

Palynology of the Early Cretaceous Hanxia Section in the Jiuquan Basin, Northwest China: The discovery of diverse early angiosperm pollen and paleoclimatic significance



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ARTICLE INFO

Article history:

Received 21 June 2015

Received in revised form 8 September 2015

Accepted 10 September 2015

Available online 21 September 2015

Keywords:

Palynology
Early angiosperm
Albian
Jiuquan Basin
China

ABSTRACT

The Lower Cretaceous deposits of the Jiuquan Basin (Northwestern China) located in central Asia are famous for the abundant and diverse fossil products with distinct characteristics of Jehol Biota. However, few early angiosperm remains have been published in their entirety. This study presents a palynomorph record from the recently reported fossil-bearing Zhonggou Formation of the Hanxia Section in the Jiuquan Basin. Here, we first discovered abundant and diverse angiosperm pollen with 16 taxa, which can be classified into four morphological types: tricolpate, polyaperturate, monosulcate and etrachotomocolpate apertures. The palynomorph assemblages contain a large number of biostratigraphically significant palynomorphs, such as numerically abundant tricolpate and rare polyaperturate angiosperm pollen grains, which indicate an Early Albian age for the Zhonggou Formation of the Hanxia Section. The overall palynomorph assemblage is dominated by the *Perinopollenites*, followed by the *Classopollis*; bisaccate pollen indicate Taxodiaceae-dominant vegetation types. As such, a relatively temperate and humid climatic condition is suggested for this area. Furthermore, two palynomorph assemblages can be distinguished in a stratigraphically upward order with an obviously increasing *Classopollis* content, indicating a gradual aridification trend during the Early Albian. This climatic change may affect the diversification of early angiosperms based on the correlation with the stratigraphic distribution of discovered angiosperm pollen.

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1. Introduction

The diversification of angiosperms marks the profound change of the Mesozoic flora evolution. In particular, the radiation of the flora during the late Early Cretaceous represents one of the most radical changes in the evolution of Mesozoic terrestrial ecosystems, which include the change from ferns, conifers and cycads- to angiosperm-dominated flora within a time span of approximately 30 Ma (Lidgard and Crane, 1988; Crane et al., 1995; Hochuli et al., 2006). In this stage, an obvious vein density increase and phylliform complication was exhibited by the angiosperm mesofossil records (Archangelsky et al., 2009; Doyle, 2011; Feild et al., 2011). The early angiosperm pollen showed a sharp increase in morphology and abundance (Doyle and Robbins, 1977; Heimhofer et al., 2007; Heimhofer and Hochuli, 2010; Zhang et al., 2014). However, these fossil records are not comprehensively representative of the global fossil distribution. In particular, these flowering plant

fossil records from the spacious inland of continents are relatively scarce.

The Jiuquan Basin is located in the northwest inland area of China, and contains a set of thick Lower Cretaceous deposits. This sedimentary sequence is famous for a variety of well-preserved fossils, such as birds, plants, insects, amphibians, mollusks, etc. (e.g. Hong, 1982; Hu and Xu, 2005; You et al., 2006; Deng and Lu, 2008). In recent years, the fossil-bearing top Zhonggou Formation of the Hanxia Section was repeatedly referenced for its numerous well-preserved fossils (Deng and Lu, 2008; Du et al., 2013; Dong et al., 2014; Zheng et al., 2015). This area was even regarded as the westernmost extension of Jehol Biota for the similar fossil assemblage and taphonomic characteristics (e.g. Chen, 1988; Wang, 1990; Zhou, 2006). However, it lacks the typical angiosperm remains (megafossil and microfossil) compared with the traditional Jehol Biota of western Liaoning, China. On the other hand, the Lower Cretaceous of Jiuquan Basin has substantial chronological uncertainties because of the lack of an effective fossil index or reliable absolute ages, although there are abundant fossil materials and volcanic lava layers (Li and Yang, 2004).

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In this study, we present a detailed palynological record including the early angiosperm pollen from the Zhonggou Formation of the Hanxia Section in the southwestern Jiuquan Basin. Based on our palynological data, we attempted to 1) provide a valuable biostratigraphic control for the Lower Cretaceous strata and 2) decipher the aspects of angiosperm diversification and paleoenvironments within this region.

2. Geological setting

The Jiuquan Basin is located at the convergence zone between the Qilian orogeny belt and the Altyn fault (Fig. 1); it is a small-sized petroliferous basin on the western end of the Hexi Corridor Basin group, north of the Qinghai–Tibet Plateau, with an area of 22,000 km² (Li et al., 2006; Pan et al., 2006; Chen et al., 2014). It is filled with Permian, Jurassic, Cretaceous and Cenozoic deposits. The Lower Cretaceous, as the main source of rock, is always a keystone strata of research. The thickness of which significantly varies from 1500 to 3000 m. There are three formations that are divided from the bottom to the top, the Chijinbao, Xiagou and Zhonggou formations. The Chijinbao and Xiagou formations have two coarse–fine–coarse–grained sedimentary cycles. The fine-grained sedimentary rocks are mainly composed of black oil shale, carbonaceous shale and gray mudstone. The Zhonggou Formation is characterized by the calcareous-clastic sedimentary rock with a grayish green color that distinctly differs from the underlying Chijinbao and Xiagou formations. From the middle, the reddish calcareous mudstone interlayers begin to emerge with a thickness of 20–30 cm for the single layers (Fig. 2). The Zhonggou Formation is well exposed at the Hanxia and Xinminbao sites. The presently published fossil materials were all collected from the Hanxia site (e.g. Du et al., 2013). In the western basin, there are also several layers of basaltic and andesitic lava

interbedded within the lacustrine mudstone. The volcanic facies is more complicated, in which flood basalt facies, crater facies, and volcanoclastic facies all occur in this area.

So far, a large amount of diverse fossils were discovered from the Lower Cretaceous in the Jiuquan Basin. The fossil types include insects, ostracods, conchostracans, charophytes, bivalves, paleo-birds, megafossil plants, sporopollen, etc. (e.g. Hong, 1982; Hu and Xu, 2005; You et al., 2006; Deng and Lu, 2008). The characteristics of the fossil association can be correlated with the Jehol Biota. As such, it is also defined as the western extension of the Jehol Biota (e.g. Chen, 1988; Wang, 1990; Zhou, 2006). Therefore, the studied Hanxia section is one of the most productive fossil-bearing sites. In recent years, a large number of well-preserved fossils were published, such as dragonflies (*Hemerospicus baissicus*, Zheng et al., 2015) and megafossil plants (*Pseudofrenelopsis*: Deng et al., 2005; *Brachyphyllum*: Du et al., 2013; *Equisetum*: Sun et al., 2013; *Athrotaxites yumenensis* sp.: Dong et al., 2014; and others, Deng and Lu, 2008; Dong et al., 2013). These fossil records provided important paleoclimatic and ecological information for the inland of East Asia during the Early Cretaceous.

Although rich in paleontology, the precise geological age and correlation of the Lower Cretaceous strata in the Jiuquan Basin remain unresolved, leading to various interpretations of its stratigraphic age. This stratum was first assigned to the Upper Jurassic. Until the 1970s to '80s, the age of the Early Cretaceous was proposed based on palynomorph and fish fossils (Hsü and Jiang, 1974; Ma, 1984; Jiang and Yang, 1986). However, studies on a more precise determination of the stratigraphic age are limited. Liu (2000) investigated palynological records from the Hanxia Section studied herein and established assemblages of *Cicatricosisporites*–*Schizaeoisporites*–*Classopollis*–*Jiaohepollis* for the Xiagou and Zhonggou formations, which were assigned to the

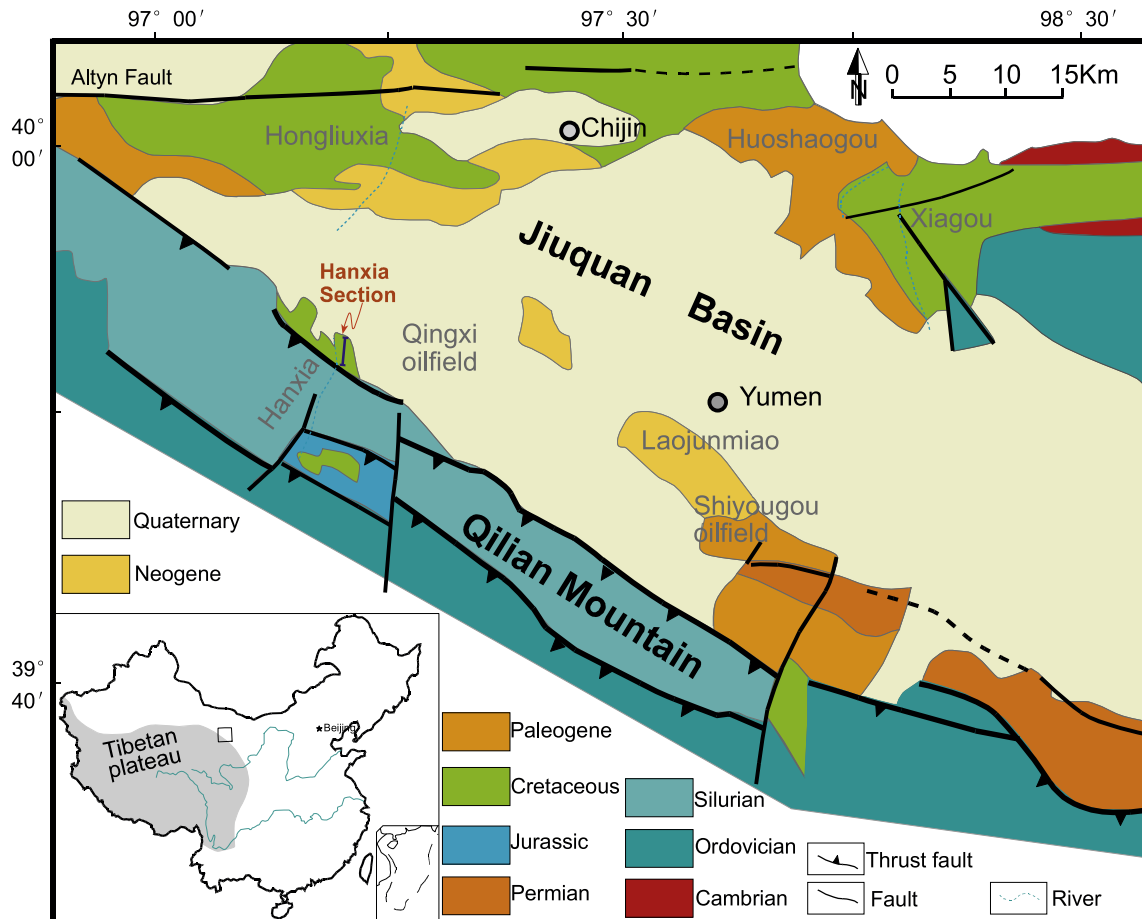


Fig. 1. Geological sketch map of the western Jiuquan Basin and the location of the studied section.

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