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Peter Paul Vaughn
1973, pp. 99-105. https://doi.org/10.56577/FFC-24.99

in:

Monument Valley (Arizona, Utah and New Mexico), James, H. L.; [ed.], New Mexico Geological Society 24 th Annual Fall Field Conference Guidebook, 232 p. https://doi.org/10.56577/FFC-24

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VERTEBRATES FROM THE CUTLER GROUP OF MONUMENT VALLEY AND VICINITY

by

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INTRODUCTION

Fossil vertebrates have been known from the Cutler sediments of northern New Mexico since the late nineteenth century, and subsequent collections by a number of workers have revealed a fauna of fair variety (Romer, 1960), but published reports of Permian vertebrates from Monument Valley appeared only much later, and the faunal list to date is not long. Baker (1936) mentioned vertebrate remains found in the Halgaito Shale near the San Juan River shortly west of the Honaker Trail, and in the Organ Rock Shale both north of and southeast of Train Rock, but no intensive effort at collection was made until Professor Charles L. Camp, of the University of California at Berkeley, led a field party in 1942 to prospect in the general vicinity of Monument Pass. Additional specimens have been found near the Three Sisters pinnacles in 1950 by Mr. John R. Dyer of Bismarck, North Dakota. These collections have been described in detail in a series of papers cited below, and they have been analyzed from the viewpoint of paleozoogeography (Vaughn, 1966b, 1970; Olson and Vaughn, 1970). In the meantime, vertebrates have also been described from the Cutler Group of southwestern Colorado (Lewis and Vaughn, 1965). The following is a summary of what is presently known of Permian vertebrates from Monument Valley and vicinity; the field indications are that many bones remain to be uncovered.

It may be appropriate to comment on the stratigraphic terminology. Cross and Howe (1905) named the Cutler Formation for a sequence of red beds in southwestern Colorado. This name was extended to southeastern Utah by Baker and Reeside (1929), who assigned to this formation the Halgaito, Cedar Mesa, Organ Rock, DeChelly and Hoskinnini units, the red-beds units (Halgaito, Organ Rock, Hoskinnini) as tongues and the light-colored, cross-bedded sandstone units (Cedar Mesa, DeChelly) as members. This usage was followed in later papers by a number of authors, but since the work of Stewart (1959), the Hoskinnini has generally been treated as a member of the overlying Moenkopi Formation. Wengerd and Matheny (1958) proposed group status for the Cutler sediments, a suggestion adopted by Baars (1962), who used the terms Halgaito Shale, Cedar Mesa Sandstone, Organ Rock Shale and DeChelly Sandstone for the included formations, and who referred to the Cutler sediments near the source of the red-beds materials in southwestern Colorado as the Cutler Group—undifferentiated. Ohlen and McIntyre (1965) used the same terminology, making it clear, however, that the lower parts of the Cutler Group in southwestern Colorado are of Late Pennsylvanian age, stratigraphically equivalent to the formations of the Hermosa Group underlying the Cutler Group in Monument Valley; but formational designation of the Cutler in both southwestern Colorado and southeastern Utah persisted, e.g.,

in the paper by McKee, Oriel and others (1967). The terminology of Baars will be followed here. Based on comparisons of vertebrate fossils from the Cutler of Monument Valley with those from the Lower Permian of north-central Texas, it would seem that the Halgaito Shale and Cedar Mesa Sandstone are of Wolfcampian age and that the Organ Rock Shale is probably the equivalent of beds near the boundary of the Wolfcampian and Leonardian provincial series (Vaughn, 1970). The fossils from the DeChelly Sandstone are not helpful in determination of age, but the DeChelly is probably no younger than Leonardian (Baars, 1962).

Of the divisions of the Cutler in Monument Valley and immediately nearby, only the Halgaito and Organ Rock shales have yielded bones. No vertebrates are known from the Cedar Mesa Sandstone (apparently of shallow-water marine origin according to Baars, 1962) and in the DeChelly Sandstone where vertebrate fossils have been found in the form of trackways only. Somewhat farther afield, bones have been recovered from the Elephant Canyon Formation, the northern, marine equivalent of the Halgaito (Baars, 1962); and also in the undifferentiated Cutler sediments in Lisbon Valley south of La Sal, along the Colorado River east of Moab and in the area south of Dead Horse Point.

In both the Halgaito and the Organ Rock, occurrences of bones are, with rare exceptions, limited to what are apparently stream-channel deposits; within these deposits they are found in limestone and clay-pellet conglomerates and in shallow-angled, cross-bedded sediments of finer grains within and immediately above and along the lower lateral edges of conglomeratic lenses. The fossiliferous beds stand out as resistant ledges more somber in color than the brightly colored red shales and sandstones surrounding them. These ledges are discernible even at considerable distance, and the finding of fossils is hence fairly easy, although the actual extraction may be more difficult, usually requiring the application of hammer and chisel. The greatest contrast with occurrences of bones in the classic collecting grounds in the Cutler of northern New Mexico and the Wichita and Clear Fork groups of north-central Texas (Lower Permian) is the absence, in Monument Valley, of "bog" and "pond" deposits.

In the Halgaito, bones are found at several levels but always above the horizon of the A limestone, which marks, in the region of Lime Ridge, a thickening of the marine Rico Formation at the expense of the overlying Halgaito Shale (O'Sullivan, 1965). The fossiliferous conglomerates of the Halgaito, examined mostly in the general region of Lime Creek Valley (Valley of the Gods), are of variable thickness, from less than a foot to about twenty-five feet. Fragmentary, but numerous pieces of bones, scales and teeth are found in the conglomerates, but rarer specimens occur in the closely associated sandstones.

Some of the more fossiliferous localities are: along Lime Creek in NW$^1/_4$ sec. 21, T. 41 S., R. 19 E., in the Valley of the Gods in NW$^1/_4$ sec. 29 and NE$^1/_4$ sec. 34, T 40 S., R. 19 E. and in Johns Canyon in SW'/ sec. 25, T. 40 S., R. 17 E. An easily accessible locality where scales of crossopterygian fishes and teeth of xenacanth sharks may be found in the conglomerates is the immediate area of the Mexican Hat pedestal in SW$^1/_4$ sec. 32, T. 41 S., R. 19 E.

The productive stream-channel deposits of the Organ Rock Shale are much more limited in level, with the only really good producing layers lying thirty to forty feet above the uppermost typical sandstone of the Cedar Mesa, as measured in the area north of Hoskinnini Mesa. The thickness of this stream-channel complex varies, but is typically about five to fifteen feet. Some productive sites are: the general area southeast of Monument Pass in SW'/4 sec. 17 and NW$^1/_4$ sec. 20, T. 43 S., R. 17 E.; outliers southeast of Train Rock in NE$^1/_4$ sec. 11, T. 43 S., R. 15 E.; the area immediately north of Hoskinnini Mesa (especially around the base of a bell-shaped butte in SW$^1/_4$ sec. 7, T. 43 S., R. 14 E.) and the sides of low buttes about a mile north of Organ Rock Monument near the center of the northern half of sec. 16, T. 42 S., R. 14 E. In general, the Organ Rock yields more complete specimens than does the Halgaito. As in the Halgaito, impressions and casts of plants are encountered in the finer-grained parts of the stream-channel layers; and plants, as well as trackways, are also found in fine-grained sediments higher in the section. Unlike the Halgaito, the Organ Rock is only locally productive north of the San Juan River, at about which latitude the producing stream-channel complex seems to grade into the uppermost Cedar Mesa Sandstone. Nevertheless, a few bones have been found north of the river, along the Clay Hills and along the southern flank of Elk Ridge south of the Bear's Ears, but these are isolated occurrences at somewhat higher levels. Farther north, bones have been found in the Organ Rock along Indian Creek near the Needles country, but they are far from plentiful.

THE FAUNA

Although the fossils recovered from the Halgaito Shale are fragmentary, the fragments are large enough and include enough diagnostic parts to make identification not too difficult. In most cases, it has been possible to identify specimens down to the level of species, but generic designation will suffice for present purposes. Remains of the ubiquitous freshwater sharks of Early Permian time, *Xenacanthus,* are common; their characteristic teeth with two large, divergent prongs and an intermediate cuspule are encountered almost everywhere in the conglomeratic lenses. Almost as common are large, shiny scales whose microstructure clearly indicates that they are of rhipidistian crossopterygian fishes, of which cranial and vertebral parts have also been found. It was thought at first that these remains pertained to the genus *Ectosteorhachis,* well known from the Lower Permian of north-central Texas and long assumed to be the last surviving rhipidistian, but subsequent finds, including vertebrae quite distinct from those in *Ectosteorhachis,* have necessitated recognition of the new genus *Lohsania* (Thomson and Vaughn, 1968). Scales of primitive actinopterygian fishes (palaeoniscoids) are rare, as are signs of the lungfish *Gnathorhiza.* This lungfish is recognized on the basis of a number of its peculiar toothplates, found high in the Halgaito shortly beneath the contact with the Cedar Mesa Sandstone; although its representation in the collections is scanty, the presence of *Gnathorhiza* is of paleozoogeographic significance, as will be brought out below.

Amphibians of both the better known labyrinthodont-kind and the less understood lepospondylous-kind are known from the Halgaito, but in very limited variety as compared with the list of amphibians known from north-central Texas. Of labyrinthodonts, there are remains of the large rhachitome *Eryops* (including excellent skulls) and the remarkable *Platyhystrix,* a creature with long, laterally-flattened, erect spines attached to its vertebrae (fig. 1). The cranium of *Platy-*

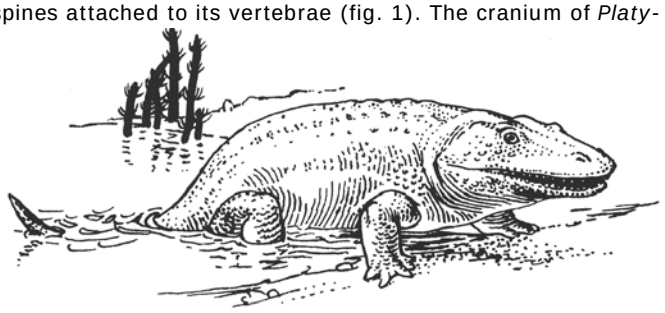

Figure 1.

A reconstruction of the Lower Permian amphibian Eryops, *which was about five or six feet in length. Reprinted from "The Age of Reptiles" with the kind permission of E. H. Colbert and W. W. Norton and Company, Inc.*

hystrix remains almost completely unknown, but the construction of the central parts of the vertebrae clearly labels it as a rhachitomous labyrinthodont. Of lepospondyls, the nectridean *Diplocaulus,* a bizarre form with long, horn-like extensions of the posterolateral parts of its skull, is known on the basis of its distinctive vertebrae, as is also a tiny representative of the limbless, somewhat snake-like aistopods; the Halgaito aistopod, whose remains are found in association with *Gnathorhiza,* is probably referable to the genus *Phlegethontia.*

Diadectes (fig. 2), a cotylosaur with transversely widened teeth who subsisted conceivably on vegetable matter and molluscs and whose classification as advanced labyrinthodont amphibian or very primitive reptile is a matter of contention, is known from several collecting sites in the Halgaito. A few vetebrae suggest the presence of a limnoscelid, a member of another group of cotylosaurs whose affinities are currently in dispute. Pleycosaurs, a very primitive mammal-like reptile in the broadest sense of the term, is represented by several kinds: the apparently aquatic *Ophiacodon;* the *Edaphosaurus,* a seeming herbivore with a large battery of palatal teeth and with long, tuberculated extensions of the neural spines of its vertebrae and a sphenocodont, one of those pelycosaurs most similar to the truly mammal-like reptiles of later Permian time, the therapsids.

In the canyons tributary to Comb Wash north of the San Juan River, along the eastern edge of Grand Gulch Plateau, are found exposures of what Sears (1956) called a "lower soft" part of the Cedar Mesa Sandstone, but which seems more likely to be the southernmost extension of the marine Elephant Canyon Formation grading into and overlapping the Halgaito Shale. These beds are not to be confused with the gypsiferous facies of the Cedar Mesa Sandstone somewhat farther south (O'Sullivan, 1965). Almost any limestone sample taken from these canyons will yield, upon etching with dilute

Figure 2.

A reconstruction of the Lower Permian cotylosaurian reptile, Diadectes. *It was about six to eight feet long. Reprinted from "The Age of Reptiles" with the kind permission of E. H. Colbert and W. W. Norton and Company, Inc.*

acids, tiny vertebrae, nor quite a millimeter long, that seem to be of actinopterygian fishes whose vertebral structure was remarkably advanced as compared with other Early Permian actinopterygians (Vaughn, 1967). Actinopterygian teeth and scales are also found in these limestones, as well as shark teeth and various invertebrates including foraminifers, gastropods, pelecypods, crinoids and echinoids. A limestone in Arch Canyon has also yielded a dermal plate of a rhipidistian crossopterygian fish, probably washed northward from the Halgaito delta into marine waters. These tiny vertebrae are also found in the Elephant Canyon Formation north of Elk Ridge, in the areas of Gibson Dome, Cane Creek anticline and the type locality of the formation near the confluence of the Green and Colorado rivers.

The list of vertebrates known from the Organ Rock Shale is even shorter than that for the Halgaito. Signs of palaeoniscoid fishes are extremely rare; interestingly, most of the scales of these fishes recovered from the Organ Rock are found in coprolites, presumably representing remnants of the meals of their carnivorous neighbors. No xenacanth sharks, crossopterygians, nor lungfishes have as yet been found. *Eryops* is scantily represented, as is another rhachitomous labyrinthodont similar to the well known *Zatrachys* of northern New Mexico. A single lower jaw seems to be of the rhachitome *Trimerorhachis.* Excellent, nearly complete skeletons of *Seymouria* in a range of stages of maturity have been obtained in the region a short distance south of Monument Pass. This anthracosaurian labyrinthodont has long been cited in textbooks for its close approach in many features to the reptilian level of structural organization, although it now seems clear that this was not actually ancestral to reptiles. Examples of this latter class are also known from much older beds, lower in the Pennsylvanian.

One of the most noteworthy finds in the Organ Rock was made by Professor Camp, who discovered in 1942 an almost perfect skeleton of a very advanced anthracosaur southeast of Monument Pass. This phylogenetically important form, named *Tseajaia campi* (Vaughn, 1964), has recently been described and analyzed in detail (Moss, 1972) and has given us welcome insights into the origins of the diadectid cotylosaurs, presenting us with a morphological link between these and the more typical labyrinthodont amphibians. Of course, *Tseajaia* was too late in time actually to have given rise to the diadectids—representatives of which are known in the Upper Pennsylvanian. *Diadectes* itself is also known from the Organ Rock, in the form of a species of larger size than that known from the Halgaito; good specimens, including cranial materials with characteristically widened teeth, have been found at a number of sites.

Pelycosaurs found in the Organ Rock include an *Ophiacodon* of larger size than that in the Halgaito, and at least three sphenacodonts *(Edaphosaurus* seems not to be present). There is a species of *Sphenacodon,* poorly known but apparently comparable to *S. ferocior* (fig. 3) of northern New Mexico;

Figure 3.

The skeleton of the pelycoasaur Spenacodon, *which is about 10 feet long. From Romer and Price, 1940.*

this is a sphenacodont with vertebral neural spines of relatively normal length. In addition, there are two sphenacodonts with greatly elongated neural spines: *Ctenospondylus* and *Dimetrodon* (fig. 4). The recognition of these two forms in southeastern Utah is surprising. *Ctenospondylus,* with long, laterally-flattened spines, had been known only from north-central Texas, and on the sole basis of a few vertebrae found in 1881; the Monument Valley specimens are relatively plentiful and include not only vertebrae but good cranial and other parts, so that *Ctenospondylus* is now fairly well known. Although *Dimetrodon,* a well publicized pelycosaur with extremely long,

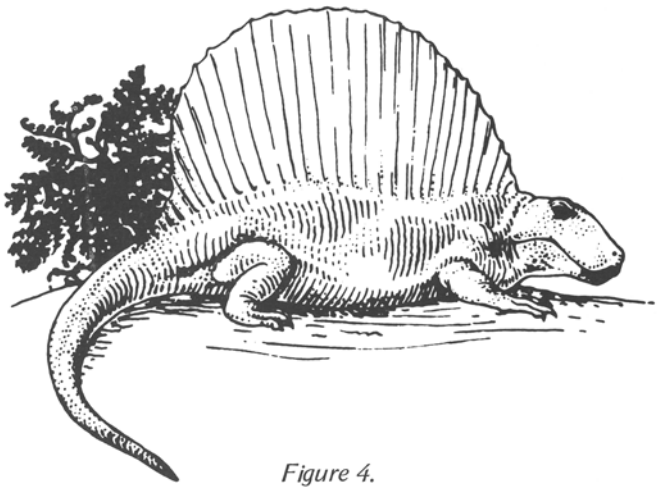

Figure 4.

Reconstruction of the carnivorous pelycosaurian reptile, Dimetrodon. *Large specimens are 10 feet long. Reprinted from "The Age of Reptiles" with the kind permission of E. H. Colbert and W. W. Norton Company, Inc.*

rounded spines (and probably one of the dominant carnivores of its time) has been known from numerous materials from north-central Texas for many years. It has never been reported from New Mexico despite the long history of collection in that area, and consequently its discovery in Monument Valley was quite unexpected. Its presence in southeastern Utah allows certain paleozoogeographic insights and this will be elaborated below.

There are undoubtedly many more forms to be discovered in the Organ Rock Shale. Trackways found here and there may be frustrating, but they do indicate the presence of amphibians and reptiles of kinds not yet known from skeletal materials.

Vertebrate trackways are abundant in the DeChelly Sandstone and are found at many localities, but large suites are exposed only where erosion has properly planed the originally leeward slopes of aeolian dunes that make up the formation. There is an excellent site just west of Tsegi-ot-sosi Canyon, at 36°50'16" N., 110°24'31" W., that can be reached by traveling the road that leaves the highway just north of Owl Rock. Here, on the steep north bank of a tributary of Oljeto Wash, there are scores of trackways left by tetrapods of many different sizes, almost all heading up-dune. This phenomenon, seen also in the Coconino Sandstone of the Grand Canyon, was explained by McKee (1944) who showed that lizards walking up slopes of dry sand leave well-defined tracks even when the slope is as steep as thirty degrees, but that the downslope trackways are largely erased by the partly sliding motion of the animal and slumping of the sand. Downslope trackways, showing clear signs of sliding motion, are occasionally found in the DeChelly, as at the site west of Tsegi-ot-sosi where the sand seems to have been pitched less steeply (Vaughn, 1963). McKee felt that the preservation of the trackways may have been due to formation of a thin crust by dew or mist, with subsequent burial by dry sand. Such trackways are fascinating, presenting us with a vivid picture of the animal's activity, but they tell us too little about the morphological nature of the trackmakers. These trackways are very difficult to match up with forms known from the Halgaito and Organ Rock shales on the basis of skeletal remains, but they do give us a fringe picture of faunas that existed peripheral to the deltaic areas of disposition in which bones were preserved.

COMPARISONS WITH OTHER EARLY PERMIAN VERTEBRATE FAUNAS

Details of age determinations of the Cutler units in Monument Valley on the basis of vertebrate fossils have been given in other papers (Vaughn, 1962, 1964, 1966a, 1970). The best comparisons are with the extensive lists of vertebrates known from the Wichita and Clear Fork groups of the Lower Permian of north-central Texas (Romer, 1958), although comparisons with vertebrates known from the undifferentiated Cutler sediments, Abo Formation and Sangre de Cristo Formation of New Mexico have also been useful. If the Lueders Formation is taken as the uppermost unit of the Wichita Group, as is usually done, it may be said that the faunas from the Monument Valley Cutler indicate equivalence in age to those reported from roughly the lower two-thirds of the Wichita. In terms of the boundary between the Wolfcampian and Leonardian provincial series, the line is usually drawn at some horizon within or near the Admiral Formation of the Wichita Group (Dunbar and others, 1960; McKee, Oriel and others, 1967). In these terms, it may be more specifically stated that the Halgaito vertebrates indicate early Wolfcampian age, and the Organ Rock vertebrates latest Wolfcampian or earliest Leonardian. The age of the DeChelly cannot be decided on the basis of its trackways but is probably no younger than Leonardian (Baars, 1962). These determinations are based on the relative degrees of evolutionary development of various taxa recognized in both Monument Valley and north-central Texas; there are enough forms in common, most of them congeneric species, to allow these statements even though there are also significant differences between the faunas.

More remarkable than the differences between the faunas of the Cutler Group in Monument Valley and the Wichita Group in north-central Texas is the overall similarity of these two as contrasted with the fauna known from the Cutler and equivalent sediments of northern New Mexico. Although there is general likeness between all three of these regions (in the common posession of such forms as *Eryops, Diadectes, Ophiacodon* and *Edaphosaurus)* the northern New Mexico record lacks such elements as rhipidistian crossopterygians, *Seymouria, Diplocaulus* and *Dimetrodon.* The absence of *Dimetrodon* is particularly striking in view of the ease with which even fragments of its spines may be identified and the long history of collection in the area. This absence was long ascribed to the presence of the Early Permian Midcontinental seaway between the Texas and New Mexico regions, but now that *Dimetrodon* is known from Monument Valley it would seem that the seaway did not pose an effective barrier to distribution. The explanation may lie in distinction between what may be called true deltaic and "somewhat more upland" vertebrate faunas.

Figure 5 shows the prominent Wolfcampian positive areas and seaways superimposed on outlines of states in the Four Corners and the Midcontinent. The outlines of the positive areas are taken from the maps by McKee, Oriel and others (1967). The seaways are based on deposits of limestone, dolomite, gypsum, anhydrite and halite formed during Wolfcampian time. The names used for the positive areas follow the usage of these authors; the combined positive areas of the Four Corners states are generally referred to as the Ancestral Rocky Mountains. The encircled letters in Figure 5 stand for areas of collection of vertebrate fossils of Wolfcampian age: "L" and "M," the Cutler Group in Lisbon Valley and the general vicinity of Monument Valley, southeastern Utah; "P," the undifferentiated Cutler sediments near Placerville in southwestern Colorado; "A," the undifferentiated Cutler near Arroyo de Agua in Rio Arriba County and the Abo Formation near Jemez Springs in Sandoval County, northern New Mexico; "R," the Sangre de Cristo Formation near Ribera in San Miguel County, northern New Mexico; "C," a locality in the Abo Formation in the Caballo Mountains, southern New Mexico; "S," localities in the Laborcita and Abo formations along the Sacramento escarpment in southern New Mexico; "T," the Wichita Group of north-central Texas; and "0," equivalent strata in northern Oklahoma.

Inspection of Figure 5 will show that the Monument Valley and Texas regions were near the borders of persistent seaways in Wolfcampian time, as were also the Lisbon Valley and Oklahoma regions from which similar faunas are known. These regions would seem to represent true deltaic conditions, and this is corroborated by the lithology: Romer (1958) has summarized the evidence for the deltaic nature of the Wichita Group; Baars (1962) has reconstructed the depositional site of

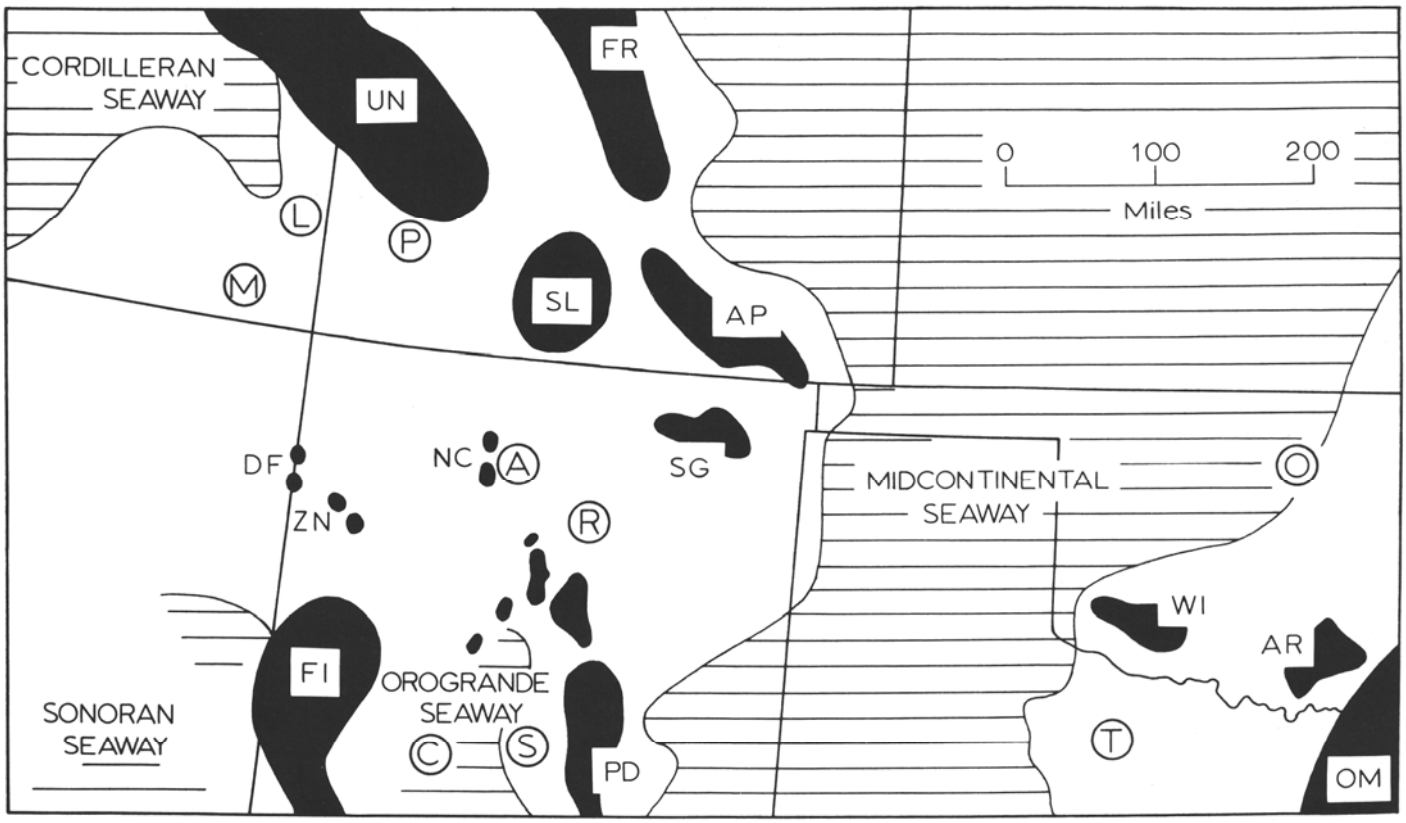

Figure 5.

Simplified map of Wolfcampian positive elements and seaways superimposed on outlines of states in the Four Corners and the Midcontinent; based on maps by McKee, Oriel and others (1967). Encircled letters indicate areas of collection discussed in the text. Positive elements: 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.

the Halgaito as a marginal marine mud flat and that of the Organ Rock as a broad coastal plain. The northern New Mexico collecting areas, in constrst, seem to represent "somewhat more upland" conditions, farther removed from the seaways as well as close to the margins of positive elements; note especially the arc of small positive elements separating this region from the Orogrande seaway to the south. The area of collection near Placerville in southwestern Colorado also seems to lack the faunal elements noted as absent from northern New Mexico. Although there is a seymouriid of a different kind, and this may also be characterized as "somewhat more upland," it seems significant that this area lay close to the southwestern flank of the Uncompahgre highland of Wolfcampian time. A test of the hypothesis that rhipidistian fishes, *Seymouria, Diplocaulus* and *Dimetrodon* are truly deltaic markers has been carried out in southern New Mexico through collection in the Abo Formation of the Caballo Mountains and the interfingering Laborcita and Abo formations along the Sacramento escarpment; all of these forms except *Seymouria* have been found (Vaughn, 1969; Olson and Vaughn, 1970). As the map shows, these areas lay near marine waters in Wolfcampian time. The rhachitomous labyrinthodont *Trimerorhachis* may be another marker (found in all the true deltaic areas including southern New Mexico), but its presence in southeastern Utah is indicated by only a single lower jaw from the Organ Rock Shale. Preliminary prospecting of roughly equivalent beds in the region of the Sonoran seaway in eastern Arizona has turned up scales of rhipidistians. Thus is seems that the presence or absence of at least certain faunal elements may be correlated with relative degrees of proximity to persistent seaways of the time.

Beyond the similarities and differences noted above, each of the faunal areas shows its own peculiarities. It would be unwise to make much of negative records in the Four Corners of forms known from north-central Texas, in view of the much longer and more intensive history of collection in the latter region, but this same history makes the absence of certain forms in Texas seem all the more significant. For examples, *Tseajaia* (Monument Valley) and the rhachitomous labyrinthodont *Chenoprosopus* (northern New Mexico) remain unknown in the Midcontinent. Possibly the Midcontinent seaway did have some filtering effect, even though it seems not to have acted as a barrier.

The picture is further complicated by the pattern of distribution of the short-spined pelycosaur *Sphenacodon,* which is known from southeastern Utah and both northern and southern New Mexico, but not from the Midcontinent. For reasons not yet clear, its distribution is a matter of restriction to the general region of the Ancestral Rocky Mountains. Perhaps in some way related to this is the presence of another short-spined sphenacodont, *Cutleria,* in southwestern Colorado close to the flank of the Wolfcampian Uncompahgre highland (Lewis and Vaughn, 1965). *Cutleria* is the sole described American representative of the haptodontine subfamily,

known otherwise only from Europe. It has been postulated by Olson (1962) that the haptodontines were the sphenacodonts closest to the ancestral roots of the mammal-like therapsid reptiles. This is relevant to the present discussion inasmuch as Olson has also shown that in the North American record the therapsids make their first appearance rather suddenly and in some variety, in the lowermost Upper Permian. Possibly they were derived from upland sphenacodonts as yet undiscovered and perhaps undiscoverable due to their having lived beyond the bounds of the deltaic basins. *Cutleria* may provide us with a glimpse into the nature of such upland pre-therapsids.

CLIMATIC CONSIDERATIONS

It seems evident that the climate became progressively drier during the course of Early Permian time in north-central Texas. Romer (1958) pictures comparatively well-watered conditions during the time of deposition of the Wichita Group, with a flora of relatively lush nature in places, and an abundance of fishes and aquatic tetrapods. Romer sees a record of drier conditions in the flora, fauna and sediments of the Clear Fork Group, conditions perhaps similar to those of the present Colorado delta. In roughly the middle parts of the Clear Fork Group are found burrows of the aestivating lungfish *Gnathorhiza,* a reliable sign of seasonal drought. Olson (1958) interprets the lithology and faunas of the upper parts of the Clear Fork Group as indicating a continuing trend to drier conditions, with vertebrates and plants becoming restricted to the immediate vicinities of water courses. The highest parts of the Clear Fork Group contain extensive evaporite deposits.

A similar trend in southeastern Utah is discernible in an examination of the fossil vertebrates of the Cutler Group in Monument Valley, but it would also seem that drier conditions set in earlier in southeastern Utah than in north-central Texas. Vertebrate remains are restricted to the vicinities of stream-channel deposits as low as the Halgaito, and this restriction persists in the Organ Rock. The intervening Cedar Mesa Sandstone has an extensive gypsiferous facies. Nowhere does one see obvious pond deposits, although such are common in the Wichita Group. Remains of xenacanth sharks are numerous in the Halgaito conglomerates but are unreported from the Organ Rock. Whereas in Monument Valley rhipidistian fishes are not found above the level of the Halgaito, in the Midcontinent they persist practically throughout the Wichita Group. The characteristic lungfish of the Wichita Group is the apparently non-aestivating *Sagenodus,* and the aestivating *Gnathorhiza* does not appear until the highest levels of the Wichita are reached. There is as yet no evidence of *Sagenodus* from Utah, where *Gnathorhiza* appears at a much lower horizon in the Halgaito Shale than in the Midcontinent. The apparently bog-dwelling *Edaphosaurus* is known from as high as the lower Clear Fork Group in Texas, but it has not been found above the Halgaito in Monument Valley, although remains of the seemingly aquatic pelycosaur *Ophiacodon* are known from both the Halgaito and Organ Rock. Low in the undifferentiated Cutler sediments of Lisbon Valley (northeast of Monument Valley) are found, among other forms, the lungfish *Gnathorhiza,* the nectridean amphibian *Diplocaulus* and another lepospondylous amphibian, *Lysorophus* (Vaughn, 1965); this is a combination characteristic of the Clear Fork Group in Texas and seems to be associated with signs of drier and more seasonal climates (Olson and Vaughn, 1970). The longer list of amphibians reported from the undifferentiated Cutler of northern New Mexico may denote somewhat damper conditions there, but it is certainly a mistake to compare the labyrinthodonts in ecological requirements to the amphibians of present times.

The data from the fossil plants is consonant with the vertebrate evidence. The trend within the area of Monument Valley is shown by the presence in the Halgaito Shale of remains of *Calamites,* arborescent lycopods and kinds of seed ferns that suggest a fair supply of moisture, whereas the Organ Rock Shale contains such forms as *Supaia, Yakia* and *Walchia;* these latter three are known also from the Hermit Shale of the Grand Canyon, whose flora White (1929) analyzed as evidence of a semi-arid climate. On a broader geographic scale, the plants corroborate the indications of earlier onset of drier conditions in the Four Corners than in the Midcontinent. Read and Mamay (1964) have shown that Wolfcampian floras were essentially alike throughout the United States but that the Leonardian floras indicate a marked geographic diversity. Of particular relevance to present considerations is their demonstration that the early Leonardian (upper Wichita level) floras west of the Ancestral Rocky Mountains lack those elements that normally grew under well-watered conditions and that these floras apparently existed in a much more rigorous climate than did the contemporaneous floras farther east.

Could these differences have been due to a rain shadow cast over parts of the Four Corners area by the Ancestral Rocky Mountains? Opdyke (1961) has noted that the directions of slope of Permian aeolian deposits in the western United States point to winds from the north and northeast and has suggested that what is now the southwestern United States may have lain, during Early Permian time, in a belt of prevailing easterlies near the equator, in accord with paleomagnetic data. The crest of the Uncompahgre highland may have reached, in Wolfcampian time, a mile or greater above the surrounding country (Dane, 1931; Kirkland, 1963). This would have accounted for late Tertiary changes in altitude of similar magnitude in the Sierra Nevada and would have brought about the widespread desert environments in the resultant rain shadow (Axelrod, 1957).

The analyses and explanations that have been presented here are, of course, to be regarded as only tentative; to be strengthened, weakened or perhaps demolished by future finds. It must be remembered that the list of vertebrates known from the Cutler Group in Monument Valley is still meager. The proffered conclusions do, however, seem to be consistent with the data and they may serve their purpose as a working hypotheses.

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