DISCOVERY OF A TETRAPOD BODY FOSSIL IN THE LOWER PERMIAN YESO GROUP, CENTRAL NEW MEXICO

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Abstract—The lower Permian Yeso Group records arid coastal plain, shallow marine and evaporitic deposition across much of central New Mexico during Leonardian time. Generally considered to have few fossils, recent study of Yeso Group strata has uncovered a diverse fossil record of marine microorganisms (mostly algae and foraminiferans), terrestrial plants and tetrapod footprints. We document the discovery of a tetrapod body fossil in the Yeso Group—a partial skeleton of a varanopid eupelycosaur. The fossil consists of the natural molds of articulated bones in two pieces, part and counterpart, that were preserved in a sandstone bed of the lower part of the Arroyo de Alamillo Formation in the southern Manzano Mountains. The fossil-bearing sandstone is interpreted as an eolian sheet sand. The casts preserve part of the pelvis(?), 18 caudal vertebral centra, both femora, tibia-fibulae, and most of the pedes, largely in close articulation, of a single individual. The skeleton is of a relatively small (femur length = 62 mm, total length of the preserved cast from the pelvis to tip of the incomplete tail = 325 mm) and gracile eupelycosaur most similar to *Varanops*. In New Mexico, various early Permian eupelycosaurs are known from the older strata of the Bursum Formation, Abo Formation, and Cutler Group, so this discovery extends the eupelycosaur fossil record in the state into younger early Permian strata. It also indicates that a substantial community must have been present on the arid coastal plain during deposition of the Arroyo de Alamillo Formation, as the varanopid is a generally large, early Permian predator that likely fed on smaller vertebrates and arthropods. Furthermore, this discovery indicates the potential for additional discoveries of tetrapod body fossils in Yeso Group strata.

INTRODUCTION

In New Mexico, Upper Pennsylvanian-lower Permian red beds have long produced an important record of tetrapod fossils—bones, footprints and coprolites (e.g., Berman et al., 2015; Hunt and Lucas, 2015). Among these tetrapod fossils is a particularly significant fossil record of eupelycosaurs (basal synapsids)—eothyridids, edaphosaurids, varanopids, ophiacodontids and sphenacodontids. Indeed, much of what we know about some of these eupelycosaurs, especially sphenacodontids, is based on New Mexico fossils (e. g., Spielmann et al., 2010).

These eupelycosaur fossils come from fluvial strata of the Cutler Group in northern New Mexico and the Abo Formation in northern and southern New Mexico, strata of Cobrean-Coyotean (Virgilian-middle Wolfcampian) age (e.g., Lucas et al., 2015; Lucas, 2018). The upper part of the lower Permian section across New Mexico includes strata of the Yeso Group, a unit of mixed marine-nonmarine origin (Lucas et al., 2013). Lower Yeso strata were mostly deposited on the arid coastal plain northwest of the Permian basin of West Texas and southeastern New Mexico.

Long considered to be essentially unfossiliferous, field research in the Yeso Group during the last decade has uncovered a diverse record of marine microfossils (mostly algae and foraminiferans), trace fossils (notably tetrapod footprints) and terrestrial plant fossils (e. g., Lucas et al., 2013; Vachard et al., 2015; Lucas and Krainer, 2017; Voigt and Lucas, 2017). The recent discovery of a mold of an incomplete, articulated skeleton of a eupelycosaur in lower Yeso strata adds a vertebrate body fossil to the growing list of Yeso Group fossils. This specimen is described here, and its implications for the biota of the arid coastal plain during early Yeso deposition are also discussed.

PROVENANCE

The fossil was found by one of us (ET) in 2016 at the Abo Unit of the Salinas Pueblo Missions National Monument. Map coordinates are in the NMMNH database under locality 12030 and are available to qualified researchers.

The fossil is a natural mold of bones in two pieces, part and counterpart, preserved in the collection of the National Park Service at the Salinas Missions National Monument. It was collected from a laminar sandstone bed of the lower part of the Arroyo de Alamillo Formation of the Yeso Group (Fig. 1). The horizon is unit 4 of the Abo Ruins measured stratigraphic section of Lucas et al. (2016). The age of the Arroyo de Alamillo Formation is early Leonardian (Lucas et al., 2013)

The fossil-bearing sandstone is fine-grained, quartz-rich and pale reddish brown (10R5/4) to grayish red (10R4/2) unweathered, which weathers to blackish red (5R2/2), and is in part encrusted by white (N9) caliche. Lucas et al. (2016) interpreted the fossil-bearing sandstone as an eolian sand sheet in a dominantly eolian-deposited local section of the Arroyo de Alamillo Formation.

DESCRIPTION AND IDENTIFICATION

The molds (Figs. 2-3) preserve part of the pelvis?, 18 caudal vertebral centra, both femora and tibia-fibulae and most of the pedes, largely in close articulation, of a single individual. The two blocks are here labelled A (part) and B (counterpart). Block A (Fig. 2) preserves less of the tail than does block B (Fig. 3), in which the distal part of the tail was originally covered by a caliche crust that has been removed. The skeleton is of a relatively small (femur length = 62 mm, total length of the preserved cast from the pelvis to tip of the incomplete tail = 325 mm) and gracile eupelycosaur most similar to *Varanops*. Identification as a varanopid thus seems certain. Most synapomorphies of the Varanopidae are features of the skull (e. g., Reisz, 1986; Benson, 2012), but relatively long and slender

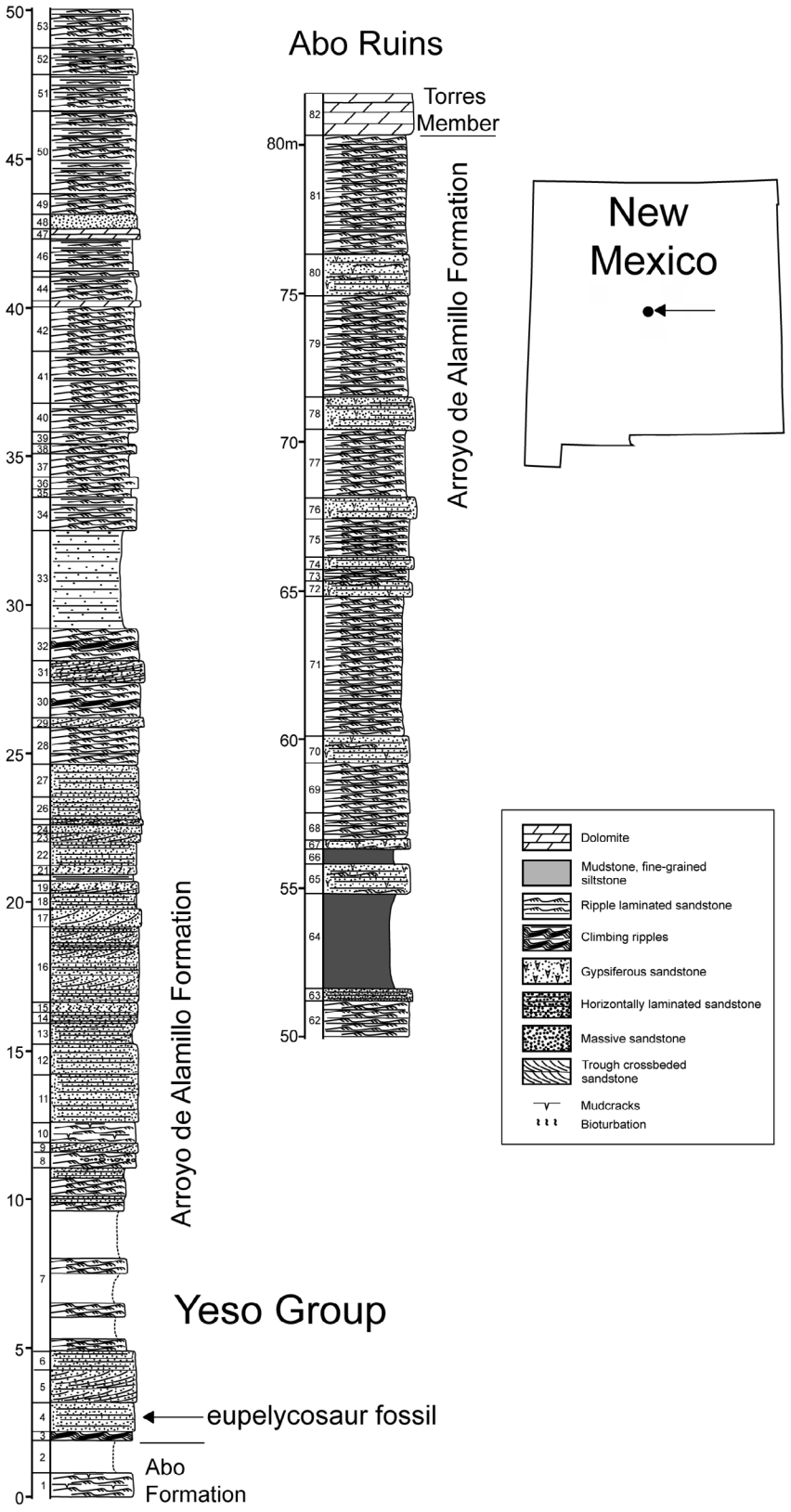


FIGURE 1. Index map and stratigraphic section of the Arroyo de Alamillo Formation (Yeso Group) at the Abo Ruins showing the eupelycosaur fossil site in the lower Yeso Group of central New Mexico.

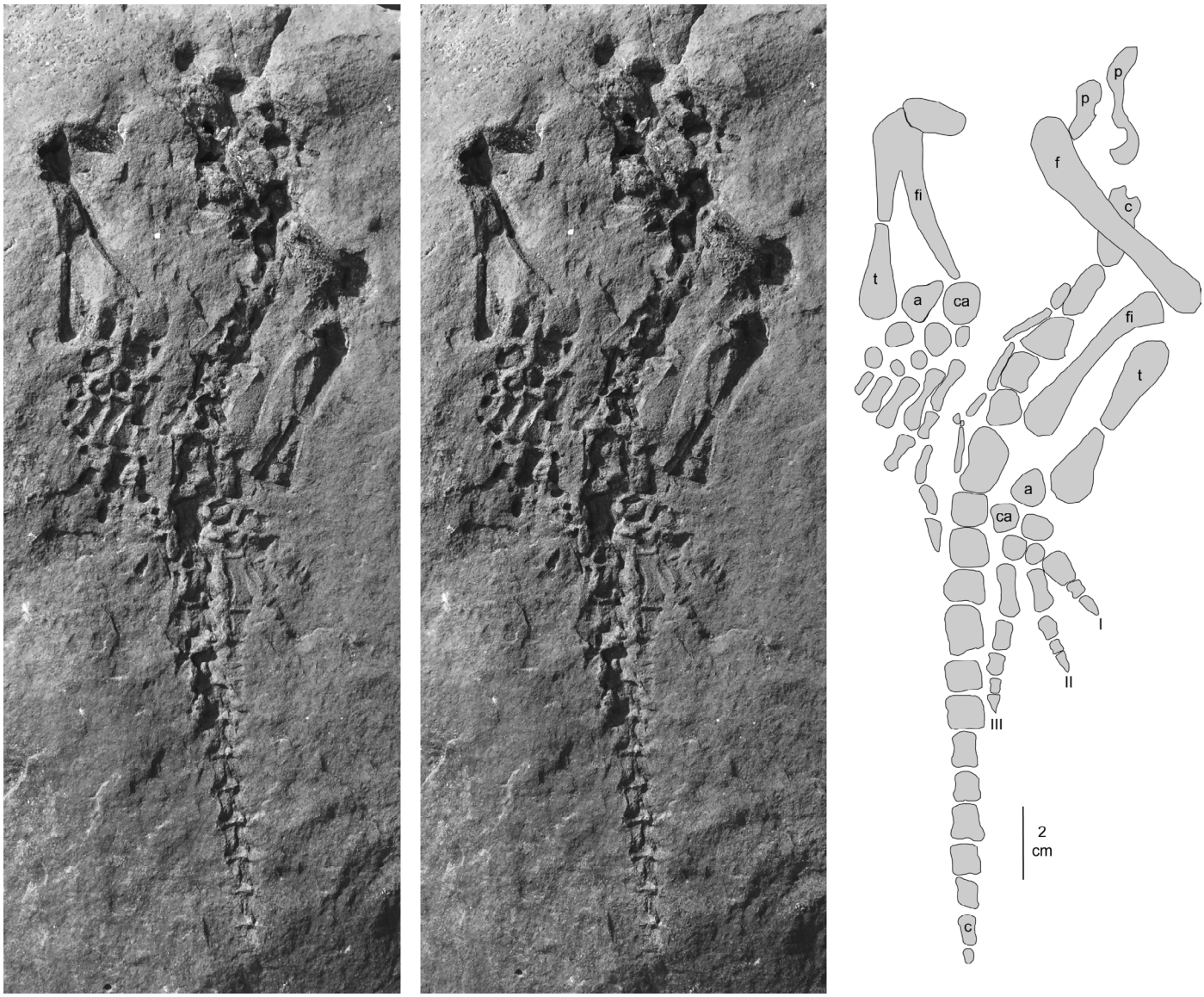


FIGURE 2. Block A, stereophotograph and bone map of sandstone cast of incomplete skeleton of a varanopid eupelycosaur from the lower Permian Arroyo de Alamillo Formation (Yeso Group) in central New Mexico. Abbreviations are: a = astragalus, c = caudal vertebra, ca = calcaneum, f = femur, fi = fibula, p = pelvis, t = tibia, digits I-V are numbered.

limbs and a calcaneum that is longer than wide and nearly the same size as the astragalus are features of the Yeso specimen that appear to also be synapomorphioes of the Varanopidae.

The caudal vertebrae number 18, but do not include the distalmost portion of the tail. All of the centra are amphicoelous, slightly waisted spools that are 9-11 mm long, and have proximal articular surfaces that are 6-8 mm wide and distal articular surfaces that are 5-8 mm wide. The anterior 13 caudal vertebrae are all subequal in size, whereas the succeeding five become progressively smaller.

The pelvis is very difficult to interpret. What may be the ventral margins of the two ischia appear to contact each other along the midline, but this is not certain.

The femur is a nearly straight bone with a straight lateral margin, a concave medial margin and expanded proximal and distal ends. It is 62 mm long, has a proximal width of 13 mm and a distal width of 19 mm. The proximal articular surface is flat to very slightly convex, whereas the distal end is weakly divided by the popliteal groove into two articular surfaces, one for the tibia and the other for the fibula. It is worth noting that there is not a pronounced size difference or proximal-distal offset of these distal articular surfaces, as in many eupelycosaurs, notably sphenacodontids. Instead, these surfaces are of nearly equal size and are little offset, as in *Varanops* and some ophiacodontids (Romer and Price, 1940, fig. 36).

The tibia is a nearly straight bone with expanded and thick proximal and distal ends. It is 54 mm long, and 11 mm wide at its proximal and distal ends. Both its lateral and medial margins are concave. A prominent cnemial crest is evident along the proximo-anterior part of the bone. This bone is relatively gracile for a eupelycosaur tibia, and closely resembles that of *Varanops* (Romer and Price, 1940, fig. 38).

Like the tibia, the fibula is gracile for a eupelycosaur and closely resembles that of *Varanops* (Romer and Price, 1940, fig. 39). This slender and curved bone is 55 mm long and 12 mm wide at its proximal and distal ends, which are only slightly wider than the shaft. The medial margin of the fibula is strongly concave, whereas the lateral margin is nearly straight. The proximal end appears to have a triangular cross section, whereas the distal end is flattened.

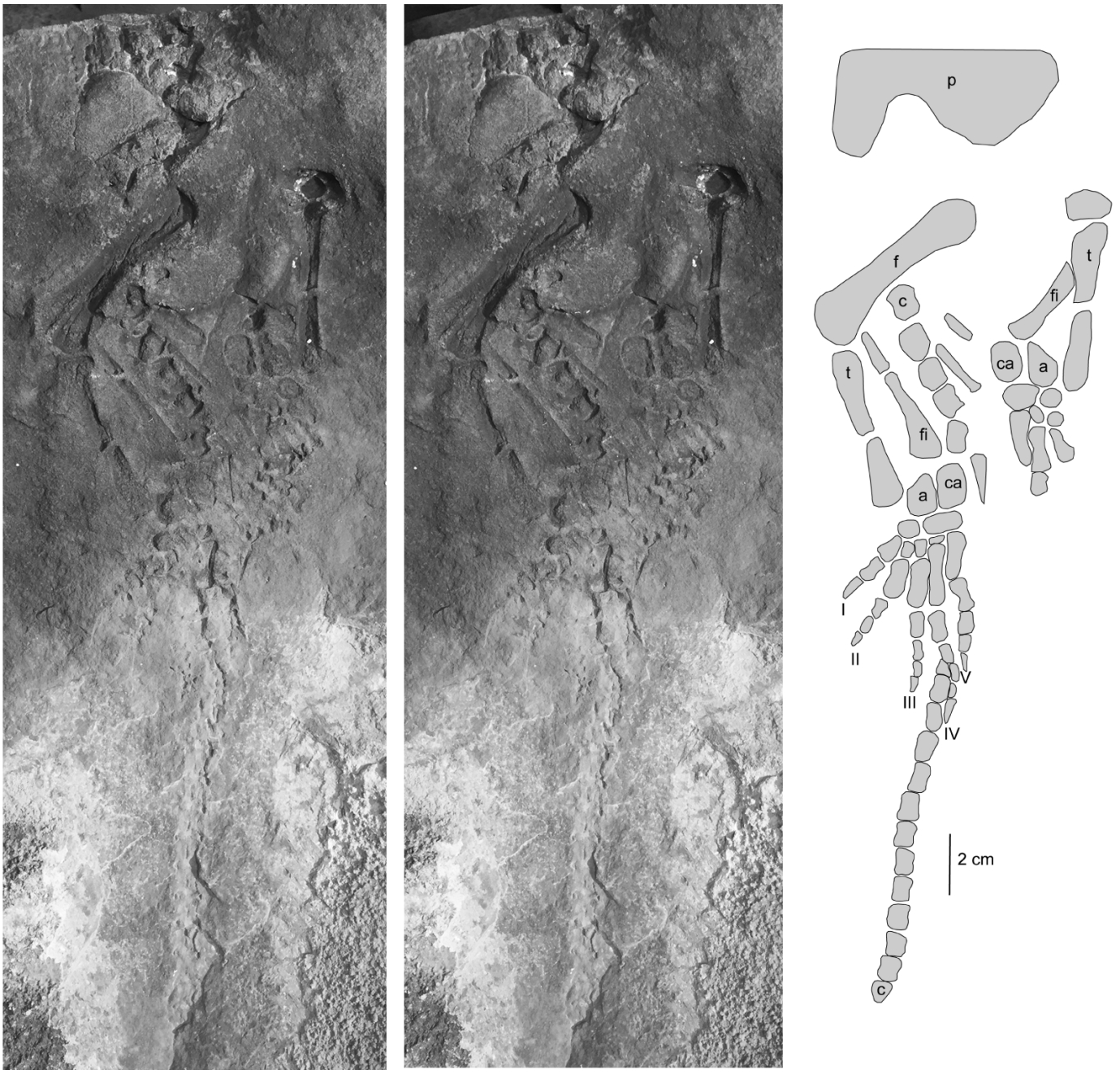


FIGURE 3. Block B, stereophotograph and bone map of sandstone cast of incomplete skeleton of a varanopid eupelycosaur from the lower Permian Arroyo de Alamillo Formation (Yeso Group) in central New Mexico. Abbreviations are the same as in Figure 2.

Among eupelycosaurs, the pedes of the Yeso fossil are most similar to those of *Varanops* (Romer and Price, 1940, fig. 41). Thus, the astragalus and calcaneum are of nearly equal size—10 mm wide. The calcaneum is nearly round, whereas the astragalus is trapezoidal due to its prominent tibial and fibular facets, which are nearly at right angles to one another. The medial centrale is much larger than the lateral centrale. The three lateral, distal tarsals are of nearly equal size. The digits increase in length from I to IV, with digit V shorter than digit IV but longer than digits I and II. The phalangeal formula of the pes is 2-3-4-5-4. The ungual phalanges are relatively long and pointed (claws). Lengths of the measurable digits (including their metatarsals) are digit I = 22 mm, II = 31 mm, digit III = 43 mm, IV = 55 mm and V = 40 mm.

DISCUSSION

In North America, varanopid eupelycosaurs have a temporal range of Cobrean-Littlecrotonian (Virgilian-late Leonardian) and they are known from the middle Permian in Russia and South Africa (Modesto et al., 2011; Lucas, 2017, 2018). Thus, although the record documented here is the youngest varanopid fossil from New Mexico (early Leonardian), it is within the temporal range of the entire family in North America.

As noted above, the Arroyo de Alamillo Formation yields a sparse terrestrial flora dominated by walchian conifers. Invertebrate traces are indicative of the *Diplichnites* guild of the *Scoyenia* ichnofacies, a mobile invertebrate epifauna (e.g., Buatois et al., 1998). Tetrapod footprints indicate the presence of small temnospondyl amphibians, captorhinomorph reptiles

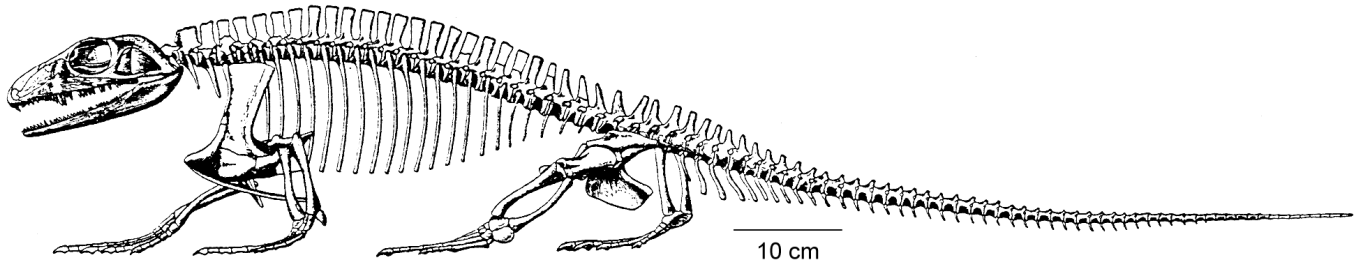


FIGURE 4 Reconstructed skeleton of *Varanops* (after Romer and Price, 1940).

and araeoscelid diapsids. The track assemblage is dominated by small captorhinomorph footprints. Eupelycosaur footprints assigned to the ichnogenus *Dimetropus* are common in the Abo Formation but essentially absent from overlying Yeso Group strata (Voigt and Lucas, 2017).

Varanopids have been interpreted as agile, terrestrial predators (e.g., Romer and Price, 1940; Olson, 1965; Langston and Reisz, 1981). The incomplete varanopid skeleton documented here is the largest tetrapod known from the lower Yeso Group. So, as currently known, the Yeso varanopid was likely the apex predator of the local biota. As such, this animal fed on smaller tetrapods as well as arthropods and possibly fishes. The varanopid fossil and other Yeso terrestrial fossils thus indicate that a complex community of plants, arthropods and tetrapods lived on the early Permian arid coastal plain during early Yeso deposition. This community was likely localized on the coastal plain by the availability of freshwater. Its presence based on the existing fossil record of the Arroyo de Alamillo Formation indicates that much remains to be discovered, so the search for a more extensive fossil record from the lower Yeso Group should continue.

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