Palaeozoic insects from China with discussion on their ages

YE-HAO WANG, MING-LI WAN, HUA ZHANG, CHEN-YANG CAI & DI-YING HUANG*
State Key Laboratory of Palaeobiology and Stratigraphy, Center for Excellence in Life and Paleoenvironment, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China

Abstract

The late Palaeozoic is the key period for understanding the origin and early evolution of insects, but Palaeozoic insects from China are poorly explored. Up to now, a total of 53 Carboniferous–Permian species, 27 Permian species and 1 Carboniferous–Permian species (12 orders or 2 superorders) have been described. Recently, with the development of biostratigraphy and isotope chronology, new insights into the stratigraphy of China and its timescale have been greatly improved. In this study, we discuss the ages of published Palaeozoic insects from China and summarize 23 Carboniferous species, 57 Permian species and 2 Carboniferous–Permian species.

Keywords: Late Palaeozoic, insect fossils, Carboniferous, Permian

Introduction

Misof et al. (2014) dated the origin of insects to the Early Ordovician (~479 Ma), insect flight to the Early Devonian (~406 Ma) and major extant lineages to the Mississippian (~345 Ma) based on phylotranscriptomic evidence. The earliest known convincing pterygote insects appeared in the Upper Mississippian, i.e., Delitzschala bifferfeldensis from the upper Serpukhovian of Bitterfeld/Delitzsch area, Germany (Brauckmann et al., 1996). Several early small-sized fossils from the the Moscovian (France and Germany) and Gzhelian (France) were reported, suggesting that some forms of Recent insects (Eumetabola) have emerged at that time (Nel et al., 2014). The Pennsylvanian, a significant epoch for the radiation of insects, witnessed the radiation of early insects that occurred worldwide (e.g., Brauckmann et al., 2003).

Palaeoentomological studies of Palaeozoic insects in China was initiated by Lin (1978), who described two species from the Upper Permian Xuanwei Formation, Guizhou Province. Other Palaeozoic insects were later described by some Chinese palaeoentomologists (e.g., Hong, 1980, 1983; Lin, 1982; Peng et al., 2005; Chen et al., 2021). The well-known Qilianshan Entomofauna established by Hong (1998) yielded the majority of Carboniferous insects of China (e.g., Peng et al., 2005; Zhang et al., 2006, 2013; Béthoux et al., 2011, 2012a, b; Gu et al., 2011, 2014a, 2017; Su et al., 2012; Li et al., 2013a, b; Wei et al., 2013; Pecharová et al., 2015; Du et al., 2017; Chen et al., 2021). Most described Permian insects from China (Fig. 1) have been reported from the upper Guadalupian Yinping Formation, Anhui Province (Lin, 1982; Lin et al., 2010; Ponomarenko et al., 2014; Szwedo & Huang, 2019; Fu & Huang, 2020; Huang et al., 2007, 2020a, b, 2022).

Despite the remarkable progress made on the Palaeozoic stratigraphy in China, the ages of the fossiliferous deposits are often mis-interpreted by most palaeoentomologists. For example, the insects from Taiyuan and Shanxi formations were assigned to the late Carboniferous (Hong, 1980, 1983, 1985a, b), but the formations should belong to, the late Pennsylvanian—early Cisuralian and early Cisuralian respectively (Shen B. et al., 2021, 2022). Gu et al. (2014b) summarized the Palaeozoic insects of China, but the ages simply followed the original publications. Nevertheless, with the recent development of biostratigraphy and isotope chronology, the stratigraphy and timescale of the Palaeozoic of China have been refined based on multiple lines of evidence. Therefore, it is necessary to re-consider the ages of Palaeozoic insects of China. In this study, we present a list of Palaeozoic insects of China with revised ages (Fig. 2).
Material and methods

We presented new photographs of some published Palaeozoic insects by using a digital camera attached to a Zeiss Discovery V16 microscope (Fig. 1). Photographs were refined and composed in Adobe Photoshop 2020. The illustrations were made by using Adobe Photoshop 2020. The newly photographed fossils are housed in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing.

Results

The Tupo Formation

Sze & Lee (1945) established Tupo Coal Series, and asserted the age of this strata belonged to the late Carboniferous based on plant fossils, and the series is correlated to the Benxi Formation of North China. The lithology of the Tupo Formation is represented by grayish sandstones alternated with dark siltstones, shales and mudstones, occasionally intercalated with marls, bioclastic carbonate lenses, as well as the thin coal seams (Bureau of Geology and Mineral Resources of Ningxia Hui Autonomous Region, 1996). The deposits of this formation yielded very rich terrestrial animal fossils in the alternated beds of terrestrial and marine sediment along a coastal area, and the insects often occurred in the black shales (Lu et al., 2002; Peng et al., 2005). The Qilianshan entomofauna was discovered from the Tupo Formation and assigned to Namurian C that is the late Bashkirian (Brauckmann et al., 1994; Hong, 1998; Wang et al., 2019). Peng et al. (2005) described the first insect fossils, and attributed them to the Bashkirian (Namurian B–C in the original text). A detailed geological study of the Tupo Formation near the Xiaheyan Village was provided by Zhang et al. (2013), who suggested the fossiliferous layers belong to the upper part of the Tupo Formation. Besides, some authors considered the synonyms of the Tupo formation, i.e., Yanghugou Formation, Hongtuwa Formation, Zhongwei Formation (Zhang et al., 2013; Wang et al., 2019; Li et al., 2021). Li et al. (2021) suggested that the Yanghugou Formation in North Qishanshan region belongs mainly to the early Bashkirian–Gzhelian, Pennsylvanian. We suggest that the insect-bearing beds of the Tupo Formation are correlated to the Benxi Formation.

The Benxi Formation

The Benxi Formation was established in Benxi City, Liaoning Province (Bureau of Geology and Mineral Resources of Henan Province, 1997). This formation is composed of alternating sandstones and mudstones representing marine-continental deposits with the widely distributed bauxitic rock layer at the bottom (Zhao et al., 2021). Fossil insects from the Benxi Formation were poorly known from the Kaiping Basin, Tangshan City, Hebei Province (Mathieu, 1939). In recent years, we have collected hundreds of insects from the Benxi Formation, Kaiping Basin. Some blattids were reported from Benxi group in Weibei Coal Mine, Shaanxi Province, but without illustrations and descriptions (Feng & Shang, 1980). Huang et al. (2022) reported some dictyopteran tegmina from the black shales of the upper part of Benxi Formation at Western Hills, Beijing. According to the conchostracan study, the Benxi Formation in Taiyuan City (Shanxi Province) and Kaiping Basin (Hebei Province) was suggested as the middle-late Moscovian to early Kasimovian and more likely the early Kasimovian in age (Liao et al., 2019, 2020). Wang et al. (2019) assigned the age of Benxi Formation of Taiyuan City to the late Moscovian–early Kasimovian. Shen B. et al. (2022) suggested this formation in Beijing, Hancheng City of Shaanxi Province and Baode County, Gaoping City and Taiyuan City of Shanxi Province belonged to the Moscovian–early Gzhelian.

The Taiyuan Formation

The Taiyuan Formation was derived from the Shanxi System, which is the lower part of the coal-bearing strata of the Late Palaeozoic in North China. The lithology of this formation is characterized by alternated marine-continental shales interbedded with several cyclothems composed of sandstones, coals and limestones (Bureau of Geology and Mineral Resources of Shanxi Province, 1997). Fossil insects from the Taiyuan Formation are relatively rare. Hong (1983) reported Hsiopterytes rotundus from Caocun, Chengcheng County, Shaanxi Province and assigned it to the early Late Carboniferous. Huang et al. (2018) discovered Phyloblatta beijingensis in Seshufen Village, Mentougou District, Beijing and suggested its age close to the Carboniferous-Permian boundary. The Taiyuan Formation crossing the boundary of Carboniferous and Permian corresponding to the Kasimovian of Pennsylvanian–Asselian of Cisuralian was suggested by recent studies (Wang et al., 2019; Shen S. et al., 2019; Li et al., 2021; Shen B. et al., 2021). Shen B. et al. (2022) attributed the Taiyuan Formation in Baode County, Gaoping City and Taiyuan City, Shanxi Province to the late Gzhelian–early Asselian, late Pennsylvanian–early Cisuralian.

The Shanxi Formation

The Shanxi Formation is widely distributed in North China. This formation is composed of multiple cyclothems formed by terrestrial sandstones, shales and coals interbedded with several abnormal marine strata containing Lingula.
and Bivalvia (Bureau of Geology and Mineral Resources of Shanxi Province, 1997). Some insects have been described from the Shanxi Formation at Gancaoshan and Renmazhuang, Xiangning County, Linfen City and Xishan, Taiyuan City, Shanxi Province. (Hong, 1980, 1985a, b). The age of the Shanxi Formation is argued for a long time, i.e., cross Carboniferous-Permian boundary, early Permian or late Carboniferous (Tianjin Institute of
The insect fossils were suggested as late Carboniferous in age (Hong, 1980, 1985a, b). Here we adopt the recent studies by Shen B. et al. (2021, 2022), who assigned the Shanxi Formation in Baode County, Gaoping City and Taiyuan City, Shanxi Province to the Asselian, Early Cisuralian.

The Lower Shihhotse Formation

The Lower Shihhotse and the Upper Shihhotse formations are derived from the Shihhotse System in Dongshan Mountain, Shanxi Province (Bureau of Geology and Mineral Resources of Shanxi Province, 1997). The lithology of the Lower Shihhotse Formation is characterized by a set of light-grey gravelly-coarse sandstones, grey-white medium-coarse sandstones and grey-green lithic quartz sandstones dominated by intracontinental deposition (Chen L. et al., 2001; Chen R. et al., 2022). Hitherto, four insect species have been described from the Lower Shihhotse Formation. Hong (1983) reported *Sunopterites hejinensis* in Modigou, Hejin City, Shanxi Province, but its exact systematic position remains uncertain (Gu et al., 2014b). Hong (1985b) described another two species, *Pinegia? meidigouensis* and *Anthohymen hejinensis* from the Renmazhuang Village, Xiangning County, Linfen City and Modigou, Hejing City, Shanxi Province. Lin and Liang (1988) reported *Phyloblatta parviradia* from the north of the Dayugou Coal Mine, Gongyi City, Henan Province. All published insects from the Lower Shihhotse Formation have been considered as the early Permian in age (Hong, 1983, 1985b; Lin & Liang, 1988). Shen S. et al. (2019) attributed the Lower Shihhotse Formation to the late Sakmarian–Roadian, the early Cisuralian–early Guadalupian. Shen B. et al. (2021, 2022) suggested that the range of the Lower Shihhotse Formation was very short, and assigned the Lower Shihhotse Formation in Baode County, Gaoping City and Taiyuan City, Shanxi Province to the late Asselian, early Cisuralian and the formation in Yuzhou City and Yongcheng City, Henan Province to early Sakmarian, Cisuralian.

The Upper Shihhotse Formation

The Upper Shihhotse Formation consists mainly of thick sandy mudstones with thin layer of fine-grained sandstones representing sediments from deltaic to alluvial plain depositional facies (Ma et al., 2021). Only one insect, *Aissoblatta brachyna*, was reported from the Upper Shihhotse Formation in Fangshan, Yuzhou City, Henan Province (Lin & Han, 1985), who attributed this
stratum to late Permian. Shen B. et al. (2021) attributed the Upper Shihhotse formation in Yuzhou City to the early Sakmarian–early Kungurian, Cisuralian.

The Yinping Formation

The Yinping Formation was established in 1987 (Regional Geology of Anhui Province, 1987) and distributed mainly in South Anhui Province (Lin et al., 2010). The lithology of this formation is mainly represented by the gray and dark gray siltstones and black shales deposited under palaeoenvironment varying from coastal marine to lagoon, and insect fossils were excavated from the black shales. Lin (1982) first reported two insects, *Yinpingia caesia* and *Dikerocoleus divisus* from Houdong Village, Chaohu City, Anhui Province. These species were attributed to the Gufeng and the Longtan formations, respectively (Lin, 1982). Lin et al. (2010) and Ponomarenko et al. (2014) stated that the *Y. caesia* and *D. divisus* were collected from the Yinping Formation. To date, a total of 14 species have been described from the Yinping Formation (Lin, 1982; Lin et al., 2010; Huang et al., 2007, 2020a, b; Ponomarenko et al., 2014; Szweed & Huang, 2019; Fu & Huang, 2020a, b; Huang et al., 2022). The age of the Yinping Formation was attributed to the last part of the Capitanian (Zhang et al., 2019), or considered as crossing the Guadalupian-Lopingian boundary (Yao et al., 2015). Shen B. et al. (2021) assigned the Yinping Formation in Nanjing City, Jiangsu Province to the late Capitanian–early Wuchiapingian. Fossil insects were collected from the lower part of the Yinping Formation (e.g., Lin et al., 2010; Huang et al., 2020a), so that the fossiliferous strata should be assigned to latest Capitanian, Guadalupian.

The Longtan Formation

The Longtan Formation was derived from the Longtan Coal Series in Longtan Town, Nanjing City, Jiangsu Province (Bureau of Geology and Mineral Resources of Guizhou Province, 1997). The lithology of this formation consists of black carbon shales, silty mudstones, sandstones, siltstones, marlites, and coals, which indicate marine-continental sediments. Hitherto, only two hemipteran insects, *Furcascytina radia* and *Scopiprosbole caespis*, have been discovered from the Longtan Formation in Benniu Town, Wujin District, Changzhou City, Jiangsu Province and an unknown locality of Tongling City, Anhui Province, respectively (Lin, 1982). The Longtan Formation was dated to the Wuchiapingian, early Lopingian (Shen et al., 2019), and the Wuchiapingian for the Longtan Formation in Nanjing City, Jiangsu Province (Shen B. et al., 2021).

The Xuanwei Formation

The Xuanwei Formation originated from the Xuanwei Coal Series in Xuanwei City, Yunnan Province (Bureau of Geology and Mineral Resources of Guizhou Province, 1997). This formation is mainly composed of grey fine-grained sandstones, siltstones, silty mudstones, mudstones and coal seams, among which bearing coal seams is the major difference from the overlaying Kayitou Formation (Dai et al., 2008). The palaeoenvironment is represented by the terrestrial facies of floodplains, swamps, rivers and deltas (Bureau of Geology and Mineral Resources of Guizhou Province, 1997). Insects from the Xuanwei Formation were extremely sparse, with only two blattids, *Cubitoabilla concina* and *Cubitoabilla fidelis*, described by Lin (1978) from the Qingyun Village, Fuyuan County, Qujing City, Yunnan Province and Mazongling, Nayong County, Bijie City, Guizhou Province, respectively. Regarding the validity of the Kayitou Formation, some assigned the Kayitou Formation to the upper part of the Xuanwei Formation and suggested that the Xuanwei Formation belongs to the Late Permian to the Early Triassic (e.g., Bureau of Geology and Mineral Resources of Yunnan Province, 1996). Shen B. et al. (2021) attributed the Xuanwei Formation in Xuanwei City to the early Wuchiapingian–late Changhsingian, Lopingian.

The Kayitou Formation

The Kayitou Formation was derived from the Kayitou sand-shale layers named by Zhuquan Wang and Qingchang Bi when they investigated the Yangcheng Coal Mine in 1940 (Wang, 2001). The lower part of this formation is yellow-green, gray-green, and brownish yellow combination of siltstones, conglomerates, clay and shales, and the lithology is similar with the Xuanwei Formation, but does not contain coal seams at the base, which is used to define this formation (Wang, 2001). The upper part of this formation is yellow-green, gray-green, brownish yellow siltstones, clay and shales combination interspersed with purple-red rock, and the proportion of purple-red rock increases from bottom to top (Wang, 2001). To date, insects unearthed from the Kayitou Formation are rare. Lin (1978) described the first species, *Chauliodites fuyuanensis*, at the Qingyuan Village, Fuyuan County, Qujing City, Yunnan Province, which was considered as the Early Triassic. Liu et al. (2021) reported the second insect, a bristletail named *Dasyleptus sinensis*, from the green-greyish layer of the upper part of the Kayitou Formation in the adjacent locality of C. *fuyuanensis*, Yinchanggou Coal Mine, and indicated the species belonged to the Latest Permian. The Kayitou sand-shale layers were originally attributed to the late Permian or Triassic (Wang, 2001). Some considered the Kayitou Formation as the lower part of the Feixianguan or Yelang formations as the lowest Triassic, or the upper part of Xuanwei Formation as the uppermost Permian or lowest Triassic (Bureau of Geology and Mineral Resources of Yunnan Province, 1990, 1996; Bureau of Geology and...
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<th>Refined age</th>
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<td>Robin et al., 2016</td>
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<td>Latest Bashkirian (Latest Duckmantian) to Middle Moscovian (Bolsovian), Early Pennsylvanian</td>
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</table>

| Dictyoptera                  |                   |                                               |                                   |                    |                   |
| *Aissoblatta brachyna*       | Upper Shihhotse Formation | Fangshan, Yuzhou City, Henan Province | Late Permian                      | Cisuralian         | Lin & Han, 1985  |
| *Angusticubitus caohunensis* | Bexi Group        | Weibei Coal Mine, Shannxi Province           | late Middle Carboniferous         | Middle-Late Pennsylvanian | Feng & Shang, 1980 |
| *Atimoblatta carbonica*      | Bexi Group        | Weibei Coal Mine, Shannxi Province           | late Middle Carboniferous         | Middle-Late Pennsylvanian | Feng & Shang, 1980 |
| *Cubitoblatta concina*       | Xuanwei Formation | Qingyun Village, Fuyuan County, Yunnan Province | Late Permian                      | Lopingian          | Lin, 1978        |
| *Cubitoblatta fidelis*       | Xuanwei Formation | Mazongling, Nayong County, Guizhou Province | Late Permian                      | Lopingian          | Lin, 1978        |

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**Coleoptera**

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Mineral Resources of Guizhou Province, 1987, 1997; Wang, 2001). Others believed that the Kayitou Formation represented a transitional stratum extending from the Lopingian to the Lower Triassic (Wang, 2001; Zhang et al., 2016; Scholze et al., 2020). Shen S. et al. (2019) and Shen B. et al. (2021) assigned the Kayitou Formation as late Changhsingian, Lopingian.

**Conclusion**

To date, a total of 23 carboniferous species, 57 Permian species and 2 Carboniferous–Permian species, placed in 12 orders and 2 superorders have been described from the Palaeozoic of China in light of our discussion on the ages (Table 1). Currently, discoveries of Carboniferous insects of China are largely confined to the North China Block, and fewer from South China (Fig. 2). The Permian insects are mainly from South China, but they are sporadically reported in North China (Fig. 2).

Compared with the international research of Palaeozoic insects, relatively fewer Palaeozoic insects of China have been studied, mainly including those from the Pennsylvanian Xiaheyan Entomofauna in Ningxia and the Guadalupian Yinping Entomofauna in Chaohu, Anhui Province. However, the Carboniferous and Permian terrestrial strata and marine-nonmarine strata in China are relatively well-developed, so there is a great potential for further exploration of Palaeozoic insects in China.

**TABLE 1. (Continued)**

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<td>Su et al., 2012; Li et al., 2013a</td>
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</table>

**Palaeodictyoptera**

| Namuroningsia elegans           | Tupo Formation | Xiaheyan Village, Zhongwei County, Ningxia Hui Autonomous Region | Namurian B-C, Late Carboniferous | Pennsylvania | Prokop & Ren, 2007 |

**Palaeoneura qiligouensis**

| Sinodonbaria jarmilae           | Tupo Formation | Xiaheyan Village, Zhongwei County, Ningxia Hui Autonomous Region | Namurian B-C, Bashkirian, Late Carboniferous | Pennsylvania | Li et al., 2013b |
| Tythospilaptera wangae          | Tupo Formation | Xiaheyan Village, Zhongwei County, Ningxia Hui Autonomous Region | Namurian, early Late Carboniferous | Pennsylvania | Liu et al., 2015 |

**Paraplecoptera**

| Tonia fuyuensis                 | Kayitou Formation | Qingyun Village, Fuyuan County, Yunnan Province | Triassic | latest Lopingian | Lin, 1978 |

**Plecoptera**

| Gulou carpenteri                | Tupo Formation | Xiaheyan Village, Zhongwei City, Ningxia | Pennsylvania | Pennsylvania | Béthoux et al., 2011 |
| Phyloblatta sp.                  | Benxi Formation | Kaiping Basin, Tangshan, Hebei Province | Middle-Late Pennsylvanian | Mathieu, 1939 |
| Soomylacris sp.                  | Benxi Formation | Kaiping Basin, Tangshan, Hebei Province | Middle-Late Pennsylvanian | Mathieu, 1939 |

**Incertae sedis**

| An insect wing fragment        | Taiyuan Formation | Yangquan City, Shanxi Province | Early Permian | Late Pennsylvanian–early Cisuralian | Wang et al., 2019 |
| Sunopterites hejinensis        | Lower Shihhotse Formation | Modigou, Hejin City, Shanxi Province | Early Permian | Cisuralian | Hong, 1983 |

| Wulasua maculata               | -                        | Wulasu Valley, Inner Mongolia | Permian     |                   | Tan, 1980 |

Note: "-" indicating no available data from the original paper.
For example, our research group has recently collected hundreds of insect fossils in the Benxi Formation of the Kaiping Basin in Tangshan, Hebei Province, and the Yinping Formation in Chaohu City, Anhui Province. Continuing to study these fossil insects will further strengthen our understanding of the early evolution of insects. The Carboniferous-Permian icehouse was the longest-lived ice age of the Phanerozoic (Montañez & Poulsen, 2013), and a more accurate understanding of the fossil records of insects during this critical period will help to understand the evolution of the terrestrial ecosystem and palaeoclimate at that time, especially the icehouse-greenhouse transitions.

Acknowledgements

This paper is dedicated to the memory of the pioneer of Chinese palaeoentomological research, Professor Qi-Bin Lin, who passed away in August 2022. We are grateful to two anonymous reviewers for improving the manuscript. This research was funded by the National Natural Science Foundation of China (41925008 and 42288201) and the Strategic Priority Research Program of the Chinese Academy of Sciences (XDB26000000).

References


Lin, Q.B. (1978) Upper Permian and Triassic fossil insects of...
https://doi.org/10.1080/00379271.2010.10697639
https://doi.org/10.1080/08912963.2019.1692342
https://doi.org/10.1007/s13146-021-00729-2
https://doi.org/10.1080/08912963.2019.1692342
https://doi.org/10.1126/science.1257570
https://doi.org/10.1146/annurev-earth.031208.100118
https://doi.org/10.1038/nature12629
https://doi.org/10.1080/03115518.2015.993299
https://doi.org/10.1007/s11430-017-9228-4
https://doi.org/10.1134/S0031030114101010
https://doi.org/10.1016/j.palwor.2019.04.007
https://doi.org/10.1007/s11430-021-9909-9
https://doi.org/10.1007/s11430-017-9228-4
https://doi.org/10.1163/187631212X624205
https://doi.org/10.1111/j.1755-6724.1945.mp25001010.x
https://doi.org/10.11646/palaeontologist.2.2.6
Palaeogeography, Palaeoclimatology, Palaeoecology, 531, 108630.
https://doi.org/10.1016/j.palaeo.2018.01.021
https://doi.org/10.1016/j.palaeo.2015.07.002
https://doi.org/10.1080/14772019.2011.634443
https://doi.org/10.3390/en14248500


