The Discovery of a Tritylodont from the Xinjiang Autonomous Region

Ailing Sun and Guihai Cui
(Institute of Vertebrate Paleontology, Paleoanthropology, Academia Sinica)

Vertebrata PalAsiatica
Volume XXVII, No. 1
January, 1989
pp. 1-8

Translated by Will Downs
Department of Geology
Bilby Research Center
Northern Arizona University
November, 1990

Abstract

The text reports the first discovery of the Tritylodontia from northwest China. The specimens are assigned to *Bienotheroides zigongensis,* conspecific with the taxon derived from the Dashanpu dinosaur fauna of Zigong, Sichuan Province, suggesting the lower Xiaximiao Formation may be correlated to the Wucaiwan Formation. The discovery of several new morphological characters on the new specimens supplements previously insufficient descriptions.

Introduction

This text describes material assigned to the Tritylodontia discovered 31 kilometers north of Jiangjunmiao, in the Kelameili region, northeast Junggar Basin, Xinjiang Autonomous Region. Specimens were collected from the Wucaiwan Formation in 1984 by a vertebrate paleontological collecting expedition. After analysis of the cranial morphology, the material is determined to be taxonomically consistent with *Bienotheroides zigongensis*.

The type specimen for *Bienotheroides zigongensis* consists of a single skull, lacking the dorsal section and mandibles. Consequently, many cranial suture lines are unknown. The discovery of the Xiunjiang specimens now permits more precise cranial and mandibular descriptions of this taxon. This is the first discovery of the Tritylodontia from northwest China, as previous localities are known only from the provinces of Yunnan and Sichuan.

Fossil specimens include three incomplete skulls and skull fragments, mandibles, and post-cranial elements. Specimen numbers are assigned as follows:

V7909: An incomplete skull, left femur, proximal left humerus, four caudal vertebrae, and several fragmentary limb elements. Locality number 84004.

V7910: A weathered skull with only the cranial outline remaining, but preserving a relatively complete mandible. Locality number 84005.

V7911: An anterior section of skull with a large portion of the mandible. Locality 84007.

V7912: A right maxilla with six molariform teeth, a section of incisor, right mandible with four teeth, eight isolated vertebrae, a left femur, tibia, ulna, and other fragments.

V7913: one quadrate associated with a (?) hyoidal element. Locality 84004.

Remaining fragmentary skeletal elements not enumerated.

Description

The cranial description is based principally upon specimen V7909. The skull length is 112 mm. Although the specimen has incurred relatively extensive damage upon the posterior side of the left orbit and posterior nasals, the general condition of preservation is very good as it displays relatively conspicuous cranial suture lines. Particularly well preserved and excellently exposed is the medial aspect of the left mandible displaying the point of articulation to the cranium.

The nasals are relatively broad. Anteriorly, the breadth of the left and right premaxillae is 15 mm, which abruptly increases to 25 mm at the zygomatic arches; consequently the dorsal aspect of the skull appears acutely convex. Extremely distinct sutures are swollen to form crests demarcating the nasals from the neighboring lacrimals and premaxillae. The medial suture of the left and right nasals is also slightly but conspicuously swollen. A process composed jointly of the

left and right nasals projects from the most anterior section of the skull, but its anterior extremity is broken. A pair of extremely deep sulcuses may be observed at the posterior section of the nasals. In dorsal aspect the nasals form two valleys with a central peak. The walls surrounding the deep sulcuses have an extremely glossy surface.

The nasal fossa of the Tritylodontia has been consistently recognized to be confluent. To date, no specimen has ever been observed in which the nasal fossa is divided by a dorsal branch of the premaxilla, or an internarial bar. The senior author of this paper has, however, noticed on the type specimen of *Bienotheroides wanxienensis* (V4734) the presence of a broken process on the anteromedial portion of the premaxilla. This suggests the presence of a small and thin dorsal branch of the premaxilla. The two deep sulcuses with a central peak on specimen V7909 differs from the cartilaginous anterior nasal septum of the Mammalia, but very possibly represents an osteological connective structure receiving the dorsal septum of the premaxilla. It is believed here that the remnants of an internarial bar on the premaxilla is still present. However, there is no trace of a septomaxilla.

The premaxilla is rather extended and is consistent with other specimens of *Bienotheroides* in that it articulates directly with the lacrimal, at which point, the maxilla is completely concealed. The root of the robust second incisiform tooth creates a strong swelling on the premaxilla.

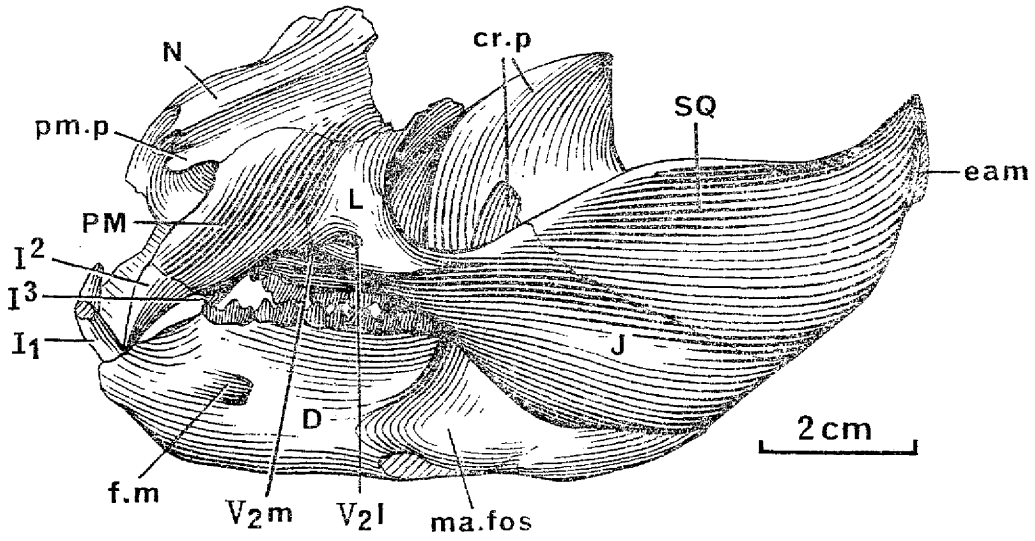


Figure 1. *Bienotheroides zigongensis* (V7909), lateral view of skull.
For abbreviations see page 6.

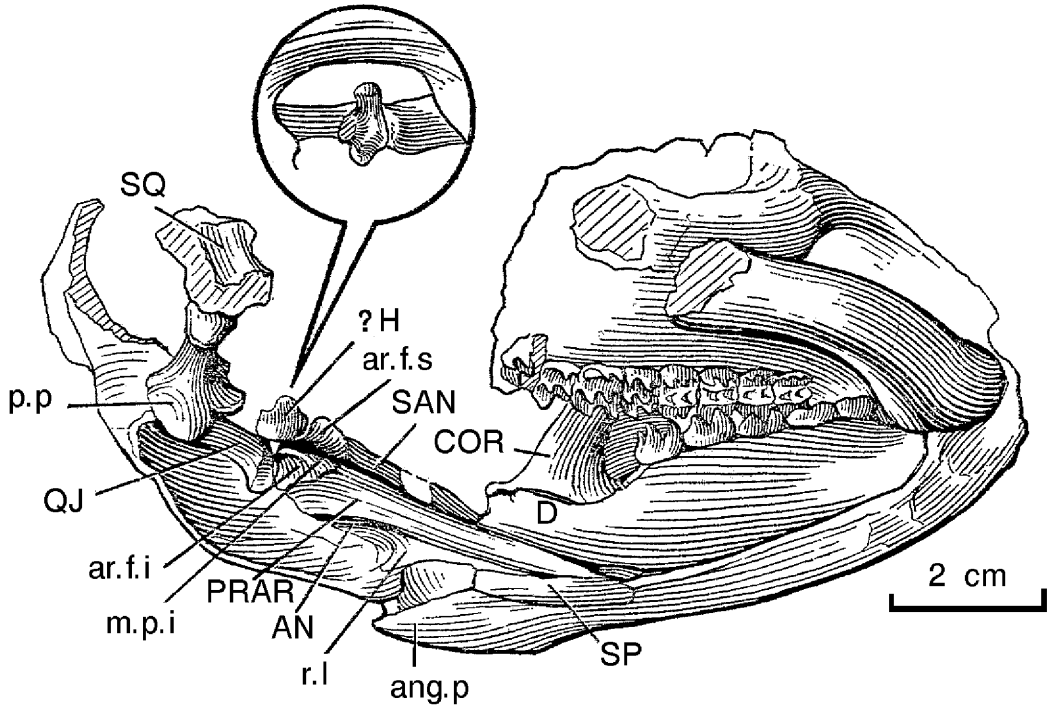
The semi-circular lacrimal forms the anterior margin of the orbit, and is bounded by the nasal, premaxilla, and jugal. Conspicuous openings represent the tripartite foramena for the "lacrimal branch" and "maxillary branch" (V_2m and V_2l) of the infraorbital. Their locations are consistent with those on *B. wanxienensis*.

The expansive zygomatic arch is an important feature distinguishing this species from other tritylodontids, whereas a semicircular or fan-shaped surface extends ventrally from the jugal. The anterior base of the zygomatic arch is expansive. It surrounds the maxilla and extends into an approximately 12-13 mm high neck. Posteriorly the jugal and squamosal also differ from other species by increasing in depth dorsoventrally. The suture for these two elements crosses the center of the zygomatic arch transversely, where it is slightly swollen. The broadest point accross the zygomatic arches reaches 38 mm. Posterior to the midline its ventral border rapidly ascends, and at its posterior terminus its thickness is reduced to 15 mm. The squamosal thickens at the medial

side of the terminus to form the concavity of the external auditory cavity. Deformation has caused the external auditory meatus to be compressed shut, although its impression is still present.

Only the left side of the specimen preserves the occipital region where a relatively complete paroccipital process and a portion of the squamosal may be observed. The paroccipital process is rather robust and hourglass shaped. The concavity beneath its dorsal margin forms the ventral margin of the post-temporal foramen. The terminus of the paroccipital process is well developed, appearing as round anteriorly while narrow and long posteriorly. This is consistent with the genus *Bienotheroides*. The lateral margin of the occipital process on *B. wanxienensis* is not complete; however, it is apparently not as robust as on this specimen.

Specimens V7910 and V7911 are not adequate to supplement this description.



The left mandible of V7909 is preserved in articulation with the skull. Its coronoid process is broken and shifted anteromedially. A 40 mm anterior portion of the right mandible is preserved. There is a 6-10 mm separation of the mandibular symphysis, with the articulation point of each ramus extremely smooth and glossy, indicating the relatively active kenetic nature between the left and right mandibles of this taxon.

The anterior end of the dentary is slightly extended, but the degree of anterior extension is not equivalent to the type specimen of *B. wanxienensis*. The mental foramen is situated beneath and between the first and second cheek teeth, or slightly more anterior than *B. wanxienensis*. The angular process is relatively well preserved, extremely pointed, and long. The same elements on specimen V7910 conform to these observations.

Specimen V7909 displays the posteromedial accessory jaw bones (also designated postdentary elements) in superb preservation and may supplement prior deficient descriptions. Consistent with *B. wanxienensis,* the coronoid is shaped as an isosceles triangle withthe posterior section of the triangular base extending posteriorly, to possibly facilitate the shallow groove of the posterodorsal margin for the deep temporal muscles. The position of the coronoid is further

anterior than that of *B. wanxienensis*. Utilizing the center of this element as a reference point for measurement, a ratio may be constructed to illustrate the distance between this point and the posterior and anterior ends of the mandible. On this specimen the ratio is 1:1.85, whereas on *B. wanxienensis* it is 1:2.74. There is a quite distinct suture between the base of the coronoid and the posterior angle of the dentary. Posteriorly, the surangular is preserved with a piece broken out of its center. Its long and thin anterior end is compressed beneath the posterior angle of the dentary. The surangular is fused with the articular, but the contact between these two elements is still visable.

The prearticular is flat, and it extends ventrally to the surangular. Its posterior margin runs along the ventral margin of the articular, and reaches the articulation point of the mandible. Its total length is 41 mm. Only the posterior end of the splenial is preserved.

An extremely distinct suture line is present ventrally between the angular and prearticular. A triangularly shaped thin plate extends ventrally from the center of the angular that is undoubtedly the reflected lamina. The anterior margin of this lamina is rather complete although the posterior margin has sustained some damage. It is, however, evident that the terminus is quite unlike the rounded projection on *Cynognathus* (Kermack et al., 1973).

Specimen V7909 displays a relatively complete articular region of the mandible (Fig. 2), with distinct sutures between the articular and the other elements. The articular fossa itself is composed of two fossae: the inferior articular fossa (ar.f.i.) and the superior articular fossa (ar.f.s.). Compared to other cynodonts, the position of these features is rotated medially to cause the two surfaces to be arranged dorsoventrally, unlike *Cynognathus,* which displays a lateromedial arrangement. The superior articular fossa is relatively large with its surface directed medially. The same fossa on *Cynognathus* is spoon-shaped due to the enclosure of its anterior end. The Xinjiang specimen is consistent with *B. wanxienensis* in that the surface of the superior articular fossa is tongue-shaped with an unenclosed anterior end, allowing for relatively large anterior-posterior movement between the mandibular articulation and the quadrate. The inferior articular fossa is relatively small and like the superior fossa is not enclosed anteriorly, but still linked posteriorly to the quadratojugal. Consequently, it is possible to observe this articulation surface on the quadratojugal. A sharp crest lies between the superior and inferior articular fossae, the anterior end of which is strongly swollen and should equate to the insertion for the internal pterygoideus as noted in the genus *Oligokyphus*. A retroarticular process is not preserved. The lateral surface of the articular is smooth and with the exception of the posteriorly swollen margin of the articular surface for the quadrate, there are no other noteworthy characters.

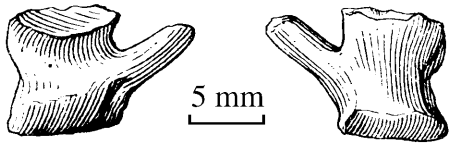


Figure 3. Quadrate of *Bienotheroides zigongensis* (V7913).

The quadratojugal is rod-shaped, like *B. wanxienensis*, but more robust. This element is approximately 20 mm in length. It is slightly flattened laterally and its superior end penetrates the auditory cavity at the lateral side of the squamosal. The terminus of the mandible's articular end is thickly swollen and projects laterally, causing the articular surface to be inclined laterally.

The V7909 skull preserves a small osteological element (Fig. 2) medial to the quadratojugal that is difficult to interpret. From the perspective of its position, lying medial to the quadratojugal and dorsal to the superior articular fossa of the articular, the element should be the quadrate. Morphologically, however, this is impossible, as the element is long and gracile with one extremity

broad and the other narrow. The broad end is triangular with a round process at its terminus. There is a robust swelling that houses a round articular fossa at the lowest angle of the triangle; the other angle consists of a flat process. The other extremity is a flat surface, the breadth of which is equivalent to the shaft. The terminus at this end, however, is incomplete. The lateral margin is convex while the medial margin is correspondingly concave. At the center of the element is a swollen longitudinal crest.

At the right posterior side of this specimen are two additional small and separated elements unarticulated with any of the surrounding bones. One of these is a quadrate, to be described later in the text. The other element is morphologically consistent with the aforementioned minute object. At the center of this element is a broken fissure or post-mortem gap. One extremity has a conical terminus with a robust rounded swelling in addition to a flat posterior process. The other extremity is columnar with an oblique fossa at its terminus.

Initially, these two additional elements were naturally interpreted as something exotic; however, after undergoing careful scrutiny it was observed that these two small elements unexpectedly arise from the same side. After careful consideration, there is no alternative but to recognize these as being derived from a different individual. As a result, a separate specimen number, V7913, is provided to this small broken element and the quadrate that is preserved with it. However, this small and gracile element is preserved with a 1-2 mm gap. Because the terminal end of the element on V7909 is incomplete, the total length of this element should be appropriately extended to 12 mm, which is 2 mm longer than the equivalent element of specimen V7909. It appears more appropriate to consider extending the length of this feature by 2 mm.

Two interpretations may be made of the minute element:

This cranial element may be a stapes, such that the robust, rounded swelling may be interpreted as the dorsal process, the columnar-shaped process at the distal end would be the quadrate process, and the oblique fossa at the opposite extremity would be the foot-plate of the stapes. This model may be considered extremely derived compared to stapes of other advanced cynodonts by its preservation of such a robust dorsal process. There is, however, not the slightest trace of a stapedial foramen. Consequently, due to the absence of prior precise tritylodontid stapedial descriptions, it is not possible to readily recognize this element as a stapes.

A second interpretation would characterize this element as a hyoid, as there is some resemblance to that on the North American *Kayentatherium* (Sues, 1986, Fig. 17 B). Sues described a basihyal element on one of his specimens and gave appropriate interpretations for each individual feature. It is very reasonable to interpret the element of *Kayentatherium* as a hyoid due to its flattened morphology, as opposed to the long rod-like morphology of the Chinese specimen.

The basicranium of the type specimen of *Bienotherium yunnanensis* possesses a long osteological element with a slight curvature that C.C. Young interpreted as a stapes, although it now may be more appropriate to consider this element a hyoid.

The quadrate, as represented by specimen V7913 (Fig. 3), displays a relatively well-preserved surface for articulation with the articular. A concave facet at the top of its dorsal extremity facilitates its articulation with the paroccipital process. Half of the margin of this facet is incomplete, but should represent the damaged remnants of a dorsal process. From a general perspective this is more robust than the quadrate of *B. wanxienensis;* however, a satisfactory comparison is not possible as the preservation of the latter's morphology is not ideal and its position is shifted.

This quadrate is also extremely atypical, for an offshoot that is completely fused to the quadrate extends tangentially and superiorly to the articular surface, and lacks any trace of a suture.

However, due to the weathered nature of preservation it is not possible to ascertain whether its position is lateral or medial. If one regards this element as the quadratojugal that is fused to the quadrate, then the quadratojugal would appear too short and small, unlike the completely preserved quadratojugal on specimen V7909. Hence, this feature is more appropriately considered the stapedial process of the quadrate. *Kayentatherium* also possesses a stapedial process; however, its shape tends to be more thin and flat and it is fused to the dorsal process of the quadrate to form a plate.

The type specimen of *Bienotheroides zigongensis* from Sichuan Province is rather incomplete, consisting of only six isolated left and right cheek teeth. The Xinjiang specimen (V7909) preserves a complete left dental battery (Figs. 1 and 2).

The remnants of a first incisiform tooth root with a breadth of 3 mm may be noted most anteriorly. The second incisiform tooth is robust and sharply pointed, slightly flattened, and displays a sharp ridge on the anterior, lateral and posterior margins. The crown is 12 mm in length and 7 mm in breadth at the tooth root. The third incisiform tooth is extremely small and is situated approximately 3 mm from the second molariform tooth. Its breadth is merely 3 mm at its root.

The upper dentition has seven functional molariform teeth, with one unerupted posterior tooth in the dental trough. Specimen V7909 is an aged individual. Four anterior maxillary teeth have undergone extensive occlusal wear with the central cusps worn flat. The degree of occlusal wear diminishes successively from front to back.

The upper molariform teeth are square, with slightly rounded corners. Two tooth cusps are present labially, with the posterior cusp noticeably larger than the anterior cusp. Three cusps are present in the central row with the two posterior cusps crescent-shaped, and the most anterior cusp relatively small and cone-shaped. Three cusps are present lingually, with the central cusp largest, the posterior cusp smaller, and the anterior cusp smallest.

The two large lower incisiform teeth that are present are equivalent in size. They project anteriorly, but not to the degree that they are completely level with the axis of the mandible. These incisiform teeth are anteroposteriorly (dorsoventrally) flattened to form a shovel-like morphology, with shallow corners on their lingual side. The second incisiform tooth is exposed on the right side of specimen V7909; however the tooth crown is broken. On specimen V7910 it is still possible to observe the trace of a tooth root. The distance between the lower incisiform teeth is smaller than between the upper second and third incisiform teeth.

The mandible of specimen V7911 preserves a total of six cheek teeth, five of which are functional. The lower cheek teeth are rectangular in morphology and are 6-7 mm long anteroposteriorly. Two rows of tooth cusps are present, each with two cusps lingually and labially, having a crescentic morphology, and with lateral walls that extend posteriorly, or in opposition to the upper molariform tooth cusps. All the cusps are equivalent in size and stylar cusps may be observed on all the teeth.

Portions of post-cranial elements are preserved. With the exception of two left femura from specimens V7909 and V7912, the rest of the material is incomplete. Analysis of the material suggests that there is no difference from the post-cranial elements described by Sun and Li (1985). It would therefore be redundant to describe it here

Comparison

With regard to genus, the tritylodontid material from Xinjiang manifests all the diagnostic characters of the genus *Bienotheroides,* including an extremely compressed rostral region, a ventrally extended jugal, extremely expanded zygomatic arches, and axis of the basicranium

(pterygoid and anterior section of the sphenoid) short, broad, flattened and lacking corrugated or angled structures. The maxilla is compressed. The premaxilla, lacrimal, and palatine can be distinguished laterally and ventrally where they come into direct contact.

With regard to species, *B. zigongensis* has independent characters distinguishable from *B. wanxienensis*. In addition to the maxillary tooth cusp formula of 2◊3◊3 described in the Sichuan type specimen, the Xinjiang specimens display several supplementary features including: (1) a long and sharply pointed angular process of the dentary; (2) an anteriorly shifted coronoid; (3) a quadrate and quadratojugal more robust than *B. wanxienensis*; and (4) a lacrimal not as expansive as *B. wanxienensis*.

The type specimen of *B. zigongensis* was collected from the Lower Xiaximiao Formation of Sichuan, the same sediments that produce the Sichuan dinosaur fauna. There are several controversies surrounding the stratigraphic position that produced *B. wanxienensis*. However, the Wancang specimen was derived from the *Mamenchisaurus* beds of the Upper Shaximiao Formation (Zhiming Dong, pers. comm.). Consequently, it is proposed here that it is extremely likely that *B. wanxienensis* was derived from the Upper Xiaximiao Formation.

The more primitive morphology of *B. zigongensis* (such as the tooth cusp formula and the aforementioned items three and four) suggests a derivation from a lower stratigraphic position than the type of *B. wanxienensis*. As conspecific taxa are derived from Xinjiang and Sichuan, the Wucaiwan Formation of Xinjiang may be correlated to the Lower Xiaximiao Formation of Sichuan, particularly from the perspective of the Tritylodontia.

Explanation of Abbreviations

An	angular
ang.p.	angular process of dentary
Ar.f.i.	inferior articular fossa
ar.f.s.	superior articular fossa
COR	coronoid
cor.p.	coronoid process of dentary
D	dentary
f.m.	mental foramen
?H	?hyoidal element
I	incisor
J	jugal
L	lacrimal
ma.fos.	masseteric fossa
m.p.i	insertion for the internal pterygoideus
N	nasal
PM	premaxilla
pm.p	premaxillary process of nasal
p.p.	paroccipital process
PRAR	prearticular
Q	quadrate
QJ	quadratojugal
r.l.	reflected lamina
SAN	surangular
SP	splenial
SQ	squamosal
V_2l	lacrimal branch of V_2
V_2m	maxillary branch of V_2

Bibliography

Clark, J.M. and J.A. Hopson, 1985; Distinctive mammal-like reptile from Mexico and its bearing on the phylogeny of the Tritylodontidae. *Nature* **135**(6018), 398-400.

Fourie, S., 1974; The cranial morphology of *Thrinaxodon liorhinus* Seeley. *Ann. S. Afr. Mus.*, **65**, 337-400.

He, X.L. and Cai, K.J., 1984; Tritylodontia from Zigong, Dashanpu. *Report of the Chengdu Academy of Geology*, series 2 (No. 33), 33-45 (in Chinese).

Hopson, J.A., 1966; Origin of the mammalian middle ear. *Am. Zoologist*, **6**, 437-450.

Kemp, T.S., 1982; Mammal-like reptiles and the origin of mammals. London, Academic Press. 363 pp.

Kemp, T.S., 1983; The relationships of mammals. *Zool. J. Linn. Soc.*, **77**, 353-384.

Kermack, K.A., F. Mussett, and H.W. Rigney, 1973; The lower jaw of *Morganucodon. Zool. J. Linn. Soc.* **53**(2), 87-175.

Kühne, W.G., 1956; The Liassic therapsid *Oligokyphus*. London, British Museum (natural history), 149 pp.

Miao, D. and J.A. Lillegraven, 1986; Discovery of three ear ossicles in a multituberculate mammal. *National Geographical Research* **2**(4), 500-507.

Parrington, F.R., 1955; On the cranial anatomy of some gorgonopsids and the synapsid middle ear. *Proc. Zool. Soc. Lond.* **125**, 1-40.

Sues, H.D., 1986; The skull and dentition of two tritylodontid synapsids from the Lower Jurassic of Western North America. *Bull. Mus. Comp. Zool.* **151**(4), 217-168.

Sun, A.L., 1984; The skull of the tritylodontid *Bientotheroides* (Tritylodontia, Reptilia) from Sichuan Province. *Scientia Sinica*, Series B, 1984 (3), 257-268 (in Chinese).

Sun, A.L., 1986; New Material of *Bienotheroides* (Tritylodontia, Reptilia). *Vertebrata PalAsiatica* **24**(3), 165-170 (in Chinese).

Sun, A.L., and Li, Y.H., 1985; The Postcranial Skeleton of a Jurassic Tritylodontid from Sichuan Province. *Vertebrata PalAsiatica* ***23*** (2), 135-151 (in Chinese).

Young, C.C., 1982; *Bienotheroides.* Posthumous Papers of C.C. Young. *Science Press*, 10-13 (in Chinese).