



<https://doi.org/10.11646/palaeoentomology.2.2.8>

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Late Triassic fossil insects from the Laohugou Formation of northern China (Qinhuangdao, Hebei Province)

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Abstract

Triassic insect fossils from China are very limited. Here we report on numerous insect fossils discovered in the Upper Triassic Laohugou Formation at Heishanyao, Qinhuangdao, Hebei Province. These fossils are represented mainly by forewings of cockroaches and coleopteran elytra. The insect assemblage is most similar to that from the Upper Triassic Momonoki Formation of Japan. Fossils of the Laohugou Formation have been poorly known, so our discovery of new fossil insects bear significance for understanding the biota and sedimentary environment of this formation. The Mesozoic stratigraphic division in the Liujiang Basin has been controversial, and the usage of stratigraphic units has been inconsistent. Here we refine the stratigraphic sequence, from the bottom to the top, of the Upper Triassic Laohugou Formation, the Lower-Middle Jurassic Yaopo Formation, the Upper-Middle Jurassic Longmen Formation, the Upper Jurassic Tiaojishan Formation, and the Lower Cretaceous Zhangjiakou Formation. The Laohugou Formation is scattered in various basins in western Liaoning and northern Hebei, with the lower part mostly characterized by thick layers of complex conglomerates, suggesting a regional tectonic uplift. There is a sedimentary discontinuity between the Laohugou Formation and the Yaopo/Beipiao Formation, reflecting the uplifting activities during the late Late Triassic-early Early Jurassic in eastern China. The Laohugou Formation is overlaying on various ancient strata, representing the first regional unconformity of the northeastern margin of the North China Craton.

Keywords: Triassic, Laohugou Formation, Liujiang Basin, fossil insects, stratigraphy, North China Craton

Introduction

The Liujiang Basin in Qinhuangdao City (Hebei Province, China) has relatively complete stratigraphic development and a clear geological structure. There is a National Geopark based on this basin, representing an important teaching base for geological universities in China. The geological survey of the Liujiang Basin began 150 years ago by the German geologist F.P.W. Richthofen. A century ago Ye & Liu (1919) established the Liangjiashan Limestone and gradually formed a relatively complete stratigraphic sequence.

The Mesozoic strata in the Liujiang Basin are generally developed and the outcrops are well exposed. Although it has long been used as a teaching base for many universities, the division of the Mesozoic strata and the usage of the lithostratigraphic units are inconsistent. The corresponding geological time scale has not been updated for a long time, making the age of the fossils ambiguous. We here argue that the Mesozoic strata in the Liujiang Basin can be divided into the Upper Triassic Laohugou Formation, the Lower-Middle Jurassic Yaopo Formation (or Mentougou Formation), the Upper-Middle Jurassic Longmen Formation, the Upper Jurassic Tiaojishan Formation, and the Lower Cretaceous Zhangjiakou Formation from the bottom to the top. These strata have been given their respective sequence and different formation names in various geological guide books. In particular, some suggested that the Late Triassic sediments are developed in the basin, which is not accepted by others (e.g., Liu & Ma, 2006; Wang, 2011; Wang, 2016).

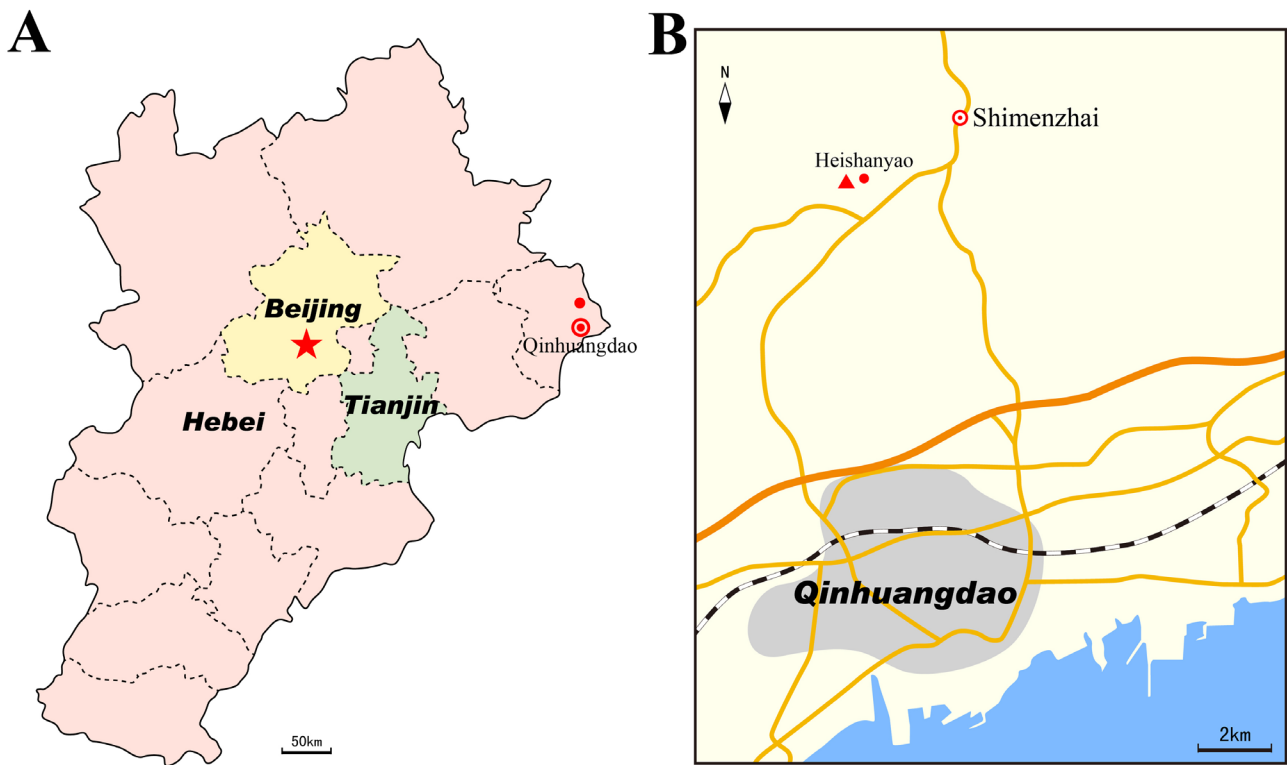


FIGURE 1. Map of the fossil locality. **A**, Hebei Province of northern China with red dot indicating the location of the fossil locality. **B**, Detailed location of the fossil locality (red triangle) in Qinhuangdao City.

The fossils presented in this paper were collected from the Heishanyao Village, Shimenzhai Township, Funing District, Qinhuangdao City, Hebei Province (Fig. 1). Yang established the Heishanyao Formation at 1983. According to the current lithostratigraphic scheme, the Heishanyao Formation has been abandoned (Hebei Provincial Bureau of Geology and Mineral Resources, 1997). This stratum is equivalent to the Laohugou Formation. We have recently collected numerous insect fossils (mainly cockroach forewings) from the black shales and siltstones in the middle of the Laohugou Formation. Late Triassic insects are rarely reported from China (e.g. Fang *et al.*, 2013), and here we discuss the age and assemblage characteristics of the fossil insects from this locality.

Geological setting

The Laohugou Formation was established at the Laohugou Village, Goumenzi Township, Lingyuan City, Liaoning Province. It refers to a set of conglomerates, pebbly coarse sandstones, feldspar sandstones and siltstone strata that are unconformably distributed over various ancient strata. This formation sometimes contains carbonaceous shale and coal lines and is covered by the Beipiao Formation or other younger strata (Liaoning Provincial Bureau of

Geology and Mineral Resources, 1997). According to our recent stratigraphic surveys, the Laohugou Formation is in fact widely distributed in northern Hebei and western Liaoning, and its bottom has thick layers of complex conglomerate, which belongs to rubble stones and is unconformably overlaying on older stratum, the middle and upper parts are clastic rocks sandwiched with coal lines, and rarely with volcanic rocks. It is covered by the Yaopo/Beipiao Formation or Mentougou/Beipiao Group or conformably integrated with the volcanic rocks of the Shuiquangou Formation, and is unconformably or disconformably overlaying on ancient strata of different ages. The Laohugou Formation in the Yanliao area is equivalent to the Yanchang Formation in the Ordos Basin and the Huangshanjie Formation in the Juggler Basin. The Laohugou Formation in northern Hebei has been often mistakenly called the Xingshikou Formation. In the present studied area, the Laohugou Formation that yields numerous insect fossils is a set of gray-yellow pebbly coarse sandstones, siltstones, black interbed carbonaceous shales, which contains coal lines (Fig. 2A–E). This formation is generally considered to be about 160 m thick, rich in plant fossils and with a few bivalves and insects (Wang, 2011). The Laohugou Formation at this locality is unconformably overlaying variegated sandstones of the Upper Permian Sunjiagou Formation and is covered by the complex breccia of the bottom of the overlying

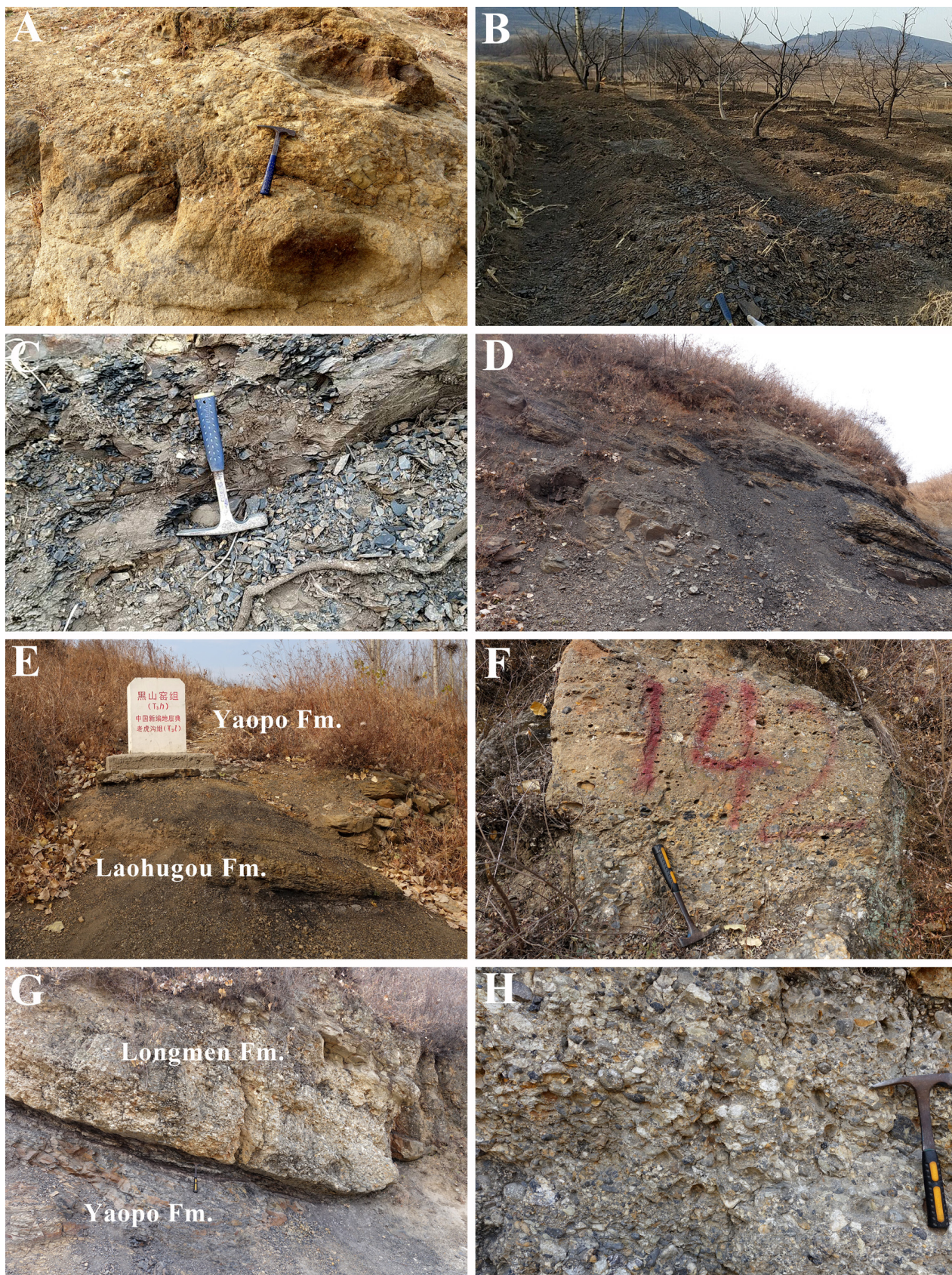


FIGURE 2. The geological background of the fossil locality. **A**, The pebbly sandstone of the Lower section of the Laohugou Formation. **B**, The fossil layers in the field. **C**, The close photo of the black shale where yielded fossil insects. **D**, The top section of the Laohugou Formation showing the interbeds of black shale and siltstone. **E**, The boundary mark of the Laohugou and Yaopo formations. **F**, The bottom conglomerate of the Yaopo Formation. **G**, The boundary of the Yaopo (black shale) and Longmen (conglomerate) formations. **H**, The thick layers of conglomerate of the bottom Longmen Formation.

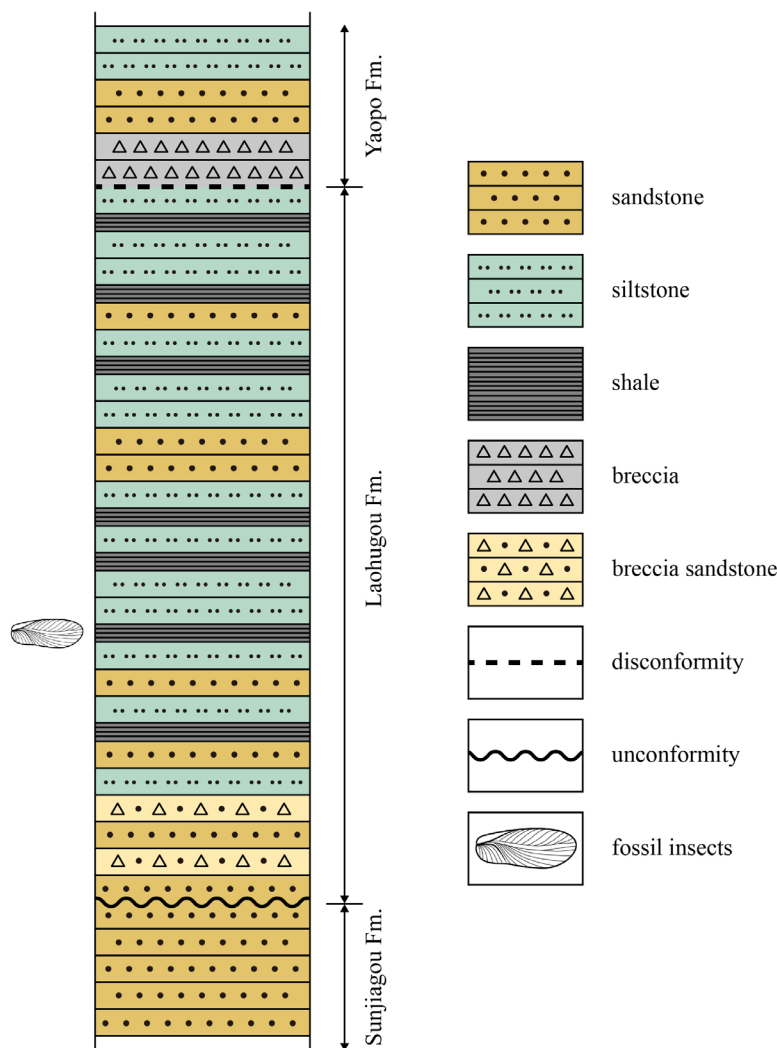


FIGURE 3. The stratigraphic column of the Late Triassic Laohugou Formation near the Heishanyao Village.

Yaopo Formation in either disconformity or unconformity (Fig. 3). The well-known *Coniopteris-Phoenicopsis* flora (Liu & Ma, 2006) is developed at the bottom of the Yaopo Formation, which marks the beginning of the Middle Jurassic.

There are different opinions in various geological guide books for the stratigraphic division of the Mesozoic geological section at Heishanyao in the Liujiang Basin (e.g., Liu & Ma, 2006; Wang, 2011; Wang, 2016). The landmarks in this National Geopark have recently been also replaced, suggesting difficulties in stratigraphic divisions of this stratum. Here we generally agree with the latest stratigraphic division of the National Geopark. The bottom of the Laohugou Formation (the Heishanyao Formation as referred to in the park) is defined as the unconformity of the Sunjiagou Formation. The top of this formation is defined as below the conglomerates of the overlying Yaopo Formation (the Mentougou Formation/Group as referred to in the park) (Fig. 2E, F). The Mentougou Group refers to the Yaopo Formation +

the Longmen Formation. The group initially includes the underlying Nandaling Formation and even the Xingshikou Formation. At present, the Longmen Formation can be separated from the Yaopo Formation according to the thick layers of bottom conglomerate, and the “Longmen Conglomerate” in the Heishanyao Section is particularly developed (Fig. 2G), which should be divided separately, and should not be called the Mentougou Group or the Xiahuayuan Formation. The difference between the Longmen and Haifanggou formations is that the “Longmen Conglomerate” has better sorting and smaller gravel diameter (Fig. 2H), and the Longmen Formation rarely develops volcanic rocks and clastic rocks, whereas the tuff in the Haifanggou Formation is well developed (Huang, 2019).

The overlying and underlying strata of the Laohugou Formation in the Liujiang Basin are distinctly missing. The underlying strata lack of most Early Triassic, all Middle Triassic, and early Late Triassic sediments, and overlying strata lack late Late Triassic and almost

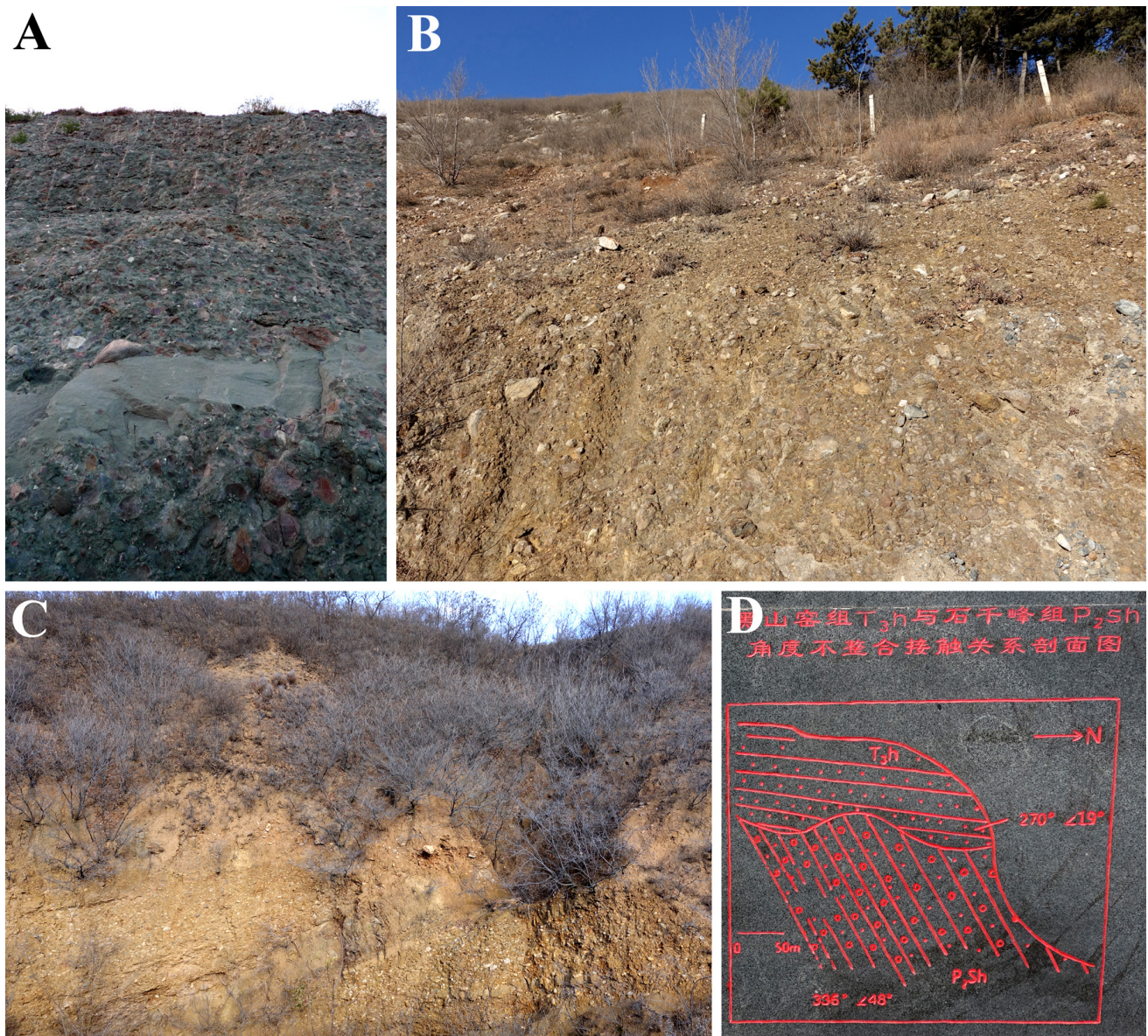


FIGURE 4. The bottom of the Laohugou Formation in different basins. **A**, The bottom complex conglomerate of the “Xingshikou” Formation at Chengde area, Hebei Province. **B**, The bottom complex conglomerate of the Laohugou Formation at the Niuyingzi Basin, Lingyuan City, Liaoning Province. **C**, The bottom complex conglomerate of the “Yangcaogou” Formation at Beipiao City, Liaoning Province. **D**, The monument from the Liujiang National Geological Park showing the unconformity between the Heishanyao Formation (=Laohugou Formation) and Shiqianfeng Formation (=Liujiagou Formation) at the Heishanyao Village.

all Early Jurassic sediments. The bottom of the Yaopo Formation is near the Early-Middle Jurassic transition. Huang (2019) suggested that eastern China was elevated to the mountain-plateau in the late Late Triassic-early Early Jurassic, so there was a general lack of early Early Jurassic sediments. Therefore, the construction of the sandstone at the bottom of the Laohugou Formation suggests a tectonic uplift before the deposition (Fig. 4A–C), and another tectonic uplift occurred at the end of the Triassic period upper the Laohugou Formation. During the two periods of uplifting, there was a lack of sediments in the Yanliao area, which makes the Laohugou Formation very important. The coal in the Laohugou Formation is

not well developed, but fossils are rich, which records important clues of the Late Triassic palaeoclimate, geological development and biota evolution in the Yanliao area. In addition, it is generally believed that the North China Craton was destroyed during the Yanshan Movement period. It is generally believed that the first unconformity on the northern margin of the North China Craton appears below the Tiaojiang Formation, namely the Yanshan Movement-Phase A (Wong, 1927). However, in fact, the first regional unconformity of the northeastern margin of North China Craton should be below the Laohugou Formation (Fig. 4D). There was obvious geological movements and volcanic response in the Late Triassic. This

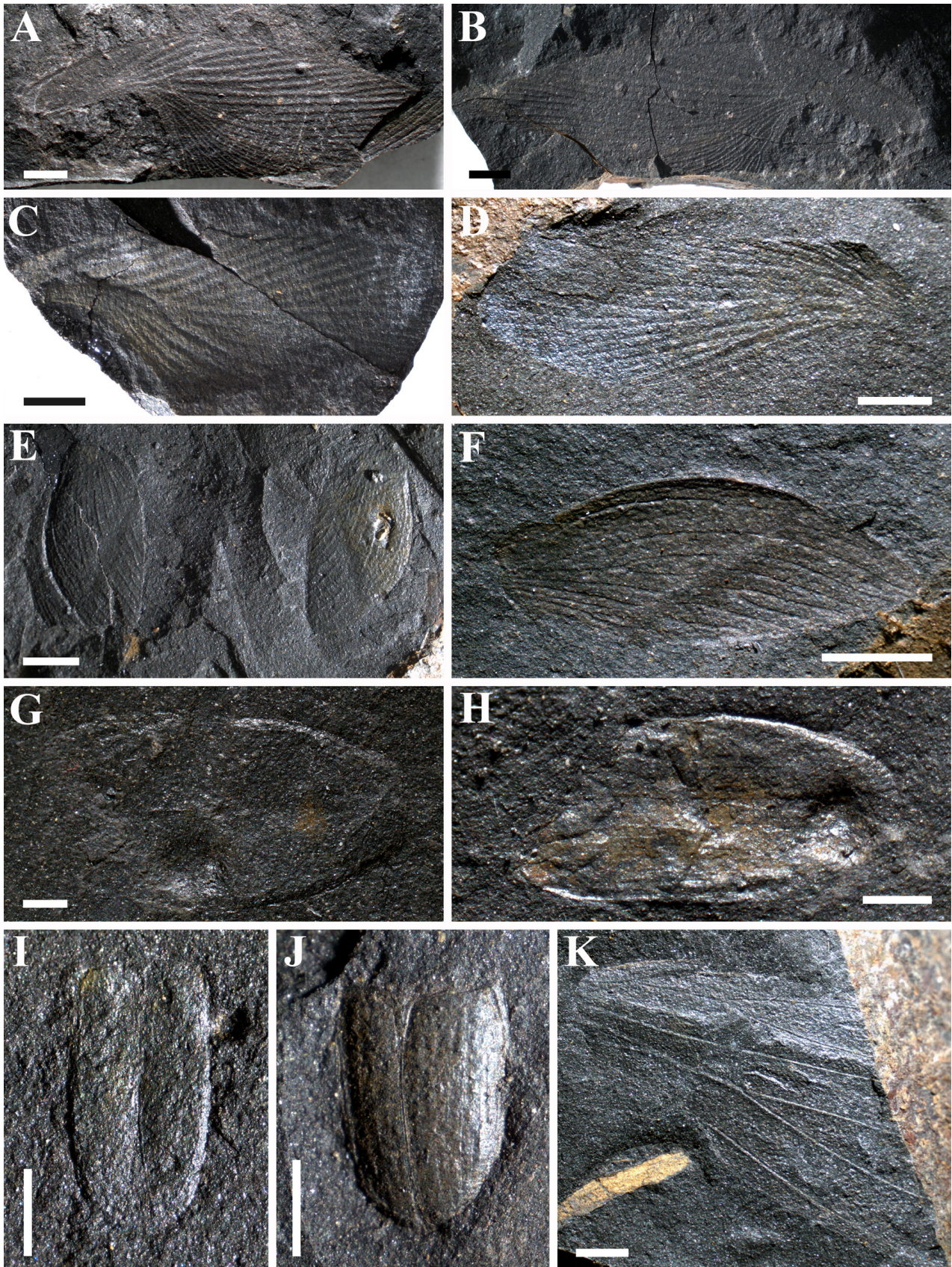


FIGURE 5. Fossil insects from the Upper Triassic Laohugou Formation at the Heishanyao Village, Shimenzhai Township, Funing District, Qinhuangdao City, Hebei Province, China. **A–F**, The fore wings and clavi of cockroach. **A**, *?Rhipidoblattina* sp. **B**, *?Rhipidoblattina* sp. **C**, *Caloblattina* sp. **D**, Dictyoptera unidentified. **E**, Two isolated clavi of cockroach. **F**, An isolated clavus. **G–H**, The fragments of beetles. **G** and **H**, incomplete body. **I** and **J**, beetles without head. **K**, Hemiptera unidentified, basal part of the wing. Scale bars represent 2 mm in **A–F**, **K**, and 1 mm in **G–J**.

tectonic movement before Laohugou the deposits may not be part of the Indosinian Movement, but is related to the late tectonic movement of the Palaeo-Asian Ocean tectonics.

Discussion

Chang & Wang (1993) reported fossil cockroaches from the Beipiao Formation near Heishanyao Village. They suggested that these fossils were found from the top of the black shale in the upper section of Beipiao Formation. Some attributed the Laohugou Formation at this locality to the Beipiao Formation (e.g. Wang, 2016), whereas some other authors assigned all the Jurassic strata below the volcanic rocks of the Tiaojishan Formation into the Beipiao Formation (e.g. Liu & Ma, 2006). According to the stratigraphic division in this paper, this section develops black shales in the middle-upper Laohugou Formation, the upper Yaopo Formation, and the top of the Longmen Formation. In addition to the Laohugou Formation, we also found numerous cockroach forewings in the black shale at the top of the Longmen Formation. Because of the inconsistent stratigraphic division and formation nomenclature, it remains elusive whether the fossils described by Chang and Wang (1993) were collected from the black shale in the upper Laohugou Formation or the upper part of Yaopo Formation or even the Longmen Formation. The author (DYH) consulted Jianping Chang, one of the original authors of the paper, but he could not remember the exact fossiliferous layers. The upper section of the Beipiao Formation they described may not belong to the Laohugou Formation. The fossil insects documented by Chang and Wang (1993) contain mainly small beetles, small to medium-sized cockroaches, and a few homopterans. The clavi of cockroaches are often detached, and the forewings are more abundant than the hindwings; beetles are represented by isolated elytra. Among them, four new species belonging to three extinct genera (*Rhipidoblattina*, *Liadoblattina* and *Triassoblatta*) were established. The age of fossil layer was considered to be Early Jurassic. Hong (1998) established the evolutionary sequence of insect fossils in northern China, and the Qinhuangdao Entomo-assemblage was attributed to the Early Jurassic Beipiao Entomofauna. Since the top of the Beipiao Formation at this locality is probably the top of the Longmen Formation, it cannot be ruled out as a possibility of Late Jurassic (Huang *et al.*, 2018; Huang, 2019).

The insect-bearing layers here reported are distinct lower than those described by Chang and Wang (1993), and the ages of these fossils may differ significantly. The fossils we reported have a Late Triassic age, whereas

the latter may of Middle-Late Jurassic age. The newly collected insect fossils are from the middle and lower layers of the Laohugou Formation (Figs 2B, C; 4). Hundreds of fossil insects were collected, including mainly cockroach forewings, rarely hind wings, and the clavi of forewings are disarticulated. There are also disarticulated parts of coleopterans, such as isolated elytra, articulated elytra, body parts. These beetles are mostly characterized by Polyphaga and a few Archeostemata. In addition, there are a small number of Hemiptera and possibly Diptera (Fig. 5).

Obviously, the fossil preservation conditions of the Laohugou Formation at this locality is far from perfection, and no complete insects are discovered. Although the clavi of cockroach's forewings are detached, the elytra of some coleopterans are still connected. The black shale and siltstone are rich in plant remains, and it is likely that the preservation environment of these fossil insects was a lake-marsh one. Because the clavi are basically detached, the taphonomic process is slow, and the insect bodies have been rotten and decomposed. However, there is no significant difference in the amount of forewings and clavi, indicating the absence of obvious transportation which may cause differential sorting.

The insect fossils here reported have little implications for age determination. Insect fossils are mainly cockroach forewings (Fig. 5). Due to the limited variation of the features, many taxa of cockroaches have a long history and do not have significance for biostratigraphic correlation. In terms of the overall assemblage, the cockroaches here presented are close to those from the Upper Triassic Momonoki Formation in Japan; the latter has produced numerous cockroach forewings mostly attributed the genus *Triassoblatta* (Fujiyama, 1973). The new fossil cockroaches can be assigned into two genera: *Rhipidoblattina* and *Caloblattina*. *Rhipidoblattina* contains many described species, generally found from the Early Jurassic to Early Cretaceous (Barna, 2014), and type species was reported from the Late Triassic of UK. Some species are close to *Rhipidoblattina*, but the anterior margin is obviously protruding, differing from described species, so it is placed herein with uncertainty. *Caloblattina* is generally reported from the Late Triassic to Late Cretaceous (Vrsanský & Ansoerge, 2007). The systematic position of some species of *Triassoblatta* from the Momonoki Formation of Japan and from China may be problematic, and their positions require further confirmation. A small number of bivalve fossils associated with insects are difficult to identify due to incomplete preservation. However, numerous species of *Shaanxiconcha* were found from the Laohugou Formation in the Niuyingzi Basin of Liaoning Province and the Yangcaogou Formation (the lower section = the Laohugou Formation) in the Yangcaogou Basin of Beipiao, which

can be compared with the Yanchang Formation in the Ordos Basin and are of typical Late Triassic biota (Mi *et al.*, 1993). The bivalves of the Xingshikou Formation (= the Laohugou Formation) in Chengde, Hebei Province are rich in *Ferganoconcha* spp., and it is believed that they are also present in the Upper Triassic Huangshanjie Formation in the Junggar Basin of Xinjiang and the Yanchang Formation of the Upper Triassic of Shaanxi (Mi *et al.*, 1993). The systematic position of these bivalves is controversial, but they are similar to the bivalves found in the present paper. There are also many plant fossils associated with insect fossils, such as *Nilssonia* sp. and *Pterophyllum* sp., which have little biostratigraphic significance. Earlier researchers carried out a detailed study on the plant fossils of the Laohugou Formation of the present locality, indicating that *Pterophyllum sinense*, *Anomozamites* cf. *minor* and *Ctenis* cf. *japonica* are only found in the Late Triassic, *Glossophyllum* and *Cycadocarpidium* mainly found in the Late Triassic, and *Neocalamites carrerei*, *Marttiopsis asiatica*, *M. horensis*, *Dictyophyllum nathorsti* and *Clathropteris meniscioides* as common elements of the Late Triassic. Therefore, the age of this flora is late Late Triassic (Wang, 2011). This conclusion is consistent with the biostratigraphic studies of the Laohugou Formation in other regions (Mi *et al.*, 1993).

The Xingshikou Formation in Chengde area, Hebei Province is in fact the Laohugou Formation. The bottom is thick layers of complex conglomerate (Fig. 4A), and the upper part is fine clastic rocks with coal lines, rich in animal and plant fossils. The Shanggu Section in this area yielded typical *Eucalyptus minuta* assemblage, corresponding to the Late Triassic Norian (Mi *et al.*, 1993). Recently, some authors have carried out zircon-based uranium-lead dating of the “Xingshikou Formation” and obtained an absolute age of 227.6 ± 2.2 Ma (Meng *et al.*, 2019; the original ages of Fig. 3 and Fig. 4 are inconsistent with the stratum, and the original authors confirmed the above data), belonging to the Late Triassic Norian/Carnian, consistent with the biostratigraphic correlations. Meng *et al.* (2019) renamed the “Xingshikou Formation” in Chengde area as a new lithostratigraphic unit, Xiaolanwo Formation, which is not necessary. The “Xingshikou Formation” in Chengde is a Late Triassic sediment, which should be the Laohugou Formation according to its lithological characteristics. A few insect fossils have been reported in the Laohugou Formation (=Xingshikou Formation in original paper) in Chengde, including Odonata and Coleoptera (*Sinophlebia shangguensis* and *Uskatocoleus chengdeensis*; Mi *et al.*, 1993). However, these insect fossils are not comparable to those from the Laohugou Formation in Qinhuangdao, increasing the biodiversity of the insect fauna of this formation.

Conclusion

The Laohugou Formation is scattered in northern Hebei and western Liaoning. Within this formation, the middle and upper fine clastic rocks preserve numerous insect and plant fossils. Although these insect fossils are not well preserved, they as inheritance of the Tongchuan Entomofauna (e.g., Hong *et al.*, 2002; Hong, 2007; Zheng *et al.*, 2018) are important for understanding the Late Triassic insects in northern China. The complex conglomerate in the lower part of the Laohugou Formation has the characteristics of molasse formation, reflecting the uplifting tectonic movement. The Laohugou Formation is overlaying on various ancient strata mostly in unconformity, indicating that the tectonic movement and volcanic response have occurred in the northeastern margin of the North China Craton before the Yanshan Movement, which is characterized by a few magmatic activities in the Laohugou Formation and relatively large-scale volcanic eruptions in the overlying Shuiquanguo Formation.

Acknowledgements

We are grateful to Jianping Chang, Yanhong Pan, Shaofeng Liu and Guoli Wu for their valuable information. We thank Yan Fang and Dany Azar reviewed this manuscript and made some valuable comments. This work was supported by the National Key Research and Development Program of China (2016YFC0600406), the Strategic Priority Research Program of the Chinese Academy of Sciences (XDB26000000 and XDB18000000), and the National Natural Science Foundation of China (41688103).

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