**Supplemental data**

**Description of the Jinggou section (starting point: 37°05’34.4”N, 106°03’56.3”E), Zhangenbao Formation (after Wang *et al.*, 2016a)**

|  |  |  |
| --- | --- | --- |
| Miocene Zhangenbao Formation | | |
| Upper member | | |
| 30 | Massive, light-brown (5YR5/6) siltstones, occasionally intercalated with thin-bedded (< 20 cm thick) light-pink-brown (5YR6/4) mudstones | not to top |
| 29 | Thick-bedded, light-brown (5YR5/6) mudstones, occasionally intercalated with sandy or silty lumps, with branched vugs on the fissure surfaces that are dotted with iron-manganese components; a middle layer of gypsum is present at the base | 0.4 m |
| 28 | Massive, light-brown (5YR5/6) siltstones, occasionally intercalated with thin-bedded (< 20 cm thick) light-pink-brown (5YR6/4) mudstones | 3.5 m |
| 27 | Massive, moderate-orange-pink (10R6/6) medium gypsous quartz sandstone, contact-cemented; gypsum is more aggregated at the lower part | 0.7 m |
| 26 | Massive, dark-yellowish-orange (10YR6/6) silty mudstones, with intensive thin to moderately thick layers of gypsum epigenetically developed in the cracks; most gypsum layers are horizontally occurring and some are vertically occurring | 8 m |
| 25 | Thin-bedded, moderate-greenish-yellow (10Y7/4) mudstones, intercalated with a thin layer of gypsum in the middle | 0.2 m |
| 24 | Massive, dark-yellowish-orange (10YR6/6) silty mudstones, with thin to moderately thick layers of gypsum epigenetically developed in the cracks; most gypsum layers are horizontally occurring and some are vertically occurring; gypsum layers are less intensive than that in the horizon 26 | 9 m |
| 23 | Massive, light-pink-brown (5YR6/4) mudstones, occasionally dotted with iron-manganese components on the fissure surfaces | 1.5 m |
| 22 | Massive, grayish-orange (10YR7/4) muddy siltstones, intercalated with many medium-to-thin-bedded light-pink-brown (5YR6/4) mudstones; thin to moderately thick layers of gypsum epigenetically developed in the vertical cracks | 10.5 m |
| 21 | Massive, yellowish-gray (5Y7/2) fine subarkoses, contact-cemented; upward graded to massive, grayish-orange-pink (5YR7/2) or yellowish-gray (5Y7/2) siltstones | 5 m |
| Upper-middle member | |  |
| 20 | Massive, dark-yellowish-orange (10YR7/4) siltstones, partially showing light-olive-brown (5Y5/6) and pale-greenish-yellow (10Y8/2) stripes, containing medium-bedded, moderate-reddish-orange (10R4/6) muddy pebbles; at the lower part, there is a lenticular, dark-yellowish-orange (10YR6/6) or pale-green (10G6/2) medium-to-fine subarkoses that is 15 m in length and 5 m in height. | 30 m |
| 19 | Massive, yellowish-gray (5Y7/2) fine subarkoses, intercalated with many thin-bedded, moderate-orange-pink (10R6/6) very fine muddy sandstones; at the lower part, there is a layer (20 cm in thickness) of yellowish-gray (5Y7/2), contact-cemented coarse gypsous subarkoses; containing *Alloptox gobiensis*, *Platybelodon tongxinensis*, *Zygolophodon gobiensis*, *Hispanotherium matritense*, *Bunolistriodon intermedius*, *Palaeomeryx* sp. , *Turcocerus* sp. (*Aphanobelodon zhaoi* occurs in this horizon, but not exactly in the described section) | 25 m |
| Lower-middle member | | |
| 18 | Massive, light-brown (5YR5/6) mudstones, partially intercalated with pale-greenish-yellow (10Y8/2) or yellowish-gray (5Y7/2) siltstones or fine sandstones | 10 m |
| 17 | Massive, moderate-greenish-yellow (10Y7/4) and yellowish-gray (5Y7/2) fine subarkoses, partially showing light-olive-brown (5Y5/6) stripes | 3 m |
| 16 | Interbedded fine-to-middle-bedded dark-yellowish-orange (10YR6/6), partially moderate-yellow (5Y7/6) siltstones and mudstones, showing vertical cleavages. | 5 m |
| 15 | Massive, yellowish-gray (5Y7/2) medium-to-fine subarkoses with cross-beddings and normal graded-bedding; showing singular or lenticular angular muddy lumps (2–3 cm in diameter) | 6.5 m |
| 14 | Interbedded fine-bedded dark-yellowish-orange (10YR6/6) or yellowish-orange (10YR7/4) siltstones and mudstones, partially intercalated with very fine sandstones; dotted with iron-manganese components (1 mm in diameter); in the middle part, fine-bedded, pale-greenish-yellow (10Y8/2) carbonated siltstones and medium-bedded, moderate-reddish-brown (10R4/6) mudstones are intercalated; containing *Alloptox gobiensis* | 7 m |
| 13 | Massive, yellowish-gray (5Y7/2) medium-to-fine subarkoses, partly showing light-olive-brown (5Y5/6) stripes; partly intercalated with fine-bedded coarse quartz sandstone, contact-cemented and showing cross-bedding; showing singular or lenticular angular muddy lumps (1–2 cm in diameter); containing *Platybelodon tongxinensis*, *Bunolistriodon intermedius* | 18 m |
| Lower member | | |
| 12 | Massive, moderate-reddish-brown (10R4/6) silty mudstones, intercalated with a thick-bedded (60 cm), pale-greenish-yellow (10Y8/2) marl that is 1.5 m height from the base | 4.5 m |
| 11 | Massive, dark-yellowish-orange (10YR6/6) siltstones | 2 m |
| 10 | Massive, light-brown (5YR5/6) mudstones | 2.5 m |
| 9 | Massive, light-brown (5YR5/6), partially moderate-yellow (5Y7/6) muddy siltstones; partially dotted with iron-manganese components on the fissure surfaces; at the upper-middle part, there are two layers of thin-bedded, pale-greenish-yellow (10Y8/2) marls | 3.9 m |
| 8 | Massive, yellowish-gray (5Y7/2) or dark-yellowish-orange (10YR6/6) medium-to-fine subarkoses, partially intercalated with fine-bedded very coarse sandstones or fine conglomerates, showing cross-beddings; containing singular or lenticular angular muddy lumps that are poorly sorted (7–8 cm in diameter for larger ones and ~1 cm for smaller ones); containing *Cricetodon* sp. | 6.0 m |
| 7 | Massive, light-brown (5YR5/6) mudstones | 1.5 m |
| 6 | Massive, yellowish-gray (5Y7/2) and moderate-yellow (5Y7/6), and partially changing to light-bluish-gray (5B7/1), medium-to-fine subarkoses, partially intercalated with fine conglomerates and occasionally intercalated with muddy lumps (1 cm in diameter); containing *Alloptox gobiensis*, *Protanancus tobieni*, *Bunolistriodon intermedius* | 21.9 m |
| 5 | Fine-bedded, yellowish-orange (10YR7/4) partially changing to light-brown (5YR5/6) or pale-greenish-yellow (10Y8/2) siltstones | 10.9 m |
| 4 | Massive, yellowish-gray (5Y7/2) or moderate-yellow (5Y7/6) fine (partially medium-to-coarse) subarkoses, partially showing light-olive-brown (5Y5/6) stripes | 3.2 m |
| 3 | Massive, grayish-orange-pink (5YR7/2) medium-to-coarse, contact cemented gypsous debris quartz sandstones upward graded to yellowish-orange (10YR7/4) medium-to-fine debris quartz sandstones; at the lower part there are lenticular sandstones and conglomerates; the conglomerates are mainly consisted of quartz sandstones intercalated with chlorites and quartz that are 2–3 mm in diameter, occasionally ~2 cm in diameter; at the lower part there are also subangular, poorly sorted (20 cm in diameter for larger lumps and ~5 cm for smaller ones) muddy lumps; containing *Alloptox gobiensis* | 23.1 m |
| 2 | Massive, light-brown (5YR5/6) normally graded siltstones, partially intercalated with pale-greenish-yellow (10Y8/2) siltstones | 21.6 m |
| 1 | Medium-bedded, dark-greenish-gray (5GY4/1) middle-to-fine gypsous breccias, poorly sorted and clast-supported; the breccias mainly contain gypsum and some quartz sandstones | 4 cm |
| ~~~~~~~ unconformity ~~~~~~~ | | |
| Oligocene Qingshuiying Formation | | |
| 0 | Interbedded, fine-to-medium layers of moderate-orange-pink (10R6/6), greenish-gray (5GY4/1), and moderate-yellow (5Y7/6) silty muddy stones; containing large amount protogenetic gypsum | not to bottom |

**Table S1.** Basic information of all individuals of *Aphanobelodon zhaoi* gen. et sp. nov. Dental age determination after Tassy (2013); body mass estimation after Christiansen (2004); and dental microwear counting after Solounias & Semprebon (2002)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Specimen no. | Type state | Preserving state | Repairing state | Den-tal age | Age-sex | Hume-ral length (mm) | Body mass (kg) | Scratch/pit no. in micro- wear |
| HMV1880 | holo-type | skull and  partial skeleton | skull repaired | XX | adult female |  |  | 14/27 |
| HMV1919 | para-type | complete skeleton | unrepaired | XIX | adult male | 678 | 2066.8 | 10/55 |
| HMV1921 | para-type | complete skeleton | partially repaired | XIX | adult female | 569 | 1302.3 | 13/32 |
| HMV1920 | para-type | complete skeleton | unrepaired | ?XVII | subadult female | 505 | 951.0 |  |
| HMV1918 | para-type | complete skeleton | unrepaired | ?IX | subadult  male | 545 | 1162.5 |  |
| HMV1916 | para-type | complete skeleton | unrepaired | ?I | juvenile | 225 | 113.0 |  |
| HMV1917 | para-type | complete skeleton | unrepaired | ?VI | juvenile |  |  |  |
| HMV1912 | para-type | complete skeleton | unrepaired | ?VII | juvenile |  |  |  |
| HMV1913 | para-type | complete skeleton | unrepaired | XVIII | subadult  female | 565 | 1278.3 |  |
| HMV1914 | para-type | postcrania | unrepaired |  | ?sub-adult |  |  |  |

**Table S2.** Cranial measurements from *Aphanobelodon zhaoi* gen. et sp. nov. (HMV1880, the holotype), after Tassy (1996).

|  |  |
| --- | --- |
| maximal length measured from the occipital border | 895 |
| length of cerebral part | 322 |
| length of premaxilla | 584 |
| length of incisive fossa | 564 |
| length of nasal bones from the tip to the upper border of the nasal fossa | 26 |
| maximal supraorbital width | 154 × 2 |
| posterior rostral width (as measured between the infraorbital foramina) | 160 |
| anterior rostral width | 92 |
| width of nasal bones at the upper border of the nasal fossa | 33 × 2 |
| width of nasal fossa | 149 |
| minimal cerebral width between temporal lines | 122 |
| maximal length measured from the condyles | 889 |
| length of zygomatic arch measured from the processus zygomaticus of the maxilla to the posterior border of the glenoid fossa | 389 |
| length of orbitotemporal fossa measured at the level of the zygomatic arch | 223 |
| palatal length from the anterior grinding tooth to the choanae | 260 |
| length of basicranium from the choanae to the foramen magnum | 267 |
| thickness of processus zygomaticus of the maxilla | 131 |
| maximal cranial width across the zygomatic arches | 174 × 2 |
| width of basicranium between the lateral borders of the glenoid fossae | 147 × 2 |
| maximal width of choanae | ca. 52 |
| internal maximal width of the palate | ca. 39 |
| external maximal width of the palate | ca. 170 |
| internal width of the palate measured at the anterior grinding teeth | ca. 37 |
| minimal palatal width between the inter-alveolar cristae (maxillary ridges) | 26 |
| sagittal height of occipital | 224 |
| occipital width | 160 × 2 |
| height of premaxilla | 72 |
| facial height measured at the anterior grinding tooth | 90 |
| height of the maxilla ventral to the processus zygomaticus | 65 |
| height of the orbit | 96 |
| cranial height measured from the top of the cranium to the pterygoid process | 358 |
| length of basicranium from the condyles to the pterygoid process | 251 |
| facial length measured from the tip of the rostrum to the pterygoid process | 672 |
| length of the orbitotemporal fossa measured from the squamosal to the anterior border of the orbit | 279 |
| mid-cranial length measured from the external auditory meatus to the ventral border of the orbit | 286 |
| mid-cranial height measured from the pterygoid process to the dorsal border of the orbit | 337 |

**Table S3**. Mandibular measurements from *Aphanobelodon zhaoi* gen. et sp. nov. (HMV1880, the holotype), after Tassy (1996).

|  |  |
| --- | --- |
| maximum length | 1127 |
| symphyseal length | 451 |
| alveolar distance (from the most salient point of the trigonum retromolare to the symphyseal border of the corpus) | 392 |
| ventral length measured from the gonion (angulus mandibular) to the tip of the symphysis | 988 |
| maximum width | ca. 152 × 2 |
| mandibular width measured at the root of the rami | 226 |
| width of corpus measured at the root of the ramus | 93 |
| width of corpus measured at the anterioralveolus (or the grinding tooth if the alveolus is entirely resorbed) | 65 |
| posterior symphyseal width | ca. 145 |
| anterior symphyseal width | 221 |
| maximum symphyseal width | 233 |
| minimum symphyseal width | 100 |
| maximum width of rostral trough | 194 |
| minimum width of rostral trough | 40 |
| internal width between anterior alveoli (or grinding teeth if the alveoli are resorbed) | ca. 35 |
| maximum height of corpus (measurement taken perpendicular to the ventral border of the corpus) | 122 |
| height of corpus measured at the root of the ramus (measurement as above) | 115 |
| rostral height measured at the symphyseal border (measurement taken perpendicular to the ventral border of the symphyseal rostrum) | 111 |
| rostral height measured at the tip of rostrum (measurement as above) | 47 |
| maximum mandibular height measured at the condyle perpendicular to the ventral border of the corpus | 252 |
| maximum depth of ramus | 209 |
| depth between gonion and coronoid processes | 251 |
| height between gonion and condyle | 193 |
| mid-alveolar length measured on the buccal side between the anterior alveolus (or grinding tooth if the alveolus is resorbed) and the root of the ramus | 263 |

**Appendix S1.** Characters of shovel-tusked elephantiforms

Most of the following characters are adopted or slightly modified from the two previous studies: Shoshani 1996 (S96) and Tassy 1996 (T96). Others were selected specifically for this study. The characters are polarized with respect to *Deinotherium* as the outgroup. All characters are treated as unordered.

0. Upper tusks: absence. States: 0 = present; 1 = absent.

1. Upper tusks: in lateral view. After T96:76, S96:7. States: 0 = curving ventrally; 1 = relatively straight.
2. Upper tusks: enamel band. After T96:72, S96:6. States: 0 = present; 1 = absent.
3. Upper tusks: in anterior view. After S96:9. States: 0 = nearly parallel, 1 = divergent.
4. Lower tusks: in lateral view. After T96:77, S96:11. States: 0 = curving dorsally; 1 = curving ventrally.
5. Lower tusks: shape of cross-section. After T96:74, S96:15. States: 0 = flat, 1 = pyriform or subcircular.
6. Lower tusks: thickness index (I = height/width). States: 0 = I between 0.25 and 0.75, 1 = I smaller than 0.25, 2 = I larger than 0.75.
7. Lower tusks: inner structure. Dentinal tubules are embedded in the lower tusks in some taxa, i.e. *Platybelodon* and *Konobelodon*; in contrast to the concentric lamination in others. States: 0 = concentric lamination, 1 = dentinal tubules.
8. Lower tusks: apical end. States: 0 = without a cutting edge, 1 = possessing a cutting edge.
9. Lower tusks: exposed ratio (R = exposed lengh/symphyseal length). States: 0 = R smaller than 0.4, 1 = R between 0.4 and 1, 2 = R larger than 1.
10. Lower tusks: width index (I = width/exposing length). States: 0 = I between 0.3 and 0.6, 1 = I smaller than 0.3, 2 = I larger than 0.6.
11. Lower tusks: direction of the right and left one. States: 0 = parallel or slightly convergent; 1 = divergent.
12. Premolars: absence of premolars. After T96:86, S96:27, modified. States: 0 = P2 or p2 present; 1 = P2 and p2 absent; 2 = P2, p2, and p3 absentt.
13. Intermediate cheek teeth: loph(id) number. After T96:101–104, S96:32, 33, 39, 40, modified. States: 0 = 3rd loph(id) not fully formed; 1 = typical trilophodont; 2 = 4th loph(id) forming at least on m2.
14. Molars: compression of interloph(id). States: 0 = relatively open; 1 = relatively compressed.
15. Molars’ pattern. After T96:106, S96:60. States: 0 = bunodont; 1 = lophodont.
16. Molars: posttrite central conules. After T96:113, S96:55. States: 0 = no posttrite central conules; 1 = rudimentary posttrite central conules; 2 = completed posttrite trefoils.
17. M3: loph number. After T96:99, S96:34. States: 0 = dilophodont; 1 = trilophodont; 2 = tetralophodont; 3 = pentalophodont or more.
18. m3: lophid number. After T96:16, S96:35. States: 0 = dilophodont; 1 = trilophodont; 2 = tetralophodont; 3 = pentalophodont or more.
19. Molars: anancoidy. After T96:133. States: 0 = absent; 1 = rudimentary pseudo-anancoidy; 2 = strong pseudo-anancoidy.
20. Cheek teeth: cementum. After T96:116, S96:63. States: 0 = weak; 1 = heavy.
21. Cranium: distance between the temporal lines. After S96:73. States: 0 = sagittal crest present; 1 = temporal lines separated.
22. Cranium: in lateral view (Prado & Alberdi 2008: character 37). States: 0 = flat; 1 = slightly arched.
23. Maxilla: facial part. States: 0 = not elongated; 1 = anteriorly elongated.
24. Nasal aperture: After S96:78. States: 0 = not retracted; 1 = retracted to above the orbit.
25. Nasal aperture: After T96:43, and S96:79. States: 0 =relatively narrow; 1 = relatively wide.
26. Basicanium: After T96:60, modified. States: 0 = not erected; 1 = slightly erected; 2 = very erected.
27. Infraorbital formen: duplication on maxilla. After T96:41, S96:38. States: 0 = always present; 1 = sometimes present or absent.
28. Symphysis: elongation index (I = symphyseal length/length of cheek tooth row). After T96:48, 2, S96:94, modified. States: I between 0.8 and 1.0, 1 = I smaller than 0.8, 2 = I between 1.0 and 1.3, 3 = larger than 1.3.
29. Symphysis: flattened. States: 0 = flattened; 1 = not flattened.
30. Symphysis: broadness index (I = symphyseal width/length). States: 0 = I between 0.3 and 0.6; 1 = I larger than 0.6; 2 = I smaller than 0.3.
31. Symphysis: Enlargement (E = minimal symphyseal width/maximal symphyseal width) States: 0 = E between 0.4 and 0.8; 1 = E larger than 0.8; 2 = E smaller than 0.4.
32. Symphysis: anterior border: States: 0 = anteriorly oblique from both lateral sides to median axis; 1 = almost straight.
33. Symphysis: distance between the posterior border and the cheek tooth row. After T96:50. States: 0 = close to each other; 1 = remote.
34. Symphysis: degree (D) of ventral deflection. After T96:51, modified. States: 0 = D smaller than 10°; 1 = D between 10° and 30°; 2 = D between 30° and 50°; 3 = D larger than 50°.
35. Ramus: degree (D) of posterior inclination. 0 = D between 90° and 100°; 1 =D between 100° and 120°; 2 = D larger than 120°; 3 = D smaller than 90°.
36. Angular process. After T96:49, S96:96. States: 0 = protruded; 1 = not protruded.
37. Symphysis: transverse ridge at the narrowest part. States: 0 = absent; 1 = present.

**Appendix S2.** Character states of shovel tusked Elephantiformes. Data source: *Deinotherium*, data from Mottl (1969); *Phiomia serridens*, from Andrews (1906) and Mastumoto (1924); *Archaeobelodon filholi*, from Tobien (1973); *Serbelodon barbourensis*, from Frick (1933); *Protanancus brevirostris*, and *Protanancus tobieni*, from Wang *et al.* (2015); *Protanancus macinnesi*, from Tassy (1986); *Protanancus chinjiensis*, from Tassy (1983); *Amebelodon fricki*, from Barbour (1927); *Konobelodon britti*, from Lambert (1990); *Konobelodon atticus*, from Konidaris *et al.* (2014); *Torynobelodon dangheensis*, from Wang & Qiu (2002); *Torynobelodon barnumbrowni*, from Barbour (1929), *Platybelodon danovi*, from Borissiak (1929); *Platybelodon tongxinensis*, from Guan (1991) and Wang *et al.*, (2013) *Platybelodon grangeri* and tetralophodont *Platybelodon*, from Osborn & Granger (1932) and Wang *et al.* (2013); *Aphanobelodon zhaoi* gen. et sp. nov, from the present article.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Taxon | 0 | 1  0 | 2  0 | 3  0 |
| *Deinotherium* | 1---11200- | -00001-00- | 01010001-1 | -1103300 |
| *Phiomia serridens* | 0000000000 | 0001000110 | 0000000000 | 00000000 |
| *Ar. filholi* | 0000000000 | 0011001220 | 0101110020 | 01001100 |
| *S. barbourensis* | 0000000000 | 2011000220 | 01??1?1000 | 01001010 |
| *Pr. brevirostris* | 0000000002 | 1011001220 | 0101111020 | 10011110 |
| *Pr. tobieni* | 0000000001 | 0011001231 | 0???111020 | 00111110 |
| *Pr. macinnesi* | 000?00000? | ?011001231 | 0???1110?0 | ???1??10 |
| *Pr. chinjiensis* | 0???00000? | ?011001?32 | 0???11?030 | 22?12110 |
| *Am. fricki* | 000?000001 | 1011002332 | 0???11?030 | 00012010 |
| *K. britti* | 000000010? | ?112102332 | 0???111??0 | ??012010 |
| *K. atticus* | 0110000102 | 1112101331 | 1210112120 | 01012010 |
| *T. barnumbrowni* | 0?1?001112 | 10?1000220 | 0???11?020 | 10101110 |
| *T. dangheensis* | 0?1?001110 | 1011000220 | 0???1??020 | 1011???0 |
| *Pl. danovi* (type) | 0111001110 | 2021000231 | 1101110030 | 00111110 |
| *Pl. tongxinensis* | 0111001111 | 0021001231 | 1101110030 | 00111210 |
| *Pl. grangeri* | 0111001110 | 2021001331 | 1101110030 | 00111211 |
| tetralophodont *Pl.* | 0111001110 | 2022001331 | 1101110030 | 00111211 |
| *Ap. zhaoi* | 1---001010 | 2011001231 | 1101110030 | 00111110 |

**Supplemental Figure Captions**

**Figure S1.** Sketch for the taphonomy of *Aphanobelodon zhaoi* gen. et sp. nov., drawn by Mr. Rong Zhao, the discoverer.

**Figure S2.** Partial unrepaired skeletons of *Aphanobelodon zhaoi* gen. et sp. nov. showing the original taphonomic states (e.g. articulated bones).