

# New specimens of pareiasaurs from the Upper Permian Sunjiagou Formation of Liulin, Shanxi and their implications for the taxonomy of Chinese pareiasaurs

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**Abstract** New pareiasaur specimens from the Sunjiagou Formation of Xuecun, Liulin, Shanxi, China are described. These new specimens comprise two marginal teeth from the upper jaw (IVPP V 18613) and an incomplete left dentary with teeth (IVPP V 18614). They provide novel anatomical information and allow the direct comparison of *Sanchuansaurus pygmaeus* with *Huanghesaurus liulinensis*. The two taxa cannot be differentiated by the known features, and both taxa are declared junior synonyms of *Shansisaurus xuecunensis*.

**Key words** Liulin, Shanxi; Upper Permian, Sunjiagou Formation; pareiasaurs

## 1 Introduction

Pareiasaurs are some of the most primitive, herbivorous parareptiles and were abundant all over the world in the Permian. Pareiasaurs are mostly known from specimens from South Africa and Russia, but they are also reported from other countries (Lee, 1997a,b). Six pareiasaur genera have been named based on Chinese materials (Young and Yeh, 1963; Young, 1979; Cheng, 1980; Gao, 1983, 1989); among them, three were collected from the Sunjiagou Formation of the Upper Permian in Xuecun Town, Liulin County, Shanxi Province: *Shansisaurus xuecunensis*, which was named on the basis of postcranial elements (Cheng, 1980); *Huanghesaurus liulinensis*, which was based on right ramus of a lower jaw and some postcranial elements (Gao, 1983); and *Sanchuansaurus pygmaeus*, which was based on an incomplete right maxilla with teeth (Gao, 1989). Lee (1997b) presented a comprehensive taxonomic revision of pareiasaurs, and recognized eleven species from South Africa, two species from Russia, three species from China, and one each from Brazil, Germany, and Scotland. In recent years, three new pareiasaur taxa were reported and one each from Niger, Morocco and Russia (Sidor et al., 2003; Jalil and Janvier, 2005; Bulanov and Yashina, 2005).

Recently, several new pareiasaur specimens were rediscovered in the collection of IVPP. They include two upper jaw teeth (IVPP V 18613) and one incomplete left dentary with teeth (IVPP V 18614). According to the field records, V 18613 was excavated together with the holotype of *Huanghesaurus liulinensis* (IVPP V 6722) from the same locality (Beigou

Village, Xuecun Town) and same horizon (topmost part of the Sunjiagou Formation) at the same time, while V 18614 was excavated from the lower part of the Sunjiagou Formation in Tianjialing Village, Xuecun Town, which produced the holotype of *Shansisaurus xuecunensis* (IGCAGS V 301) and the holotype of *Sanchuansaurus pygmaeus* (IVPP V 6723). The new specimens are not as well preserved as the known holotypes, but they supply some previously unknown anatomical information and provide a chance to review the taxonomy of the Chinese pareiasaurs from the Sunjiagou Formation. *Shitienfenia permica* was also reported from the Sunjiagou Formation, and the available material has no jaw element or any tooth (Young and Yeh, 1963); so this taxon is excluded from this study and will be discussed later.

**Institutional abbreviations** IGCAGS, Institute of Geology, Chinese Academy of Geological Sciences, Beijing; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing.

## 2 Description

### 2.1 New specimens from Beigou Village, Xuecun Town (IVPP V 18613)(Fig. 1A-C)

In pareiasaurs, the teeth on the upper jaw are quite different from those on the lower jaw in morphology; e.g., the teeth from the upper jaw have lower, more pointed crowns and less cusps than the teeth from the lower jaw in *Pareiasuchus* and *Scutosaurus* (Lee, 1997a; Lee et al., 1997). Therefore, these two teeth are identified as teeth from the upper jaw. They resemble each other in having a broad fan-shaped crown, which expands mesiodistally, and curves lingually, with a convex labial surface and a concave lingual surface. The cusps on the crown have slightly worn, and their number ranges from 9 to 11. The cusps are mesiodistally

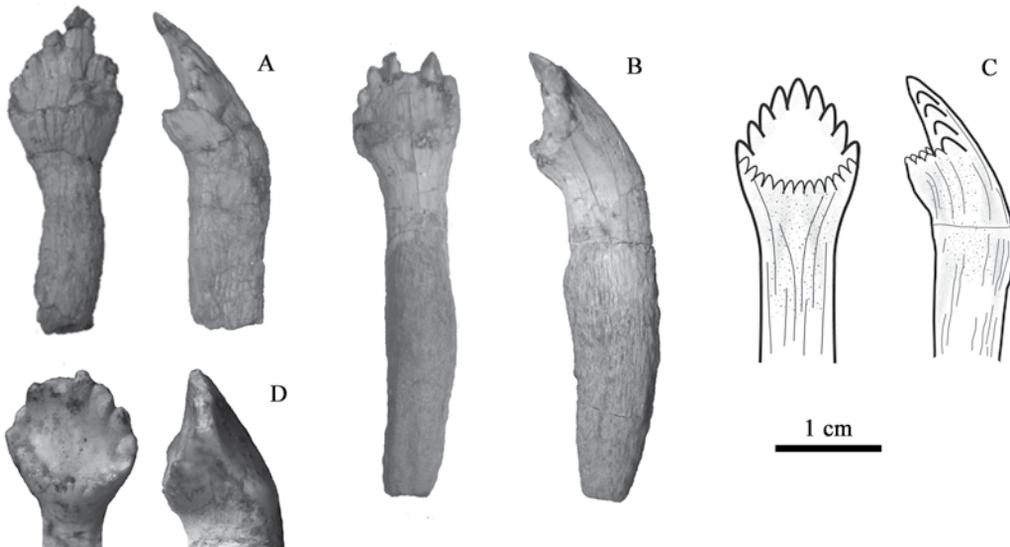


Fig. 1 The lingual and anterior or posterior view of IVPP V 18613-1 (A), V 18613-2 (B) and the restoration of them (C), and two teeth (D) from the holotype of *Sanchuansaurus pygmaeus* (IVPP V 6723) in lingual and anterior views

distributed on the apex of the crown, three in the middle and three to four on each lateral side. The three central cusps are closer together than are the cusps on the lateral sides. A horizontal cusped cingulum is present on the lingual surface of the crown.

## 2.2 New specimen from Tianjialing Village, Xuecun Town (IVPP V 18614)(Fig. 2A-C)

The preserved portion of the dentary is robust, and measures 195 mm in length. A large rounded hole in the dentary might reflect poor preservation and preparation. Comparison with other pareiasaurs such as *Pareiasuchus nasicornis*, suggests that a much smaller foramen intermadibularis medius (FIM below) might exist in this position (Lee et al., 1997). A shallow depression anterior and posterior to the FIM on the medial surface is related to the attachment of *Musculus intramadibularis*. Lacking the splenial, the medial surface of the dentary is exposed. The dentary forms the dorsal wall of the Meckelian canal on the medial surface of the lower jaw. The canal, which contained the Meckel's cartilage, extends horizontally from the symphysis and leads posteriorly.

Fifteen mandibular teeth and four newly erupted teeth are preserved in V 18614. In addition, two alveoli lie mesially to the tooth row, close to the mandibular symphysis. The missing posterior portion of the dentary might have carried additional teeth, in which case the estimated total number of teeth in each dentary would be at least 18. These teeth are closely spaced so that their crowns overlap slightly to form a continuous cutting edge. The crown is not recurved lingually. As in all other pareiasaurs, the dentary teeth decrease in size posteriorly. All functional teeth are incomplete to some degree, and their crowns more or less damaged. Fortunately, two newly erupted teeth are well preserved. From these teeth, it can be inferred that 17 cusps are distributed across the tooth crown. The cusps are evenly arranged along the margin of the crown. The labial surface of the mandibular teeth is smooth and featureless,

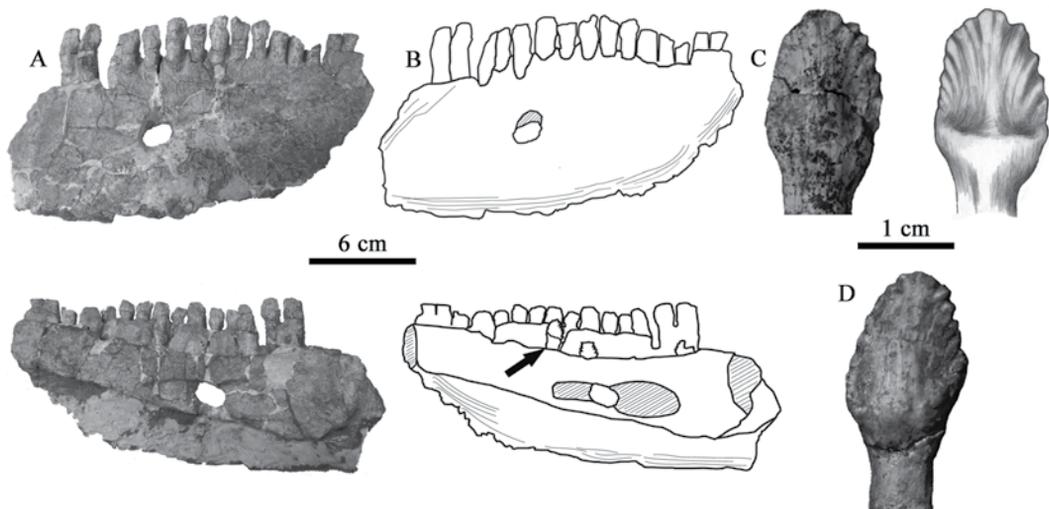


Fig. 2 The photograph (A) and the outline (B) of IVPP V 18614 in lateral and medial views, arrow indicates the newly erupted tooth that is best preserved, enlarged and illustrated in lingual view in C, and the tooth (D) from the holotype of *Huanghesaurus liulinensis* (IVPP V 6722) in lingual view

while the lingual surface bears a distinct triangular ridge, which is wide near the base of the crown and narrows towards the tip. Both of the lateral sides of the ridge are slightly concave. A cusped cingulum is absent even in newly erupting teeth (Fig. 2C).

### 3 Comparison and discussion

IVPP V 18613 was excavated from the same locality as the holotype of *Huanghesaurus*. In addition, they are compatible with the lower teeth on the holotype of *Huanghesaurus* (Fig. 2D) in size, and their differences in morphology mirror the heterodonty of many pareiasaurs, therefore most likely they come from the same species or even the same individual and can be referred to *Huanghesaurus*. Morphologically, these two teeth also show same features as the teeth of the holotype of *Sanchuansaurus* in being fan-shaped with 9 to 11 cusps unevenly arranged across the tooth crown. In addition, every tooth of V 18613 and *Sanchuansaurus* has a cusped cingulum on the lingual surface, separating the crown from the root (Fig. 1). Therefore, V 18613 can be referred to *Sanchuansaurus*.

According to the field records, V 18614 (Fig. 2A-B) was collected from the lower part of the Sunjiagou Formation of Tianjialing Village, Xuecun Town, together with the holotype of *Sanchuansaurus*. Not far from this locality, the holotype of *Shansisaurus* was collected from the upper part of the Sunjiagou Formation. Therefore, V 18614 most likely belongs to *Sanchuansaurus pygmaeus*, but we do not exclude the possibility that it belongs to *Shansisaurus xuecunensis*. If V 18614 belongs to *Sanchuansaurus*, it represents an individual that is rather larger than IVPP V 6723, and we can infer that V 6723 belongs to a juvenile rather than being a small adult as inferred by Gao (1989) in the specific name “*pygmaeus*” (meaning dwarf). Juvenile pareiasaurs are relatively rare compared to adults (Lee, 1997b), which may be the result of a rather short juvenile period compared to adulthood, or that juvenile pareiasaurs frequented habitats less amenable to preservation than those occupied by adults (Spencer and Lee, 2000).

Morphologically, the dentary and the teeth of V 18614 show no clear differences from those of the holotype of *Huanghesaurus liulinensis*. The teeth on both specimens are leaf-shaped with 17 cusps evenly arranged across the crown, and the lingual surface of every tooth bears a distinct triangular ridge, which is wide near the base of the tooth and narrows towards the tip of the crown (Fig. 2). Gao (1983) and Lee (1997b) stated that a cusped cingulum is absent in IVPP V 6722, but a few cusps are observed along the base of the tooth crown on some teeth (Fig. 2D). This is similar to *Scutosaurus*, in which the cusped cingulum is present only on some teeth of the upper jaw, so this feature can vary within the same individual (Lee, 1997b). If we accept that V 18614 belongs to *Sanchuansaurus*, the features of dentary and dentary teeth also cannot differentiate *Sanchuansaurus pygmaeus* from *Huanghesaurus liulinensis*. In addition, if we accept that V 18614 belongs to *Shansisaurus xuecunensis*, these features confirm that *Huanghesaurus liulinensis* could be a junior synonym of *Shansisaurus xuecunensis* as proposed by Lee (1997b).

Therefore, we propose that there perhaps is only one valid pareiasaur taxon, *Shansisaurus xuecunensis*, from the Sunjiagou Formation of Xuecun Town, Liulin County.

#### 4 Systematic paleontology

##### **Reptilia Laurenti, 1768**

##### **Parareptilia Olson, 1947**

##### **Pareiasauria Seeley, 1888**

##### ***Shansisaurus xuecunensis* Cheng, 1980**

**Synonyms** *Huanghesaurus liulinensis* Gao, 1983; *Sanchuansaurus pygmaeus* Gao, 1989.

**Holotype** IGCAGS V 301, a vertebra, left scapulocoracoid and femur.

**Referred specimens** IGCAGS V 302, an incomplete right humerus; IVPP V 6722, an incomplete skeleton, including right ramus of lower jaw, 13 vertebrae, left scapulocoracoid, clavicular girdle and left fore-limb and manus. IVPP V 6723, right maxilla with teeth; IVPP V 18613, two upper jaw teeth; IVPP V 18614, an incomplete left dentary with teeth.

**Locality and horizon** Xuecun, Liulin, Shanxi, China; Sunjiagou Formation.

**Revised Diagnosis** size fairly large; two exits for the infraorbital canal in maxilla are further apart; 18 teeth in each upper jaw; cusped cingulum present on every maxillary tooth on the lingual surface and 9-11 cusps arranged unevenly around crown, 3 in the middle, 3-4 anteriorly and posteriorly; 20 teeth in each lower jaw; mandibular teeth with triangular ridge on lingual surface and 17 cusps arranged evenly around crown; cusped cingulum absent on dentary teeth but with a few cusps on the base of crown; scapula blade plate-like and four times as long as the glenoid; dorsal edge of posterior coracoid oriented posteroventrally; cleithrum absent; torsion in humerus 40 degrees; ectepicondyle a wide rectangular flange; entepicondylar foramen present and visible in distal dorsal view; olecranon process large; proximal end of femoral shaft curved slightly preaxially; postaxial flange of femur oriented posteriorly, narrower in the middle; internal trochanter not visible in dorsal view.

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## 山西柳林孙家沟组锯齿龙类新材料及其分类学意义

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**摘要:** 记述了产自山西柳林县薛村镇附近上二叠统孙家沟组的锯齿龙类新材料, 包括两个单独的上颌齿和一个保存有牙齿的不完整齿骨。这两颗上颌齿与柳林黄河龙

(*Huanghesaurus liulinensis*)正型标本来自同一地点同一层位且大小相当, 由于同一地点未发现过其他的锯齿龙类, 推测它们是同种甚至可能是同一个体而且应归入黄河龙; 然而在形态特征上这两颗牙齿与矮小三川龙(*Sanchuansaurus pygmaeus*)正型标本上的牙齿完全相同, 可以归入三川龙。新发现的齿骨与矮小三川龙和薛村山西龙(*Shansisaurus xuecunensis*)正型标本产自同一地点, 层位与三川龙相同, 低于山西龙的层位, 推测很可能也属于三川龙, 但是也不排除属于山西龙的可能性; 在形态特征上与黄河龙正型标本在齿骨及其下颌齿的形态特征上未见明显差异, 可以归入黄河龙。由于柳林黄河龙与薛村山西龙头后骨骼特征也基本一致, 认为柳林薛村仅有一个属种的锯齿龙, 矮小三川龙和柳林黄河龙应为薛村山西龙的晚出同义名。

关键词: 山西柳林, 上二叠统, 孙家沟组, 锯齿龙类

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## References

- Bulanov V V, Yashina O V, 2005. Elginiid pareiasaurs of eastern Europe. *Paleont J*, **39**(4): 428–432
- Cheng Z W(程政武), 1980. Mesozoic stratigraphy and paleontology of the Shaanxi-Gansu-Ningxia Basin. **2**(7), *Vertebrate fossils*. Beijing: Geological Publishing House. 115–119(in Chinese)
- Gao K Q(高克勤), 1983. A new pareiasaur from Liulin, Shanxi. *Vert PalAsiat(古脊椎动物学报)*, **21**(3): 193–203(in Chinese with English summary)
- Gao K Q, 1989. Pareiasaurs from the Upper Permian of north China. *Can J Earth Sci*, **26**: 1234–1240
- Jalil N, Janvier P, 2005. Les pareiasaures (Amniota, Parareptilia) du Permian supérieur du Bassin d'Argana, Maroc. *Geodiversitas*, **27**: 35–132
- Lee M S Y, 1997a. Pareiasaur phylogeny and the origin of turtles. *Zool J Linn Soc*, **120**: 197–280
- Lee M S Y, 1997b. A taxonomic revision of pareiasaurian reptiles: implications for Permian terrestrial palaeoecology. *Mod Geol*, **21**: 231–298
- Lee M S Y, Gow C E, Kitching J W, 1997. Anatomy and relationships of the pareiasaur *Pareiasuchus nasicornis* from the Upper Permian of Zambia. *Palaeontology*, **40**: 307–335
- Sidor C A, Blackburn D C, Gado B, 2003. The vertebrate fauna of the Upper Permian of Niger—II, preliminary description of a new pareiasaur. *Palaeont Afr*, **39**: 45–52
- Spencer P S, Lee M S Y, 2000. A juvenile *Elginia* and early growth in pareiasaurs. *J Paleont*, **74**: 1191–1195
- Young C C(杨钟健), 1979. A new Late Permian fauna from Tsiyuan, Henan. *Vert PalAsiat(古脊椎动物学报)*, **17**(2): 99–113(in Chinese)
- Young C C(杨钟健), Yeh H K(叶祥奎), 1963. On a new pareiasaur from the Upper Permian of Shansi, China. *Vert PalAsiat(古脊椎动物学报)*, **7**(3): 195–214(in Chinese)