

## Chapter 2

# The Lipotyphla of Yushe Basin

Lawrence J. Flynn and Wen-Yu Wu

**Abstract** Insectivoran mammals have been recovered by Sino-American field teams from various localities in each formation of the Yuncu and Tancun subbasins. They were an important component of late Miocene through Pliocene faunas of North China. One hedgehog has been found in late Pliocene and Pleistocene localities. Moles, however, are diverse and occur throughout the Miocene and Pliocene section, with one early Pliocene record of the water mole *Desmana*. The Yushe collection includes the Pliocene talpine *Scaptochirus*, which is at present the oldest fossil of this genus. Shrews are also diverse, including multiple representatives of the tribes Soricini, Nectogalini, and Beremendiini. Presence of a blarinine suggests immigration of this element from North America by 6 Ma, and morphological similarity with beremendiines suggests that recognition of these groups should be reviewed. The early Pleistocene Haiyan Formation has yielded only *Sorex*, and to date only *Crociodura* has emerged from the Pleistocene loess. Declining insectivoran diversity corresponds with a hypothetical decline in mean annual temperature. The insectivoran component of Yushe shows affinity with fossil and living faunas of North China, and a majority of elements are shared broadly across Eurasia. Two taxa at least (*Yunosaptor* and *Soriculus*) also occur in South China, indicating former wide distribution

of these genera, and suggesting southward retraction of their preferred paleohabitat from Shanxi Province since the Pliocene.

**Keywords** Yushe Basin • North China • Late Neogene • Lipotyphla • Insectivores • Shrews • Moles

### 2.1 Introduction

Across North China, Late Cenozoic deposits reveal high species richness among micromammals of late Miocene and Pliocene age. Certain productive localities, such as Ertemte and Bilike, both Inner Mongolia (Fahlbusch et al. 1983; Qiu and Storch 2000), attest to this diversity within the insectivoran component of small mammal communities. Yushe Basin demonstrates this richness for Shanxi Province as well. One aspect of the importance of Yushe is in its aggregate of successive localities. While no single Yushe sample is as large as that of Ertemte or Bilike, in aggregate, the Yushe localities show great insectivoran richness. Of the many insectivoran specimens described in this chapter, nearly all were recovered by our field parties. An exception is the excellent (large) specimen of *Erinaceus* found in 1935 for Childs Frick and the American Museum of Natural History (AMNH) by Quan-Bao Gan.

The diversity of insectivorans as preserved in the Late Cenozoic deposits of Yushe Basin matches that seen today in North China, although some taxa imply changes in distribution. The composition of the fauna also suggests that the Yushe region insectivoran fauna showed significant differences from both South China and northern Asia (Inner Mongolia northwards).

Our progress in this study depended not only on the fine fossil collections of the Institute of Vertebrate Paleontology

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Note: This chapter includes one or more new nomenclatural-taxonomic actions, registered in Zoobank, and for such purposes the official publication date is 2017.

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L.J. Flynn (✉)  
Department of Human Evolutionary Biology, and the Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, MA 02138, USA  
e-mail: ljflynn@fas.harvard.edu

W.-Y. Wu  
Laboratory of Paleomammalogy, Institute of Vertebrate Paleontology and Paleoanthropology Chinese Academy of Sciences, 142 Xizhimenwai Ave., Beijing 100044, People's Republic of China  
e-mail: wuwenyu@ivpp.ac.cn

and Paleoanthropology (IVPP) in Beijing, but also on the recent mammal collections of the AMNH and of the Museum of Comparative Zoology (MCZ) at Harvard University, and of the Kunming Institute of Zoology (KIZ). Measurements are in millimeters unless otherwise noted.

## 2.2 Systematics

The relationships of the higher categories of small mammals loosely called “insectivores” remain controversial. Insectivorans, as traditionally conceived, are not monophyletic, but the core group of hedgehogs, moles and shrews is a natural group and most workers (e.g., McKenna and Bell 1997) utilize the higher taxon Lipotyphla Haeckel, 1866 for them. Currently, it appears that Solenodontidae is sister taxon to Lipotyphla (Douady and Douzery 2009) and the more inclusive group is modified as Eulipotyphla. Because the possible relationships of Erinaceidae, Talpidae, and Soricidae have varying support, we list them in that order without subordinal grouping.

### 2.2.1 Family Erinaceidae Fischer, 1814

*Erinaceus* Linnaeus, 1758

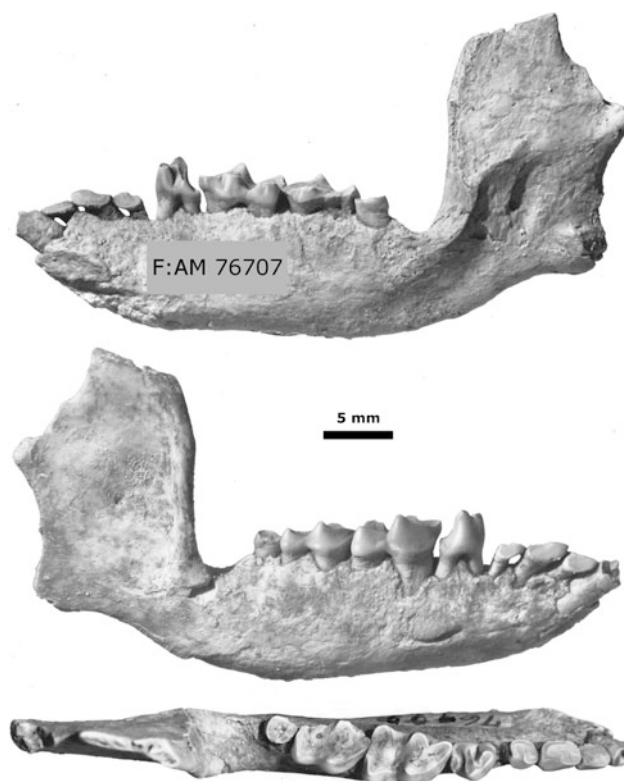
*Erinaceus olgae* Young, 1934

Referred material: V8893, complete left m1 from late Pliocene locality YS5. F:AM 76707, right mandible bearing complete dentition, including enlarged lower incisor (damaged tip) and three antemolars between it and p4, plus three molars; minor breakage anteriorly and at the condyle, the angle, and the coronoid process. Specimen collected in 1935 from the Nan Zhuang Gou area by Q.-B. Gan (“Buckshot”), who was employed by Childs Frick.

Distribution: Hypodigm material from Zhoukoudian (Localities 1, 2). Additional material from Yushe Basin: V8893 collected in 1987 from locality YS5, Mazegou Formation, 3.3 Ma; Nan Zhuang Gou specimen from a unit, probably loess, overlying the mid-Pliocene sediment.

Revised diagnosis: Large species of *Erinaceus* characterized by reduced paraconid on p4: paraconid is low and the paralophid is directed anterolingually; cingulum is absent on p4 and weak on lower molars.

Remark on nomenclature: Young (1934) named this species to honor Mrs. Olga Hempel-Gowen, “indefatigable secretary of the Cenozoic Laboratory”. The published spelling of the species was “olgai”, which is corrected here as *Erinaceus olgae*.



**Fig. 2.1** *Erinaceus olgae*, right dentary with dentition, F:AM 76707, in medial (above), lateral, and dorsal (below) views (photography by Chester Tarka, AMNH)

Description: F:AM 76707 is a well-preserved dentary with moderately worn dentition (Fig. 2.1). The dentary bone is comparable in living *Erinaceus amurensis*, whose present range includes the Yushe area (Corbet 1988). The ventral border of the dentary is straight, depth uniform at about 8 mm from p4 to m3. Anterior from p4, the dentary bears a laterally thickened and strong symphysis that accommodates the long root of the enlarged incisor. Posteriorly the ramus narrows, with rising angle. The ascending ramus is vertical and coronoid is high. The condyle is positioned 5 mm above the tooth row. The mental foramen is low on the dentary, below the posterior part of p4, and the mandibular foramen is in the ascending ramus behind m3.

The dentition includes the procumbent incisor, generally considered the homologue of i2. It is followed by three simple antemolars, the middle one largest, and usually considered the canine. These teeth are worn, with a longitudinal crest located buccal to their midline. Each has a single root that projects posteriorly. The three are crowded together, combined length of 7.6 mm, and are followed by a small diastema. The second and third antemolars have low

posterior heels, suggesting structures comparable to the p4 talonid. Of the three antemolars, only the second suggests a hint of a buccal cingulum. The two-rooted p4 has a high trigonid and low talonid shelf below the level of the occlusal surface of m1. The trigonid is shortened longitudinally. Its paralophid projects anterolingually, but does not reach as far lingually as the metalophid, and bears a paraconid smaller and lower than the protoconid. The nearly transverse metalophid plunges steeply lingually, has a sloping wear facet, and bears a very low metaconid at the lingual border of the tooth. The talonid is hardly more than a posterior cingulum with enamel slightly raised posterolabially.

Molars decrease in size posteriorly. The first two are elongated, with large trigonids. Metalophids are transverse, and paralophids project anterolingually, reaching nearly as far lingually as metalophids, their smooth external walls gently curved. The protoconid is the highest cusp. The hypoconid and entoconid dominate the talonid basin. The cristid obliqua joins the base of the protoconid. At this state of wear, a small entocristid anterior to the entoconid is evident, and is apparently larger on m2. The reduced m3 is a worn, rounded basin. If its developmental homologue is a trigonid, it appears to have a strong metaconid. A weak cingulum is present on m1-2, strongest anterobuccally and between protoconid-hypoconid, faint at the protoconid. The first molar is wider posteriorly than anteriorly; m2 is wider anteriorly.

The fresh m1, V8893, is beautifully preserved, with two large roots, and is smaller than m1 of F:AM 76707 (Table 2.1). It shows a small entocristid, not yet worn and in the form of a small cusp. A low marginal crest extends anteriorly from the entocristid, but the entocristid is isolated from the large entoconid immediately posterior to it. A weak, intermittent cingulum occurs anterobuccally, between hypoconid-protoconid, and posteriorly. The posterior cingulum continues buccally from an entoconid shelf.

The shelf is evident but nearly hidden in F:AM 76707, and neither m2 nor m3 show a posterior cingulum on that specimen.

**Discussion:** Both Yushe specimens represent a large *Erinaceus*. They conform to the descriptions of *Erinaceus olgae* from Zhoukoudian 1 and 2 (= *Erinaceus olgai* Young, 1934), sites assigned an age close to the Brunhes/Matuyama boundary, ca. 0.7 Ma. The provenance of V8893 is clear, given the local setting (YS5 is the top of a small hill), and is dated paleomagnetically to 3.3 Ma. Given the preservation and circumstance of collection in 1935, F:AM 76707 probably did not come from the early Pliocene deposits of Nan Zhuang Gou, but from overlying Pleistocene deposits, likely ~1 Ma in age. In addition to size appropriate for *E. olgae*, this specimen displays a reduced p4 with shelflike talonid and compressed trigonid with low paraconid and metaconid. The diagnostic value of this premolar morphology is largely untested, but the fossil specimens assigned to this species appear to be distinct from *Erinaceus* presently living in China. Specimen V8893 of significantly greater age is appreciably smaller (see Table 2.1), but matches size of some specimens from Zhoukoudian (Young 1934). Both Yushe specimens have only a vestigial cingulum on the molars. V8893 would represent the oldest known specimen of *E. olgae*, and therefore a taxon that ranged through the Plio/Pleistocene faunal turnover of Yushe Basin (Flynn et al. 1991).

Other late Cenozoic records of *Erinaceus* in China include “*E. mongolicus*” Schlosser (1924) from Ertemte. Contrary to original indications, Fahlbusch et al. (1983) pointed out that this is a small hedgehog; it may represent the genus *Hemiechinus*. *E. koloshanensis* Young and Liu, 1950, was named for material from the early Pleistocene of Sichuan. Also assigned to this smaller *Erinaceus* is material from the Nihewan area described by Teilhard and Piveteau (1930). Corbet (1988) notes that careful comparisons with *Hemiechinus* are lacking. As concerns the lower dentition, it

**Table 2.1** Dimensions (length, width) for teeth and total p4 – m3 length in described insectivoran mandibular specimens (mm)

	p4	m1	m2	m3	p4 – m3
<i>Erinaceus olgae</i>					
V8893		5.2, 3.3			
F:AM 76707	3.4, 2.8	6.2, 4.4	5.7, 4.0	2.7, 2.0	16.9
<i>Yanshuella yushensis</i>					
V8915	1.45, 1.00	2.53, 1.80	2.75, 2.30	2.38, 1.63	8.73
V8916	1.53, 1.03	2.33, 2.03	*	2.35, 1.60	8.05
V8917 (worn)		2.20, 1.93	2.45, 2.05		
<i>Soriculus praecursus</i>					
V8898.1	1.48, 0.95	1.71, 1.09	1.62, 0.95	1.48, 0.76	5.07
V8898.2			1.52, 0.95	1.14, 0.58	
<i>Beremendia pohaiensis</i>					
V2671		2.90, 1.86	2.33, 1.48	1.48, 0.86	
V8900		3.00, 1.86	2.43, 1.67	1.71, 1.05	

\* p4 – m3 length may be underestimated due to absence of m2

appears that *Hemiechinus* more typically has a highly reduced metalophid/metaconid, lacks a cingulum, and has m3 relatively more reduced than does *Erinaceus*. If these features are valid at the generic level, then *E. koloshanensis* and *E. olgae* appear to be correctly assigned to genus. However, *E. olgae* would be unusual for *Erinaceus* in its reduced molar cingulum.

## 2.2.2 Family Talpidae Fischer, 1814

Subfamily Talpinae Fischer, 1814

Tribe Talpini Fischer, 1814

*Scaptochirus* A. Milne-Edwards, 1867

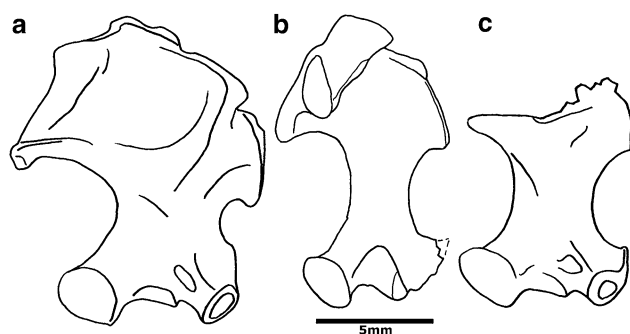
*Scaptochirus* sp.

1991 *Scaptochirus* Tedford et al., in part

1994 *Scaptochirus* sp. Flynn and Wu

Referred material: V8913, right humerus from YS93 in the Mazegou Formation, about 3.5 Ma; V8910, broken left lower molar from YS4 (talonid width, 1.5 mm), Gaozhuang Formation, 4.3 Ma, both of Yuncu subbasin (Figs. 2.2a, and 2.3a).

Description: The well-preserved humerus shows damage of only the spike-like tip of the deltoid process and the ectepicondylar process (terminology of Hutchison 1968). The specimen is much like that of extant *S. moschatus* in being relatively broad, indicating strong fossorial adaptation. Humerus measurement (Table 2.2) follows Storch and Qiu (1990), who modified somewhat the measurement categories of Storch and Qiu (1983). The proximal breadth approaches total length. The greater tuberosity and teres tubercle are flared out with associated crests to dominate the humerus.



**Fig. 2.2** Comparisons of talpid humeri: **a** *Scaptochirus* sp., right humerus V8913; **b** *Yunoscaptor* sp., left humerus V8840; **c** *Yanshuella yushensis*, right humerus V8914. *Yunoscaptor* V8840 shown in posterior view for comparison with the others in anterior view; its small deltoid spike is reconstructed from V8921, in which the spike is preserved. Scale bar = 5 mm for all

Distally, the condyles are widely separated with the capitulum and fossa for the M. flexor digitorum ligament marginal in position; this yields a broad measurement 6, well over half the length of the humerus. The shaft is stout, its breadth nearly half the length (Table 2.2). The long axis of the head is angled medially with respect to the long axis of the humerus as in talpines and scalopines. The pectoral prominent ridge is relatively distal, due to the greatly expanded proximal end of the humerus and distal extension of the teres tubercle. It borders a triangular proximal depression on the anterior side of the bone, extends distally nearly two thirds the humerus length, and ends in a low pectoral tubercle. In keeping with other Talpini, the scalopine ridge is an undeveloped faint line and the notch between head and lesser tuberosity is shallow (see Hutchison, 1968). The teres tubercle and the entepicondylar process are so expanded that the medial reentrant between them is only a small, circular hole, as in living *Scaptochirus*.

The broken molar (Fig. 2.3a) preserves a slightly worn talonid, but the trigonid is broken off at the base of the metalophid. The tooth is consistent with m2 of *Scaptochirus* in size (width, 1.5 mm) the presence of a strong entostylid (terminology of Engesser, 1980) low and posterior to the entoconid, and in that the talonid is as wide as the metalophid. The hypoconid (height, 2 mm) arches upward and lingually. The cristid obliqua reaches the middle of the metalophid. The V-shaped talonid basin is open lingually.

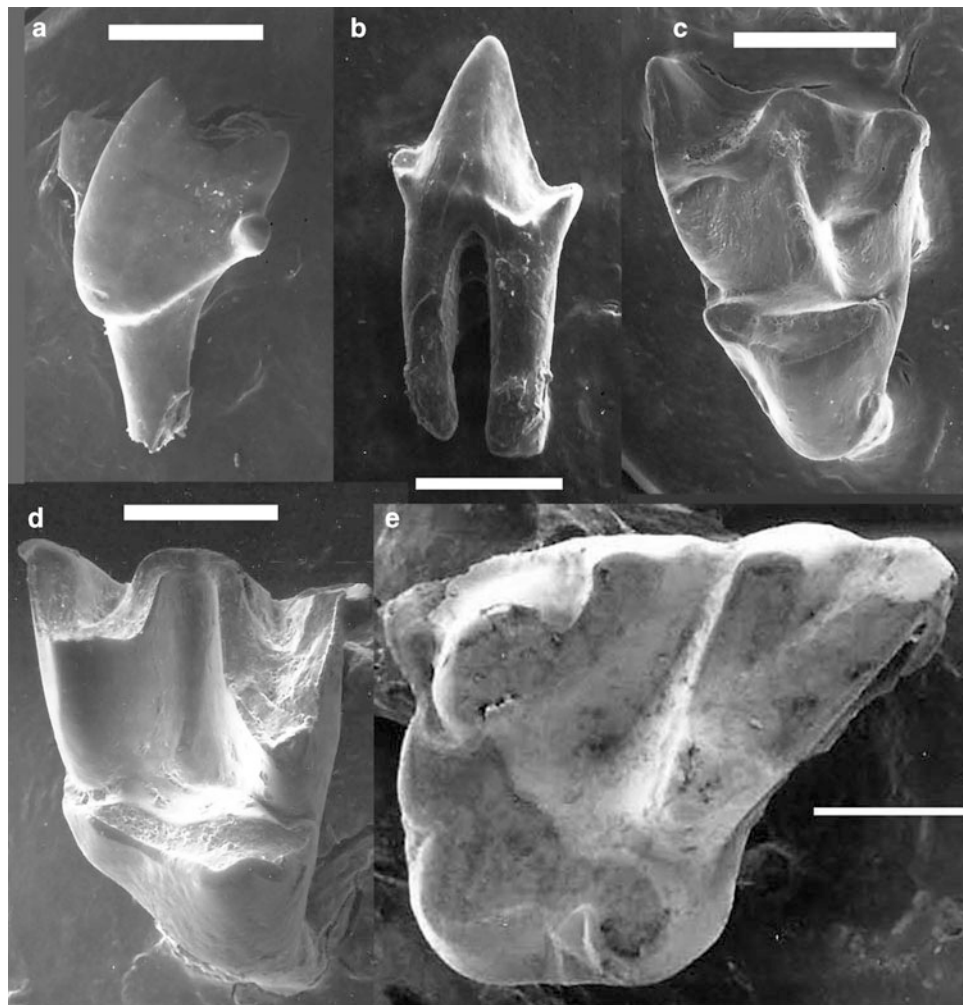
Discussion: This record is a welcome surprise for the Yushe fauna. The humerus is fully modern and of appropriate size for *Scaptochirus moschatus*, which lives today in northeastern China. It is also highly comparable with material from Zhoukoudian that has been given the name *Scaptochirus primitivus* Zdansky, 1928. Although subsequent workers have disputed the distinctness of these two species, the presence of *Scaptochirus* in the Zhoukoudian fossil record is well supported there by dentitions. Zhoukoudian material is plentiful and includes the distinctive hypertrophied p2 of the genus.

The Yushe molar resembles both living and fossil specimens. Furthermore, unpublished Frick collection material from Shouyang supports presence of the same taxon elsewhere in the late Neogene of Shanxi Province. The Yuncu specimens represent the oldest (Pliocene) records of *Scaptochirus* pending evaluation of the Shouyang fossil occurrence. Yushe material is close to *S. moschatus* in size, but differs from the smaller species *S. jiangnanensis* from the early Pleistocene of Anhui Province (Jin and Liu 2008).

**Table 2.2** Dimensions of talpid humeri (following Storch and Qiu 1990)

Measurement	1	2	3	4	5	6
Specimen						
<i>Scaptochirus</i> sp.						
V8913	14.10	10.08	4.61	5.29	8.48	11.52
<i>Yanshuella yushensis</i>						
V8914		10.43	6.38	3.90	7.64	
<i>Yunoscaptor</i> sp.						
V8894	12.13	9.62	6.96	2.76	5.66	7.73
V8895	12.86	9.16	6.15	2.70	6.53	6.8+
V8919	12.04	9.37	6.43	2.76	5.69	7.64
V8920			6.92	2.99	6.21	
V8921		8.30	5.59	2.64	5.57	

*Measurements* (1) length, (2) length from distal end of teres tubercle to condyles, (3) length from proximal end of teres tubercle to condyles, (4) shaft breadth (parallel to condyles), (5) condyle breadth, (6) proximal breadth



**Fig. 2.3** Scanning Electron Microscope (SEM) views of talpid teeth. **a** *Scaptochirus* sp. talonid V8910 in posterobuccal view; **b** and **c** *Yunoscaptor* sp., p4 V8908.3 in buccal view and M2 V8906 in occlusal view, respectively; **d** *Yanshuella yushensis* sp. nov., M2 V8912 in occlusal view; **e** *Desmana* sp., M2 V8905 in occlusal view. Scale bars are 1 mm

Tribe Scalopini Fischer, 1814

*Yanshuella* Storch and Qiu, 1983

*Yanshuella yushensis* sp. nov.

1991 *Yanshuella primaeva* Tedford et al.

1991 *Yanshuella primaeva* Flynn et al.

1994 *Yanshuella primaeva* Flynn and Wu.

1997 *Yanshuella primaeva* Flynn et al.

Holotype: V8915, right dentary broken anteriorly and at superior and posterior parts of the ascending ramus, with enlarged alveolus for i3, single alveolus for c1, and preserved p2–4, m1–3 (Fig. 2.4).

Type locality: YS161, Jiayucun, Tancun subbasin of Yushe Basin, uppermost part of Mahui Formation, about 5.8 Ma.

Hypodigm: V8915; V8916, left dentary with i3 alveolus, canine stub, p2–4, m1, and m3 from YS159; V8917, right dentary fragment with m1–2 from YS143; both Mahui Formation of Tancun subbasin; V8911, broken left M2 from YS8, and V8912, right M2 in maxilla fragment from YS9 (Fig. 2.3d), both Mahui Formation of the Yuncu subbasin. All sites 6.3–5.8 Ma. Referred right humerus fragment V8914 from YS99, Mazegou Formation of Yuncu subbasin, about 3 Ma.

Etymology: Species name in reference to the geographic setting.

Distribution: Presently known only from the Yushe Basin.

Diagnosis: Largest species of *Yanshuella*; p2 and p3 two-rooted; p4 robust, but lacking strong anterior cusp; cristid obliqua of m2–3 joins the metalophid lingual to the midline; weak buccal cingula on lower dentition; M2 with symmetrical W-shaped ectoloph, curled parastyle and metastyle, moderately cleft mesostyle, strong metaconule and smaller paraconule, weak and broken ectocingulum, short metacingulum and abbreviated paracingulum.



**Fig. 2.4** Photograph of holotype V8915, right dentary with dentition of *Yanshuella yushensis*, in dorsal (above) and lateral (middle) views; molar dentition expanded below. Scale bars = 1 mm

Description: This large mole is represented by mandibles and a few isolated elements. The holotype dentary preserves enough of the ascending ramus to indicate that it arose perpendicularly from the horizontal axis. The ventral border of the mandible undulates slightly, rising to its highest point above the anterior portion of m1. Depth is 2.7 mm below m2. The one prominent mental foramen lies below the anterior portion of p4; a second one occurs behind p4 in V8917. The symphysis ends below p2–p3 boundary. A retromolar gap of 1.5 mm lies between m3 and the ascending ramus.

Tooth formula of the dentary includes a large i3 rooted below p3, canine, p2–4, m1–3. The anterior dentition is crowded, the canine small, the premolars two-rooted. The crowded condition is suggested by the *en echelon* nature of p2–3, whose long axes are oblique to the tooth row. Canine and incisors procumbent, but premolars less so. From anterior tip of inclined p2 through vertical p4, the premolar row is 3.4 mm in V8915; it is 3.6 mm in V8916. Anterior border of canine alveolus to posterior wall of p4 is 3.9 and 3.8 mm, respectively. Anterior border of canine alveolus to posterior wall of m3 is 10.7 and 10.3 mm, respectively. The molar row is longer in the holotype, but p4 is larger in V8916. The base of the small canine preserved in V8916 is anteroposteriorly compressed, slightly oblique and oriented posterolingually. Its orientation anticipates the oblique aspect of p2–3, whose roots are obliquely placed, one anterolabial and one posterolingual, and whose crowns are correspondingly oblique. There is one principal cusp on these teeth, with a weak posterolingual ridge plunging to a small basal shelf or cingulum at that corner of the tooth. The canine appears to be smallest, followed by p2 in size; p3 is larger, and its cingulum, though faint, appears to encircle the tooth and supports a small basal posterolingual cusp.

Table 2.1 records measurements of p4 and molars. The former is markedly larger than anterior teeth, wide relative to some moles, and is dominated by a high cusp. The cusp is central medio-laterally, but anterior in position and with a posterolingual ridge that plunges to a shelflike posterior cingulum. The cingulum squares the back of the tooth and bears a distinct posterolingual cusp. Though faint labially, the cingulum is prominent along the lingual side of the tooth and bears a small anterolingual tubercle in V8916 (V8915 is damaged). The more worn V8916 bears a distinct posterolingual wear facet.

Molars are high-cusped, especially buccally, with trigonids higher than talonids, and with m2 largest, m1 wider posteriorly, m3 wider anteriorly. Trigonids and talonids are open lingually, except for m3, in which the talonid is blocked by an entocristid running anteriorly from the entoconid. The trigonid of m1 is less acute than that of the other molars. Its paraconid is lower and smaller than in the other molars. Anterior walls of trigonids are slightly convex and bear a weak cingulum; posterior walls of trigonids and of

talonids are parallel, straight, vertical walls. The anterior cingulum terminates lingually in a low cusp, the parastylid. The parastylid of each molar abuts the talonid cusp of p4 or the entostylid of m1 and m2. The parastylid increases in prominence posteriorly. Entostylid is lacking in m3. The labial cingulum is undeveloped except between protoconid and hypoconid. The cristid obliqua intersects the trigonid lingual to the midline in m1, more lingually in m2–3. In the latter teeth, it approaches the metaconid, which bears a posterior fold, reminiscent of an undifferentiated metastylid.

The paracone and metacone of M2 (Fig. 2.3d) are nearly symmetrical, except that the paracone extends somewhat more lingually. Parastyle and metastyle are curled and add to the symmetry, as does the divided mesostyle, which in occlusal view is a smooth inverted U-shape. The tooth is wider than long (length, width = 2.38, 2.73). The protocone has a broadly open V-shape. The metaconule is prominent, but the paraconule is smaller. Cusp walls are rather tall; metacingulum and paracingulum descend steeply from metaconule and protocone, respectively. Short metacingulum ends below metacone base; paracingulum ends lingual to paracone. The ectocingulum is undeveloped, except in valleys buccal to paracone and metacone. Three roots including a large lingual root are present, plus a small rootlet below the paracone.

The broken humerus (Fig. 2.2c) is associated here based on size (larger than those attributed to *Yunosaptor*; see below) and similarity to that of *Yanshuella primaeva*. It is more heavily built, with thicker shaft and more distal teres tubercle (apparently more adapted toward fossorial behavior), than is that of *Yunosaptor*. Broken proximally, measurements 1 and 6 cannot be made. One additional feature consistent with assignment as *Yanshuella* is the slight development of the pectoral ridge and absence of a pectoral tubercle at its distal terminus.

Discussion: Storch and Qiu (1983) described abundant and complete mole material from Ertemte, Inner Mongolia, recognizing two forms. The more common and larger mole was present in original collections described by Schlosser (1924) under the name of *Scaptochirus primaevus*. Storch and Qiu (1983) were able to describe this taxon definitively, and gave it the new generic name *Yanshuella*. As isolated teeth were discovered in Yushe Basin, it was believed that the same species was present there (Flynn et al. 1991, 1997). More material, including mandibles and a humerus, show that the Yushe species differs from *Yanshuella primaeva*. In addition to larger size, the Yushe taxon shows two roots on anterior premolars, more lingual intersection of the cristid obliqua with the trigonid, and weaker cingula on both upper and lower teeth. These features show that while the common large mole of Yushe is similar to that of Mongolia, it is not the same, although its long chronologic span at Yushe likely encompasses the age of Ertemte and Harr Obo. *Y. yushensis*

is also larger than *Y. columbianus* (Hutchison, 1968) of Oregon.

Most of the specimens referred to *Yanshuella primaeva* occur in the Mahui Formation of Tancun and Yuncu subbasins of Yushe Basin from localities clustering about 6.3 to 5.8 Ma. The referred humerus occurs in much younger deposits, the upper part of the Mazegou Formation (Yuncu subbasin) at 3 Ma. The humerus, also large for *Y. primaeva*, implies an independent lineage for this mole in Yushe Basin.

*Yunosaptor* Storch and Qiu, 1990

*Yunosaptor* sp.

Referred material: V8906 right M2 from YS97, (length, width = 2.02, 2.46); V8907.1, left m2 fragment, and V8907.2, right m2 or m3 trigonid from YS4; V8908.1, left M2 (worn, 2.25, 2.70), V8908.2, right p3, V8908.3, left p4, and V8908.4, right m2 or m3 trigonid, from YS 50; all Gaozhuang Formation localities, about 4.3 to 4.7 Ma. V8918, right m2 from YS143, and five humeri V8909, 8840, 8919, 8839, 8921 from YS1, YS151, YS152, YS154, YS157, respectively, all Mahui Formation of the Tancun subbasin, about 6 Ma (Fig. 2.3b, c).

Distribution: *Yunosaptor scalprum* Storch and Qiu, 1990 was named for material from the late Miocene Shihuiba Formation, Lufeng County, Yunnan. In the Yushe Basin the related mole occurs in Mahui and Gaozhuang formations of Yuncu subbasin (YS 50 near Nanzhuanggou, YS4 between Gaozhuang and Zhaozhuang, and YS97, Chuan Ze Gou, 0.8 km northwest of Nan Zhuang Gou). YS143 and all humeri are from the Mahui Formation of the Tancun subbasin. Temporal range is >6.0 to 4.3 Ma.

Description: This mole is smaller and lower crowned than the other common mole of Yushe, *Yanshuella yushensis*. Its molars are more gracile and its smaller humerus is less heavily built. M2 is asymmetrical externally in that the metacone wing of the ectoloph extends straight posterolabially much farther than does the paracone wing. The parastyle is curled in V8908.1, not in V8906. The mesostyle is undivided. There is no noticeable metastyle. The metaconule is prominent and the paraconule is a faint bulge on the preprotocrista. The ectocingulum is present in the paracone and metacone valleys only. There is a weak cingulum around the protocone, and the metacingulum and paracingulum are short. There are three major roots and a small, central rootlet.

Both specimens attributed to this taxon as premolars are two-rooted. V8908.2 is a blunt and low crowned p3 with larger anterior root. Its main cusp is anterior in position, lateral to the midline of the tooth. Dominating the cingulum is a posterior heel with a small cusp. V8908.3 is a sharp-cusped p4 (length, width = 1.4, 0.8). Its trenchant main cusp is compressed mediolaterally, nearly vertical lingually and curving inward buccally. A cingulum encircles

the tooth, bears a small anterior cusp, and a posterior raised heel capped by a transverse talonid cusp. Of the two long roots, the posterior is heavier.

Lower molars are represented by a corroded tooth and fragments. V8918 is missing enamel labially. Its length, 2.05 mm, may be somewhat reduced by corrosion. This tooth is considered to represent m2 because trigonid and talonid are subequal in size, the cristid obliqua intersects the trigonid near the lingual side of the tooth at a metastylid, the talonid is closed by an entocristid, there is a prominent cusp (parastylid) anterolingually, and there is a small entostylid (possibly abbreviated by enamel loss). V8907.2 is a trigonid of similar size and dimensions, but its parastylid is much smaller. V8908.4 also has a small parastylid, but is larger, with more widely open trigonid (relatively longer) and appears to have a more labial cristid obliqua. Despite its larger size it may represent m1 (possibly another taxon).

The humerus (Fig. 2.2b) is represented by four left specimens, three nearly complete, and one right fragment. These are scalopine in structure, as evidenced by the mediolaterally-directed head and the prominent, raised scalopine ridge. The shaft is relatively slender. The teres tubercle does not extend as far distally as in other moles (hence measurement 3 is relatively large). The pectoral ridge terminates lateral to the midline of the humerus in a small, raised pectoral tubercle. Other features correspond to those of *Y. scalprum*.

Discussion: In all features, the Yushe sample of *Yunosaptor* matches the type species of the genus *Y. scalprum* from Lufeng, Yunnan, although that locality is older, perhaps near 7 Ma. Discrepancies are minor and, at present, can be attributed to individual variation. A few humeri seem relatively large, but m2 (V8918) is a bit small. M2 is consistent in ectoloph shape, mesostyle simplicity, and length-width ratio. Lower p4 is consistent in cusp disposition, including the anterior cingulum cusp. Lower molars show the metastylid. The scalopine humerus shows a medial pectoral tubercle. Still, the material is insufficient to demonstrate occurrence of the same species in Yushe Basin, and we cite it as indeterminate at the species level.

Subfamily Desmaninae Mivart, 1871

*Desmana* Gldenstaedt, 1777

*Desmana* sp.

1991 *Desmana kowalskae* Flynn et al.

1994 *Desmana kowalskae* Flynn and Wu

1997 *Desmana kowalskae* Flynn et al.

Referred material: V8905, left M1 (3.72, 2.89 mm);

Fig. 2.3e.

Locality and age: YS50, early Pliocene Gaozhuang Formation, Yuncu subbasin, 4.7 Ma.

Distribution: *Desmana* is widespread, if uncommon, throughout Eurasia. A similar form, probably identical, is

known from the Bilike fauna of Inner Mongolia, also early Pliocene in age (Qiu and Storch 2000).

Description: The molar is trapezoidal in outline with nearly parallel short lingual and long buccal walls. The anterior wall is transverse, but the distal wall is oblique due to the posteriorly-jutting metacone-metacrista, which makes a large, oblique shearing crest. The protocone is large, but worn low, the paracone is small, and the metacone is a high cusp. The protocone is anterior in position, more anterior than the paracone. Posterior to the protocone is a smaller metaconule, inflated as an independent cusp. The metaconule joins the protocone via a small accessory cusp between them, but is isolated from the metacone. A short lingual cingulum spans the gap between protocone and metaconule. The paraconule is a swelling of the thick protoloph. Its posterior arm joins the paracone, and its anterior arm is confluent with the thin anterolabial cingulum. The external border of V8905 is slightly convex, consisting of an isolated parastyle, a postparacrista, and a pre- and post-metacrista. The postparacrista and premetacrista lead to a double mesostyle that is broadly divided. The deep trigon basin drains lingually between the two mesostyles. The pre- and postmetacrista make a narrow V-shape, terminating posterolabially in a metastyle. The metastyle lies at the end of the posterior cingulum; the parastyle is bordered by a cingulum at the anterobuccal corner of the tooth. There are three roots plus a small, central rootlet.

Discussion: The low crown height, construction of the metacone and paracone, and strength of the metaconule are all consistent with reference to *Desmana*. Among known *Desmana*, V8905 represents a large species, but it is smaller than living *D. moschata* or Pliocene *D. thermalis*. Its size and width/length ratio (0.78) are consistent with *D. kowalskae*. Flynn et al. (1991) used this identification, but Rzebik-Kowalska (1994) considered the species indistinguishable from *D. nehringi*. In addition, Qiu and Storch (2000) noted differences from *D. kowalskae* in their larger desman sample from Bilike, Inner Mongolia. Therefore, we now consider the Yushe desman as indeterminate to species.

This large talpid indicates aquatic habitat, for example streams or ponds. It is therefore a strong indicator of moist conditions with permanent water. No desmans occur in eastern Asia today. Their presence in both Bilike and Yushe Basin speak to widespread mesic conditions throughout much of Asia during early Pliocene time.

### 2.2.3 Family Soricidae Fischer, 1814

Subfamily Soricinae Fischer, 1814

Tribe uncertain

*Paenelimnoecus* Baudelot, 1972

cf. *Paenelimnoecus* sp.

Referred material: V8841.1, left lower incisor; V8841.2-3, right upper incisors.

Locality and age: YS145, upper Mahui Formation of Tancun subbasin, about 5.8 Ma.

Description: This small shrew is represented by three specimens of anterior dentition from one locality. While lacking red pigmentation, the generally off-white teeth show faint yellow tinges that may indicate leached pigment. This is most convincingly demonstrated by the yellow cusp tips of V8841.2, in contrast to the rest of the tooth, which is white. V8441.1, lower incisor broken at the base (2.1 mm length preserved), is simple and bicuspluate, posterior to the tip. Upper incisors show a posterior cusp that in lateral view is short relative to the principle cusp. The principle cusp is simple, and the talon supporting the posterior cusp is relatively long in labial view. The better preserved V8441.2 (1.43 mm long) shows a strong labial cingulum.

Discussion: *Paenelimnoecus*, a small shrew known across Eurasia, has been considered an allosoricine, but is here unaffiliated with a tribe. *P. obtusus* Storch (1995) was named for the late Miocene Ertemte fauna of Inner Mongolia, and this species or a related form occurs in the early Pliocene Bilike fauna of Inner Mongolia (Qiu and Storch 2000). Presence of a similar shrew in the late Miocene of Tancun subbasin, Yushe Basin, would not be surprising. The Yushe specimens are close in size to those of Bilike, but a bit smaller than typical for the type material of *P. obtusus* from Ertemte. The specimens from locality YS145 attest, in any case, to presence of a small shrew in the late Miocene of Yushe Basin.

Tribe Soricini Fischer, 1814

*Sorex* Linnaeus, 1758

*Sorex* sp.

1991 *Sorex* sp. Flynn et al.

1994 *Sorex* sp. Flynn and Wu

1997 *Sorex* sp. Flynn et al.

Referred material: V8894.1, left M1; 8894.2, right dentary fragment with worn m1; 8894.3, right upper incisor, and 8894.4, left upper incisor.

Locality and age: YS120, Haiyan Formation, Yuncu subbasin, ~2.2 Ma, reversed lower part of the Matuyama chron.

Description: Specimens are heavily pigmented red, the pigment generally well preserved. M1 is nearly as long as it is wide (1.15, 1.30; Fig. 2.5a). The posterior wing of the ectoloph is longer than the anterior end due to an elongate postmetacrista. The ectoloph is W-shaped, with the mesostyle lingual to the line joining the parastyle and metastyle. Conules are not developed. The metaloph is a weak ridge

intersecting the posterior arm of the protocone. No protoloph is evident. Other than the strong anterior arm of the protocone, which intersects the paracone low on its anterior face, there is no anterior cingulum. Lingual and posterior to the protocone is a short cingulum that is confluent with the posterior cingulum. The hypocone, weakly connected to the protocone, shows a posterior spur. Posterior emargination of the hypocone flange is moderate.

The upper incisor (lengths, 1.25, 1.35 mm; Fig. 2.5b) is strongly arcuate in profile. Its posterior cusp is prominent. The major cusp is weakly fissident (possessing a slight bifurcation near the apex). Its labial cingulum is weak.

V8894.2 is a dentary fragment lacking the posterior end and broken in front of m1. It contains a worn m1 and the roots of m2–3. Alveolus length of m1–3 is 3.64 mm. The mental foramen is below the anterior root of m1. The worn first molar (length, width relative to the long axis of the tooth row = 1.60, 0.85) overhangs the dentary on its lateral side. The paraconid and metaconid are widely spaced, the trigonid draining lingually. The cristid obliqua intersects the posterobuccal corner of the protoconid. The entoconid-entocristid closes the talonid basin.

Discussion: The material of this mid-to-large-size shrew is insufficient to establish identity with similar known species. It is consistent with *Sorex* in pigmentation, the fissident incisor, and in morphology of the molars. It is about the size of living *S. excelsus* from Yunnan, but perhaps more similar morphologically to the smaller northern *S. cinereus*. The material presents enough information to rule out identification with *Sorex* species previously described from the late Miocene Ertemte (Storch 1995). It is approximately the same size as *S. pseudoalpinus* identified at Ertemte, but has a less fissident incisor, and smaller hypocone with weak metaloph present. The Yushe material resembles “*Sorex* sp.” from Zhoukoudian Locality 3 described by Pei (1936).

Tribe Nectogalini Anderson, 1879

Subtribe Neomyini Repenning, 1967

*Soriculus* Blyth, 1854

*Soriculus praecursus* Flynn and Wu, 1994

1991 *Episoriculus* n.sp. Flynn et al.

1994 *Soriculus praecursus* Flynn and Wu

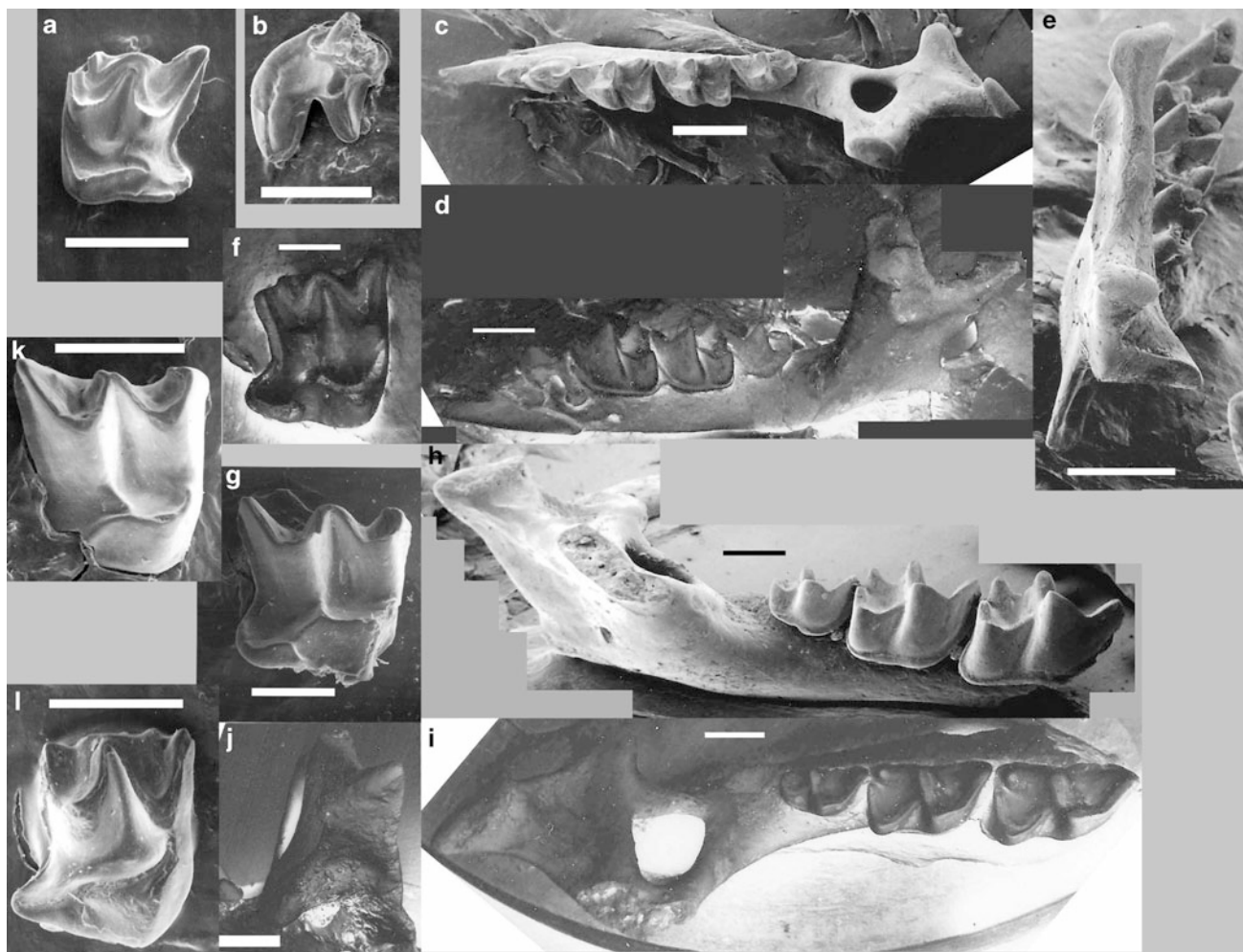
1997 *Soriculus praecursus* Flynn et al.

Holotype: V8898.1, complete left dentary with all teeth.

Hypodigm: V8898.1; 8898.2, left dentary fragments with m2–m3; 8898.3–0.4, two isolated right M2 (Fig. 2.5c–f).

Type Locality and age: YS50, early Pliocene Gaozhuang Formation, Yuncu subbasin, 4.7 Ma, presently known only from Yushe Basin.

Diagnosis: Smaller than *S. nigrescens* (Gray, 1842), about the size of *S. (Chodsigoa) lamula*, Thomas, 1912 with



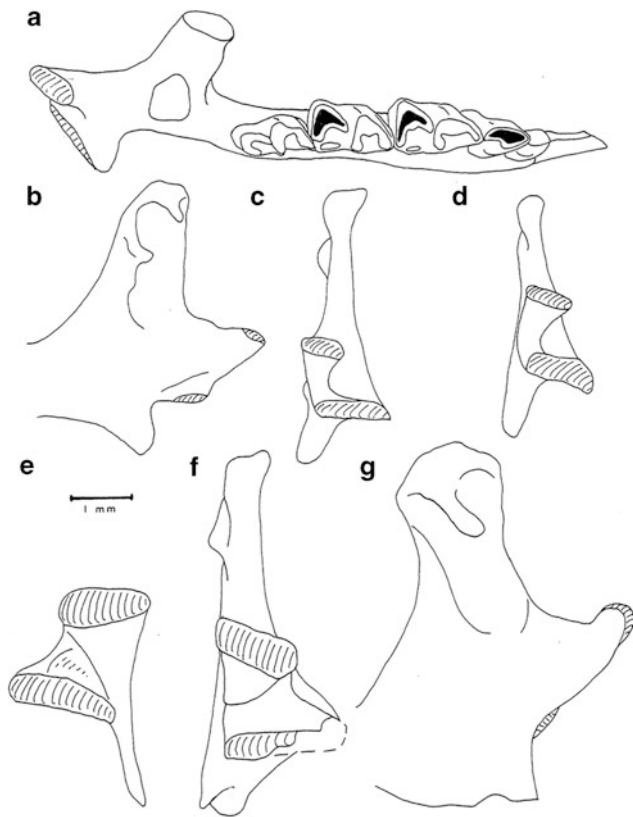
**Fig. 2.5** SEM views of shrew mandibles and molars. **a, b** *Sorex* sp., left M1 V8894.1 and V8894.2, right upper incisor; **c–e** V8898.1 *Soriculus praecursus* left mandible, in **c** dorsal view, **d** lateral view, **e** posterior view of articulation, and **f** V8898.3 *Soriculus praecursus* right M2; **g** V8895.1 *Lunanosorex lii* right M1; **h–j** V8900 *Beremendia pohaiensis* right mandible, in **h** dorsolateral view, **i** dorsal view, **j** posterior view of articulation; **k** V8897 cf. *Sulimskia* sp. right M1; V8899 *Crocidura* sp. right M2. Scale bars: 1 mm

crowded anterior dentition, labial incisor flange ending below back of p4; lower condyle not transversely elongated and not anterior in position; coronoid process strong and high, inclined slightly, with short spicule midway to upper sigmoid notch; lower cheek teeth uncompressed laterally, differing from the smaller *S. (Episoriculus) caudatus* (Horsfield, 1851); m3 not greatly reduced; M2 with weak hypocone and not deeply emarginated.

**Description:** No new material has been assigned to this taxon since its description (Flynn and Wu 1994), but new measurements are presented in Table 2.1. The structure of the mandible is much like closely related living forms that cluster as Subtribe Neomyini. The double articulation is L-shaped, the interarticular area being a slender, sculpted ridge (Fig. 2.6). The upper arm of the articulation and the coronoid process tilt laterally from the ramus in posterior view. The lower articulation is separated from the lower sigmoid notch by a reentrant. These

features are similar to the condition in the larger *Soriculus nigrescens* and *Neomys fodiens* (Pennant, 1771), and to *S. (E.) caudatus*, although the coronoid of the former two has a distinct anterior inclination of its tip. *S. (Chodsigoa)*, although similar in size to *S. praecursus* differs also in its heavier condyle, anteriorly displaced lower articulation, and more tilted coronoid process. The small coronoid spicule extends half way down the sigmoid notch. Position and relatively large size of the internal temporal fossa and mandibular foramen resemble *S. (E.) caudatus*. Mental foramen lies below the middle of m1.

The lower incisor shows both wear and damage, but appears relatively short and suggests that accessory cusps were minor. A low posterior cusp is suggested by a widening of the wear surface, dorsally on the enamel; any more anterior cusps are not in evidence. Incisors of some living soriculines (e.g., *Chodsigoa*) are also weakly cuspluate. *Episoriculus* tends to have two cusplues. The incisor has



**Fig. 2.6** Drawings of shrew mandibles featuring articulation morphology. **a–c** *Soriculus praecursor* holotype V8898.1 in dorsal, lateral and posterior view; **d** posterior view of modern *Episoriculus caudatus* (MCZ 20726); **e** posterior view of articulation of *Beremendia pohaiensis* (V8900); **f, g** *Luananosorex lii* (V8895.4) in posterior and lateral views

strong lingual and buccal cingula, and its exposure extends rather far posteriorly on the buccal side to below p4 and the trigonid of m1. Posterodorsal to this is the mental foramen, below the front of the talonid of m1. Premolars are damaged buccally, but show a cingulum on both sides. The first antemolar, known as a1, shows one elongate wear facet, is crowded between the incisor and the following premolar (p4), and extends on the lateral side under half of p4. The buccal flange of p4 sweeps posteriorly much farther than does the lingual part of the tooth, to a point below the middle of the trigonid of m1, and well below the level of the base of the molar row. The tooth is elongate, highest crowned along its median axis. Its apex is a relatively small trigonid, which wears as a lingually sloping triangular surface. There is an abbreviated talonid, with high buccal wall that continues the trigonid wear facet. The talonid is open and drains lingually.

The molar row is 4.33 mm long. The first molar is largest and overhangs the talonid of p4. The trigonid V shape is broadly open lingually due to the anteriorly projecting paraconid. The paraconid is the lowest cusp of the trigonid; the protoconid is highest, its apex at the midline of the tooth.

The molar is widest posteriorly at the acute-angle hypoconid. The cristid obliqua intersects the protoconid. The entoconid is high and slopes anteriorly to close the talonid basin, but lacks an entoconid crest. There is a narrow trough posterior to the entoconid. A cingulum encircles the tooth. The second molar is similar, but the trigonid makes a more acute angle, the paraconid being less anteriorly directed, and the anterior and posterior widths are equal. The last molar is smallest, its talonid reduced as is typical for m3. Its cingulum is fainter than in m1–2. The talonid is a double-cusped, small and enclosed basin. The cristid obliqua is directed toward the metaconid. The two specimens show variation in size, the m3 being relatively smaller in V8898.2.

The fossil upper molars are identified as M2 due to their proportions (width slightly greater than length) and the nearly symmetrical ectoloph. The ectocingulum is limited to the external paracone and metacone valleys. The crescentic hypocone is joined to the protocone by a low ridge. The hypocone flange, sculpted posteriorly, is continuous with the posterior cingulum. The pre- and postprotocristas make a symmetrical V-shape. The preprotocrista intersects the base of the paracone, but other than locally at the intersection, there is no precingulum. The postprotocrista terminates as a wear feature short of the metacone, but is continued by a weak and low metaloph.

Two upper incisors from YS50 were briefly mentioned by Flynn and Wu (1994). These large specimens are assigned to *Luananosorex* (below).

Discussion: Hoffman (1986) and McKenna and Bell (1997) consider *Soriculus* as a genus containing a number of species previously assigned to distinct genera *Chodsigoa* and *Episoriculus*. The differences between living species are minor and their polarities are undemonstrated, so the latter taxa are retained as subgenera. Affinity of Pliocene fossils to a living subgenus would be difficult to defend. The Yushe shrew, while unlike living species, is therefore assigned to *Soriculus*, *sensu lato*, without implying subgeneric relationship.

Taxa related to *Soriculus* (*Soriculus*) other than *Neomys* show little pigment, and pigment is at best doubtfully preserved in the fossils. Living *Chodsigoa* and *Chimarogale*, for example, show almost none. *Soriculus* has a bit more pigment, *Episoriculus* more. Concerning mandibular morphology, there are resemblances to *Episoriculus*, but also to *Soriculus* and *Neomys*. *Chodsigoa* is distinct in its heavier and more twisted articulation. One distinction of the fossil mandible is that the tip of its coronoid process inclines slightly anteriorly, while that of *Episoriculus* is nearly vertical. Dentally, the Yushe taxon resembles *Episoriculus* in that the anterior dentition is crowded, the external flange of p4 reaches well below the level of the molar row, and the talonid of m3 is basined with two cusps. *Chodsigoa* has a more reduced m3 talonid and lesser p4 flange reaching only somewhat below the level of the molars. *Soriculus*

*nigrescens*, a more fossorial species, also has a conservative p4, and its molars appear laterally compressed. The Yushe species resembles *Chodsigoa* in incisor morphology, both having weak dorsal cuspules. *Episoriculus* p4 has a more prominent posterior (pigmented) cusp, and tendency to show a second cuspule. Living *Soriculus* species tend to have a more sectorial p4, without a triangular trigonid wear facet. In p4 morphology, then, the Yushe shrew is likely primitive. Since it shows a mosaic of soriculine as well as distinctive features, we assign the new species as *Soriculus praecursus* without attribution to subgenus.

Other fossil soriculines include a Pleistocene species from Zhoukoudian. Originally “*Neomys bohlini*,” Repenning (1967) transferred the species to *Chodsigoa*, based partly on jaw morphology. *Soriculus* (*Chodsigoa*) *bohlini* (Young 1934) has a different jaw articulation and is smaller than *Soriculus praecursus*. Kotlia (1991) named an Indian form *Episoriculus repenningi* from 2.4 Ma deposits in Kashmir. This diminutive species occurs near the range of living *Episoriculus*, exhibits two cuspules on the lower incisor, and p4 extending below the molar row, making subgeneric assignment reasonable. Jin and Liu (2008) named *Soriculus fanchangensis*, an early Pleistocene species from Anhui Province, which is much smaller than *S. praecursus*.

Late Pliocene *E. giberodon* from Poland was assigned to *Episoriculus* by Repenning (1967) when he reviewed soriculines, and raised the subgenera to generic rank. De Bruijn et al. (1970) added good material from the Isle of Rhodes, Greece. In distinction from other subgenera, the assignment is defended by a number of features that remain to be evaluated for polarity. Recognition of this material as having affinity to living *Episoriculus caudatus*, if valid, would indicate an extraordinarily wide distribution for this group of shrews.

On balance, *Soriculus praecursus* seems to share most features with *Episoriculus*, but there are differences in p4 morphology, simplicity of the incisor, and apparent lack of pigment. The Yushe species is somewhat larger than *E. caudatus*, slightly smaller than *Chodsigoa hypsibia*, and near the present geographic range of *Chodsigoa*. Because the generic status of the living subgenera and their cohesiveness with fossil species remain untested, we do not attempt formal affiliation with a living subgenus. The Yushe taxon probably points toward the suite of features that were primitive for the last common ancestor of the *Soriculus* group.

Tribe Beremendiini Reumer, 1984

*Beremendia* Kormos, 1934

*Beremendia pohaiensis* (Kowalski and Li, 1963)

1991 *Peisorex* n.sp. Flynn et al.

1994 *Peisorex pliocaenicus* Flynn and Wu

1997 *Peisorex pliocaenicus* Flynn et al.

1996a *Beremendia pohaiensis*, in part, Jin and Kawamura.

Referred material: V8900, right dentary with m1–m3 (Fig. 2.5h–j).

Locality and age: YS5, Mazegou Formation, Yuncu subbasin, late Pliocene about 3.3 Ma.

Distribution: In addition to Yushe Basin, the species is known from Plio-Pleistocene deposits of Liaoning (Haimao) and Hebei (near Tangshan) Provinces (Jin and Kawamura 1996a).

Description: The single Yushe specimen is a large dentary with molars, broken below m1 through the mental foramen, which is below the front of the talonid of m1. The coronoid process is broken so that anterior inclination cannot be evaluated, but enough is present to show that the process diverges strongly laterally from the horizontal ramus. The condyle is preserved, showing a large, protruding, and ventrally shifted lower articulation, and triangular upper articulation with broad interarticular area. The internal temporal fossa is enormous, but the mandibular foramen is not as large as in other specimens of the species.

Molars decrease markedly in size posteriorly, the first being largest, the third less than half its size. Their lingual walls are arrayed in a straight line, with the small m3, therefore, in a relatively lingual position. Teeth are measured with respect to this major axis. Roughly parallelograms, therefore, length is measured with reference to the postero-labial corner of the tooth and tip of the proto-lophid (width is the maximum perpendicular to length; see Table 2.1). Tooth color is dark in the fossil, but it is not clear whether this reflects original iron staining. While m1 widens slightly posteriorly, m2 is nearly as wide posteriorly as anteriorly. Trigonids are widely open lingually, having a long, anteriorly directed proto-lophid. Paraconids are nearly as tall as the metaconids. The cristid obliqua intersects the trigonid wall lingual to the protoconid. The sharp entoconid has an entoconid crest that continues anteriorly to the trigonid, closing off the talonid. However, there is a narrow trough posterior to the entoconid and adjacent to the posterolophid that traverses the back of the talonid from the hypoconid. The trigonid of m3 is a small version of that of m2, but the tooth is markedly smaller, in large part due to the diminutive talonid. The tiny talonid is encircled by a low crest that originates (like the cristid obliqua) at a point lingual to the protoconid, passes the position of the hypoconid and posterolophid, and stops at the position of the entoconid, leaving a gap between it and a lingual crest running from the trigonid. There is a strong buccal cingulum on all of the molars. The lingual cingulum is weak in m1, faint on m2, and is only hinted anteriorly on m3.

Discussion: This large shrew is represented by only one specimen in Yushe Basin. Flynn and Wu (1994) realized its similarity to *Peisorex pohaiensis* Kowalski and Li 1963, but were impressed by difference in size. The type specimen of

*Peisorex pohaiensis*, V2671, has m1–m3 length of 6.12 mm, while that of V8900 is 6.64 mm (remeasured). This difference of V8900 being 8.5% bigger is less than the 15% reported by Flynn and Wu (1994), but explained by three factors. First, the teeth of V8900 are slightly larger than those of holotype V2671. Second, the dental arcade is curved in V2671, with m2 and m3 successively slightly lingually canted with respect to m1. Third, m3 is relatively smaller in V2671 (see Table 2.1). Although m1 and m2 are not much different in size between the two specimens, the impression from the total molar row is that V8900 is larger.

In their important study of new fossils of large shrews from Haimao, near Dalian, Liaoning Province, Jin and Kawamura (1996a) recognized that a sample including a skull and mandibles represents the genus *Beremendia*, well known from Europe. Their skull material compares quite well to *Beremendia fissidens*. The Haimao material was seen to be conspecific with *Peisorex pohaiensis* and assessed as showing sufficient variation to include V8900. Thus, *Peisorex* is a junior synonym of *Beremendia*, and *P. pliocaenicus* Flynn and Wu 1994, is a junior synonym of *B. pohaiensis*. The differences noted between V8900 and V2671 are minor, and Jin and Kawamura (1996a) quite rightly note that the sizes of m1 and m2 are close. Among known specimens, the largest are the oldest and new fossils possibly will suggest a size decrease in this lineage after 3.3 Ma, the age of the Yushe specimen.

*Lunanosorex* Jin and Kawamura, 1996b

*Lunanosorex lii* Jin and Kawamura, 1996b

1991 Blarinini Flynn et al.

1994 cf. *Blarinoides* sp. nov. Flynn and Wu

1997 cf. *Blarinoides* sp. Flynn et al.

Referred material: V8895.1, right M1 (Fig. 2.5g); V8895.2, left M1; V8895.3, right m1; V8895.4, a posterior portion of a left dentary (Fig. 2.6); all from locality YS87; V8896.1, broken right M2, and V8896.2,–0.3, two upper right incisors, from YS50.

Distribution: Yushe material from YS87, Mazegou Formation, Yuncu subbasin, 3.5 Ma, and from YS50, early Pliocene Gaozhuang Formation, Yuncu subbasin, 4.7 Ma. Type material from Yinan, Shandong Province, and referred material from Bilike, Inner Mongolia.

Description: The dentary fragment preserves the coronoid, slightly damaged condyle, and short angular process. It represents a large shrew (tip of coronoid to inferior border of dentary is 6.5 mm), but is not as big as *Beremendia pohaiensis*. The specimen is figured in Flynn and Wu (1994). The condyle has a broad interarticular area and is not greatly deflected medially. The lower articulation is not shifted anteriorly in position and is slightly visible in labial view. The superior pterygoid fossa is a small, shallow basin with a weak spicule. The shallow external temporal fossa

extends down the coronoid to the level of the superior sigmoid notch. The coronoid process is spatulate, with a strong, high coronoid spicule; masseteric fossa small and shallow. Internal temporal fossa uninflated, but with a trough-like depression rising up the coronoid. Below this level is the small mandibular foramen. The coronoid is labially deflected and tilted slightly anteriorly.

Except for the projecting metastylar wing, M1 (Fig. 2.5g) is nearly square in outline (dimensions of V8895.1 = 2.43, 2.38; slightly damaged V8895.2 = 2.29, 2.38). The ectoloph is somewhat asymmetrical, the metacone being larger than the paracone; also there is a strong parastyle, an arcuate mesostyle, and no metastyle. The protocone, opposite the paracone, and the metacone border a deep trigon basin. Preprotocrista approaches the paracone, but ends in a minute paraconule at the base of the paracone. The postprotocrista makes a slightly raised intersection with an oblique ridge running posterolingually to the hypocone. The intersection could be homologous to a metaconule, and from it a transverse ridge extends to the base of the metacone. The expansive hypocone flange is gently emarginated near the midline of the tooth. Lingually, a crest rims the flange and the small hypocone is located on this marginal crest. The crest is continuous with a postcingulum. From the hypocone, a weak lingual cingulum runs to and fades at the protocone. The anterior face of the protocone is furrowed vertically, without precingulum.

The referred M2 from the older locality YS50 is nearly as wide (2.28 mm) as the first molars. Its hypocone flange is broken off, but preserved length is 1.81 mm. The ectoloph is symmetrical. Its parastyle is cusplike, but the mesostyle and metastyle are uninflated. As in M1, there is a small paraconule and a raised area in the position of a metaconule, where a faint ridge leads to the hypocone. There is a weak anterior cingulum. V8895.3 is broken, missing its lingual third and anterior termination of the protolophid. Preserved length is 2.6 mm. It is considered m1 because talonid width (at least 1.7) would be considerably greater than trigonid width. The cristid obliqua intersects the back of the trigonid at the midline of the tooth, relatively more lingually than in *Beremendia*. Although damaged, the entoconid and entoconid crest appear to close the talonid basin. The buccal cingulum is prominent.

Two upper incisors are referred here. One is broken at the base but shows a long, curved, laterally compressed root. The other, 3.09 mm long, has a procumbent and large major cusp. It is not fissident, consistent with observations on this tooth by Qiu and Storch (2000).

Discussion: Previously, Flynn and Wu (1994) compared V8895.4 to *Blarinoides*, a blarinine from the Pliocene of Europe. Jin and Kawamura (1996b) referred it to their new genus *Lunanosorex*, currently considered a member of Tribe Beremendiini. *Lunanosorex* shares with *Beremendia* a

massive jaw articulation with large interarticular area, and *Beremendia* had been grouped among Blarinini, due largely to this feature. However, Reumer (1984) recognized a suite of features to defend tribal attribution to Beremendiini: pigmented teeth, upper incisor fissident, upper antemolars diminish in size posteriorly with A4 hidden, M3 and m3 small, robust ramus with anterolaterad inclination of coronoid process and short, blunt angular process, curved and acuspulate lower incisor. *Beremendia pohaiensis* matches this diagnosis (Jin and Kawamura, 1996a), but the upper incisor of *Lunanosorex* is not fissident and its lower incisor is weakly bicusculate (Qiu and Storch 2000). As to pigmentation, we suspect that the color is leached from the Yushe specimens. There is some coloration of specimens, but not the obvious pattern of shrew pigmentation. Interestingly, the coloration of V8895.2 and V8895.3 appears reversed, with areas near cusp tips bleached light and the rest of the crowns darker (reddish to beige in the case of V8895.3). As more specimens become available, it will be appropriate to review the diagnoses of Blarinini and Beremendiini.

The species level identification for the Yushe material could be taken as tentative. Qiu and Storch (2000) decided that the smaller dental sizes in the Bilike sample of *Lunanosorex* prevented secure identification as *L. lii*. The Yushe sample includes somewhat younger material and appears to be of appropriate size for the type specimen of *L. lii*. We see no morphological evidence to contradict that assignment.

Tribe Blarinini Stirton, 1930

*Sulimskia* Reumer, 1984

cf. *Sulimskia* sp.

1994 cf. Blarinini, Flynn and Wu

Referred specimen and age: V8897 (Fig. 2.5k), right M1 from Yuncu subbasin locality YS32, Mahui Formation, 6.0 Ma.

Description: The M1 (buccal length 1.62, width 1.95 mm) is wider than long, although length could be underestimated due to breakage of the hypocone flange. The paracone and metacone are high-walled with narrow, straight wings that comprise a high ectoloph. The ectoloph does not extend deeply into the tooth, due to presence of a buccal shelf at both the paracone and metacone. The protocone is also relatively high, with steep buccal wall, so that the trigon basin is deep. The parastyle is weakly cusped. Unlike the more symmetrical ectoloph of M1 in *Lunanosorex*, the ectoloph of V8897 is asymmetrical because the metacone wing is longer than the paracone wing. The preprotocrista ends at a small paraconule, which is located at the base of the paracone. The postprotocrista joins the metacone without distinct metaconule. A ridgelike crest descends posteriorly from the midpoint of this crista to the hypocone. However, the hypocone and its flange are broken away. Apparently the flange extends less than half way across the tooth, again

unlike *Lunanosorex*, and continues buccally as a narrow posterior cingulum. There is a faint internal and posterior cingulum, but no apparent buccal cingulum.

Discussion: This specimen is insufficient for species identification. It is of appropriate size for *Sulimskia*, but does not match closely known species. Morphologically, with the deep trigon basin, high paracone and metacone with buccal shelf, hypocone ridge and small hypocone flange, and the weak cingula, it matches the description of *Sulimskia zieglerei* from Bilike, Inner Mongolia. However, based on this material, a small species of *Lunanosorex* could not be ruled out. *Sulimskia* is another genus that calls for review of the content of Blarinini and Beremendiini.

Subfamily Crocidurinae Milne-Edwards, 1868

*Crocidura* Wagler, 1832

*Crocidura* sp.

1994 *Crocidura* Flynn and Wu

1997 *Crocidura* Flynn et al.

Referred specimen and age: V8899 (Fig. 2.5l), right M2 from YS83, Red Lishi loess of Yuncu subbasin, Yushe Basin, early Pleistocene.

Description: This white molar is worn and damaged buccally, but shows several important features. It is relatively wide with W-shaped ectoloph, deep transversely, but ectoflexus (buccal border) shallowly sculpted. The metacone is larger than the paracone; conules are absent. The protocone is not pinched, its arms defining an angle  $>90^\circ$ . The preprotocrista or protoloph abuts the paracone. There is no metaloph directed toward the metacone. Instead, a postprotocrista is directed posteriorly toward the hypocone, which is low and uninflated. There is a weak lingual cingulum. The small hypocone flange slopes gently labially, is invaginated less than half way across the tooth, and is continued by a cingulum extending to the buccal margin of the tooth. Lingual length: 1.57; width: 1.76 mm.

Discussion: The common living *Crocidura* in Shanxi Province and eastward throughout Hebei and Liaoning is *C. shantungensis* (Jiang and Hoffmann 2001). This small species is considerably smaller than the Yushe specimen, but about the size of *C. wongi* named by Pei (1936) for samples from Zhoukoudian. Pei (1936), however, felt that *C. wongi* was smaller than *C. coreae*, the latter now seen as a synonym of *C. shantungensis* (Jiang and Hoffmann 2001). Whether or not *C. wongi* should be subsumed under *C. shantungensis*, the Yushe white-toothed shrew is quite different.

The Yushe *Crocidura* is clearly smaller than *C. fuliginosa*. Today, *C. attenuata* lives west of the Yellow River (Jiang and Hoffmann 2001), not far from Yushe, and V8899 is of comparable size, but the two differ. Structures of upper molars of *C. attenuata* are compressed anteroposteriorly, such that the ectoloph appears to make a narrower and

deeper W-shape, and the trigon is wider transversely. *C. vorax* of Yunnan is somewhat smaller, but a better structural match. No further conclusion can be supported about V8899, other than that it attests to presence of a large *Crociodura* in the early Pleistocene of Yushe.

## 2.3 Conclusions

Like other well-represented faunas in China, the Yushe insectivores are diverse. The late Miocene of Yushe records two moles, *Yanshuella* and *Yunosaptor*, and at least two shrews, a blarinine and a smaller form represented by indeterminate fragments. Pliocene Gaozhuang and Mazegou assemblages retain the Miocene mole genera, and add the derived, extant mole *Scaptochirus* and the water mole *Desmana*. Yushe Pliocene shrews include two large beremendiinines, a soriculine, and the small cf. *Paenelimnocus*. There appears to be a decline in insectivoran diversity toward the end of Pliocene time, although the large hedgehog, *Erinaceus olgae*, persisted in Yushe Basin. Haiyan Formation localities yield only *Sorex*, and the Pleistocene loess produces *Crociodura*. This decline in diversity, if not a sampling effect, may echo cooling climate; Reumer (1984) hypothesizes that lower mean annual temperature corresponds with lower insectivoran diversity. Jin et al. (1999) saw a similar decline in diversity and modernization among insectivores in the Pliocene of North China.

Of the common moles in the terminal Miocene and Pliocene of Yushe Basin, we have recognized two taxa that otherwise have separate northern and southern distributions. Tedford et al. (1991) noted *Yanshuella* in the Gaozhuang Formation and more recently we found it in the Mahui Formation. The Yushe species *Yanshuella yushensis* has close affinity with northern *Y. primaeva* from Ertemte and Harr Obo, Inner Mongolia, but shows some differences. The Yushe taxon ranges well into the Pliocene, presumably younger than either latest Miocene Ertemte or early Pliocene Harr Obo. The Yushe material demonstrates a size difference and some morphological differences, including two roots on anterior premolars, which distinguish the species from *Y. primaeva*.

The second common Yushe mole was difficult to characterize until the Lufeng material of *Yunosaptor* was described (Storch and Qiu 1990) and more Yushe material was found. The Yushe specimens are somewhat younger than the Lufeng *Y. scalprum*, but do not demonstrate different species level status. This mole suggests a level of faunal similarity with South China in the late Miocene. A less common mid-Pliocene mole, an early record in China of *Scaptochirus*, is closely related to living northeast China *S. moschatus*.

Shrews include large species assigned to *Beremendia* and *Lunanosorex*. Previously we felt that the latter was a blarinine (Flynn and Wu 1994). Although current workers place it in Beremendiini, we suggest that its tribal affinity may need review. A smaller shrew is a soriculine, but it does not preserve autapomorphies of any living subgenus. For that reason it is classified as *Soriculus* without reference to an extant subgenus. Concerning the younger records of small shrews, neither *Sorex* nor *Crociodura* from Yushe are easily matched with living species. Other regions of China record *Anourosorex* Milne-Edwards, 1872 in the Pleistocene (Zheng 1985), but this southern genus is not in evidence at Yushe.

Our recognition of shrew taxa relies largely on condyle structure of the dentary bone and on molar morphology. Tooth pigmentation has limited usefulness: it appears to be leached diagenetically from some specimens. Interestingly, cusp tips of teeth attributed to *Beremendia* are lighter in color than the main bodies of crowns.

Paleobiogeographically, the Yushe Lipotyphla show considerable affinity with eastern China (region around Hebei and Liaoning) and especially with Zhoukoudian. The hedgehog, *Scaptochirus*, *Lunanosorex*, *Beremendia*, and *Sorex* all compare closely with taxa from sites in eastern China (Cai 1987; Jin and Kawamura 1996a, b). Some genera (*Yanshuella*, the erinaceid) show a degree of faunal similarity with continental interior localities of Inner Mongolia and some lipotyphlans such as *Beremendia*, *Soriculus* and *Desmana* were widespread across northern Eurasia (Kretzoi 1959). Also, a degree of faunal communication with North America is suggested by presence of a late Miocene blarinine. The taxa shared with southern China, *Yunosaptor* and *Soriculus*, may indicate mild climate with adequate moisture that allowed northward expansion of taxa having southern ranges. The Yushe Lipotyphla attest to some biogeographic fluidity of its members, but share affinity primarily with nearby localities of eastern China, a coastal subprovince of North China.

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