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INTRODUCING THE MAZONGSHAN DINOSAUR FAUNA

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ABSTRACT—The Mazongshan Dinosaur Fauna (MDF) includes all dinosaurs recovered from the late Early Cretaceous Xiagou and Zhonggou formations in the Mazongshan area of Gansu Province in northwestern China. Currently, 11 distinctive dinosaur genera have been recovered in this fauna, representing three theropods, two sauropods, four hadrosauroids, and two neoceratopsians. Four features can be recognized for the MDF: (1) the presence of large herbivorous theropods, such as the therizinosaur *Suzhousaurus* and ornithomimosaur *Beishanlong*; (2) the presence of diverse basal hadrosauroids, represented by at least four genera; (3) an abundance of basal neoceratopsians, represented by numerous individuals of *Auroraceratops*; and (4) an apparent lack of psittacosaurids. The MDF is unique and different from any other known dinosaur faunas, including that from the Jehol Biota.

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Abbreviations: CAGS IG: Institute of Geology, Chinese Academy of Geological Sciences, Beijing, China; CCDP: China-Canada Dinosaur Project; IVPP: Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; MDF: Mazongshan Dinosaur Fauna; SADP: Sino-American Mazongshan Dinosaur Project; SJDP: Sino-Japanese Silk Road Dinosaur Expedition; SSE: Sino-Swedish Expedition

INTRODUCTION

This volume aims to provide comprehensive and precise anatomical descriptions of *Auroraceratops rugosus* (You et al., 2005, 2012), geologically characterize and date the Yujingzi Basin, and explain the taphonomic processes that led to the preservation of *Auroraceratops* in this unit. The high quality of some of the additional specimens allows the anatomy of *Auroraceratops rugosus* to be studied in detail, with the cranial and postcranial anatomy described by Morschhauser et al. (2019a, b) and the syncervical anatomy described by Li et al. (2019). This new anatomical information provides a basis for reevaluating the phylogenetic position of *Auroraceratops* (Morschhauser et al., 2019c). C. Suarez et al. (2019) review the preservation and taphonomic history of the Yujingzi Basin specimens, with a focus on the rare earth element (REE) history. M. Suarez et al. (2019) provide a more detailed look at the geology and dating of the formations of the Yujingzi Basin. This is a critical contribution because the extensional inland basin tectonics that controlled deposition in the terrestrial ecosystems now represented by the many important paleontological localities in Central Asia results in a discontinuous and laterally restricted sedimentary record (Jerzykiewicz, 2000). This makes the dating of localities and the correlations between them significantly less precise than contemporaneous localities in larger-scale tectonic regions (e.g., western North America) or with frequent marine influence (e.g., Europe) (Jerzykiewicz, 2000; Eberth et al., 2001; Dashzeveg et al., 2005). The dating and correlation of the *Auroraceratops* localities, indeed, of the entire Mazongshan area, have significant implications for understanding the radiation of vertebrate clades in Asia during the first half of the Cretaceous.

This introductory paper will focus on the MDF, within which *Auroraceratops* is a key component. We will review its history of discovery, provide a refined geological time framework, and introduce its key members. We hope this will not only provide necessary background to *Auroraceratops* but also make broader sense of dinosaur faunal turnover in the Early Cretaceous of northern China.

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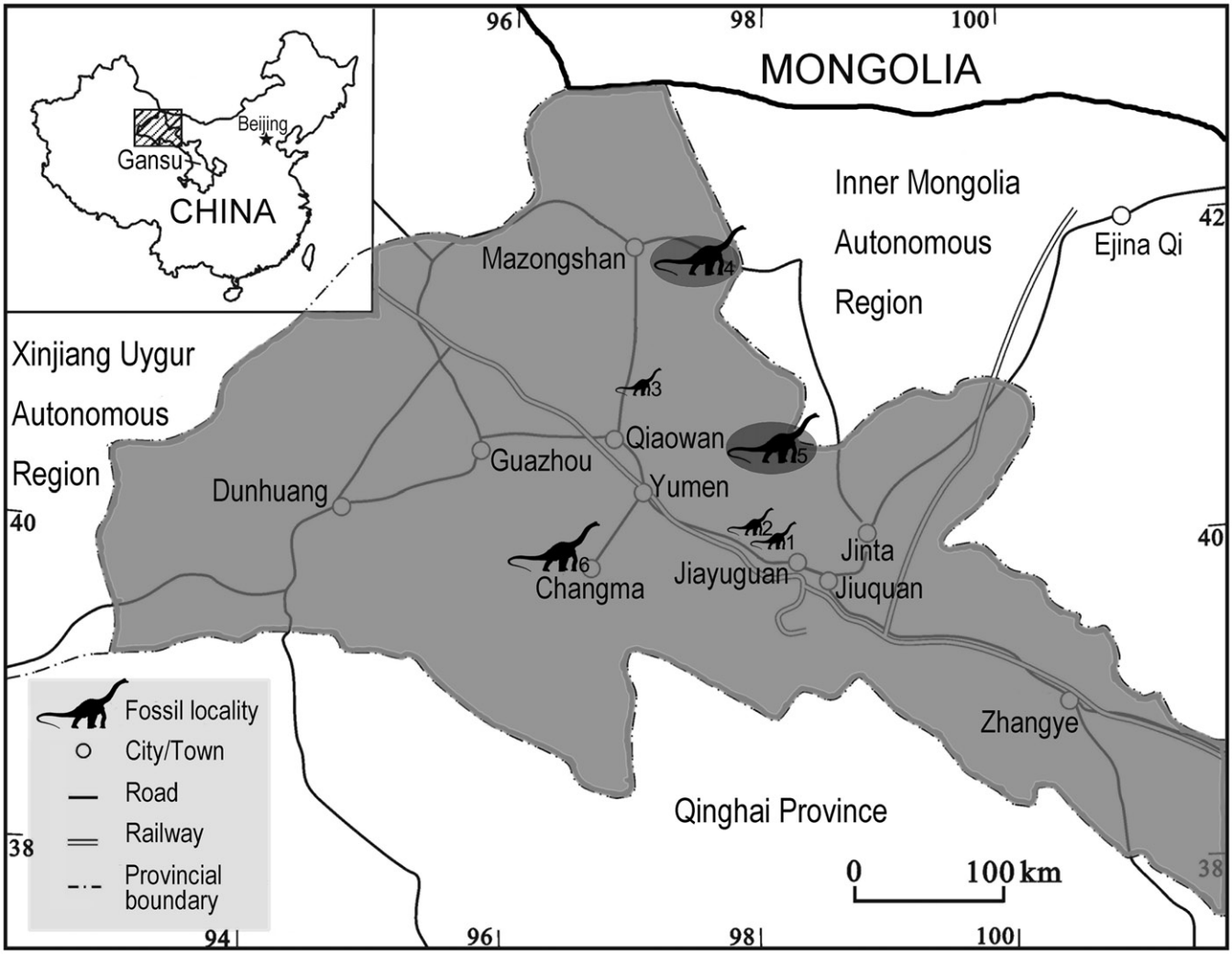

FIGURE 1. Lower Cretaceous dinosaur localities in northwestern Gansu Province. 1, 2, and 3 are Bohlin's localities (1, Chia-yu-kuan; 2, Hui-hui-pu; 3, Ehr-chia-wutung); 4, Gongpoquan Basin (shaded area); 5, Yujingzi Basin (shaded area); 6, Changma Basin.

HISTORY OF DISCOVERY

The first dinosaurs in the Mazongshan area were discovered by the Sino-Swedish Expedition (SSE; also known as the Sino-Swedish Northwest Scientific Expedition) during August 1930 to May 1931 (Bohlin, 1953). The SSE collected fragmentary dinosaur remains at three localities (Fig. 1). These were described by Bohlin in his large monograph (Bohlin, 1953). In the vicinity of Chia-yu-kuan (modern Jiayuguan), an unnamed small theropod tooth, a spatulate sauropod tooth (*Chiayusaurus lacustris*), a crushed partial skull and fragmentary skeleton with abundant osteoderms of a nodosaurid named *Heishansaurus pachycephalus*, and a new species of *Microceratops* (*M. sulcidens*) were reported. From the nearby locality of Hui-hui-pu (now Xinminpu = Xinminbao) at the foot of the Hei Shan (Black Mountain), Bohlin described but did not name two sauropod teeth. However, he applied the name *Stegosaurides excavatus* to two vertebrae and a partial dermal spine, believing them to document a stegosaurid. The final locality was at Ehr-chia-wutung, about 40 km north of the modern town of Qiaowan northwest of Yumen City. Here he collected a tiny jaw fragment of a presumed nodosaurid that bore five teeth in alveoli. He named it *Peishansaurus philemys*.

Bohlin clearly demonstrated that there were dinosaurs in this part of Gansu, but none of the dinosaurs he named are regarded as valid today. Barrett et al. (2002) regarded *Chiayusaurus lacustris* as a nomen dubium, Eusauropoda indet. *Heishansaurus* was treated as a nomen dubium, Ankylosauria indeterminate (Coombs, 1971; Maryańska, 1977; Sullivan, 2006; Arbour and Currie, 2016), although Maryańska et al. (2004) listed it as a pachycephalosaur. *Peishansaurus* and *Stegosaurides* were treated as nomina dubia, Ankylosauria indeterminate (Coombs, 1971; Maryańska, 1977; Vickaryous et al., 2004), or ?Thyreophora indeterminate (Arbour and Currie, 2016). Also, the exact horizons of these fossils are hard to judge, although they should be Early Cretaceous in age. Actually, the Hui-hui-pu area has received intense geological study in the past (Ma et al., 1984; Niu, 1987). The type sections of the Xiagou and Zhonggou formations are located in the village of Xinminpu (= Bohlin's Hui-hui-pu, Fig. 1), and the underlying Chijinqiao and Chijinpu formations also exist in this area. This more than 1,000-m-thick section probably spans the

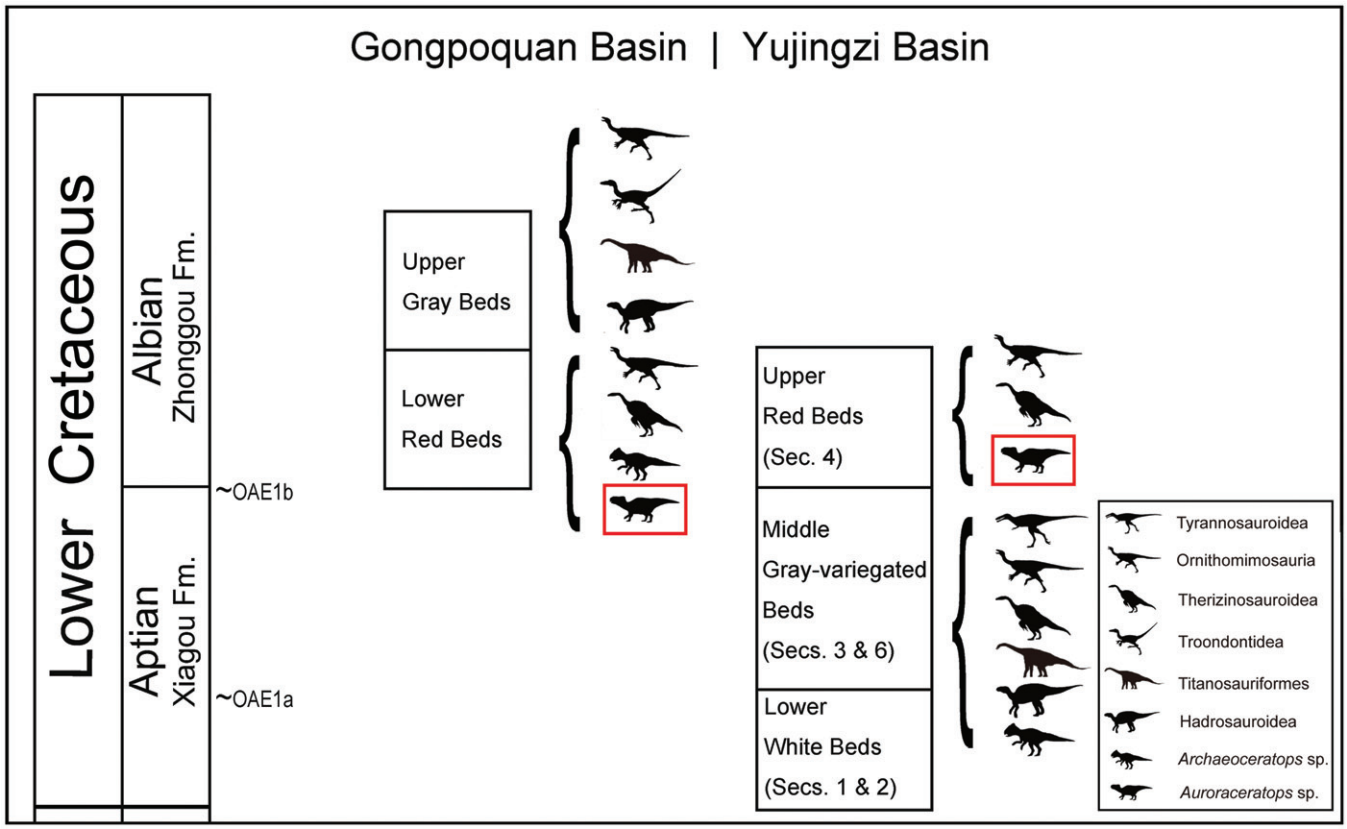

FIGURE 2. Major groups of dinosaurs recovered in their respective units in the Gongpoquan and Yujingzi basins, emphasizing the presence of *Auroraceratops* in the red beds in both basins.

whole Early Cretaceous, a potentially ideal place to study terrestrial transitions during this interval.

Gongpoquan Basin

Bohlin's first two sites are along the He Xi Corridor, which borders the Mazongshan area to the south, and his third site is actually in the Houhongquan Basin of the Mazongshan area (Fig. 1, Bohlin's locality 3). Many years later, in the 1960s, local geologists discovered dinosaur bones here, as well as a lizard (Li, 1985). Further north, in the Gongpoquan Basin, dinosaur remains were observed by members of the Lanzhou Institute of Desert Research of the Chinese Academy of Sciences in 1986. These discoveries were brought to the attention of the China-Canada Dinosaur Project. In 1988, a reconnaissance trip by CCDP members was conducted in the Gongpoquan Basin, with encouraging discoveries, but no further exploration. However, Mazongshan was the first priority of Zhi-Ming Dong of the Institute of Vertebrate Paleontology and Paleoanthropology, and this was his first priority for the coming Sino-Japanese Silk Road Dinosaur Expedition (1992 and 1993) (Dong, 1997a).

Led by Dong and Yoichi Azuma of the Fukui Prefectural Museum of Japan, and including two of Dong's students (Jun-Chang Lü and Hailu You), SJDP spent almost 2 months in the summer of 1992 in the Gongpoquan and Suanjingzi basins. The results of SJDP were published by Dong (1997a). Except for a new species of *Psittacosaurus* discovered in the Suanjingzi Basin of Inner Mongolia (Xu, 1997), all other dinosaurs are from the Gongpoquan Basin of Gansu Province. The most important discovery is a small basal neoceratopsian, *Archaeoceratops oshimai* (Dong and Azuma, 1997). Several new species of genera identified elsewhere were also reported: '*Probactrosaurus*' *mazongshanensis* Lü, 1997 (now *Gongpoquansaurus mazongshanensis* You, Li, and Dodson, 2014), *Nanshiungosaurus bohlini* Dong and You, 1997 (now '*Nanshiungosaurus*' *bohlini* (Li et al., 2007; Zanno, 2010), and *Sinornithoides* sp. (Dong, 1997b). A new genus of hypsilophodontid, *Siluosaurus zhangqiani* Dong, 1997c, was named on the basis of two teeth but is now considered invalid (Weishampel et al., 2004).

You entered the University of Pennsylvania in 1996, and his committee members (Peter Dodson, Neil Shubin, and Zhexi Luo) endorsed his dissertation on Mazongshan dinosaurs. Supported by the University of Pennsylvania, Carnegie Museum of Natural History, and IVPP, the Sino-American Mazongshan Dinosaur Project lasted for 4 years (1997–2000). Led by Luo and You, the field crew included Justin Georgi, Jason Downs, and Michael Shapiro from the U.S.A. and many from IVPP. They explored both the Gongpoquan and the Suanjingzi basins, and the first result of this expedition was on the biostratigraphy and paleoenvironment of the dinosaur-bearing sediments in the Mazongshan area (Tang et al., 2001). Following this, major results were published in 2003, including a new basal hadrosauroid *Equijubus normani* discovered in 2000 (You et al., 2003b), a basal titanosauriform *Gobititan shenzhouensis* discovered in 1999 (You et al., 2003a), and a large ornithomimosaur pes (Shapiro et al., 2003). *Archaeoceratops oshimai* was also restudied (You and Dodson, 2003). A few years later, another basal ceratopsian, *Auroraceratops rugosus* (You et al., 2005), was reported from the Gongpoquan Basin, but the specimen was collected by Daqing Li's team in late 1990.

TABLE 1. List of dinosaurs at the specific level in the Mazongshan Dinosaur Fauna.

Taxon			Gongpoquan Basin	Yujingzi Basin	Additional references
Saurischia	Theropoda	Tyrannosauroidea		*Xiongguanlong baimoensis* Li et al., 2009	
		Ornithomimosauria	cf. *Beishanlong grandis* (= cf. Ornithomimidae; Shapiro et al., 2003)	*Beishanlong grandis* Makovicky et al., 2009	Makovicky et al., 2009
		Therizinosauroidea	'*Nanshiungosaurus*' *bohlini* Dong and You, 1997	*Suzhousaurus megatherioides* Li et al., 2007	Li et al., 2008; Zanno, 2010
		Troodontidae	*Sinornithoides*sp. Dong, 1997b		
	Sauropoda	Titanosauriformes	*Gobititan shenzhouensis* You et al., 2003a	*Qiaowanlong kangxii* You and Li, 2009	D'Emic, 2012; Mannion et al., 2013; Upchurch et al., 2015
Ornithischia	Ornithopoda	Hadrosauroidea	*Equijubus normani* You et al., 2003b	*Jintasaurus meniscus* You and Li, 2009	McDonald et al., 2012, 2014
		Hadrosauroidea	*Gongpoquansaurus mazongshanensis* (Lü, 1997) You et al., 2014	*Xuwulong yueluni* You et al., 2011	
	Ceratopsia	Neoceratopsia	*Archaeoceratops oshimai* Dong and Azuma, 1997	*Archaeoceratops yujingziensis* You et al., 2010	You and Dodson, 2003; This memoir
			Auroraceratops rugosus You et al., 2005	*Auroraceratops* sp. You et al., 2012	This memoir

Yujingzi Basin

The potential of dinosaurs in the Yujingzi Basin was first pointed out by Zhi-Lu Tang of IVPP during a drive from Jiayuguan to the Gongpoquan Basin in 1999 during the SADP. It was SADP members (Luo, You, and Georgi) who first discovered dinosaurs in the Yujingzi Basin, and some dinosaurs collected from the basin in 2000 are still reposited at IVPP. A joint project was conducted in the Yujingzi Basin in the summer of 2002, led by You (then at the Institute of Geology of Chinese Academy of Geological Sciences) and Xing Zhang of Gansu Provincial Museum. The original plan was to work there for the whole summer, but after discovering and collecting plenty of material that was similar to those from the Gongpoquan Basin, the team decided to explore another site in the Changma Basin about 200 km southwest (Fig. 1), where the first Chinese Mesozoic bird (at that time second oldest fossil bird in the world) was discovered in 1981 (Hou and Liu, 1984). It turned out to be the beginning of an extraordinary series of bird discoveries (You et al., 2006; Ji et al., 2011; Wang et al., 2013, 2015), but this is not the focus of the present memoir. Collections by this expedition are held at CAGS IG and Gansu Provincial Museum, including the holotype of *Archaeoceratops yujingziensis*.

In 2004, a partnership was formed by You and Daqing Li of the former Fossil Research and Development Center of the Third Geology and Mineral Resources Exploration Academy of Gansu Province in Lanzhou. In July of 2004, after finding tens of fossil birds in Changma, You first introduced Li, Dodson, Matt Lamanna, and Ken Lacovara to the Yujingzi Basin. This 1-day reconnaissance initiated great discoveries at the Yujingzi Basin in the following years. You and Li have collaborated frequently since then, making Gansu host to one of the richest Early Cretaceous dinosaur faunas in China. In the Yujingzi Basin, the team has reported four new dinosaur genera (*Suzhousaurus megatherioides* Li, Peng, You, Lamanna, Harris, Lacovara, and Dodson, 2007, *Qiaowanlong kangxii* You and Li, 2009a, *Jintasaurus meniscus* You and Li, 2009b, and *Xuwulong yueluni* You, Li, and Liu, 2011).

In 2006, a University of Kansas team (led by Luis González and Greg Ludvigson, including then students Marina Suarez and Celina Suarez) started chemostratigraphic and geochemical taphonomy work here. In 2006–2007, Mark Norell, Peter Makovicky, and members from Peking University (Ke-Qin Gao and others) further explored the red beds in the north of the basin and discovered the 'graveyard' of *Auroraceratops*. This team also studied the theropods *Xiongguanlong baimoensis* Li, Norell, Gao, Smith, and Makovicky, 2009, and *Beishanlong grandis* Makovicky, Li, Gao, Lewin, Erickson, and Norell, 2009. Further field work refining the stratigraphy of the Yujingzi Basin was done by Nan Peng and others from the CAGS IG, and the taphonomy and precise stratigraphic context of the *Auroraceratops* specimens were mainly studied by Morschhauser between 2009 and 2011 as part of his dissertation at the University of Pennsylvania.

GEOGRAPHIC AND GEOLOGICAL SETTING

'Ma Zong Shan' means 'Horse Mane Mountain' in Chinese, and it refers to a mountain range in the northwestern corner of Gansu Province in northwestern China (Fig. 1). The Mazongshan area now administratively belongs to the town of Mazongshan of Subei Mongolian Autonomous County, Jiuquan City, Gansu Province. It occupies an area of about 38,000 km^2, borders Mongolia to the north, and separates Nei Mongol Autonomous Region (Inner Mongolia) in the east and Xinjiang Uygur Autonomous Region in the west. Its southern border is along the ancient Silk Road, which is also known as the He Xi Corridor in Gansu Province. 'He' means 'River' and 'Xi' means 'West' in Chinese, and the He Xi Corridor is a belt of oases between the Gobi Desert to the north and the Tibetan Plateau to the south, just west of the northwest corner of the Yellow River. Many oasis cities are located along the He Xi Corridor, including Jiuquan, Jiayuguan, Yumen, and Dunhuang.

The Mazongshan area is also called the 'Black Gobi' by the local Mongolian people, and it can be considered as the southwestern corner of the whole Gobi Desert. As in other parts of the Gobi Desert, dinosaur-rich Mesozoic rocks are well exposed here, but with a conspicuous and important difference: the ages of these rocks are Early Cretaceous (Tang et al., 2001), rather than the Late Cretaceous age of most of the dinosaur-bearing horizons in the Gobi (Dashzeveg et al., 2005).

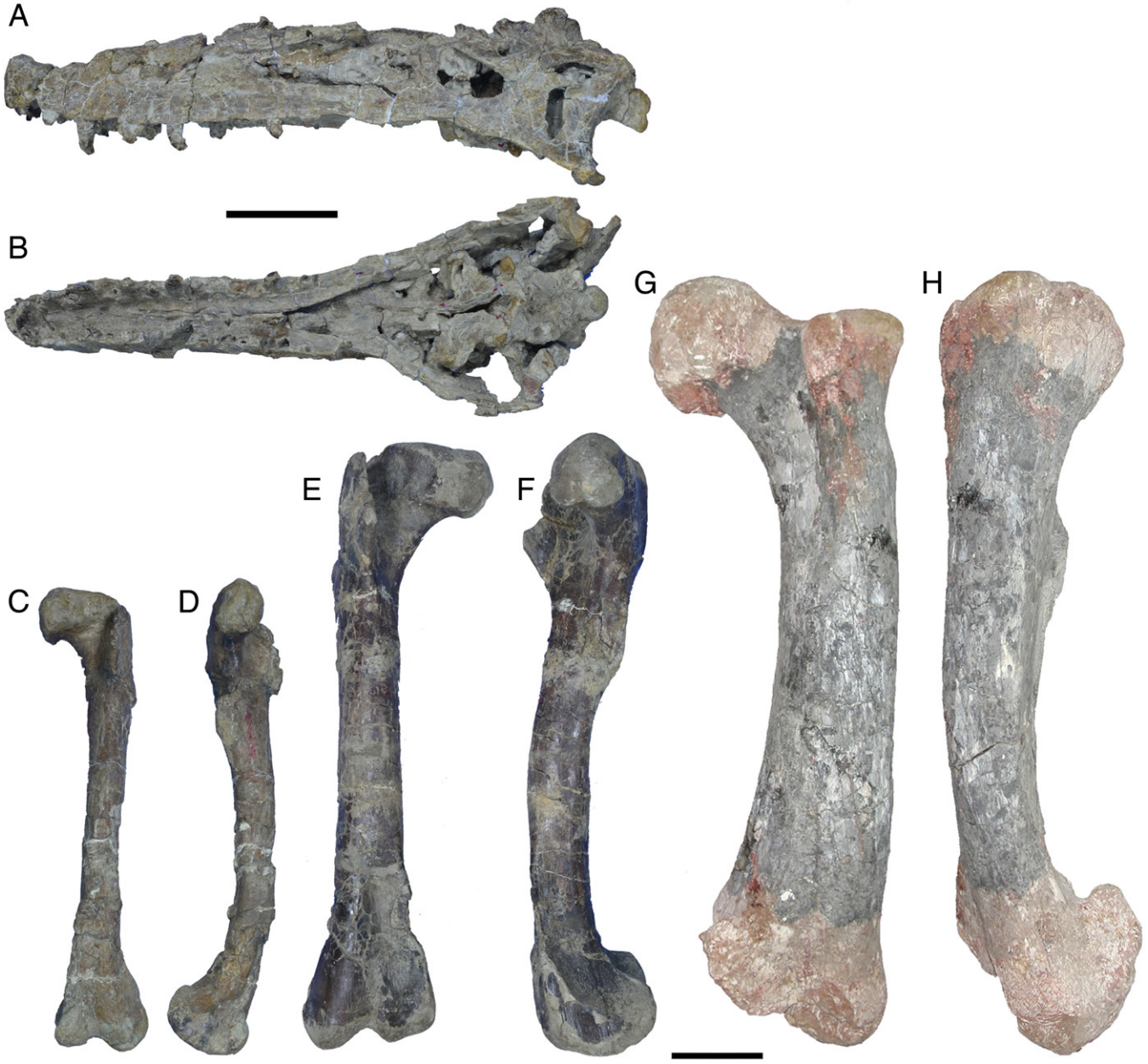

FIGURE 3. Theropod dinosaurs from the Mazongshan Dinosaur Fauna. **A**, **B**, skull of the tyrannosauroid *Xiongguanlong baimoensis* in left lateral (**A**) and ventral (**B**) views; **C**, **D**, left femur of the tyrannosauroid *Xiongguanlong baimoensis* in anterior (**C**) and medial (**D**) views; **E**, **F**, right femur of the ornithomimosaur *Beishanlong grandis* in anterior (**E**) and medial (**F**) views; **G**, **H**, left femur of the therizinosaur *Suzhousaurus megatherioides* in anterior (**G**) and lateral (**H**) views. Scale bars equal 10 cm.

However, few geological investigations were conducted in this area prior to the recent dinosaur discoveries. Results of the SJDP and SADP indicate an Albian age for the dinosaur-bearing rocks in the Gongpoquan Basin, mainly based on the presence of angiosperm palynomorphs (Dong, 1997d; Tang et al., 2001; You, 2002). Extensive field work in the Mazongshan area and the neighboring southern Jiuquan area by the CAGS IG reasonably viewed these two areas as a single whole and tried to explain its tectonic history (Peng et al., 2011; Peng, 2012). These works obtained radiometric dates for the boundary of the Xiagou and Zhonggou formations in the Jiuquan area and suggested that the dinosaur-bearing rocks in the Mazongshan area could potentially be correlated with these two formations.

A major step forwards is made by M. Suarez et al. (2019). Based on chemostratigraphic studies, the two dinosaur-bearing horizons in the Yujingzi Basin can be assigned to the Xiagou and Zhonggou formations, respectively, and the contact between them is at approximately the Aptian-Albian boundary. This result corroborates two previous results from the Jiuquan area: one is the radiometric date (113 Ma) of the boundary between the Xiagou and Zhonggou formations in the Hanxia section (Peng et al., 2011), and the other is the early Aptian age (124–120 Ma) for the bird-bearing layers in the lower section of the Xiagou Formation in the Changma Basin based on chemostratigraphy (Suarez et al., 2013).

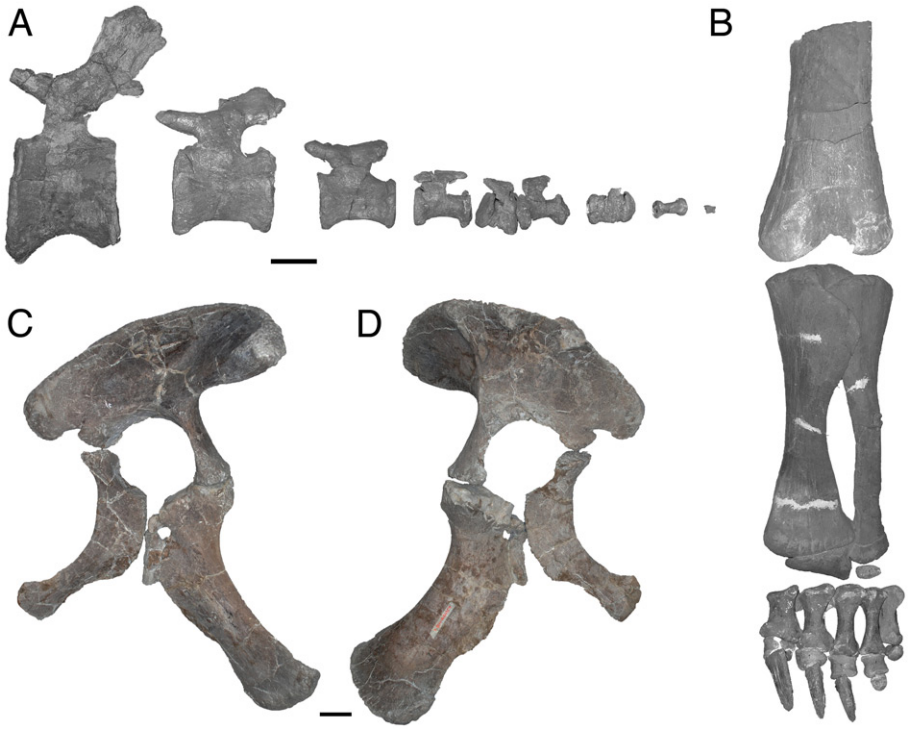

FIGURE 4. Sauropod dinosaurs from the Mazongshan Dinosaur Fauna. **A**, selected caudal vertebrae of *Gobititan shenzhouensis* in left lateral view; **B**, right hind limb of *Gobititan shenzhouensis* in anterior view; **C**, **D**, right pelvic girdle of *Qiaowanlong kangxii* in lateral (**C**) and medial (**D**) views. Scale bars equal 10 cm.

The follow up question is how to correlate the dinosaur-bearing beds in the Yujingzi Basin with those in the Gongpoquan Basin about 100 km away? To answer this, a field survey was conducted in the summer of 2014, and we (You and Li) found that in the Gongpoquan Basin, the *Auroraceratops rugosus* holotype-bearing red beds underlie the gray beds that yielded most of the dinosaur taxa (Zhang et al., 2015). This confirms Tang et al.'s (2001) previous work that suggested the presence of the lower red beds and upper gray beds in the Gongpoquan Basin, and that the red beds preserve the neoceratopsian *Archaeoceratops* and a therizinosaur, whereas the gray beds yield all of the other dinosaur taxa. This is interesting because in the Yujingzi Basin, the dinosaurs recovered from the red beds are mainly referable to *Auroraceratops* and therizinosaurs, and we can thus tentatively correlate the two red beds based on the presence of these taxa (Fig. 2). Tang et al. (2001), however, combined the sections and dinosaurs in the Gongpoquan Basin and the neighboring east Suanjingzi Basin of Inner Mongolia, but our extensive field work suggests that the Cretaceous beds in the Mazongshan and Jiuquan areas cannot be easily correlated. As of this publication, our working hypothesis is that the gray-variegated beds in the Yujingzi Basin belong to the upper portion of the Xiagou Formation and have an Aptian age, the red beds in both the Yujingzi and Gongpoquan basins represent the beginning of the Zhonggou Formation with an early Albian age, whereas the gray beds in the Gongpoquan Basin are probably early–mid-Albian in age (Fig. 2).

During the late Aptian–early Albian, a large lake surrounded by low hills probably existed in the Mazongshan and Jiuquan areas, and dinosaurs could wander around without barriers (Peng, 2012). The gray-variegated beds in the Yujingzi Basin were deposited in lowland environments with a coastal influence and are overlain by the Albian Zhonggou Formation, which lithologically consists of abundant red fluvial deposits. The rich preservation of ceratopsians and therizinosaurs in the red beds could reflect their preferred niches close to the rivers and lakes, whereas hadrosauroids and sauropods probably lived not far from the lake shore. However, ceratopsians and therizinosaurs are also found in the gray-variegated beds in the Yujingzi Basin, and taphonomic studies should help to explain the details about where and how these dinosaurs once lived in this area. In the Gongpoquan Basin, a return to lacustrine-dominated conditions is represented by the gray beds. This is consistent with other work that shows a return to widespread lacustrine deposits in the upper part of the Zhonggou Formation (Du et al., 2015).

MAZONGSHAN DINOSAUR FAUNA

The MDF includes all dinosaurs recovered from the Xiagou and Zhonggou formations in the Mazongshan area. Its age spans from the mid-Aptian (after ocean anoxic event 1a, a globally widespread occurrence of black shales related to changes in the global carbon cycle) to at least early Albian (M. Suarez, 2019), and its distribution could extend to neighboring areas as long as they satisfy the key features of this fauna (see below). Currently, 11 distinctive dinosaur genera have been recovered in this fauna, representing three theropods, two sauropods, four hadrosauroids, and two neoceratopsians (Table 1). None of these genera have been reported elsewhere.

The three theropods are the tyrannosauroid *Xiongguanlong baimoensis*, the ornithomimosaur *Beishanlong grandis*, and the therizinosaur *Suzhousaurus megatherioides* (Fig. 3). *Xiongguanlong* was recovered from the gray-variegated beds in the Yujingzi Basin. It preserves a complete skull, a complete presacral vertebral column, the right ilium, and the left femur. It is a medium-sized tyrannosauroid close to adulthood, with

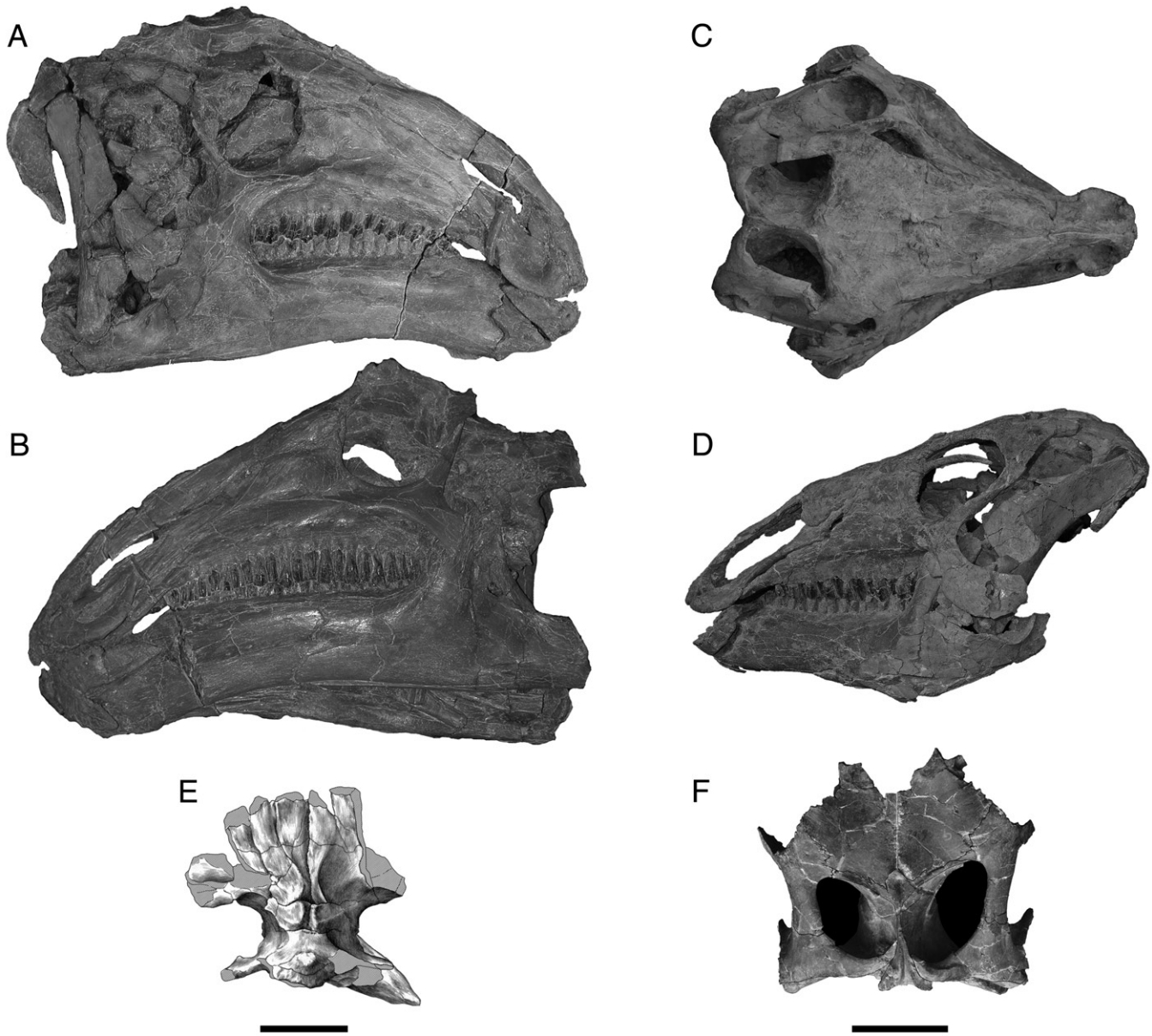

FIGURE 5. Hadrosauroid dinosaurs from the Mazongshan Dinosaur Fauna. **A**, **B**, skull and mandible of *Equijubus normani* in right (**A**) and left (**B**) lateral views; **C**, **D**, skull and mandible of *Xuwulong yueluni* in dorsal (**C**) and left lateral (**D**) views; **E**, partial skull of *Gongpoquansaurus mazongshanensis* in dorsal view; **F**, partial skull of *Jintasaurus meniscus* in dorsal view. Scale bars equal 10 cm (**A**–**D**, **F**) and 5 cm (**E**).

an estimated body mass of 272 kg, skull length of 504 mm, and a femur length of 510 mm (Li et al., 2009). The most conspicuous feature is its narrow elongated muzzle, which is unusual among tyrannosauroids, and present elsewhere only in *Alioramus* and *Qianzhousaurus* from the Maastrichtian of East Asia (Lü et al., 2014). Phylogenetically, *Xiongguanlong* has more derived features than Jehol tyrannosauroids, some of which achieved large body size (Ji et al., 2009; Xu et al., 2012). *Xiongguanlong* is the best-preserved mid-Cretaceous (mid-Aptian–Santonian) tyrannosauroid; other tyrannosauroids reported from this time interval include *Alectrosaurus* from the early Late Cretaceous of the Gobi (Gilmore, 1933; Currie, 2000), *Timurlengia* from Central Asia (Averianov and Sues, 2012; Brusatte et al., 2016), as well as a premaxillary tooth from the Lower Cretaceous Cloverly Formation of Wyoming (Zanno and Makovicky, 2011).

Beishanlong was recovered from the gray-variegated beds in the Yujingzi Basin and is represented by postcranial elements of a young adult, with an estimated body mass of 626 kg (Makovicky et al., 2009). An isolated large foot from the gray beds in the Gongpoquan Basin (Shapiro et al., 2003) is referred to *Beishanlong* (Makovicky et al., 2009). The length of its metatarsal II is 43.5 cm, which is longer than that of the holotype (36.6 cm). *Beishanlong*, which is claimed to be the largest ornithomimosaur of its time, is now considered to be the most basal member of Deinocheiridae, the sister group of Ornithomimidae (Lee et al., 2014). Within Ornithomimosauria, deinocheirids represent a clade of large-bodied animals with a robust build, in contrast to the small- and medium-sized gracile ornithomimids. Two other ornithomimosaur specimens have been recovered from the red beds in the Yujingzi and Gongpoquan basins, respectively: the Yujingzi specimen

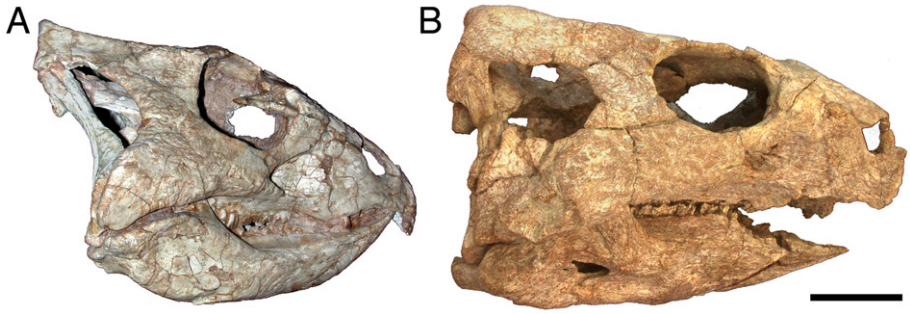

FIGURE 6. Neoceratopsian dinosaurs from the Mazongshan Dinosaur Fauna. **A**, skull and lower jaw of *Archaeoceratops oshimai* in right lateral view; **B**, skull and lower jaw of holotype of *Auroraceratops rugosus* in right lateral view. Scale bar equals 5 cm.

probably represents the same species of *Beishanlong* (Makovicky et al., 2009), whereas the Gongpoquan specimen is a different taxon (You, unpubl. data). *Beishanlong* is larger than the roughly coeval *Harpymimus* (256 kg), and much larger than *Shenzhousaurus* (Ji et al., 2003) and *Hexing* (Jin et al., 2012) from the Jehol Biota of northeastern China. The femoral lengths are 660 mm, 191 mm, and 135 mm for *Beishanlong*, *Shenzhousaurus*, and *Hexing*, respectively. The specimen of *Hexing* is claimed to be an adult (Jin et al., 2012).

Suzhousaurus megatherioides is represented by the holotype from the gray-variegated beds and a second specimen from the red beds in the Yujingzi Basin (Li et al., 2007, 2008). No cranial material has been reported so far, but the overlap and anatomical similarity between the pubes of the two specimens indicates that they belong to the same species. *Nanshiungosaurus bohlini* Dong and You, 1997, was recovered from the red beds in the Gongpoquan Basin and is represented by a series of cervical vertebrae. Although this taxon is no longer assigned to the genus *Nanshiungosaurus*, whether it belongs to *Suzhousaurus* or represents a new genus can only be resolved pending more discoveries with overlapping material (Li et al., 2007; Zanno, 2010). *Suzhousaurus* is the largest theropod in the MDF, with a femur length of 84 cm and an estimated body mass of 1,361.5 kg, about double the weight of *Beishanlong* (Zanno and Makovicky, 2012). Phylogenetically, *Suzhousaurus* is the latest diverging of the Early Cretaceous therizinosaurs, with *Alxasaurus elesitaiensis* from Inner Mongolia, *Beipiaosaurus inexpectus* and *Jianchangosaurus yixianensis* from western Liaoning, and *Falcarius utahensis* from Utah all diverging more basally (Pu et al., 2013). Compared with the other four known Early Cretaceous therizinosaurs, *Suzhousaurus* achieved a huge mass; the estimated body masses of *Alxasaurus*, *Falcarius*, and *Beipiaosaurus* are 358.2, 127.7, and 27+ kg, respectively (Zanno and Makovicky, 2012). The mass of *Jianchangosaurus* cannot be directly compared with the other Early Cretaceous therizinosaurs because the only known specimen is a juvenile, with a femur length of 206.6 mm and total length of 1,880 mm, smaller than the 4–5 m long *Falcarius* (Pu et al., 2013).

The two sauropods in the MDF are *Gobititan shenzhouensis* from the gray beds in the Gongpoquan Basin and *Qiaowanlong kangxii* from the gray-variegated beds in the Yujingzi Basin (Fig. 4). *Gobititan* is represented by an articulated series of 41 middle and distal caudal vertebrae, including the terminal one and a left hind limb missing the upper portion of the femur. Its tibia is about 90 cm long. *Qiaowanlong* is represented by eight cervical vertebrae (C4–C11) and a complete right pelvic girdle. The longest centrum (C10) is 41 cm long excluding the condyle. *Qiaowanlong* was originally reported as a brachiosaurid, with a close relationship to the North American *Sauroposeidon* (You and Li, 2009a). However, subsequent cladistic analyses have placed these two taxa as basal somphospondylans, the sister group of brachiosaurids (Ksepka and Norell, 2010). Titanosauriform phylogeny has attracted many cladistic analyses recently, and an emerging consensus seems to be the recovery of a monophyletic Asian clade, Euhelopodidae, including both *Gobititan* and *Qiaowanlong* (D'Emic, 2012; D'Emic et al., 2013; Mannion et al., 2013; Upchurch et al., 2015). The only named sauropod from the Jehol Biota is *Dongbeititan* (Wang et al., 2007), which is recovered as one of the basal-most titanosauriforms or even the sister taxon to Titanosauriformes (Mannion et al., 2013; Upchurch et al., 2015).

Four basal hadrosauroids have been found in the MDF (Fig. 5). *Equijubus normani* and *Gongpoquansaurus mazongshanensis* are from the gray beds in the Gongpoquan Basin, whereas *Jintasaurus meniscus* and *Xuwulong yueluni* are from the gray-variegated beds in the Yujingzi Basin. *Equijubus* and *Xuwulong* are represented by single articulated specimens including the cranium, whereas *Gongpoquansaurus* and *Jintasaurus* preserve partial skulls (Lü, 1997; You et al., 2003b, 2011, 2014; You and Li, 2009b; McDonald et al., 2014). Phylogenetically, *Equijubus* and *Xuwulong* are sister taxa, and they are more basally diverging than *Gongpoquansaurus* and *Jintasaurus* (McDonald et al., 2012). All four of these hadrosauroids are later diverging than *Jinzhousaurus* and *Bolong* from the Jehol Biota, although the latter may be a very basal hadrosauroid or more closely related to *Iguanodon* than to members of the Hadrosauroidea (McDonald et al., 2012; Norman, 2015).

The ceratopsians *Archaeoceratops oshimai* and *Auroraceratops rugosus* were recovered from the red beds in the Gongpoquan Basin (Dong and Azuma, 1997; You and Dodson, 2003; You et al., 2005) (Fig. 6). A second species of *Archaeoceratops*, *A. yujingziensis* You, Morschhauser, Dodson, and Li, 2010, comes from the gray-variegated beds in the Yujingzi Basin, from a quarry with hadrosauroid material (You et al., 2010). *Auroraceratops* sp. from the red beds in the Yujingzi Basin reported by You et al. (2012) is the focus of this memoir, and it is here considered to belong to *A. rugosus*. Although the relationship between *Archaeoceratops* and *Auroraceratops* is not well resolved, both are from nodes diverging later than *Liaoceratops* from the Jehol Biota (Farke et al., 2014; Zheng et al., 2015). To date, no psittacosaurids have been discovered in the MDF. The only other ceratopsian reported from the region, *Psittacosaurus mazongshanensis* (Xu, 1997), is actually from the Suanjingzi Basin, which lies east of the Gongpoquan Basin in Nei Mongol and is therefore not part of the MDF.

DISCUSSION AND CONCLUSION

Based on the reviews of You and Luo (2008) and Zhang et al. (2015) on the dinosaurs from the Mazongshan area, and the above overview with an emphasis on comparison with Jehol dinosaurs, at least four features can be recognized for the MDF: (1) the presence of large herbivorous theropods, such as the therizinosaur *Suzhousaurus* and the ornithomimosaur *Beishanlong*; (2) the presence of diverse basal hadrosauroids, represented by at least four genera; (3) an abundance of basal neoceratopsians, represented by numerous individuals of *Auroraceratops*; and (4) an apparent lack of psittacosaurids.

Compared with dinosaurs in the Jehol Biota (Zhou, 2014), all taxa in the MDF are from nodes diverging later than those for species in the Jehol Biota in their respective phylogenies. In the Jehol Biota, both therizinosaurs and ornithomimosaurs are small, only one species of neoceratopsian and two species of hadrosauroids/hadrosauriforms have been recovered, and the most common specimens are psittacosaurids. Most of the Jehol dinosaurs are recovered from the Yixian and Jiufotang formations of the Jehol Group, which are Barremian to early Aptian in age, whereas the MDF is mid-Aptian to Albian in age. The MDF provides a window for future works to investigate dinosaur faunal turnover in the mid-Cretaceous, and this could be directly related to the beginning of the Cretaceous Terrestrial Revolution (Lloyd et al., 2008; Benton, 2010).

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