New materials of micromammal fossils from Longyadong Cave in Luonan Basin, Shaanxi, central China: Postprint

Authors: LI Yong-Xiang, Song-Mei Hu, WANG She-Jiang, ZHANG Yun-Xiang, WANG She-Jiang

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Abstract

This paper describes some micromammal fossils which were excavated from the South Longyadong Cave in the Luonan Basin, eastern Qinling Mountains of Shaanxi Province, central China. The fauna include 15 mammals consisting by Scapanulus oweni, Nasillus andersoni, Uropsilinae gen. et sp. indet., Soriculus sp., Ochotona cf. O. alpina, Belomys parapearsoni, Allocricetus ehiki, Proedromys bedfordi, Allophaiomys deucalion, Eospalax sp., Niviventer preconfucianus, Apodemus asianicus, Apodemus sp., Hystrix brachyura subcristata, Trogontherium cuvieri. Among them, the Nasillus andersoni and the Ochotona cf. O. alpina are the newly discovered fossil species. The fossil assemblage characteristics of newly micromammal faunal is similar to the North Longyadong Cave Fauna, and the geological age should not be later than early Middle Pleistocene. It might be a fauna of late Early Pleistocene. But in recent years, the thermoluminescence age of fossiliferous strata corresponding are 356.6$\pm$17.8$kaBP, 273.9\pm13.7kaBPand210.5\pm$10.5 kaBP. The fauna is including both the south and the north animals, the animal combination obviously has the characteristics of the transition between the south and the north of China.

This paper describes the micromammal fossils excavated from the South Longyadong Cave site in the Luonan Basin of the eastern Qinling Mountains between 1995 and 1997, including Scapanulus oweni, Nasillus andersoni, Uropsilinae gen. et sp. indet., Soriculus sp., Ochotona cf. O. alpina, Belomys parapearsoni, Allocricetus ehiki, Proedromys bedfordi, Allophaiomys deucalion, Eospalax sp., Niviventer preconfucianus, Apodemus asianicus, Apodemus sp., Hystrix brachyura subcristata, Trogontherium cuvieri, among others. The fauna includes both southern-type and northern-type animals, and the assemblage clearly exhibits characteristics of a transitional zone between

southern and northern China. Among these, Nasillus andersoni and Ochotona cf. O. alpina are newly discovered fossil species. The newly discovered micromammal fossil assemblage is similar to that of North Longyadong Cave, showing a relatively ancient nature, and is mostly dated to the late Early Pleistocene or early Middle Pleistocene. However, the thermoluminescence (TL) ages of the fossil-bearing strata at the South Longyadong Cave site are $(356.6\$\pm7.8)kaBP, (273.9\pm3.7)kaBP, and(210.5\pm\$0.5)$ kaBP, respectively, and recent new transfer-optically stimulated luminescence (TT-OSL) dating data have further verified the thermoluminescence dating results, yielding a stratigraphic age of approximately 400,000 to 200,000 years ago.

Full Text

New Materials of Micromammal Fossils from Longyadong Cave in Luonan Basin, Shaanxi, Central China

LI Yong-Xiang[1], *HU Song-Mei[2], WANG She-Jiang[3]*, ZHANG Yun-Xiang[1]

[1]State Key Laboratory of Continental Dynamics, Department of Geology, Institute of Cenozoic Geology and Environment, Northwest University, Xi' an 710069, China
[2]Shaanxi Provincial Institute of Archaeology, Xi' an 710054, China
[3]Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, China

*Corresponding authors

Abstract

This paper describes micromammal fossils excavated from the South Longyadong Cave in the Luonan Basin, eastern Qinling Mountains, Shaanxi Province, central China. The fauna comprises 15 mammalian species: *Scapanulus oweni*, *Nasillus andersoni*, Uropsilinae gen. et sp. indet., *Soriculus* sp., *Ochotona* cf. *O. alpina*, *Belomys parapearsoni*, *Allocricetus ehiki*, *Proedromys bedfordi*, *Allophaiomys deucalion*, *Eospalax* sp., *Niviventer preconfucianus*, *Apodemus asianicus*, *Apodemus* sp., *Hystrix brachyura subcristata*, and *Trogontherium cuvieri*. Among these, *Nasillus andersoni* and *Ochotona* cf. *O. alpina* represent newly discovered fossil species. The characteristics of this newly identified micromammal faunal assemblage are similar to those of the North Longyadong Cave fauna, suggesting a geological age no later than the early Middle Pleistocene, possibly representing a late Early Pleistocene fauna. However, recent thermoluminescence dating of the fossil-bearing strata has yielded ages of $356.6\$\pm17.8kaBP, 273.9\pm13.7kaBP, and210.5\pm\$10.5$ kaBP. The fauna includes both southern and northern Chinese animals, with the

assemblage clearly exhibiting transitional characteristics between the southern and northern faunas of China.

Keywords: South Longyadong Cave, Luonan Basin; Pleistocene; micromammal fossils

Introduction

The Longyadong Cave (consisting of two caves oriented northwest-southeast and separated by approximately 30 m, both referred to as Longyadong) in the Huashilang area of the Luonan Basin, eastern Qinling Mountains, represents two Paleolithic cave sites investigated during the 1980s and 1990s. Excavations were conducted by Northwest University (Xue, 1987; Xue et al., 1998, 1999a, b) and the Shaanxi Provincial Institute of Archaeology (Wang et al., 2004; Wang and Huang, 2001, 2002; Wang, 2005, 2008), yielding materials including *Homo erectus* molars, abundant stone artifacts, and mammalian fossils. Mammalian fossils collected from the upper layers of both the North and South caves were previously studied by Xue et al. (1999b), while materials excavated from the South Cave between 1995–1997 were primarily studied by the Shaanxi Provincial Institute of Archaeology (Wang, 2005, 2008).

Based on mammalian fossils and assemblage characteristics from Longyadong, Xue et al. (1999a, b) correlated the fauna with the Gongwangling fauna and assigned it to the late Early Pleistocene. In contrast, Wang et al. (Wang and Huang, 2001; Wang, 2005, 2008) used thermoluminescence (TL) dating of deposits from the South Cave to suggest a Middle Pleistocene age, with an absolute age of approximately 500–200 ka. More recently, Sun et al. (2013) applied the thermally transferred optically stimulated luminescence (TT-OSL) technique to sediments from inside and outside the cave, obtaining absolute ages of approximately 400–200 ka.

The micromammal fossils described herein all originate from the South Longyadong Cave, representing a small portion of specimens excavated systematically by the Shaanxi Provincial Institute of Archaeology between 1995–1997. We identified 15 mammalian species from these materials, which were recovered from layers 2, 3, and 4 (the lithic-bearing layers), with the majority coming from layer 4 (Wang, 2005, 2008). Most of the micromammal fossils examined in this study derive from layer 4 of Test Pit 5 outside the cave (T5-4), with a few specimens from layer 4 and 5 of Test Pit 1 (T1-4, T1-5) and layer 4 of Area I inside the cave (I-4) .

Abbreviations: LV = Longyadong vertebrate fossil number; L = length, W = width, H = height; W1 = trigonid width, W2 = talonid width.

Systematic Paleontology

Class Mammalia Linnaeus, 1758
Order Insectivora Bowdich, 1821
Family Talpidae Gray, 1825
Genus *Scapanulus* Thomas, 1912
***Scapanulus oweni* Thomas, 1912** ([Figure 1: see original paper]A–C;)

Material: One left mandible with i2–m3 (m3 broken) (LV 12).
Horizon: I-4, Area I inside the cave, layer 4.
Measurements: See . Mandibular depth below m1/m2/m3: 2.11/2.58/2.37 mm.

Description: The anterior portion of the mandibular horizontal ramus is broken, with i1 missing. The dental formula is $2 \cdot 1 \cdot 3 \cdot 3$. The ventral margin of the mandible rises below m1, the ascending ramus inclines slightly posteriorly, the masseteric fossa is deep, and the mental foramen opens anterodorsally beneath the anterior root of p4. Based on the broken first incisor alveolus, the first incisor is very small, while the second incisor is well-developed, plate-like, and as tall as p4, exceeding c, p2, and p3 in height. The canine is flattened and conical, lower than the second incisor but higher than p2 and equivalent to p3. Although small, p2 possesses a distinct metaconid and two roots. p3 and p4 increase successively in size and share similar morphology.

In m1, the paraconid is lowest, the protoconid highest, and the hypoconid slightly lower than the metaconid. The trigonid basin opens lingually, with the distance between protoconid and metaconid markedly smaller than that between hypoconid and entoconid, making the talonid significantly larger than the trigonid. The oblique crest terminates at the midline of the posterior trigonid wall, and a weak entocristid renders the talonid basin semi-enclosed lingually. The entostylid is larger than the parastylid.

The m2 crown structure resembles that of m1, but the paraconid and parastylid are enlarged, and the distance between protoconid and metaconid increases, making the trigonid and talonid nearly equal in size. The mesoconid is well-developed, the oblique crest extends lingually and connects with the mesoconid, creating a deep external valley. The mesoconid connects with the entocristid, nearly closing the talonid basin. The parastylid is slightly larger than the entostylid.

The m3 trigonid resembles that of m2 but is relatively smaller, with an enlarged parastylid. The entire talonid basin is broken; however, based on the preserved basal morphology, the oblique crest also extends to the lingual margin.

Comparison and Discussion: The Longyadong South Cave specimen exhibits a very small first incisor, a particularly well-developed second incisor, a canine smaller than the second incisor, and lower premolars (p2, p3, p4) that increase successively in size and all possess two roots. Among the molars, m2 is largest and m1 smallest, with the oblique crests of m2 and m3 deflected lin-

gually. These features are consistent with the extant *Scapanulus oweni* (Zheng et al., 2010).

Middle Pleistocene specimens of *Scapanulus oweni* from the Shanyangzhai fauna show dental characteristics and dimensions consistent with the Longyadong South Cave specimen, both approaching the extant species and differing significantly from Early Pleistocene similar forms (Li et al., 2016). *Scapanulus cf. S. oweni* from the Early Pleistocene Renzidong Cave in Fanchang (Jin et al., 2009) differs from the extant species in having two similarly sized incisors, a single-rooted p3, m3 as the smallest molar, and oblique crests of m2 and m3 that are not lingually deflected, along with smaller overall size.

Genus *Nasillus* Thomas, 1911
***Nasillus andersoni* Thomas, 1911** ([Figure 2: see original paper];)

Material: One broken anterior skull portion with left P2–M1, right P4–M2, and anterior alveoli (LV 14); one broken right mandible with p2–m3 (LV 15).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: See .

Description: The skull is broken ([Figure 2: see original paper]A). P2 is relatively large with two roots and a single cusp. P3 is small, single-cusped, and single-rooted. P4 is molarized, with a large paracone, no anterior cingulum, a non-bladelike buccal margin, a small protocone, and a non-concave posterior margin. The protocone and hypocone of M1 and M2 are confluent in dentine. The first incisor alveolus is enormous, the second is smaller, and subsequent alveoli decrease in size, indicating caninized incisors and reduced canines. The dental formula is $2 \cdot 1 \cdot 4 \cdot 3$. The incisor alveoli are elongated and oval, diverging posteriorly, with a long rostrum and small orbits.

The mandible is relatively well-preserved ([Figure 2: see original paper]B). p4 is largest, p2 second largest, and p3 very small. Two mandibular foramina are located beneath p4 and m1, respectively. The angular process is slender, while the coronoid and articular processes are broken. m2 is the largest tooth in the lower dentition. The crown is low, the fossae are semi-enclosed, and three alveoli are present anteriorly, with the first being large. The dental formula is $1 \cdot 1 \cdot 3 \cdot 3$.

The specimen differs from other talpid genera in its unique dental formula, non-bladelike buccal margin of P4, non-concave posterior margin, relatively large first lower incisor, and very small p3 (Zheng, personal communication). This species is primarily distributed in western Sichuan (Zhang, 1997; Wang, 2003) and has not been recorded in the present study area of Luonan. Its ecological characteristics include montane forest and grassland habitats. No fossil occurrences have been reported previously.

Uropsilinae gen. et sp. indet. ([Figure 1: see original paper]D–F;)

Material: One broken left mandible with p2–m2 (LV 13).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.

Measurements: See . Mandibular depth below m1/m2/m3: 2.79/3.21/3.16 mm.

Description: The mandible is robust, with two mental foramina located beneath p2 and p4; the anterior foramen is positioned lower. The anterior margin of the ascending ramus is relatively steep. The dental formula is $2 \cdot 1 \cdot 3 \cdot 3$. Based on alveolar morphology, the first incisor is small, the second incisor large, and the canine alveolus is oval and smaller than the second incisor alveolus, equivalent in size to p2. p2 is small with two roots; p3 and p4 each have two roots and increase successively in size, with the posterior portion of the crown widening and the posterior cingulum of p4 well-developed and connected to the metaconid.

In m1, the paraconid is small, the trigonid is small and high, and the talonid is low and spacious. The trigonid basin opens lingually, while the talonid basin is closed. The entocristid is deflected buccally, intersecting the obliquely extending oblique crest at the midline of the posterior trigonid wall. The parastylid is smaller than the entostylid.

The m2 crown structure resembles that of m1, but the trigonid is widened and equivalent in size to the talonid. The entocristid is not buccally deflected. The oblique crest still terminates at the midline of the posterior trigonid wall, the parastylid is enlarged, and exceeds the entostylid in size.

Comparison and Discussion: The Longyadong South Cave specimen possesses only two lower incisors, distinguishing it from talpine genera and placing it within Uropsilinae. Its body size, dental formula, and principal dental morphology (e.g., large second incisor, absent p1, p2, p3, and p4 with two roots increasing successively in size, m2 larger than m1) are similar to *Scapanulus* (). However, it differs from *Scapanulus* in its robust mandible, steep anterior margin of the ascending ramus, buccally deflected entocristid of m1, and non-lingually deflected oblique crest of m2. It also differs from *Scapanulus cf. S. oweni* from Renzidong Cave, which has a slender mandible and single-rooted p2 and p3 (Jin et al., 2009).

The lower premolars of the Longyadong South Cave specimen all possess two roots, and the lower molars have well-developed entocristids, resembling the North American fossil genus *Mystipterus*. However, due to limited comparative material, we refrain from assigning it to a specific genus or species.

Family Soricidae Gray, 1821
Genus *Soriculus* Blyth, 1854
***Soriculus* sp.**

Material: One broken left mandible without teeth (LV 11).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: Mandibular depth below m2/m3: 1.16/1.06 mm.

Description: The specimen is very small. The horizontal ramus is slightly concave below m2, and the external temporal fossa is shallow (distinctly different

from *Sorex* and *Crocidura*). The entire condylar articulation comprises two articular surfaces: the lower surface is approximately rectangular and relatively long, while the upper surface is smaller, damaged, and nearly square, roughly parallel to the mandibular articular surface. The two surfaces are united by an intermediate bony bridge, with the lower surface extending medially, creating an overall L-shaped morphology ([Figure 3: see original paper]D).

Comparison: Based on mandibular morphology, the Longyadong South Cave specimen resembles *Soriculus* from Chenggong Sanjiacun and Anhui Fanchang (Qiu et al., 1984:283, fig. 2; Jin et al., 2009:116, figs. 4.9, 4.11). However, it is significantly smaller in size, approaching *Episoriculus* sp. (mandibular height: Longyadong *Soriculus* sp.: 1.06; Fanchang *Episoriculus* sp.: 0.97; Fanchang *S. fanchangensis*: 1.25*; Jianshi* S. hypsibius*: 1.29*; Chenggong *S. leucops*: 1.23. = measurements from figures, in mm). Due to the fragmentary nature of the specimen and lack of preserved teeth, we tentatively assign it to *Soriculus*.

Order Rodentia Bowdich, 1821
Family Petauristidae Miller, 1912
Genus *Belomys* Thomas, 1908
***Belomys parapearsoni* Zheng, 1993** ([Figure 4: see original paper]A–B;)

Material: One broken skull with left P4–M3 and right P3–M1 (LV 27).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: See .

Description: The skull is severely damaged, preserving only the ventral surface and bilateral tooth rows ([Figure 4: see original paper]A–B). The left P3 is broken and positioned close to P4; the right P3 is missing, but its alveolus is distinct and single. P4 has a triangular occlusal surface with three roots, the anterior root extending anteriorly. M1 is smaller than M2, rectangular with a buccolingual width exceeding its anteroposterior length, and possesses four enamel pits anteriorly. M2 resembles M1 but is larger with more developed pits. M3 is simpler than M1 and M2, with obvious posterior constriction.

Comparison and Discussion: The principal dental structures of the specimen, including the anterior cingulum, anterior style, four main cusps, and associated small pits and accessory crests, resemble those of *Belomys pearsoni* from Longgupo (Zheng, 1993:28, fig. 17c). However, distinct differences exist: smaller size (), more lingually protruding P4, M1 length and width both smaller than M2, absent metacone on M3 with a nearly circular occlusal surface, completely closed posteromedial region, non-expanded connection between metaconule and posterior cingulum, most robust lingual root, and simpler, rounder buccal tooth folds.

Belomys parapearsoni was established by Zheng (1993) as a new species based on isolated teeth from Longgupo, Sichuan, and remains the only fossil species of this genus. Xue et al. (1999b) subsequently reported a left M3 from Longyadong, Shaanxi, which differs little from the Longyadong South Cave specimen except for slightly smaller M3 dimensions (). The specimen described here, from layer

4 of Test Pit 5 outside Longyadong South Cave (T5-4), represents the best-preserved material known for this species, preserving nearly complete bilateral maxillary tooth rows despite being a single specimen.

Family Cricetidae Fisher von Waldheim, 1817
Genus *Allocricetus* Schaub, 1930
***Allocricetus ehiki* Schaub, 1930** ([Figure 4: see original paper]C;)

Material: One broken right mandible with m1–3 (LV 26).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: See .

Description: The anterior wall of m1 is smooth, with an isolated lingual anteroconid. The anterolophid connects with the anterior wall of the protoconid and the anterior arm of the anterior cingulum of the metaconid. The buccal anteroconid is completely continuous with the anterolabial cingulum and anterolophid. Heavy wear has widened the main cusps, including the buccal anteroconid, metaconid, protoconid, entoconid, hypoconid, and posterior cingulum, making them broad and continuous. Two cingular cusps are present: one at the edge of the second internal valley on the lingual side of the crown midline, and another at the edge of the posterior external valley on the buccal side ([Figure 4: see original paper]C).

The main cusp morphology of m2 resembles that of m1, but the lingual anterior cingular cusp is absent, and no mesoconid is observed. Heavy wear has closed or semi-closed the internal and external valleys, with a cingular cusp present at the edge of the external valley.

In m3, the hypoconid and entoconid are reduced, narrowing the posterior portion of the crown without reducing its length. Heavy wear has completely closed the internal and external valleys, forming enamel loops distributed across the occlusal surface. The second internal valley is divided into inner and outer loops by a small spur on the anterior wall of the mesolophid. The third and fourth internal valleys are completely closed into two loops that do not reach the crown margin.

Comparison and Discussion: The new specimen is smaller than *Allocricetus varians* and matches the dimensions of *A. ehiki* from Zhoukoudian Locality 18. It also exhibits a mesolophid reaching the crown margin and an isolated lingual anteroconid, supporting its identification as *Allocricetus ehiki* (Zheng, 1984, 2004).

Family Arvicolidea Gray, 1821
Genus *Proedromys* Thomas, 1911
***Proedromys bedfordi* Thomas, 1911** ([Figure 5: see original paper]A–B;)

Material: One broken maxilla with bilateral M1 and left M3 (LV 16); two right mandibles with m1–2 (LV 21–22); one right mandible with m1–3 (LV 23).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: See .

Description: The maxilla is severely damaged ([Figure 5: see original paper]A). M1 has four nearly closed, alternately arranged triangles posterior to the anterior loop, with a shallow concavity at the lingual posterior internal angle that does not form a true third reentrant angle. M2 is missing. M3 is simple, with a very small third triangle posterior to the anterior loop; the second and third triangles are not closed, and the third buccal and lingual reentrant angles are indistinct.

All three right mandibles are broken but preserve complete dentitions ([Figure 5: see original paper]B). The m1 anterior loop is simple, without accessory reentrant angles. m3 has two buccal reentrant angles that are very small, with no anterior external reentrant angle.

Comparison and Discussion: The specimen dimensions approach those of *Microtus cf. M. ratticepoides* from layer DO-7 of the Dongyaozitou section (m1 length 2.8–3.0 mm, width 1.1–1.2 mm). However, the new specimen exhibits simpler morphology, lacking the lingual reentrant angle on the m1 anterior loop. *Proedromys cf. P. bedfordi* (also known as *Microtus bedfordi*) reported by Xue et al. (1999b) from the North Longyadong fauna has a simple m1 anterior loop without traces of a fifth lingual reentrant angle, relatively small enamel loops, and closed triangles between anterior and posterior loops, closely resembling the specimens described here except for minor size differences (). Based on morphological characteristics, our specimens should be assigned to *Proedromys bedfordi*.

Genus *Allophaiomys* Kormos, 1932
***Allophaiomys deucalion* Kretzoi, 1969** ([Figure 5: see original paper]C;)

Material: One broken left mandible with m1–3 (LV 17); one right and one left broken mandible with m1–2 (LV 18–19); one broken left mandible with m1 (LV 20).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: See .

Description: All mandibles preserve incisors ([Figure 5: see original paper]C). The m1 is small, with five closed or semi-closed triangles between the anterior and posterior loops. Buccal reentrant angles are shallower than lingual ones. The anterior loop morphology is simple, without accessory lingual reentrant angles. m2 has four slightly offset triangles anterior to the posterior loop, but the triangles are not closed. Its morphological features and size are similar to specimens from North Longyadong, though the latter are slightly larger, with shallower third and fourth lingual reentrant angles on m1 and more closed triangles on m2 (Xue et al., 1999b:314, fig. 3a, c–e).

Comparison and Discussion: The m2 triangles of the Longyadong South Cave specimen are not closed, resembling the morphology of *Eothenomys praechinensis* from Tianqiao fissure (Zheng, 1993) and *Clethrionomys rutilus* from Jinniushan (Zhang, 1993). However, its m1 morphology differs significantly from both and more closely resembles *Allophaiomys pliocaenicus* from

North Longyadong (Xue et al., 1999b). Both Longyadong (North and South) assemblages should be assigned to *Allophaiomys deucalion*, as this species has a relatively short anteroconid complex on m1 (anteroconid complex length/tooth length < 42) and relatively large tooth width (enamel loop 6 width/buccal third-lingual fourth reentrant angle width > 33) (van der Meulen, 1974; Zhang et al., 2011). The North Longyadong material is typical, with values of 35.54 (<42) and 37.4 (>33). In our specimen, the anteroconid complex measures 39.64 (<42), but the enamel loop/tooth width ratio is <33 at only 22. Overall, the Longyadong South Cave material exhibits a trefoil-shaped anteroconid complex, an elliptical anterior cap, interrupted enamel layers on the anterolabial side of the anterior cap and on the medial and lateral sides of the posterior loop, and very small tooth length (), all indicating closer affinity to *A. deucalion*.

Family Siphneidae Leroy, 1941
Genus *Eospalax* Allen, 1938
***Eospalax* sp.** ([Figure 6: see original paper]A;)

Material: One right mandible with m1–3 (LV 28); one left mandible with m1–2 (LV 29); two isolated upper teeth (LV 30–31).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: See .

Description: The right mandible is nearly complete ([Figure 6: see original paper]A). The m1 anterior loop is elliptical, with no enamel on the anterior wall. The buccal portion of the tooth' s longitudinal axis is significantly larger than the lingual portion. The lingual anterior reentrant angle is shallow, while the buccal anterior reentrant angle is V-shaped. The anterior loop is short, and the lingual posterior reentrant angle axis obliquely intersects the tooth' s midline. The individual is distinctly small ().

Comparison and Discussion: Zheng (1997) summarized the basic characteristics and taxonomic assignments of m1 in three skull types of zokors. The morphological features of the Longyadong specimen are completely consistent with *Eospalax*, differing markedly from *Myospalax (Eospalax) fontanieri* from Luochuan (Tuojiahe, Dongtangou) in its significantly smaller size (). *Eospalax* first appeared in the middle-late Early Pleistocene and persists to the present (Liu, 1985; Tong et al., 1995), with many species known. Due to limited material, we refrain from assigning these specimens to a specific species.

Family Muridae Gray, 1821
Genus *Niviventer* Marshall, 1976
***Niviventer preconfucianus* Zheng, 1993** ([Figure 6: see original paper]B;)

Material: One right mandible with m1–3 (LV 32).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: See .

Description: One right mandible with a complete dentition, broken posteriorly

([Figure 6: see original paper]B). The diastema measures 4.0 mm. m1 lacks a mesostylid, with a small and posteriorly positioned buccal anteroconid. The posterior portion of the tooth is slightly wider than the anterior portion. A small spur extends anteriorly in front of the connection between hypoconid and entoconid. No anteromedian style is observed, and the posterior cingulum cusp is small, with a basal width approximately half the crown width. Molars m1 and m2 possess buccal posterior accessory cusps, while m3 is simple and lacks a buccal posterior accessory cusp.

Comparison and Discussion: *Niviventer preconfucianus* was established by Zheng (1993) as a new species based on material from Longgupo, Sichuan, and remains the only fossil species of this genus. It differs from the extant *N. confucianus* in its developed buccal posterior accessory cusps on m1 and m2 and buccal anterior style on m2. Xue et al. (1999b) reported one left m1 representing this species from the Longyadong fauna, with a clear buccal posterior accessory cusp. The present specimen shows almost no difference except for slightly smaller size (), with m1 length representing 0.44 of the molar row length. We therefore assign it to *Niviventer preconfucianus*.

Genus *Apodemus* Kaup, 1829
***Apodemus asianicus* Zheng, 2004** ([Figure 6: see original paper]C;)

Material: One right mandible with incisor and m1–3 (LV 33); one right m1 (LV 35).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: See .

Description: One right mandible with a broken posterior articular region ([Figure 6: see original paper]C). The masseteric crest inferior branch is robust, expanded anteriorly, and extends anteriorly to below the anterior m1. The mental foramen is large, positioned directly anterior to the masseteric crest anterior end. The ascending ramus originates beside m2. m1 possesses a small but high anteromedian cusp and well-developed anterior, median, and posterior styles. m2 develops an anterior style but lacks a posterior style; the median style comprises two small but distinct cuspules on a strongly developed cingulum base, located medially and posteriorly on the buccal side of the protoconid. m3 lacks buccal styles and cingula ([Figure 6: see original paper]C1).

Comparison and Discussion: The new specimen resembles *Apodemus asianicus* from Jianshi (Zheng, 2004:167–172, fig. 5.36d–h, table 5.41) and *A. latronum* from Longgupo (Zheng, 1993:138–141, fig. 65c–e, table 25) in both morphological features and size.

When establishing the new species based on Jianshi and Wushan material, Zheng (1993, 2004) noted that *A. asianicus* differs from *A. latronum* in its significantly smaller size and more isolated, anteriorly projecting anteromedian cusp on m1, as well as more developed buccal styles on m2. The Longyadong South Cave specimen shows a prominently isolated, anteriorly projecting anteromedian cusp on m1 ([Figure 6: see original paper]C1) and relatively weakly developed buccal

styles on m2, though its size is not significantly smaller (). We assign it to *Apodemus asianicus*.

***Apodemus* sp.** ([Figure 6: see original paper]D)

Material: One broken left mandible without molars (LV 34).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: m1–3 alveolar length: 3.4 mm; diastema length: 3.3 mm; mandibular depth below m1: 2.6 mm.

Description: The mandibular masseteric crest anterior end extends beyond the m1 anterior margin, with a robust inferior branch that expands anteriorly. The mental foramen is round, positioned anterior to the masseteric crest anterior end. The ascending ramus originates between m2 and m3. All lower molars are missing, but alveoli are clear. In occlusal view, the distance between the lower tooth row (alveoli) and ascending ramus is very small, with the ascending ramus directly adjacent to the alveolar wall beside m1, gradually diverging at m2 but remaining narrow.

Comparison and Discussion: After repeated comparison with hamster and wood mouse specimens, this edentulous mandible ([Figure 6: see original paper]D1, 2) most closely approaches *Apodemus asianicus*. In labial view, the masseteric crest extends far anteriorly, exceeding the m1 anterior margin; the ascending ramus inclines posteriorly; a distinct depression is present above the masseteric crest at the horizontal ramus midline; the incisor root prominence is high beneath the posterior horizontal ramus and ascending ramus; the ascending ramus is relatively gentle, and the horizontal ramus ventral margin is straighter; and the individual is small. Hamsters and house mice show weaker development of the depression above the masseteric crest and incisor root prominence, and hamsters have a relatively larger distance between the lower tooth row and ascending ramus, clearly differing from our specimen. We therefore assign it to *Apodemus* sp.

Order Lagomorpha Brandt, 1855
Family Ochotonidae Thomas, 1897
Genus *Ochotona* Link, 1795
***Ochotona* cf. *O. alpina* Pallas, 1773** ([Figure 6: see original paper]E–G;)

Material: One broken left maxilla with P3–M2 (LV 36); one right mandible with p3–m3 (LV 37); one right mandible with p3–m2 (LV 38); four right and three left mandibles with p4–m3 (LV 39–45); one right p3 (LV 39.1).
Horizon: T5-4, Test Pit 5 outside the cave, layer 4.
Measurements: Maxillary and dental measurements: P3–M2 length 4.5 mm, M1 width 2.0 mm. Mandibular measurements see .

Description: The teeth are small. The p3 has a deep lingual posterior reentrant angle opposite the buccal posterior reentrant angle, creating a three-lobed occlusal surface that widens gradually from anterior to posterior, forming a triangle ([Figure 6: see original paper]F3). The lingual posterior reentrant angle

is deep, extending more than halfway across the occlusal surface, with minimal space between it and the opposite buccal posterior reentrant angle. All four reentrant angle posterior walls are relatively straight and nearly perpendicular to the tooth' s midline.

Comparison and Discussion: Compared with previously reported pikas, the Longyadong South Cave specimens are very small, representing the smallest known individuals (). Their p3 morphology is also distinctive ([Figure 6: see original paper]F3, G).

The p3 of *Ochotona hyperborea* from Jinniushan similarly has four reentrant angles but differs markedly in its oblique anterior reentrant angle posterior wall, shallow and strongly posteriorly inclined lingual posterior reentrant angle, and relatively larger size. *Ochotona nihewanensis* from Nihewan also has a deep posterior internal reentrant angle, but all its reentrant angles point obliquely posterointernally, unlike the transverse orientation in the Longyadong specimens. Additionally, the anteroconid of *O. nihewanensis* is relatively larger than the posteroconid in both length and width. Among extant pikas, only *Ochotona alpina* Pallas, 1773 (also known as the alpine pika, Zhang, 1997) exhibits the morphological features of opposite anterior internal and external reentrant angles with a deep anterior internal reentrant angle, but its anteroconid is shorter and wider (Zheng, personal communication), and the species is larger, exceeding even *O. hyperborea* in size (Mammal Research Team of Institute of Zoology, 1958). Considering these factors, we tentatively assign the new specimens to the similar species *Ochotona* cf. *O. alpina*.

Family Hystricidae Burnett, 1830
Genus *Hystrix* Linnaeus, 1758
***Hystrix brachyura subcristata* Swinhoe, 1870** ([Figure 7: see original paper]A;)

Material: One left mandible with p4–m2 and incisor (LV 46); one right m2 (LV 46.1).
Horizon: T4-4, Test Pit 4 outside the cave, layer 4.
Measurements: See .

Description: The left mandible is relatively well-preserved, with p4–m2 and incisor; m3 is missing, and the posterior portion of the mandible is broken ([Figure 7: see original paper]A). The mandible is robust overall, with thick, short incisors and low cusps. Brownish-yellow enamel is distributed mainly on the lower portions and medial/lateral sides near the lower margin of the teeth. In labial view ([Figure 7: see original paper]A1), the masseteric crest is well-developed, originating posteriorinferior to m1 and extending posteriorinferiorly as a raised, wing-like ridge. The mental foramen is located lateral to the lowest point of the diastema depression, anterior to the p4 root. The lower cheek teeth have buccal folds extending to the root. In lingual view ([Figure 7: see original paper]A2), the medial mandibular surface is relatively straight. In occlusal view ([Figure 7: see original paper]A3), the lower cheek teeth are nearly rectangular

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P4 is largest and nearly rectangular, with four transverse enamel folds extending to the root. The buccal fold extends to the root, while the lingual fold extends shallowly, less than half the existing crown height. m1 is smaller than p4, with fold positions similar to p4, but the buccal fold does not connect with the lingual fold, creating five closed enamel circles on the occlusal surface besides the buccal fold. m2 resembles m1, but the second pair of internal and external folds connect, similar to p4.

Comparison and Discussion: These dental features closely resemble *Hystrix subcristata* (= *Hystrix brachyura subcristata*, Malayan porcupine, South China subspecies, Wang, 2003) described from the West Taipingshan Cave at Zhoukoudian (Cheng, 1996). Tong (2005) compared porcupine fossils from the Zhoukoudian area with fossil and extant species, assigning them to two species: *Hystrix subcristata* (*Hystrix brachyura subcristata*) and *Hystrix lagrelii*. Based on morphological features and size ([Figure 7: see original paper]A;), the Longyadong South Cave specimens should be assigned to *Hystrix brachyura subcristata* (= crestless porcupine *Hystrix subcristata*, Tong, 2005). Compared with Tianyuan Cave specimens, the Longyadong teeth are more square, with larger m1 and m2, approaching the characteristics of specimens from Zhoukoudian Loc. 9 and 13 (Tong, 2005:135, table 3).

Research indicates obvious differences between early fossil and more recent specimens. The well-preserved mandible from Zhoukoudian Loc. 13 (Teilhard and Pei, 1941:61, fig. 49) is distinctly more robust than Tianyuan Cave and extant specimens (Tong, 2005:144, fig. 7), with the minimum mandibular height at the mental foramen significantly greater than in the latter two groups. The overall mandibular morphology appears short and robust in the early fossil, while the latter two appear slender. The West Taipingshan specimen shares these characteristics: "mandible robust, horizontal ramus appearing shallow and thick" (Cheng, 1996). The Longyadong South Cave specimen clearly resembles early fossil specimens, with a short, robust mandible, thick and short incisors, and an incisor tip approximately level with or slightly lower than the molar occlusal surface, contrasting with the generally longer, more curved incisors of Tianyuan Cave and extant specimens whose incisor tips are much higher than the molar occlusal surface (Tong, 2005).

Family Castoridae Gray, 1821
Genus *Trogontherium* Fischer, 1809
***Trogontherium cuvieri* Fischer, 1809** ([Figure 7: see original paper]B;)

Material: One broken right mandible with broken incisor and p4–m3 (LV 47).
Horizon: T1-5, Test Pit 1 outside the cave, layer 5.
Measurements: See .

Description: The specimen is severely damaged and deformed ([Figure 7: see original paper]B), but preserves a relatively complete tooth row with a broken p4 anterior portion. In occlusal view, the buccal folds of the lower cheek teeth

extend between the median and posterior folds, but except for p4, the enamel folds of lower molars m1–3 are closed into loops rather than typical external and internal folds. The folds and grooves are simple and closed, with large size differences between premolars and molars. p4 is largest, with several folds of equivalent length. m1 has a small anterior fold, slightly larger posterior fold, and largest median and buccal folds of equivalent length. m2 resembles m1 but has a larger occlusal surface and slightly longer anterior and posterior folds. Although m3 has a small occlusal surface, both anterior and posterior folds are elongated, with four folds of equivalent width, the anterior fold being longest and nearly traversing the entire occlusal surface. The buccal folds of p4, m1, and m2 extend posteriorly with slightly anteriorly curved tips, more obvious in m1 and m2 but absent in m3.

Comparison and Discussion: The simple enamel folds and fewer plications of the described material resemble *Trogontherium cuvieri* from Jinniushan and Zhoukoudian, clearly differing from *Castor fiber* and *Sinocastor cf. S. zdanskyi* (Zhang, 1993:61, fig. 40; Young, 1934:52–57). Like the Tangshan specimen (Young, 1934: fig. 18A), all buccal folds of the Longyadong South Cave specimen extend between the median and posterior folds, differing from Zhoukoudian and Jinniushan specimens. However, its p4 and m3 are relatively straight with indistinct curvature, while m1 and m2 curve distinctly anteriorly, similar to Zhoukoudian Locality 1 specimens (Young, 1934: fig. 18B). Comprehensive analysis suggests that the Longyadong South Cave giant beaver enamel fold characteristics are intermediate between Zhoukoudian Locality 1 and Tangshan specimens, consistent with the m1 and p4 occlusal surface length index analysis presented below.

Studies show that the m1 and p4 occlusal surface length index (ratio of the two) is 64.5 in giant beavers and 85 in modern beavers (- , 1961:165). The m1 and p4 occlusal surface length indices for giant beavers from several localities are shown in . The data (- , 1961; Zhang, 1993; Young, 1934) demonstrate that the m1 and p4 occlusal surface length index is clearly age-related: earlier forms show greater differences between the two teeth, while more recent forms show more uniform tooth sizes. Combined with the enamel fold characteristics described above, the Longyadong South Cave specimen exhibits relatively primitive features, and its age is likely late Early Pleistocene, intermediate between Tangshan and Zhoukoudian Locality 1, and should be no later than early Middle Pleistocene.

Discussion

The micromammal fossils identified from Longyadong South Cave comprise 15 species, five of which are identical to those reported by Xue et al. (1999b) from the North Longyadong fauna: *Soriculus* sp., *Belomys parapearsoni*, *Proedromys bedfordi*, *Allophaiomys deucalion*, and *Niviventer preconfucianus*. These mem-

bers are generally considered characteristic or exclusive to the Early Pleistocene. Additionally, *Allocricetus ehiki* and *Apodemus asianicus* are mainly known from Early Pleistocene faunas such as Zhoukoudian Locality 18 and Jianshi. Although *Hystrix brachyura subcristata* is an extant species, its robust morphology and other features link it more closely to early faunas such as Zhoukoudian Loc. 13 and West Taipingshan Cave. While *Trogontherium cuvieri* is primarily known from the Middle Pleistocene, analysis of enamel fold characteristics and the m1/p4 occlusal surface length index from several localities suggests that the Longyadong South Cave fauna may predate Zhoukoudian Locality 1. The extant species *Scapanulus oweni* occurs in the Middle Pleistocene Shanyangzhai fauna, and its similar form also appears in Renzidong Cave. Only *Nasillus andersoni* and *Ochotona* cf. *O. alpina* represent extant species appearing in the fossil record for the first time.

The micromammal assemblage analyzed here is temporally consistent with previous studies based mainly on fossils from North Longyadong (Xue et al., 1999b), suggesting a late Early Pleistocene or early Middle Pleistocene age. However, this clearly differs from recent dating results for Longyadong South Cave sediments (Wang and Huang, 2001; Wang, 2005, 2008; Sun et al., 2013).

The 15 micromammal species identified primarily derive from layer 4 of Test Pit 5 outside Longyadong South Cave (12 species), with a few (3 species) from layer 5 of Test Pit 1, layer 4 of Test Pit 4, and layer 4 of Area I inside the cave (). Corresponding thermoluminescence ages for these strata are $356.6\pm17.8 kaBP (middle of layer 4 inside the cave), 273.9\pm13.7 kaBP (upper part of layer 4 inside the cave), and 21$ kaBP (layer 5 of test pit outside the cave) (Wang, 2005, 2008).

The Longyadong South Cave fauna clearly exhibits mixed southern and northern Chinese elements, including southern-type animals such as *Apodemus asianicus*, *Belomys parapearsoni*, *Soriculus* sp., *Niviventer preconfucianus*, *Nasillus andersoni*, and *Hystrix brachyura subcristata*, and northern-type animals such as *Ochotona* cf. *O. alpina*, *Allocricetus ehiki*, *Allophaiomys deucalion*, *Proedromys bedfordi*, and *Trogontherium cuvieri*. The extant *Scapanulus oweni* is currently distributed mainly in central and western China.

Xue et al. (1999) analyzed 36 mammalian species from North and South Longyadong and concluded that the Longyadong fauna, coexisting with *Homo erectus* and cultural remains, represents a transitional fauna between the Palearctic and Oriental realms due to its location in the Qinling Mountains but within the Yellow River basin. The micromammal fossil assemblage studied here similarly demonstrates these transitional characteristics between northern and southern Chinese faunas.

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Note: Figure translations are in progress. See original paper for figures.