

# A manus dominated pterosaur track assemblage from Gansu, China: implications for behavior

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**Abstract** The Yangouxia dinosaur tracksites are well known for a diverse assemblage of tetrapod tracks preserved as natural impressions (concave epireliefs) on large bedding planes, representing a locally widespread surface marking the transition from a sand- to a mud-dominated sequence in the Hekou Group. Previous ichnological studies at these large sites have focused on the morphology and ichnotaxonomy of the tracks, including a single trackway representing the first pterosaur tracks reported from China. Here, we report a distinctly different assemblage associated with minor sandstones in the mud-dominated sequence 20 m above the main tracksite level. This assemblage consists of at least 20 pterosaur manus track casts attributed to a single ichnotaxon (*Pteraichnus*). No pes tracks have been identified. These tracks mostly occur in random orientations, although one possible trackway segment is inferred, to represent walking progression.

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Manus-only pterosaur track assemblages are common and likely reflect differential registration depths of manus and pes and/or sub optimal preservation conditions. The tracks are associated with distinctive invertebrate traces including *Cochlichnus*, *Spongeliomorpha* and *Paleophycus* and suggest the pterosaurs were likely feeding on the invertebrate tracemakers.

**Keywords** Early Cretaceous · Gansu Province · Yangouxia · Pterosaurs · *Pteraichnus* · Lanzhou-Minhe Basin

## 1 Introduction

Pterosaurs are the earliest known flying vertebrates. The group flourished worldwide from the Late Triassic until the Late Cretaceous [1] and is represented by thousands of fossil specimens [2]. Most Chinese pterosaur material comes from the Jehol fauna, in western Liaoning, northern Hebei and southeastern Mongolia [3, 4]. A few pterosaur

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specimens have also been founded outside of the Jehol fauna, such as *Dsungaripterus* from Urho, Xinjiang [5] and *Huanhepterus* from Qingyang, Gansu [6].

In recent years, considerable gaps in the fossil record of Chinese pterosaurs have begun to be filled by the discovery of numerous pterosaur tracksites. These sites include: Yanguoxia in Gansu [7, 8], Dongyang in Zhejiang [9, 10], Jimo in Shandong [11], Qijiang in Chongqing [12], Urho in Xinjiang [13, 14], and Zhaojue in Sichuan [15]. Both manus and pes tracks are present at all of the aforementioned tracksites usually in recognizable pairs and often in well-defined trackways. Among these sites, Yanguoxia in Gansu is of historical importance because it was the first site in China from which pterosaur tracks were reported [7, 8]. These tracks occur as part of a single trackway named *Pteraichnus. yanguoxiaensis* by Peng et al. [7].

In 2013, one of us (MGL) discovered a second pterosaur tracksite at Yanguoxia, Gansu (Fig. 1), 300 m north of the original tracksite described by Peng et al. [7] (No. 1), and at a different stratigraphic level 20 m above the main tracksite level from which the original trackway was reported. This is here referred to as the Yangouxia pterosaur tracksite, as to date it has yielded only pterosaur tracks. At this new site, only manus prints are preserved, without associated pes tracks. Similar manus-only pterosaur tracks have been described from the Summerville [16] and Blackhawk Formations of Utah, America [17] and the Rio Limay Formation of Neuquén, Argentina [18]. Such

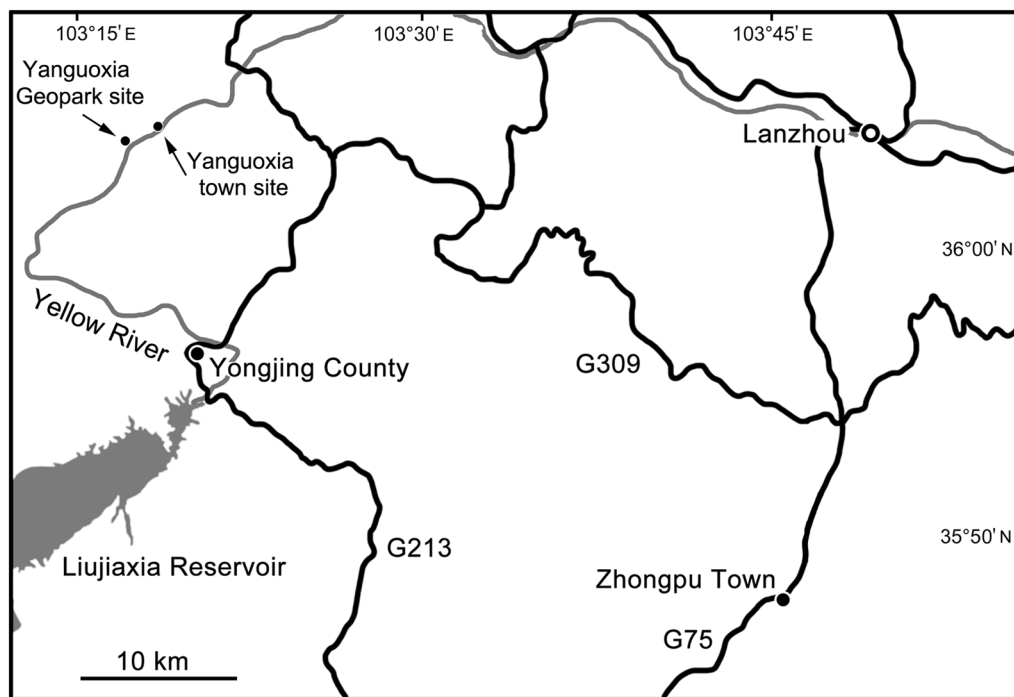
tracks are generally considered as evidence that manus tracks were more deeply impressed than pes tracks.

## 2 Geological setting

The Lanzhou-Minhe Basin is situated at the border of Gansu and Qinghai provinces and spans 11,300 km<sup>2</sup> (Fig. 1). The Lanzhou-Minhe Basin is a fault basin that developed from the Middle Qilian uplift zone. The red clastic rocks that dominate the basin constitute a single lithological unit, 3,482 m thick and have long been regarded as part of the Hekou Group [19–21]. The Hekou Group is Early Cretaceous in age [22] and is divided into eight informal formation-level units [23].

The whole of the Lanzhou-Minhe area is an inland freshwater lake basin [20]. Within the basin, dinosaur tracks have been discovered at the littoral zone of the border of a former lake basin [24]. The original pterosaur tracksite described by Peng et al. [7] and the pterosaur tracksite described in this paper in the Yanguoxia both occur in the sixth informal formation-level unit defined by Chen [20] and characterized as a shallow-shore lacustrine facies composed of fine gray and gray-green sandstone.

During the course of the present study, two sections were measured, one at the Yangouxia main tracksite area, which includes the new Yangouxia pterosaur tracksite reported here and the other on the west side of Yangouxia



**Fig. 1** Map showing the position of the footprint locality, the Yanguoxia pterosaur tracksite, Gansu Province, China

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