NEW EARLY EOCENE MAMMALIAN FOSSILS FROM THE HENGYANG BASIN, HUNAN CHINA

SUYIN TING

LSU Museum of Natural Science, Louisiana State University, 119 Foster Hall, Baton Rouge, LA 70803; Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, P. O. Box 643, Beijing 100044, China

YUANQING WANG

Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, P. O. Box 643, Beijing 100044, China

JUDITH A. SCHIEBOUT

LSU Museum of Natural Science, Louisiana State University, 119 Foster Hall, Baton Rouge, LA 70803

PAUL L. KOCH

Department of Earth Sciences, University of California, Santa Cruz, CA 95064

WILLIAM C. CLYDE

Department of Earth Sciences, University of New Hampshire, Durham, NH 03824-3589

GABRIEL J. BOWEN

Department of Earth Sciences, University of California, Santa Cruz, CA 95064

YUAN WANG

Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, P. O. Box 643, Beijing 100044, China

ABSTRACT

New fossil mammal materials found in the upper Lingcha Formation of the Hengyang Basin, Hunan, China, include a complete skull of *Hopalodeces hetangensis* and a taxon new to the fauna, *Diacus scinsi, n. sp. H. hetangensis* is the morphologically least derived species of the genus and currently is the earliest known record of the genus. *D. zengi, n. sp.* is the second Asian early Eocene record of the genus and represents the last occurrence of the genus in Asia.

The Lingcha Formation includes two fossiliferous intervals. The upper contains about 12 species belonging to 7 mammalian orders, and the lower has yielded one mammalian species and one reptilian species. Biostratigraphic, chemostratigraphic, and magnetostratigraphic study in the Lingcha Formation indicates that the transient carbon isotope excursion that marks the Paleocene-Eocene boundary as currently advocated is present in the upper Lingcha Formation. The fauna from the upper Lingcha Formation occurs within the excursion interval, and is of earliest Eocene age. It is correlated with the Wasatchian-0 faunal zone in the Big Horn Basin, Wyoming, North America. The lower Lingcha Formation is of Paleocene age.

INTRODUCTION

The late Paleocene through early Eocene was a period of significant global climatic and biotic change (Kennett et al., 1991; Koch et al., 1992; Koch et al., 1995; Thomas and Shackleton, 1996; Zachos et al., 1993). It was an important time in the evolutionary history of mammals. The modern mammalian orders Perissodactyla, Artiodactyla, and Primates *sensu stricto*, made their first appearances in the fossil record during the Paleocene/Eocene transition on the Holarctic continents. Discoveries
of Asian Paleocene and early Eocene fossil mammals strengthen the current hypothesis that some modern mammalian orders, which eventually dominated the Holarctic faunas, may have originated in Asia and spread to other continents during the Paleocene/Eocene transition (Beard, 1998; Beard and Dawson, 1999; Dashzeveg, 1988; Krause and Maas, 1990; McKenna, 1998; Sloan, 1987; South China "Red Beds" Research Group, IVPP, 1977; Zhai, 1978). The Asian record across the Paleocene/Eocene boundary is poorly understood when compared to records from its Holarctic neighbors, North America and Europe. Therefore, in the year 2000, we studied the biostratigraphy, magnetostratigraphy of the Lingcha Formation, Hengyang Basin, Hunan, China (Fig. 1; Li et al., 1979): to investigate the Asian Paleocene/Eocene climatic and biotic changes, to test the dispersal hypothesis, and to provide better evidence for intercontinental correlation. This site is one of two currently known Asian localities with a continuous Paleocene/Eocene sedimentary record (the other being the Nemegt Basin, Mongolia).

Herein we report the new mammalian fossil materials collected during the trip in 2000 to the Hengyang Basin. Materials include a complete skull of *Hapalodectes hetangensis* and a taxon new to the fauna, *Dissacus zengi*, sp. n.

**ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ac</td>
<td>aperture of cochlear fenestra</td>
</tr>
<tr>
<td>as</td>
<td>alisphenoid canal</td>
</tr>
<tr>
<td>asc</td>
<td>alisphenoid canal; av</td>
</tr>
<tr>
<td>C</td>
<td>canine</td>
</tr>
<tr>
<td>ef</td>
<td>ethmoid foramen</td>
</tr>
<tr>
<td>f</td>
<td>frontal</td>
</tr>
<tr>
<td>fo</td>
<td>foramen ovale</td>
</tr>
<tr>
<td>fr</td>
<td>foramen rotundum</td>
</tr>
<tr>
<td>glf</td>
<td>glenoid fossa</td>
</tr>
<tr>
<td>hf</td>
<td>hypoglossal foramen</td>
</tr>
<tr>
<td>iof</td>
<td>infraorbital foramen</td>
</tr>
<tr>
<td>la</td>
<td>lachrymal</td>
</tr>
<tr>
<td>laf</td>
<td>lachrymal foramen</td>
</tr>
<tr>
<td>M3</td>
<td>third upper molar</td>
</tr>
<tr>
<td>map</td>
<td>mastoid process</td>
</tr>
<tr>
<td>mx</td>
<td>maxilla</td>
</tr>
<tr>
<td>na</td>
<td>nasal</td>
</tr>
<tr>
<td>obf</td>
<td>orbital fossa</td>
</tr>
<tr>
<td>oc</td>
<td>occipital</td>
</tr>
<tr>
<td>P1</td>
<td>first premolar</td>
</tr>
<tr>
<td>p</td>
<td>parietal</td>
</tr>
<tr>
<td>paf</td>
<td>palatine dorsal foramen</td>
</tr>
<tr>
<td>pal</td>
<td>palatine foramen</td>
</tr>
<tr>
<td>pg</td>
<td>postglenoid foramen</td>
</tr>
<tr>
<td>pgp</td>
<td>postglenoid process</td>
</tr>
<tr>
<td>pm</td>
<td>premaxilla</td>
</tr>
<tr>
<td>poc</td>
<td>paroccipital process</td>
</tr>
<tr>
<td>pr</td>
<td>promontory of cochlear</td>
</tr>
<tr>
<td>prs</td>
<td>promontory artery sulcus</td>
</tr>
<tr>
<td>ps</td>
<td>presphenoid</td>
</tr>
<tr>
<td>sc</td>
<td>sagittal crest</td>
</tr>
<tr>
<td>sof</td>
<td>supraorbital foramen</td>
</tr>
<tr>
<td>spf</td>
<td>sphenopalatine foramen</td>
</tr>
<tr>
<td>sf</td>
<td>stapedius fossa</td>
</tr>
<tr>
<td>sq</td>
<td>squamosal</td>
</tr>
</tbody>
</table>

**INSTITUTIONAL**

AMNH = Department of Vertebrate Paleontology, American Museum of Natural History, New York; IVPP = Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing; LSU = Louisiana State University, Baton Rouge; PIN = Paleontological Institute, Mongolian Academy of Sciences, Ulz Bator; USGS = Paleontology and Stratigraphy Branch, U.S. Geological Survey, Denver, Colorado; YPM-PU = Princeton University Collection at Yale Peabody Museum, New Haven, Connecticut.
SYSTEMATIC PALEONTOLOGY

Order Acreodi Matthew, 1909 (classification based on McKenna and Bell, 1997)
Family Hapalodectidae (Szalay and Gould, 1966)
Ting and Li, 1987
Genus Hapalodectes Matthew, 1909
Hapalodectes hetangensis Ting and Li, 1987

Specimen.—A complete adult skull with right and left dentition P1-M3 (IVPP V12385, Fig. 2–4).
Locality.—Near Jixianwan village, Hengdong County, Hengyang Basin, Hunan Province, China (27°05'N, 111°57'E; Fig. 1).
Horizon.—Upper Lingcha Formation, Early Eocene.

Description.—The cranial and dental morphology of the specimen IVPP V12385 is almost identical to that of previously described specimens IVPP V5253 and V5254. V12385 is slightly smaller and more slender than V5254, but larger than V5253, a subadult individual (Ting and Li, 1987). The skull of V12385 is narrow and long, with a laterally expanded braincase. In dorsal view, most of the long, narrow nasal contacts the maxilla. The maxilla is deep and extends dorso-ventrally. The premaxilla is small and restricted to the tip of the snout. A large infraorbital foramen is situated above P1 in the maxilla. The frontal is square and small compared to the maxilla, with two supraorbital foramina on each side as in V5254. The frontal-nasal, frontal-maxilla, and frontal-lachrymal sutures are short. The facial expansion of the lachrymal comprises a prominent narrow ridge, which limits the lachrymal to inside the orbital region. The postorbital constriction is very obvious. Unlike the skull of V5253, the skull of V12385 bears a long, high sagittal crest along the mid-line of the parietal, extending from the postorbital constriction to the end of the skull where it meets the occipital crest. The occipital crest is strongly developed and U-shaped in posterior view. The condyyles are transversely elongated and separated by a notch. The squamosal is much wider than the parietal and expands laterally. In lateral view, the anterior border of the orbit is above M1 instead of above P4 as in V5253. There is an oval scar in the supraorbital region, indicating the presence of a bony bar closing the orbit posteriorly. The posterior opening of the supraorbital foramen is located anterior to the scar of the bony bar. The lachrymal foramen is behind the strong ridge that forms the anterior border of the orbit. A large posterior opening of the infraorbital foramen lies below the lachrymal foramen. The sutures between the frontal, maxilla, orbitosphenoid, and alisphenoid in the orbital region are not clear; however, the sphenopalatine foramen, palatine dorsal foramen, ethmoid foramen, orbital fissure, and foramen rotundum are situated as in V5253. In ventral view, the anterior end of the palatine extends as far anteriorly as P4. There are more small foramina distributed in the palatine than are seen in V5253. The anterior palatine foramina are located at the level of M1 and the posterior ones are at the level behind M3. The glenoid fossa is transversely elongated and limited by a prominent postglenoid process posteriorly. The oval postglenoid foramen is situated interior-dorsal to the postglenoid process. The size and position of the alisphenoid canal and foramen ovale are the same as in V5253. The morphological features in the basisphenoid region are the same as in V5253. However, the piriform

Fig. 2.—Dorsal view of the skull of Hapalodectes hetangensis (IVPP V12385). Scale = 1 cm.
fenestra in V12385 is almost closed, forming two small foramina, unlike the situation in V5253, in which the piriform fenestra is a large rectangular fissure. The foramina of the facial nerve, hiatus fallopii, and medial internal carotid artery sulcus in V5253 can not be seen clearly in V12385.

The upper dentition of V12385, except for incisors and canines, is preserved with some damage on each side. The P1-3 are transversely compressed. Judging from the shape, they may have had a single cusp. P1 is close behind the canine and separated from P2 by a diastema. P3 and P4 are double-rooted. P1 is triangular with three roots. The labial part of the crown of P4 is damaged. A small hypocone is close behind the protocone on P1. M2 is larger than M1, but similar in morphology. Both are T-shaped with well-developed protocone, paracone, and metacone, with the hypocone smaller than protocone. M1 is much smaller than M1 and M2. There is only one cusp, the protocone, on the lingual side of M1.

**Skull Measurements of Hapalodectes hetangensis (IVPP V12385) (in mm; L: length, W: width)**

- Length (from back of the occipital to the anterior tip of the premaxilla) = 80.1.
- Width at the postorbital constriction = 6.0.
- Temporal fossa length (from the most posterior point of the occipital crest to the back of the supraorbital process) = 40.8.
- Occipital height (from the midventral border of the foramen magnum to the dorsal rim of the occipital) = 21.4.
- Width between mastoid processes = 22.9.
- Tooth row length (parallel to the palatine midline, from the posterior rim of M1 to the front of the premaxilla) = 33.1.
- Length from back of the postglenoid process to the condyle = 19.5.
- Dentition measurements can be found in Table 1.

**Family Mesonychidae Cope, 1875**

**Dissacus Cope, 1881**

**Dissacus zengi, new species**

**Holotype.**—A subadult partial skull, with erupting upper left and right canines, left DP1 and right DP4, erupting left and right P1 and left P1, and right M2, and associated lower jaws, with erupting lower left and deciduous right canines, left and right DP3, left and right P2, and left and right M2 (IVPP V13040, Fig. 5A–D).

**Etymology.**—Species named in memory of the late Jiongtao Zeng, former officer, Science and Technology Committee, Hengdong County, Hunan Province, in recognition of his assistance in our field work during the 1980s and early 1990s.

**Locality and Horizon.**—Same as that of specimen IVPP V12385.

**Diagnosis.**—Smaller than other species of Dissacus. Differs from the others in having more com-
pressed lower molars, more reduced paraconid and metaconid on lower molars, and smaller metacone on M².

*Description.*—The anterior part of the skull is preserved in the specimen IVPP V13040. The nasal is narrow. The infraorbital foramen is above P³. The lachrymal has a large facial exposure. The lower jaw has a high coronoid process. The depth of the horizontal ramus does not vary from anterior to posterior. Only one mental foramen can be seen under P₃ on both sides.

Fig. 4.—Lateral view of the skull of *Hapalodectes hetangensis* (IVPP V12385). A. Right side. B. Left side. Scale = 1 cm.
Both upper canines are erupting and situated ca. 2 mm posterior to the suture between premaxilla and maxilla. The breakage of the left maxilla reveals that the canine is long but slender. DP is small with a conical crown curved backwards. The diastema between canine and DP is 5.5 mm long. DP is molarized and has three roots. Paracone and metacone are equal in size. The protocone is lingual to the paracone and as high as the paracone and metacone. A tiny bulge at the posterior base of the protocone may represent an undeveloped hypocone. Both paracone and metastyle are very small. No ectocingulum is present. The surface of the crown of the erupting M is slightly damaged. As in other mesonychids, three major cusps are prominent on the molar. The metacone is smaller than the paracone and connected with the latter at the base. The protocone is as large as the paracone. The paracone and metastyle are not well developed.

The lower deciduous canine is long but not robust. Both DP are preserved in good condition. The trigonid is as wide as the talonid and slightly longer than the latter. The paraconid is relatively large and anterior to the protoconid. The protoconid is the most prominent cusp and is much higher than the paraconid. The metaconid is an incipient bulge antero-lingual to the protoconid. Both M are erupting and the right one was exposed in the breakage of the dentary. The paraconid is very small and lies anterior to the protoconid. The metaconid is a bulge on the lingual side of the protoconid. The cristid obliqua extends to the labial edge of the talonid. Dentition measurements can be found in Table 2.

**Discussion.**—The species *Hapalodectes hetangensis* was erected based on a complete subadult skull (IVPP V5253) and an anterior part of an adult skull (IVPP V5254) (Ting and Li, 1987). V5253 was the first complete skull known for the genus and provided detailed cranial information. The specimen IVPP V12385 described above is the second complete skull known for the species. V12385 differs from V5253 in having a much larger skull, a mastoid process fused with the paroccipital process and a closed piriiform fenestra. These may be differences between an adult and a subadult individual. The large canine and strongly developed sagittal and occipital crests in both V12385 and V5254 may be sexually dimorphic differences from V5253, which may represent a female individual. The upper canine is considerably narrower for its length in V5253 compared to V12385 (Fig. 6A), strengthening the idea that V5253 is female. M in *H. hetangensis* (V5253) is proportionally narrower than in *H. anthracinus* and *H. leptognathus* (Fig. 6B). In V5253, skull width and tooth row length are proportionally greater in comparison to skull length than in V12385, and its occipital width is greater in proportion to occipital height in comparison to V12385 (Fig. 6A). The teeth of V5254 are slightly larger than those of V12385. V5254 also differs from V12385 in having a rougher bony surface, a more prominent ridge-like lachrymal anterior to the orbit, and a wider anterior part of the palate.

The hapalodectids have remained rarely discovered early Eocene fossils since they were first reported (Osborn and Wortman, 1892; Matthew, 1909). The genus *Hapalodectes* includes five species, *H. leptognathus* and *H. anthracinus* of North America, and *H. serus*, *H. hetangensis*, and *H. sp. n.* of Asia (Szalay, 1969; Szalay and Gould, 1966, Ting and Li, 1987; Tong and Wang, 1998; Zhou and Gingerich, 1995). Zhou and Gingerich (1995) proposed two possible lineages of *Hapalodectes*, one with a metaconid in the lower molars (*H. hetangensis*, *H. leptognathus*, and *H. sp. n.*) considered less derived, and the other without it (*H. serus* and *H. anthracinus*). The lower third molars in most of the species are the longest of the lower molars (Szalay, 1969:3). However, the unerupted M of *H. hetangensis* in V5253 is slightly smaller than M and M. *H. hetangensis* also has a very reduced upper third molar. In V12385, M has only one tiny cusp occurring in the posterior lingual side of the tooth. *H. hetangensis* has been considered to be the least derived species because of its small size and the occurrence of a metaconid in the lower molars (O’Leary and Rose, 1995; Ting and Li, 1987; Zhou and Gingerich, 1995). Compared to a newly reported species, *H. sp. n.* from the Wutu Formation,
Fig. 5.—*Dissacus zengi* (IVPP V13040). Scale = 1 cm. A. Lateral view of the skull. B. Ventral view of the skull. C. Lateral view of the lower jaw. D. Occlusal view of the lower jaw.

Shandong, China (Tong and Wang, 1998), *H. hetangensis* is slightly smaller, has less molarized P² and P³, and has a less developed parastyle and hypocone in its upper molars (Tong and Wang, personal communication, 2003). *H. hetangensis* may be considered less derived morphologically than *H. sp. n. H. anthracinus* has been considered to be the earliest record of *Hapalodectes* based on its occur-
Fig. 6.—Logarithm of ratio diagrams (Simpson, 1941; Simons, 1960) comparing selected Asian and North American *Hapalodectes* and *Dissacus* specimens. Diagrams allow visual comparison of proportion without size being a factor. Values are differences of logs of measurements of various specimens compared to a standard. Where proportions are similar to the standard, measurements occur in straight vertical lines. Samples different in proportion from the standard, but similar in proportion to each other, are parallel. Measurements are from O’Leary and Rose (1995), other than those on new material from Hengyang, on *H. hetangensis* (IVPP V5253) from Ting and Li (1987), and on *H. leptognathus* (Szalay, 1969). Some points are connected to emphasize relationship. A. Upper teeth and skull measurements of selected *Hapalodectes* and *Dissacus* using IVPP V12385 as a comparative standard. B. Lower teeth and mandible measurements of selected *Hapalodectes* and *Dissacus* using IVPP V5253, the *H. hetangensis* type specimen, as a comparative standard.
rence in the Wa-1 zone of the early Wasatchian (O’Leary and Rose, 1995; Zhou and Gingerich, 1995). Authigenic soil carbonates from the Lingcha Formation record the negative carbon isotope excursion (CIE) that marks the Paleocene/Eocene boundary, allowing direct comparison of the age of the Hengyang Basin faunal horizons relative to faunas from other sections where this chronostratigraphic marker has been identified. The upper Lingcha fauna, where *H. hetangensis* was found, occurs within the ca. 80,000 yr interval represented by the CIE (Bowen et al., 2002). In the Bighorn Basin of Wyoming, the first occurrence of Wasatchian mammals (Wa-0 zone; Gingerich, 1989) is ca. 2 meters above the carbon isotope minimum, but Wa-1 fossils do not occur until after the end of CIE (Bowen et al., 2001). Based on this evidence, Bowen et al. (2002) and Ting et al. (2003) suggested that the upper Lingcha fauna is of earliest Eocene age, and is time-correlative with the earliest Wasatchian (Wa-0 zone). Because *H. hetangensis* came from the upper Lingcha fauna, it appears to provide the earliest known record of *Hopalodectes*.

*Dissacus* is one of the primitive mesonychids, distributed in the Paleocene and early Eocene strata in Asia, North America, and Europe. Five Asian species have been reported: *D. rotundus* (Wang, 1975) from the Shanghuan Asian Land Mammal Age (ALMA), *D. indigenus* (Dashzeveg, 1976), *D. serratus* (Chow and Qi, 1978; Meng et al., 1998), and *D. magushanensis* (Yan and Tang, 1976) from the Gashatan ALMA, and *D. sp.* (Tong and Wang, 1998) from the Bambanian ALMA. The new species from the upper Lingcha Formation, Hengyang Basin, is slightly smaller than *D. sp.* from the Wutu Bambanian fauna (Tong and Wang, personal communication, 2003), and smaller than *D. serratus*, *D. magushanensis*, and *D. indigenus*. It differs from the three Gashatan species in having lower molars more compressed (Fig. 6B), cristid obliqua of talonid laterally located, more reduced paraconid and metaconid of M2, and metacone on M2 relatively smaller. All Asian species of *Dissacus* are smaller than the North American species, for which measurements are available in O’Leary and Rose (1995). *D. zengi* is considerably smaller than *D. praenuntius* from the Wa-0 zone (Gingerich, 1989), early Wasatchian *D. willwoodensis*, and late Wasatchian *D. serior*, from the Big Horn Basin, Wyoming (O’Leary and Rose, 1995). It also differs from *D. praenuntius* in having a very reduced parastyle and metastyle on M2, narrower M2 (Fig. 6B), more reduced metaconid on M2, and labially located cristid obliqua on M2. M2 of *D. zengi* is also proportionally narrower than in *D. willwoodensis* and *D. lon- gaevus* (Fig. 6B). The mandibles of *D. zengi*, *D. magushanensis*, and *D. serratus* are shallower and more slender than those of all North American species.

*D. zengi* is a taxon new to the upper Lingcha fauna and a second record of *Dissacus* for the Bambanian ALMA (the other being in the Wutu fauna). The age of the Wutu fauna needs further investigation (Bowen et al., 2002); thus the new species of *Dissacus* from Hengyang is the first Asian specimen that can be confidently assigned to the Eocene. It is currently the last known occurrence of the genus in the Asian record, since there is no record of *Dissacus* in subsequent Bambanian faunas. Ting et al. (2003) have suggested that the upper Lingcha fauna, the fauna of the Bamban Member of the Nar- an Bulak Formation, and the Wutu fauna might represent a cohort of transitional earliest Bambanian faunas. Therefore, *D. zengi* may represent an earliest Bambanian species. The co-occurrence of the earliest known *Hopalodectes* and latest known Asian *Dissacus* within the upper Lingcha fauna supports the interpretation that this collection represents the faunal transition between Gashatan and later Bambanian assemblages, and reinforces the importance of this collection for studies of the Paleocene/Eocene faunal turnover in Asia.

ACKNOWLEDGMENTS

This paper is dedicated to Malcolm Carnegie McKenna in recognition of his efforts on a multidisciplinary study of the Paleocene/Eocene boundary (Lingcha Formation, Hengyang Basin, Hunan, China, 2000). The field work in the Hengyang Basin was funded by National Geographic Society Grant 6528-99. We greatly appreciate the support of the Society. Yuanqiang Wang and Yuang Wang’s work was also supported by the Major Basic Research Project, Ministry of Science and Technology, China (G2000077700). G. J. Bowen was also supported by the National Science Foundation Graduate Research Fellowship Program. Our special thanks go to the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, and the Hengdong County Office, Hunan, China, for their arrangements and aid in the field. Professor Yongsheng Tong and Jingwen Wang, IVPP, provided unpublished materials for comparison and significant discussion on the specimens. Shuhua Xie, IVPP, collected the specimen IVPP V12385 during the field trip, prepared the type specimen of *D. zengi* n. sp., and assisted the principle author in preparation of the dentition of specimen V12385. Priscilla McKenna helped collecting in the field. Wenlong Shen, IVPP, drew the figures of the specimen IVPP V12385. Jie Zhang, IVPP, took the picture of specimen
IVPP V13040. Kerry Lyle, Louisiana State University, took the stereophotos of specimen IVPP V12385. Mary Lee Eggart, Louisiana State University, helped draft the map and other illustrations. Ruth Hubert, LSU Geoscience Associates, critically read the manuscript. We express our sincere thanks to all of them.

LITERATURE CITED


