A new reconstruction of the skull of *Euhelopus zdanskyi* (Saurischia: Sauropoda).

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Euhelopus zdanskyi was described by Wiman (1929) from the "Cretaceous" of Shandong, China. His misinterpretation of the palatine and pterygoid bones of the cranium, and the recent discovery of further cranial elements, enables a new reconstruction of the skull to be made. The Mengyin Formation from which *Euhelopus* was extracted, is now thought to be Late Jurassic in age, not Cretaceous.

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Introduction.

The sauropod genus *Helopus* was erected in 1929 by Wiman from material sent to him from China in 1922 during the Sino-Swedish palaeontological collection effort (Mateer and Lucas, this volume). Specimens representing two individuals were collected by Zdansky in 1922 from localities near Ningxiachou in central Shandong province.

The material, which included several theropod fragments, was recovered from the Mengyin Formation, previously thought to be of early Cretaceous age; following the studies of fossil conchostracans by Chen (1982), it would appear that the Mengyin Formation is late Jurassic.

Not all of the material sent to Wiman was described in his 1929 monograph, including a number of elements belonging to *"Helopus"*. This omission, together with some misinterpretations of the skull (Janensch, 1935; McIntosh & Berman, 1975), makes it necessary, especially in the light of sauropod findings, to reevaluate *Euhelopus*. In 1956, Romer noted (1956, p. 621) that the name *Helopus* was preoccupied and suggested the name *Euhelopus* instead.

Subsequent to Wiman's monograph, Young (1935) described further dinosaurian material from the same area, some of which is almost certainly from the same individual ('specimen A') described by Wiman. Zdansky (verbal comm., 1982) mentioned that he did not complete the recovery of 'specimen A' since he was compelled to return to Beijing. Since 'specimen A' comprises the anterior part of the animal, and Young's (1935) material comprises the humerus, scapula, and coracoid, it is not unreasonable to agree that Young's and Wimans's material belong to the same individual.

The most important material, and that principally considered here, is from 'specimen A' consisting of several skull bones (Figs. 1–5) in the collections of the Paleontological Museum, Uppsala, Sweden (PMU.R233 a-δ).

Material

Frontal (PMU.R233t) (Fig. 1, c–d) – The frontal is fairly flat. The anterior margin, as in *Camarasaurus* (comparisons with *Camarasaurus* are based upon Gilmore (1925) and the authors' unpublished material), is sinuous but apparently does not project near the medial line. It is a thinner bone than in *Camarasaurus*. On the ventral side there occurs a subdued ridge for articulation with the laterosphenoid and orbitosphenoid. On the posterior margin a triangular process projects backwards and outwards in contrast to the relatively straight posterior border in *Camarasaurus*.

Squamosal (PMU.R233a) (Fig. 1, a–b) – Wiman misinterpreted the position of the squamosal by inverting the left bone and placing it on the right side articulating with the right postorbital. In contrast to

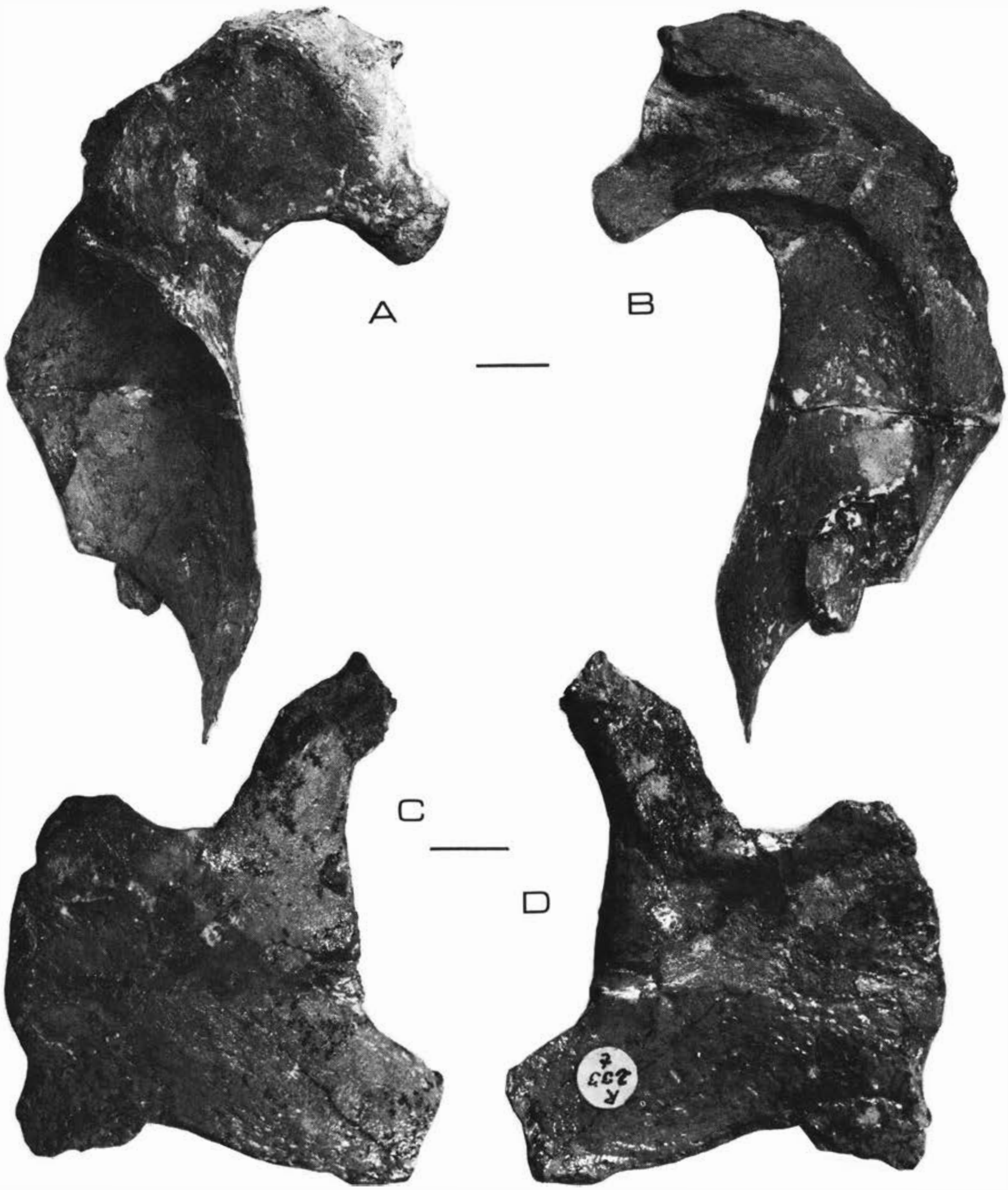

Fig. 1. Cranial bones of *Euhelopus zdanskyi,* holotype. a-b, medial and external views of the left squamosal, PMU. R233a. c-d, upper and lower views of the right frontal, PMU. R233t. The black bars represent one cm. (one scale for a-b, and one scale for c-d).

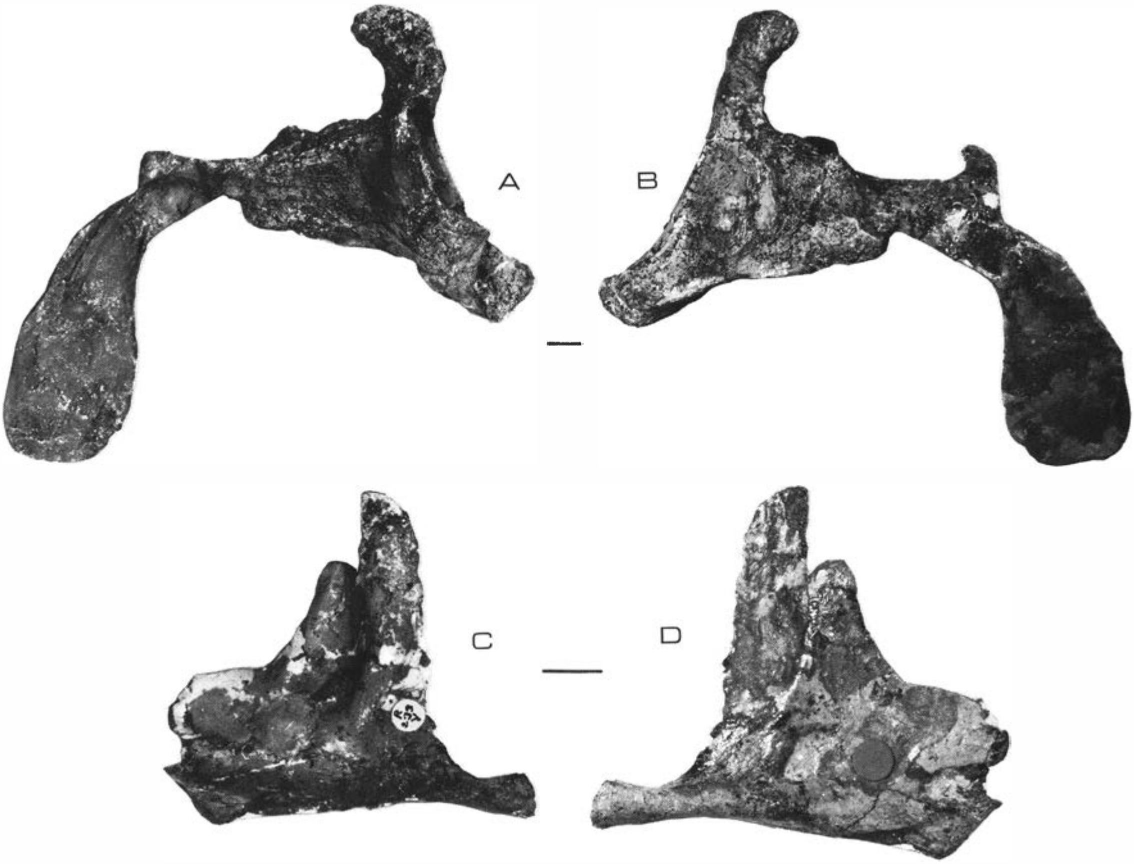

Fig. 2. Cranial bones of *Euhelopus zdanskyi,* holotype. a-b, external and medial views of the right quadrate (upper) and pterygoid (lower), PMU.R233a. c-d, external and medial view of right palatine. PMU.R.233j. The black bars represent one cm. (one scale for a-b, and one scale for c-d).

Wiman's interpretation of an incomplete squamosal, this bone is actually nearly complete and is virtually identical to that of *Brachiosaurus* (Janensch, 1935) and very similar to that of *Camarasaurus.* Awareness of Wiman's inversion of this bone leads to a substantial revision of the geometry of the skull. Despite this error, his placement of the postorbital is, nonetheless, correct.

Quadrate and Quadratojugal (Fig. 2, a–b; Fig. 3, e–f) – Wiman's identification of the lateral flange of the quadrate as part of the quadratojugal is incorrect. The actual quadratojugals are similar to those of *Camarasaurus* and *Brachiosaurus* though more slender; but the lower rear angle of curvature is more acute than in the former.

Lachrymal (PMU.R233, β) Fig. 3, a–d) – This element is straight and slender and the right lachrymal is nearly complete. The lower border of the lachrymal meets irregularly with the maxilla. The posterior dorsal process of the maxilla, separating the naris and anteorbital fenestra, abuts the anterior margin of the lachrymal near its proximal end. Although the median rim of the foramen is missing, the position of the latter is clear and lies approximately two–thirds of the way up the shaft.

Palatine (PMU.R233γ,δ) (Fig. 2, c–d) – The two elements described by Wiman as vomers are clearly the nearly complete palatines (Janensch, 1935; McIntosh & Berman, 1975). The right bone is virtually undistorted. The upwardly projecting dorsal blade divides into a larger blade and a smaller median one. The posterior margins of each presumbly articulate with the pterygoid; however, the preservation of the latter is such that the nature of the articulation is obscure. This division is in marked

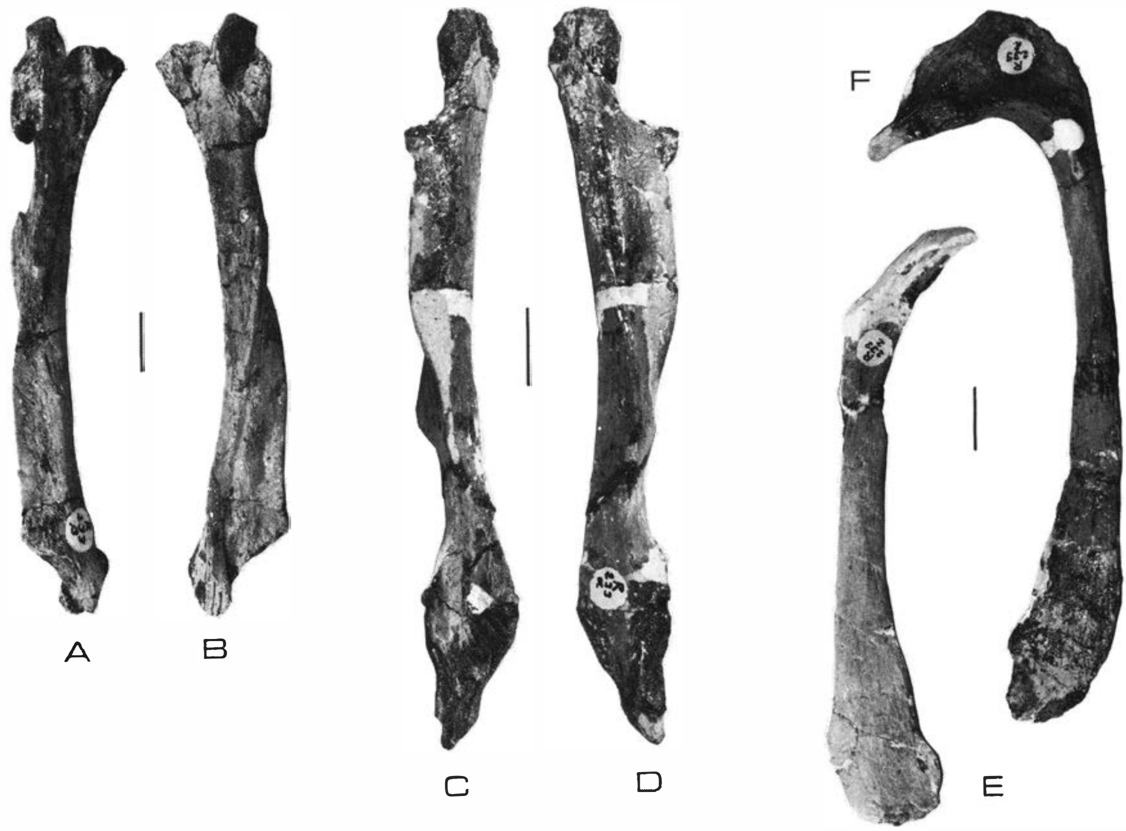

Fig. 3. Cranial bones of *Euhelopus zdanskyi.* a-b, frontolateral and posterolateral views of the right lachrymal, PMU.R233ß. c-d, medial and external views of the left lachrymal, PMU.R233∝. e-f, medial views of the left respectively right quadratojugals, PMU. R233z and å. The black bars represent one cm. (one scale for a-b, one scale for c-d, and one scale for e-f).

contrast with that of *Camarasaurus,* which has a simple large 'sail' and also *Brachiosaurus,* which is also simple, but curves laterally. The anteriorly projecting arm for articulation with the maxilla is shorter than in *Camarasaurus*. Whereas the posterior margin is at a simple acute angle, that of *Euhelopus* is clearly very different, although obscured by the poor preservation of the pterygoid.

Pterygoid (PMU.R233a) (Fig. 2, a–b) – The anterior half of the pterygoid is preserved and reconstructed in such a manner as to be ambiguous. Immediately posterior to the ectopterygoid process there appears to be a break suggesting that the lateral positioning of the bone is incorrect. Anterior to the process, the bone is heavily reconstructed so that the extent and form of the anterior blade is difficult to ascertain. Wiman's reconstruction differs markedly from that of any sauropod and quite clearly projects too far up into the skull.

Angular (PMU.R233s) (Fig. 4, c–d) – The right angular is nearly complete lacking only a small part of the anterior and posterior ends. The ventro-medial border is robust, but this thins posteriorly to accommodate the prearticular. It closely resembles that of *Camarasaurus*.

Prearticular (PMU.R233r) (Fig. 4, a–b) – The left prearticular lacks a small amount of both the very fragile anterior and posterior ends as well as the upper part of the dorsal blade. Again, it resembles that of *Camarasaurus*.

Surangular (PMU.R233r) – The right surangular is complete except for the posterior tip. As figured by Wiman (posterior, 1929; Plate 1, fig. 6), the mandible is made up of the dentary and surangular alone, causing the posterior end to appear very shallow. When the angular is added, a more camarasaurid configuration emerges. Wiman's diagram of the left

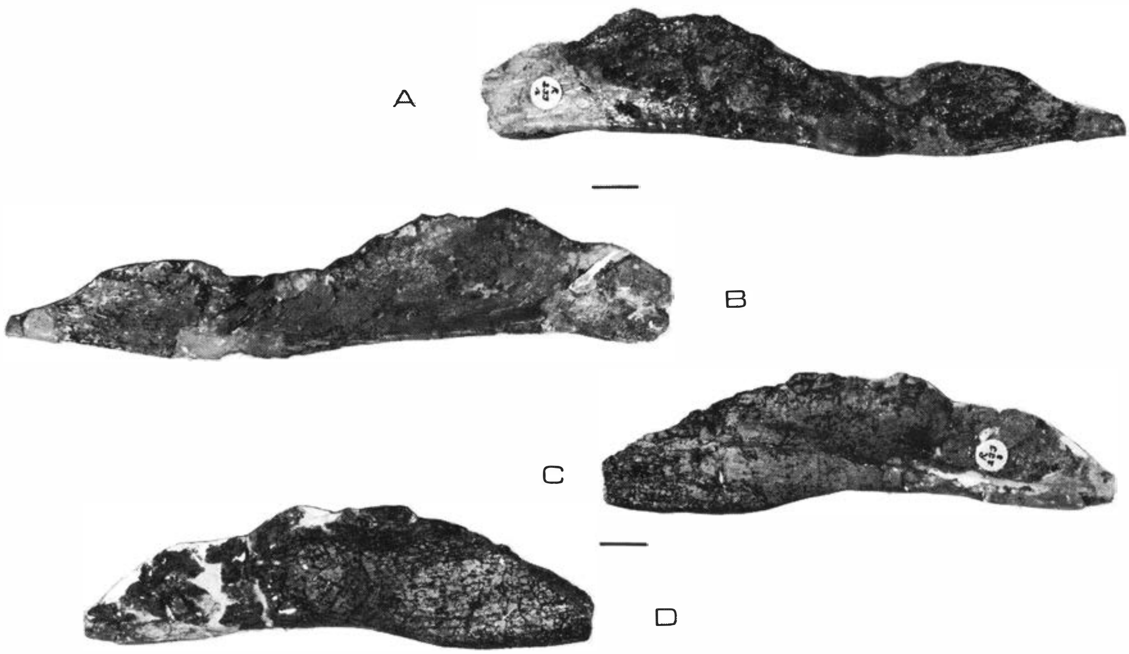

Fig. 4. Jaw bones of *Euhelopus zdanskyi.* a-b, lateral and medial views of the right prearticular, PMU.R233r. c-d, upper and lower views of the right angular, PMU.R233s. The black bars represent one cm (one scale for a-b, and one scale for c-d).

mandible clearly reveals that the lower posterior part of the jaw is reconstructed with plaster.

Pes (PMU.R234 f–n) (1929: Plate 4, fig. 12) – Wiman indicates that the pes from specimen B is tetradactyl, but all sauropods are pentadactyl: the fifth metatarsal is clearly missing. Also, in his figure the anterior and posterior surfaces of the first metatarsal are reversed. Clearly, phalanges I–1, II–2, and several others are missing.

Since *Euhelopus* is now thought to be Upper Jurassic and not Lower Cretaceous (Chen, 1982), then *Euhelopus* is not younger than *Camarasaurus.* Further, the more massive skull of *Camarasaurus,* which in sauropods is not regarded as a primitive condition, contrasts with that of *Euhelopus* (Fig. 6).

The vertebral formula of *Euhelopus* is much greater (17 cervicals and 14 dorsals) than both *Camarasaurus* (12 cervicals and 12 dorsals) and *Brachiosaurus* (13 cervicals and 11–12 dorsals). The diplodocids and apatosaurids both have the same (15 cervicals and 10 dorsals), but *Mamenchisaurus* (Young, 1954) has a formula closer to *Euhelopus* (19 cervicals and 11–12 dorsals).

The humerus and femur of 'specimen A' are, in all probability, from the same individual, and give a ratio of 0,99. This is a significant departure from other sauropod ratios except for *Brachiosaurus* which has highly developed shoulder neural spines: *Euhelopus* does not. Even *Opisthocoelicaudia* (Borsuk-Białynicka, 1977) has a much lower ratio (0.72) despite this genus being placed in the Euhelopinae by Borsuk–Białynicka.

Summary

The systematics of sauropods are far from clear so it is not safe to state how *Euhelopus* is related to sauropod phylogeny. However, the following similarities can be noted with other genera:

1. *Euhelopus* would appear to be contemporaneous with the camarasaurids, brachiosaurids and diplodocoids; the late Jurassic saw an acme in sauropod diversity (Romer, 1966).

2. The skull, in general, is comparable to *Camarasaurus* except for being much more delicate. The pterygoids and palatines are, however, of a unique form – quite different from other sauropods.

Fig. 5. Cranial elements of *Euhelopus zdanskyi,* holotype, PMU.R233a. a-b, external and medial views of the right premaxillae and maxillae. c-d, medial and external views of the left premaxillae and maxillae. The black dots represent one cm. (one scale for a-b, and one scale for c-d).

3. The neural spines are widely bifurcated in *Euhelopus* and, in the shoulder region, a small process is present between the neural spines. Brachiosaurs have no bifurcation of the neuralspines, but the camarasaurs do; only diplodocoids have a bifurcation and a medial process like *Euhelopus*.
4. The humerus: femur ratio in *Euhelopus* (0,99) is significantly higher than any sauropod except *Brachiosaurus*.
5. The vertebral formula is extremely high, approaching that of *Mamenchisaurus*.

Euhelopus is a camarasaurid-like sauropod with certain, but significant, features characteristic of other genera normally thought to be distantly related to the camarasaurs.

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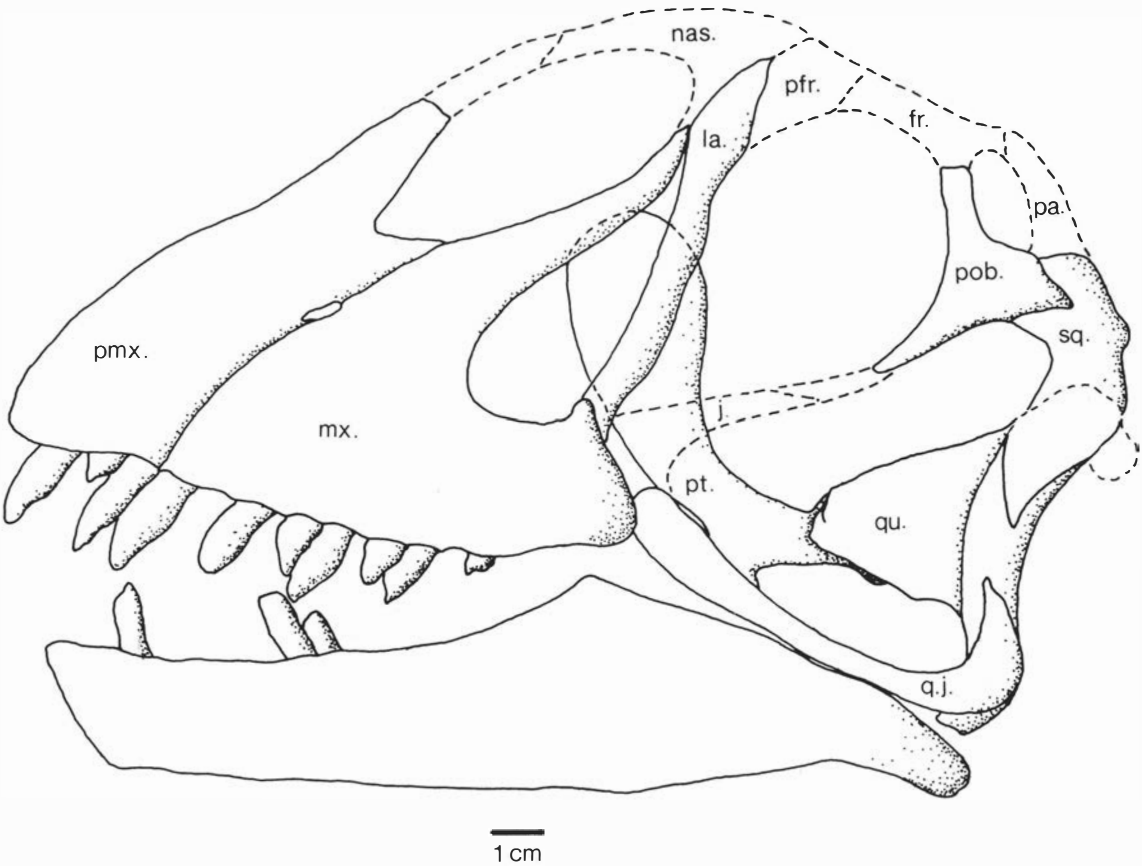

Fig. 6. A reconstruction of the skull of *Euhelopus zdanskyi* based upon specimen PMU.R233a. See Wiman (1929, Pl. 1) for comparison. The palatines have been omitted for clarity.

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