EARLY PERMIAN VERTEBRATES FROM SOUTHERN NEW MEXICO AND THEIR PALEOZOOGEOGRAPHIC SIGNIFICANCE

By Peter Paul Vaughn
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EARLY PERMIAN VERTEBRATES FROM SOUTHERN NEW MEXICO AND THEIR PALEOZOOGEOGRAPHIC SIGNIFICANCE

By Peter Paul Vaughn

ABSTRACT: A rhipidistian crossopterygian fish and the long-spined pelycosaur *Dimetrodon* are reported for the first time from the Lower Permian of New Mexico. The rhipidistian comes from a band that seems to pass from a nodular layer in the uppermost part of the Laborcita Formation southward into stream-channel deposits in the lowermost part of the Abo Formation, along the Sacramento Mountains escarpment in Otero County. In the same band are found remains of a pleuracanth shark, the primitive fish *Acanthodes* sp., palaeoniscoid fishes, an edopid labyrinthodont amphibian similar to *Edops*, *Platyhystrix* cf. *P. rugosus* and another dissorophid labyrinthodont, and pelycosaurs referable to *Ophiacodon*, *Sphenacodon* and *Edaphosaurus*. *Dimetrodon* is represented by vertebral parts from the Abo Formation in the Caballo Mountains in Sierra County. This discovery of a rhipidistian and *Dimetrodon* in southern New Mexico, in the region of the "mean shoreline of the Wolfcampian seas" plotted by Kottlowski (1963), seems to partially verify the prediction that these vertebrates are to be found only as members of faunas that lived near the borders of persistent seaways, in "eu-deltaic" situations. Although these two forms are known also from southeastern Utah, northern Oklahoma and north-central Texas, they remain unreported from northern New Mexico despite the collection of a large and varied fauna from that area. The Wolfcampian vertebrates of northern New Mexico seem to have lived under "somewhat more upland" conditions. These analyses are consonant with paleogeographic reconstructions of positive elements and seaways. Evidence is reviewed to show that the "Midcontinental seaway" could have formed only a partially effective obstacle to distribution of vertebrates between the Four Corners and the Midcontinent. An analysis of Permian floras by Read and Mamay (1964) corroborates evidence drawn from vertebrates that drier conditions in the Early Permian set in earlier in the Four Corners than in the Midcontinent. It is suggested that the extensive system of Early Permian positive elements in Colorado and New Mexico formed the backbone of an upland partial obstacle to distribution at least as effective as the "Midcontinental seaway."

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INTRODUCTION

In 1966, I published a comparison of the Early Permian vertebrate faunas of the Four Corners region and north-central Texas. That paper was prompted by new finds and by the prevalent opinion that many of the differences between the well known faunas of north-central Texas and northern New Mexico were to be explained by the presence of a water barrier between these areas. I pointed out that new discoveries of vertebrates in the Cutler Group in southeastern Utah, including a rhapidistian crossopterygian fish and the long-spined pelycosaurian reptile Dimetrodon, cast doubt on the long-term effectiveness of such a barrier, and noted that the presence of these animals in southeastern Utah indicates special resemblance to the Early Permian fauna of north-central Texas. I suggested that the resemblance is due to environmental similarity in that both north-central Texas and southeastern Utah were deltaic regions in Early Permian time, near the borders of persistent seaways, whereas the absence of certain forms—including rhapidistians and Dimetrodon—in northern New Mexico could perhaps be accounted for by the "somewhat more upland" condition of the latter area in Early Permian time.

For Wolfcampian (earliest Permian) time, then, I strove to draw a distinction between what may be called, for lack of better designations, by the guarded terms "eu-deltaic" and "somewhat more upland" vertebrate faunas. Naturally, the northern New Mexico deposits—in the Cutler Formation in Rio Arriba County and the Abo Formation in Sandoval County—do not represent truly upland conditions inasmuch as they were, after all, formed in basins of sedimentation; the term "somewhat more upland" is used here simply to indicate regions relatively farther removed from borders of persistent seaways. What was attempted was analysis, albeit crude, of environmental "preferences" of certain Wolfcampian forms based on their known distributions as correlated with data on positions of highlands—or at least positive areas—and seaways. The remarkable fact is that the method, however crude, did seem to help explain distributions. Correlation with paleogeographic reconstructions based on non-faunal grounds seems to offer a useful aid to our understanding of distributional patterns of ancient vertebrates, and it may offer direct indices to the habitats of particular forms. It is unhappily true that such studies must, by their very nature, rely to some degree on negative evidence for non-presence of faunal elements, and many conclusions must be regarded as tentative. Nevertheless, continuation of such efforts seems worthwhile in an attempt better to understand distributions of Late Paleozoic vertebrates, on a continental scale, in terms of environment, as far as possible without recourse to analogy with modern forms.

The four faunal elements that I listed in 1966 as common to southeastern Utah and north-central Texas—but unreported from northern New Mexico—are: the rhapidistian Ectosteorhachis, the nectridean amphibian Diplocaulus, the labyrinthodont amphibian Seymouria, and the pelycosaur Dimetrodon. Since that time, it has been learned that the rhapidistian found in Utah is really
not *Ectosteorchachis*, but a new form called *Lohsania* (Thomson and Vaughn, 1968), that is only the second known Permian rhipidistian; nevertheless, no rhipidistian at all had been known from the New Mexico Permian, and the presence of such fishes in both Texas and Utah still seems to indicate special resemblance. The discovery of *Dimetrodon* in Utah removed what was perhaps the most dramatic difference between the Early Permian vertebrate faunas of the Four Corners and the Midcontinent, but until now *Dimetrodon* has remained unreported from New Mexico.

To test the hypothesis that these four elements are to be found in “eucrataic” as opposed to “somewhat more upland” deposits, my field party went southward in New Mexico in the summers of 1966, 1967 and 1968, to prospect along the “‘mean’ shoreline of the Wolfcampian seas” plotted by Kottlowski (1963:57, and Fig. 12). Good exposures along this “mean shoreline” were found in the Caballo Mountains in Sierra County and along the western flank of the Sacramento Mountains in Otero County. Figure 2 indicates both these areas. They lie, roughly, along the transitional belt between the red-beds facies of the Abo Formation to the North and the limestone facies of the Hueco to the South. The figure, based on maps published by McKee, Oriel, *et al.* (1967), gives a less detailed boundary for the “Orogrande seaway” separating the Caballo Mountains and Sacramento Mountains localities than may be found in Kottlowski’s paper, because it is a larger-scale map intended to serve a broader-ranging discussion below.

Among other items, readily identifiable remains of a rhipidistian and of *Dimetrodon* were found, and this is the first report of either of these forms from New Mexico. Although *Diplocaulus* and *Seymouria* have not (yet) been found in southern New Mexico, the presence of a rhipidistian and of *Dimetrodon* would seem to provide at least partial verification of the prediction.

**LOWER PERMIAN VERTEBRATES FROM THE SACRAMENTO ESCARPMENT**

Otte (1959) and Pray (1961) have presented thorough studies of the uppermost Paleozoic strata exposed along the Sacramento Mountains escarpment in Otero County, New Mexico. Pray’s maps cover the area east and southeast of Alamogordo, and Otte’s cover the area east of Tularosa and southeastward to merge with Pray’s area near the town of La Luz. Particularly important are the Laborcita and Abo Formations. Because of the interfingering relationships between these two formations, it is best to quote from Otte (1959: 96) at length:

“In the central part of the Sacramento Mountains and the southeastern part of the map area, the Abo formation overlies with sharp angular unconformity strata of Pennsylvanian and Mississippian age. The area to the west and northwest was one of essentially continuous deposition from late Pennsylvanian through early Permian time, with no major unconformity separating the deposits. Gradual emergence of the area and retreat of the marine waters toward
the west and northwest caused interfingering of the uppermost Laborcita and lowermost Abo strata in the area north of Domingo Canyon. The base of the Abo formation occurs 200 feet stratigraphically above the upper contact of the Bursum formation as mapped by Pray (1952 [a reference to Pray's then unpublished dissertation]).

Otte named the Laborcita Formation and defined it to include a lower portion previously known as the Bursum Formation plus approximately 200 feet of strata previously assigned to the lower part of the Abo Formation. Otte's general description (1959:95) of this formation is as follows:

"The Laborcita formation is about 500 feet thick in the southeastern part of the area. The thickness increases to about 1,000 feet toward the northwest. The lithologic and faunal characteristics of the sediments show that abrupt lateral transitions from open-marine conditions, in the northwest and west, to terrestrial flood-plain environments, in the southeast and east, occurred repeatedly within a distance of a few miles. On the basis of fusulinid identifications, the Laborcita formation is very late Virgilian and early Wolfcampian in age. The uppermost 250 feet of the Laborcita formation near Tularosa is in part the time equivalent of the lowermost Abo beds toward the south and east. The Pennsylvanian-Permian boundary, which by earlier stratigraphers was taken at the base of the Abo formation, occurs 90 feet above the base of the Laborcita formation, as determined on the basis of fusulinids."

Recently, Steiner and Williams (1968) have restudied the Laborcita fusulinid fauna and have come to the conclusion that all of the Laborcita Formation is Wolfcampian in age. There is some possibility of confusion in reading the papers published by Otte and Pray. Otte referred to Pray's work while it was still in the form of an unpublished dissertation. Although Pray's paper bears a lower bulletin number, in the same series, than Otte's, Pray's paper was published later (1961) than Otte's (1959). This is important in a choice between the designations Bursum and Laborcita. Although Pray mapped the Bursum Formation along the Sacramento Mountains escarpment, he preferred Otte's broader designation, Laborcita, as shown by his remark (Pray, 1961:91): "Otte... named the section between the top of the Fresnal group and his Abo contact the Laborcita formation. This term is clearly preferable to the use of Bursum in the Sacramento Mountains area; however, as the lower horizon was used as the base of the Abo in preparing the writer's geologic map and sections of the area, the term Bursum is used in this report." The present paper follows Otte's nomenclature.

Figure 1, based on Otte's maps, shows the relationship between the Laborcita and Abo Formations in much simplified style—traces of faults, Pennsylvanian formations, Tertiary intrusives, and covering Quaternary de-
Figure 1. Simplified map of relationships of Laborcita and Abo Formations near Tularosa, along the Sacramento Mountains escarpment in southern New Mexico. The significance of marker beds 49, 53 and 55 is discussed in the text. Filled-in circles represent localities where vertebrate fossils have been collected. Based on maps by Otte (1959).
positors are omitted. In the area north of Tularosa, Otte drew the Laborcita-Abo boundary at the top of his marker bed 55 (a limestone); south of this, in approximately the area between Tularosa and Domingo Canyons, he drew the base of the Abo lower down, at the bottom of his marker bed 53 (a conglomerate); still farther south, beginning between Domingo and Laborcita Canyons, the base of the Abo is dropped to the bottom of marker bed 49 (a conglomerate). These considerations are pertinent to the present report because the vertebrate fossils found by my field party come from both the Laborcita and Abo Formations—but all from about the same horizon.

Figure 1 also shows the general areas in which vertebrates were found; these are indicated by filled-in circles. For ease in reference, they will be called: the “locality north of Tularosa” (in the upper left-hand corner of the figure), the “Tularosa Canyon locality,” the “locality south of Tularosa Canyon” (almost due east of Tularosa), the “locality north of Domingo Canyon,” the “Domingo Canyon locality,” the “Laborcita Canyon localities,” the “locality between Laborcita and Cottonwood Canyons,” and the “Cottonwood Canyon localities.” The northern two—the locality north of Tularosa and the Tularosa Canyon locality—are in the uppermost part of the Laborcita Formation; all the others are in the lowermost part of the Abo Formation.

At the Tularosa Canyon locality, in NE¼ sec. 21, T. 14 S, R. 10 E, the vertebrates are found in nodules weathered from a green-gray shale several feet thick that lies about 40 feet below marker bed 55, about 50 feet below the top of the Laborcita Formation as Otte draws the boundary in this region. The nodules are of various shapes from spheres to dumbbells, but mostly they are biscuit-shaped. There is a great range of sizes, but most of the biscuits are about 10 to 15 cm in greatest length. Some of the nodules can be traced into irregular calcareous masses within the shale. It is evident that the nodules are concretions formed in place, that is, they were not secondarily deposited. The bedding planes, with very low-angle crossbedding, pass horizontally through the nodules into the shale. Polished sections reveal no concentric structure except for a dark, unoxidized core whose border parallels the weathered outer surface. Most of the sediment is very fine-grained, but there are lenses of slightly coarser clastic materials in which most of the larger bones occur. The nodules are readily attacked by weak acids; most of the fossils were prepared in this way.

The most common remains, by far, are of the acanthodian fish Acanthodes sp., and scales of this form have been recovered from both the nodules and the shale, although most of the specimens at hand are in nodules because of the ease with which these can be collected. The fossils may lie anywhere within the nodules but, naturally, most of the collection consists of nodules with bones exposed at the surface. Scales of the acanthodian occur singly and also in various sized patches in which they are articulated with one another—the largest patch found is about 5 by 7 cm. Many pectoral spines, a scapula, and
other acanthodian elements have also been found and these, as well as the scales in both their gross and microscopic structure, correspond in every way with descriptions of these elements in Acanthodes. One of the pectoral spines, UCLA VP 1718, is 54 mm long. To my knowledge, remains referable to Acanthodes have been reported from only two other sites in the Lower Permian of the western hemisphere: from the Dunkard Group of West Virginia (Romer, 1952) and from the Wichita Group of north-central Texas (Dunkle and Mamay, 1956). The presence of this fish provides no definite indication of the kind of waters in which the deposit was formed; according to Zangerl and Richardson (1963), at least the Pennsylvanian species of Acanthodes with which they dealt lived in waters of a wide range of salinity.

Besides Acanthodes, the nodules from the Tularosa Canyon locality have yielded numerous partial stems of Calamites, scales of palaeniscoid fishes, a vertebra of the pelycosaurian reptile Sphenodon cf. S. ferox—a form known also from northern New Mexico—and, what is most pertinent to this report, scales and a partial dermal skull bone with the cosmoid microstructure typical of rhipidistian crossopterygian fishes.

Prior to this, a fragmentary Lower Permian rhipidistian would have been almost automatically referred to Ectosteorhachis, but, as mentioned earlier, a second genus of Lower Permian rhipidistians is now known on the basis of remains from the Cutler Group of southeastern Utah (Thomson and Vaughn, 1968). Although the vertebrae in this new rhipidistian, Lohsania, are quite different from those in Ectosteorhachis, no difference in the structure of the scales has yet been noted; hence, in the absence of other than dermal parts, it seems unwise to attempt at this time even generic identification of the rhipidistian from southern New Mexico. Nevertheless, this discovery is interesting inasmuch as it is the first record of a rhipidistian from New Mexico, and it is noteworthy that it was found in the region of Kottlowski’s (1963) “mean shoreline of the Wolfcampian seas.”

A small collection of similar nodules and inter-nodular shale was made at the locality north of Tularosa, in NE 1/4 sec. 31, T. 13 S, R. 10 E, not far above a porphyry sill. The distance below marker bed 55 is about 50 feet; this is greater than the interval at the Tularosa Canyon locality, but Otte points out that the Loboanita Formation thickens considerably toward the Northwest, and this is well shown in his diagram of stratigraphic sections (1959:Pl. 4). Thus it is likely that the nodular shale here lies at the same horizon as at the Tularosa Canyon site. Fossils from this locality include acanthodian scales, a rhipidistian scale, and a tooth of a pleuracanth shark—a common fresh-water component of Early Permian vertebrate faunas.

The fossiliferous layer of the Tularosa Canyon locality is easily recog-
nized again at the locality south of Tularosa Canyon, in SW ¼ sec. 22, T. 14 S, R. 10 E. Acanthodian scales are as abundant as at the Tularosa Canyon locality. *Calamites* is present, and there is an impression of a partial leaf, probably of a seed fern. Palaeoniscoïd scales are not uncommon, and there is also a fragmentary palaeoniscoïd jaw in which the small enamel cap can be seen on some of the teeth. A plane within one nodule shows a “splatter” of palaeoniscoïd scales similar to remains that have been interpreted as gastric residues by Zangerl and Richardson (1963). There are well preserved ripidistian scales; for future reference, one of these has been catalogued as UCLA VP 1720. There are also some fragments of large tetrapod bones, but these cannot be identified. Although this locality is only about a mile south-south-east of the Tularosa Canyon locality (uppermost Laborcita Formation), it lies within the area in which Otte (1959) drops the base of the Abo Formation from the top of marker bed 55 down about 135 feet to the bottom of marker bed 53, and it is thus technically in the lowermost part of the Abo Formation—as are also all the localities to the South.

The fossiliferous layer of the above localities cannot be continuously traced southward, due to extensive Quaternary cover. The next place south in which bone was found is the locality north of Domingo Canyon, in about the center of sec. 36, T. 14 S, R. 10 E. All that was found here is a small fragment of tuberculated bone, probably of a labyrinthodont amphibian, in a green-gray sandstone.

We searched at various horizons farther south, but all the productive localities lie within one band about 50 feet thick. This band is generally in the form of a sandwich with a sandstone-conglomerate above, a coarse conglomerate with quartzite pebbles below, and mudstone with some nodular limestone between. As measured in Laborcita and Cottonwood Canyons, the lower conglomerate lies about 225 feet above the base of marker bed 49—which, according to Otte, forms the base of the Abo Formation in the area of these canyons. This conglomerate-mudstone complex is shown in Otte’s measured section taken northeast of La Luz (1959: Pl. 11). Otte shows the lower conglomerate as 15 feet thick and the upper conglomerate as four feet thick, but there is much lateral variation in thickness. Besides the vertebrate fossils described below, this band contains petrified wood, sometimes fairly large logs, in many places including some where bone was not found; the wood is commonly associated with ores of copper. Bones come from both the conglomerate and the mudstone, but most were taken from finer-grained lenses within the conglomerates. Most of the fossils are fragmentary and there are many items that remain unidentified.

It cannot be said with certainty that the conglomerate-mudstone complex of the Domingo, Laborcita and Cottonwood Canyon localities lies at exactly the same horizon as the nodular layer of the northern localities, and it would be even more difficult to say that there is lithologic continuity between the
two. Nevertheless, there are reasons to suspect a relationship. The northern nodular layer and the southern conglomerate-mudstone complex are the only bands in which we found vertebrate fossils, and these bands lie within the zone of time-equivalence of the uppermost part of the Laborcita Formation and the lowermost part of the Abo Formation. If one inspects Otte's diagram of stratigraphic relationships of the Abo and Laborcita Formations (1959:Pl. 13), it will be seen that his projection northward of the base of marker bed 49 brings it to lie about 260 feet below the top of the Laborcita Formation (marker bed 55) in the region of the nodular layer in Tularosa Canyon. The nodular layer is about 50 feet below the top of the Laborcita Formation and thus about 210 feet above the projected base of bed 49. This is very close to the stratigraphic distance of the conglomerate-mudstone complex above the base of bed 49—about 225 feet. An estimate of at least approximate equivalence of the nodular layer and the conglomerate-mudstone complex would be in accord with Otte's observation (1959:95) that "The lithologic and faunal characteristics of the sediments [of the Laborcita Formation] show that abrupt lateral transitions from open-marine conditions, in the northwest and west, to terrestrial floodplain environments, in the southeast and east, occurred repeatedly within a distance of a few miles." Although none of the vertebrate elements from the nodular layer in Tularosa Canyon indicates a marine origin for the deposit, there are beds both above and below that contain marine invertebrates. Some of these invertebrates occur in nodules similar to those of the vertebrate-bearing layer, and such nodules with marine invertebrates are found also in the area of the locality north of Domingo Canyon. Thus, it seems not unreasonable to suggest that the Tularosa Canyon vertebrate-bearing layer may be a somewhat marineward extension of the conglomerate-mudstone complex of the localities in Domingo Canyon and farther south.

The principal Domingo Canyon locality is in NW 1/4 sec. 6, T. 15 S, R. 11 E, but fossils were also collected from nearby sites. Fine-grained sandstones in this area have yielded a number of fragments of bone, and there is abundant wood in association with copper ores; impressions of "Walchia" leaves were also found. From a coarse sandstone have come a rhipidistian scale, and also partial neural spines similar to the complete spines found in Cottonwood Canyon and tentatively identified below as Edaphosaurus cf. E. novomexicanus.

The most interesting fossil from the region of the Domingo Canyon locality consists of parts of the posterior moiety of the skull of a large labyrintherodont amphibian, UCLA VP 1727, recovered from a rounded block of reddish-brown sandstone that was found loose in the bed of the wash, about a half to three-quarters of a mile downstream from the fossiliferous layer. The dermal roofing bones show the pattern of "sculpture" typical of labyrintherodonts. Only fragments of the circumorbital and cheek regions remain, but the skull table between the orbits and back to the hind border of the postparietals and tabulars is fairly well preserved even though a few of the elements are incomplete and
somewhat displaced. Not all the sutures can be easily followed, but it can be seen that, as is characteristic of rhachitomes, there is a broad contact between the supratemporal and postparietal bones; and the boundaries of an intertemporal bone can be made out—this primitive element is extremely rare among Permian rhachitomes. Fragments of the braincase are present, and of the palate there are preserved large portions of the pterygoids in the region of their articulation with the braincase. The palatal surface of the pterygoid bears a shagreen of tiny denticles that extends not only forward from the basal articulation, but also back onto the quadrate ramus. The bowed medial borders of the pterygoids enclose moderately developed interpterygoid vacuities, that is, the vacuities were much wider than in any described anthracosaur, but they were somewhat narrower than in the rhachitome Eryops. The processes of the pterygoids that articulated with the braincase are smoothly finished medially, and it is quite clear that they were not suturally united with the basipterygoid processes; the basal articulation was mobile. These features are characteristic of edopoid rhachitomes, and the specimen fits closely the description of Edops craigi given by Romer and Witter (1942). Displacement of elements prevents the taking of a reliable suite of measurements, but the width of the dermal skull roof across the tabulars was about 115 mm. The corresponding measurement calculated from the illustrations given by Romer and Witter is about 190 mm, but these authors point out that the illustrated skull is close to maximum size and that other, fragmentary remains indicate smaller individuals. The only other large edopoid from the American Permian is Chenoprosopus—known only from northern New Mexico—but there are obvious differences between it and the form from Domingo Canyon. In Chenoprosopus the skull is narrow and the hind border of the postparietals is markedly convex, whereas the Domingo Canyon form resembles Edops in that the width across the pterygoids indicates a wide, flattened skull and the hind border of the postparietals is concave. Besides, the basal articulation in Chenoprosopus is sutural, at least in the adult (Langston, 1953). In the lack of better materials, the conservative course is to identify UCLA VP 1727 as an edopid rhachitome close to, if not congeneric with, Edops craigi. E. craigi is known only from the lower part of the Wichita Group in north-central Texas and is thus Wolfcampian in age. The presence of a closely similar edopid in the lowermost Abo Formation in Otero County is interesting in that it increases the resemblance of the Early Permian vertebrate fauna of southern New Mexico to the deltaic fauna of north-central Texas.

Vertebrate fossils were taken from a number of sites in Laborcita Canyon, but the two most productive localities are in NE1/4 sec. 18 and NW1/4 sec. 17, T. 15 S, R. 11 E. The more western of these two lies at the end of a spur and hence may appear, in Figure 1, to lie stratigraphically lower, but the two are actually within the same conglomerate-mudstone complex. Petrified logs were found in abundance along the north wall of the canyon. Many of the
fragments of bone from the Laborcita Canyon localities seem to pertain to pelycosaurian reptiles, and it has been possible to identify one fragmentary vertebra as of *Ophiacodon* sp. and one neural spine as of *Sphenacodon* sp. The *Sphenacodon* spine is of a size intermediate between those of *S. ferox* and *S. ferocior*, both of which are known from northern New Mexico—a vertebra of *Sphenacodon* cf. *S. ferox* was found at the Tularosa Canyon locality. One poorly preserved vertebra may represent *Edaphosaurus* sp.

The Laborcita Canyon localities have also yielded remains of at least two kinds of dissorophid labyrinthodont amphibians. From the eastern locality, a "sculptured" neural spine about 240 mm long above the zygapophyses, thin from side to side and anteroposteriorly expanded, unquestionably marks the presence of a species of *Platyhystrix*, a genus known also from southeastern Utah (Vaughn, 1966), southwestern Colorado (Lewis and Vaughn, 1965) and northern New Mexico (Langston, 1953). This specimen, UCLA VP 1732, may be safely identified as *Platyhystrix* cf. *P. rugosus*. Seven articulated dorsal vertebrae with attached ribs (UCLA VP 1722), also from the eastern locality, are of quite a different dissorophid, although one of about the same general size as *P. rugosus*. These vertebrae, of normal rhachitomous structure with short neural spines, are each about 50 mm tall from the bottom of the intercentrum to the top of the pitted plate of dermal "armor" that is solidly fused to the spine. The plates are small, not much wider than twice the diameter of the narrowest part of the spine. Detailed features of this form cannot be quite reconciled with published descriptions of any of the numerous dissorophids presently known—within which there is much variation in the pattern of the "armor"—but the materials are not sufficient to justify the naming of a new taxon. A partial skull (UCLA VP 1721) from the western locality is also of a dissorophid. Large parts of the braincase, of weathered dermal bones in the region of the orbits, and of the pterygoids are present. Unfortunately, only very small areas of the surface of the dermal bones are preserved, and the pattern of the "sculpture" cannot be characterized other than by saying that it exists. The pterygoids carry a shagreen of tiny teeth, and the interpterygoid vacuities are enormous. In transverse section, the skull has the deep, almost subrectangular outline typical of advanced dissorophids. This was a large form; the width between maxillary rims, measured in a transverse plane through the centers of the orbits, was about 115 mm. This skull seems to be appropriate in size to either the *Platyhystrix* spine or the short-spined vertebrae. It would be most interesting to be able to demonstrate that it belongs to the mysterious *Platyhystrix*, in which the cranium is so far known only from tuberculated scraps collected in northern New Mexico (Langston, 1953), but more and better materials are needed. A pelvis of dissorophid aspect was found in close proximity to the *Platyhystrix* spine. It may be hoped that further collection in this area will soon make it possible to supplement our meager knowledge of this strange, long-spined labyrinthodont.
Only scraps of bone were recovered from the locality between Laborcita and Cottonwood Canyons, in SW¼ sec. 17, T. 15 S, R. 11 E, but these serve to demonstrate the continuity of the fossiliferous band.

Both Cottonwood Canyon localities are in NE3¼ sec. 20, T. 15 S, R. 11 E. The locality on the south side of the canyon yielded some dermal bone and a few phalangeal elements of a labyrinthodont amphibian. On the north side, in a calcareous sediment that lies just above a conglomerate and that passes laterally into a mauve sandstone with abundant petrified wood, we found well preserved remains definitely referable to the pelycosaurian reptile Edaphosaurus. These materials, UCLA VP 1719, include four very closely associated vertebrae, two of which are nearly complete, and parts of several ribs. The direction of curvature of one of the neural spines indicates that the vertebrae are from the posterior dorsal region. The centra are about 26 mm long, 24 mm high, and 23 mm wide. The posterior zygapophysial surfaces lie about 40 mm above the bottom of the centrum. The neural spine of one of the vertebrae was somewhat more than 410 mm long, and it shows the lateral tubercles characteristic of the genus. Comparison with measurements of centra in various species of Edaphosaurus published by Romer and Price (1940) shows that UCLA VP 1719 fits into the size range of both E. novomexicanus—known from northern New Mexico—and E. boanerges—known from the Wichita Group of north-central Texas. Romer and Price point out that because E. novomexicanus is inadequately known, it is difficult to distinguish the two species without good materials of cervical vertebrae. Geographical grounds alone would not seem to offer sufficient basis, but a difference in horizon might provide some justification for tentative identification. Steiner and Williams (1968), on the basis of the fusulinid fauna, come to the conclusion that the Laborcita Formation is correlative with the Pueblo and lower Moran Formations of north-central Texas. E. boanerges is known from the Putnam and Admiral Formations, which lie above the Moran within the Wichita Group. Correlation with the Texas column of the beds in northern New Mexico from which E. novomexicanus is known is inexact, but since Romer and Price feel that E. boanerges is slightly more advanced morphologically, it may not be unreasonable to assume that E. novomexicanus is from a somewhat lower horizon. In view, then, of the fact that UCLA VP 1719 comes from that part of the Abo Formation that is a time-equivalent of the uppermost part of the Laborcita Formation, stratigraphic considerations perhaps warrant tentative identification as Edaphosaurus cf. E. novomexicanus. There is no evidence that the partial neural spines found at the Domingo Canyon locality belong to a different species.

Vertebrates found in the Laborcita and Abo Formations of Otero County:

Elasmobranch fishes

A pleuracanth

Acanthodian fishes
Acanthodes sp.
Palaeoniscoid fishes
   One or more kinds
Crossopterygian fishes
   A rhipidistian
Labyrinthodont amphibians
   Edopid rhachitomes
      A form similar to Edops
   Dissorophid rhachitomes
      Platynystrix cf. P. rugosus
      A probable new form
Pelycosaurian reptiles
   Ophiacodon sp.
   Sphenacodon cf. S. ferox
   Sphenacodon sp.
   Edaphosaurus cf. E. novomexicanus

DIMETRODON FROM THE CABELLO MOUNTAINS

Using the geologic map published by Kelley and Silver (1952), my field party searched for vertebrates in the Abo Formation of the Caballo Mountains and found productive localities in about the center of sec. 36, T. 14 S, R. 4 W and in NW 1/4 sec. 6, T. 15 S, R. 3 W, Sierra County. Plants, bones of labyrinthodont amphibians, and footprints were found at the first locality, and labyrinthodont bones were also found at the second locality. Because this new source of Lower Permian vertebrates seems so promising, a more extensive search is planned in this area, but the remains described below, from the second locality, are of immediate interest to this report and will be discussed now.

UCLA VP 1724, 1725 and 1726 are fragments of neural spines that show the figure-8 cross-section characteristic of the pelycosaurian reptile Dimetrodon. The largest (1725) is about 70 mm long. That the fore and aft grooves are nearer to one another than the spine is wide shows that this fragment is from about midway along a spine. The width is about 15 mm. Another fragmentary neural spine, UCLA VP 1733, found along with the others, shows the characteristic transition from the compressed, laterally flattened proximal portion to the transversely expanded distal portion. A centrum with a partial neural arch was found in immediate proximity to the fragmentary spines and is probably part of the same animal. The centrum has a sharp ventral keel, the floor of the neural canal is thoroughly ossified, and enough is left of the neural arch to show that it was laterally excavated; it is thus clear that this specimen, UCLA VP 1723, is of a sphenacodontid pelycosaur, and this rules out any possibility of confusion with the poorly known edaphosaur Lupeosaurus. The centrum is slightly distorted, but it was about 33 mm long, 28 mm wide, and
36 mm high. The posterior zygapophyses lie about 50 mm above the bottom of the centrum. These dimensions fit into the range of *Dimetrodon limbatus* known from north-central Texas and described in detail by Romer and Price (1940). The Caballo Mountains specimens may be provisionally referred to *Dimetrodon* aff. *D. limbatus*.

In Texas, *D. limbatus* occurs in the Admiral and Belle Plains Formations of the Wichita Group and thus straddles the boundary between the Wolfcampian and Leonardian Series (see Dunbar, et al., 1960). It is noteworthy that similar vertebrae have been reported from the Organ Rock Shale of the Cutler Group, southeastern Utah, and that the Organ Rock is probably earliest Leonardian in age (Vaughn, 1966). The few vertebral parts from the Abo Formation of the Caballo Mountains hardly offer sufficient grounds for detailed assessment of age, but it would seem that they are from a higher horizon than the fossils described from the uppermost Laborcita and lowermost Abo Formations of the Sacramento escarpment, and it cannot be said with assurance that they are Wolfcampian, although the Abo Formation is generally considered to be almost wholly of that age (Dunbar, et al., 1960). Nevertheless, they are certainly at least very close to Wolfcampian in age, and it is hence of considerable interest that these remains of a species of *Dimetrodon* were found in the region of Kottlowski's (1963) "mean shoreline of the Wolfcampian seas." This is the first report of *Dimetrodon* from New Mexico.

**Paleozoogeographic Considerations**

The rhipidistian from the Laborcita and Abo Formations of Otero County and the species of *Dimetrodon* from the Abo of Sierra County seem to verify the prediction that these elements were to be found in New Mexico in strata in the region of interfingering of marine and terrestrial sediments. The presence of these elements along Kottlowski's "mean shoreline of the Wolfcampian seas" lends support to the distinction between "eu-deltaic" and "somewhat more upland" Early Permian faunas, and perhaps the edopid from Otero County supplements this support.

Figure 2 is a simplified map of Wolfcampian highlands—or at least positive areas—and major seaways superimposed on outlines of states in the Four Corners and Midcontinental regions. Areas of collection of Wolfcampian—and to some extent lowest Leonardian—vertebrate fossils are indicated by letters within circles: "C" and "S" represent the Cabello Mountains and Sacramento escarpment areas in southern New Mexico discussed above; "L" and "M" stand for localities in the Cutler Group in Lisbon Valley and the general vicinity of Monument Valley in southeastern Utah discussed in my earlier paper (1966), which gives references to other papers on these faunas; "P" stands for the fauna from the undifferentiated Cutler Formation near Placerville in southwestern Colorado described by Lewis and Vaughn (1965); "A" stands for the vertebrates known from the Cutler Formation around
Figure 2. Simplified map of Wolfcampian positive elements and seaways, based on maps by McKee, Oriel, et al. (1967). The names of the seaways are informally derived from names of geosynclines, basins and negative belts. Positive elements are drawn in black: AP, Apishapa; AR, Arbuckle Mountains; DF, Defiance; FI, Florida Islands; FR, Front Range; NC, Nacimiento; OM, Ouachita Mountains; PD, Pedernal; SG, Sierra Grande; SL, San Luis; UN, Uncompahgre; WI, Wichita Mountains; ZN, Zuni. Letters within circles indicate general areas of collection of Wolfcampian—and to some extent lowest Leonardian—vertebrates: in Utah, L, Lisbon Valley, and M, Monument Valley; in Colorado, P, Placerville; in New Mexico, A, Arroyo de Agua and Jemez Springs, C, Caballo Mountains, R, Ribera, and S, Sacramento escarpment; in Oklahoma, O, northern; and in Texas, T, north-central.

Arroyo de Agua in Rio Arriba County and the Abo Formation near Jemez Springs in Sandoval County, northern New Mexico, that have been summarized by Langston (1953) and Romer (1960); “R” stands for as yet undescribed vertebrates known from the Sangre de Cristo Formation near Ribera in San Miguel County, northern New Mexico; “T” stands for the well known Lower Permian vertebrates from the Wichita Group in north-central Texas summarized by Romer (1958); and “O” represents vertebrates from the Wellington Formation of northern Oklahoma summarized by Olson (1967).

The outlines of the positive areas and seaways are based on maps published by McKee, Oriel, et al. (1967). The positive areas are taken from their Plate 9, which shows these areas in the time of deposition of rocks of “interval A”—essentially equivalent to the Wolfcampian Series. The outlines of the seaways are taken from their Figure 4, which shows the “Distribution of significant chemical sediments of interval A at time of maximum extent of sea.” They draw boundaries between limestone, dolomite, anhydrite and gypsum, and halite deposits, but this differentiation is not made in the simplified
diagram presented here. The map in the present report differs in substantial ways from the one I used in 1966. Better information, from McKee, Oriel, et al., now permits the drawing of a much more extensive “Midcontinental seaway” rather than the restricted “Leonardian seaway” I drew then. The “Sonoran” and “Orogrande seaways” have been added in southern Arizona and New Mexico, with the boundary of the latter corresponding essentially to the belt of gradation mapped by Kottlowski (1963:Fig. 12) from the red-beds facies of the Abo Formation into the Hueco Limestone. I have included the southeastern Utah “Elephant Canyon seaway” of my 1966 map in the “Cordilleran seaway” of the present map. The positive areas of the “Florida Islands” in New Mexico and the “Ouachita Mountains” in Texas have been added, and other positive areas have been broken into smaller units. The cluster of small units north and northwest of the Pedernales positive element in New Mexico seems to be especially important.

Of the collecting areas indicated in Figure 2, the northern Oklahoma and north-central Texas localities in the Midcontinent, the Lisbon Valley and Monument Valley localities in southeastern Utah, and the Caballo Mountains and Sacramento escarpment localities in southern New Mexico seem to represent “eu-deltaic” conditions, near borders of persistent seaways. Romer (1958) has described the deltaic nature of the Wichita Group of north-central Texas, and I have pointed out the evidence for deltaic conditions during the times of deposition of the red-beds units of the Cutler Group in southeastern Utah. The faunas from the Midcontinent and southeastern Utah all include a rhipidistian, the nectridean amphibian Diplacaulus, the labyrinthodont amphibian Seymouria (with some question in Oklahoma; see Olson, 1967), and the pelycosaur Dimetrodon. A difference between the faunas from the two sides of the “Midcontinental seaway” is that the Midcontinental rhipidistian is Ectosteorhachis, whereas only Lohsansia has been definitely recognized in southeastern Utah (Thomson and Vaughn, 1968), although it is not yet clear that Ectosteorhachis does not occur there too. It is not possible with the limited materials at hand to determine the generic identity of the rhipidistian from southern New Mexico. Ectosteorhachis is not included in Olson’s (1967) faunal lists of the Wellington Formation of Oklahoma, but he has told me that it does occur there. It must be noted that the part of the Wellington Formation from which the “eu-deltaic markers” come is probably an upper Wichita equivalent (Olson, 1967) and thus probably earliest Leonardian rather than strictly Wolfcampian in age, but this seems close enough for a broad-ranging comparison. Although the rhipidistian and Diplacaulus from southeastern Utah have been reported from Wolfcampian horizons within the Cutler Group—the rhipidistian from both the Halgaito Shale in Monument Valley and a conglomerate low in the undifferentiated Cutler sediments of Lisbon Valley, and Diplacaulus from the latter place—Seymouria and Dimetrodon have heretofore been reported in that region only from a lowermost Leonardian horizon, the Organ Rock Shale
of Monument Valley (Vaughn, 1966). Recently, however, a fragmentary neural spine of *Dimetrodon* sp., UCLA VP 1728, has been found in the Halgaito Shale; and it is also of interest that *Diplocaulus* (UCLA VP 1729) is now known from the Halgaito too. To date, of the four "markers," only a rhigidistian and *Dimetrodon* are known from the southern New Mexico areas discussed in previous sections of this report, but it is fair to say that the program of collection in these areas is still in its very early stages.

The fossiliferous parts of the Cutler Formation around Arroyo de Agua in Rio Arriba County and of the Abo Formation near Jemez Springs in Sandoval County, northern New Mexico, seem clearly to be equivalent to the lower—Wolfcampian—parts of the Wichita Group of north-central Texas (Langston, 1953; Romer, 1960). Despite intensive search in this region since the last century, a search that has resulted in collection of a large and varied fauna, no signs of rhigidians or of *Diplocaulus, Seymouria* or *Dimetrodon* have been reported. The lack of a rhigidistian record is especially striking; when present, scales of these fishes are usually abundant and obvious. The seaway between northern New Mexico and the Midecontinent can no longer be cited as an effective barrier to faunal distribution, now that the above elements are known from southeastern Utah. The explanation, as I indicated in 1966, probably lies in a "somewhat more upland" position of the northern New Mexico areas in Wolfcampian time. Figure 2 shows these areas as relatively far removed from the borders of seaways, and it may be important to note that an arc of small positive elements, extending northwestward from the Pedernal highland, separates these areas from the basin of the "Orogrande seaway." Much of the difference between the Early Permian faunas of northern New Mexico and the Midecontinent may have been due, not to a water barrier, but to environmental dissimilarity in terms of relative degree of approach to truly deltaic conditions; and the finds of a rhigidistian and *Dimetrodon* along the "mean shoreline of the Wolfcampian seas" in southern New Mexico would seem to corroborate this hypothesis. There is, nevertheless, the possibility that the "Midecontinental seaway" did form a partially effective barrier—or better, filter. The pelycosaur *Sphenacodon* is known from southeastern Utah, southern New Mexico, and also northern New Mexico, but it is unreported from the Midecontinent. The long-spined labyrinthodont amphibian *Platyhystrix* is known from southeastern Utah, southwestern Colorado, northern New Mexico and now also southern New Mexico, but not from the Midecontinent, although somewhat similar forms have been found in north-central Texas.

Beds low in the Sangre de Cristo Formation near Ribera in San Miguel County, northern New Mexico, have recently yielded a fair number of vertebrate remains, but none of the "eu-deltaic markers" has been seen there, although the nature of the deposits should have made rhigidistian scales easily visible if present. A few vertebrates have also been found farther south in New Mexico, in the Abo Formation in Socorro County—but still north of the
Caballo Mountains and Sacramento escarpment localities; these are elements known also from northern New Mexico (Langston, 1953).

The undifferentiated Cutler Formation near Placerville in southwestern Colorado has yielded a fair-sized vertebrate fauna that may show some special resemblance to the north-central Texas fauna in the inclusion of the pelycosaur Mycterosaurus (Lewis and Vaughn, 1965). An approach to the "eu-deltaic" faunas may also be indicated by the presence of a primitive seymouriid, known unfortunately from only a single vertebra, but the lack of any sign of rhipidistians is noteworthy. As in southeastern Utah and northern and southern New Mexico, Platysphyrinx is present. Although it lived close to the southern end of the Uncompahgre highland, the southwestern Colorado fauna may have been somewhat intermediate between the faunas of southeastern Utah and northern New Mexico.

The complete picture is still vague, but it would seem that on a large scale, Early Permian vertebrate faunas were fairly much alike throughout at least the western part of the United States although seaways may have formed filters affecting distribution of certain elements; and on a smaller scale, many of the differences between local faunas can be accounted for by environmental dissimilarities such as differing degrees of proximity to truly deltaic conditions. Invocation of water barriers should be a last resort in attempts to explain differences.

The predictability of discovery of rhipidistians and Dimetrodon in "eu-deltaic" as opposed to "somewhat more upland" deposits, which has been at least partially verified in New Mexico, provides a more refined analysis of the habitat of these forms, and it may be hoped that such refinement can be extended. Certain vertebrates, whose fossils are rare in either the Four Corners or the Midcontinent, may lengthen the list of strictly "eu-deltaic" elements. For example, the pelycosaur Ctenospondylus is known only from southeastern Utah and north-central Texas, but its remains are extremely rare in Texas. The edopid labyrinthsodont from southern New Mexico reported above, which may belong to the genus Edops known otherwise only from north-central Texas, may be another of these elements. It must also be noted that the various local faunas each seem to contain elements uniquely their own; for examples, the seymouriamorph-diadectomorph intermediate Tseajia is known only from southeastern Utah, the pelycosaur Culeria is known only from southwestern Colorado, and the cochleosaurid edopoid Chenoprosopus is known only from northern New Mexico (see Vaughn, 1966, for references).

A recent analysis of upper Paleozoic floras by Read and Mamay (1964) corroborates my earlier opinion that drier conditions set in earlier in the Four Corners region, at least in southeastern Utah, than in the Midcontinent. Because such considerations are potentially important to a continuing analysis of faunal differences, the evidence may be briefly reviewed.

The lithology and faunas of the famous Lower Permian red beds of
north-central Texas indicate a history of increasing dryness. Romer (1958: 165-166) has summarized his view of conditions during the time of deposition of the Wichita Group (the upper part of which straddles the Wolfcampian-Leonardian boundary): "the flora is in part xerophytic . . . but in some deposits . . . was of a lush nature, and the considerable quantity of remains of fishes and of tetrapods obviously aquatic to amphibious in habits indicates an abundance of water. The picture as a whole suggests conditions comparable to those of lower Mesopotamia where swamp and desert regions may lie in close proximity." In the Clear Fork Group (Leonardian), above limestones of the Lueders Formation deposited during an interval of extensive marine transgression, the sediments are of a more oxidized nature except in pond deposits, and Romer pictures conditions similar to those of the Colorado River delta. In the Arroyo Formation, burrows of the aestivating lungfish Gnathorhiza are found, and this is a clear indication of seasonal drought; such burrows are also found in the overlying Vale Formation. Olson (1958) has interpreted the evidence from the lithology and faunas of the Vale and the succeeding Choza Formation as an indication of a continuing trend to drier conditions during later Clear Fork time. There were apparently extended periods of drying in Vale time; in Choza time, vertebrates and plants became restricted to the vicinity of water courses. The higher parts of the Choza Formation are characterized by evaporite deposits.

In southeastern Utah, the Cutler Group consists of, in ascending order: the Halgaito Shale, the Cedar Mesa Sandstone (apparently of shallow-water marine origin), the Organ Rock Shale, and the De Chelly Sandstone (aeolian dunes with vertebrate fossils in the form of trackways only). These formations are discussed in my earlier paper (1966) which gives references to reports on stratigraphy and faunas. The Halgaito and Organ Rock Shales are deltaic redbeds units, the former of Wolfcampian age and the latter probably earliest Leonardian. That the transition from Halgaito to Organ Rock conditions included increasing dryness is indicated even by the scant flora known to date: the Halgaito yields such plants as Calamites, arborescent lycopods, Callipteris and Neuropteris, whereas Supala, Yakia and Walchia come from the Organ Rock. But there is also evidence that the onset of drier conditions occurred earlier than in the Midcontinent. Even as low as the Halgaito, vertebrate remains are restricted to the vicinity of stream-channel deposits, and this restriction persists in the Organ Rock. In neither of these formations are there pond deposits, although they are common in the Wichita Group. Pleuracanth sharks are known from the Halgaito but not from the Organ Rock. Palaenopsiscoid fishes are not common in the Halgaito, and they are exceedingly rare in the Organ Rock. Whereas in Utah rhipidistians are not found above the horizon of the Halgaito, in the Midcontinent they persist practically throughout the Wichita Group in north-central Texas (Romer, 1958) and in Oklahoma reach as high as the Garber Formation, which is probably a lower Clear Fork equiva-
lent (Olson, 1967). In Utah, the aestivating lungfish *Gnathorhiza* appears at a much lower horizon, in the Halkgaito Shale, than in north-central Texas. In Texas, the lungfish of the Wichita Group is the apparently non-aestivating *Sagenodus*, and *Gnathorhiza* does not appear until the horizon of the Arroyo Formation—approximately middle Leonardian—is reached (Romer, 1958) although it is present in an upper Wichita equivalent—lowest Leonardian—in Oklahoma (Olson, 1967). The faunas from the Cutler Group in southeastern Utah are poor in the aquatic labyrinthodonts that are such common elements of the Wichita faunas. Although *Eryops* and *Platyhystrix* are known from the Halkaito, and possible remains of *Eryops* and a zatracheid from the Organ Rock, there are as yet no signs of the obviously highly aquatic forms *Trimerorhachis* and *Archeria*. Conditions may have been somewhat moister in parts of northern New Mexico, as indicated by the presence of an amphibian similar to *Archeria* in the Abo Formation near Jemez Springs (Langston, 1953), but to the southeast near Ribera, lungfish burrows high in the Sangre de Cristo Formation indicate at least seasonal drought (see Vaughn, 1966).

Read and Mamay (1964) show that Wolfcampion florals were essentially alike throughout the United States, but that the Leonardian floras show marked geographic diversity. Of particular significance to the present discussion are the differences between the *Supaia* flora—west of the ancestral Rocky Mountains—and the *Gigantopteris* flora—east of the mountains. Roughly speaking, the *Supaia* flora is the Leonardian flora of the Four Corners, and the *Gigantopteris* flora is the Leonardian flora of the Oklahoma and Texas parts of the Midcontinent, extending into southeastern New Mexico. Read and Mamay make a distinction between “older” (upper Wichita) and “younger” (Clear Fork) *Gigantopteris* floras. They (1964:17) characterize the older *Gigantopteris* flora as “a vigorous association that grew under much milder ecologic conditions than did the [contemporaneous] *Supaia* flora.” Of the latter, they say (*loc. cit.*) that “The sediments contain mud cracks and molds of salt crystals, which suggest a relatively rigorous climate . . . The flora itself lacks . . . elements that normally grew under swampy or nearly swampy conditions. The evidence thus suggests that the *Supaia* flora represents the remnants of a lush flora that became impoverished by an unfavorable environment and was barred from eastward dissemination by the Ancestral Rocky Mountains.” Not only is this broad analysis applicable in detail to the changes seen in progression from the Halkaito to the Organ Rock Shale, but in the general trends it portrays it complements the evidence from the vertebrate faunas that drier conditions appeared earlier in the Four Corners than in the Midcontinent. The causes for this differential are obscure, but Opdyke (1961), on the basis of directions of slope in aeolian deposits, came to the conclusion that the prevailing Early Permian winds of the southwestern United States were from the North and Northeast; he related this to a lower paleolatitude calculated from paleomagnetic data for continental drift. Is it possible that the ancestral Rocky Moun-
tains threw something of a rain shadow over parts of the Four Corners area?

The developing climatic picture may permit certain refinements in explanation of detailed differences between the Lower Permian vertebrate faunas from the two sides of the ancestral Rocky Mountains. It may help explain, for example, the earlier appearance of aestival lungfish in southeastern Utah and perhaps also the earlier disappearance of rhipidistians. In broader terms, it helps in an understanding of the generally less aquatic aspect of the Four Corners faunas; Romer (1960:52) has remarked that Wichita conditions seem to have been "less arid than those of the Abo-Cutler, and this is reflected in the relative composition of the fauna, the New Mexican beds being conspicuously poor in their representation of aquatic forms."

These considerations also suggest that the extensive system of Early Permian positive elements in Colorado and New Mexico may have formed the backbone of an upland partial obstacle to vertebrate distribution at least as effective as the "Midcontinental seaway."

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LITERATURE CITED


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