SI Text

Details of Phylogenetic Analysis.

An additional known ptolemaiidan, *Qarunavus meyeri* (Simons and Gingerich 1984), was excluded from the analysis because it is known only from a juvenile mandible, and could have been scored for only two of the nineteen characters.

An exhaustive search retrieved a single tree, regardless of how multiple state characters were treated. Ordered analysis (all multistate characters are ordered) produced one tree of length 32 and a consistency Index (CI) of 0.656. Unordered analysis produces one tree of length 31 and a CI of 0.677.

PAUP* 4.0b10 was used for the cladistic analysis.

Characters and Character States

1. p4 cristid obliqua:
0 absent
1 present, long, and trenchant

2. p4 metaconid:
0 absent
1 present and small
2 present and large

3. Molar entocristid morphology:
0 smooth
1 with cuspules

4. Molar entoconids:

0 large

1 reduced or absent

5. m3 paraconid:

0 widely spaced from metaconid

1 present and situated close to metaconid

2 fused with metaconid

6. P3 protocone:

0 absent

1 present

7. P4 metacone:

0 absent

1 present

8. P4 protocone:

0 very small

1 enlarged

9. P4 parastyle:

0 absent or very small

1 present

10. P4 metaconule:

0 absent

1 present

11. M1-2 mesial cingulum:

0 absent

1 present

12. M1-2 distal cingulum:

0 absent

1 present

13. M1 preparacrista:

0 present and long

1 short or absent

14. Orientation of M1-2 postprotocrista:

0 meets metacone

1 courses distal to metacone

15. M1-2 conules:

0 absent

1 multiple

16. M1-2 mesostylar cusp:

0 absent

1 present

17. M1-2 paracone-metacone fusion:

0 based fused

1 bases widely separate

18. M1-2 stylocone:

0 absent

1 present

19. M1-2 parastylar lobe:

0 absent

1 present

Character Matrix:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Prokennalestes trofimovi	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1
Todralestes variabilis	0	1	0	0	0	?	0	0	1	0	1	1	0	1	0	0	0	1	1
BQ2 gen nov	1	1	1	0	2	0	0	1	0	0	1	1	1	0	0	1	1	0	0
Cleopatrodon ayeshae	0	0	0	1	1	1	0	1	0	1	0	0	1	1	1	0	0	0	0
Kelba quadeemae	1	2	1	1	0	1	1	1	0	0	1	1	1	0	1	1	1	0	0
Ptolemaia grangeri	0	2	0	0	1	?	1	1	1	1	0	0	1	1	0	0	0	0	0

Tooth rotation.

The p2 in KNM ME 14 appears to be rotated in the jaw. It is clear that the tooth has not been inadvertently glued incorrectly into the mandible. Magnified inspection of the specimen reveals no cracks or glue residue, and the alveoli around the root of the tooth are complete and fit closely to the tooth such that removal of the tooth from the jaw would certainly have caused damage to the jaw. The existence of “extreme tooth rotation” in mammalian dentitions has been documented in the past, although it is rare (1). In general, it appears that tooth rotation greater than 135° (extreme rotation) is more common in premolars than in molars, incisors, or canines; more common in upper than lower dentitions, and more common on the left side (KNM ME 14 is a left mandible). Although the upper dentition of this individual is not preserved, extreme tooth rotation has never been documented in occlusal pairs (corresponding upper and lower teeth). Given the morphology of the p2 of *Kelba*, it is unlikely that the rotation of this tooth would have been very disruptive to occlusion or chewing mechanics.

Descriptions of Individual Specimens.

KNM-SO 23296. This is a crushed and distorted anterior part of the skull. Dorsally, everything posterior to approximately the posterior end of the nasals is lost. Parts of the left maxilla are also missing (SI Fig. 4). Ventrally, the specimen includes the entire palatal region, although the right premaxilla and parts of the palatine are lost. Of the dentition, only the right I1-C and left M1 are missing. The skull is compressed, so that the left posterior palate overlaps the right and is not visible in ventral view (Fig. 2*C*). The specimen is also distorted in the sagittal plane, so that the right side lies about 15-20 mm anterior to the left. There is relatively little distortion within the right and left sides, however, so the course of the cheek tooth rows in mildly bent arcs is readily apparent.

The nasals have an anterior border with a strong notch, while the median and lateral ends are longer, giving it the shape of an inverted V. The medial ends of the nasals are pointed, but do not meet anteriorly. The infraorbital foramen is situated far forwards, about level with the anterior root of P3. The maxilla bulges out from this point onwards into a gentle arc until it forms the anterior root of the zygomatic arch. The space between this bulging part of the maxilla and the maxilla-nasal suture is gently dorsolaterally concave. The anterior orbital margin is gently ellipsoid and has a small, centrally located protrusion that may be the lacrimal tubercule. Ventrally, the incisive foramina are long and slender with the anterior border at distal margin of I3, and ending at the middle of the canine. The lateral border of the nasal aperture inclines posteriorly ending above the midline of the canine. Both the sphenopalatine and dorsopalatine foramina are visible in the left orbit and set in a common fossa. The posterior end of the palatine (visible on the left side) extends posteriorly beyond M3 and appears to have a postpalatine torus.

The complete incisor row is present on the left side. The incisors form a gentle arc. The three incisors are all small and similar in morphology, with size increasing gradually from I1 to I3. They are cylindrical in outline and lightly worn, with the wear surface set at a relatively steep angle to the crown of the tooth. They are small relative to the size of the postcanine dentition. The I3 is followed by a diastema of about 5 mm. All three

incisors exhibit wear on their lingual face. In I1 the wear facet is very short, in I2 it extends the length of the crown, while in I3 it extends halfway to a small lingual cusp. The left upper canine is broken about 10 mm from the cementoenamel junction. It is elliptical in cross-section, with a sharper posterior than anterior apex. It is more or less straight in its preserved part and is followed by a diastema of ≈7 mm, longer than that between I3 and C.

The P1 is a slender tooth. The main cusp is situated somewhat anterior to the midline of the tooth. There is no anterior accessory cusp, but there is a faint cingulum surrounding the entire tooth, strongest on the lingual and distal faces. The P2 is similar in form to the P1, but is considerably larger. The apex of the main cusp is again situated slightly in front of the middle of the tooth. There is a thickening of the cingulum mesiolingually and the lingual and distal parts of the cingulum are well developed. The P3 is larger than P2. The main cusp is situated further anteriorly than in P1 and P2, and there is a small incipient cusp developed mesiolingually on the cingulum (similar to the condition in P2, but more developed. There is a distinct posterior accessory cusp and a strong cingulum surrounds the tooth. At the distolingual corner of the cingulum there is a large cusp (protocone) that causes the tooth to broaden out significantly.

The P4 is molariform and relatively worn, with dentine exposed on all three major cusps. A metacone is present but is slightly smaller than the paracone. These two cusps are bounded buccally by a strong cingulum that runs along the entire buccal length of the tooth and around the antero- and posterobuccal corners. No parastyle is present, and there are no crests emerging from the paracone (no preparacrista). The protocone is the largest cusp. It is V-shaped and has strong pre- and postprotocristae with no sign of paraconule or metaconule (although the tooth is worn). The postprotocrista meets with the distal cingulum rather than with the lingual face of the metacone. The protocone sits at the lingual margin of the tooth, but is bordered mesio- and distolingually by cingula.

The M1 is missing on the left side and extremely worn on the right, so that all occlusal morphology is obliterated. It is similar in occlusal outline to the M2 (see below), but is

smaller and had a less prominent metastyle, so that the distobuccal cingulum is less developed. The lingual cingulum is continuous around the whole protocone. There is a small protrusion on the cingulum of the mesiolingual corner of the tooth, which we are referring to as the pericone.

The M2 is the largest cheek tooth. Both right and left M2 in this specimen show significant wear on the three main cusps and along the pre- and postprotocristae. The paracone and metacone are subequal in size, while the protocone is much larger. There is a small postmetacrista delimiting a short extension of the buccal cingulum distally. The buccal cingulum bears a small metastyle at its posterior corner. The metastyle is separated from the postmetacrista by a shallow groove. The protocone is V-shaped, with strong pre- and postprotocristae. The lingual cingulum is discontinuous at the lingual margin of the protocone, but is well developed mesially and distally and bears a small pericone at the mesiolingual corner.

The M3 is similar in morphology to M1 and M2 but is mesiodistally foreshortened. The paracone is much larger than the metacone and has a well developed cingulum on its buccal side. The buccal cingulum around the metacone is much more weakly developed. The protocone is much larger than the lingual cusps. The preprotocrista is stronger than the postprotocrista. The postprotocrista ends in a metaconule that is nearly as large as the metacone. The lingual cingulum is robust and bears a small pericone on its mesiolingual corner.

Measurements (are maxima measured in mm; MD, mesiodistal length; BL, buccolingual length): MDI2 2.8; MDI3 3.3; MDC 7.8; BLC 5.3; MDP1 5.3; BLP1 2.5; MDP2 8.4; BLP2 3.7; MDP3 8.4; BLP3 7.2; MDP4 10.1; BLP4 11.8; MDM1 10.1; BLM1 12.6; MDM2 10.5; BLM2 13.0; MDM3 7.6; BLM3 12.9. All measurements are from right side, except I1-C.

M 19087 Holotype: Savage (2) reports this as a right M2, but we suggest that it may in fact represent the left M1. The cingulum is strong, but the buccal shelf is more poorly developed with no metastyle. The cingulum is continuous lingually, but is much weaker

than around other parts of the tooth. The pre- and postprotocristae are equally developed and have a relatively strong paraconule and metaconule, not seen on any of the other upper molars. The mesostyle is present and unworn. The preprotocrista does not meet with the paracone, but instead joins with the mesial cingulum. There is a very small cusp mesial to the paracone on the mesial cingulum linked to the paracone by a very short and small crest. This is different from the configuration of this area on the M2 in KNM SO 23296.
Measurements: MD 10.4; BL 12.3.

M 19095: This specimen is an almost unworn left M3. The metacone is considerably smaller than the paracone. The pre- and postprotocristae are equally developed, but while there is a weak metaconule (less developed than in KNM SO 23296), there is no trace of a paraconule. The mesial and distal cingula are present, but they are less strongly developed than in KNM SO 23296, and no not extend as far lingually. This gives the tooth a more triangular appearance. There is no trace of a pericone and the buccal cingulum is very strongly developed.
Measurements: MD 7.1; BL 12.2.

KNM MW 181: This tooth is likely an upper M1, although there is a possibility that it is a dP4. It is very poorly preserved, likely having passed through the digestive tract of a carnivore. The cingulum is well developed, particularly mesially, and although the pericone is not tall, it is well developed. The cingulum is continuous around the paracone, although weaker lingually. The metacone and paracone are well separated with a large mesostyle between them. There is a metaconule at the end of the postprotocrista, which meets with the metacone. The preprotocrista appears to meet with the mesial cingulum, although there is a small accessory crest that runs to the lingual face of the paracone.
Measurements: MD 9.4; BL 12.2.

KNM SO 1555: Is a broken left upper molar, likely M2. It is broken lingually, so that the protocone is preserved, but the lingual cingulum and pericone are missing. The buccal cingulum is well developed posteriorly, but there is no metastyle on the posterobuccal

cingulum. The mesostyle appears to be present, but is very weak and closely applied to the protocone. Despite being almost completely unworn, there is no trace of a metaconule or paraconule. The postprotocrista meets the lingual face of the metacone, while the preprotocrista meets with the mesial cingulum. This appears to be the normal condition for an M2.
Measurements: MD 10.7.

KNM-SO 5669: This specimen is an isolated upper right molar, likely M2. The paracone is slightly larger than the metacone and somewhat taller. The buccal cingulum is broad and opens into a broad shelf distally, but there is no metastyle cusp. The cingulum is discontinuous lingually, and is less well developed distally than in other M2s. The protocone is by far the largest cusp. It is V-shaped, and the pre- and postprotocristae show no trace of a paraconule or metaconule. The preprotocrista meets with the mesial cingulum, although there appears to be a very faint accessory crest that runs to the lingual face of the paracone. The postprotocrista meets with the lingual face of the metacone. The pericone is very well developed, while the mesostyle is very poorly developed. This specimen resembles the M2 in KNM SO 23296 in overall morphology, but is mesiodistally shorter and has a much larger pericone.
Measurements: MD 9.9; BL 15.3.

KNM-ME 14: This is a left mandibular ramus with c-p4, m3. The ventral half of the ramus is missing below the alveoli for m1 and posterad and the entire ramus posterior to about 5 mm behind m3 is missing.

The ramus is long and slender. There are three mental foramina. The anterior is ventral to the anterior end of p1, the middle ventral to the posterior root of p2, and the posterior ventral to the anterior end of p4. The symphyseal rugosity is nearly horizontal and extends along the ventral part of the ramus to the middle of p2.

The canine is broken about 5 mm above the cementoenamel junction. It is relatively procumbent and somewhat mediolaterally compressed. The p1 crown is broken. It is a

two-rooted tooth, rather small and slender with the apex well anterior to the middle of the tooth. The p2 is elliptical in cross-section and very tall. A weak cingulum surrounds most of the tooth, best developed mesially and distally. The anterior face is concave and there is a minute bump in the mesial cingulum. The posterior face is nearly vertical and there is no posterior accessory cusp. The tooth appears to be implanted backwards in the jaw, which we believe is the true morphology and not a case of improper gluing. This may be a case of extreme tooth rotation, sometimes found in mammals (1).

The p3 is nearly symmetric, with the apex nearly at the middle of the tooth. There are anterior and posterior accessory cusps developed from the cingula. The anterior accessory cusp is only slightly smaller than the posterior. The anterior and posterior faces of the main cusp are also nearly symmetric and vertical. The tooth is considerably lower than p2.

The p4 is molariform. That it is the adult tooth was confirmed by x-ray imaging, which showed well-formed tooth roots and that there are no adult teeth waiting to erupt in the jaw. The paraconid is very low and set at the middle of the anterior end of the tooth. The postparacristid is nearly horizontal and meets with the much more vertical preprotocristid at a shallow notch. The protoconid is the tallest of the trigonid cusps and also the largest seen in occlusal view. It is set on the buccal edge of the tooth. The protoconid is bounded posteriorly by a postprotocristid that joins a trenchant cristid obliqua via a distinct postvallid notch. The metaconid is somewhat lower than the protoconid and set almost directly lingual to it. They are separated by a sharp, but not very deep, notch. The talonid is low and broad, with a tall hypoconid. There is a very low cusp and postcristid at the posterolingual corner, but no distinct entoconid. There is a weak cingulum along the buccal side of the tooth.

The m1 and m2 are lost, but the alveoli indicate that the molariform cheek teeth increased in size gradually from p4 to m2, while m3 is probably only marginally larger than m2.

The m3 has a generalized tribosphenic pattern that is very like that of p4, described above. In order of height and size the trigonid cusps are protoconid, paraconid, and metaconid. All trigonid cusps are separated by steep sided notches. The paraconid is large and triangular and set at the anterolingual end of the tooth. It bears a strong postparacristid. The protoconid is set at the buccal margin of the tooth and is also triangular in occlusal view. The protocristid is distinct and its buccal and lingual parts meet in a notch. The metaconid is set directly lingual to the protoconid. The talonid is slightly narrower and shorter than the trigonid. There is a relatively deep hypoflexid. It has a strong hypoconid with a cristid obliqua set at the posterobuccal end of the tooth and a crestiform entoconid set on the lingual side. Between them there is a small hypoconulid. Measurements: MDc 6.3; MDp1 5.1; BLp1 2.6; MDp2 7.5; BLp2 4.0; MDp3 7.9; BLp3 4.8; MDp4 9.9; BLp4 6.1; MDm3 11.6; BL(tal)m3 7.2; MD(trig)m3 6.0.

KNM-LG 470: The morphology of this isolated lower molar is very similar to that of the m3 of KNM-ME 14 described above. Differences include a relatively longer talonid that is less buccolingually compressed; a more mesiodistally compressed trigonid, paraconid relatively larger, small shelf present on the buccal side between the trigonid and talonid, hypoconid slightly more centrally located, no distinct entoconid, cingula somewhat more extensive. These differences suggest to us that this specimen is probably an m2.
Measurements: MD 11.3; BL(tal) 7.4; MD(trig) 5.8.

KNM-BN 10036: This specimen is identical in all respects to KNM-LG 470 but is very slightly smaller. We identify this specimen also as an m2.
Measurements: MD 10.9; BL 7.1; MD(trig) 5.7.

KNM-CA 2821: This specimen resembles the previous two in nearly all particulars, but the trigonid is more mesiodistally compressed. The entire tooth is mesiodistally shorter, and this may represent the m1.
Measurements: MD 10.2; BL 7.2; MD(trig) 5.7.

KNM-SO 1690: This specimen is a p2 that resembles the p2 of KNM ME 14 in all particulars, but is about 2/3 as tall.
Measurements: MD 6.2; BL 3.1.

1. Van Nievelt AF, Smith KK (1997) *Arch Oral Biol* 42:587-591.
2. Savage RJG (1965) *Bull Br Mus (Natural History), Geology* 10:241-316.