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TRIASSIC ROCKS AND FOSSILS

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INTRODUCTION

The traveler who journeys to northern New Mexico for the first time cannot help but be impressed by the colorful exposures of the Mesozoic sequence. In the extraordinarily brilliant cliffs there is a succession of red, cream and purple Triassic below, yellow, orange, white, mauve and chocolate Jurassic above, and brown Cretaceous at the top. Indeed, the succession of the Mesozoic sediments in the Chama valley, as exposed in the cliffs and badlands along Canjilon Creek and at Ghost Ranch, constitutes one of the finest and most beautiful scenes in North America.

To the stratigrapher and sedimentationist the Triassic of northern New Mexico is an especially valuable record of continental deposition formed during the early part of the Mesozoic period, in which stream channel and pond deposits are of prime importance. To the paleontologist these beds are of significance because of the fossils contained within them; fossil logs that show us the nature of the vegetation during this segment of earth history, pelecypods and other invertebrates and an occasional fish that record some of the life of the stream channels, and large amphibians and reptiles that reveal the nature of the dominant animals of that distant day.

The Field Conference will traverse these interesting Triassic beds in two areas, in the valley of the El Rito River, to be crossed by the party on the first day of the meeting, and more extensively in the drive along Canjilon Creek to Ghost Ranch, at Ghost Ranch, and in the journey from there through Youngsville and Coyote to Gallina, on the last day of the conference.

A BRIEF AND INCOMPLETE HISTORICAL REVIEW

During the great era of western exploration after the Civil War, Edward Drinker Cope, the pioneer American vertebrate palaeontologist, journeyed through this region, on a trip that he made in 1874 from Santa Fe to Tierra Amarilla and beyond. On this journey he picked up a few fossils of Triassic vertebrates. But the first comprehensive collecting of fossils from the Triassic beds of the Chama River valley was done in 1881 by David Baldwin, who in that year worked this region for Cope. Baldwin, one of the colorful characters who enlivened the early history of vertebrate palaeontology in this country, had, for several years before he began his work in the Triassic of the Chama valley, collected for Marsh, Cope's great rival, spending months at a time (usually in the winter) in the field accompanied only by his more or less faithful burro. Baldwin finally came to feel that Marsh did not appreciate his efforts and did not give him the recognition he justly deserved, so he transferred to Cope, needless to say much to the annoyance of Marsh. His collections, containing various types, constitute the real beginning of our knowledge about the Triassic fauna of northern New Mexico and are now at the American Museum of Natural History.

After the field work of Baldwin there was a lapse of many years until 1911, when three very famous palaeontologists, Williston of Chicago, Case of Michigan and von Huene of Tübingen spent an eventful summer in the Chama valley. They were accompanied by Paul Miller, Williston's well-known field man and preparator. Most of their work was in the Permian beds around Coyote, but they did give some attention to the Triassic of the region.

Within recent years field work in the Triassic sediments of this area has been prosecuted with especial vigor by Camp and Welles for the University of California, by White and Price for Harvard and by the present writer for the American Museum of Natural History. The results of these expeditions are the fine collections of phytosaurs at Berkeley, the thecodont repitle, **Typothorax,** at Cambridge and extensive materials of the early dinosaur, **Coelophysis** at New York.

Modern stratigraphic work on the Triassic of the Chama valley has been done by Darton (published in 1928), by Wood and Northrop (published in 1946 and in succeeding years) and more recently by Harshbarger and by Repenning.

THE STRATIGRAPHIC SEQUENCE OF THE TRIASSIC SEDIMENTS

The Triassic sediments of northern New Mexico form a sequence of sandstones, siltstones and clays of a highly variegated nature, with a total maximum thickness of perhaps 700 or 800 feet. All of these sediments are included within the Chinle formation, but by their nature they may be subdivided into several successive members, to be discussed below. The Moenkopi formation of lower or middle Triassic age is absent in northern New Mexico, the result of a thinning of the Moenkopi from west to east, with a final pinching out of the formation in the vicinity of the New Mexico-Arizona boundary, so that the Chinle formation of this region rests unconformably upon the Cutler (or Abo) formation of Permian age, these two formations being separated by an hiatus that represents middle and late Permian and early and middle Triassic times. The Chinle is succeeded above by Jurassic beds, the age and relationships of which have been the subject of considerable dispute during past years. It is now generally agreed, however, that the Jurassic cliff-forming sandstone immediately above the Chinle is an expression of the Entrada formation, and if this be so, then there is a considerable hiatus in this area between the top of the Chinle and the base of the Entrada.

The members of the Chinle formation that are present in northern New Mexico and their nomenclature is as follows.

	Members	Tetrapod Fossils
Chinle formation	Petrified Forest member	Coelophysis, a primitive theropod dinosaur Phytosaurus (Machaeroprosopus), a phytosaur Typothorax, an armored thecodont reptile Eupelor (Buettneria) a metoposaur, one type of labyrinthodont amphibian
	Poleo sandstone member	
	Salitral shale tongue	
	Agua Zarca sandstone member	

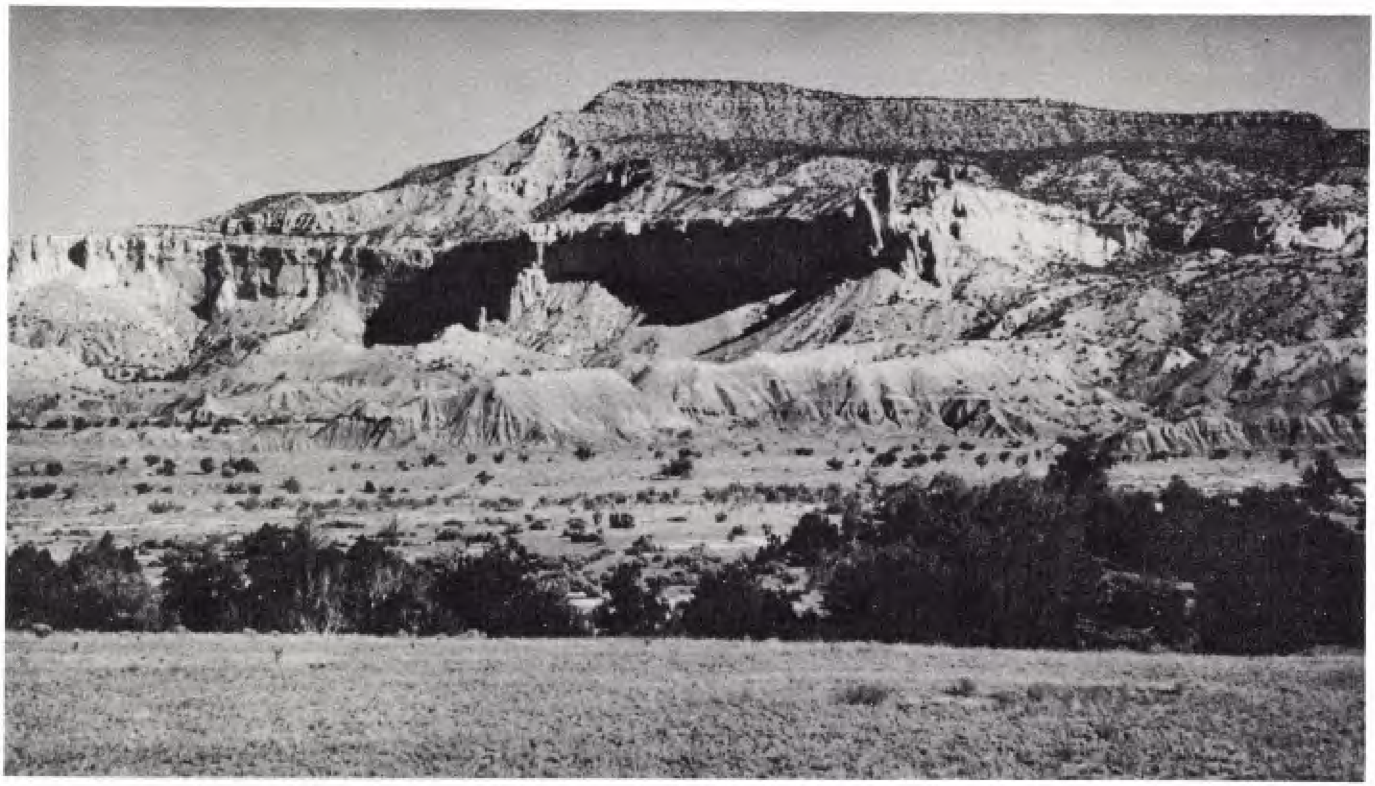

Figure 1. The Mesozoic section at Ghost Rranch, New Mexico. From Colbert, 1950.

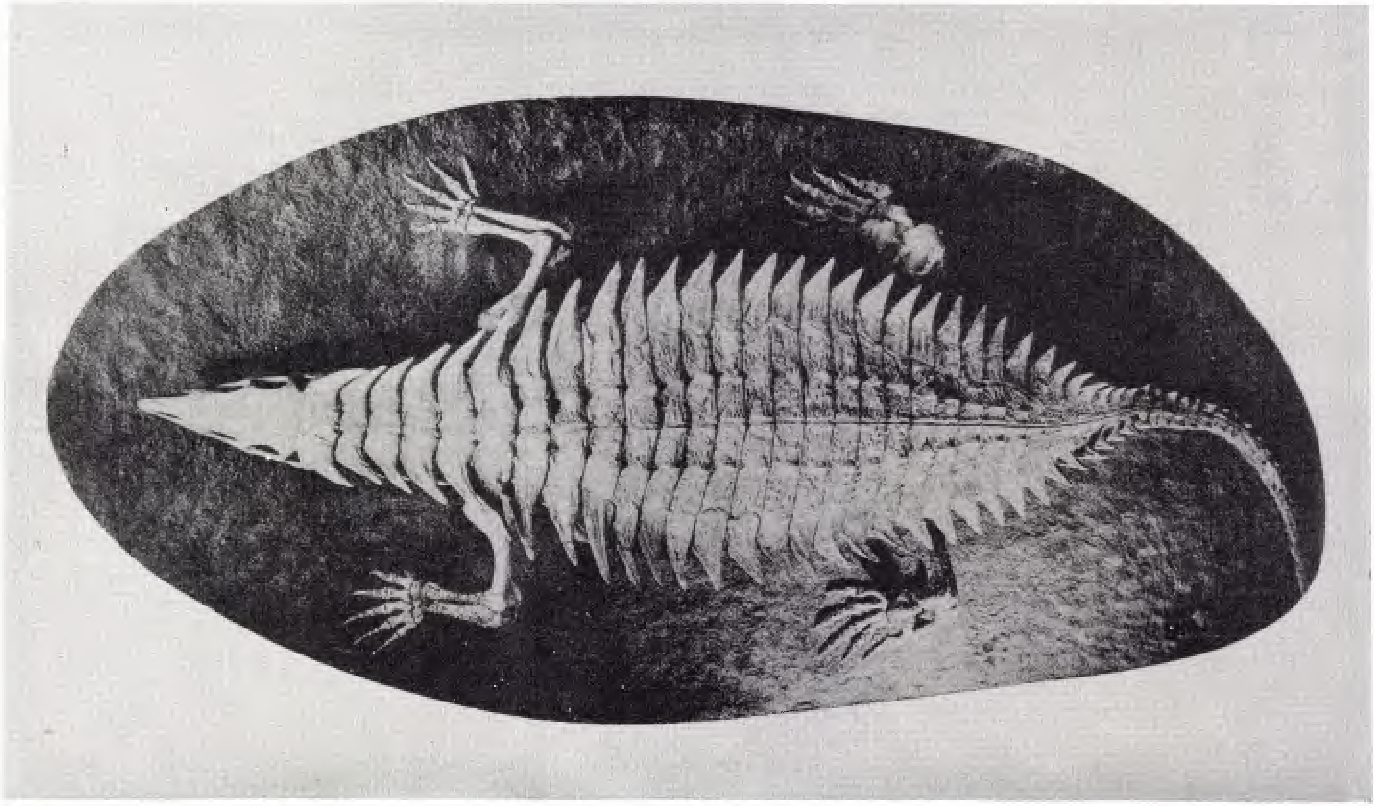

Figure 3. The skeleton of the upper Triassic pseudosuchian, **Typothorax** as exhibited in the Texas Memorial Museum, Austin. From Sawin, 1947.

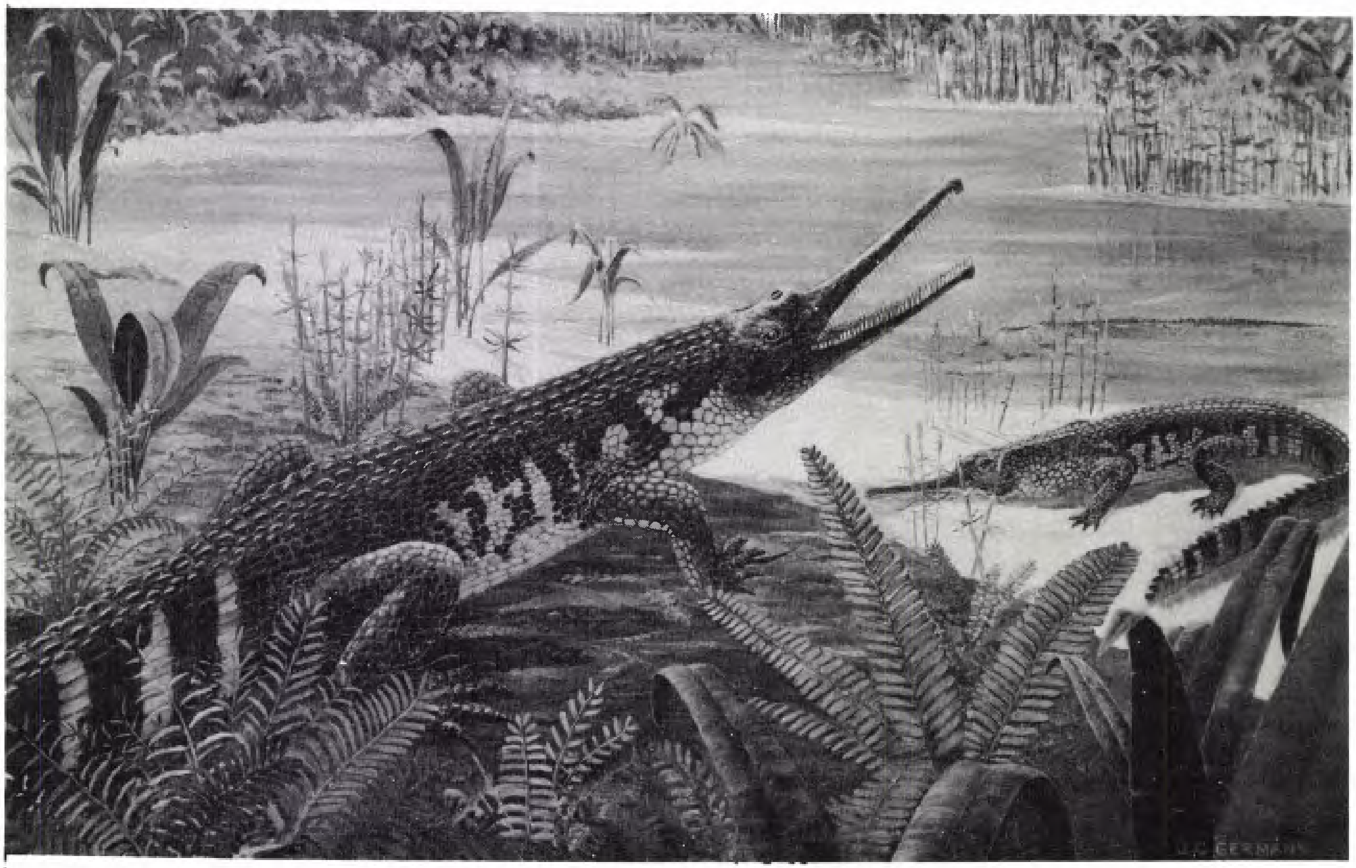

Figure 2. Restoration of the upper Triassic phytosaur, **Rutiodon**. American Museum of Natural History.

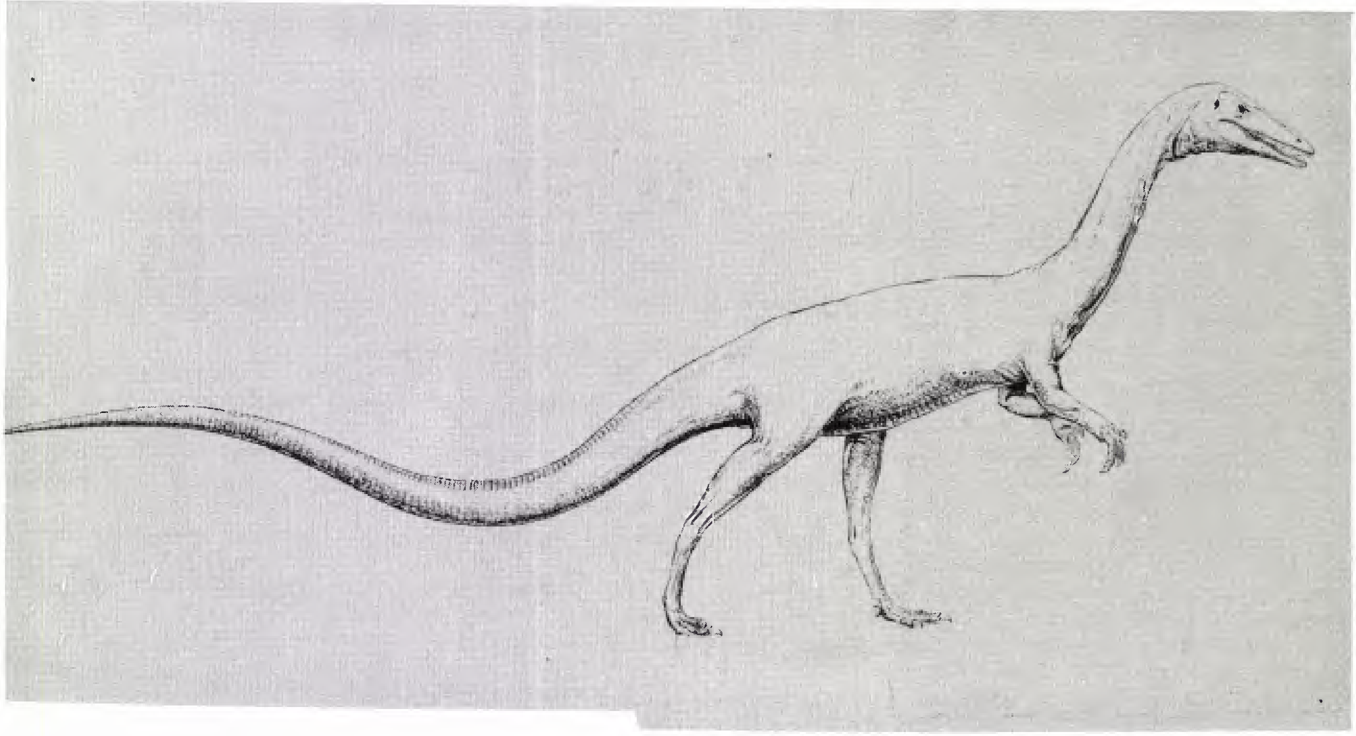

Figure 4. Restoration of the upper Triassic dinosaur, **Coelophysis.** American Museum of Natural History.

Figure 5. Skulls of the upper Triassic metoposaurid amphibian, **Eupelor** as exhibited in the United States National Museum. From Colbert and Imbrie, 1956.

The Agua Zarca sandstone and the Salitral shale, both comparatively thin, were named by Wood and Northrop in 1946 upon the basis of stratigraphic relationships observed along Agua Zarca Creek and Salitral Creek, west of Coyote. The Agua Zarca, up to 100 feet in thickness and found immediately above the Permian sediments, consists of conglomeratic sandstones with occasional beds of siltstone. The Salitral shale, also some 100 feet thick at the type locality, is a variegated shale with limestone concretions. These two members may not be everywhere present or recognizable; they are nicely seen not far from the type localities in the striking Permian-Triassic monocline that is so clearly visible from the road just to the west of Coyote.

The Poleo sandstone, named from Poleo Mesa to the west of Coyote, of which this sandstone forms the cap, is a relatively thin member generally no more than about 60 feet in thickness. It is none the less quite resistant, and thus is apt to form prominent topographic features, such as the top of Poleo Mesa, just mentioned, or heavy ledges, seen at various places on Ghost Ranch. It is a very light colored, almost white sandstone, strongly cross-bedded.

In the Chama River valley the bulk of the Chinle formation is composed of what has recently been designated as the Petrified Forest member, named from the Petrified Forest of Arizona, where it is so widely and beautifully exposed. In northern New Mexico the lower portion of this part of the Chinle formation consists of soft clays and siltstones that form rounded badlands and long talus slopes beneath the colorful Mesozoic cliffs. The colors of these soft beds are quite varied, and grade from light shades through soft reds and browns to purples, a range that is similar to that seen in the type area. Above these soft beds, which may have a total thickness of 300 or 400 feet, are a hundred feet, more or less, of alternating hard sandstones and thin shales that compose the basal portions of the vertical cliffs. This upper segment of the Petrified Forest member is noteworthy by reason of the alternation of sediments, just mentioned, which frequently gives it a banded, or more properly a corrugated appearance, resulting from the differential weathering of the sandstones and shales. The sandstone layers, particularly noticeable because of the prominent manner in which they stand out, show a degree of lateral variation that is completely confusing to anyone who has the fond notion of tracing individual bands from one place to the next. Indeed, they thicken and thin and pinch out in the course of a few hundred yards, and they vary indiscriminately in their frequency between localities; all in all a nice indication of their origin as fresh-water deposits. The upper few feet of the Petrified Forest member are marked by channels and fissures in which are deposited downwardly extending tongues from the overlying Entrada sandstone.

The Correo sandstone, the topmost member of the Chinle formation in New Mexico, is not seen in the Chama River valley. Its type exposure is at Correo, New Mexico, where it forms a resistant cliff or hard, brownish sandstone that contains fragments of tetrapod bones. It is also found along the back slope of the Sandia Mountain block, east of Albuquerque, and at other localities.

THE CHINLE FAUNA

The Chinle fauna, or such of it as is here present, is for all practical purposes confined to the Petrified Forest member of the formation in northern New Mexico. Any fossils found in other units are apt to be so very fragmentary as to be of little value to the paleontologist. The Petrified Forest member has yielded some rich harvests of ancient

CORRELATION OF CONTINENTAL TRIASSIC

BEDS IN NORTH AMERICA

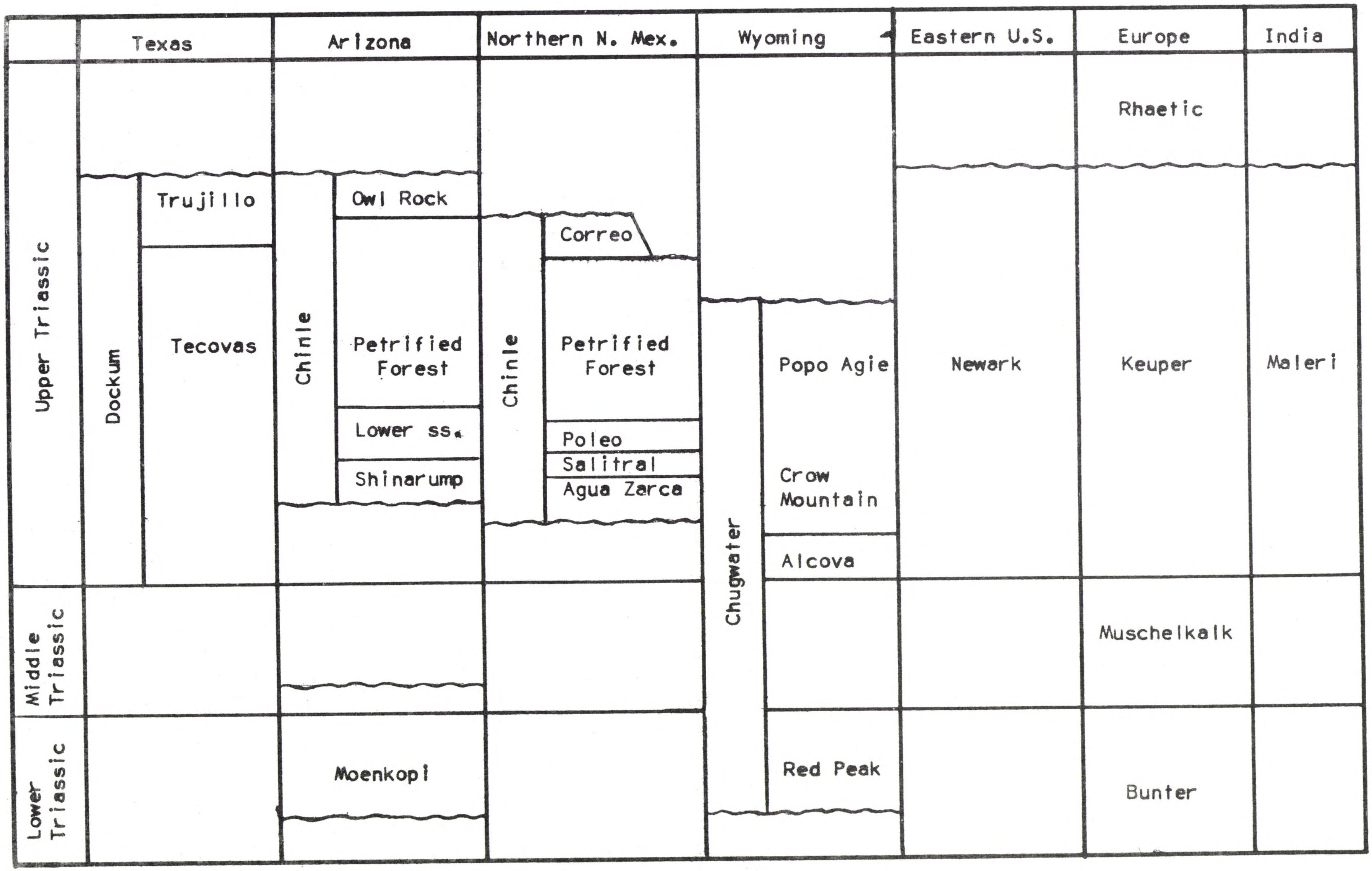

Figure 6.

reptiles, particularly in the exposures from Ghost Ranch on the east to Gallina on the west. Of amphibians and fish there are indications but the record of these vertebrates depends for its details upon discoveries made in other regions. So it is that the vertebrate fauna from the Triassic sediments of northern New Mexico is quite limited in terms of genera and species, but abundantly rich in specimens, thereby giving us a detailed knowledge concerning various aspects of the anatomy, the ontogeny and the ecological relationships of certain types.

Three interesting reptiles come from this region, and all of the best discoveries have been made at Ghost Ranch. The first of these is the phytosaur belonging to the genus **Phytosaurus**, generally referred to in the literature on the Triassic of western North America as **Machaeroprosopus**. This reptile is known from a considerable series of skulls and skeletons collected by the University of California parties in the Chinle badlands a short distance in front of the cliffs that lie a half mile or so to the west of the Ghost Ranch headquarters. The fossils show a range of size indicating probable sexual dimorphism as well as the progressive changes brought about in the skull during ontogenetic growth. Some very fragmentary fragments of snouts found here by American Museum collectors are interesting in giving evidence of what may have been the largest and the smallest phytosaur skulls of which there is evidence. If extrapolations from these fragments are valid, then the largest skull must have been a very massive one indeed, perhaps five feet or more in length, while the smallest was a rather tiny specimen no more than six or eight inches long.

The phytosaurs were large crocodile-like reptiles living the type of life during Triassic times that crocodiles were to live in later geologic ages. They had long, narrow jaws like those of a modern gavial, set with numerous conical teeth. The nostrils were on the top of the skull, just in front of the eyes, instead of being at the tip of the snout as in the crocodiles, and in this respect the phytosaurs would seem to have been better fitted for an aquatic life than were the reptiles that succeeded them. They had long bodies, and long, deep tails, well adapted for swimming. The legs were relatively short but strong. The body was covered with heavy bony armor on the back and sides, which in life was in turn covered with horny plates. These reptiles, in spite of their close resemblance to crocodiles, were not ancestral to the latter, but rather were paralleled by the crocodilians. At the end of Triassic times the phytosaurs became extinct, and the crocodiles, having their beginnings during the transition from the Triassic to the Jurassic periods, imitated very closely the adaptations that within early Mesozoic times made the phytosaurs such successful reptiles.

The second reptilian type so characteristic of the Chinle formation in this region is the pseudosuchian, **Typothorax**, of which excellent material was obtained by Harvard University collecters in the Chinle badlands a few miles to the east of the Ghost Ranch headquarters. **Typothorax** was a heavily armored reptile, with broad, quadrangular plates completely covering the neck, the back and the tail, and with sharp spines forming a sort of protective armament along the sides of the body. Such protection was effective and necessary in an environment where the aggressive phytosaurs were so numerous. The skull in **Typothorax** was comparatively small and the teeth quite unsuited for a carnivorous diet, which leads to the conclusion that this reptile was a plant-eater. The limbs were stout, as would be necessary in an animal burdened with a heavy casing of armor. It seems probable that **Typothorax** was an upland reptile, living on the high ground between stream courses, and feeding upon succulent vegetation. Perhaps for this reason its fossils are much less common than are those of of the aquatic or semiaquatic vertebrates that occur in the Chinle beds.

The third of these reptilian types is **Coelophysis**, a primitive theropod dinosaur, known from very scanty evidence until the summer of 1947, when an American Museum of Natural History party uncovered a deposit at Ghost Ranch that contained numerous complete, articulated skeletons, representing individuals ranging in age from very young animals to large adults. This remarkable association of fossil skeletons was found in a canyon back of the Ghost Ranch headquarters. It possibly indicates the simultaneous death of a large group of animals in circumstances such that quite complete, articulated skeletons were preserved - a rather unusual occurrence in the history of dinosaur collecting. Some phytosaur bones were found associated with the skeletons of this dinosaur.

Coelophysis was a small, lightly built dinosaur, the adult skeleton of which is about eight feet in length. The bones are hollow like those of a bird, and it is quite evident that this dinosaur was very slender, weighing perhaps no more than 40 or 50 pounds. It walked in a semi-erect position on strong, bird-like hind limbs. The front limbs were small, and the hands were adapted as grasping organs, to aid in feeding, and were not used in locomotion. The neck and tail were long and slender. The skull, carried at the end of the sinuous neck, was elongated and very lightly constructed, a system of rather delicate arches and bony plates that in spite of their fragile appearance were none the less strongly braced and quite able to absorb the shocks of biting and chewing. The long jaws were set with sharp teeth.

Evidently **Coelophysis** was an active, agile hunter, preying upon small reptiles and other animals that it was able to catch. It must have lived for the most part in upland environments, where it could range freely across open ground or lurk in the foliage of the Triassic forests to waylay its prey.

Something should be said at this place about **Eupelor** (commonly referred to in the literature by its preoccupied name, **Buettneria**) even though good materials of this amphibian do not occur in the Chama River Valley. Fragmentary fossils do show that **Eupelor** inhabited the region, and a remarkable concentration of superb specimens has been mined by various institutions at Lamy, not so very far away.

This was a stereospondyl amphibian, one of the last of the labyrinthodonts, these being the giants among the amphibians, so prominent in vertebrate faunas of late Paleozoic and Triassic age. **Eupelor** was one of the largest of the stereospondyls, with a massive and extraordinarily flat skull, two or three feet in length, on a strangely weak skeleton that, including the head, was perhaps six or seven feet long. It should be said that although the skeleton was generally weak the shoulder girdle, like the skull, was remarkably massive. But throughout most of the skeleton there was a marked reduction of bone, and it is evident that cartilage made up a large part of the skeletal support. The limbs and feet were ridiculously small.

It seems almost certain that this amphibian was unable to leave the water, because the limbs were obviously inadequate for locomotion on land. Consequently it is safe to assume that **Eupelor** inhabited the ponds and rivers of late Triassic times, where it preyed upon fish. The numbers of fossils of this amphibian found in many Chinle outcrops indicate that **Eupelor** was quite abundant in the Chinle fauna.

The reptiles briefly discussed above give us a picture of a land inhabited by active and well adapted vertebrates, a scene prophetic in a sense of what was to come during Jurassic and Cretaceous times, when dinosaurs and other large reptiles dominated the earth. The little dinosaur, **Coelophysis**, and the armored pseudosuchian, **Typothorax**, lived on the higher ground between watercourses, the one a predator feeding on small game, the other a vegetarian. The phytosaurs lived along the streams that flowed through jungles of auracaria-like trees and ferns, where they probably fed largely upon fish, but did not shun anything they could overpower by virtue of their strength and ferocity. The giant amphibians, as represented by **Eupelor**, were constant inhabitants of the streams and ponds, where they also fed upon fishes. The fishes were the heavily scaled holosteans and their relatives, related to modern garpikes, and lungfishes not very different from the modern lungfish of Australia. All in all we get the impression of an environment not unlike some modern tropical regions, say the Amazon basin.

RELATIONSHIPS OF THE CHINLE FAUNA

The Chinle vertebrates from northern New Mexico can be regarded as belonging to what was essentially a widely spread fauna that occupied most of North America during late Triassic times. The same fishes (so far as they are known), amphibians and reptiles that characterize the Triassic sediments of the Chama River valley are found in the long expanse of Chinle exposures that runs northwestwardly through the Painted Desert in Arizona, from St. Johns and the Petrified Forest to Cameron and beyond. These vertebrates occur in the Chinle beds of Utah, though not so abundantly as in the sediments to the south. They also characterize the Dockum beds of Texas, and with minor differences, the Popo Agie beds of Wyoming. They are typical of the Newark beds of eastern North America, from North Carolina through Pennsylvania and New Jersey to the Connecticut Valley of New England. Evidence is just beginning to accumulate to suggest that the upper Triassic vertebrate fauna also extended northeastwardly into Nova Scotia.

Of course when fossils are as widely distributed over a large continental area as are the Chinle, Dockum, Popo Agie and Newark vertebrates, certain differences between localities are noticeable. But in the case of these Triassic vertebrates, especially the tetrapods, the differences are of minor importance, while conversely the resemblances are particularly striking. Such differences as do occur are for the most part in the nature of the presence or absence of various genera in one locality as compared with another, and most of such differences can be regarded as the reflections of local ecological conditions or the result of accidents of preservation and of collecting. The resemblances across the continent are indeed to be expected. Today many genera of amphibians and reptiles are of continental extent, the contrasts between one continental subdivision and another being reflected in specific or subspecific differences.

Moreover, the resemblances among the late Triassic vertebrates that extend throughout North America continue eastwardly into northern and central Europe, where the classic Keuper fauna is characterized by the presence of amphibians very close to **Eupelor**, by phytosaurs generically the same as those of North America, by armored pseudosuchians and by primitive theropod dinosaurs. Consequently it is evident that there was a close physical relationship between North America and Europe during late Triassic times, a connection that allowed the free excange of land-living tetrapods from the one continental block to the other. And this relationship extended at least as far as India, where in the upper Triassic Maleri beds are found amphibians and phytosaurs that may be equated with those of Europe and North America.

CORRELATION OF THE UPPER TRIASSIC OF NORTHERN NEW MEXICO

From what has been said above it is evident that the various late Triassic vertebrate faunas of North America are rather closely correlative with each other, and with similar faunas in Europe and India. In short, these several assemblages of fishes, amphibians and reptiles may be placed within the classic Keuper of Europe. But there is some evidence, based upon the phytosaurs, that may indicate slight differences in age between some of the North American formations. Thus the genera **Paleorhinus** and **Angistorhinus,** found in the Popo Agie and Dockum beds, are more primitive than **Phytosaurus** in the Chinle and in the Newark. **Phytosaurus** is not found in the Popo Agie sediments, so this horizon may be slightly older than the Chinle and Newark. But the Dockum beds contain all three of these genera. Is it possible, therefore that **Phytosaurus** appears at an earlier date in the Dockum than it does in the Chinle and Newark, or conversely is it possible that **Paleorhinus** and **Angistorhinus** are primitive survivors in the Dockum beds, coexistent with the advanced phytosaurs that so closely unite the Chinle, Dockum and Newark levels? This last possibility must be seriously considered, for the paleontological record is replete with instances of primitive forms surviving into ages later than those of their typical development. Therefore it must be realized that the Popo Agie, too, may be fully as late in age as the Chinle, although the absence of the more advanced phytosaurs in this horizon may indicate, as mentioned above, that the Triassic beds in Wyoming are in fact older than those of New Mexico and Arizona. If this be true, then **Eupelor** has to be regarded as a long-persisting genus, because it is quite characteristic of all of the North American upper Triassic horizons. As in so many problems of correlation, the relationships of the continental Triassic beds of North America are still not completely settled.

CONCLUSION

The foregoing discussion has attempted to outline the nature of the continental Triassic beds of northern New Mexico, and the relationships and significance of the fossils they contain. It has been indicated that these Triassic sediments are very similar to upper Triassic beds in other parts of New Mexico and Arizona, and also to beds of similar age in Texas, Wyoming and eastern North America. The fossils show the essential unity of the upper Triassic vertebrate fauna of North America, and moreover they indicate how closely related this large, comprehensive fauna is in many ways to the Keuper fauna of Europe, and even to the similar Maleri fauna of India. When one goes farther afield, particularly into the southern hemisphere, the resemblances decrease.

The discovery a few years ago of a magnificent series of **Coelophysis** skeletons at Ghost Ranch, shows that there is still much to be learned about the Triassic fauna of this region. Suddenly a dinosaur, which hitherto had been known from very fragmentary evidence, became one of the most completely documented of dinosaurs. This leads us to think that other Triassic vertebrates from North America, known from insufficient materials, may in time become established upon a solid basis of fossil evidence. Moreover, there are new things still to be discovered. It is a fact that our knowledge of late Triassic tetrapods in North America is for the most part based upon the remains of large animals. There must have been many small amphibians and reptiles living in those days, just as there are today, of which no inklings have as yet been revealed. It is to be hoped that our knowledge of the Triassic land-living vertebrates will in future years be enriched by the discovery of some of these smaller forms.

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(The inclusive bibliography of this committee report contains numerous references pertinent to the present contribution.)