *Trematops* from red shale about 10 miles south and a little east of Snyder. This site, which has not been precisely located, appears to be a little to the east of the East Manitou site. The specimen was the basis of a new species of *Trematops*, *T. thompsoni* Mehl, but in 1941 it was considered to be synonymous with *T. milleri* Williston (Olson, 1941). The specimen is now in the collections of the Stovall Museum (OUSM 2-1-S36). The character that Mehl used for specific differentiation from *T. milleri* was the apparent absence of an internarial fenestra. As pointed out in 1941 (Olson, 1941), this region is somewhat damaged by separation of the premaxillae. It does, however, appear that any internarial fenestra that may have been present must have been small. This feature is quite variable in known specimens of *T. milleri* and, although the Oklahoma specimen exceeds the known variation to a minor degree, it still seems best to consider it as *T. milleri* rather than as a distinct species as suggested by Mehl.

Mehl, following Gould (personal communication) called the beds Clear Fork. He was unable to find the exact bed from which the specimen came because of slumping, and some doubt remains as to the exact site. The beds are clean red shales and are lithologically similar to those in which *T. milleri* occurs in the Texas section. This occurrence seems to be a good basis for assigning the beds in this general area to the Arroyo.

OTHER REDBEDS

Reconnaissance studies of exposures between Davidson and Frederick and northwest of Frederick did not reveal any fossiliferous beds, although there have been some informal reports of finds in the Davidson area. The beds appear to have some potential for vertebrate fossils and additional searches might be fruitful.

In the vicinity of Hess, Jackson County, to the north and east of the village, are good exposures of red shale capped by thick sandstones and conglomerates. In the green and red capping conglomerates fragments of bone have been found, but no identifiable specimens have been obtained. Northward, toward Altus along U. S. Highway 283, additional exposures of red shales occur. Small breaks are present north of Altus as well. These have potentialities for production of vertebrates but as yet none has been found.

SUMMARY

A good section of part of the Wichita and the lower part of the Clear Fork is exposed from a few miles west of Waurika and westward to the longitude of Altus. Exposures also are present east of Waurika for several miles, but these have not been searched for vertebrates. The stratigraphy is in need of careful and detailed study, for work to date has been general and uncoordinated. The currently known distribution of vertebrates is that shown in figure 3.

The stratigraphic range, in terms of the Texas section, appears to be from the Admiral Formation, through the Belle Plains and Clyde, and into the Arroyo. The westernmost beds are possibly post-Arroyo. Carried eastward from the Waurika sites the section probably would include beds older than Admiral, but as yet no studies have been made to confirm or deny this possibility on the basis of vertebrate content.

The westernmost beds are generally called Hennessey, but this practice leads to confusion because they are not equivalent in age to the Hennessey beds to the north. Lithologically the deposits resemble some parts of the Fairmont Member of the Hennessey, but the Fairmont Member appears to be correlative with the Choza of Texas, whereas the Clear Fork of Tillman and Jackson Counties is, in large part at least, an Arroyo equivalent. It seems clear that these beds relate more closely to the Texas Arroyo deposits, exposed south of the Red River, than to the Hennessey to the north in Oklahoma.

Detailed study of the Wichita and Clear Fork beds, with definition and naming of subunits, is necessary. Once this has been done and the vertebrates and other fossil remains have been studied and described, this area should take its place along with the Texas section as an important contributor to an understanding of the life and physical conditions of this portion of the Early Permian.

South-Central Oklahoma

In McClain and Garvin Counties occur somewhat isolated exposures which display sections of heavy sandstones and gray to maroon shales. From several of these have come remains of vertebrates (figure 4), mostly fragmentary but in some instances sufficiently well preserved to provide good stratigraphic markers.

Placement of the sites in their proper stratigraphic positions is difficult and at present has not been fully accomplished. The principal reference for this purpose is the study of Garvin County by Dott (1927). He recognized a section of 1,100 feet between the Pontotoc terrane, at the base, and the Duncan Sandstone, at the top. He subdivided this into eight units, largely on the basis of persistent and partially mappable sandstone beds. The lower two units were placed in the Stillwater formation (an abandoned name), the third, fourth, and fifth in the Wellington Formation, the sixth and seventh in the Garber Sandstone, and the eighth in the Hennessey Shale, with reference to the Hennessey as defined in north-central Oklahoma. All of this was considered as part of the Enid group, following Aurin, Officer, and Gould (1926).

Most of the exposures over these two counties, below the Hennessey, are sandstones that are consistently barren of vertebrates. In most places where shales are encountered, vertebrates have been found. The sandstones, however, dominate the topography, and shales tend to be covered with vegetation. Altogether five sites have been located and fossils have come from a sixth which was not precisely located in our studies. As far as can be determined, these sites fall in units 1, 2, and 5 of Dott. They are all in beds that now can be considered roughly as Wellington equivalents. One near Byars, McClain County, was described earlier (Olson, 1965a; Branson, 1965). The others have not been mentioned previously in the literature.

BYARS SITE

The Byars site (pl. 1A) comprises a rather large series of exposures that occur about 3 miles southwest of Byars, McClain County, in SW¼ SW¼ sec. 33, T. 5 N., R. 2 E. (figure 4, site 5). Branson (1965) determined the horizon to be unit 1 of the Enid group of Dott, lying in about the middle part of the 140-foot section, as measured close to the area of the vertebrate site. This position places the bone-bearing deposit in the lower part of the Stillwater formation, equivalent to the lower part of the Gearyan. Anderson (1927, p. 11) suggested that the lower part of unit 2 is Wellington, thus placing the site in the Stillwater, but from the map, the Wellington seems to be the proper assignment (Branson, 1965).

Branson (1965) has given the following section:

BED	DESCRIPTION	THICKNESS (FEET)
5	Pleistocene gravel	5
4	White cross-bedded sandstone	3
3	Maroon mudstone	8

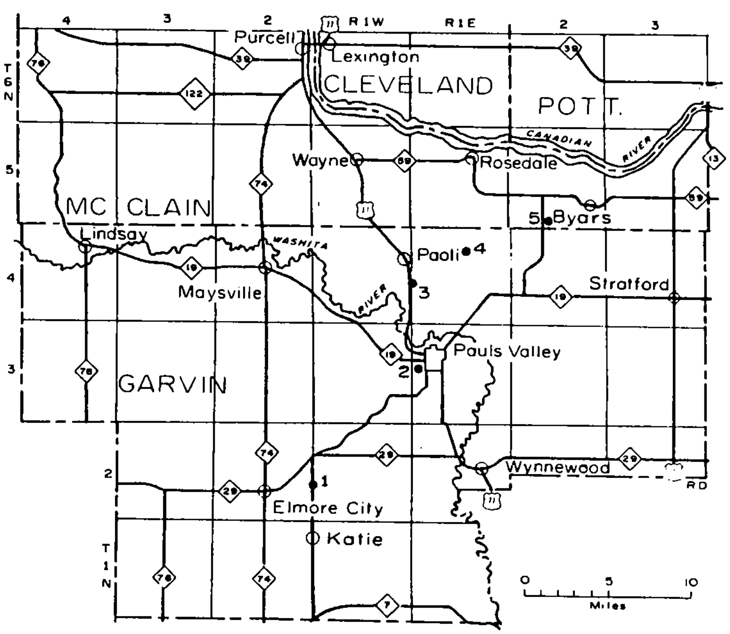


Figure 4. Map of south-central Oklahoma, showing locations of known vertebrate sites. All sites are in rocks of Wellington age.

1 North Katie site
2 South Pauls Valley site
3 Southeast Paoli site
4 South Rosedale site
5 Byars site

BED	DESCRIPTION	THICKNESS (FEET)
2	Mudstone, hematite concretions, probably source of vertebrate fossils	3
1	Mudstone, variegated	30

Bed 1 can be somewhat further subdivided, as follows:

DESCRIPTION	THICKNESS (FEET)
Red shale (mudstone) with white sandstone stringers and ironstone lenses	10
Gray shale (mudstone) with some sandstone lenses, nodular	12
Maroon to red shale (mudstone), highly nodular, ironstone nodules with plant impressions	8

The lower part, based on my measurement, employs the term shale in place of mudstone, corresponding to usage elsewhere in this paper. The plant impressions in ironstone nodules are excellent and represent a type of fossil that is found throughout this south-central part of Oklahoma.

Vertebrates have come only from bed 3. Two genera have been identified (Olson, 1965b):

Zatrachys serratus Cope
Diadectes sp.

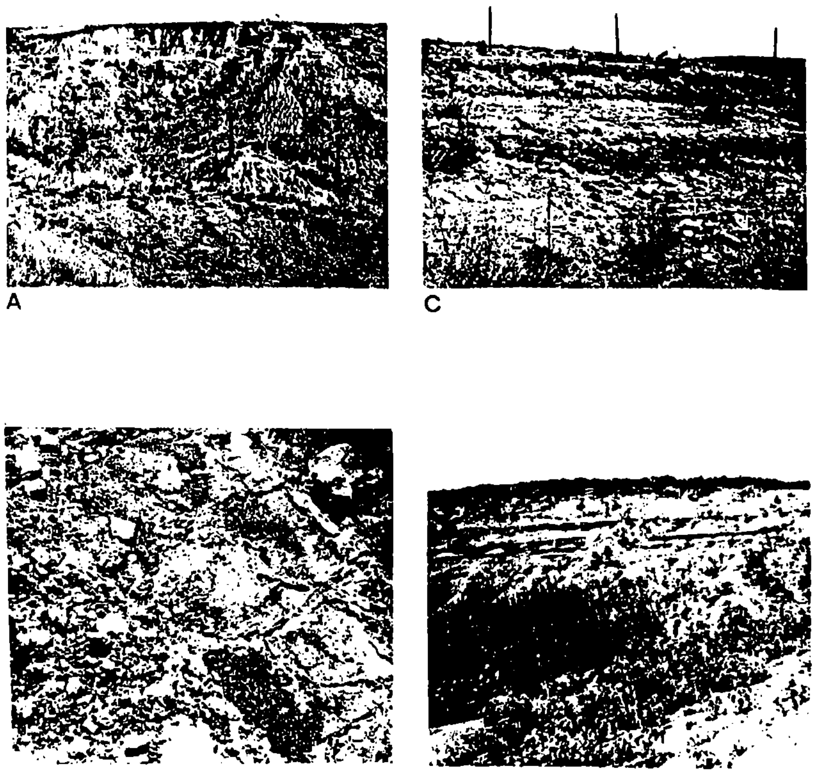
The specimens are well preserved. *Zatrachys serratus* consists of a skull and lower jaws, *Diadectes* sp. of six vertebrae. *Zatrachys serratus* is known from Texas and occurs in the Cutler Formation of New Mexico (Langston, 1953). It occurs in the lower and middle Wichita beds in the Texas section and closely related species occur in later beds. *Diadectes* sp. provides no stratigraphic data beyond the indication of an Early Permian age. From what little is at hand, it would appear that the Byars deposit is to be placed somewhere in the middle or upper part of the Wichita, perhaps at the stratigraphic level of the Admiral or Belle Plains. Its position in the stratigraphic section makes it one of the oldest known land-vertebrate-bearing Permian deposits in Oklahoma, low in the Wellington, and, in view of the thickness of overlying beds, perhaps an Admiral rather than a Belle Plains equivalent.

SOUTH ROSEDALE SITE

The South Rosedale site, in NW¼ sec. 10, T. 4 N., R. 1 E., Garvin County, includes a fairly large series of breaks, with excellent exposures. Only a few fragments of vertebrates have as yet been found. The section is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
5	Red shale, plus soil, mostly sandy	5
4	Capping sandstone in places, fine, brown to green shale	

Plate I



A. Byars site. View is toward the northeast. The light-colored beds near the top of the slope mark the approximate level at which vertebrate fossils were found.

B. Perry site 4. Dolomite with filled mud cracks.

C. Perry site 4. View is toward the northeast. Alternating layers of shale and dolomite in which the dolomite contains bone fragments. The uppermost dolomite includes some lungfish burrows.

D. Perry site 6. View is toward the east. The irregular light-colored lenses in the upper third of the section are a vertebrate- and plant-bearing sandy shale, which is overlain by the McCann Sandstone (= Fallis Sandstone) and a bone-bearing dolomite.

	and sandy shale in places. Some copper-bearing lenses, some conglomerate. Fragments of bone	15
3	Even red-brown shale. Green sandstone channels	20
2	Red to orange-yellow shale. Lenses of sandstone in places, to 5 feet. Weathers to form iron oxide nodules, with plant impressions. Barite crystals	15
1	Gray shale, weathers to form red nodules	6

This sequence appears to fall into unit 2 of Dott. It is in a shaly phase and appears to occupy about the upper 60 feet of Dott's section, which totals 145 feet. His section was measured just south and a little east of the site where vertebrates have been found and was in a zone of somewhat higher sandstone content.

The only identifiable vertebrates from this site are fragments of *Dimetrodon* sp. and a partial jaw of *Eryops* cf. *E. megacephalus*. They came from the shale near the base of the section. Plant impressions are found in ironstone nodules at the base of the section and some impressions along with bone fragments occur in bed 4. Nothing in the fauna provides a good basis for age determination.

SOUTHEAST PAOLI SITE

The Southeast Paoli site comprises extensive exposures in NW¼ sec. 19, T. 4 N., R. 1 E. The section is similar to that of the South Rosedale site and the stratigraphic level appears to be the same (i.e.,

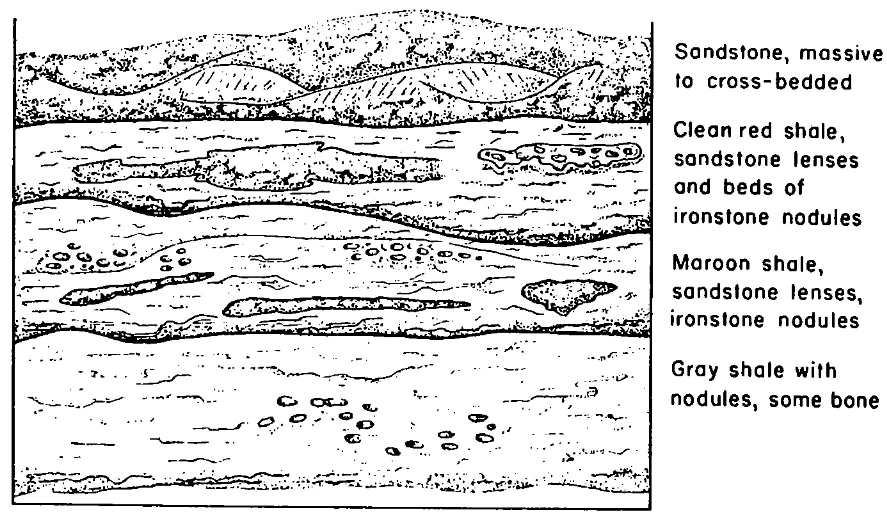


Figure 5. Generalized section showing the nature of the Wellington beds at the Southeast Paoli site. The section is approximately 45 feet thick. Irregularity of bedding, lateral variation, and the presence of nodules in the shales are characteristic of the Wellington rocks in the south-central region.

Dott's unit 2). Fragments of bone have come from the basal gray shale. Of these, one is a fragment of *Edaphosaurus* (probably *E. boanerges*, on the basis of its size), suggesting possible equivalency to the Admiral Formation of Texas.

Figure 5 diagrammatically shows the nature of the deposits. They appear to be entirely nonmarine and to have been formed in relationship to a river and flood-plain regimen that altered considerably from time to time, but persisted through the general area over the full time of deposition.

South of this site, about 2 miles south of Paoli, a railroad cut provides a section about 30 feet thick. Fern-bearing nodules occur, but no bones were found.

SOUTH PAULS VALLEY SITE

On a diagonal road south of Pauls Valley, SW¼ sec. 19, T. 3 N., R. 1 E., Garvin County, occur excellent exposures. The section is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
5	Tertiary or Quaternary beds cutting into bed 4. Thick, yellow clay, with cross-bedded sandstone in places	15
4	Maroon shale, some light-colored bands	15
3	Yellow, brown, reddish shale, some sandstone lenses, thin lateral sandstone stringers	5
2	Gray shale, some nodules, bones	6
1	Maroon shale to base	4

The South Pauls Valley site contains scraps of bones in bed 2 and an abundance of fern impressions in ironstone nodules. The bone fragments appear to be *Eryops* and are not stratigraphically definitive. The outcrops appear to fall into unit 2 of Dott and to be at about the same level as the exposures around Paoli.

NORTH KATIE SITE

About 3.5 miles north of Katie, Garvin County, to either side of the north-south road are fair exposures of sandstones and shales. On the west side of the road, 0.5 mile north of SE cor. sec. 24, T. 2 N., R. 2 W., some fragments of bones have been found. Figure 6 is a diagrammatic sketch of the outcrop. These bones pertain to *Dimetrodon* but are insufficient for species identification. This section is considerably higher in the section than the ones noted above in south-central Oklahoma, being assignable to unit 5 of Dott, and lying near the upper part of the 90-foot section of this unit.

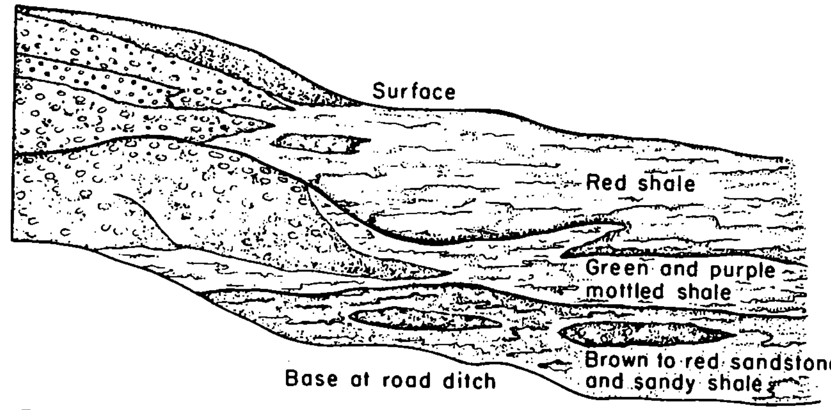


Figure 6. Diagram of the exposures at the North Katie site. The section is about 10 feet thick. Rapid lateral variation, irregular bedding, and interfingering of lenses of different composition and texture are characteristic. Bones were present in the conglomerates shown at the upper left-hand corner of the diagram.

SUMMARY

Vertebrate remains occur in the shales, mudstones, and fine conglomerates which underlie the Hennessey Formation in McClain and Garvin Counties. They occur in units 1, 2, and 5 of Dott (1927), and appear to be in beds equivalent to the Wellington Formation. No remains have been found in units 6 and 7, which are Garber equivalents under Dott's scheme.

The vertebrates give only uncertain evidence on the stratigraphic position of the beds in which they occur, other than that they are somewhere in the middle or upper part of the Wichita Group. Specimens from sites in units 1 and 2 show some indications of being Admiral equivalents. Presumably the materials from unit 5 are considerably more recent, but the scrappy remains neither confirm nor negate this age assignment.

Prospects for additional materials from this area, while not good, are not totally bad. Scrappy material collected by William Villines, now of Davis, Oklahoma, including *Eryops* and *Dimetrodon*, is present in the Stovall Museum. It came from a site south of Rosedale that we were unable to locate in the time available. Undoubtedly such sites will in time add to the vertebrates now known and may possibly lead the way to concentrations of fossils that will give a more adequate understanding of the vertebrates. From what is now known, it appears that the beds of this region and those of the southwest have closer affinities to the sections to the south, that is, in Texas, than to those lying to the north in Logan, Noble, and Kay Counties.

Fissure Sites

In the folded Arbuckle limestone of the Wichita Mountains occur fissures which were produced by solution along joint planes and filled with clays and conglomerates. In two localities, one in Comanche County and one in Caddo County, Permian vertebrates have been found in these fissures. One of these sites is well known, the Richards Spur, or Ft. Sill, locality in Comanche County; the other, south of Carnegie in Caddo County, has not been previously reported. It has yielded much less material.

RICHARDS SPUR (FT. SILL) SITE

The Dolese Brothers limestone quarry, at Richards Spur, SW¼ sec. 31, T. 4 N., R. 11 W., Comanche County (fig. 3), has been the source of by far the greatest number of specimens of Permian vertebrate fossils known from Oklahoma. Quarrying and collecting have depleted the site, but new fissures are still uncovered by quarrying operations from time to time.

Specimens occur in fissure fillings in the Arbuckle limestone. The fillings are composed of soft clays and coarser sediments, including coarse conglomerates. In various places where collections have been made, the fissure deposits were literally packed with bones, whereas elsewhere the clays carried little or nothing. Much of the material was disarticulated but partial skeletons and complete skulls and jaws occasionally have been encountered.

Many collections were made from the fissures, and the materials are widely scattered. There are large collections at the Field Museum, Yale University, the University of California at Berkeley, and the University of Kansas, and many smaller ones at other places. A rather large number of limited studies of the materials has been made, dealing with one or another genus and species. Specimens from this site have played important parts in more extensive studies as well. Among the more important are those of Price (1935), Gregory, Peabody, and Price (1956), Vaughn (1958a), Peabody (1961), Fox (1962), and Fox and Bowman (1966). Olson and Miller (1951) made use of these materials in a biometric analysis of captorhinomorph species.

Despite extensive collecting and research on this excellent assemblage, no systematic study has as yet been made. One is badly needed, but it is an undertaking of considerable magnitude both because of the quantity and diversity of specimens and because of the wide scattering of collections. A number of undescribed genera are known to be in the materials and probably there are others not

recognized. Some of the named genera and species also appear to pose taxonomic problems. A full study is far beyond the scope of the present summary. At present the following list of genera and species can be compiled:

Chondrichthyes
- *Xenacanthus* sp.

Amphibia
- *Euryodus* cf. *E. primus* Olson
- *Cardiocephalus* cf. *C. sternbergi* Broili

Reptilia
- *Captorhinus aguti* Cope
- *Labidosaurus* cf. *L. hamatus* Cope
- *Colobomycter pholeter* Vaughn
- *Delorhynchus priscus* Fox
- *Thrausmosaurus serratidens* Fox

This fauna has many peculiar features. It is composed entirely of small animals and the great majority appear to be primarily terrestrial. *Xenacanthus* seems out of place and is, as far as I know, represented only by a tooth. In addition to the named amphibians, there is an aistopod (Gregory, Peabody, and Price, 1956), a possible embolomere, and one or more small labyrinthodonts. Some extremely small jaws appear to represent an amphibian of undetermined relationships. Among the reptiles is a carnivorous captorhinomorph and at least one moderately large undetermined pelycosaur. By far the most abundant are the remains of *Captorhinus*, and these have been well studied (Price, 1935; Fox and Bowman, 1966). The small pelycosaurs need considerable work. They appear to be ophiacodonts of the general eothyridid type. The named genera have been based on partial skull materials, but there are jaws and postcranial elements that may pertain to one or the other.

It has been suggested by various persons, for example by Fox and Bowman (1966), that the age of the deposits in the fissures is Arroyo. The occurrences of *Captorhinus aguti*, *Labidosaurus* cf. *L. hamatus*, *Euryodus* cf. *E. primus*, and *Cardiocephalus* cf. *C. sternbergi* all suggest this to be the case. The pelycosaurs are not definitive, for they are unknown elsewhere.

Colobomycter and *Delorhynchus* seem to be nitosaurids, or at the general eothyridid level, and thus primitive. *Thrausmosaurus* is considered a sphenacodontid by Fox. Remnants of primitive pelycosaurs do occur in the Arroyo, *Bayloria* being an example, but they are not characteristic of it. Presumably the predominance of the small, rather primitive pelycosaurs is a feature peculiar to this assemblage, resulting in part from the nature of deposition and in part from the nature of the interspecies population from which the assemblage was drawn.

SOUTH CARNEGIE SITE

In an abandoned quarry of the Roosevelt Materials Company Carnegie plant, 11.2 miles south of the center of Carnegie, Caddo County, occur a few fissure fills similar to those at the Richards Spur site. These have not been previously reported in the literature. They were called to my attention by David B. Kitts, with whom I visited the site. The deposits are in NE¼ sec. 6, T. 5 N., R. 13 W. Bones occur in clay and conglomerates, much as at Richards Spur. Preservation, however, is poor and only rather badly broken specimens have been found. Production has come only from two fissures in the Arbuckle limestone and the prospects for finding significant amounts are poor.

Captorhinus is abundant and a few jaws of the small, undetermined amphibian, also known from the Richards Spur site, have been found. As far as can be determined, the deposits were formed in the same way and at the same time as were those at Richards Spur. Keith J. Carlson prepared and studied the materials and made them available for this report

CENTRAL, NORTH-CENTRAL, AND NORTHERN OKLAHOMA

The Early Permian vertebrate sites in this region occur in a band that passes northward from the latitude of Norman, Oklahoma, averaging about 50 miles wide but broadening to about 100 miles in its more northern parts. At the southern end the highest formation, the Hennessey, extends considerably farther westward than do the other beds. Except for fossil-bearing sites in the vicinity of Norman, few are known south of the Cimarron River. North of the river they are numerous in the vicinity of Perry in Noble County, but are relatively few and scattered farther north.

WELLINGTON SITES

The richest known Permian sites in Oklahoma, except for those at Richards Spur, occur in the Wellington Formation of Logan, Noble, and Kay Counties (figure 7). In the northern part of this area, the beds are predominantly gray shales, with interbedded thin dolomites and local thin, red to gray sandstones. Along an arcuate zone that is convex to the east, these predominantly gray beds grade southward into redbeds (Aurin, Officer, and Gould, 1926; Anderson, 1941). Southwest of this line, in the vicinity of Perry the beds become increasingly red, but retain the shale-dolomite lithology. Southward to central Logan County the amounts of sandstone increase, with reduction of dolomites and shale. From the Cimarron River southward, sandstone and red shale predominate, with the latter prominent in outcrops.

Raasch, in an unpublished thesis (1946a, 1946b) gave a thickness of 820 feet for the Wellington Formation in Noble County. This is from the base marked by the Herington Limestone to the top marked by the Garber Sandstone. To the east of the area treated by Raasch, from about the latitude of the Canadian River in Pottawatomie County and northward through Lincoln and Noble Counties to southern Kay County, occurs the Fallis Sandstone, named by Patterson (1933). This is a complex clastic unit that contains a total of seven sandstones (Billings, 1956), some of which extend westward as thin wedges into the predominantly shale and dolomite beds of the Wellington. The thickness is 310 feet in Noble County (Billings, 1956). There and to the east it forms eastward-facing scarps, each sandstone characteristically having a dolomite at its base.

In the outcrop areas of the Fallis Sandstone, the sandstones rather than the interbedded shales tend to be the more prominent. Little evidence of vertebrates is found in the thick, massive sandstones and no traces have been encountered in the few red shales that can be seen in the outcrops. In the thin sandstone wedges, however, a few excellent vertebrate remains have been found. Gould's (1900) McCann Sandstone, at the McCann site in Kay County, appears to be the seventh (uppermost) Fallis sandstone. Below this occur the "insect beds" (Carpenter, 1947). Billings (1956) placed the insect beds just below the seventh sandstone of the Fallis whereas Tanner, in an unpublished comment upon this section, placed them below the sixth. This is a matter of detailed interpretation, and the general position of the vertebrate-bearing sandstones in Raasch's section is clear, lying about 240 feet below the Wellington-Garber contact.

PERRY SITES

Perry, in south-central Noble County, is more or less in the middle of an area of richly fossiliferous Wellington beds. To date a number of collections have been made from these beds and studies of the materials are in progress. Much remains to be done both in collecting and in analyzing the assemblages. Detailed stratigraphy

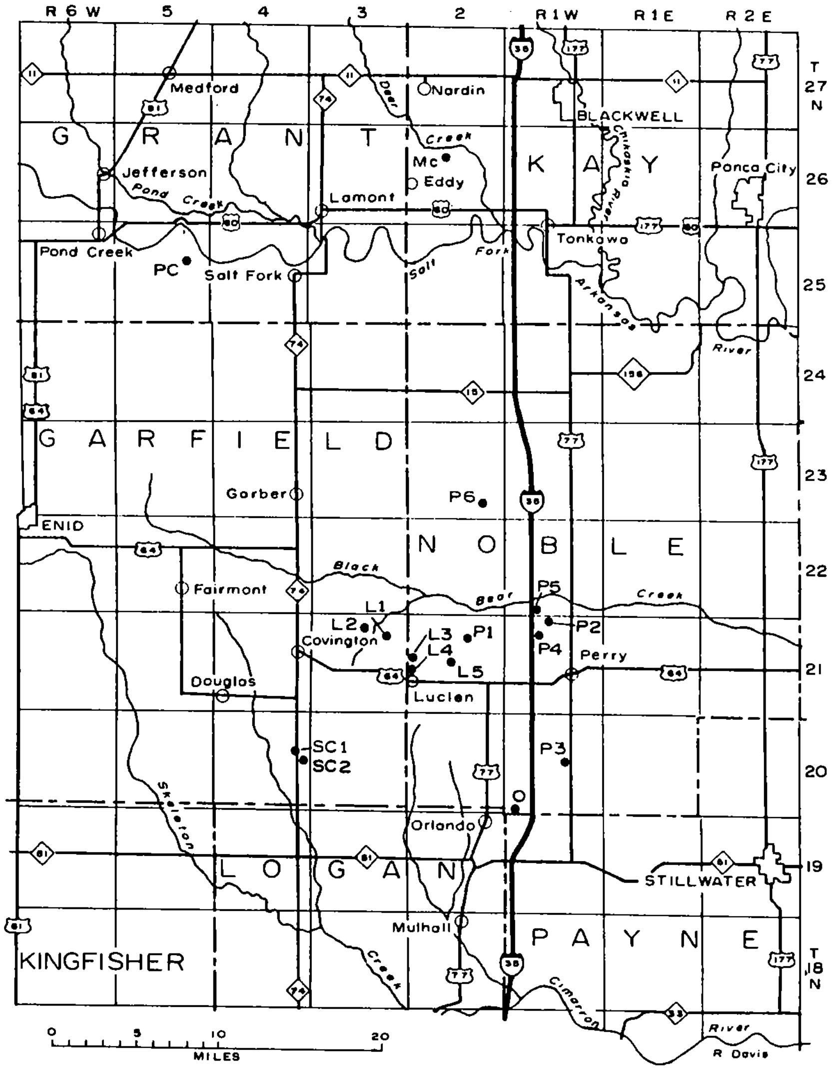


Figure 7. Map of central and north-central Oklahoma, showing locations of vertebrate sites.

L1-L5	Lucien sites; all in Lucien Member of Garber Formation	P1-P6	Perry sites; all in Wellington Formation
Mc	McCann Quarry site (Eddy or Nardin of others); McCann Sandstone of Wellington Formation	PC	Pond Creek site; Garber Formation
O	Orlando site; Wellington Formation	SC1, 2	South Covington site; 1, Hennessey-Garber transition beds; 2, Hayward Member of Garber Formation

also must be worked out. Most of the vertebrate remains have come from interbedded shales and dolomites, with some from thin sandstones. The Raasch section is generally applicable, but, in this area, gray beds occur to the north and east and redbeds to the south and west. In addition to the usual shales, lenses of coarse conglomerate occur in some of the exposures.

The ecological situation appears to be that of a shoreline environment, with the shoreline fluctuating rather markedly over short intervals. Raasch (1946a) interpreted part of the series as cyclothemic with the ideal cycle as follows:

5. Dark, lumpy clay shale, channels or lenses and redbeds
4. Dark, fissile, laminated shales
3. Argillaceous dolomitic limestone
2. Dark, fissile, laminated shale
1. Conglomerate and mudstone grit.

Fossil vertebrates occur in all units of this series. Terrestrial animals are encountered in particular in units 1 and 5, and fish are not uncommon in 2, 3, and 4. Lung fish are abundant in the dolomites, in part at least in burrows. The "insect beds" have an excellent representation of well-preserved insect remains (Carpenter, 1947) and in various beds conchostracans are abundant (Raymond, 1946). Small pelecypods occur throughout the section, but are rarely abundant. Few other invertebrates are encountered. Plant remains in the shales, sandy shales, mudstone grits, and conglomerates include, for the most part, tree trunks and fragments of branches, and poor impressions of fronds. In a few places, as at Red Rock and Perry site 6, excellently preserved remains of a wide variety of plants, including leaves, fronds, and seeds, are present.

Perry Site 1

Perry site 1 is on a tributary of Black Bear Creek northwest of Perry in SW¼ NE¼ sec. 10, T. 21 N., R. 2 W., Noble County. It was discovered during a search for insect localities by a group from Oklahoma State University at Stillwater and was brought to the attention of David B. Kitts. He made extensive excavations and studies of the locality, taking ten large fossil-packed blocks of shale and dolomite from the site. These contained a large series of skulls and considerable postcranial material of the amphibian *Trimerorhachis*. Later he asked me to visit the site with him and to aid in the study of some of its aspects.

This is one of the richest Permian vertebrate sites in the United States and a full study will take many years. Literally thousands of skulls of *Trimerorhachis* are present along with innumerable lung-fish burrows, many of which contain remains of *Gnathorhiza*. At present Keith J. Carlson, of Gustavus Adolphus College, is making a study of *Gnathorhiza* from this and nearby sites, with special attention to the stratigraphy and to the conditions of deposition. To date about 30 skulls of *Trimerorhachis* have been prepared and these will form the core for a study of various aspects of this amphibian.

Only preliminary remarks can be included in this report. The rock sequence is made up of redbeds, primarily red shale and red to gray dolomite. Exposures extend for several hundred yards. The base of the principal dolomite is marked by a fringe of tightly packed lung-fish burrows that penetrate into an underlying calcareous, and in places sandy, red to green shale. The burrows are from about 2 to 6 inches in diameter and some are as much as 11 inches long. *Gnathorhiza* is abundant in the burrows, for the most part represented by fragmentary remains. In the shale penetrated by the burrows, skulls and partial skeletons of *Trimerorhachis* are common. The dolomite is overlain by a dolomitic red shale. This bed carries the extremely high concentration of remains of *Trimerorhachis*.

This section is approximately at the level of the "insect beds," but the precise relationship has not as yet been established. At the base of the section and well exposed about 0.25 mile to the south of the main outcrops, is a bed of coarse sandstone and fine conglomerate. This bed carries vertebrates, largely fragmentary, and has produced a skeleton of *Labidosaurus oklahomaensis*, not known from the other parts of the section.

The current faunal list is as follows:

Fish
Gnathorhiza sp.
Amphibia
Trimerorhachis insignis Cope
Reptilia
Labidosaurus oklahomaensis Seltin
Dimetrodon sp.

Other animals are present, including a small, odd lepospondylous amphibian, but additional study is required for precise identifications.

Perry Site 2

Perry site 2 is in NE¼ sec. 4, T. 21 N., R. 1 W., Noble County. It was noted as a vertebrate site in the records of the Stovall Museum

prior to our studies. A section of about 25 feet includes a dolomite at the base, about 10 feet of red shale, and a gray shale with lenses of sandstone and conglomerate up to about 8 feet in thickness. Lung fish have come from this site, and plant and bone fragments occur in the conglomerates. The only identifiable vertebrate is *Gnathorhiza* sp., known from fragments in burrows.

Perry Site 3

Perry site 3 is south of Perry in SW¼ SE¼ sec. 15, T. 20 N., R. 1 W., Noble County. Bones occur scattered in a coarse, red-brown conglomerate-breccia that forms lenses of various thicknesses. A section taken along the road cut which forms the exposure is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
8	Conglomerate and coarse sandstone, with ironstone nodules. Bone fragments	1.6
7	Light-red, sandy shale	3.6
6	Conglomerate, brecciated in places, with fragments up to 1 inch in greatest diameter. Bone, some large pieces, many scraps, and "bone meal" in places	1.6
5	Red, sandy shale, hard near top	6.0
4	Sandy dolomite, gray; with irregular red patches	1.0
3	Red shale, somewhat sandy	2.0
2	Sandy dolomite, green to gray	2.0
1	Clean red shale	6.0 to base

This type of deposit is transitional between the typical Wellington to the north, in which shale and dolomite predominate, and the red sandstone and shale sequences to the south, as exposed along the "palisades" of the Cimarron River. Except for the Orlando site, described below, this is the southernmost vertebrate-producing site in the northern Wellington. It is in the upper part of the section, but the precise position has not been determined.

Some specimens from this site were present in the Stovall Museum when this study was undertaken, and a few were added by our party. By far the best preserved specimens are jaws of *Trimerorhachis*. Only the following determinations have been possible:

Chondrichthyes
Xenacanthus sp.
Amphibia
Trimerorhachis insignis Cope
Eryops sp.

Perry Site 4

Perry site 4 (pls. IB, IC) is a short distance northwest of Perry at a road corner in NW¼ NE¼ NW¼ sec. 9, T. 21 N., R. 1 W., Noble County. The section includes the "insect beds," being about 1 mile southeast of one of Carpenter's sites (Carpenter, 1947), and is composed of the usual gray shales and dolomites. The dolomites show strong mudcracks in a bed near the base of the section. In a layer of gray shale at the base of the section occur abundant remains of rather badly macerated paleoniscoid fish. Individuals were rather large, perhaps as much as 8 inches long. *Xenacanthus* sp. is present and there are fragments of *Gnathorhiza* in the dolomites.

One-half mile east, in SE¼ SW¼ SW¼ sec. 4, T. 21 N., R. 4 W., is a small exposure of a lenticular mass of sandstone and shale. This carries scraps of bone from which *Gnathorhiza* and *Dimetrodon* were identified.

Perry Site 5

Exposed in a road cut and quarry northwest of Perry in SE¼ NE¼ sec. 32, T. 22 N., R. 1 W., Noble County, are the gray shales and dolomites typical of the Wellington rocks in this region. Insect localities of Carpenter (1947) are present in sections 33 and 34, close to this site, here called Perry site 5. About 20 feet above the base of the section, a gray, argillaceous dolomite carries lung-fish burrows containing excellent specimens of *Gnathorhiza* sp.

This site was discovered by Keith J. Carlson, who has made extensive collections from it. Along with other sites it is providing material for a detailed study of *Gnathorhiza*. As yet no other genera have been identified from this site.

Perry Site 6

Along with Perry site 1, Perry site 6 (pl. ID) is one of the more productive and more promising yet found in this area. These two and the Orlando and McCann sites provide a major share of faunal information about the northern Wellington. Perry site 6 is located in SE¼ SE¼ sec. 26, T. 23 N., R. 2 W., Noble County. Vertebrates are abundant, and some have been identified. Preparation is difficult and time consuming and a full faunal list will not be completed in the near future. Of particular interest is an abundant, lightly structured reptile, which occurs in the sandstones and dolomites and which is so atypical of the Early Permian that neither its identity nor affinities have as yet been determined.

A section measured from the base to the top about 30 feet north of the east-west section-line road is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
21	Argillaceous, gray dolomite; bones	0.7
20	Deep-gray shale	0.2
19	Red sandstone, medium to coarse; bone, conchostracans	1.6
18	Black to maroon shale	4.0
17	Yellow shale	3.0
16	Lenticular yellow, gray to red fossiliferous shale, with sandstone lenses to 3 feet in thickness. Limonitic, with selenite crystals. Vertebrates and tree trunks, fronds, leaves, seeds	10.0
15	Blue-gray shale	1.0
14	Red sandstone	1.0
13	Gray shale	1.6
12	Gray dolomite	0.7
11	Red shale, nodular at top	2.0
10	Dolomite and shale in thin alternating layers	1.0
9	Gray shale	2.0
8	Gray dolomite	0.1
7	Gray shale	1.8
6	Red shale	1.1
5	Impure gray dolomite	0.4
4	Red nodular shale	0.6
3	Gray, dolomitic shale	0.9
2	Gray shale	5.0
1	Gray dolomite	0.9

The uppermost sandstone, bed 19, appears to be equivalent to the upper sandstone of the Fallis Sandstone, and lies a short distance above the "insect beds." This places it in Raasch's section about 240 feet below the base of the Garber. The "insect beds" appear to lie at the base of the section in the beds included between 1 and 5. More precise location has not been possible and no insect remains have been found. The upper beds 16 through 21 represent a shift in conditions of deposition from aquatic to terrestrial and back to aquatic. Bed 16 clearly was formed under swampy conditions. The shales are highly leached and vegetation is abundant. Small sandstone lenses appear to represent deposits formed in streams. The overlying shales of beds 17 and 18 mark a return to more strictly aquatic conditions, with the shales of bed 18 seemingly representing a stagnant, muddy bottom in shallow water. Bed 19 indicates the advent of new conditions, in which water currents were more active but not confined to stream channels. The sands and included bones indicate deposition along a shore margin, in zones of active currents that continuously scoured and filled, reworking the materials being deposited. Sandstone beds thicken and thin rapidly, ranging from 1 foot to more than 3 feet in thickness. The thicker portions overlie black, sandy, and pebbly shale that contains a wealth of fragmentary vertebrate remains, largely fish. Elsewhere the sandstone is underlain by even-bedded, black to maroon, unfossiliferous sandy shale.

The most diverse faunal assemblage at this site has come from bed 16. In bed 18, and passing into the base of bed 19, is a massive concentration of flattened bones. These seem in large part to pertain to fish and to the undescribed reptile noted above. Remains of this reptile also occur in bed 19, as isolated bones in the red sandstone, and in bed 21, in partially articulated but badly replaced skeletons. This was a long-limbed creature with slender teeth and vertebrae with broad, flared zygapophyses. It does not pertain to the captorhinomorphs and at present there is no basis for presuming it to be pelycosaurian. Tentatively a suggestion of relationships to the group represented by *Araeoscelis* seems the soundest, but the evidence is inadequate. Additional collecting and study of fully prepared materials should solve this interesting problem.

A faunal list from the shales of bed 16 is as follows:

Chondrichthyes
- *Xenacanthus* sp.

Amphibia
- *Trimerorhachis insignis* Cope
- *Eryops* sp.
- *Diplocaulus* cf. *D. magnicornis* Cope

Reptilia
- *Ophiacodon uniformis* (Cope)
- *Dimetrodon* cf. *D. limbatus* (Cope)

Bed 18 carries scales of paleoniscoids and a deep-bodied platysomid, represented in our collections by segments of the body. The fauna is clearly Wichita in age and presumably equivalent to either the Admiral or Belle Plains Formation of Texas. As now known, the genera and species are not sufficient for a more specific reference.

ORLANDO SITE

The Orlando site (pl. IIA) is the best known of the vertebrate-producing localities in Oklahoma, with the possible exception of Richards Spur. It is about 2 miles northeast of Orlando in Noble County in SE¼ sec. 31, T. 20 N., R. 1 W. The site was discovered by Mr. Frank Furman. Collections have been made by a number of different parties, with the result that they are widely scattered. Major collections are at The University of Oklahoma, the University of

Kansas, the Field Museum, and the University of Michigan. There are smaller collections elsewhere. E. C. Case, S. W. Williston, and Herman Douthitt were among the persons who have studied these collections. An account of the locality and its fossils was given by Smith (1927).

Specimens are fragmentary and in most cases are encased in hard nodules. After weathering and erosion, nodules are concentrated at the surface, but the concentration in the enclosing sediments is low, and recovery by quarrying operations is impractical. The collecting has been almost entirely from the surface. Much of it has been over an area about 8 by 15 feet, but actually the nodules extend along the section for 200 or 300 feet. Since the time of early collecting, road building and petroleum exploration and production in this area have altered the site considerably. A new section, taken in 1965, is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
6	Heavy massive to platy sandstone, cross-bedded in places. Brown through much of its thickness, but green at the base	15.0
5	Red shale, apparently uniform, but mostly covered	30.0
4	Yellow sandstone	0.6
3	Red shale, mostly covered	10.0
2	Gray shale, with sandstone in thin interbedded lenses. Passes into red and brown nodular shale along the exposure with recurrent gray patches. Sandstone lenses up to 8 inches thick. This is the bone-producing layer	1.6
1	Red shale, concretionary in places	5.0 to base

The bone-bearing shales at the Orlando site are in the upper part of the Wellington Formation. Raasch (1946a) placed them no more than 180 feet from the base of the Garber, and Smith (1927) also gave their position as about 180 feet from the Garber contact. Without a more definitive study than has yet been made, the precise position cannot be determined. The best estimate now available is that the beds lie about 100 feet below the Wellington-Garber contact.

The Wellington at this site is lithologically different from that around Perry and northward. Redbeds predominate and there are thick, persistent beds of gray to brown, cross-bedded sandstone. To the south the percentage of sandstone increases, and with this increase the occurrence of fossil-bearing sites decreases rapidly. Some scraps have been reported near Mulhall, about 6 miles south of Orlando. Fairly extensive studies carried out in the course of our work in 1965 failed to reveal any other sites.

Plate II

A. Orlando site. Close-up of the bone-bearing shale. Note the abundance of bone-bearing nodules concentrated at the surface by weathering.

B. McCann Quarry site. View is toward the northeast. Terrane and exposure on which the measured section (p. 53-54) was taken.

C. Lucien site 1. View is toward slightly west of south. Bone-bearing shale occurs in the vicinity shown and to the right of it. Bone is abundant but scrappy. The measured section (p. 59-60) was taken beginning at the tank in the foreground and passing through the bone bed.

D. Pond Creek site. View is toward a little west of north. The base of the lowest green conglomerate is at the head of the figure. The conglomerate is overlain by plant-bearing shale and by green conglomerate, shown by the light-colored beds under the knoll near the center of the photograph. A skeleton of *Dimetrodon grandis* came from the top of the shale shown at the extreme left of the photograph.

A large suite of vertebrates occurs at the Orlando site, including genera and species that are rare or unknown elsewhere. These have been described and figured, but little attention has actually been paid to them. The only comprehensive studies were those of Case (1902, 1915) and Smith (1927). Many mentions of the Orlando fossils have been made in the literature, but none has been more than a passing reference. Since the time that Case made his study in 1902, much new material has been collected. His 1915 listing was based mainly on the original collections. Smith's study, which was a master's thesis, was far from adequate and added little.

The fauna is badly in need of a revision and such a study is now under way. Because the matrix is difficult to remove and the specimens are fragmentary, this study will take considerable time. The most current faunal list given herein was compiled without any attempt to describe new materials or to reevaluate the taxonomy of questionable genera and species.

Case (1915) gave the following faunal list:

Sagenodus dialophus Cope
Diplocaulus salamandroides Cope
Trimerorhachis insignis Cope
Trimerorhachis leptorhynchus Case*
Crossotelos annulatus Case
Cricotus hypantricus Cope
Cricotillus brachydens Case
Seymouria baylorensis Broili
Pleuristion brachycoelus Case
Edaphosaurus claviger Cope

In his earlier description of the Orlando fauna (1902) Case also included the following in his list:

Diplocaulus magnicornis (?) Cope
Diplocaulus limbatus (?) Cope
Eryops megacephalus Cope
Embolophorus ? sp.
Pariotichus ordinatus Cope
Pariotichus sp.
Diacranodus (*Pleuracanthus*) *compressus* (?) Newberry

*Case (1915) described this species from Orlando, but in his list, clearly in error, he listed it as from Nardin (= McCann quarry). In 1911 Case dropped the species as indeterminate. If referrable at all, it appears to pertain to *Cricotillus*.

Smith (1927) added *Gnathorhiza pusilla* Cope to these lists, but did not include a number of the genera and species listed by Case.

Studies of the collections at the Stovall Museum and the Field Museum, along with new collections made in 1965, have made it possible to present a somewhat more complete and more accurate listing. The same general principles pertain to the recognition of genera and species by Case and others at Orlando as those discussed for the Taylor locality on page 19, and the revision given below is cast within the framework noted there. The fauna, as it can be presently determined, is as follows:

Chondrichthyes
- *Xenacanthus* sp.

Osteichthyes
- *Gnathorhiza* cf. *G. serrata* Cope
- *Sphaerolepis arctata* (Cope)

Amphibia
- *Archeria* sp.
- *Trimerorhachis insignis* Cope
- *Eryops megacephalus* Cope
- *Cricotillus brachydens* Case
- *Diplocaulus magnicornis* Cope
- *Crossotelos annulatus* Case
- *Lysorophus tricarinatus* Cope
- *Seymouria baylorensis*? Broili

Reptilia
- *Captorhinus* cf. *C. aguti* Cope
- *Pleuristion brachycoelus* Case
- *Dimetrodon* cf. *D. limbatus* (Cope)
- *Edaphosaurus* cf. *E. boanerges* Romer

Xenacanthus sp. is represented by teeth and fragments of chondrocrania and jaws. The remains are not abundant and not suitable for specific assignment. Case suggested the presence of *Sagenodus* in 1902 and listed this genus in 1915. Our studies have not shown the genus to be present. It may be that Case took fragments of *Gnathorhiza*, which is present, to be *Sagenodus*, the common Wichita lung fish. It is, of course, possible that *Sagenodus* was in the collections he studied, but it has not come to my attention and hence its presence is questionable at best. A number of specimens of *Gnathorhiza* are present and these compare favorably with *G. serrata* from Texas, except that they are considerably larger and the angle between the median ridge and the bowed outer blade is slightly different. The range of variation in *Gnathorhiza serrata* is not known, so the significance of these differences is not clear.

Sphaerolepis arctata is actually a form genus and species, a name used for small, tooth-studded plates. This was described from the Pennsylvanian of Vermillion County, Illinois (Cope, 1877). No differences are apparent between the Illinois specimens and those from Texas and Orlando.

Archeria sp. is Case's *Cricotus*. The latter was named from Illinois, and, as noted earlier, Romer (1957) has shown that the Permian embolomeres of this type should be referred to *Archeria*. A few central elements represent this genus in the assemblage and species reference is not possible.

Trimerorhachis insignis Cope makes up about 1 percent of the total assemblage. The materials are mostly fragmentary, but enough is present to allow reference to this broadly defined species. *Eryops megacephalus* is scarce in the Orlando deposits. As in the case of *Trimerorhachis*, species assignment is possible because of the latitude of variation generally accepted for the genus and species.

Cricotillus brachydens Case is an extremely interesting small amphibian known only from fragments. The type is part of a pair of narrow jaws, indicating a narrow, long-snouted skull. A partial skull from a smaller individual, originally designated as the holotype of *Trimerorhachis leptorhynchus* Case (KU 350) and later dropped as indeterminate (Case, 1911), probably belongs to this genus and species. This amphibian is, as far as is known, unique to the Orlando site.

About 45 percent of all remains at the Orlando site pertain to *Diplocaulus*. These are mostly fragmentary, but some skull parts are sufficiently well preserved to show the features of the orbits, nares, and "horns" that are characteristic of *D. magnicornis*. There is no evidence of the distinctive *Diplocaulus brevirostris* Olson, which is the species indicated by Case in his use of the invalid species *D. limbatus*. The small individuals referred to *D. salamandroides*, a species known from the Pennsylvanian of Illinois, quite certainly pertain to *D. magnicornis*, being young individuals (Olson, 1951). It appears that all of the specimens of this common amphibian can best be referred to the single species *D. magnicornis*.

Crossotelos annulatus Case is only slightly less abundant than *Diplocaulus magnicornis*. The two have been confused in identifications in the collections, although differentiation of vertebrae, which are the main parts known, is not difficult. This genus needs a thorough study and the fragmentary nature of the remains makes this difficult. At present only vertebrae and some associated limb material can be assigned definitely. Various skull and girdle parts have been referred to the genus in Orlando collections, but, although the references may be correct, the basis for such assignments is tenuous. Apparently there was at one time a complete skeleton of this amphibian that was lost prior to study. This genus is known elsewhere only from rare material. Other specimens are one (CNHM UR 334) from the Mabelle Member of the Lueders Formation near Lake Kemp, Baylor County, Texas, and another (CNHM UR 293) from the Craddock bone bed in the Arroyo Formation, south of Lake Kemp in Baylor County. In addition, some materials from lung-fish burrows in the vicinity of Perry appear to be close to this genus.

Lysorophus is represented by specimens consisting of vertebrae and ribs. Reference to *L. tricarinatus* is in keeping with the usual reference of all such material from the Lower Permian of Texas to this species. The species was named from the Pennsylvanian of Vermillion County, Illinois (Cope, 1877). Vertebrae from the Lower Permian show no evident differences from the Pennsylvanian ones and there is no morphological basis for separation (see p. 20).

The studies of Orlando materials that I have made have not revealed *Seymouria baylorensis*. Case noted this genus and it is clear that he based his conclusions on materials other than those to which I have had access. It is possible that this genus and species, or at least this genus, is present.

Pleuristion brachycoelus Case is a distinct genus and species and does not seem to be known from elsewhere. It was based on a few vertebrae and its position was given by Case (1902) as uncertain. The type is KU 351 and this includes foot bones, ribs, and a limb bone, as well as the vertebrae. A skull in the Field Museum collections (CNHM UC 678) has been referred to the genus, but this assignment must be considered questionable because of the lack of association with vertebrae. It may well be the skull of *Pleuristion,* but this cannot be demonstrated at present. Additional specimens of this animal are in the collections, and studies in progress should improve knowledge of it considerably.

Captorhinus is present and reference to the broad species *C. aguti* is probable. Identification is based mainly on jaws and parts of skulls. The genus is not common. *Dimetrodon* occurs sparingly in the beds at the Orlando site. About 0.5 mile to the east are more complete remains that quite certainly pertain to *D. limbatus.* All of the remains from Orlando could well belong to this species, but they are too fragmentary for definite assignment.

Tentative reference of *Edaphosaurus* to *E. boanerges* is based mostly on size, for only parts of neural spines have been found. It is possible that they may pertain to *E. cruciger* or, of course, to a species not known from the better preserved Texas materials.

The cast of this fauna is suggestive of that of the upper Wichita formations of Texas, either the Admiral or Belle Plains. It is not definitive with respect to one or the other of these two and some elements suggest a Clyde or Arroyo equivalency. The gray band of sediment from which the specimens came probably represents a lake deposit, and the fauna for the most part includes animals that in character and abundance suggest such an environment of deposition. A limited ecological type such as this must necessarily cause some difficulties in determination of age relationships on the basis of contained faunas. *Diplocaulus,* so common at Orlando, is not an important genus in the Wichita of Texas, but is abundant in the Arroyo. *Gnathorhiza* similarly is more abundant in the Clear Fork than in earlier beds. *Lysorophus* is primarily a Clear Fork genus in Texas. Each of these, however, occurs under conditions which suggest seasonality, conditions appropriate to aestivation. *Gnathorhiza* and *Lysorophus* definitely were aestivators and *Diplocaulus* is a common associate of these in the Clear Fork. Hence these have less significance as age indicators than do other genera and species.

Dimetrodon and *Edaphosaurus* are both important in this regard, and they suggest Wichita rather than Clear Fork equivalency. This assignment is supported by *Archeria* as well, although the genus does occur as high as the Clyde in Texas. *Crossotelos* occurs in the Lueders, just above the Clyde, and in the Arroyo in Texas, but is not known earlier. Once again, this may be a matter of facies control. An odd item is the absence of *Ophiacodon,* normally a member of an assemblage of the type found at Orlando. It does occur at Perry site 6, the assemblage of which has various resemblances to that at Orlando. It may appear among the fragmentary materials when these are analyzed more thoroughly. To date, however, it is unrecorded.

The evidence now at hand is not entirely unequivocal with respect to age assignment. It points more to late Wichita than to anything else, but Clyde assignment is not impossible. The balance of the faunas does not suggest the Arroyo, although some Arroyo elements are present. Unless the species of *Edaphosaurus* and *Dimetrodon* have been seriously misjudged, Arroyo equivalency seems unlikely, and even Clyde equivalency seems less probable than Belle Plains or possibly even Admiral.

MORRISON SITE

Smith (1927) reported a site near Morrison in Noble County, about 15 miles east of Perry. His location is "300 feet north of the southeast corner of sec. 18, T. 21 N., R. 3 E., in a road ditch on the east side of the road about one half mile southeast of Morrison." *Dimetrodon* and *Cricotus* (=*Archeria*) were reported. The collector, A. H. Loechmann, indicated the stratigraphic position as 400 feet above the Neva Limestone, placing it in the middle of the Wellington section. This would make it one of the oldest sites in this part of the State.

The site is now covered and we were unable to find any trace of it or of the specimens in the Stovall Museum. The specimens may, of course, be part of a rather large amount of unlabeled vertebrate material. Smith identified two species of *Dimetrodon* from astragali, *D. incisivus* and *D. dollovianus*. Without access to the specimens these identifications cannot, of course, be checked. It seems improbable, however, from his descriptions, that the materials are adequate for assignment on the basis of the criteria considered necessary by Romer and Price (1940).

MC CANN QUARRY SITE

Over the years the McCann quarry (pl. II B) has been worked for rock slab and from time to time excellent vertebrate fossils have been obtained. The quarry is on Deer Creek, 8 miles west and 4 miles south of Blackwell (about 9 miles southwest in a direct line) and 2.5 miles northeast of Eddy, in Kay County. It is in NE¼ sec. 16 and SW¼ sec. 9, T. 26 N., R. 2 W. Max Smith, who is at present working this property, graciously gave us permission to study the site and make new collections.

A partial skeleton was found here by Gould in 1897. Williston (1899) identified the specimen as *Eryops megacephalus* Cope. Case mentioned it along with other materials in 1902. Later Moodie (1911) gave the specimen a new species name, *Eryops willistoni* Moodie, and the specimen, so named, is now in the collections at the University of Kansas (KU 348). Case (1902) discussed the site briefly and in 1915 gave a faunal list. Among other items, he listed *Trimerorhachis leptorhynchus* Case, which is clearly in error (see footnote, p. 47). In early studies, the McCann quarry was called the Nardin site (Case, 1902; Gould, 1900). Later it was called the Eddy site by Stovall, and at present it is generally called the McCann Quarry, or McCann, site. All of these designations refer to the same place.

In 1936 W. O. Wethington wrote to J. Willis Stovall at The University of Oklahoma concerning materials that had been collected during quarry operations. These were obtained in large part by J. W. Bowdin of Lamont, Oklahoma. Eventually, although some of the specimens were lost, much of the collection came into the possession of the Stovall Museum. Stovall (1948) described a jaw of *Archeria*, naming a new species on the basis of the specimen *Archeria victor* Stovall. In his discussion he noted that associated with *Archeria* were *Captorhinus, Dimetrodon, Trimerorhachis, Eryops,* and indeterminate remains. He included a stratigraphic section and placed the vertebrate-producing beds in the uppermost Wellington. He noted that the occurrence appears to extend the stratigraphic range of *Archeria* into the Arroyo, but, as pointed out below, this follows from a faulty assignment of the strata in the Wellington section.

The most recent study of materials from this site was that by Seltin (1959), in which he designated a new species of *Labidosaurus, Labidosaurus oklahomaensis* Seltin, on the basis of the materials that were the specimens of *Captorhinus* of Stovall. These same materials entered into the study of species by Olson and Miller (1951).

Almost all of the specimens have been a by-product of quarrying. In 1965 my party spent several days at the site, making excavations at various places. The site yielded a great deal of scrap and widely scattered well-preserved specimens. In places the bone is highly concentrated, forming a "bone conglomerate." Full preparation of our materials will take a long time and almost certainly will turn up new small vertebrates. It is possible at present, however, to present a fairly complete picture of the nature and extent of the deposits and their fossil content.

Geology.—A section taken in 1965 at the most extensive exposures, at the northernmost end of the quarry sites, is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
14	Soil	1.0
13	Platy sandstone, mostly brown	0.5
12	Red sandstone and shale	0.7
11	Thin calcareous sandstone, white to yellow	0.1
10	Red sandy shale, some yellow sandstone at base, bones in base	1.5
9	Red to brown sandstone, in places grading into sandy shale and bed 8 below, in others cutting into 8. Main source of bones	1.5
8	Banded gray and brown sandstone, rippled-marked, with two layers in places. Fragments of bones, conchostracans	0.8
7	Red shale, brownish-green streaks	1.5

6	Dolomite, thin and interbedded in light-gray shale	0.7
5	Green to gray shale	4.0
4	Even-bedded red shale	5.5
3	Black shale with small amounts of dark dolomite	1.0
2	Gray shale, reddish at base, grading to gray-green. Even-bedded and structureless	5.0
1	Pink and gray dolomite	0.3

This section differs in several respects from the one given by Stovall (1948). His was taken somewhat to the south of the one presented here. Pinching out of beds may account for part of the difference, but I have been unable to reconcile other differences, despite having had his section in hand when we made our field studies.

Bones occur in beds 8 and 9 of our section and in bed 6 of his. He stated that bed 6 passes into a shale to the north, but hand leveling to the site where his section appears to have been taken shows that our bed 9 is the same as his bed 6. There is no outlier of Garber Sandstone above the section as he suggested. Stovall's section appears to have as its base our bed 3.

Raasch's study (1946a) places the McCann Sandstone (named by Gould, 1900) about 240 feet below the base of the Garber Sandstone. It appears to be a lens of the Fallis Sandstone, which lies just above the "insect beds" (see discussion, p. 39). The sandstone in this area is highly variable both in composition and thickness. It ranges from about 2 to 6 feet in thickness. In part it is a coarse-grained, somewhat porous sandstone, but this grades laterally into dense, gray to yellow sandstone and in places there are clay-gall inclusions. Cross-bedding is present in some places and the dense, gray sandstone shows a fine banding. The sandstone passes downward without a definite break into argillaceous sandstone, which in turn merges with a gray and yellow shale. At the base of the sandstone, and at places in its

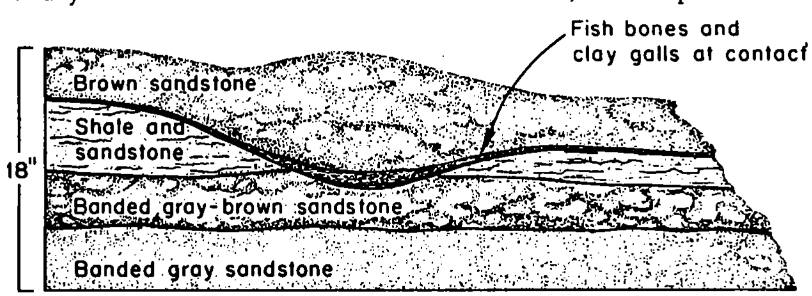


Figure 8. Diagram of the McCann Sandstone at the McCann quarry, showing the several sands and the channeling of one into others. Bone scraps tend to be concentrated in the scour troughs, but occur throughout. Conchostracans are abundant in the two lower sandstones. The best preserved vertebrates occur in the brown sandstone at the top of the section. Thickness is about 5 feet.

body, are scour and fill structures with concentrations of bone fragments at the contacts (figure 8).

Vertebrate remains occur in all phases of the sandstone, mostly as small fragments. Along with the bone fragments are abundant conchostracans, called *Estheria* by Gould (1900). Few remains of plants have been found.

The beds in the measured section appear to be predominantly nearshore deposits, in part marine. However, there is a rapid shift from marine to terrestrial or very nearshore marine conditions, as represented by the deposition of the McCann Sandstone (see discussion of Perry site 6, p. 42). Tanner (1955, 1959), in a study of the Fallis Sandstone and the Garber Formation, concluded that the shoreline was far to the south and that the sandstones were deposited in a marine environment. He placed the shoreline between 75 and 100 miles away. The presence of abundant terrestrial vertebrates argues strongly to the contrary, for the floating of such a variety of remains in good condition over any such distances in marine water seems out of the question. The interpretation of the deposition of the McCann Sandstone at this site is similar in most respects to that at Perry site 6, and presumably similar conditions pertained.

Vertebrates.—The faunal list now available is given below. Study of small bones in the recently made collections will probably add to the number of genera and will make more definitive the assignments of some of the fish. Among the larger animals taxonomic changes are less likely.

Chondrichthyes
- *Xenacanthus* sp.

Osteichthyes
- *Sphaerolepis arctata* Cope
- paleoniscoids

Amphibia
- *Archeria victor* Stovall
- *Trimerorhachis insignis* Cope
- *Eryops megacephalus* Cope
- *Diplocaulus* cf. *D. magnicornis* Cope

Reptilia
- *Labidosaurus oklahomaensis* Seltin
- *Dimetrodon* cf. *D. limbatus* (Cope)
- *Edaphosaurus* cf. *E. boanerges* Romer

Xenacanthus is represented by numerous scattered teeth. No species identification is possible. Fragmentary remains of osteichthyes are abundant. Tooth plates of *Sphaerolepis arctata* (assigned to this species with recognition that it is a "form" species) are common. Some of the fish scrap probably belongs to this genus, but some scales clearly are paleoniscoid, of the type found in the Perry sites.

The four amphibians are represented by excellent specimens. *Eryops megacephalus* Cope is best known from the specimen KU 348, the holotype of Moodie's *Eryops willistoni*. Reexamination of this specimen with the current concept of *E. megacephalus* in mind shows it to fall well within the limits of variation of that broadly conceived species. The major differences cited by Moodie (1911) are the sculpture pattern and the outline of the posterior part of the jaw. The features of the McCann specimen are matched in various specimens of *E. megacephalus* from Texas. Presumably scraps of *Eryops* from this site also pertain to this species.

Archeria victor Stovall appears to be a valid species. In addition to the jaw designated as a holotype (Stovall, 1948), there are centra of an embolomerous amphibian that presumably belong to this species, although they have no distinctive features. *Diplocaulus* is known from a partial skull (OUSM 2-1-S10). This specimen is excellently preserved but lacks the horns. No differences from *D. magnicornis* can be detected, although it has not been possible to check the configuration of the distal parts of the horns to rule out the possibility that it is *D. recurvatus* of the Vale Formation. Clearly it is not *D. brevirostris* or *D. salamandroides*. The age probably rules out assignment to *D. recurvatus*, but, because the array of criteria necessary for determination is incomplete, the assignment to *D. magnicornis* has been left tentative.

An excellent skull of *Trimerorhachis* (OUSM-2-S17) is, in all respects, comparable to skulls of *T. insignis* and reference to this broadly conceived species seems unquestionable.

Labidosaurus oklahomaensis is represented by a suite of well-preserved specimens. Assignment to *Labidosaurus* rather than *Captorhinus*, as suggested by Stovall, was based upon the presence of but a single row of maxillary and dentary teeth (Seltin, 1959). Unquestionably this species is distinct from *Labidosaurus hamatus* of the Texas Arroyo. *Dimetrodon* is represented by vertebrae, limb bones, and teeth. The slender spines and short vertebrae support assignment to *D. limbatus*, but the assignment is not entirely certain. Only fragments of spines of *Edaphosaurus* are present. These probably pertain to *E. boanerges*, on the basis of size, but only tentative reference is possible.

This assemblage is not highly definitive with respect to age relationships to the Texas section. The common species are mostly long lived. *Diplocaulus magnicornis* is typically Arroyo in Texas, but the several Oklahoma sites show it to be a consistent part of earlier faunas. *Archeria* occurs as high as the Clyde in the Texas section, but is not known in the Arroyo. This restriction may be a matter of change of conditions of deposition, accompanying reduction of rainfall and increase in seasonality, so that it is not out of the question that this genus may have persisted on to later times (see discussion under Pond Creek site). Both *Dimetrodon* and *Edaphosaurus* suggest late Wichita affinities, but in neither case is species assignment certain. It does seem clear that the McCann *Dimetrodon* is not *D. giganhomogenes* or *D. grandis* and that the *Edaphosaurus* is not *E. pongias*, typical Arroyo species. The data suggest that a Belle Plains equivalency is most probable, but certainly Clyde age, or even Admiral, cannot be completely ruled out.

GARBER SITES

The Garber Formation (figs. 7, 9) is well defined for a considerable distance north of the Cimarron River, but southward it becomes less readily distinguishable from the Wellington in surface outcrop. Most of the fossiliferous sites occur in the northern portions. These, for the most part, are restricted to the lower and more shaly parts. The massive Garber sandstones carry few vertebrate remains and those that have been found are extremely fragmentary. In Noble and Logan Counties two members of the Garber are recognized, the Lucien and Hayward, respectively. The Lucien has a high content of red shale, but the Hayward is predominantly sandstone. These members were defined by Aurin, Officer, and Gould (1926), with the members named for the towns of Lucien and Hayward. The total thickness in this area is 600 feet. It is probable that continued search for new sites in the Lucien Member will produce good results, for, during the short time available for field study, we were able to add to what had been known previously. The Hayward presents a more difficult problem. It is by no means impossible that concentrations of vertebrates will be found in its massive and cross-bedded sandstones, but prospects in general are poor. Extensive studies in good outcrops along Interstate Highway 35 from Oklahoma City northward to the Cimarron River failed to produce so much as a scrap of vertebrate material. Both shales and sandstones were searched through a period of several days by George Olson and Keith Carlson. The more productive sites are in the vicinity of Lucien in Noble County.

LUCIEN SITES

The five sites in the vicinity of Lucien are grouped because of their geographic, stratigraphic, and sedimentologic similarities. For the most part, the vertebrate assemblages that they have yielded are meager. All have come from the Lucien Member of the Garber Formation.

Lucien Site 1

Lucien site 1 is the Lucien site of Smith (1927). It is in NE¼ NE¼ sec. 11, T. 21 N., R. 3 W., about 4 miles north of Lucien (fig. 7). Exposures cover a small area around a cattle tank (pl. IIC) and are predominantly red shale, sandy red shale, whitish shale, and massive sandstone. Over the northern part of the area of exposure, sandstone predominates and in places it gives way to mudstone conglomerate. Because there is strong lateral variation, no section can express the full nature of the deposits. One section, measured by George Olson from northwest to southeast through the bone-bearing site, is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
5	Soil and sand	1.6
4	Red shale, varying in thickness. Basal portion gradational to bed 3. Carries green bands and lenses	12.0
3	Dark-red shale with purple nodular layers. Banded horizontally and diagonally by green layers. Lenses of conglomerate up to 3 feet thick, passing into white sandstone in places. To the north replaced in part by sandstone	9.0
2	Red shale with ironstone concretions. Patches of maroon and gray shales. Bones occur in these patches	5.0
1	Massive sandstone, badly slumped so no accurate thickness can be obtained. Base at water's edge (of tank).	10.0

One small concentration occurs in bed 2 and a specimen of *Diplocaulus* was found by Smith in the white sandstone, probably in bed 3. The specimens, except for the one of *Diplocaulus* are fragmentary. Smith (1927) gave a faunal list as follows:

Pleuracanthus gracilis Newberry
Pleuracanthus compressus Newberry
Diplocaulus magnicornis Cope
Diplocaulus sp.
Dimetrodon sp.

He also listed an unidentified jaw (OUSM 3-4-S1), suggesting it might be a seymouriamorph. The dentition, sculpturing, and the articular structure leave no doubt that this is actually a jaw of *Diplocaulus*.

In the course of our studies, we collected a large number of additional specimens. Much of Smith's material was not identified by labels affixed to the bones and subsequent handling has resulted in mixing that makes identification impossible in many cases. Thus much of what is included in this report is based on the newly collected materials. Only one genus, *Eryops*, was added by our studies. Spines, teeth, and fragments of cartilage represent *Xenacanthus* sp. (*Pleuracanthus* in Smith's list). As in other collections, information is insufficient for species assignment and, judging by his description, this was presumably the case for Smith's material as well. The fragments of *Dimetrodon* could be equally placed as *D. giganhomogenes*, *D. limbatus*, *D. dollovianus*, or *D. loomisi*. *Eryops* is known only from intercentra, which are not diagnostic below genus level.

Diplocaulus is by far the most abundant vertebrate, outnumbering all others by about 20 to 1. However, none of the skulls is complete and none shows characters needed for species determination. The orbital position in some fragments is appropriate for either *D. magnicornis* or *D. recurvatus*. Probably the materials pertain to the former, but this cannot be demonstrated. A revised faunal list is as follows:

Chondrichthyes
  Xenacanthus sp.
Amphibia
  Eryops sp.
  Diplocaulus cf. *D. magnicornis* Cope
Reptilia
  Dimetrodon sp.

Age of site.—The Lucien site 1 lies in the Lucien Member of the Garber Formation. The massive sandstone of bed 1 appears to be the basal sandstone of this formation, overlying the Wellington Formation. A section taken in NE¼ sec. 20, T. 21 N., R. 2 W., about 4 miles southeast of Lucien site 1, measured eastward along the road from a small tank at the lowest level of exposure, is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
8	Red and gray platy sandstone, channeled into red shale, with some green sandy shale at base	7.0
7	Structureless red shale	10.0
6	Red and green, coarse to fine sandstone and fine conglomerate, lenticular and local	1.0
5	Red shale, uniform and structureless	4.0

4	Green-gray sandstone	1.0
3	Uniform red shale	4.0
2	Massive sandstone, red and green, channeled into underlying red shale	10.0
1	Red shale	3.0 to base

Here bed 2 is considered to be the base of the Lucien, being the lowest "Garber-type sandstone" (see Aurin, Officer, and Gould, 1926) in this region. The underlying shale is Wellington. This ties in with a similar contact at other places in this area where a more extensive section of Wellington is present. On the basis of lithology, the sandstone of bed 2 is thought to be equivalent to the sandstone of bed 1 at Lucien site 1. The level is appropriate, but tracing between the two in outcrop is not possible. Beds 3 through 7 of this section are considered equivalent, in general terms, to beds 2 through 5 at Lucien site 1.

The fauna gives no definitive indications of relationships to the Texas section. A position anywhere between the Admiral and upper part of the Vale Formations is possible. The absence of *Archeria* and *Ophiacodon* from what appear to be pond deposits may carry some weight, suggesting Arroyo or Vale age, but such evidence is extremely untrustworthy for a single deposit with a limited assemblage.

Lucien Site 2

Lucien site 2 is a second site reported by Smith (1926). It is in SW¼ sec. 3, T. 21 N., R. 3 W., about 4 miles northwest of Lucien. A jaw was found in conglomerate but was not identified. It lay just below a massive cap sandstone, which appears to represent the base of the Hayward Member of the Garber Formation. Scraps were found here in the course of our studies in this region, but nothing could be identified. The bones appear to lie in a shale bed, about 2 feet below the Hayward Sandstone and thus are uppermost Lucien. Smith's specimen is not identifiable in the collections of the Stovall Museum. Further study of this site may possibly produce better remains. For the present, nothing can be done to assess its faunal content or age relative to the Texas section.

Lucien Site 3

Good exposures occur at Lucien site 3 in NW¼ SW¼ sec. 18, T. 21 N., R. 2 W. The section totals about 40 feet and is predominantly red shale with some sandstones and mudstones. Lateral variation is so rapid that no section can be considered representative. In general the deposits are similar to those at Lucien site 1. Limonitic and hematitic layers occur and from these come plant impressions

in ironstone nodules. To the west of this site, in secs. 13, 14, T. 12 N., R. 3 W., heavy conglomerates are present, indicating strong stream action. The deposits at this site, like those at Lucien site 1, appear to have been deposited marginal to a major river system, with deposition in small areas of ponded waters.

Scraps of bone occur at various levels in this site, coming mostly from the fine-grained, green conglomerates. Some of them are identifiable and the following list has been compiled:

Chondrichthyes
- *Xenacanthus* sp.

Amphibia
- *Trimerorhachis* sp.
- *Eryops* cf. *E. megacephalus* Cope
- *Dimetrodon* sp.

This section clearly falls within the Lucien Member of the Garber Formation, probably at about the same level as that at Lucien site 1. The fauna is not definitive in age relative to the Texas section, except that it is Early Permian.

Lucien Site 4

Lucien site 4 lies on the property of Allen Johnson in NW¼ sec. 19, T. 21 N., R. 2 W. An exposed section of about 20 feet consists largely of red shale with lenses of fine-grained conglomerate and platy, green sandstone. A few lenses of mudstone conglomerate occur in the middle part of the section. The environment of deposition appears to be much the same as that at Lucien site 3.

Fossils are present but they are fragmentary. The following list has been compiled from what was observed in the field and partly collected:

Chondrichthyes
- *Xenacanthus* sp.

Amphibia
- *Trimerorhachis* cf. *T. insignis* Cope
- *Eryops* sp.
- *Diplocaulus* sp.
- *Diadectes* sp.

Reptilia
- *Dimetrodon* cf. *D. giganhomogenes* Case

The coincidence of *Diadectes* and of *Dimetrodon*, the latter probably referable to *D. giganhomogenes*, suggests age equivalency to the Arroyo of Texas. *Diadectes* occurs no higher than the Arroyo, except for a single vertebra, which may have been derived from Arroyo deposits, in the lower part of the Vale (Olson, 1956b) and *D. giganhomogenes* does not occur below the Arroyo. The problems are of two types. First is the matter of the identification of the species. Skull fragments, ribs, a humerus, an ulna, a fibula, and vertebral spines of *Dimetrodon* were present. All suggest *D. giganhomogenes*, but a series of vertebrae with the central part of the spine is needed for positive identification. Even with positive identification, of course, age equivalency based on one or two species remains problematical, depending upon an assumption that the life of the species over its full range was about the same. The best estimate of age is that this site is an Arroyo equivalent, but this is highly tentative.

Lucien Site 5

Lucien site 5, about 2 miles east of Lucien in S½ (mostly SE¼) sec. 16, T. 21 N., R. 2 W., has yielded some fragmentary remains of vertebrates. The section is much like that in NE¼ sec. 20, T. 21 N., R. 2 W., given under discussion of Lucien site 1. The following have been identified.

Chondrichthyes
  Xenacanthus sp.
Amphibia
  Diplocaulus sp.
Reptilia
  Dimetrodon sp.

Nothing is now known to give any indication of age other than Early Permian.

Summary

The vertebrates so far found in the Lucien Member of the Garber Formation are all fragmentary. They were associated with major river systems but deposited largely away from major stream channels either in small ponds or in secondary channels. Circumstances are such that it seems probable that concentrations of better preserved specimens may exist in this general area. Search so far has not revealed them, but the field work has not been exhaustive. Information relating to precise age relationships to the Texas section is meager. The best guess is that these deposits are equivalent in age to the Arroyo beds of Texas and the relatively scant evidence for this has been given in discussions of the particular sites.

BEAN FARM SITE

The Bean Farm site is about 10 miles northeast of Edmond in Logan County. Fossils have come from the southwest part of the property in SW¼ sec. 24, T. 15 N., R. 2 W. (fig. 10). At present the section is not well exposed and we were unable to determine the precise location of the specimens that were obtained earlier from this site. The section consists largely of cross-bedded to massive sandstone with coarse-grained conglomerate at the top. The specimens appear to have come from the conglomerate. This area is heavily forested and has few exposures. Other exposures in the vicinity show a similar lithology. The site is close to the Garber-Wellington contact and, in view of its position, appears to be in the basal Garber rather than in the Wellington.

Two excellent specimens have come from this site. One includes the chondrocranium and arches of *Xenacanthus*. They are badly flattened but show the structure well. The other specimen is a skull and vertebral column of *Diplocaulus magnicornis* in excellent condition. A second specimen of *Diplocaulus magnicornis* also has come from this site, but its condition is poor.

The exposures at the Bean farm are similar to those encountered over a broad north-south band extending from Interstate Highway 35, on the west, eastward for about 20 miles. This is an area covered for the most part by oak forests, but along the section-line roads outcrops are encountered with fair frequency. Sandstones predominate in the outcrops but in places there are red and purple shales, mudstone conglomerates, and local massive lenses of conglomerate. In the course of our work, a number of traverses were made across this region from the latitude of Oklahoma City northward to the Cimarron River, but they failed to reveal any vertebrate remains whatsoever. This does not mean, of course, that none is present, for other sites similar to that on the Bean farm presumably exist. Finding them will be largely a matter of chance.

Both the Garber and Wellington Formations are represented over this area. The contact between them is not clear, for there is little change in lithology from west to east as revealed in the scattered outcrops. The central and eastern parts are dominated by the Fallis Sandstone. Were fossils to be found in the eastern part of the area, they would carry rather well down into the Lower Permian and to be of considerable interest. The lithology, for the most part, however, is such that future discoveries seem unlikely.

HAYWARD SITES

The Hayward Member of the Garber is predominantly sandstone. It is about 350 feet thick and stands out as a ridge former. At places there are shales, sandy shales, and conglomerates. The member as a whole is made up of lenticular masses which give the impression of having been deposited as bars in major streams. Tanner (1955) has made a case for the deposition of such lenses under marine conditions. To the north, the sandstone thins and the Hayward Sandstone cannot be recognized in the northern counties.

The Hayward Member of the Garber is largely unfossiliferous. A few reports of scraps of vertebrates have been made. The remains have either not been collected or not preserved, so none of them serves to indicate the nature of the animals involved. While searching for a locality south of Covington, Garfield County, reported by William Wrather to the Stovall Museum many years ago (see discussion under Garber-Hennessey transition beds, p. 77), we found a small pocket of fossiliferous maroon shale in the Hayward Sandstone. This site lies in NE¼ NE¼ sec. 13, T. 20 N., R. 2 W. A section taken from west to east through the bone-bearing lens is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
10	Sandstone, green, grading to red. A complex bed forming two sandstones with shale between in places	8.0
9	Red shale, clean and structureless	5.0
8	Nodular red shale	1.0
7	Red shale, nodular in places, some fissile sandstone	15.0
6	Green sandy shale, hard, ledge forming	1.0
5	Red shale, even and structureless	20.0
4a	Intermittent local bed, purple shale, with bones	1.5
4b	Massive red sandstone, hard, medium grained; purple bed 4a included near top where present	10.0
3	Coarse, cross-bedded mudstone	10.0
2	Massive, coarse, hard cross-bedded sandstone; forms falls in streams	15.0
1	Even red shale to base	8.0

The uppermost bed is close to the Garber-Hennessey contact, although this contact is not exposed in this place. All of the specimens came from a single pocket and are fragmentary. Most were scraps of *Dimetrodon*, but some pertain to *Diplocaulus* and some, tentatively, to *Eryops*. These identifications are in no way definitive of the precise age of the deposit. They merely suggest that it may be worthwhile to continue searches in the Hayward Member. As it now stands, this sandstone complex represents a nearly barren 300- to 350-foot section between the presumed Arroyo equivalents of the

Lucien Member and the probable Vale equivalents found at the Garber-Hennessey transition as discussed in the next section (p. 73).

POND CREEK SITE

The Pond Creek site (pl. IID) is one that has been known since the beginning of the century and has been mentioned and described in a number of publications. It is in the Garber Formation, but it cannot be placed properly in either the Lucien or the Hayward Member because these units do not persist as entities in Grant County. The site is about 5 miles east of the village of Pond Creek, Grant County, in NE¼ NW¼ sec. 14, T. 25 N., R. 5 W. It is on the property of Price Shaeffer, who kindly gave us permission to work on his land.

Geology.—Exposures form a northward-facing amphitheater to the south of the east-west section-line road and across the road for a short distance to the northwest. Vertebrate remains are concentrated in the central portion, in a spur that projects northward from the main wall of the cut. The fossils occur in sandy shale, fine conglomerate, and even red shales. Deposition appears to have resulted from stream action. Most of the remains are fragmentary but partial skeletons of *Dimetrodon* are present. Plant-bearing lenses are closely associated with the bone-bearing beds.

A section was measured from the creek bed, just south of the section-line road, southward through the bone-bearing deposits, as follows:

BED	DESCRIPTION	THICKNESS (FEET)
7	Pleistocene sand and soil	15.0+
6	Evenly bedded red shale, some green bands	10.0
5	Red shale, sandy in places, vertebrates	6.0
4	Fine green conglomerate, vertebrates	0.6
3	Light red to maroon and purple shale, green lenses and stringers. Bones, plants	4.0
2	Green conglomerate, vertebrates	0.3
1	Even-bedded red shale, green patches and lenses	10.0 to base

Vertebrate remains occur in beds 2 through 5. The greatest concentration is in the green conglomerates, but all the materials are fragmentary. Bed 5, near its upper margin, contained a partial skull and skeleton of *Dimetrodon*, mostly articulated. Associated were fragments of *Diplocaulus*. From lower in this shale came remains of *Labidosaurus*.

To the east and west of the line of the section roughly represented by section 2 in figure 9 strong lateral variations occur. The westernmost part (sec. 1, figure 9) is composed largely of uniform

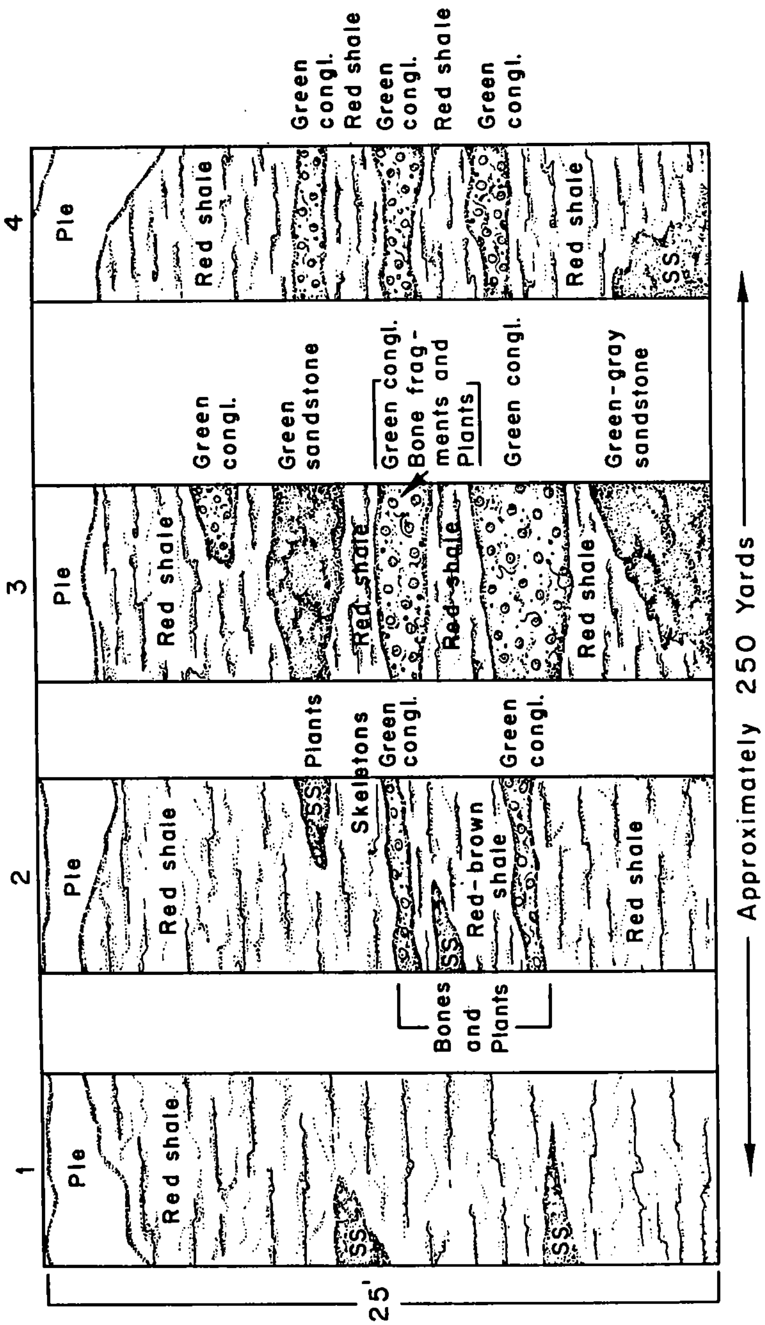


Figure 9. Columnar sections from west (1) to east (4) at the Pond Creek site. The greatest concentration of bone is in section 2 (see also pl. IID). The series passes from flood-plain deposition in the west to predominantly stream deposition in sections 2 and 3, with some flood-plain deposition high in section 4.

red shale that carries no fossils. The clastics tend to become coarser eastward. Section 2 in the figure merges into section 3, which carries several layers of conglomerate that interfinger with a thick basal lens of sand. This lens appears to represent the site of the major stream course. Gypsum and gypsum veins occur sparingly in this complex. The coarse clastics carry fragments of bones and plants. Section 4 is at the east end of the outcrop. It is largely conglomeratic, but the thick basal lens of sandstone is absent. Bones occur in the coarse, green conglomerate.

Vertebrates.—Fossils are reasonably abundant, but mostly fragmentary. Various collectors have visited this site and several small collections have been made. Some were deposited at The University of Oklahoma, and some appear to have gone elsewhere and in part, at least, lost. Case made a collection in 1910 and Smith another in 1926. Some of Case's material is at the University of Michigan. Unfortunately much of what Smith collected was inadequately labeled and, with mixing over the years, identities have become confused. As a result, problems have arisen, such as the occurrence of *Archeria* at this site, which is of considerable importance in regard to both faunal composition and age.

Case presented a faunal list in 1915 and Smith one in 1927. These are as follows:

Case (1915)

Pleuracanthus quadriseriatus Cope
Diacranodus texensis Cope
Gnathorhiza pusilla Cope
Platysomus palmaris Cope
Diplocaulus salamandroides Cope
Eryops megacephalus Cope
Diadectes (Nothodon) maximus Case
Captorhinus angusticeps Cope
Labidosaurus hamatus Cope
Poliosaurus uniformis Cope
Dimetrodon gigas Cope
Dimetrodon incisivus Cope

Smith (1927)

Pleuracanthus gracilis Newberry
Pleuracanthus compressus Newberry
Sagenodus periprion Cope
Gnathorhiza pusilla Cope
Sphaerolepis arctata Cope
Diplocaulus salamandroides Cope
Eryops megacephalus Cope
Trimerorhachis sp. Cope
Cricotus sp.
Bolosaurus striatus Cope
Poliosaurus sp. Cope
Clepsydrops sp.
Dimetrodon incisivus (?) Cope
Dimetrodon dollovianus Cope
Naosaurus sp.

These lists show some clear-cut differences and others that reflect more the problems of terminology and understanding. Smith's study, as a master's thesis, was not critical and has errors. It is of use, however, as the most recent listing of the fauna and as one based on more extensive collections than any made previously. Both lists include species not known to occur together in the same formation in Texas, especially those of *Dimetrodon*, if the determinations of Romer and Price (1940) are followed. In their work Romer and Price noted the presence of *Dimetrodon giganhomogenes** at this site, and possibly of *D. grandis* on the basis of size. The latter is probably the equivalent of Case's *D. gigas*.

A restudy of all the material in the older collections at the Stovall Museum and the new materials collected has resulted in the list that follows. Specimens at the University of Michigan, Harvard,† and the American Museum of Natural History have not been restudied.

- Chondrichthyes
  - *Xenacanthus* sp.
- Osteichthyes
  - Dipnoi
    - *Gnathorhiza* cf. *G. serrata* Cope
    - *Sagenodus* sp.
  - Rhipidistia
    - *Ectosteorhachis* sp. (= *Megalichthyes*)
  - Actinopterygia
    - *Sphaerolepis arctata* (Cope)
    - *Platysomus* sp.
- Amphibia
  - *Archeria* sp.
  - *Trimerorhachis* sp.
  - *Eryops megacephalus* Cope
  - *Diplocaulus magnicornis* Cope
  - *Diadectes* sp.
- Reptilia
  - *Captorhinus* cf. *C. aguti* Cope
  - *Labidosaurus hamatus* Cope
  - *Dimetrodon grandis* (Cope)
  - *Dimetrodon giganhomogenes* (Case)
  - *Edaphosaurus* sp.

The above list is conservative, especially with respect to species assignment. Much of the material is so fragmentary that it is misleading to give assignment below the generic level. The differences

*Romer and Price (1940) list Case's *D. giganhomogenes* as *D. gigashomogenes*.

†Professor Romer, on request, wrote me concerning *D. giganhomogenes*. He stated that the evidence of its presence was not unequivocal. From his description, however, it seems likely that the assignment is correct.

between the listing given here and those of Case and Smith require explanation.

All fresh-water shark materials, in keeping with the practice throughout this paper, are assigned to the genus *Xenacanthus* without species designation. *Pleuracanthus*, a commonly used name, is invalid (Olson, 1946). Teeth and fragments of cartilage are sufficient only for assignment to the form genus *Xenacanthus*. The teeth are robust and of the type generally called *X. texensis*, but this must be considered more a morphological type than a systematic taxon.

The only specimen of *Gnathorhiza* available for study resembles *Gnathorhiza serrata* in form, but is considerably larger than the known representatives from Texas. It probably belongs to this species, but evidence is insufficient for confident reference. A fragment of a tooth of *Sagenodus* is present in the collections that we made. It is large, heavy, strongly denticulated, and somewhat *Ceratodus*-like, but too fragmentary for species determination. Smith (1927) listed *Sagenodus periprion*. It was not possible to find the specimens upon which he based this determination in the collections of the Stovall Museum. *Sagenodus* teeth without data on sources are present and it is possible that these are the material that Smith used. On the other hand, they may have come from the Texas Permian. Smith figured a specimen of *Sagenodus vinslovi*, but it is not certain whether or not this is from Pond Creek. At present any determination beyond the presence of *Sagenodus*, in a broad sense, goes beyond the evidence.

Scales that appear to pertain to *Ectosteorhachis* and *Platysomus* are in the collections, but species assignments are not possible. A few small toothed plates of *Sphaerolepis* are present and within defined limits can be referred to *S. arctata*.

Some centra that clearly pertain to an embolomere, presumably *Archeria*, are in the collections said to come from Pond Creek. Some have been identified as vertebrae of *Pleuracanthus* and others as *Cricotus*. There is no sound reason for doubting that they came from the Pond Creek site, but some minor matters raise some doubts. They are not the same color as most specimens, being purplish rather than red. Case did not list such specimens or the genus in his list and we did not find any such material in our collecting. Various collections from Texas have been in the same drawers with the Pond Creek materials, and mixing may have resulted. Smith, however, stated that they did come from Pond Creek. If additional collecting does turn up *Archeria*, the matter will be settled. If not, there will be no positive answer. The importance lies in the fact that, if this is a valid occurrence, it appears to be the only known case in which *Archeria* persists into beds of Arroyo age.

Fragments of *Trimerorhachis* and *Diadectes* are present. They are insufficient for species assignment, but the specimens of *Eryops* probably can safely be referred to *E. megacephalus*.

The strong tendency of Case and, following him, Smith to assign specimens of *Diplocaulus salamandroides* is evident in their Pond Creek lists, as it was in those given earlier for other sites. Without doubt the larger specimens at this site belong to *D. magnicornis* and, as in other cases, it is highly probable that the smaller individuals identified as *D. salamandroides* are immature individuals of the same species.

Smith's list includes *Bolosaurus* and he included a figure of this genus in his report. Nothing in the collections remotely resembles *Bolosaurus* and the figure is convincing only as long as it is not realized that it is a copy of a figure of *Bolosaurus* from Texas, a fact not made clear in the thesis. Authentic evidence is lacking that *Bolosaurus* comes from Pond Creek.

Captorhinus is known from vertebrae, partial skulls, and partial jaws. The generic assignment is unquestionable, but species assignment is uncertain. Were such materials found in the Arroyo of Texas or at Richards Spur, they would be placed in *C. aguti*, which is a broad form species. This assignment is the most reasonable for the Pond Creek specimens as well. Our collections contain vertebrae and skull and jaw materials of *Labidosaurus* that represent a large species with heavy sculpture of the skull plates. Evidently they pertain to *Labidosaurus hamatus*, the species characteristic of the Arroyo Formation in Texas.

In our collecting we found no trace of *Edaphosaurus* (*Naosaurus* of Smith). He figured a fragment, presumably from Pond Creek, and its generic identity is beyond question. On this basis it is retained in my list.

Dimetrodon is abundant. A partial skeleton, skull, and jaws were obtained in our collecting. These clearly pertain to *Dimetrodon grandis*. Romer and Price (1940) indicated the presence of *D. giganhomogenes* on the basis of vertebrae (see footnote, page 68). The various other species listed by Case and by Smith were based largely upon materials that were not complete enough for assignment and the names were given prior to the time that Romer and Price brought order into the taxonomy of *Dimetrodon*. Our collections did not include any materials of *D. giganhomogenes*, but on the basis of the

Romer and Price assignment this species is being retained for the present.

Both Case and Smith recognized the presence of *Poliosaurus*, a synonym of *Ophiacodon*. In the case of Smith's assignment at least, the specimens appear to be caudal vertebrae of *Dimetrodon*. Case's materials have not been restudied but probably his assignments also were based on specimens of this nature. The list presented here does not include *Ophiacodon* in the belief that these identifications were in error and the supporting fact that we found no trace of this genus in our collecting. Smith also identified *Clepsydrops*, a genus from the Pennsylvanian of Illinois. As Romer and Price (1940) pointed out for Texas collections, such assignments were based on misconceptions of the age and faunal relationships of the Illinois and Midcontinent Permocarboniferous assemblages (see Case, 1900; Cope, 1877).

Stratigraphy and age of beds.—The exposures at Pond Creek are isolated and cannot be related to others by direct surface tracing. The position in the column is clearly Garber, for the beds lie between well-defined Wellington to the east and Hennessey to the west. Their lithology and general position relative to the contacts above and below suggest that they are equivalent to the Lucien Member of the Garber. The beds may, however, be somewhat younger than those in the Lucien area. Nothing more definitive can be said at present.

The faunal list, with some exceptions, suggests that these deposits correlate with the Arroyo Formation of Texas. *Dimetrodon grandis* and *Labidosaurus hamatus*, for which identification is clear, are the more striking members. *Dimetrodon giganhomogenes*, if it be assumed that the presence is authentic, is a strong indicator of an age no earlier than that of the Arroyo Formation. *Diplocaulus magnicornis* is primarily an Arroyo species in Texas, but it is a common species in earlier deposits in Oklahoma and its presence seems to be more an ecological than temporal index. *Captorhinus aguti* and *Gnathorhiza serrata* are both Clear Fork species, but in each case the determination of their presence at Pond Creek is tentative. Most of the other genera and species are permissive of correlation with the Texas Arroyo, but are not in themselves definitive.

Archeria and *Sagenodus* pose problems. Both are typically Wichita. The question of the presence of *Archeria* has been raised but not answered. *Sagenodus* is present, but the only certain representative is a large, heavy partial tooth plate, which is not a typical Wichita form, although similar plates are known from Wichita beds.

It is not, of course, expected that all genera and species had precisely equivalent ranges over the areas in question. The general characteristics of the faunal assemblage are more important in determination of age relationships. In the case of Pond Creek, the cast of the fauna is distinctly Arroyo, with some possible persistence of a few genera and species that are typically from earlier beds in the Texas section. This locality thus strongly supports the assignment of at least part of the Garber as a correlative of the Texas Arroyo.

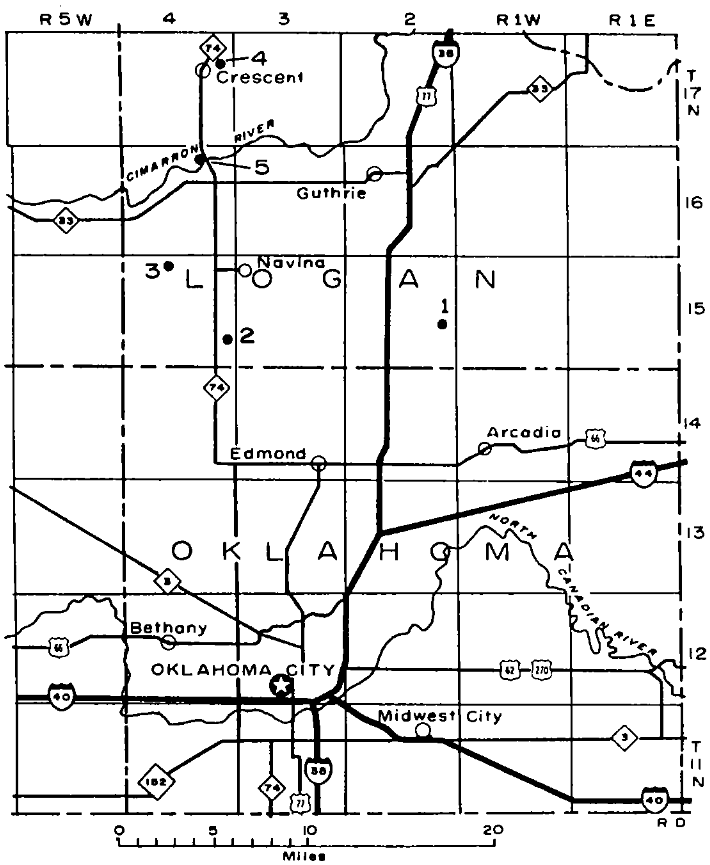


Figure 10. Map of central Oklahoma, showing locations of fossil sites north of Oklahoma City. The principal sites for *Cotylorhynchus* are south of the area shown here.

1 **Bean Farm site; Garber Formation**
2 **Northwest Edmond site; Hennessey-Garber transition beds**
3 **Navina site; Hennessey Formation; source of holotype of *Cotylorhynchus romeri***
4 **Crescent site; Hennessey-Garber transition beds; source of holotype of *Labidosaurikos meachami***
5 **South Crescent site; Hennessey-Garber transition beds (pl. IIIA).**

HENNESSEY-GARBER TRANSITION ZONE

The Garber and Hennessey Formations meet in a transitional zone rather than in a sharp contact (figure 11). This zone consists of a 50-foot section marked by alternating and lenticular masses of sandstone and shale which interfinger in complex patterns. The shales are predominantly red and blocky, of the Hennessey type, but contain some sandy green bands and lenses. The sandstones are massive to cross-bedded and of the typical Hayward type. Lenses of fine mudstone conglomerate, rich in organic matter, also occur in the transition zone.

The transition phase is characteristic of the contact along much of the line of exposure from east of Norman, in Cleveland County, northward through Oklahoma County and into Logan County. West of the transition zone occur the characteristic Hennessey red shales, with minor lenses of sandstone and mudstone. These give way farther to the west to evenly bedded red-brown shales marked by resistant, indurated shale layers. To the east are the characteristic upper Garber sandstones.

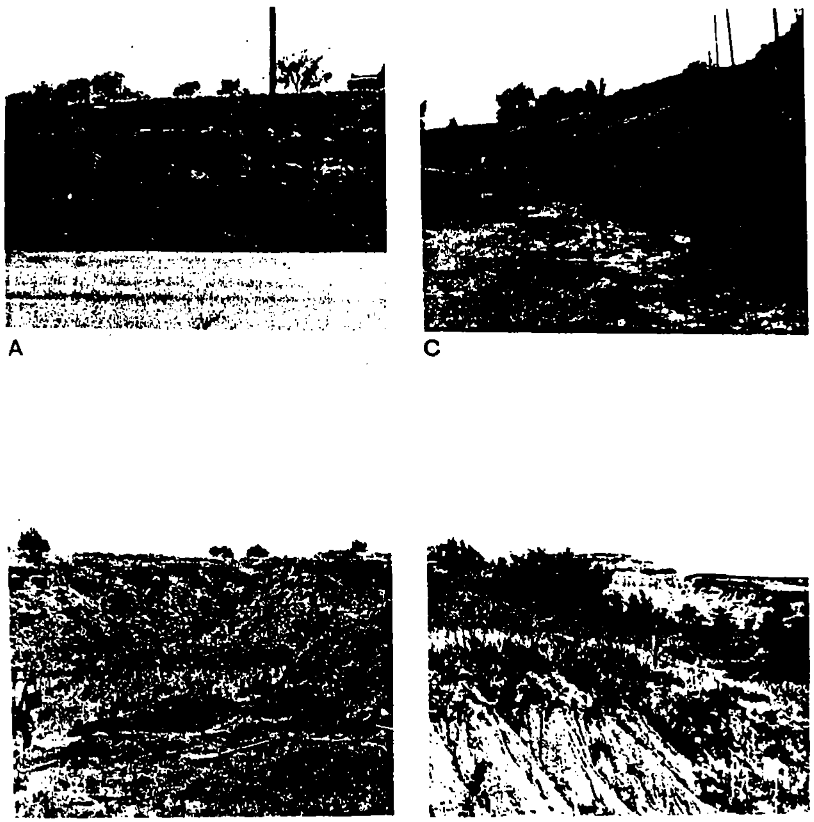
Fossils have been found at several places along this band of transition. The producing sites have yielded a distinctive faunal assemblage, not known from the underlying Garber or from the overlying Hennessey. Specimens from sites known prior to the present study have been assigned to the Garber or to the Hennessey, depending upon whether specimens occurred in sandstone or in shale. The sites known to date are discussed below. The chances for discovery of additional sites and an enlargement of the knowledge of the faunal assemblage seem to be good.

Crescent Site

A small series of exposures east of Crescent, in Logan County, has produced a limited but interesting collection (Stovall, 1950). The site is in NE¼ SW¼ sec. 12, T. 17 N., R. 4 W., concealed from observation from section-line roads (fig. 10). Exposures continue into adjacent quarter sections but no fossils have been found outside the area specified. A section of about 25 feet reveals red shales and sandstone lenses. The red shales are of the typical blocky, red Hennessey type. Immediately east of the bone-producing site, which is in red shale, are thick sandstone lenses that interfinger with the shales. They rise above the producing shales in the section.

About 0.5 mile east of the site along the north-south section-line road on the eastern margin of section 12, are typical beds of the transition series. At the top is a bed of coarse "Garber-type" sand-

Plate III



A. South Crescent site. View is toward the west. Transition beds (irregularly bedded sandstones and shales) between the Garber and Hennessey Formations. White patches (plaster) at right side of exposure show position of vertebrate fossils.

B. Hennessey site southeast of Norman (SW¼ NW¼ sec. 13, T. 8 N., R. 2 W.). View is toward the southeast. Site from which small vertebrates have come.

C. Exposure of Hennessey Formation at Purcell, south of Norman. View is toward the south. Massive Purcell lenses are shown; the base of this section is at about the level of the top of the beds shown in B, above.

D. Exposure of Hennessey Formation, capped by Duncan Sandstone, at Carmac ranch, about 9 miles southwest of Purcell. View is toward the north. The Purcell lenses are at the base of the section, with about 80 feet of shale between the lenses and the Duncan Sandstone, shown in the upper center of the photograph.

stone that ties closely with the sandstone lenses in the fossil-producing area. At the base of the section along the road is the massive sandstone of the uppermost Garber, with inclusions of conglomerate lenses and mudstone. The bone-bearing shales lie about 50 feet above this Garber sandstone.

Two genera and species have come from this site: *Labidosaurikos meachami* Stovall and *Dimetrodon giganhomogenes* Case. Two specimens of the former and nine of the latter have been identified. They were in close association, although this is not clearly indicated in Stovall's description of *Labidosaurikos meachami* (Stovall, 1950), the holotype of which is from this site. In working over the collections in the Stovall Museum, a vertebra of *L. meachami* was found in a collection of *Dimetrodon* vertebrae from this site, strongly suggesting intimacy in occurrence.

South Crescent Site

About 5 miles south of Crescent where State Highway 74 crosses the Cimarron River the road cuts have revealed excellent exposures of the Garber and Garber-Hennessey transitional beds (pl. IIIA). A few fossils have come from this site. A section taken from river level up to the road cut and through a fossiliferous zone north of the river on the west side of the road (SW¼ SE¼ sec. 2, T. 16 N., R. 4 W., fig. 10) is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
7	Pleistocene and Recent sand	15.0
6	Red shale, green-banded, grading into sandstone toward the north end of the exposure	4.0
5	Platy, red-green, cross-bedded sandstone, pinching out in places. Plant impression in red sandstone	1.6
4	Mainly red shale. Three feet above base is a zone of red and green sandstone and conglomerate. This zone is patchy and thickens northward and carries bone	4.0
3	Coarse conglomerate	1.0
2	Massive red sandstone, cross-bedded in places. Some lenses of mudstone conglomerate	28.0
1	Covered with alluvium, mostly red sandstone, to river level	6.0

The thick basal sandstone is taken to be the top of the Garber Sandstone. Between this and the Pleistocene, the beds belong to the Garber-Hennessey transition zone. About 0.5 mile to the south, in cuts along the road to the south of the river, the massive sandstone extends higher in the section and shales are poorly developed. To the east, immediately across the road from the measured section, the section is markedly different because of rapid lateral variation.

The fossiliferous bed and those immediately above it appear to represent deposits formed lateral to the moderately large stream which lay about 50 yards to the north. The bones and plants occur in lenses lying lateral to this main channel.

Several fragments of bone were found. The best is a partial skull and associated cervical vertebra of *Labidosaurikos meachami*. The brain case is well preserved and should give considerable added information concerning the morphology of this large captorhinomorph. None of the other material was identifiable. A plant frond from red sandstone appears to be a "fern" of the general *Gigantopteris* type.

Northwest Edmond Site

Exposures in southwestern Logan County, about 7 miles northwest of Edmond (NW¼ NE¼ sec. 25, T. 15 N., R. 4 W., fig. 10), were collected extensively by the staff of the Stovall Museum. The exposures are wide open and lie on a tributary of Cottonwood Creek. They are called Garber in the collection notes of the Stovall Museum, but rather seem to be in the Garber-Hennessey transition zone. Massive Garber sandstone appears at the base of the section in this area, followed by a series of shales, sandstones, and mudstones.

A section was taken here following the creek bed westward and then northward. It is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
6	Sandy soil, formed by weathering to top of bed 5, variable thickness	2.0-5.0
5	Lenticular masses of red mudstone with green streaks. Discontinuous over area of exposure. Vertebrates	0.0-1.6
4	Red shale with green sandy patches. Probably source of good *Dimetrodon* material in Stovall Museum	8.0
3	Light-colored, friable red sandstone, with green sandstone at base. Slightly cross-bedded. Some plant remains	2.6
2	Red sandy shale, cross-bedded, with green stringers, grades to red sandstone at top	7.0
1	Red to brown, massive sandstone, platy in places. Exposed in creek bottom about 150 feet north of east-west section-line road	4.0+

Excellent specimens of *Dimetrodon giganhomogenes* have come from these beds. Most have come from beds 4 and 5. Our collecting yielded remains only from the lenses of bed 5, but notes in the Stovall Museum indicate that the skeletal materials came from the red shale proper (bed 4). In addition, some fragments of *Diplocaulus* have been found in bed 5. They could pertain to *D. magnicornis*, *D. recurvatus*, or *D. brevirostris*. No traces of *Labidosaurikos* have been found.

North Edmond Site

The North Edmond site is a small area of exposures in the transition zone in SE¼ SE¼ sec. 1, T. 14 N., R. 4 W., with an exposed section about 30 feet thick. This section includes the usual red shale, sandstone, and mudstone, with rapid lateral variation. The section extends into SW¼ SW¼ sec. 6, T. 14 N., R. 3 W. Little work has been done at this site and the prospects of a good fauna seem slight. Scraps of *Diplocaulus* sp. and *Dimetrodon* sp. were found.

South Covington Site

William E. Wrather reported a few fragments of vertebrates at a site designated merely as "6 miles south of Covington." The specimens are in the Stovall Museum. The exact site from which they came has not been located but the area is predominantly one in which a thick section of Garber is overlain by transition beds to the Hennessey. The fossils are well preserved and almost certainly came from a red shale. It seems most probable that the specimens came from the Garber-Hennessey transition zone. The following have been identified:

Diplocaulus sp.
Labidosaurikos cf. *L. meachami* Stovall
Dimetrodon cf. *D. giganhomogenes* Case

Labidosaurikos is represented only by a fragment of vertebra so species assignment is not possible, although it probably does pertain to *L. meachami*, the only species known in Oklahoma. Scraps of *Diplocaulus* are present and remains of *Dimetrodon* include limb bones and pieces of spines. The latter probably can be assigned to *D. giganhomogenes*, but the available specimens are not entirely diagnostic.

Age of the Transition Beds

Although only three genera are known, they provide considerable information upon the probable correlation of beds of the transition zone with the Texas section. *D. giganhomogenes* indicates Clear Fork age, Arroyo through middle Choza. *Labidosaurikos*, however, is not known in the Arroyo, ranging from the early part of the Vale into the Choza. The Vale and Choza species were designated as *L.*

barkeri Olson (Olson, 1954). Seltin (1959), however, suggested that this species was not distinct from *L. meachami* Stovall. The specimens now at hand indicate that this is probably correct, as far as Vale specimens are concerned. These are large, heavy forms with teeth much like those of *L. meachami.* The Choza materials appear to pertain to a more lightly built form with fewer rows of teeth than are found in *L. meachami.* This interpretation depends upon the assumption that the Choza specimens have come from mature individuals, which the degree of ossification of postcranial elements suggests to be the case.

A specimen from low in the Vale, MCZ 1352, corresponds closely to *L. meachami* as far as details of the preserved jaw can show (see Romer and Price, 1940, pl. 22, for illustration of this specimen). Materials from locality KI in the middle Vale are large and robust and probably pertain to *L. meachami* as Seltin has suggested. All of these assignments suffer from the fact that almost all the materials are fragmentary.

From the information available, it would seem that *L. meachami* of Oklahoma is close to the Vale species of Texas, and that the name *L. barkeri* of Texas should be confined to Choza specimens.

On these rather weak grounds, it appears that the Garber-Hennesey transition beds are correlatives of the Vale of the Texas section. They are clearly post-Arroyo and certainly not younger than the lowest Choza.

HENNESSEY FORMATION

The name Hennessey was formally applied to a series of red shales in central and north-central Oklahoma by Aurin, Officer, and Gould (1926). Two members were recognized, a Fairmont Member, composed of about 250 feet of deep-red clay shale, and a Bison Banded Member, composed of red shales and laterally extensive green bands or streaks. The Bison Banded Member is well exposed in Garfield County but is areally restricted. The Fairmont Member is more widespread. In the northern and north-central parts of the State the Cedar Hills Sandstone forms part of the upper Hennessey, grading into the Hennessey shales southward (Fay, 1962).

The formation over its full extent is complex. As shown by Miser (1954) on the geological map, it covers a considerable area extending in a roughly northwest-southwest band from Alfalfa and Grant Counties to Norman in Cleveland County and southward

into central Stephens County. From there its outcrops bend westward to Duncan and then to central Comanche County. It continues on in a narrow band north of the Wichita Mountains well into Greer County. Exposures in Jackson and Tillman County, in southwestern Oklahoma, have been considered earlier (p. 24).

A great deal of variation in lithology occurs over this geographic range and the formation does not retain the integrity of type that is desirable for a coherent formation. It would be better treated as a group. The Bison Banded Member and the gray Hennessey, such as occurs in Stephens County, represent lithological extremes. Part of the formation is nonmarine, part nearshore marine, and part probably was deposited under fully marine conditions. A thorough study of the beds encompassed under this formational name is needed and many questions concerning the nature of its deposition and the relative ages of different parts remain to be answered.

Problems related to relative ages and the nature of deposition of vertebrate-bearing parts of the formation are relatively minor for the reason that in central and northern Oklahoma vertebrates have been found only in two places, both in the Fairmont Member and not far apart. The questions that do arise will be treated in context. The most productive region is in the vicinity of Norman, Cleveland County, where beds to the north, east, and south of the city have yielded a large number of specimens. About 40 miles to the north, in the vicinity of Navina, Logan County (figure 10), a second find has been made. Otherwise the beds so far have proven barren.

Fairly extensive exploration was carried out in the course of the current study and it failed to turn up any significant vertebrate sites outside of these two areas. Partly this seems to be a consequence of the predominantly marine character of much of the Hennessey. What production there is has come from red shales and this may also in part account for the failure to find other sites. In the Norman area only large, heavy bones find their way to the surface through the weathering of the red shales. Where a fresh cut passes through a bone-bearing layer, smaller and more delicate bones may be found, but such bones do not survive normal weathering. This situation may have resulted in the failure to find pockets that actually are present. One such site, containing small specimens, was found and worked about 20 years ago. In 1966, it was possible to locate this rich site only where surface scrap was detected by a hand-and-knee search.

Norman Sites

The red Hennessey shales around Norman, Cleveland County, are well known for their production of the large pelycosaur *Cotylorhynchus romeri* Stovall. The sites in this area are listed in a monograph on the Caseidae, of which *Cotylorhynchus* is a member (Olson, in press). They are scattered over an area about 20 miles long (north-south) and 5 miles wide eastward. Norman is more or less central to this area. The deposits are predominantly bright-red shale, which includes lenses and beds of sandstone, siltstone, and mudstone. Some of the beds are green, but the dominant color is red.

No particular distributional significance seems to attach to the finds of vertebrates. They are largely in the red shales and range through about 100 feet of section, beginning at a level about 75 feet above the base of the Hennessey Formation. Generally there tends to be some disruption of the even bedding of the red shales at the collecting sites, and mudstone conglomerates may be present. The specimens, however, are mostly in the red shale itself.

The section of the Hennessey Formation given below is typical for the Norman region. It was taken in NW¼ sec. 13, T. 8 N., R. 2 W. (pl. IIIB). The base is in a road ditch to the north of the road, 0.7 mile east of NW cor. sec. 13. The section, above the covered portion, carries southward about 50 feet east of the western margin of section 13. The measurements and lithology are as follows:

BED	DESCRIPTION	THICKNESS (FEET)
14	Coarse clastic; base of green fissile shale. Remainder coarse brown sandstone	3.0
13	Uniform red shale	2.0
12	Hard green sandstone, increasing in thickness northward	0.5
11	Red shale with local lenses of sandy shale	29.0
10	Sandy siltstone and shale, ranges in thickness from 6 inches to 6 feet (see beds 8 and 9) (= beds 8, 9, & 10)	6.0
9	Red shale, passing laterally into sandy siltstone (= bed 10)	3.0
8	Hard green sandstone, pinching out laterally, but elsewhere passing under red shale (bed 9) to merge with bed 10	1.5
7	Uniform red shale	7.0
6	Red and green thin-bedded, fissile sandy shale	5.5
5	Red shale, sandy in places, bone in 5-foot intervals beginning 5 feet above base	18.0
4	Red and green, fissile sandy shale	0.5
3	Red shale, base not exposed	5.0
2	Covered interval, some red shale in patches near top	58.0
1	Sandstone, top of brown sandstone near top of Garber-Hennessey transition zone	2.0+

Vertebrate sites occur largely in beds ranging from bed 4 to bed 13. Detailed correlations with various producing sites have not, however, been made and this must be considered an approximation.

To the south, production of vertebrates is not known beyond the latitude of Noble, Cleveland County, a little more than a mile south of the section given above. In this direction heavy sandstone lenses, part of the Purcell lens complex, become a prominent part of the Hennessey. Excellent exposures occur west of Purcell in SW¼ sec. 5, T. 6 N., R. 2 W. (pl. IIIC). The Purcell appears in the cap rock at this site. The section is as follows:

BED	DESCRIPTION	THICKNESS (FEET)
4	Coarse clastics, sandstone, shale, and siltstone. Top massive sandstone. Lower part varied, with sandstone pinching and swelling	25.0
3	Uniform red shale, little structure	20.0
2	Indurated red siltstone	2.5
1	Uniform structureless light-red shale	35.0

The upper part of this section appears, on the basis of its elevation and sedimentary characters, to be equivalent to the highest beds in the measured section to the north, in section 13. This massive series of sandstone lenses is well developed at Purcell. At the fairgrounds in Purcell, the following section was measured up the eastward-facing scarp, starting at the level of the Municipal Tennis Courts.

BED	DESCRIPTION	THICKNESS (FEET)
10	Coarse hard mudstone	30.0
9	Variegated sandstone, mudstone, and siltstone with lenses of each type. Strongly cross-bedded in places	23.0
8	Alternating sandy shale and shale, predominantly red with green streaks and patches and fine purple mudstone conglomerate	4.0
7	Uniform red shale	3.5
6	Coarse sandstone and sandy shale, green at base, red above	4.0
5	Red shale	2.5
4	Green and red sandy shale, thins laterally	3.0
3	Uniform red shale	3.5
2	Red and green sandy shale	1.1
1	Red shale, uniform and structureless	8.0 to base

Westward from Purcell, along State Highway 122, toward Criner, the Purcell lenses occur at about road level. On the Carmac ranch, in sec. 17, T. 6 N., R. 2 W., is an excellent section (pl. IIID). At the top the Duncan Sandstone forms a cap rock. Below this cap rock, the base of which marks the Duncan-Hennessey contact, a section of 80 feet of uniform red shale is exposed. The homogeneity is broken only by the presence of some indurated beds of shale, 1 to 2 feet thick, which form subdued ledges. The lower part of the section at this site, exposed mainly along State Highway 122 to the south of the main exposures, includes sandstone and mudstone lenses that appear to be roughly equivalent to the upper parts of the section at the Purcell fairgrounds. Throughout this area from section 13 south of Norman to Purcell and west to the Carmac ranch, the equavalencies are only approximate. They suggest a formational thickness of about 300 to 350 feet from the top of the Garber-Hennessey transitional beds to the base of the Duncan.

The only traces of vertebrates that have been found south of Noble are small fragments of bone and coprolites in the small exposures of Purcell lenses north and south of the highway from Purcell to Criner. The exposures look reasonably favorable for vertebrates when compared to the producing sites around Norman, but intensive searches have turned up nothing of significance.

Vertebrates.—Except for *Cotylorhynchus romeri*, vertebrate remains are scarce in the Hennessey beds around Norman. Now that they have been thoroughly collected as far as this genus and species is concerned, the beds are in large part barren of exposed vertebrate remains. The faunal list is small. To date the following have been identified:

Osteichthyes
Gnathorhiza sp.
Amphibia
Lysorophus cf. *L. tricarinatus* Cope
Reptilia
Captorhinikos chozaensis Olson
Cotylorhynchus romeri Stovall

Cotylorhynchus has been found at some 20 or more sites, all close to Norman (see Olson, in press). *Captorhinikos chozaensis* has come from three sites. One of these, in SW¼ NW¼ sec. 13, T. 8 N., R. 2 W. (pl. IIIB), has also yielded a wealth of other materials. This site is included in the section on pages 80-81. In the clean red shale, through a zone about 5 feet thick, is a concentration of

small vertebrate remains. By far the most abundant are bones of the amphibian *Lysorophus*. Most of the specimens consist of nodular agglomerations of vertebrae and ribs, in many cases including more than a single individual. Skulls are present in some nodules. In addition there are scattered specimens and from these a number of excellent skulls have been obtained. This amphibian is close to *Lysorophus tricarinatus*, but some features of the skulls suggest that the Hennessey species is somewhat different from that of the Texas Arroyo, which is generally referred to *L. tricarinatus*. Detailed studies will be necessary to assess the systematic position accurately.

In addition to *Lysorophus*, parts of skulls and jaws of other small animals are present. One is a *Captorhinikos*-like animal that may represent juvenile individuals of *C. chozaensis*. Skulls are between 1 and 2 cm long. Fragments of at least one other small amphibian or reptile, with skull length of about 1 cm, also occur. It is hoped that additional collecting and study will give better information on these creatures.

The only fish remains that have been found consist of fragments of *Gnathorhiza*. To date a partial skull, a lower tooth plate, and scraps of skull elements have been found.

The fauna, limited as it is, shows two important things. First it indicates that these beds, which lie between 75 and 200 feet above the base of the Hennessey, are equivalent to the Choza in age. This equivalence is based primarily upon the presence of *Captorhinikos chozaensis* Olson (Vaughn, 1958b; Olson and Barghusen, 1962). It may belong anywhere in the lower half of the Choza, for this genus is found throughout this part of that formation. *Cotylorhynchus romeri* is not known in the Texas formations, but in the middle Choza *Casea halselli*, which is apparently somewhat more primitive, is present.

The second important item concerning this assemblage is that it indicates that the area in which it occurs was suitable for vertebrate habitation at the time of deposition. *Cotylorhynchus* occurs partly as complete skeletons and partly as separate bones and articulated segments of skeletons. Probably the animals underwent some transportation prior to deposition. *Lysorophus*, however, occurs in the typical nodular concentrations, suggesting aestivating swarms much like those of the Texas Permian (Olson, 1956a). Clearly they lived in the area of burial. The remains of the extremely small reptile probably could not have survived any extensive transportation, and the animals from which they came also must have lived in the vicinity of burial. The Hennessey in the Norman area, judged on the basis of this evidence, was deposited under nonmarine conditions. Probably it was close to the sea margin and there may well have been short times of nonmarine deposition in a dominantly marine situation.

The assemblage is interesting in its odd bias. No large carnivores are known. A few bone-bearing coprolites have been found, the largest being about one inch long. *Dimetrodon*, which is abundant at many sites in the pre-Hennessey and the Hennessey-Garber transition zone, has not been found in the Hennessey proper. At present, evidence is insufficient for meaningful speculation of the factors that went into the production of the bias, and will remain so unless productive areas in addition to those now known can be found.

Navina Site

The holotype of *Cotylorhynchus romeri* came from the Navina site, about 4.75 miles west of Navina, in Logan County in NW¼ sec. 4, T. 15 N., R. 4 W. The section consists mostly of red shales that include lenses of sandstone and minor amounts of mudstone conglomerate. Stovall (1937) placed it about 200 feet above the base of the Hennessey Formation. Only one specimen has come from this site, not two as indicated by Stovall (see Olson, in press, for discussion).

The lithology is in all respects, similar to that in the Norman area. Schweer (1939) published a section of the Hennessey Formation from Guthrie to Kingfisher. Because it is appropriate to the area in which the Navina site is located it is reproduced, with slight modifications in form, in this paper as figure 11. In contrast to the section presented earlier, the Cedar Hills Sandstone is present and the Purcell lenses are absent. Fay (1962) noted that the name Piedmont sandstone in Shweer's section is preoccupied and thus must be dropped. The total thickness is 675 feet, evidently considerably thicker than that to the south, for which we can give only an approximate thickness of about 300 to 350 feet.

Extensive search for other vertebrate sites, near Navina and elsewhere, have failed to produce a trace of fossils of any sort. The distribution of remains appears to be extremely spotty and it is certainly not unlikely that remains will be found elsewhere in time to come. Conditions of deposition seem to differ little throughout the lower part of the Hennessey from those at producing sites around Norman and near Navina. The higher beds appear to be more consistently marine, being largely even-bedded shales with small

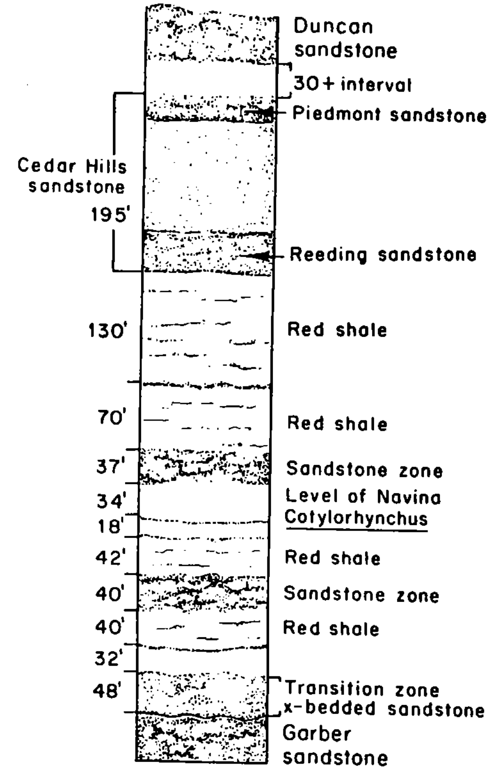


Figure 11. Columnar section of the Hennessey Formation from Guthrie, Logan County, to Kingfisher, Kingfisher County (modified from Schweer, 1939). Note Hennessey-Garber transition beds and stratigraphic level of *Cotylorhynchus romeri*, the highest occurrence of fossil vertebrates known in the Hennessey Formation.

amounts of sandstone. They weather deeply and erode to produce low, rounded hills. The chances of finding preserved materials, presuming that they do exist, are thus reduced.

Summary

The Hennessey Formation has yielded a limited but extremely interesting faunal assemblage that has come only from the lower 200 feet of the section and only from sites in the vicinity of Norman, in Cleveland County, and Navina, in Logan County. Much of the widespread Hennessey has thus far failed to yield vertebrate remains, and furthermore, it is peculiarly devoid of any fossils, vertebrate, invertebrate, or plant. It has been tested for pollen, but none has been found. The portions that have yielded vertebrates appear to be equivalent in age to the Choza Formation of Texas (Clear Fork Group). It may extend as high as the middle Choza. The underlying transition beds appear to be of Vale age. The so-called Hennessey of the southwestern part of the State (see p. 24) is an Arroyo equivalent and thus does not correlate with the Hennessey proper.

Over its full range the Hennessey includes a large variety of lithotypes and these each have considerable geographic extent and stratigraphic continuity. Until such time as a thorough stratigraphic study is made, it appears best to follow the practice of considering these different units as members, but such study may prove that consideration of the Hennessey as a group rather than a formation will be advisable.

COLLATION AND SUMMARY

The study reported in the preceding pages was undertaken as part of a broad program of study of the vertebrate animals of the Permian of Oklahoma. It was initiated after studies of the El Reno Group had shown that a better understanding of the older beds was necessary for an interpretation of their history. Neither the vertebrates nor the stratigraphy of the Lower Permian beds had received more than sporadic and passing attention, and this report is a first and preliminary step toward rectification of this situation. It has outlined the information that is now available, given tentative conclusions, and indicated the directions that work must go for solution of the problems that remain. One aim has been to establish the temporal relationships of the vertebrate localities of Oklahoma to the better known localities of Texas. A second has been to provide a framework within which the faunas of the various vertebrate-producing areas of the United States might be considered together. Oklahoma can fill an important gap in this latter endeavor.

Correlations of the Oklahoma and Texas Sections

Figure 12 has been prepared to show, as far as is now possible, the time relationships of the sections in the different regions of Oklahoma with the terrestrial Permian section of Texas. Because of the absence of a well-established and detailed nomenclature of the strata in some parts of the State, site and area designations have been used to avoid ambiguities.

WICHITA BEDS

The Wichita section of southwestern Oklahoma is essentially continuous with the Texas section, but detailed stratigraphic work will be required to bring the two into close agreement. Judged on a faunal basis, the Wichita beds, or the Wellington and Garber of some authors (see Bunn, 1930), include Belle Plains and perhaps Admiral equivalents. The majority of sites have a Belle Plains cast. The Oklahoma section also includes the Deep Red Run sites in the Wichita, or Wellington-Garber, array. Discussion of these is deferred because they appear to be Clyde equivalents. Even if they are included, no clearly Garber equivalents appear in this section of gray and maroon shales and sandstones. If the Garber is more or less an equivalent of the Arroyo, as its faunal assemblages to the north indicate, then the Garber equivalents in the southwestern

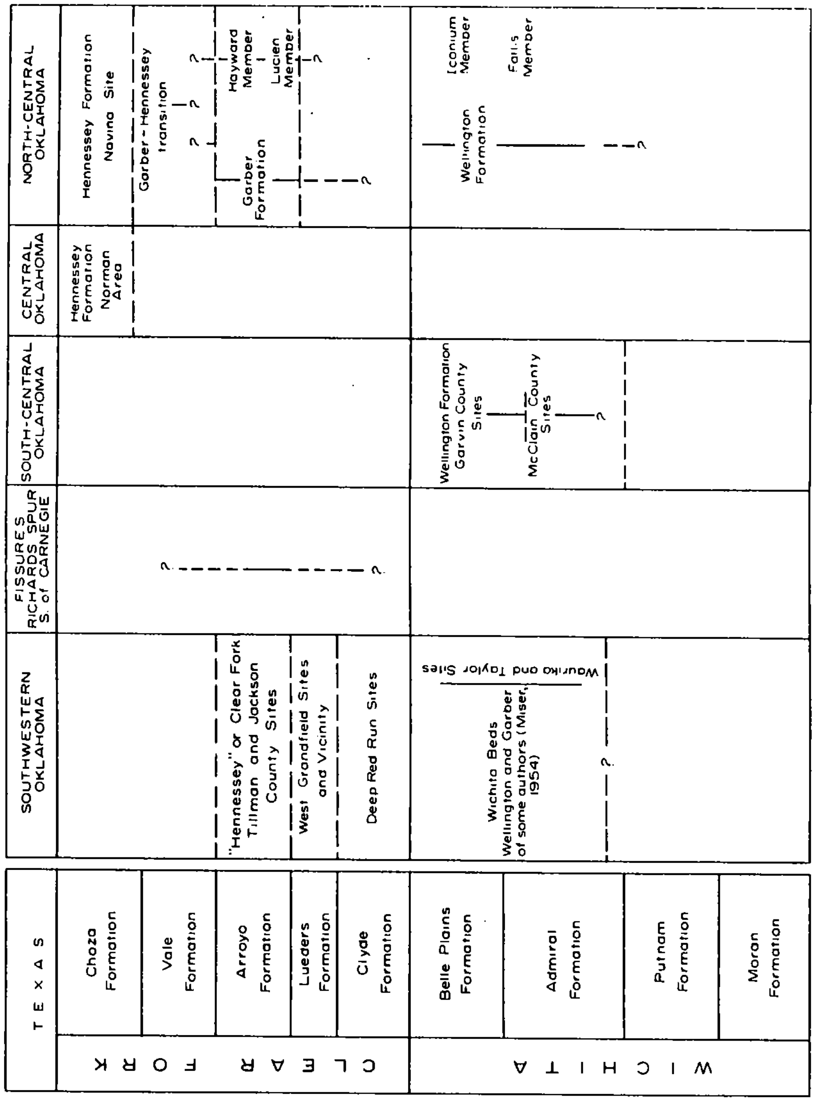


Figure 12. The temporal relationships of the vertebrate-producing sites and formations of Oklahoma and the Lower Permian formations of Texas. The Texas section is that of Archer, Baylor, Knox, Foard, and Hardeman Counties. Correlations are those indicated by vertebrate occurrences.

part of the State must be the so-called Hennessey beds at the western end of the section.

South-central Oklahoma includes sites that are clearly Wichita equivalents, apparently closely related to the Belle Plains and Admiral Formations. The oldest site is near Byars, in McClain County. No fossils are known above Dott's (1930) unit 5, which is considered to be Belle Plains. The beds of units 6 and 7, called Garber by Dott, may well be correlated with the Garber Formation, in contrast to the upper gray and maroon beds of the southwestern section.

The central part of Oklahoma, in the vicinity of Norman and somewhat to the east, includes beds that are Wellington and Garber on the basis of stratigraphic position and lithology, but no fossils have been found to confirm or deny this interpretation. From the Cimarron River northward, the Wellington is well differentiated and many fossil sites are known. In the southern portion of this region red sandstones and shales predominate, as at the Orlando site. In the vicinity of Perry, red dolomite and shale sequences are encountered, and to the north and northeast gray shales and dolomites become prominent. In each of these sections, thin sandstones, with their source to the east, are interbedded with the shales and dolomites.

The finest assemblages of Wellington vertebrates come from this region. Some of the species show close affinities with those of the Admiral and Belle Plains Formations of Texas, but the assemblages differ markedly in percentages of common genera and species and in the presence in each area of species not found in the other. Apparently faunal continuity existed between Texas and Oklahoma at this time, but local ecological conditions differed sufficiently to produce contemporary communities that exhibit significant differences. In the redbed deposits, such as at the one at Orlando, conditions appear to have been more like they were at later times in Texas, during Arroyo time, and to contrast with the general wet, lowland, marshy deposits so characteristic of the Admiral and Belle Plains of Texas. *Diplocaulus* and *Crossotelos* are dominant in the fauna. The former is abundant in the Texas Arroyo, but not in the Wichita beds. The latter genus is known in the Clyde and Arroyo of Texas, but only from a few specimens. *Lysorophus* and *Gnathorhiza*, aestivators, are present, and again are not characteristic of the Wichita beds in Texas, but well developed in the Arroyo and Vale beds of the Clear Fork. The pelycosaurs, however, are Wichita types.

The more northerly Wellington is sedimentologically different from the upper Wichita beds of Texas. The even-bedded shales and dolomites and occasional sandstones seem to have been deposited in a nearshore marine to nonmarine series of a somewhat cyclothemic nature. Like the Orlando beds, but in a different way, they contrast both in conditions of deposition and faunas with Texas deposits. Some assemblages, such as that from the sandy shale lens of Perry site 6, are typical of the Belle Plains type. The nature of deposition likewise is much the same. This seems to indicate that faunas similar to those of Texas were in the area, but that for the most part they did not live in the places represented by the deposits that we know today. The sandstone wedges, from the Fallis Sandstone, which is more fully developed to the east, include some elements from both ecological types, but on the whole are closer to the Texas faunal assemblages than to those of the gray shale and dolomite of the Wellington.

The Texas and Oklahoma areas in addition have some distinctive genera and species that cannot be accounted for on the basis of markedly different life zones alone. *Labidosaurus oklahomaensis* and *Archeria victor* are examples. These appear to have been ecological equivalents of their Texas counterparts, probably developed as a result of partial isolation that barred easy communication of some species between the regions.

ARROYO (CLEAR FORK) EQUIVALENTS

The "Hennessey" of Tillman and Jackson Counties and the Garber of north-central and northern Oklahoma appear to be equivalents of the Arroyo Formation. The faunal assemblages leave little question of this relationship, for a similar ecological zone appears to have contributed to the fossil deposits over the full range. The Lucien-Garber vertebrate-bearing deposits are restricted ecologically, being predominantly pond accumulations. This restriction reduces their usefulness in correlation, for the pond assemblages appear to have been stable. The best guide in the north is the Pond Creek site which has an unmistakably Arroyo cast.

VALE (CLEAR FORK) EQUIVALENTS

The only equivalents of the Vale Formation in the Oklahoma section, as known at present, are the sites in the Garber-Hennessey transition zone. The assignment depends upon the presence of *Labidosaurikos meachami*. This genus and species is associated with *Dimetrodon giganhomogenes* and *Diplocaulus* sp. The last two, although permissive, are not definitive. Below this zone lies the

rather thick section of Garber Sandstone, which lacks definitive vertebrates; the few specimens that have been found are fragmentary. Thus some 300 feet of section represents a significant time gap.

CHOZA (CLEAR FORK) EQUIVALENTS

The first evidence of beds that are correlative with the Choza Formation of Texas occur about 75 feet above the Garber-Hennessey transition zone. Except for one specimen from near Navina, all known materials have come from near Norman, where they range through about 125 to 150 feet of the lower part of the Hennessey Formation. The best known vertebrate is *Cotylorhynchus romeri*, known elsewhere only in the Chickasha Formation of Oklahoma and the San Angelo Formation of Texas, El Reno and Pease River Groups, respectively. The definitive species is *Captorhinikos chozaensis*. *Lysorophus*, *Gnathorhiza*, and some undetermined small reptiles are present. None of these is definitive, although they are not in conflict with a Choza assignment of the Norman Hennessey.

The upper part of the Hennessey Formation has yielded no fossils, although it has been explored rather thoroughly. It is not until the Chickasha beds at the level of the middle part of the Flowerpot Shale are encountered that identifiable vertebrates again appear. Some scraps have come from the intervening Duncan Sandstone, but they are not determinable. Perhaps in time better Duncan materials will be found. At present, however, there remains a large gap, ranging from several hundred to nearly 1,000 feet of section between the producing Hennessey beds and the fossiliferous Chickasha beds.

Paleozoogeographic and Faunal Implications

An objective of this study of the Lower Permian of Oklahoma was to determine to what extent its vertebrates may have been ancestral to those of the Chicaksha Formation of Oklahoma (Olson, 1965b) and the San Angelo Formation of Texas (Olson and Beerbower, 1953; Olson, 1962). Both of these Late Permian assemblages contain some elements that had not been identified in the earlier Permian, as known from Texas, New Mexico, or the Dunkard Series of the eastern United States. The studies made of the Lower Permian of Oklahoma now seem to indicate that this holds true as well for the deposits of this State. No definite source for the therapsid-like elements has been found.

A dominant component of the San Angelo and Chickasha assemblages, however, is the family Caseidae, represented in particular by *Cotylorhynchus* and *Angelosaurus*. It was already well known, of course, that *Cotylorhynchus* was fully evolved by Hennessey times and well represented in that formation. No clear source of this genus is known from the Clear Fork of Texas. *Casea halselli* of the Choza Formation, a contemporary, lies the closest to it. The pre-Hennessey Permian beds of Oklahoma show no trace of ancestors of *Cotylorhynchus*. On the contrary, they are in large part faunally similar to contemporary beds in Texas.

As was noted in discussion of the Chickasha faunas, the only known possible antecedent assemblage is the nearly unique one recorded at the Arroyo-Vale boundary in Texas. A possible source, much earlier, is found in New Mexico, in the Abo Member of the Cutler Formation, which is marked by the presence of *Aerosaurus*, which is close to *Varanops* of the *Cacops* bone bed. The assemblage, however, contains no caseids. It seemed possible, as this work was undertaken, that some evidence of this fauna might turn up in Oklahoma, but to date this has not been the case.

Of the several regions in North America from which pre-Hennessey Permian vertebrate fossils have come, the Texas and Oklahoma areas appear to be the most closely allied. The New Mexican faunas appear to have been about equally distinct from each of these two. The same applies to the assemblages known from the Dunkard in eastern United States. Colorado faunas appear to be more of the Texas and Oklahoma type. Evidence of faunal contact between Texas and northern Oklahoma during the time of deposition of the Oklahoma Wellington and the Garber is strong. The faunas overlap broadly, and major differences are those due mostly to the differences in the ecology of the animals that are preserved. These ecological factors probably were in large part local. A few unique animals existed in one area or the other but not in both, showing that overlap was not complete.

Only at the level of the Hennessey Formation does faunal discontinuity appear. This discontinuity was by no means absolute, for the Hennessey and Choza Formations have common genera and species. *Cotylorhynchus* is the genus that gives the two a different cast. That this genus is to be accorded considerable significance is suggested by the marked deployment in both kinds and numbers of caseids in the higher beds, the Chickasha and San Angelo Formations. The source is unknown, except as it may lie in *Casea*, the latter being known from a few finds in the Clear Fork of Texas.

The abundance of *Cotylorhynchus* in the Hennessey and later faunas, however, indicates that the Hennessey species came from an already well-established faunal complex. One of the oddities is that this complex did not seem to include *Dimetrodon*, the dominant carnivore throughout much of the Early Permian in Texas and Oklahoma up to the time of the Hennessey. *Dimetrodon* is the most abundant element in the Garber-Hennessey transition beds. It may, of course, have been an associate of *Cotylorhynchus* in the Hennessey, for its apparent absence may be a matter of preservation or sampling. But the contrary is suggested by the fact that *Dimetrodon* also is not an associate of *Cotylorhynchus* in the Chickasha and San Angelo Formations. Two specimens were found in the San Angelo, but none was found with the concentration of *Cotylorhynchus* at the Kahn quarry. The Hennessey fauna, incompletely known as it is, does appear to be something new and the one which could have provided the caseid element to the later faunas. Where this part of it came from is not known.

The Kansas deposits, as presently known, provide no help in this matter. Vertebrates are sparse and those known are low in the section. In Kansas, as in Oklahoma, much exploration remains to be done. The chances for significant results with respect to the origin of higher faunas in Kansas seem remote at present. It is not, of course, out of the question that new finds in Oklahoma will materially alter the picture, but the explorations carried out to date both in our and earlier studies offer little hope in this direction. Undoubtedly modifications will be made, but at present it appears that these will be too small to alter radically the current understanding.

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APPENDIX

List of Cataloged Specimens

The specimens listed herein are arranged according to localities and sites noted in the text; sites which yielded no identifiable specimens are not included. The term "locality" refers to an area over which a number of sites of similar age have been found. Sites are restricted collecting areas, generally covering no more than a quarter section.

The specimens listed are mostly those used as a basis for the faunal lists of the sites. In a few instances, however, specimens that were not studied firsthand are included, and the identifications are those of others.

Specimen-number prefixes indicate repositories as follows:

AMNH	American Museum of Natural History
CNHM	Chicago Natural History Museum
FM or FMNH	Field Museum
KU	Museum of Paleontology, University of Kansas
MCZ	Museum of Comparative Zoology, Harvard University
OUSM	Stovall Museum, University of Oklahoma
UM	University of Michigan
USNM	United States National Museum
YPM	Peabody Museum, Yale University

WAURIKA SITE 1

Xenacanthus sp.: OUSM 1-26-S29, 200 to 300 teeth.

Ganoids *(Ectosteorhachis?)*: OUSM 1-1-S12, fragments of skull, scales.

Diplocaulus sp.: OUSM 2-40-S5, vertebrae, limb elements, partial skull.

Archeria sp.: OUSM 2-7-S35, 16 vertebral centra, several individuals.

Trimerorhachis sp.: OUSM 2-40-S7, intercentra, skull plates, girdles, limb bones.

Eryops cf. *E. megacephalus*: OUSM 2-40-S6, fragments of skulls, vertebrae.

Diadectes sp.: OUSM 2-7-S5, 2 fragments of vertebrae; 2-25-S1, front tooth.

Ophiacodon cf. *O. uniformis*: OUSM 4-1-S10, partial maxilla; 4-40-S10, parts of several individuals, all small.

Dimetrodon cf. *D. limbatus*: OUSM 4-40-S7, parts of a small, immature individual; 4-40-S8, fragments of various individuals; 4-40-S10, several small individuals, miscellaneous elements.

Edaphosaurus cf. *E. boanerges*: OUSM 4-7-S15, 5 fragments of small individuals; 4-7-S20, spine fragment.

There are several collections other than the one listed above. The specimens listed are only those at the Stovall Museum used as the basis for assignments given in this paper.

WAURIKA SITE 2

Diadectes sp.: Skull and partial skeleton in Graffham collection, Ardmore, Oklahoma.

EAST TAYLOR SITE

Xenacanthus sp.: OUSM 1-33-S22 through 1-33-S24, coprolites; all from NE¼ NE¼ sec. 1, T. 5 S., R. 9 W.

Eryops sp.: OUSM 2-13-S3, partial femur, scrap; from NW¼ NW¼ sec. 3, T. 5 S., R. 9 W.

SOUTHWEST TAYLOR SITE

Xenacanthus sp.: OUSM 1-33-S33 through 1-33-S152, coprolites; 1-35-S3, spine (identified in collection as *Oracanthus*); 1-35-S1, spine (identified in collection as *Anodocanthus*).

Trimerorhachis sp.: UM 11670, 11671, 11685, fragments (not seen; information from Claude Hibbard).

Eryops sp.: OUSM 2-1-S33, 2 pieces of skull.

Dimetrodon limbatus: OUSM 4-7-S23, centrum; 4-10-S12, partial scapula, clavicle, vertebrae, ribs; 4-40-S12, partial skeleton, fragments of skull and jaw (young).

Edaphosaurus cruciger: OUSM 4-7-S22, spine; 4-40-S11, vertebrae, limb bones, ribs.

DEEP RED RUN LOCALITY

Cummins' Site

Ophiacodon major: AMNH 1814, 2 femora.

Dimetrodon macrospondylus: AMNH 4054, much of skull, column, some girdle and limb elements (not seen; list from Romer and Price, 1940).

Sec. 21, T. 4 S., R. 12 W.

Xenacanthus sp.: OUSM 1-35-S5, 3 spine fragments.

Eryops cf. *E. megacephalus*: OUSM 2-1-S39, partial skull; 2-40-S12, intercentrum, tooth.

Diplocaulus cf. *D. magnicornis*: OUSM 2-4-S11, posterior part of jaw; 2-7-S8, vertebra.

Dimetrodon sp.: OUSM 4-7-S21, spine, rib.

Sec. 13, T. 4 S., R. 12 W.

Diadectes sp.: USNM, unnumbered, 2 skeletons.

WEST GRANDFIELD SITE

Xenacanthus sp.: OUSM 1-35-S6, spine.

Diplocaulus magnicornis: OUSM 2-4-S12, lower jaw.

Dimetrodon cf. *D. giganhomogenes*: OUSM 4-7-S24, spine.

EAST MANITOU SITE

Orodus sp.: OUSM, unnumbered, tooth.

In addition, the Stovall Museum collections contain poorly preserved scraps, probably of *Dimetrodon* and *Eryops*.

NORTH MANITOU SITE

Xenacanthus sp.: OUSM 1-25-S24, several teeth, coprolite.

SOUTH SNYDER SITE

Trematops milleri: OUSM 2-1-S36, partial skull, jaws.

BYARS SITE

Zatrachys serratus: OUSM 2-0-S15, skull, jaws.
Diadectes sp.: OUSM 2-6-S1, 6 vertebrae.

SOUTH ROSEDALE SITE

Dimetrodon sp.: OUSM 4-7-S12, part of spine.

SOUTHEAST PAOLI SITE

Edaphosaurus cf. *E. boanerges*: OUSM 4-7-S11, fragment of a spine.

SOUTH PAULS VALLEY SITE

Eryops?: OUSM 2-12-S1, scapula, rib fragments.

NORTH KATIE SITE

Dimetrodon sp.: OUSM 4-12-S5, part of scapula.

VILLINES' SITE SOUTH OF ROSEDALE

Eryops sp.: OUSM 2-40-S4, fragments of skull, vertebrae.
Dimetrodon sp.: OUSM 4-40-S6, 2 centra, scrap.

RICHARDS SPUR SITE

The cataloged material from this site is a small part of the total collected. The specimens listed below are only a portion of the cataloged specimens, mainly those recorded in publications. Many of the specimens are composites and, in some instances, only the figured element or elements are listed. This partial list is a representative sample of the whole.

Xenacanthus sp.: FM, unnumbered, single tooth.

Cardiocephalus cf. *C. sternbergi*: KU 8967, skull; 9929, 9930, scapulocoracoids; 9931, 9932, sacral ribs; 9933, 9934, pelvis.
YPM 3681-3684, 3700, 3702, 3704, lower jaws; 3689, skulls; 3805-3812, humeri; 3813-3816, tibiae; 3818, ulna; 3819-3824, vertebrae; 3826-3829, fibulae; 3830-3833, femora; 3834-3837, radii; 3844, 3868, scapulocoracoids; 3846, 3850, pubes.

Euryodus cf. *E. primus*: YPM 3686, 3864, 3865, 3866, lower jaws; 3684, maxilla.

Captorhinus aguti: CNHM UR 338, 339, dentaries; 383-388, skulls and partial skulls; 389, 390, elements in matrix; 391, 9 anterior vertebrae; 392, front foot; 393, isolated frontal bones; 395, isolated parietal bones; 396, isolated nasal bones; 397, isolated caudal vertebrae; 398, 3 stapes; 400, scapulocoracoid; 401, about 45 partial lower jaws; 402, about 50 partial maxillae; 425, isolated premaxillae; 594-596, stapes.
CNHM UC 1699, 14 vertebrae; 4421, composite skeleton.

KU 8962, 8963, many isolated elements; 8964, pes, tibia, fibula; 8965, pes; 9780, skull elements; 9924, half skull; 9978, skull; 14745, humerus; 14748, pelvis; 14753, 14756, mandibles; 14757, scapulocoracoid; 14794, scapulocoracoid, basisphenoid.

OUSM 2-1-S9, small skull; 3-0-S14, small partial skull; 3-0-S15, partial skull; 3-0-S16, partial skeleton; 3-0-S17, partial skull and skeleton of young individual; 3-1-S9, skull; 4-1-S9, skull.
UM 39716, various parts; 50985, basisphenoids.
YPM 3854, humerus; 3855, radius; 3856, ulna; 3857, tibia; 3858, fibula.

Labidosaurus hamatus: CNHM UR 403, many dentaries; 404, many maxillae.

Colybomycter pholeter: CNHM UR 272 (holotype), partial skull.

Basicranodon fortsillensis: USNM 21859 (holotype), partial skull.

Delorhynchus priscus: KU 11117 (holotype), 11118, 11119, maxillae.

Thrausmosaurus serratidens: KU 11120 (holotype), 11121, 11122, fragments, jaws.

Mycterosaurus sp.: CNHM UR 381, tibia (identification questionable).

SOUTH CARNEGIE SITE

Amphibian, genus uncertain: FM, unnumbered, scraps of jaws.
Captorhinus aguti: FM, unnumbered, many specimens, including jaws and postcranial elements.

PERRY LOCALITY

Perry Site 1

Gnathorhiza cf. *G. serrata*: OUSM, unnumbered, many teeth, ribs, parts of of skulls and jaws.

Trimerorhachis insignis: OUSM, unnumbered, many skulls, jaws, skeletons, and isolated elements.

Crossotelos? sp.: OUSM, unnumbered, several lepospondylous vertebrae.

Labidosaurus oklahomaensis: OUSM, 3-0-S13, skeleton lacking skull.

Dimetrodon sp.: OUSM, unnumbered, tooth, spine.

Perry Site 2

Gnathorhiza sp.: OUSM 1-0-S91, several lungfish burrows containing fish remains.

Perry Site 3

Xenacanthus sp.: OUSM 1-26-S26, tooth; 1-26-S27, 1-26-S28, 3 teeth with scraps of other genera.

Trimerorhachis insignis: OUSM 2-4-S7, well-preserved jaw; 2-4-S8, poorly preserved jaw; 2-4-S9, large damaged jaw; 2-4-S10, fragment of a small jaw.

Eryops sp.: OUSM 2-1-S32, fragment of a skull.

Perry Site 4

Paleoniscoids: OUSM, unnumbered, several macerated paleoniscoids, scales, skull elements, etc. in gray shale.

Perry Site 5

Gnathorhiza cf. *G. serrata*: OUSM 1-1-S1, partial skull; 1-0-S92, bones in burrows.

In addition, many unnumbered specimens being prepared.

Perry Site 6

Xenacanthus sp.: CNHM, unnumbered, teeth from red sandstone.

Paleoniscoids: CNHM, unnumbered, small paleoniscoids from gray shales, platysomids from black shales, many scales.

Crossopterygians?: CNHM, unnumbered, many remains of a large carnivorous fish.

Trimerorhachis sp.: OUSM 2-37-S2, interclavicle.

Diplocaulus cf. *D. magnicornis*: OUSM 2-40-S9, parts of skull, jaw, vertebrae.

Ophiacodon cf. *O. uniformis*: OUSM 4-1-S8, small part of skull; 4-4-S4, part of jaw; 4-7-S18, several vertebrae, rib, teeth.

Dimetrodon sp.: OUSM, unnumbered, teeth, spine fragments, cervical vertebrae.

Reptile, unidentified: CNHM, unnumbered, many parts of skeleton, parts of jaws and skulls, small- to medium-sized reptile.

ORLANDO SITE

Xenacanthus sp.: CNHM UF 980, 2 teeth.

Gnathorhiza sp.: CNHM UF 979, 2 teeth, some scrap not from *Gnathorhiza*.
OUSM 1-26-S24, lower tooth, part of jaw; 1-26-S25, tooth.

Sphaerolepis arctata: OUSM 1-2-S5, partial palate.

Eryops sp.: OUSM 2-1-S38, skull fragment.

Trimerorhachis insignis: CNHM UR 1023 (cf. *T. insignis*), clavicle and interclavicle; 1024 (cf. *T. insignis*), interclavicles of several individuals; 1025, fragments of girdles, skull, jaw.
OUSM 2-4-S2, partial jaw.

Cricotillus brachydens: KU 394 (holotype), partial jaws; 350A, partial skull (specimen designated holotype of *Trimerorhachis leptorhynchus* Case, later abandoned as indeterminate); unnumbered specimens, 3 pieces, apparently *C. brachydens*, 1 fragmentary jaw might be from a captorhinomorph.

Diplocaulus magnicornis (or cf. *D. magnicornis*): CNHM UR 1026, jaw, fragments; 1027, vertebrae, partial jaw; 1028, parts of small individuals; 1029, fragments of skull and vertebrae; 1030, about 100 miscellaneous pieces of many individuals.
OUSM 2-0-S12, 4 vertebrae.

Lysorophus cf. *L. tricarinatus*: CNHM UR 1021, vertebrae, ribs.
OUSM 2-0-S21, vertebrae, ribs.
UM 16077, vertebrae, ribs.

Crossotelos annulatus: CNHM UR 1013, 5 dorsal vertebrae; 1014, caudal vertebrae; 1018, dorsal vertebrae, ribs; 1019, vertebrae and ribs of many individuals.
OUSM 2-10-S3, caudal vertebrae; 2-0-S13, partial skull and jaw (identified in collection as *C. annulata* without adequate evidence); 2-7-S7, 3 dorsal vertebrae; 3-34-S4, 4 caudal vertebrae.
UM 3040 (holotype), vertebrae.

Captorhinus cf. *C. aguti*: CNHM UR, 1012, 2 jaw fragments.

Labidosaurus oklahomaensis: OUSM 1-2-S5, partial skull and jaws.

Pleuristion brachycoelus: CNHM UR 678, skull and jaws (generic assignment based on inadequate evidence).

OUSM 3-0-S19, partial skeleton (questionable identification).
KU 351 (holotype), vertebrae, ribs, etc.

Dimetrodon sp.: CNHM UR 1022, teeth.
OUSM 4-25-S2, teeth.

Edaphosaurus sp.: OUSM 1-26-S25, 4-7-S13, 4-7-S14, spine fragments.

MORRISON SITE

The specimens from this site are presumably in the collections of the Stovall Museum, but it was impossible to identify them in the course of this study.

MC CANN QUARRY SITE

Xenacanthus sp.: OUSM 1-25-S17, 3 teeth.

Sphaerolepis arctata: OUSM, unnumbered, palatal tooth plates.

Paleoniscoids: OUSM, unnumbered specimens.

Archeria victor: OUSM 2-1-S2, partial skull, pelvis, shoulder girdle; 2-1-S19, partial skull; 2-0-S28, well-preserved half skull; 2-34-S1, girdle fragment.

Eryops megacephalus: OUSM 2-1-S2, parts of skull, pelvis, shoulder girdle; 2-1-S19, partial skull; 2-1-S20, skull fragments; 2-1-S21, mandible fragments; 2-1-S22, skull fragments, postcranium; 2-4-S1, partial jaw; 2-4-S13, partial mandible; 2-34-S3, skull fragments; 6-4-S2, jaw.
KU 348, skeleton, skull (holotype of *E. willistoni* Moodie).

Trimerorhachis insignis: OUSM 2-1-S11, well-preserved skull; 2-1-S15, clavicle; 2-1-S16, jaw; 2-1-S23, large lower jaw; 2-1-S24, lower jaw; 2-1-S25, partial skull, lower jaw, clavicle, scrap; 2-1-S26, miscellaneous fragments; 2-1-S28, well-preserved half skull; 2-34-S1, girdle fragment.

Diplocaulus magnicornis: OUSM 2-1-S10, excellently preserved two-thirds of a skull.

Labidosaurus oklahomaensis: OUSM 3-0-S3, skull, skeleton; 3-0-S4, partial skeleton; 3-0-S5, partial skull, partial skeleton; 3-1-S4, front of skull, jaws; 3-1-S5, partial skull, partial skeleton; 3-1-S6, large skull, foot; 3-1-S7, most of skull and jaws; 3-1-S8, snout, part of lower jaw; 3-4-S2, skull table; 3-34-S3, vertebrae, femur, parts of skull.

Dimetrodon cf. *D. limbatus*: OUSM 4-0-S29, tibia, jaw fragment; 4-1-S6, partial maxilla; 4-1-S7, partial maxilla and pterygoid; 4-7-S3, interclavicle of young individual; 4-35-S1, parts of skeleton, several vertebrae.

Edaphosaurus cruciger: OUSM 4-35-S2, spine; 4-35-S4, complete spine, partial spine.

LUCIEN LOCALITY

Lucien Site 1

Xenacanthus sp.: OUSM, unnumbered, teeth.

Eryops sp.: OUSM 2-7-S3, intercentrum.

Diplocaulus magnicornis: OUSM 2-0-S16, column, partial skull; 2-40-S2, skull fragment, atlas, vertebrae; 2-40-S3, many skull fragments, girdles, vertebrae; 3-4-S1, lower jaw.

Dimetrodon sp.: OUSM 4-13-S3, part of humerus; 4-40-S2, many fragments, teeth, vertebrae, limb pieces, jaws.

Lucien Site 3

Xenacanthus sp.: OUSM 1-1-S1, chondrocranium fragment.
Eryops sp.: OUSM 2-4-S4, partial jaw, skull fragments.
Trimerorhachis? sp.: OUSM 2-13-S2, partial immature humerus.
Dimetrodon sp.: OUSM 4-40-S3, scrap, vertebrae, spines, etc.

Lucien Site 4

Xenacanthus sp.: OUSM 1-4-S6, cartilage of jaw.
Eryops sp.: OUSM 2-7-S4, intercentrum.
Trimerorhachis sp.: OUSM 2-4-S5, 2 jaw fragments.
Diplocaulus sp.: OUSM 2-1-S30, skull fragment.
Diadectes sp.: OUSM 2-6-S4, vertebra.
Dimetrodon sp.: OUSM 4-40-S4, skull fragments, rib, humerus, ulna, spine, fibula?.

Lucien Site 5

Xenacanthus sp.: OUSM 1-25-S21, teeth, cartilage, spine fragments.
Diplocaulus sp.: OUSM 2-1-S31, skull fragments.
Dimetrodon sp.: OUSM 4-40-S5, 2 teeth, spine fragment.

BEAN FARM SITE

Xenacanthus sp.: OUSM 1-0-S90, chondrocranium, arches.
Diplocaulus magnicornis: OUSM 2-0-S11, well-preserved skull and skeleton.

SOUTH COVINGTON SITE

Fragments: OUSM, unnumbered, include *Dimetrodon* and probably *Diplocaulus* and *Eryops*.

POND CREEK SITE

Xenacanthus sp.: OUSM 1-25-S19, 1-25-S20, 1-26-S20, composite specimens with teeth and cartilage fragments; 1-35-S4, spines of several individuals.

Gnathorhiza sp.: OUSM 1-26-S23, lower tooth plate.

Sagenodus? sp.: OUSM 1-25-S18, tooth plates.

Sphaerolepis arctata: OUSM 1-36-S2, tooth plate (locality questionable).

Rhipidistian: OUSM 1-3-S2, scales.

Archeria sp.: OUSM 1-6-S1, 1-7-S4, 1-8-S1, 2-7-S1, centra (identification dubious if locality is correct; identified in collection as *Pleuracanthus* Smith).

Eryops sp.: OUSM 2-0-S18, skull fragments; 2-6-S7, large tooth; 2-10-S1, intercentrum; 2-10-S2, caudal intercentrum; 2-26-S2, large tooth.

Trimerorhachis insignis: OUSM 2-6-S3, intercentrum, palatal tooth.

Diplocaulus magnicornis: OUSM 2-0-S19, 2-1-S20, 2-1-S29, 2-1-S36, skull fragments and parts; 2-7-S2, 2 vertebrae; 2-40-S1, skull fragments, vertebrae, etc. of several individuals; 2-40-S8, miscellaneous skull fragments.

Crossotelos annulatus: OUSM 1-0-S86, caudal vertebrae (identified in collections as *Gnathorhiza;* locality assignment in collections is Pond Creek, but specimens resemble Orlando types).

Diadectes sp.: OUSM 2-6-S5, fragments of 2 or 3 vertebrae.

Captorhinus aguti; OUSM 2-0-S11, partial mandible; 3-7-S4, 5 vertebrae; 3-13-S3, distal end of humerus; 4-0-S33, partial skull, snout.
UM 10773 (identified as *Pariotichus* sp. in collections).

Labidosaurus hamatus: OUSM 3-0-S10, partial skull; 3-0-S12, partial skull, vertebrae; 3-7-S5 through 3-7-S8, vertebrae; 3-13-S2, distal end of humerus; 3-21-S1, partial femur; 3-21-S2, small limb bones (possibly *Captorhinus*).
UM 3409, skull fragments, etc.

Dimetrodon grandis: OUSM 4-0-S34, much of skeleton, partial skull; 4-1-S16, cervical vertebra; 4-7-S17, vertebral spines; 4-13-S1, parts of 2 large humeri; 4-40-S1, various parts of skull, jaws, and postcranium of young individual.
UM, unnumbered, scrap.

Dimetrodon giganhomogenes: MCZ 1342, scapulocoracoid; 1346, vertebrae (assignment uncertain but probable).

Dimetrodon giganhomogenes: MCZ 1342, scapulocoracoid; 1346, vertebrae 4-7-S6, 5 caudals; 4-7-S8, 2 centra; 4-7-S9, lumbar; 4-8-S3, centrum; 4-8-S4, intercentrum; 4-13-S2, parts of 2 humeri; 4-19-S3, phalanges; 4-32-S2, interclavicle.

CRESCENT SITE

Labidosaurikos meachami: OUSM 3-1-S1, head of humerus; 3-1-S2 (holotype), skull, jaws.

Dimetrodon giganhomogenes: OUSM 4-7-S1, anterior caudal vertebra; 4-7-S4, vertebrae, scrap; 4-8-S2, immature pubis; 4-10-31, 2 distal caudal vertebrae; 4-11-S2, rib fragments; 4-12-S2, small scapula; 4-23-S2, small femur; 4-23-S3, tibia, girdle scraps, ribs.

SOUTH CRESCENT SITE

Labidosaurikos meachami: FM UR 1031, partial skull, vertebra.

NORTHWEST EDMOND SITE

Diplocaulus magnicornis: OUSM 2-1-S17, 2 skull fragments; 2-10-S18, skull fragment (not prepared, identity uncertain).

Dimetrodon giganhomogenes: OUSM 4-0-20A, parts of 2 vertebrae; 4-0-S23, partial skeleton, more than 10 vertebrae, limbs, girdles; 4-0-S30, parts of several vertebrae; 4-0-S31, part of femur, anterior end of mandible, part of axis, fragments; 4-0-S32 (museum no. 4012), series of vertebrae (probably from this site); 4-4-S1, dentition fragments, mostly impression; 4-4-S2, fragments; 4-4-S3, anterior part of mandible.

NORTH EDMOND SITE

Diplocaulus: OUSM, unnumbered, scraps.
Dimetrodon: OUSM, unnumbered, scraps.

SOUTH COVINGTON SITE

Diplocaulus cf. *D. magnicornis*: OUSM 2-0-S17, skull fragments.

Labidosaurikos cf. *L. meachami*: OUSM 3-7-S3, vertebral fragment.

Dimetrodon cf. *D. giganhomogenes*: OUSM, unnumbered, fragments of vertebrae, spines, and ribs.

NORMAN LOCALITY

The various Norman sites in the Hennessey Formation are considered as a unit. Specimens occur through about 100 feet of section. Most specimens, except those of *Cotylorhynchus*, are from SW¼ NW¼ sec. 13, T. 8 N., R. 2 W.; some specimens of *Captorhinikos* also come from other sites.

Gnathorhiza sp.: FMNH UF 981, lower tooth.

Lysorophus sp.: FMNH UR 1034-1037, skulls; unnumbered, 50 partial skeletons.

OUSM 2-40-S10, partial column; 2-40-S11, vertebrae; 2-40-S12, partial column.

Captorhinikos chozaensis: CNHM UR 183, skull, jaws; 857, partial skull, skeleton; 858, 859, partial skeletons.

OUSM 4-1-S3, partial skull.

USNM 21275, partial skull, skeleton.

In addition, there are many skulls of small individuals from sec. 13 that may belong to this genus.

Cotylorhynchus romeri: OUSM 4-0-S2 through 4-0-S5, parts of skeletons; 4-0-S6, part of foot; 4-0-S7, most of skeleton; 4-0-S8, anterior half of small skeleton; 4-0-S9, fragments; 4-0-S10, nearly complete skeleton; 4-0-S11, 4-0-S13, parts of skeletons; 4-0-S14, part of foot, ribs; 4-0-S16, various parts of skeleton; 4-0-S17, fragments; 4-0-S18, partial skeleton; 4-0-S20, partial skull, shoulder girdle, limb bones, foot; 4-0-S21, partial skeleton; 4-0-S21 (duplicate number), partial skeleton; 4-0-S23, skull; 4-0-S24, partial skeleton; 4-0-S25, scapula, ulna, foot; 4-0-S26, partial skeleton; 4-0-S28, fragments; 4-1-S2, partial skull, lower jaws; 4-1-S5, skull, jaws; 4-8-S1, caudal vertebrae; 4-10-S2, vertebral column; 4-11-S1, scapula, forelimb; 4-32-S1, fragments; 1250, skeleton.

AMNH 7517, skeleton.

CNHM UR 272, skeleton.

MCZ 3416, skeleton.

USNM 21317, skeleton.

NAVINA SITE

Cotylorhynchus romeri: OUSM 4-0-S1, partial skull and jaws, 2 front feet, partial interclavicle.

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(*Italic number* indicates main reference)