NOTES ON THE AGE OF THE CONTINENTAL TRIASSIC BEDS IN NORTH AMERICA, WITH REMARKS ON SOME FOSSIL VERTEBRATES

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For paleontological purposes, it is sometimes unfortunate that the continental Triassic formations of North America can not in all of their parts be properly incorporated in the standard stratigraphic scheme. The standard scheme is, of course, based on marine fossils, and in North America, as in Europe, transition beds between continental and marine strata are missing. This is the cause of the difficulty. In the present paper the author has endeavored to present a generalized classification of the vertebrate-bearing Triassic beds of North America.

The Triassic deposits near the Atlantic coast and the Red Beds in the central and western regions have a different aspect. Therefore it will be best to treat them separately.

I. *Central and western regions.*—The Triassic Red Beds of these regions are the continuation of and close of a large series beginning at some places with the older Carboniferous, at others with the Permian. Though there is much local variation, the structure and color of the rocks is remarkably uniform. Fossil horizons are rare and it is therefore not easy to compare particular beds that are far distant from one another. The thickness of the Triassic is in general several hundred meters; the lower limit is not accurately fixed and the upper is sometimes badly defined. Whole divisions may be missing, and often it is not possible to detect such a hiatus by a clearly observed discordance.

Ward[1] divides his Shinarump beds in northern Arizona (Powell's original Shinarump group less the Moenkopi formation) 530 meters in thickness, into a lower group, the Shinarump conglomerate, consisting of 240 meters of coarse, cross-bedded sandstone and variegated marls; and an upper group, the Le Roux beds, 240 meters thick and consisting of a lower member of 120 meters of variegated

[1] Ward, L. F., Geology of the Little Colorado Valley, Amer. Journ. Sci., ser. 4, vol. 12, 1901, pp. 407–413.

marls and argillaceous and limy shales containing fossil parasuchians and labyrinthodonts; above it, 30 meters of sandstone, 7 meters of well bedded limestones, 25 meters of so-called "Motar Beds," limy shales with flint, and, finally, 60 meters of calcareous marls. This series of beds has been restudied by Gregory [2] and is now divided into the Chinle formation (upper 450 meters) and Shinarump conglomerate (basal 30 meters). The "Fossil Zone" of Ward is 120 to 240 meters below the top of the Chinle, about the third quarter of the formation. Fragments of bones are recorded also in the Shinarump conglomerate and in the lower part of the Chinle formation as defined by Gregory. The detailed petrologic characters are varied but the larger features are the same for long distances.

In southwestern Colorado above the Permian Cutler formation the unconformable Triassic Dolores formation may be distinguished.[3] The relations of the Dolores formation to the Chinle, the Shinarump, and the Moenkopi formations are still somewhat uncertain, though it probably includes the Chinle and the Shinarump. The lower part of the Dolores contains abundant fragmentary remains of vertebrates.

Vertebrates occur low in the Chinle formation, as Mehl [4] demonstrates in published sections from the region of the Petrified Forest, Arizona, and as noted above in the work of Gregory. Hills [5] found very well preserved fish remains (*Catopterus* cf. *gracilis*) associated with parasuchian teeth in southwestern Colorado 15 meters below the "Shinarump conglomerate" (in lower Dolores). Ward [6] found them also, as noted above, in a second and higher horizon near Tanners Crossing in the Little Colorado Valley, Ariz.

The author's experience in New Mexico [7] (west and southwest of Abiquiu) is that Parasuchians and Labyrinthodonts occur only in and below a conglomerate like Cross's Shinarump, the "Poleo sandstone," now accepted as the equivalent of the Shinarump. From what I have seen in the southern Chama River region in New Mexico. the larger part of the Triassic deposits lie above the Poleo sandstone. In these upper beds the fauna is quite different—*Typothorax*, *Episcoposaurus*, and two other Parasuchian genera, *Belodon scolopax* and *Coelophysis*. It is evident, then, that the lower fauna—*Machaeroprosopus*, *Heterodontosuchus*, *Palaeorhinus*, *An-*

[2] U. S. Geological Survey, Professional Paper 93, pp. 30–50, 1917.

[3] Cross, Whitman, Bull. Geol. Soc. America, vol. 16, 1905, p. 468.

[4] Mehl, M. G., Quart. Bull. Univ. Oklahoma, March, 1916, pp. 1–44.

[5] Hills. R. C., Note on the occurrence of fossils in the Triassic and Jurassic beds near San Miguel, Colo. Amer. Journ. Sci., ser. 3, vol. 19, 1880, p. 490.

[6] Amer. Journ. Sci., ser. 4, vol. 12, 1901, p. 413.

[7] Huene, F. v., Kurze Mitteilung über Perm, Trias u. Jura in New Mexico, Neues Jahrb. für Min., etc., Beilage Band 32, 1911, pp. 730–738, pl. 32.

gistorhinus, *Acompsosaurus*, and *Metoposaurus fraasi*—lived long before the close of the Triassic period and that there was a later vertebrate fauna.

On several occasions the writer has shown that some of the Parasuchians found in Wyoming and Arizona are of a very primitive type (*Palaeorhinus*, *Angistorhinus*), others less so, as *Machaeroprosopus* and *Heterodontosuchus*. It seems questionable whether the European genus *Phytosaurus* does not also occur here. The Labyrinthodonts all belong to the family Metoposauridae, which in Europe is of lower Keuper age. *Acompsosaurus*, as shown elsewhere,[8] is probably nearly related to the primitive parasuchian *Desmatosuchus*, and is not a Pelycosaurian.

At Morrison, near Denver, Colo., the Red Beds fall into three divisions. At the base is the coarse-grained Fountain formation, to which belong the fantastic, nearly perpendicular pillars of red sandstone in the "Garden of the Gods," near Colorado Springs, and in "Rocksbury Park," near Morrison; in the middle is the Lyons formation, to which belong the white quartzitic sandstones ("Creamy sandstones"), which are clearly visible in the landscape; and the uppermost beds, the Lykins formation, consisting of soft reddish and whitish beds, of which Williston's *Hallopus beds* near Canyon City form the upper part.[9] These directly underlie the Upper Jurassic Morrison beds. The Fountain formation is now accepted as being good Pennsylvanian;[10] Lyons sandstone, as Pennsylvanian; lower Lykins, as Permian; upper Lykins, as Triassic, and more or less an equivalent of the Chugwater formation of Wyoming.

Farther to the northwest in the region of Lander, Wyo., below the Oxfordian marine Jurassic Sundance beds (with *Belemnites*, *Gryphaea*, and *Baptanodon*), are red beds, usually designated the Chugwater formation, nearly 300 meters in thickness, in whose upper 70 meters, the "Popo Agie beds," a number of vertebrates have been found, and more recently some unios and plants described by E. W. Berry.[11] The Popo Agie beds are apparently equivalent to Knight's Jelm formation[12] of southern Wyoming and are clearly separated from the overlying marine Jurassic (Sundance) beds and the underlying red beds. From a paleontological standpoint, the writer is forced to consider the fauna of the Lander as being of the same age as the lower fauna of the Colorado Plateau. Both must be Middle Triassic. From the literature and from personal observation, it is thought that the geological data are not adverse to this conclusion. Parasuchians such as *Palaeorhinus* and *Angistorhinus*,

[8] Gondwana—Reptilien in Südamerika. Pal. Hung. 1926
[9] Williston, S. W., Journ. Geology, vol. 13, 1905, pp. 338–350.
[10] J. Henderson, Colorado Geol. Surv., Bull. 17, 1920.
[11] Journal of Geology, vol. 22, 1924, pp. 488–497.
[12] Knight, S. H., Geol. Soc. America, Bull., vol. 28, p. 168, 1917.

having a supratemporal fenestra with a high posterior border, are relatively primitive and could not possibly be of Upper Triassic age; also *Acompsosaurus* and *Desmatosuchus*, which have still more primitive characters, could hardly be expected in Upper Triassic beds. *Metoposaurus*, *Anaschisma*, and *Buettneria* must be Middle Triassic forms. They are closely related and *Metoposaurus* does not occur in Europe later than lower Keuper. Some plants and some fishes of these beds are related to those of the Atlantic coast.

FOSSILS FROM THE TRIASSIC OF CENTRAL AND WESTERN REGIONS

A. Fossils of probable Middle Triassic age:

Wyoming.—Near Lander (Willow Creek) and Wind River in the Popo Agie beds of the Chugwater formation—

Palacorhinus bransoni Williston.
Angistorhinus grandis Mehl.
Angistorhinus gracilis Mehl.
Dolichobrachium gracile Williston.
Eubrachiosaurus browni Williston.
Brachybrachium brevipes Williston..
Anaschisma browni Branson
Anaschisma brachygnathum Branson

Colorado.—Purgatoire River, in first exposure south of Bent Canyon, near Las Animas: Fragments of a large Parasuchian skull.

Eighteen miles east of Canyon City: Parasuchian fragments.

San Miguel River in sandy conglomeratic rock: Parasuchian tooth.

Silver Creek, north of Rico Mountains, at entrance of small gulch at 3,260 meters' elevation: Fragment of Parasuchian jaw with alveoli.

Utah.—Clay Hill near San Juan River: *Heterodontosuchus ganei* Lucas.

Canyon of Grand River near Moab, above Ferry, 30 miles below base of Vermillian Cliff sandstone in a conglomerate which lies unconformably above the underlying beds: Fragmentary bone.

Arizona.—Near Tanners Crossing and Holbrook, Little Colorado River—

Angistorhinus, species?
Machaeroprosopus validus Mehl.
Machaeroprosopus, species.
Heterodontosuchus ganei Lucas.
Placerias hesternus Lucas.
Metoposaurus fraasi Lucas.

Adamana: Parasuchian teeth and bones, among them being *Palacoctonus orthodon* Cope and *P. dumblianus* Cope.

Near Fort Wingate and Petrified Forest:

Palaeorhinus (aff.) *bransoni* Williston.
Acompsosaurus wingatensis Mehl.

New Mexico.—Arroyo Seco, west of Abiquiu: *Machaeroprosopus buceros* Cope.

Mesa Poleo, 40 kilometers southwest of Albiquiu: Fragments of Parasuchians and Stegocephalians.

Laguna: Fragments of Parasuchians and Stegocephalians.

Santa Rosa: Fragments of Parasuchians and Stegocephalians.

Twenty kilometers northwest of Cobra Springs: Fragments of Parasuchians.

Forty-five kilometers south of Tucumcari: Parasuchian bones.

West of San Juan: Parasuchian bones.

A. Fossils of probable Middle Triassic age—Continued.

Texas.—Sand Creek, Holmes Creek, and east bank of Blanco River near Spur, Crosby County—

Desmatosuchus spurensis Case.
Promystriousuchus oehlersi Case.
Leptosuchus crosbyensis Case.
Many Parasuchian bones.
Metoposaurus jonesi Case.
Buettneria perfecta Case.

B. Fossils of certain Upper Triassic age, from beds at Cerro Blanco, near Gallina, New Mexico:

Episcoposaurus horridus Cope.
Typothorax coccinarum Cope.
Gen. undet. *scolopax* Cope.
Coelophysis longicollis Cope.
Coelophysis bauri Cope.
Coelophysis willistoni Cope.

C. Fossils of uncertain level but thought to be Upper Triassic:

Arizona.—Near Tanners Crossing, Little Colorado River, in Yellow argillaceous sandstone—

Episcoposaurus horridus Cope.
Typothorax coccinarum Cope.
Three small saurischian vertebrae.

Texas.—West side of Blanco River, Crosby County—

Typothorax, species.[13]
?"*Phytosaurus*" *doughti* Case.
?"*Phytosaurus*" *superciliosus* (Cope).
?"*Episcoposaurus*" *haploceras* Cope.
"*Coelophysis*," species.[13]

The Middle Triassic fauna (*A*), with many primitive Parasuchians and some Labyrinthodonts but very few other forms, is distributed through Wyoming, Colorado, Utah, Arizona, New Mexico, and western Texas. The Upper Triassic fauna (*B*), as characterized by *Typothorax*, *Episcoposaurus*, and *Coelophysis*, has only been found high above Poleo sandstone (—Shinarump conglomerate). Probably the same and similar fossils in Arizona and Texas belong to an equivalent horizon.

II. *Atlantic coast region.*—Triassic deposits to an enormous thickness are lying discordantly upon ancient rocks along the east slope of the Appalachians. According to Lull, they are more than 4,000 meters thick in Connecticut and Massachuetts. Near the base of the upper half they are divided by three great seams of diabase which lie nearly horizontal with vertical thicknesses up to 400 meters. In the Connecticut basin, near the upper limit of the lower part—that is, below the so-called "anterior trap sheet"—there have been found the following Parasuchians: *Rutiodon* (?) *validus* Marsh, *R.* (?) *manhattanensis* Huene, and *Stegomus arcuatus* Marsh. Tracks have not yet been found there. They occur for the first time between the

[13] Case, E. C., Pub. 321, Carnegie Institution of Washington, 1922, p. 81, fig. 31.

"anterior" and the "main trap sheet," but become more abundant above the latter, and attain their greatest abundance above the uppermost trap sheet—the so-called "posterior trap sheet." Only in these highest beds are found the well-known Saurischia: *Anchisaurus colurus* Marsh, *A. solus* Marsh, *Thecodontosaurus polyzelus* (Cope), *Ammosaurus*, *Podokesaurus holyokensis* Talbot, and the Pseudosuchian *Stegomosuchus longipes* (Emerson and Loomis), quite different from *Stegomus arcuatus*. Numerous plants and fishes are found in the "anterior" (lower) and "posterior shales" between the three large trap sheets.

In the southern continuation of the Connecticut basin, through New Jersey, Pennsylvania, Virginia, and North Carolina, a gradual change in the character of the beds takes place. In New Jersey and Pennsylvania the Trias is divided into three groups, at the base the Stockton beds with red and sometimes shaly and argillaceous sandstone from which come the remains of *Rutiodon* (?) *Manhattanesis* (Huene), as published by Sinclair.[14] In earlier times, Lea, Leidy, and Emmons described Parasuchians from these beds. The succeeding beds are the light colored Lockatong sandstones, and above them the Brunswick series. In Virginia and North Carolina the lowest division is often shaly in character and contains large coal seams; the Phoenixville tunnel and Egypt are well-known localities of this kind. Here are found plants, fishes, Labyrinthodonts, and Parasuchians, the last two especially occuring in the lowest strata with the coal beds. In the Connecticut Valley also the Parasuchians are found only in the lower part. Lull's impression is that the Parasuchians and Labyrinthodonts of the southern localities are from lower horizons than the Saurichians of the Brunswick shales of the Connecticut Valley.[15] *Dictyocephalus* from Virginia and North Carolina, a near relative of *Metoposaurus*, must be middle Triassic. The plants, especially abundant in the South, have been compared by Fontaine,[16] and later by Stur[17] and by Ward,[18] with the flora of the "Lettenkohle" from Lunz in the northern Alps, and from Neue Welt near Basel. Jones considers the Ostracods as similar to those of the German Keuper. The rich fish fauna was considered by Agassiz and Newberry as equivalent to that of the upper German

[14] Sinclair, W. J., Amer. Jour. Sci., vol. 45, 1918, p. 457.

[15] Lull, R. S. Triassic life of the Connecticut Valley. Geol. Surv. Connecticut, Bull. No. 24, 1915, p. 80.

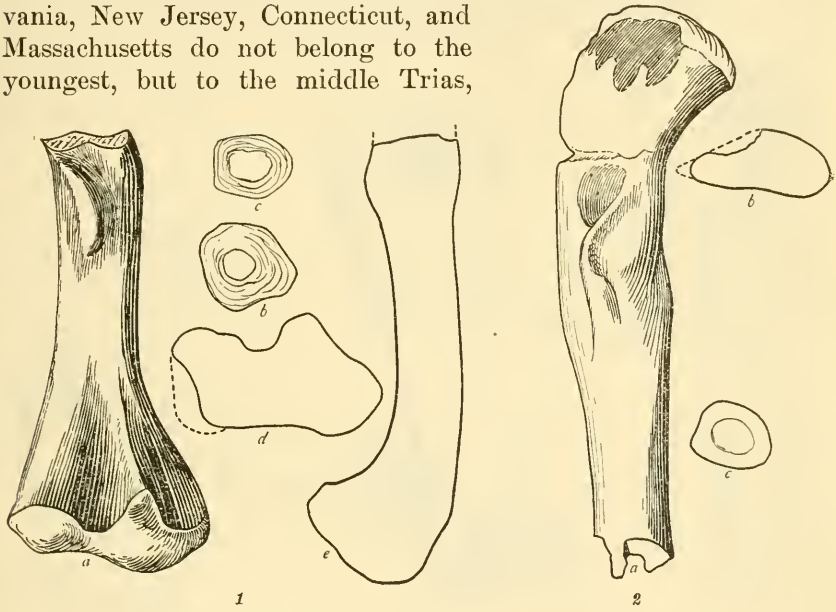
[16] Fontaine, W. M. The older Mesozoic floras of Virginia. U. S. Geol. Surv., Monogr. 6, 1883.

[17] Stur, D. Lunzer Flora in den older Mesozoic beds of the coal field of eastern Virginia. Verh. k. k. geol. Reichsanst. Wien, 1888, pp. 203–217.

[18] Ward, L. F. Status of the Mesozoic floras of the United States. U. S. Geol. Surv., 20th Ann. Rept., pt. 2, 1900, pp. 211–315.

Keuper, but Eastman,[19] having treated the whole fish fauna, and also being familiar with the European fish faunas, considers them as more ancient. He says that several species of *Seminotus* (— *Ischypterus*) are nearly related to those from Perledo and Besano in the Italian Alps, and therefore correlates the fish fauna with the upper Muchelkalk or Lettenkohle.

From all of this it must be concluded that the numerous but not yet sufficiently known Parasuchians and Labyrinthodonts from North Carolina, Virginia, Pennsylvania, New Jersey, Connecticut, and Massachusetts do not belong to the youngest, but to the middle Trias,



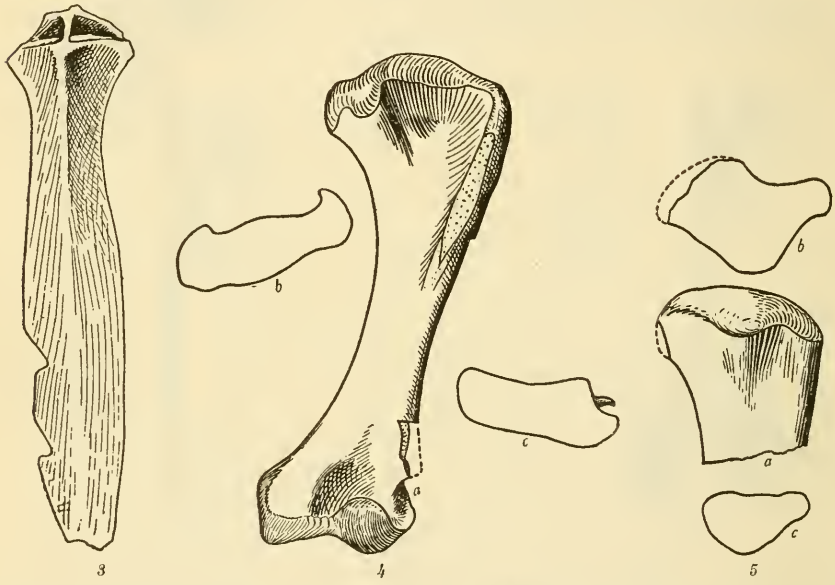
FIGS. 1–2.—1, TYPOTHORAX COCCINARUM (COPE). TRIAS (PROBABLY UPPER), FROM NEAR TANNERS CROSSING, LITTLE COLORADO VALLEY, ARIZ. U. S. NAT. MUS. NO. 5784. RIGHT FEMUR, DISTAL HALF, *a*, FROM BELOW, *b*, SECTION AT UPPER BREAK, *c*, SECTION JUST BELOW THOCHANTER, *d*, OUTLINE AT DISTAL END, *e*, LATERAL VIEW. 2, PROXIMAL EXTREMITY OF ANOTHER RIGHT FEMUR, SAME LOCALITY AS FIG. 1, NO. 2163, U. S. NAT. MUS., *a*, FROM BELOW, *b*, OUTLINE OF PROXIMAL FACE, *c*, SECTION AT DISTAL BREAK. BOTH 1 : 4 NAT. SIZE.

which would be about the time between upper Muschelkalk and lower Keuper, but that the Saurischians in Connecticut and Massachusetts belong to the upper Keuper or the Rhaetic. This also seems to be the view of Lull, who, in 1915, assembled the American evidence on this question, but without comparing extensively with European evidence.

[19] Eastman, Charles. The Triassic fishes of New Jersey. Ann. Rep. Geol. Surv. New Jersey for 1904 (1905), pp. 70–72; Triassic fishes of Connecticut. Geol. Surv. Connecticut, Bull. 18, 1911, pp. 23–26.

It is evident that these continental Triassic deposits comprise a long period, the close of which about coincides with the close of Triassic time, and whose middle and older part is about a parallel of the German "Lettenkohle." The beginning of these deposits is probably at least in the time of the earlier or later Muschelkalk.

From these considerations it seems that in the eastern Trias the equivalent of the lowest Trias is missing, and even in the central and western continental Trias such equivalents are at least not shown. Only middle and Upper Triassic deposits are evident, as has also been shown in *Neue Beitrage zur Kenntnis der Parasuchier.*[20]



FIGS. 3–5.—3, INTERCLAVICLE OF A PARASUCHIAN. MIDDLE TRIAS FROM NEAR TANNERS CROSSING, LITTLE COLORADO VALLEY, ARIZ. U. S. NAT. MUS. NO. 2153. VIEW FROM BELOW. 4, LEFT HUMERUS OF A PARASUCHIAN, SAME LOCALITY. U. S. NAT. MUS. NO. 2154, *a*, FROM IN FRONT, *b*, FROM ABOVE, *c*, FROM BELOW. 5, LEFT FEMUR, WITHOUT DISTAL END OF A PARASUCHIAN, SAME LOCALITY. U. S. NAT. MUS. NO. 2163, *a*, FROM BELOW, *b*, OUTLINE OF PROXIMAL FACE, *c*, SECTION IN MIDDLE AT NARROWEST PLACE. ALL FIGURES 1 : 4 NAT. SIZE.

In the Texas Dockum beds is the very primitive *Desmatosuchus* and such more advanced forms as *Promystriosuchus* and *Leptosuchus*. But it is possible that they are not quite of the same age.

A few specimens from the United States National Museum's collections are here figured. They had kindly been forwarded to the writer who wishes to express his thanks.

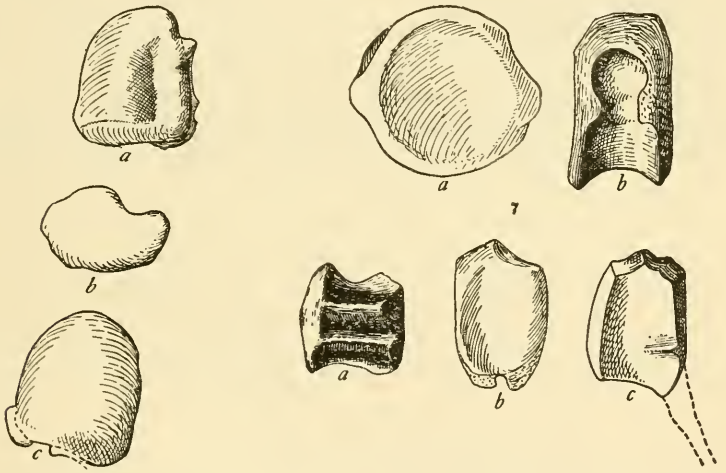
At this time I wish to express my thanks to Dr. J. B. Reeside, of the United States Geological Survey, for the valuable notes and

[20] Jahrb. Preuss. Geol. Landesanst. for 1921 (1922), vol. 42, pp. 49–160.

criticism of the geological portion of this paper, which he so kindly furnished me.

(1) *Typothorax coccinarum* Cope. Right femur in yellow sandy clay, from near Tanners Crossing, Ariz. The proximal extremity has a surprisingly large trochanter minor. Trochanter quartus and distal end are the same as in Cope's type [21] from New Mexico. It probably also belongs to the Upper Trias as in New Mexico. (Cat. No. 5784, U.S.N.M.)

(2) Parasuchian bones. There are a number from Tanners Crossing, Ariz., belonging to the Middle Triassic fauna. Among these is a good interclavicle (Cat. No. 2153, U.S.N.M.), a fair humerus (Cat. No. 2154, U.S.N.M.), a complete ulna (Cat. No. 2154, U.S.N.M.), and a femur lacking only the distal end (Cat. No. 2163, U.S.N.M.).



FIGS. 6–8.—6, PROBABLY RIGHT ASTRAGALUS OF A PARASUCHIAN. MIDDLE TRIAS FROM NEAR TANNERS CROSSING, LITTLE COLORADO VALLEY, ARIZ. U. S. NAT. MUS. No. 2160, *a*, FROM ABOVE, *b*, LATERAL VIEW, *c*, FROM BELOW. 7, DORSAL VERTEBRA OF A STEGOCEPHALIAN (METOPOSAURID), SAME LOCALITY. U. S. NAT. MUS. No. 2158, *a*, FROM IN FRONT, *b*, FROM RIGHT SIDE. 8, CAUDAL VERTEBRA OF A STEGOCEPHALIAN (METOPOSAURID). U. S. NAT. MUS. No. 2158, *a*, FROM BELOW, *b*, FROM BEHIND, *c*, FROM LEFT SIDE. ALL FIGURES 1 : 2 NAT. SIZE.

One of these bones could possibly be an astragalus; if so, it is the first known Parasuchian astragalus. It is flat, rounded below, and blunt on the lateral side. Above it is excavated along the anterior border in a narrow strip, and the larger posterior part forms a curved elevation. From the known distal end of the tibia [22] this form of astragalus was to be expected. It would fit better with *Episcoposaurus* than with *Phytosaurus* or *Mystriosuchus* (Cat. No. 2160, U.S.N.M.).

[21] See Bull. Amer. Mus. Nat. Hist., vol. 34, 1915, p. 485 and following.
[22] Idem., p. 494.

(3) Vertebrae of Metoposauridae from the Middle Trias of Tanners Crossing, Ariz. (Cat. No. 2158, U.S.N.M.). The dorsal vertebrae are broad and with flat and parallel articular faces. The dorsal side shows an inclined anterior and a similar posterior face, and between them a slightly curved or nearly flat transverse strip with no trace of the dorsal sine canal. The attachment of the rib is shown by a thickening of the anterior and the posterior lateral border in their middle height.

A middle caudal vertebra, smaller than the dorsals, is rather narrow. Its articular faces are very slightly converging upward. The upper aspect shows two faces, one inclined anteriorly, the other posteriorly. It is demonstrated more clearly than in the dorsals that this "centrum" is really a hypocentrum. From below it has a very deep median fossa and two high ridges, slowly becoming higher posteriorly, and being broken below the posterior articular face. This is the place where the bifurcated haemapophysis grew out of the hypocentrum; it was not separated from it as in reptiles, but was one single piece. At the posterior border of the hypocentrum and low down there is a small remainder of the attachment of the caudal rib.

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