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A gorgonopsian from the Wutonggou Formation (Changhsingian, Permian) of Turpan Basin, Xinjiang, China

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Abstract

Gorgonopsians were widely distributed during the Permian, and went extinct by the end of Permian. However, their fossil localities in the North Hemisphere are concentrated in the eastern European portion of Russia, except for one possible canine from the North China. A specimen from the Wutonggou Formation of Turpan Basin, Xinjiang, China, dated 253.3 Ma, is identified as a gorgonopsian based on dental features. This discovery shows that the gorgonopsians survived in northern warm temperate zone about 253.3 Ma, contemporaneous with the latest records of Russia and South Africa. This specimen may represent one of the latest records of gorgonopsians.

Keywords: Changhsingian; Permian; Gorgonopsia; Wutonggou Formation; Xinjiang

1. Introduction

During the late Permian, therapsids experienced strong diversity decrease: some went through extinction, including biarmosuchians and gorgonopsians, while others survived into the Triassic, including dicynodonts, therocephalians and cynodonts. Biarmosuchians survived into the Lystrosaurus maccaigi-Moschorhinus Subzone (LMSZ) of the Daptocephalus Assemblage Zone (Day et al., 2018; Viglietti, 2020), while gorgonopsians survived to the Russian Sokolki Fauna and South African LMSZ (Sennikov and Golubev, 2017; Viglietti, 2020). The extinction processes of these two groups are uncertain and it is unclear if they had diachronous extinctions caused by global temperature change, as have been suggested for dicynodonts (Liu et al., 2022). This is partially due to their rarity in the fossil record of the North Hemisphere. Although biarmosuchians and gorgonopsians were found to distribute in both the northern and southern hemispheres, only one possible gorgonopsian fossil is known from North China, the Jiyuan Fauna (Liu et al., 2014). The Jiyuan fauna was dominated by pareiasaurs, roughly correlated to the Ilinskoe Subassemblage of the Sokolki Assemblage (Liu et al., 2014), and located in the arid zone (Liu et al., 2021). Here, a specimen with some teeth is identified as a gorgonopsian. It is the first record from the northern warm temperate zone and represents one of the latest records of this group.

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Institutional abbreviations: HGM, Henan Natural History Museum (previous Henan Geological Museum), Zhengzhou, China; IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; PIN, Borissiak Paleontological

2. Geological setting

The specimen was collected in 2011 in the northern part of the Taoshuyuan (Taodonggou) area, Bogda Mountains, Turpan Basin, Xinjiang, Northwest China. It was discovered together with a heavily weathered dicynodont skeleton. The host rocks are sandstone and mudstone in the middle part of the Wutonggou Formation, which is a part of the Wutonggou low-order cycle that includes the Wutonggou and overlying Guodikeng formations (Figs. 1–3; Yang et al., 2007, 2010, 2021). The rocks were deposited in alternating environments of meandering stream and lake margin and delta, under a generally humid–subhumid climate (Yang et al., 2021). The fossil is located at about 142 m above the base of the Wutonggou Formation along the North Taodonggou section of Yang et al. (2021) (Figs. 2, 3). The age of the fossil horizon at the North Taodonggou section is estimated to be 253.3

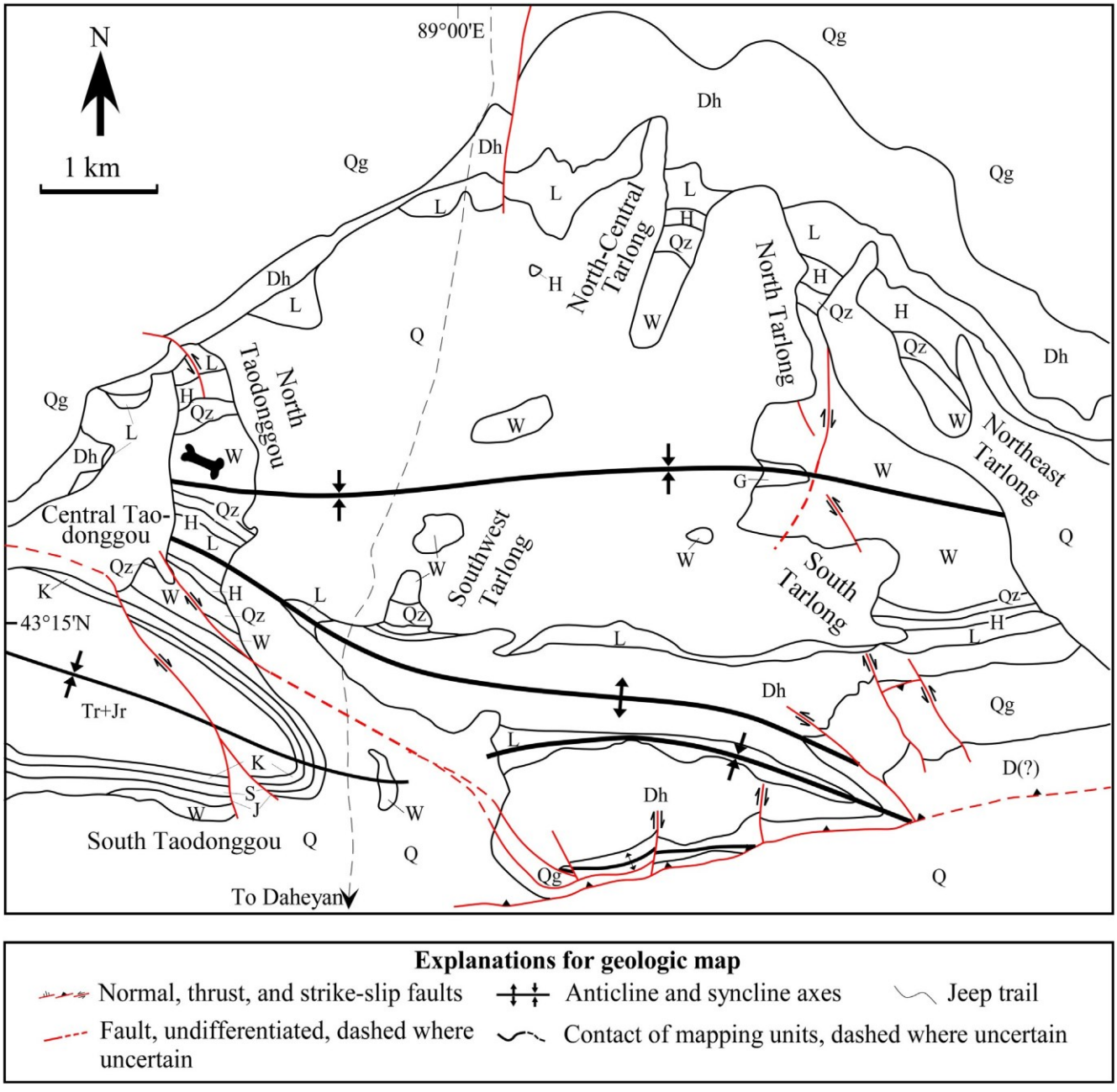

Fig. 1. Geological map of the Taodonggou-Tarlong area, Turpan Basin, Xinjiang, China, showing the locality of the specimen (bone symbol) (modified from Yang et al., 2021). Bone symbol marks the locality of the specimen. Qg – Qiergusitao Formation; Qgt – Turbidite deposits in Qiergusitao Formation, informal; D – Devonian; Dh – Daheyan Formation; L – Lucaogou Formation; Qz – Quanzijie Formation; W – Wutonggou Formation; G – Guodikeng Formation; J – Jiucaiyuan

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Formation; S – Shaofanggou Formation; Sl – Lower Shaofanggou Formation, informal; Su – Upper Shaofanggou Formation, informal; K – Karamay Formation; H – Huangshanjie Formation; HH – Huangshangie and Haojiagou formations, undifferentiated; Tr+Jr – Middle Triassic and Jurassic, undifferentiated; Q – Quaternary.

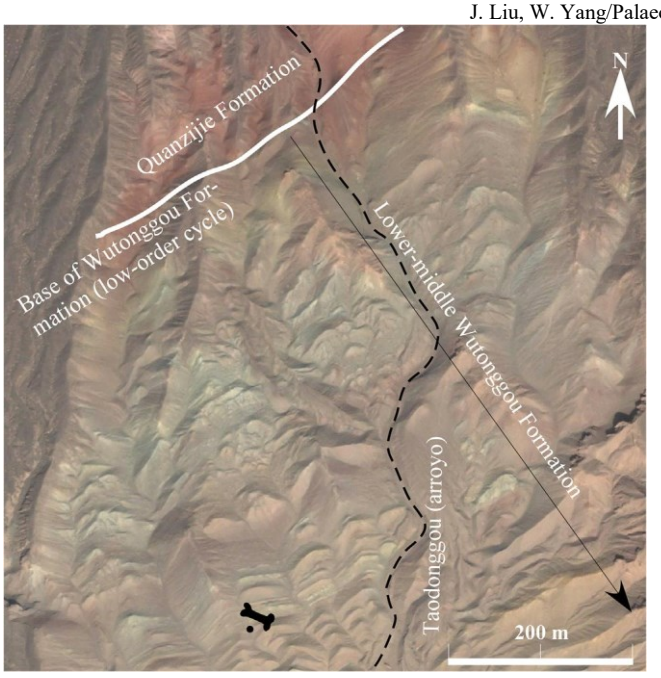

Fig. 2. Google Earth satellite image showing the fossil locality and stratigraphy in the vicinity of the collection site. Bone symbol marks the fossil locality.

Ma based on the age model of Yang et al. (2021), which is established for the Wutonggou low-order cycle in the South Taodonggou section about 3 km to the south of the collection site. The authors estimated the age of the base of the low-order cycle as 254.8 Ma at the South Taodonggou section and calculated an average sedimentation rate of 95.2 m/Ma for the low-order cycle at the North Taodonggou section. Cyclostratigraphic correlation between the South and North Taodonggou sections suggests that the base of the Wutonggou low-order cycle is synchronous (Yang et al., 2021) and, thus, the age of the low-order cycle base at North Taodonggou section is also assigned as 254.8 Ma. The age of the fossil horizon is calculated by subtracting the duration of the Wutonggou interval, which is estimated by using the average sedimentation rate, from the age of the base of the Wutonggou low-order cycle. This date of 253.3 Ma constrains the fossil to the early Changhsingian in age (Cohen et al., 2013, updated).

3. Systematic paleontology Therapsida

Broom, 1905

Gorgonopsia Seeley, 1894 (Fig. 4A–D)

Referred specimen: IVPP V 31167, incomplete tooth series, with some canines and lower postcanines. Locality: Field number 2011T15 ($43^{15}45^{00}$N, $88^{58}29^{00}$E), Taoshuyuan, Turpan, Xinjiang, China.

Horizon: Middle part of the Wutonggou Formation.

Description: This specimen was heavily weathered on the ground, showing the right upper and lower canines, the impression of left canines, and 2 right lower postcanines in matrix (Fig. 4A). The following description is based on the right tooth series.

The upper canine is oval in cross-section, with a mesiodistal diameter of 19.5 mm and a labiolingual diameter 7 mm. Both the tip of crown and the base of the root are lost, and the preserved portion measures 5 cm in height. The preserved anterior margin is slightly convex and smooth, and no serration is observed. The posterodorsal margin of the upper canine is broken, but posteroventral margin preserves a 15 mm ridge with a series of denticles on the crown base (Fig. 4B). It is similar to a canine from Jiyuan (HGM 41HIII0448) (Liu et al., 2014, fig. 5.2). The denticles are well-spaced and somewhat chisel-like, with a smooth, convex external side and flattened upper and lower sides.

The lower canine lies anteromedial to the upper canine and two canines contact each other. It is more complete but slenderer than the upper canine, measuring 60 mm in height, 5 mm in labiolingual diameter and 15 mm in mesiodistal diameter. The root has a smooth anterior margin. The anterior margin is broken on the crown base, and a 10 mm ridge with denticles is preserved on dorsal portion (Fig. 4C). The posterior margin is broken, so it is unclear if there are denticles. The serrations are worn, less distinct and more closely spaced than those on the upper canine, but there are 20 serrations within 1 cm in both upper and lower canines.

A distinct diastema separates the postcanines from the lower canine (Fig. 4A). Two preserved postcanines are laterally compressed, and the tips are missing. The anterior one is greater than 26 mm in height, 7 mm in length, and the denticles are observed on the posterior margin (Fig. 4D). The denticles are more densely spaced than those on the canines.

4. Discussion and conclusions

Initially, the grey portion of canines was regarded as the root and the black as the crown; so the specimen was identified as one animal with double canines. However, the serrations on the big canines indicate it should be an upper canine. Based on the preserved canines, the whole height of canines should be greater than 10 cm.

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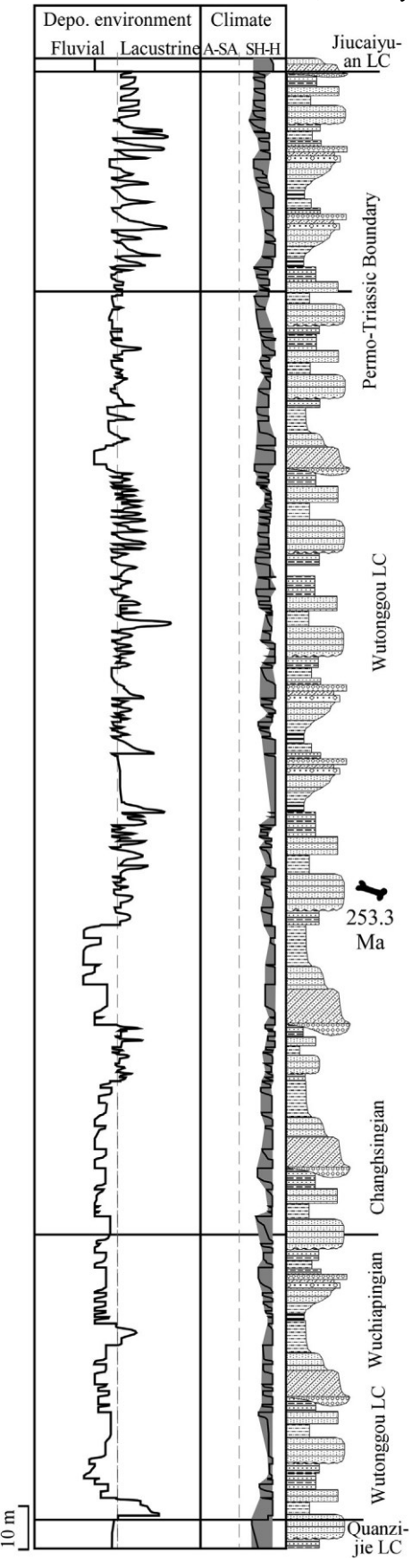
In the late Permian, the only tetrapods with a tooth series



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consisting of distinct, sharply-dermarcated canines and postcanines are therapsids, notably the subclades Biamosuchia, Gorgonopsia, Therocephalia, and Cynodontia. For these groups with a canine of 10 cm, the skull should be large in size. In Permian cynodonts, the skull is small to medium sized (Huttenlocker and Botha-Brink, 2013), and the canines are small and have no serration. Therefore, this specimen should not belong to Cynodontia. In early therocephalians, the canines are large, all teeth have serration on both anterior and posterior margins, and the postcanines are conical with slightly compressed and recurved (van den Heever, 1994). In the late Permian therocephalians, their postcanines have no serration except for Gorynychus, whose denticles decrease in size distally (Kammerer and Masyutin, 2018). This specimen has no serration on anterior margin of the upper canine, and the compressed postcanines with serration; it should not belong to Therocephalia.

In Biamosuchia, the denticles are developed on the posterior margin of upper canines in Biamosuchus (PIN 1758/2), Herpetoskylax (Sidor and Rubidge, 2006) and Leucocephalus (Day et al., 2018), on the posterior margin of the postcanine teeth of Lemurosaurus (Sidor and Welman, 2003) and Leucocephalus (Day et al., 2018). Serrated margins formed by the denticles on the canines and postcannines are common in Gorgonopsia (Ivakhnenko, 2003; Kammerer, 2016). Therefore, the specimens could belong to Biamosuchia or Gorgonopsia.

Most biarmosuchians are small-sized (skull length < 20 cm), with exceptions of some middle Permian taxa, such as Hipposaurus, Pachydectes, and Biarmosuchus (Ivakhnenko, 1999; Rubidge et al., 2006; Angielczyk and Kammerer, 2018). All known biarmosuchian specimens from late Permian have no skull greater than 25 cm, and their canines are generally less than 6 cm (Ivakhnenko, 2003; Sidor, 2003; Sidor and Welman, 2003; Sidor et al., 2004; Sidor and Rubidge, 2006; Sidor and Smith, 2007; Day et al., 2018). In Gorgonopsia, the reverse trend is true: the middle Permian taxa are small while the late Permian taxa can reach bear-size (up to 60 cm skull length) and be the apex predators, e.g., Inostrancevia and Rubidgea (Ivakhnenko, 2003; Kammerer, 2016; Bendel et al., 2018). Based on the size of the canines, this specimen is better referred to Gorgonopsia than Biamosuchia. The fine structures of the serrated ridge are consistent with those of gorgons such as Suchogorgon golubevi (Ivakhnenko, 2005). The denticles are chisel-like on the upper canine of both specimens. The current identification is limited by the incompleteness of the specimen; more complete specimens can further corroborate this hypothesis.

IVPP V 31167 is thus referred to Gorgonopsia. A possible gorgon tooth (HGM 41HIII0448) was reported from Jiyuan Fauna, Henan, China (Liu et al., 2014), and this specimen could be the second gorgonopsian specimen from China. Gorgonopsians were the dominant large carnivores of the late Permian. Their fossils are relatively abundant in the upper Permian of South Africa (Sigogneau-Russell,

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Fig. 3. Simplified composite stratigraphic section in northern and central Taodonggou area, showing the interpreted depositional environment and climatic conditions of the Wutonggou low-order cycle, including the undifferentiated Wutonggou Formation in the lower and middle parts and Guodikeng Formation in the upper part (modified from Yang et al., 2021). Bone symbol marks the position of the specimen. A-SA: arid to semiarid; SH-H: sub-humid to humid; LC: low-order cycle.

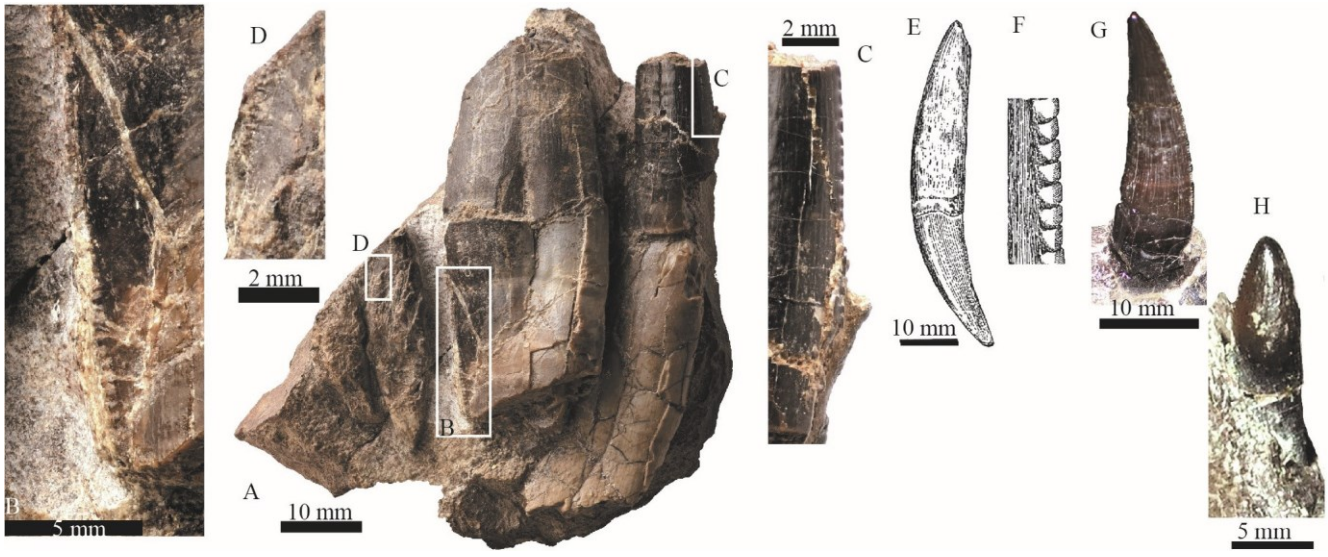

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Fig. 4. (A–D) Gorgonopsia Seeley, 1894, IVPP V 31167; (A) right tooth series in labial view; (B) distal margin of upper canine; (C) mesial margin of lower canine; (D) distal margin of first postcanine. (E–H) Suchogorgon; (E) right postcanine (PIN 4548/156) in labial view; (F) upper canine (PIN 4548/58) in labial view; (G) posterior margin of right lower canine (PIN 3713/40); (H) left lower canine (PIN 104/1767) in lingual view; (E, F from Ivakhnenko, 2005, fig. 33).

1989) and Russia (Ivakhnenko, 2003), present in the upper Permian of Zambia and Niger (Smiley et al., 2008; Sidor, 2022). The new finding fills the previously unknown terrestrial carnivorous ecological niche in the Turpan Basin, and expands the distribution of gorgonopsian to the northern warm temperate zone during late Permian (Liu et al., 2021). It also indicates the presence of a tetrapod ecosystem dominated by the gorgonopsians and dicynodonts in the northern warm temperate zone during late Permian, similar to that of Karoo Basin (Smith et al., 2012).

The gorgonopsians survived to Sokolki Fauna in Russian, Lystrosaurus maccaigi-Moschorhinus Subzone of Daptocephalus Assemblage Zone of South Africa (Sennikov and Golubev, 2017; Viglietti, 2020), roughly contemporaneous with the Xinjiang specimen, which is dated as 253.3 Ma. This specimen may represent one of the latest records of gorgonopsians. It provides information for further clarifying the extinction process of gorgonopsians during the late Permian.

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