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A NEW "MIDDLE" CRETACEOUS ZALAMBDALESTID MAMMAL, FROM A NEW LOCALITY IN JILIN PROVINCE, NORTHEASTERN CHINA

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Abstract: Fossil specimens from a new Cretaceous locality near Gongzhuling City in Jilin Province, China, include two incomplete mammalian dentaries which represent a new genus and species referable to the eutherian family Zalambdalestidae. The locality is in basin-margin outcrops of the Quantou Formation, which is widely spread in the subsurface of Songliao Basin and which has been assigned ages ranging from the Aptian to the Cenomanian stages of the Cretaceous; it seems unlikely that the Quantou Formation could be younger than Cenomanian. Both dentaries possess an enlarged, procumbent first incisor combined with an interesting mosaic of both plesiomorphic and derived dental characters compared to taxa such as *Kulbeckia kulbecke.* For example, the new Gongzhuling specimens appear to show five premolars (including an almost fully molariform ultimate premolar) combined with only three incisors and a low but single-rooted canine. The trigonids on p5 and m1 are relatively open and non-compressed. This locality is likely to emerge as an important source of new information on "middle" Cretaceous vertebrates as additional mammalian, dinosaurian, and other specimens are described from it in the near future.

Key words: "middle" Cretaceous, zalambdalestid mammal, Jilin Province, China

INTRODUCTION

During the middle and late 1990s, Mr. Zhang Pulin, having retired from the Jilin Geological Survey, located several sites with fossil bone in outcrops of the Cretaceous Quantou Formation, along the eastern margin of the Songliao Basin in Jilin Province (Fig. 1). Custody of the fossils and the locality information were transferred to the Jilin University Geological Museum before Mr. Zhang's untimely death in September of 2000. Field parties from the museum returned to the most promising locality, near Gongzhuling City, for additional excavation and collection of fossils during the summers of 2000 and 2002 (Wood *et al*., 2001; Wood *et al*. 2003). A large number of well-preserved bones and teeth of small dinosaurs, mammals, and other vertebrates, as well as several eggs, are now under study. Other than a brief report or two (Wu *et al*., 2001; Matsukawa *et al*., 1995) on non-mammalian specimens and the recent paper on a new dinosaur (Zan *et al*., 2005) from Gongzhuling, no previous reports of vertebrate fossils from Jilin have been published. A mention by Lucas and Estep (1998) of dinosaur eggs or nests in Jilin Province was a miss-statement from an earlier survey (Carpenter *et al*., 1994).

Two of the mammalian specimens, representing a new species probably related to basal zalambdalestids such as *Kulbeckia kulbecke* (Nessov, 1993; Archibald *et al*., 2001; Archibald and Averianov, 2003) are the subject of this report. The specimens are parts of small dentaries with teeth, one of which was in

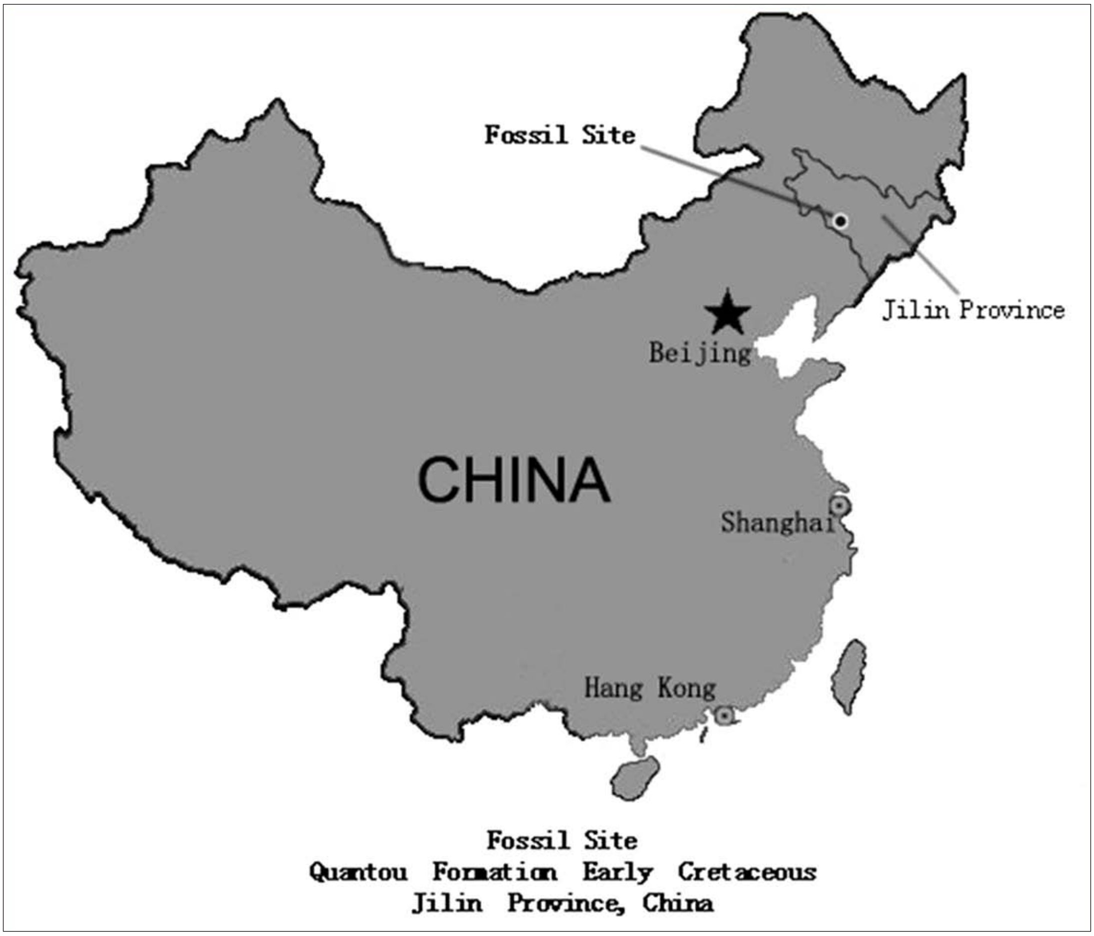

Fig. 1. Locality map for Gongzhuling fossil site and Jilin Province.

Mr. Zhang's original collection; they contain different parts of the dentition, and although unassociated, the specimens were found in the same fossil-bearing layer. As in other zalambdalestids, both specimens show an enlarged medial incisor, which in combination with otherobservable morphology suggests a high probability that the new specimens represent a single taxon. We tentatively interpret them here as conspecific. Derived zalambdalestids and basal zalambdalestids such as *Kulbeckia* have been revised recently from more complete material (Archibald and Averianov, 2003; Wible *et al*., 2004; Averianov and Archibald, 2005) and they bear directly on the lively debate currently underway, regarding the origin and dates of divergence of crown group Placentalia (Rougier *et al*., 1998; Archibald and Deutschman, 2001; Szalay, 2005; Asher *et al*., 2005) as well as the relationship of Asian Zalambdelestidae to other eutherian mammals (Wible *et al*., 2004; Averianov and Archibald, 2005). The age of the Gongzhuling locality and its fossils is currently being restudied, but previous investigations of the Quantou formation have favored dates ranging from Aptian to Cenomanian stages of the Cretaceous Period (~121-94 Ma; Gradstein *et al*., 1995), with early Cenomanian being the most likely upper limit (Guan *et al*., 1985; Ma *et al*., 1989; Gao *et al*., 1992; Liu *et al*., 1993; Chen, 1994; Chen and Chang, 1994; Li and Liu, 1994; Ye, 1994; Wang, 1995; Sun and Zheng, 2000; Himeno *et al*., 2001; Sun *et al*., 2001). *Kulbeckia* has been more securely dated in Uzbekistan and is known to have lived during the Turonian Stage (Archibald and Averianov, 2003). Thus not only do the Gongzhuling specimens represent an eastward extension of the range of the group to which they belong, they also indicate a significantly older occurrence of the group and certain, presumably derived dental characteristics than previously known (but see also Averianov and Archibald, 2005).

SYSTEMATIC PALEONTOLOGY

MAMMALIA Linnaeus, 1758
EUTHERIA Gill, 1872
ZALAMBDALESTIDAE Gregory and Simpson, 1926
ZHANGOLESTES, gen. nov.

Etymology-After Mr. Zhang Pulin, who discovered one of the specimens described and several vertebrate - rich localities in the Quantou Formation, along the eastern margin of the Songliao Basin, Jilin Province, China, and *lestes,* Greek, meaning hunter, a common name ending for basal mammals.
Type and Only Known Species-*Zhangolestes jilinensis*
Diagnosis-Medium-sized zalambdalestid with i1 large and procumbent extending posteriorly at least to the level of p5. *Zhangolestes* differs from the early zalambdalestid *Kulbekia* in the presence of three incisors, instead of four, single-rooted canine, five premolars, more open molar and premolar talonids, and a low, procumbent paraconid. Later Zalambdalestids such as *Zalambdalestes* and *Barunlestes* differ from *Zhangolestes* in further elaboration of the derived features of *Kulbeckia*; they have even more compressed trigonids, taller paraconids, smaller incisor-like canines, and much reduced m3. The p2 in *Zhangolestes* is larger and more robust than the p1, while in derived zalambdalestids it is subequal.

ZHANGOLESTES JILINENSIS, sp. nov.

Etymology-*Jilinensis,* latinized version of Jilin, after Jilin Province, China, where the specimens were collected
Diagnosis-As for the genus, for monotypic attribution.
Holotype-Jilin University Geological Museum no. Ya1.23.i: anterior portion of a left dentary containing i1-p3 plus roots or matrix impressions for at least two more teeth.
Hypodigm-Jilin University Geological Museum no. Ya2.24.i: posterior section of a right dentary broken anterior to p4, lacking most of the coronoid process, lacking all of the condyle and angle, but including broken remnants of p4, m2-3 and relatively complete p5-m1; this is the specimen that was collected by Mr. Zhang.
Locality and Horizon-Quantou Formation, northeast of Gongzhuling City, and along the eastern margin of the Songliao Basin in Jilin Province (Fig. 1). Cretaceous, most probably early Late Cretaceous.

DESCRIPTION OF SPECIMENS

The specimens are of approximately the right size and morphology to be associated, but although in the same bone-bearing layer they were recovered *in situ* about 80 meters apart laterally. We interpret them to be conspecific pending further evidence to the contrary. A reasonable reconstruction of a whole jaw can be provided by overlapping both fragments (Fig. 2; Ya2.24.i reversed). The dental nomenclature

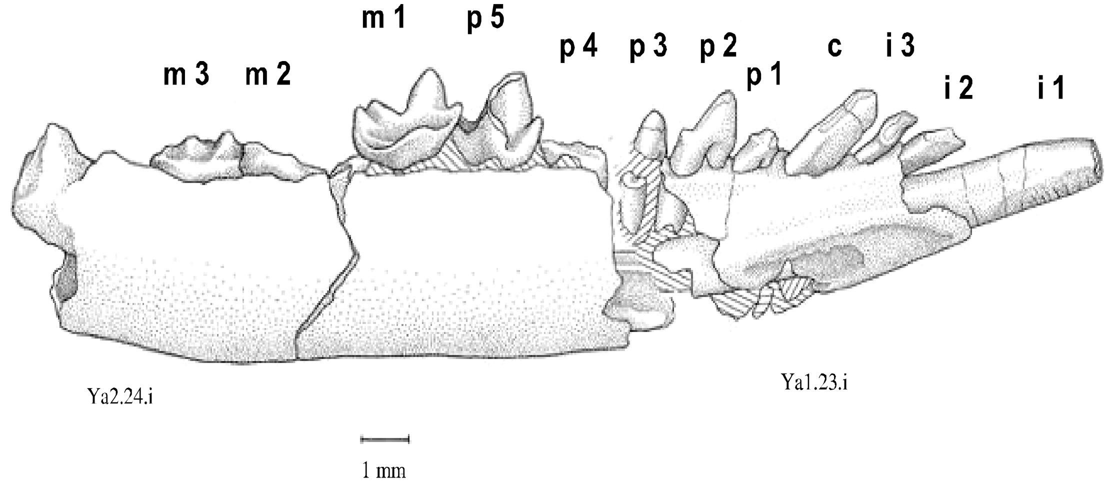

Fig. 2. Composite mandible and dentition for *Zhangolestes jilinensis*, based on specimens Ya1.23.i and Ya2.24.i (reversed); because of the breaks and lack of association the restoration and the tooth formula must be tentative pending discovery of additional specimens. Scale bar equals one mm.

assumes that the specimens do not overlap in preserved elements, and that no tooth position is lost in the combination; we must therefore admit that our interpretations of tooth formula remain conditional, pending discovery of more complete material. As with all bone from this locality, the white to pinkish coloration of the specimens suggests little or no thermal alteration and there appears to have been minimal permineralization. Pinkish to red-brownish coloration results mainly from a very thin outer coating of unidentified iron oxide minerals. As will be noted in future reports, other, more complete specimens of mammalian and non-mammalian taxa from this locality have been preserved in remarkable articulation (Zan *et al*., 2005). All specimens are curated and housed in new laboratory facilities in the Jilin University Geological Museum, Changchun.

Ya1.23.i, DENTITION

i 1 and symphysis – i1 enlarged and totally procumbent; tip broken but enamel intact where it partially covers remaining portion of crown (Fig. 3). The root extends under at least p2 but is broken and missing posteriorly so that it is impossible to determine how much farther the root may have extended. However, accepting the attribution of Ya2.24.i to the same species as Ya1.23.i as interpreted here, the root would extend back at least to the level of the p4 (Fig. 4), as in other zalambdalestids (Fostowicz-Frelik and Kielan-Jaworowska, 2002; Wible *et al*., 2004). The antero-dorsal portion of the medial surface is slightly spoon-shaped, and this area is entirely devoid of enamel. The broken cross section of the crown, in anterior view is D-shaped, with the flat part of the "D" corresponding to the concave part of the "spoon" on the medial surface. In the cross section, the enamel band is limited to the convex part of the "D"; that is, it wraps around the lateral side of the incisor, and covers the ventral surface to end completely on the medial surface as described above (Fig. 4A). Enamel is relatively thick where it ends on the edge between the lateral and medial surfaces, so that some enamel absence could have been enhanced by wear immediately medial to the dorsal edge. Enamel seems to thin posteriorly and to end around the lateral and ventral sides of the tooth at about the level of the current ventral alveolar rim. It is not clear how much of the alveolar rim may have been broken away, but comparison with other zalambdalestids suggests that a substantial portion is missing, extending between the base of the i2 and the preserved anterior extent of the dentary. The lateral side of the specimen remains in matrix. The symphysial area on the medial side of

Fig. 3. Photograph of anterior part of specimen Ya1.23.i with i1, i2, i3, c, and part of p2.

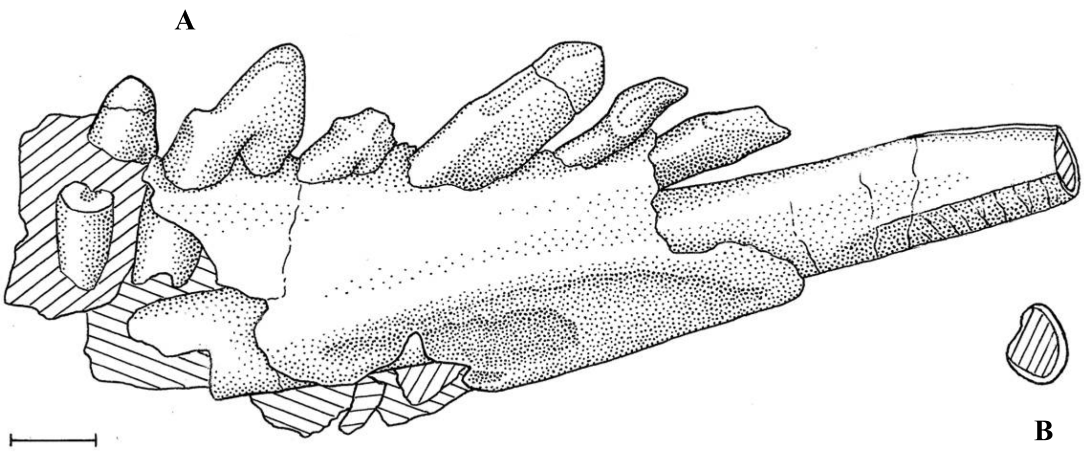

Fig. 4. A, Camera lucida drawing of specimen Ya1.23.i in entirety, and **B**, anterior view of broken i1 cross section showing distribution of enamel around labial and ventral sides. Scale bar equals one mm.

the dentary is raised, ovate, relatively smooth, and extends from near the i1 alveolus to at least the area under p1 along the ventral edge of the jaw. The extreme ventral development and great elongation of the symphysis is characteristic of mammals with strongly procumbent anterior lower incisors, including zalambdalestids. Depth of bone (dorsoventrally) at the widest point on this specimen is 3.3 mm (Table 1).

i 2 – much smaller than i1, but fully procumbent with crown extending over root of i1. The alveolus is therefore posterodorsal to that for i1. Enamel appears to be limited to the lateral surface only, but there is an apparent wear facet in the dentine of the dorso-medial surface of the tooth. Some amount of thin en-

Table 1. Measurements of specimen Ya1.23.i (by ocular micrometer, Wild-Heerbrugg M-5 stereo dissecting microscope). All measurements are in mm. **Abbreviations**: **L** = length; **i**, incisor; **p**, premolar.

Ya1.23.i	
left mandible, anterior	
Gongzhuling 2000	
Quantou Formation	**mm**
L. i1*	3.23
depth i1	1.27
L. p2-i2	6.73
L. canine at alveolus	1.5
L. p2	1.32
depth mandible at p1	3.3
*end of bone to broken tip	

Table 2. Measurements of specimen Ya2.24.i (by ocular micrometer, Wild-Heerbrugg M-5 stereo dissecting microscope). All measurements are in mm. **Abbreviations**: **p**, premolar; **m**, molar; **trd**, trigonid; **tald**, talonid.

Ya2.24.i	
right mandible, posterior	
Gongzhuling (ZPL)	
Quantou Formation	mm
p5 trd width	1.57
p5 tald width	1.37
m1 trd width	1.65
m1 tald width	1.59
m2 trd width	
m2 tald width	1.67
m3 trd width	1.37
m3 tald width	1.29
p5 length	1.98
m1 length	2.18
m2 length	2.12
m3 length	1.94
[m2-3 very approx. due to break.]	
depth mandible p5/m1	3.51
length p5-m3	9.16

amel may have been removed by wear during the life of the animal. The crown of the tooth is slightly convex dorsally.

i 3 – slightly smaller than i2, also procumbent but inclined upward at a small angle (approximately 15^{o}) to a line through the long axis of either i2 or i1. As in i2, the crown of i3 projects over the root of the preceding tooth. There is a distinct wear facet to dentine on the medial side of the crown, such that there may have been enamel covering the entire crown at eruption; additional specimens would be needed to confirm this.

c – the canine is larger than the two preceding incisors but considerably smaller than the first incisor. It is laterally compressed and apparently single-rooted. Double-rooted or constricted canines are present in *Kulbeckia* and asioryctitheres (Rougier *et al*., 1998; Archibald and Averianov, 2003; Wible 2004). The canine is inclined at an angle of about 30^{o} to the alveolar row behind it so that its tip, which is rounded, is at the same or at a slightly lower level than the top of p2 in medial view. There is a thin facet worn to dentine from the tip to the base of the crown on the dorso-medial surface of the tooth. Otherwise thin enamel seems to cover the entire crown. Given the small size of the element, it is conceivable that this canine is only partly erupted, but the degree of wear on the postcanines, and especially that on the first and second incisors, weigh against this possibility.

p 1 – p1 is double-rooted and is the smallest premolar of the series. The roots protrude from the alveoli to a height greater than that of the crown itself. The crown is slightly damaged on the lingual side, but rounded on top with a very slight heel or cuspule on the posterior side. No true diastema (defined as a space equal to at least half a tooth) separates the p1 from the canine, but a small distance intercedes between these elements more than between any other teeth.

p 2 – as long antero-posteriorly as the canine, and projecting to the same or slightly greater height in medial view. The medial or lingual profile is that of a typical premolar, recurved anteriorly and with a small saddle to the rear before rising to a small, low heel or cuspule on the posterior end of the crown. The premolar is therefore asymmetrical with the principal cusp supported almost exclusively by the anterior root. There is a very narrow facet worn to dentine, which extends from near the apex of the main cusp almost to its base on the posterior side. The p2 is the dominant premolar among the anterior ele-

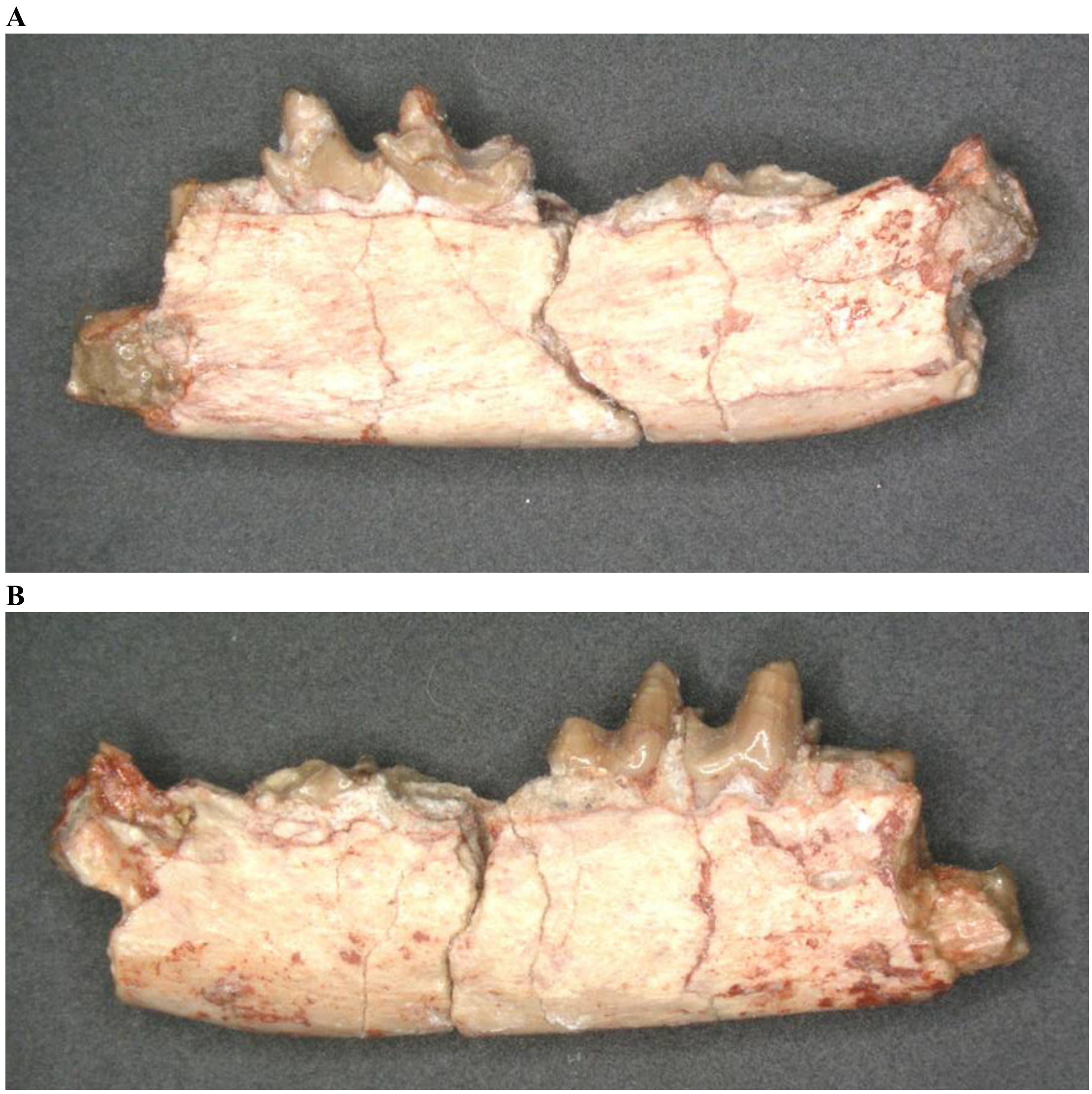

Fig. 5. Photographs of specimen Ya2.24.i. **A**, lingual view of dentary with root of i1 (unprepared), p5 and m1, and broken p4, m2, m3; **B**, labial side of specimen.

ments (p1-p3)

p 3 - heavily damaged, with one root and some part of the anterior crown present. There is a partial natural mold of the anterior crown of another premolar (larger than p2) in the matrix behind p3, but other than the simple statement of its occurrence, little more can be said about it except that it agrees with the size of a premolar predicted by the roots of the anterior elements in Ya2.24.i.

Ya2.24.i, DENTARY

Upon first inspection there was a projecting fragment on the ventral side of the broken anterior end of

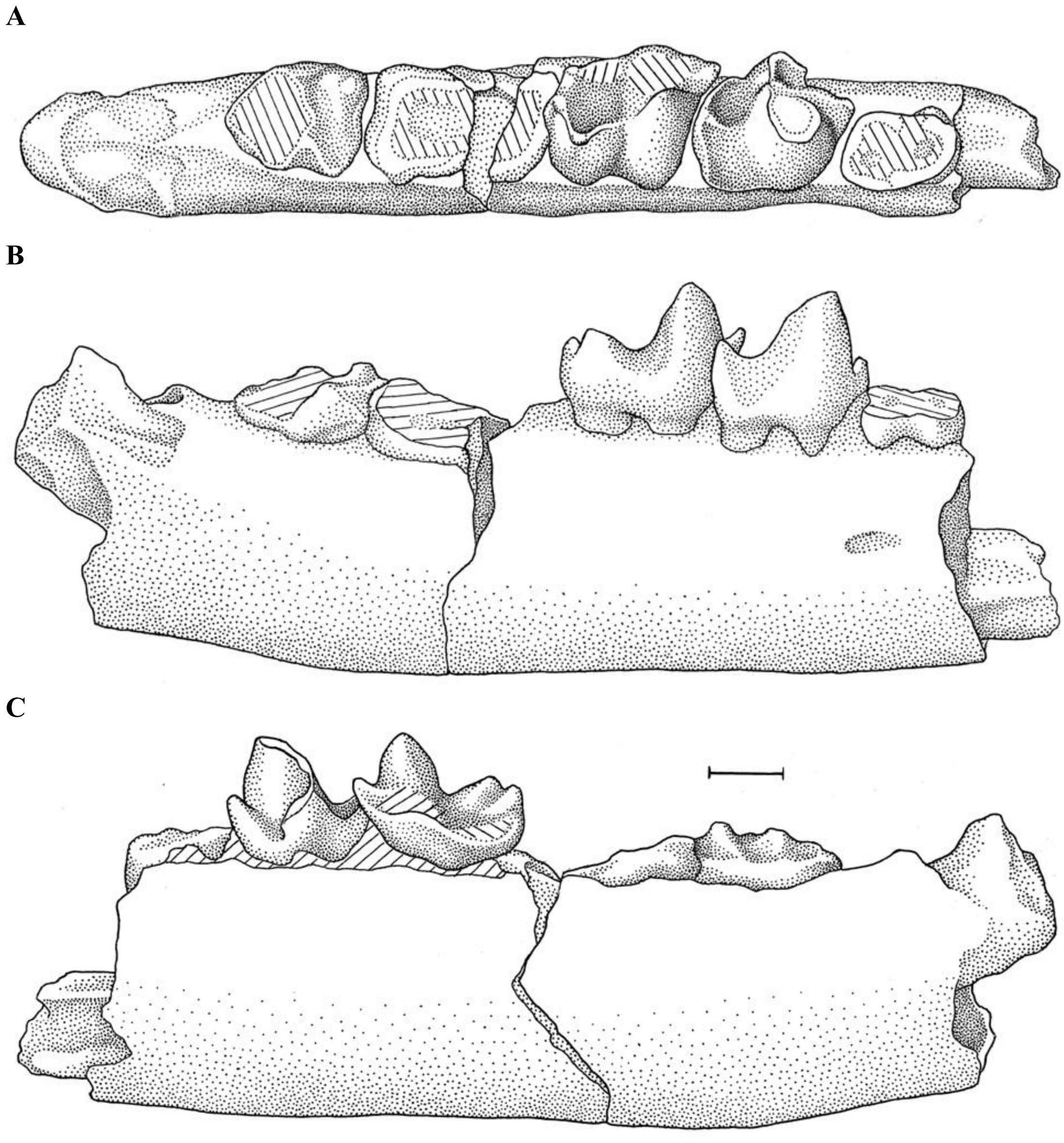

Fig. 6. Camera lucida drawings of specimen Ya2.24.i. **A**, crown view (cross hatch indicates broken areas); **B**, labial view; **C**, lingual view - note that the drawing was made after further preparation of i1 root, which is convexly open toward the lingual side. Scale bar equals one mm.

the specimen (Fig. 5). With further preparation by Mr. Amaral it is clear that this is the posterior part of the root of a large and procumbent incisor (Fig. 6). A large fracture through m2 divides the specimen into anterior and posterior portions (Fig. 7), which have been rejoined with only slight displacement. The anterior part of the coronoid process appears to rise close to the end of m3, so that there is little space between it and the molar. Bone on the lingual surface beneath the molars is smooth, with no evidence of a Meckelian sulcus. Little of the masseteric fossa is present and all of the dentary posterior to the small anterior remnant of the coronoid process has been lost. The horizontal ramus is of a fairly uniform depth with a slightly upturned ventral margin behind the level of m3. An ovate mental foramen is present on the labial side of the dentary, beneath the posterior root of p4 and reaching almost to p5. The length of p5 to m3 is 9.16 mm on Ya2.24.i, and the depth of the mandible below p5-m1 is 3.51 mm (Table 2).

Fig. 7. Stereophotos of specimen Ya2.24.i in crown view.

Ya2.24.i, DENTITION

?i1 – represented only by the root fragment projecting beyond p4 and possibly to the proximity of p5. At this position in the dentary the root is somewhat arc-shaped in cross-section, concave toward the lingual side. The labial side is closely appressed to the thin wall of bone that forms the labial side of the dentary.

p 4 – crown missing, broken off just above the junction of the roots. The tooth was two-rooted, with the posterior end apparently a little wider than the anterior end. The root section suggests a simple trigonid, perhaps represented by a single paraconid and a somewhat broader talonid. The length was somewhat less than that of p5.

p 5 – well preserved, and almost completely molariform. This tooth is shorter than the first two molars and the talonid does not have distinct cusps, but the talonid basin is fully rimmed and was clearly functional against a protocone on P5 (Fig. 7). All three trigonid cusps are distinct, robust, and also fully functional. The protoconid is the tallest cusp on this tooth, which was clearly true before the tooth sustained any wear. The top of the protoconid has an apical wear facet which is slightly inclined posteriorly, but the exposed dentine does not continue into any posterior facet such as would be caused by the anterior part of an opposing protocone or parastyle on P5. There is a small amount of wear or polish on the enamel of the antero-labial side of the protoconid. A small groove, possibly from wear, is present in the enamel from the notch where the paraconid crest meets the base of the protoconid, and slopes downward and labially toward the base of the crown. The paraconid is well defined, low, and conical, and it is displaced slightly toward the labial side of the tooth in comparison to the metaconid on the lingual margin. The paraconid does not display obvious wear and is connected to the antero-lingual wall of the protoconid by a very thin, vertical crest. There is no trace of a lingual cingulum or ornamentation on the antero-lingual margin of the crown (i.e., under the paraconid). The paraconid is clearly separated from the metaconid by a deep "V" in lingual view. The metaconid is larger and taller than the paraconid but only about half the height of the protoconid. There is some slight damage to the postero-lingual side of the protoconid and perhaps to the top of the metaconid, so that it is unclear how much of the top of the metaconid is missing from breakage and how much from natural wear. Dentine is exposed on top of the metaconid in a surface sloping toward the anterior side of the tooth. Despite the small amount of damage as mentioned, there is a clear crest of enamel (postprotocristid) uniting the lingual side of the protoconid to the top of the metaconid. A vertical postmortem crack in the tooth on the labial side of the metaconid threatens its adherence to the rest of the trigonid.

In labial view the dorsal part of the talonid comes to a sharp point at the posterior end, and there is a well-defined depression on the labial side, between the posterior wall of the protoconid and the end of the talonid. The posterior part of this indentation bears a well-defined wear facet on the enamel when viewed in the proper light. This facet would clearly correspond to the paracone of the opposing upper tooth, since there is no hypoconid on this p5 and no crest behind the posterior point of the talonid that would indicate movement past a metacone on P5. In crown view the talonid basin is completely rimmed but without marginal cusps. Most of the basin surface is worn through to dentine, which continues slightly but not very far up the posterior wall of the trigonid. A faintly worn, thin crest reaches up the trigonid wall from the labial rim of the talonid basin.

m 1 – metaconid and entoconid broken at bases and missing, but otherwise the tooth is whole and in good condition. The paraconid is pointed, has minimal apical wear, and leans anteriorly toward the talonid basin of p5. At its base the paraconid is smaller in diameter than the broken base of the metaconid. The paraconid is a distinct cusp (i.e., not very ridge-like) that does not appear to have been compressed toward the metaconid. As on p5, the paraconid is slightly labial to the lingual edge of the trigonid and therefore is not in line with the lingual margin of the metaconid. The protoconid is much taller than the paraconid, and is quite vertical in labial view. The apex of the protoconid bears an attritional facet worn to dentine, and the dentine is confluent with a worn area down the posterior side of the paraconid (posterior trigonid wall) as far as contact with the anterior part of the cristid obliqua. Because of a broken metaconid, it is not clear how far this facet extended onto the lingual portion of the posterior trigonid wall. The antero-labial side of the paraconid displays a small, polished facet on the enamel, indicating some shear with a metastylar area on P5.

The talonid of this m1 is longer than, and almost the same width as the trigonid. Although the entoconid is missing, it does not appear that the hypoconulid and entoconid were closely approximated. A small ridge descends the posterior talonid wall labially, from near the top of the hypoconulid, but it is not distinct enough to be called a cingulum in this specimen. The talonid basin is slightly excavated on the lingual side, but the hypoconid surface is worn flat and enamel has been removed by wear from virtually the entire basin. Wear facets #s 3 and 4 (*sensu* Crompton, 1971; Crompton and Kielan-Jaworowska, 1978) are present on the labial sides of the cristid obliqua and the post-hypoconid crest. The cristid obliqua is slightly longer than the post-hypoconid crest, but not to a degree that suggests that the paracone was very much larger than the metacone on the upper molar. Neither this tooth nor the p5 are strongly exaenodont, but the labial sides are slightly higher than the lingual sides on both. The trigonid height is about twice that of the talonid. Despite the uncertainty introduced by loss of the metaconid in the m1, enough remains to suggest that the trigonid was relatively open. The low trigonid/talonid height ratio, the somewhat open trigonid and the small procumbent paraconid combine to give the m1 of *Zhangolestes* a generalized eutherian appearance, which if the attribution is correct, contrasts with the comparatively derived anterior dentition of Ya1.23.i.

m 2 – represented only by roots. The fracture through the dentary has been glued together in a way that slightly exaggerates the total estimated length of the tooth.

m 3 – crown very damaged. The low and conated paraconid seems to be intact. It is possible to discern the outlines of the labial protoconid and cristid obliqua, but no other morphological details are available. It is clear, however, that m3 was the smallest of the three molars, and that it did not have a posteriorly extended talonid.

DISCUSSION

Other than having the same size and an enlarged incisor, the parts of the dentition present in Ya1.23.i do not overlap the parts in Ya2.24.i (Fig. 2), so that lacking the incisor evidence it would be possible that these specimens represent two different taxa. Ya1.23.i/Ya2.24.i are undeniably similar in two respects. Both specimens indicate a large, procumbent medial incisor, and both share "eutherian" dental morphology as it is commonly accepted today. Basal eutherians have three molars and four or more premolars, with a tendency for the ultimate premolar to be more or less molariform (Ji *et al.*, 2002). Incisor counts tend to be three above and below in later eutherians, with a greater number plesiomorphically. Metatherians always have four molars and three premolars; the ultimate premolar is always non-molariform because it never displays a talonid basin or molariform trigonid in the lower dentition and it never has a protocone in the upper dentition (Luo *et al.*, 2003).

Several unique morphological characteristics or combinations of morphological characteristics in each of these specimens indicate that, in comparison to all other known Cretaceous mammals, these specimens represent a genus and species previously unknown to science. The molariform p5 of Ya2.24.i is different from the relatively simple p5 in "middle" Cretaceous genera such as *Prokennalestes* (Kielan-Jaworowska and Dashzeveg, 1989; Sigogneau-Russell *et al.*, 1992) or *Montanalestes* (Cifelli, 1999), and

Ya2.24.i is different in the same way from *Eomaia* (Ji *et al.*, 2002) of the Yixian Formation in Liaoning Province. The fully molarized last premolar also contrasts strongly with the simple and trenchant last premolar present in asioryctitheres (Kielan-Jaworowska, 1969; Novacek *et al.*, 1997; Rougier *et al.*, 1998). In general the molarization and complexity of the last two premolars (as deduced by the broken p4 on Ya2.24.i) points towards affinities with (presumably) more derived eutherians, zalambdalestids and "zhelestids" in particular. The m1 basin with well-separated entoconid and hypoconulid (as interpreted here despite a small amount of damage in the area), as well as less compressed trigonid may indicate against affinities of *Zhangolestes* with "zhelestids". On the other hand (excepting compressed trigonid) the morphology of the p5 and m1 agrees closely with that seen among zalambdalestids (Gregory and Simpson, 1926; Kielan-Jaworowska, 1969, 1975; Archibald *et al.*, 2001; Archibald and Averianov, 2003). The p5 of Ya2.24.i is in fact very similar to p5 in *Kulbeckia* (Nessov, 1993, 1997; Archibald *et al.*, 2001; Archibald and Averianov, 2003) and also to Asian species of *Paranyctoides* (Archibald and Averianov 2001, 2003). There is also similarity with p5 of *Bobolestes*, recently revised to include *Otlestes* by Averianov and Archibald (2005). It is conceivable that Ya2.24.i represents a new species of either *Kulbeckia, Paranyctoides*, or *Bobolestes* but there are minor differences in the p5/ m1 of Ya2.24. Compared to *Kulbeckia* the p5 is subequal in height to the m1, with a trigonid open lingually in the Chinese specimen, while the last premolar is taller and the trigonid is more compressed in other zalambdalestids. In *Zhangolestes* the m1 paraconid is closer in height to the protoconid than in any other zalambdalestid, the trigonid more open and the talonid lower and broader. In so far as known, there is no procumbent and enlarged incisor in *Paranyctoides*, *Bobolestes*, or in other Cretaceous eutherians such as *Eomaia*, *Prokennalestes*, or "zhelestids". When the anterior jaw fragment is considered, the enlarged and procumbent first incisors on Ya1.23.i and Ya2.24i are, of course, very similar to the i1 morphology in *Kulbeckia* and later zalambdalestids. The distribution of enamel on the crown surface of Ya1.23.i is virtually identical to that illustrated for *Kulbeckia* (Archibald and Averianov, 2003) and *Zalambdalestes* (Fostowicz-Frelik and Kielan-Jaworowska, 2002; Wible *et al.*, 2004). On the other hand, the orientation, position, and number of the posterior incisors are quite different. Although the labial surface of Ya1.23.i is currently in matrix, there are two robust incisors directly posterior and dorsal to the first incisor – it is possible but we think very unlikely that another, smaller incisor or its alveolus could be hidden next to i1 on the labial side. In their illustration of *Kulbeckia*, Archibald and Averianov (2003) show that the procumbent first incisor is clearly flanked labially (rather than dorsally and posteriorly) by alveoli for three additional incisors. Finally, although the illustrated specimen of *Kulbeckia* appears to be immature, the position, shape, and size of its canine are all different compared to the canine of Ya1.23.i. All of these comparisons suggest that *Zhangolestes* is a new genus and also a basal member of Zalambdalestidae.

If Ya1.23.i and Ya2.24.i both pertain to the new species, *Zhangolestes jilinensis*, *Z. jilinensis* is both older than *Kulbeckia kulbeke* and compared to *K. kulbecke*, shows a mosaic of more derived characters (such as the reduction of the incisor count to 3) and more plesiomorphic characters (such as the presence of 5 premolars, relatively open trigonids and low, procumbent paraconid). Averianov and Archibald (2005) discuss the polarity of double-rooted versus single-rooted canines in zalambdalestids. The canine is double-rooted in *Kulbeckia* and single-rooted in *Zhangolestes*, but since the condition is variable in other early eutherians we are not sure at the moment how to interpret the polarity of this character. *Kulbeckia* is from the Turonian or Coniacian stages of the Cretaceous as well as from a different side of the Asian mainland (Archibald and Averianov, 2001, 2003). Even at its youngest possible age (see below) however, the Quantou Formation at Gongzhuling is probably significantly older than the strata that yield *Kulbeckia*.

In summary, the relationship of Ya1.23.i to *Kulbeckia* and thus to other zalambdalestids seems well established. The p5 of Ya2.24.i resembles that of *Kulbeckia*, and the m1 although probably more generalized than that of other known zalambdalestids appears to represent a plesiomorphic morphology for the group; when the presence of an extremely enlarged and procumbent incisor is considered, the zalambdalestid affinities of Ya2.24.i are reemphasized.

GEOLOGY AND AGE OF THE GONGZHULING LOCALITY

The fossil locality is in an outcrop of mainly red, but ranging to gray or green mudstones, interlayered with white to tan or brown sandstones (Fig. 8). The outcrop is in a man-made "barrow pit" which was the

A

B

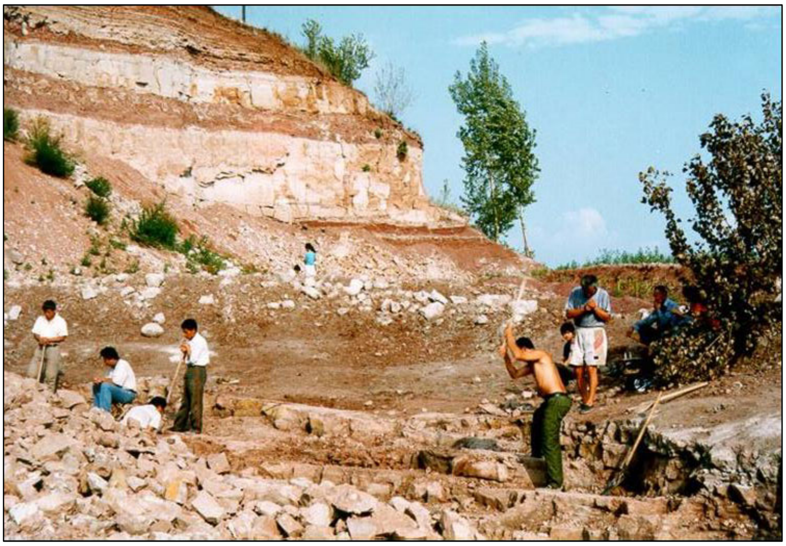

Fig. 8. Photographs (J. Chen) of fieldwork at the Gongzhuling locality during 2000. **A**, site preparation, removing overburden, looking west-north-west; **B**, excavation of the fossil-bearing layer near the discovery of Ya1.23.i, looking east-north-east.

result of road-building activities nearby (Fig. 9). Most of the fossils are from a single layer exposed low in the southeastern part of the pit. Several layers of overburden were removed with a small tracked vehicle. Excavation during 2002 was conducted under pressure of time because ownership of the land had been transferred to a private group whose members wished to begin construction on the site.

The fossilliferous stratum is 0.10 to 0.30 meters thick and is a gray to green mudstone with coarser fractions ranging up to granules or small pebbles. The larger clasts are rounded to subrounded and mostly silicic, but a few clasts may be orthoclase or other minerals. Sedimentological analysis has yet to be conducted. All formations in the Songliao Basin section, which ranges from late Jurassic to Paleogene in the subsurface, are known to be lacustrine or fluvial, with only the very briefest marine influx (if any at all) from the northeast margin (Ma *et al*., 1989; Gao *et al*., 1992; Liu *et al*., 1993; Wang, 1995). The Songliao Basin has been a major source of economically important hydrocarbons since the middle of the twentieth century (Guan *et al*., 1985; Li, 1995). The southern margin of the basin is well delineated and is completely separated from the numerous but smaller basins in western Liaoning Province.

Further work is needed to pin down the age of the Gongzhuling fossils. Chinese geologists have assigned Aptian, Albian, or Cenomanian ages to the Quantou Formation based on macro-invertebrates, plants, and microfossils (Guan *et al*., 1985; Ma *et al*., 1989; Gao *et al*., 1992; Liu *et al*., 1993; Chen,

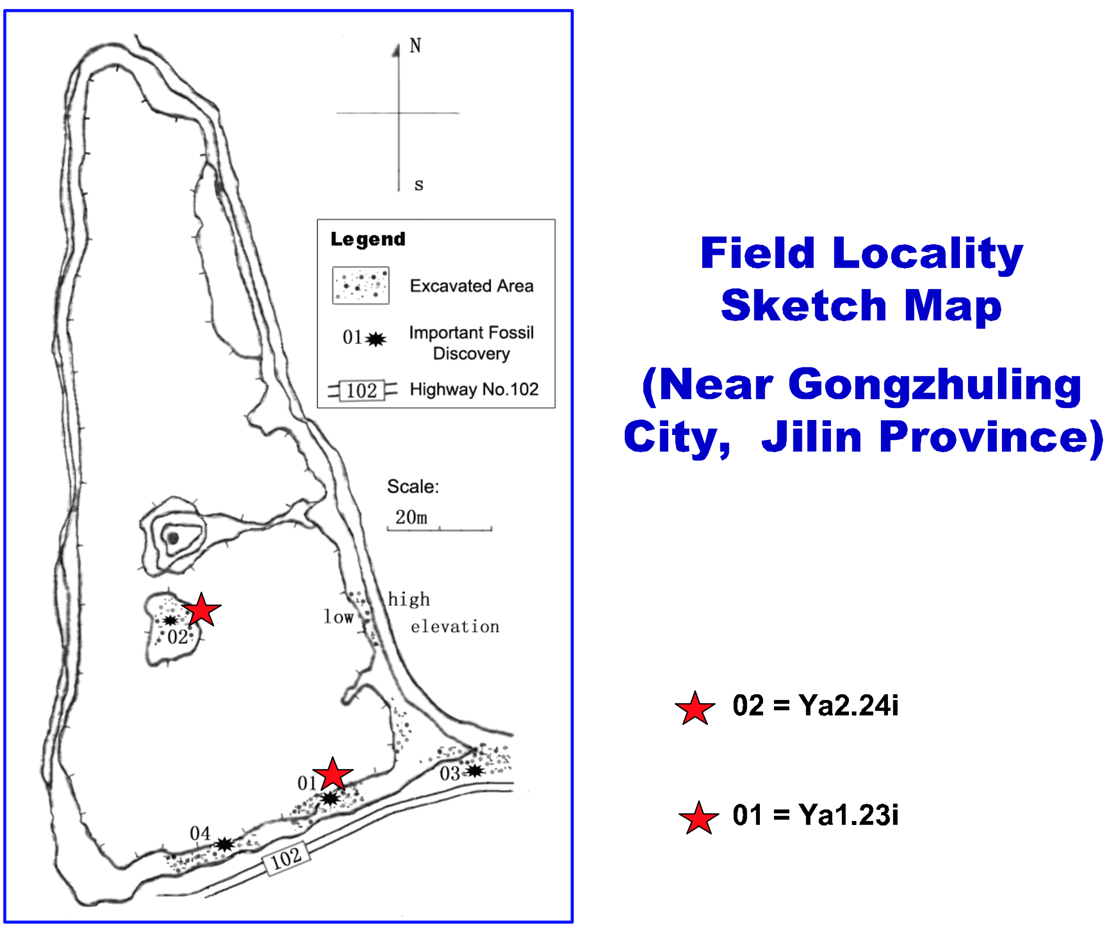

Fig. 9. Sketch map (J. Chen) of the "barrow pit" that is the site of the Gongzhuling faunule.

1994; Chen and Chang, 1994; Li and Liu, 1994; Ye, 1994; Wang, 1995; Sun and Zheng, 2000; Himeno *et al.*, 2001; Sun *et al.*, 2001). A few, relatively small-scale basaltic intrusions occur on the eastern margin of Songliao Basin but widely ranging, whole-rock radiometric dates are currently inconclusive (Zhou *et al.*, 1998). An earlier or later age for the Quantou may depend on whether an early Cretaceous rather than a late Jurassic age is accepted for parts of the Yixian Formation of western Liaoning, based on newest radiometric results as well as fossils (Swisher *et al.*, 1999; Lo *et al.*, 1999; Swisher *et al.*, 2001). Accepting a younger age for the Yixian may require that the entire Songliao section, including the Quantou, must be shifted upward in age because of the Yixian recalibration. Clearly there is a need for more work and additional evidence to bear on the correlation of strata in Songliao Basin with those in other basins, especially those in western Liaoning. At this time the vertebrate fossils offer hints but no proof. It seems unlikely, in any case, that the Quantou strata are younger than Cenomanian (Sun and Zheng, 2000; Sun *et al.*, 2001; Himeno *et al.*, 2001).

Assignment of the strata at the Gongzhuling locality to the Quantou Formation has been primarily on the basis of lithology, especially on the presence of red coloration, and on the basis of detailed (but mostly unpublished) knowledge of subsurface geology by veteran regional economic geologists such as Mr. Zhang Pulin and his colleagues. Much of the surrounding area is covered not only by vegetation and habitation, but also by various layers of Quaternary and alluvial sediments (Fig. 10). Walking out the section from a type area (near the town of Quantou in northern Liaoning Province) has therefore not been possible, and to date no microfossils, which could be compared to the type section or to well data, have been

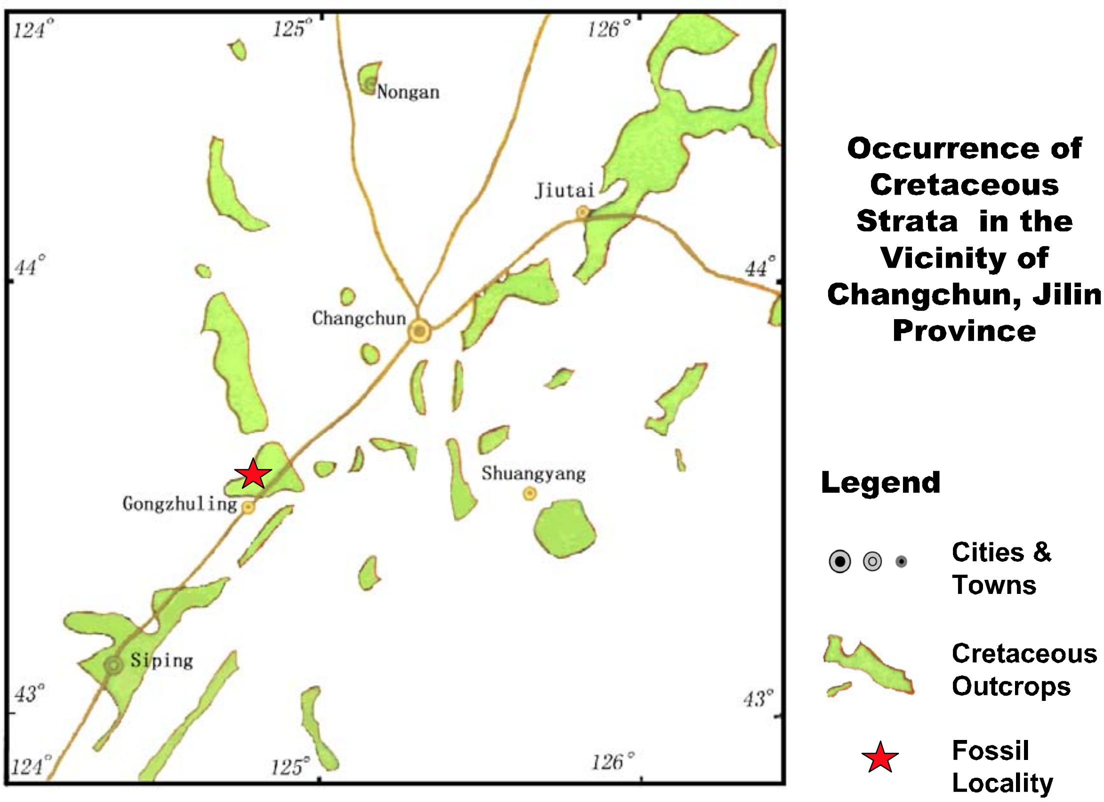

Fig. 10. Locality map (J. Chen) of the Gongzhuling locality and general occurrence of Cretaceous strata in the immediate region.

obtained from the Gongzhuling locality. Recently published surface maps (e.g., Zhou *et al*., 1998) show distribution of the Quantou Formation and other Cretaceous strata outcropping in north-south-striking bands but in a rather generalized manner.

SIGNIFICANCE OF THE NEW MAMMALS

General surveys of Chinese vertebrate paleontology have indicated that, until recently, the record of vertebrate evolution during all of the mid-Cretaceous has been poor or completely lacking in China (Lucas and Estep, 1998; Tang *et al*., 2001). It is therefore worth noting that almost anything from this time span of Aptian through Turonian is likely to produce information new to science as well as of great importance to our understanding of the origins of Late Cretaceous and Cenozoic faunas - in China and beyond (Cifelli *et al*., 1997).

Zalambdalestids are being found in several new localities of the eastern Gobi (GWR), and the Nemegt Valley (Novacek *et al*., 1998) demonstrating a widespread occurrence for zalambdalestids in Asia and likely spanning most of the Late Cretaceous. We recognize and support the hypothesis that zalambdalestids are a basal eutherian clade, with possible affinities to asioryctitheres (Novacek *et al*., 1997; Asher *et al*., 2005). The discovery of earlier Late Cretaceous taxa such as *Zhangolestes* therefore has important implications regarding the age and the early diversity of eutherians.

The age of the Gongzhuling locality is a primary issue (previous section). If the age of the strata were as old as the Aptian or even the Albian Epochs of the Cretaceous, the morphology of these two specimens would suggest that they extend certain derived eutherian characteristics to a much earlier time than previously expected. *Kulbeckia* and early "zhelestids", from Turonian to Coniacian localities in mid-Asia (i.e., Uzbekistan Archibald and Averianov, 2003) are, for example, heretofore the oldest known eutherians with molariform p5. Setoguchi *et al*. (1999) have described a somewhat older (?Cenomanian) "zhelestid" from Japan, but it is based on very limited material. Averianov and Archibald (2005) describe p5 as "semimolariform" in *Bobolestes* from the early Cenomanian. Additional work must be done, as discussed above, but currently it seems unlikely that the Quantou Formation and therefore *Zhangolestes* could be younger than Cenomanian.

Zalambdalestids have been regarded as basal members of Glires within Placentalia (Archibald *et al*., 2001; Archibald and Averianov, 2003; Averianov and Archibald, 2005) or as a specialized basal or stem eutherian group outside Placentalia (Rougier *et al*., 1998; Luo *et al*., 2002; Meng *et al*., 2003; Wible *et al*., 2001, 2004; Asher *et al*., 2005). Meanwhile, a lively discussion has been under way regarding the first occurrence and date of diversification of crown-group Placentalia, especially with regard to whether the fossil data are concordant with data from DNA studies among living taxa (Springer, 1997; Rougier *et al*., 1998; Foote *et al*., 1999; Murphy *et al*., 2001; Archibald and Deutschman, 2001; Archibald, 2003; Szalay, 2005). Eutheria, as presently defined (any mammal more closely related to placentals than to Metatheria (Rougier *et al*., 1998)), now extends to the Early Cretaceous mammal, *Eomaia*, from the Yixian Formation of Liaoning Province (Ji *et al*., 2002). *Eomaia* is understood to lie outside of crown-group Placentalia (*ibid*.), as are genera such as *Prokennalestes*, (arguably) *Bobolestes*, and probably the asioryctotheres. Averianov and Archibald (2005) have advocated that *Bobolestes*, despite no evidence of enlarged and procumbent i1, is nevertheless a basal member of Zalambdalestoidea (Gregory and Simpson, 1926) and that semimolariform p5 is synapomorphic for the superfamily. As indicated above, we support the hypothesis that zalambdalestids lie outside of crown-group Placentalia but currently we have no further evidence to add to the discussion.

Five premolars are believed to be plesiomorphic for Eutheria (McKenna, 1975; Novacek, 1986;

Sigogneau-Russel *et al*., 1992; Rougier *et al*., 1998; Cifelli, 2000; Kielan-Jaworowska *et al*., 2004) with reduction to four elements. The tooth suspected to disappear in zalambdalestids is commonly considered to be the p3 (Archibald *et al*., 2001; Archibald and Averianov, 2003, but see comments in Wible *et al*., 2004). Later zalambdalestids may have a variable number of premolars and 4 or 3 can be present, presumably as individual or specific variation (Kielan-Jaworowska, 1975; Kielan-Jaworowska *et al*., 1979; Kielan-Jaworowska and Trofimov, 1980; Wible *et al*., 2004). If Ya1.23.i, with presumably five premolars is compared with *Kulbeckia*, which has four, it is clear that the element missing in *Kulbeckia* is the tooth we interpret to be p1 in *Zhangolestes.* Our specimens may provide evidence that at least in zalambdalestids the condition of four premolars is achieved by the loss of the p1 and not the p3 as previously suggested (Archibald and Averianov, 2003). If true, this observation could mean that reduction from five to four premolars has occurred more than once among eutherians, and by more than one path of derivation.

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중국 북동부 길림성의 새로운 화석지에서 산출된 새로운 “중기” 백악기 Zalambdalestid 포유류

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요 약: 중국 길림성의 Gongzhuling 시 근처의 새로운 백악기 화석지에서 산출된 화석은 두개의 불완전한 포유류 하악골을 포함하는데 이 표본은 태반류 Zalambdalestidae과에 속하는 새로운 속과 종이다. 화석지는 Songliao분지의 넓게 분포하는 Quantou층의 가장자리에 위치하는데 Songliao분지의 시대는 Aptian~Cenomanian 으로 알려져 있다. 그러나 Quantou층이 Cenomanian 보다 더 젊을 것 같지는 않다. 두 하악골은 크고 납작한 첫 번째 앞니를 갖고 있는데 *Kulbeckia kulbecke*같은 종과 비교해 보면 원시적이고 진화적인 특징들이 흥미롭게 섞여 있다. 예를 들면, Gongzhuling 표본은 5개의 앞어금니 (거의 완전한 어금니 형태의 앞어금니)와 단지 3개의 앞니, 그리고 한 개의 낮고 단 뿌리의 송곳니를 가진다. 5번째 앞어금니와 첫 번째 어금니의 trigonids는 상대적으로 눌리지 않고 열려있는 형태다. 이 화석지는 "중기" 백악기 척추화석들에 대한 새로운 정보를 확보할 중요한 장소로 알려지게 될 것이며 가까운 미래에 이곳에서 새로운 포유류, 공룡, 그리고 다른 표본들이 기재될 것이다.

주요어: "중부 백악기", zalambdalestid 포유류, 길림성, 중국

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