Permian-Triassic insect diversity revealed by fossils from China

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Abstract. Most of the research on Paleoentomology focuses on describing morphology and classification of one species of fossil insects. However, there is little information on the temporal diversity of insects during the Permian and Triassic periods. The end-Permian mass extinction (EPME) was the greatest biological and ecological crisis of the Phanerozoic Eon on Earth, while the pattern of recovery of terrestrial ecosystem is still unclear. In this paper, the population and distribution of insects in various regions of China before and after the fifth mass extinction were studied by counting the fossil literature data of insects from the Permian to Triassic. We found the genus diversity of the proto-orthoptera decreased after the mass extinction. The Blattoidea (cockroach) showed a brief trend of extinction after the mass extinction, but soon returned to prosperity; Hemiptera's population was less affected by mass extinctions, with only minor fluctuations in diversity and subsequent prosperity beyond the Permian; The order Mecoptera is speculated to be an emerging species of the Triassic. Specific trend changes for the above four purposes may be affected by volcanic activity. Insect diversification can reflect changes in terrestrial ecology, providing a reliable example of changes in our current climate environment: scientists can predict the possible ecological impact of global warming through previous records, and take preventive measures to prevent the mass extinction of species again.

1. Introduction

Most of the research on Paleoentomology focuses on describing morphology and classification of one species of fossil insects[1-3] and the evolution history of specific organs (wings, mouthparts, etc.) [4]. However, there is little information on the temporal diversity of insects, especially during the Permian and Triassic periods [5, 6].

The end-Permian mass extinction (EPME) was the greatest biological and ecological crisis of the Phanerozoic Eon on Earth [7-12]. Ecosystem recovery after the EPME was seemingly delayed because the subsequent Early Triassic interval was characterized by recurrent, rapid global warming and harsh marine conditions [13-16]. The timing and pattern of recovery of marine ecosystems are relatively well known worldwide, but the pattern of recovery of terrestrial ecosystem is still unclear due to the highly fragmentary fossil record [17].

Terrestrial ecosystems play an important role in the global climate change [18]. Here we investigate insect fossils diversity from China during Permian and Triassic. Studies of Permian-Triassic insect diversity can provide a better understanding of how terrestrial ecosystems have responded geologically to the mass extinction event and post-extinction recovery.

2. Background

At the beginning of the Permian, the major plates closed or even disappeared, some ancient seas through complex collision effects. With the advent of fold bands, continental area increased significantly. At the end of the Permian, Pangea were first formed. Plants have completed their development to land and adapted to radiation evolution, with large forests on land, a warm and humid climate, and a large number of coal layers formed [19].

The North China Plate has been largely detached from the marine environment since the Permian, and only some areas have been affected by short-term sea invasions. In the late Permian, the arid climate was widespread throughout North China [19].

The South China plate suffered the most sea invasion in the late Paleozoic period during the Permian period, showing a new paleogeographic pattern of "South China Sea and Northern Land", but the sea invasion appeared repeated ups and downs throughout the Permian period, and it was not until the early and middle Triassic period that it completely broke away from the sea invasion and formed a pantic [19]. The South China block located in the equatorial eastern Tethys during the late Permian and the Early Triassic and Microbialite-bearing Permian-Triassic boundary sections occur widely in the shallow-marine Yangtze Platform [19].

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The continental strata in China are widely distributed in the south and north, especially in the north. The North China includes the Taiyuan Formation, the Shanxi Formation, the Shihezi Formation and the Sunjiagou Formation in Permian. The Taiyuan Formation corresponds to the Asselian-Artinskian, the Shanxi Formation corresponds to the Kungurian, the Shihezi Formation corresponds to the Roadian-Wuchiapingian and the Sunjiagou Formation corresponds to the Changhsingian. The North China also includes the Tupo Formation and the Tongchuan Formation, corresponding to the middle Triassic. The South China includes the Xuanwei Formation and the Longtan Formation in Permian, corresponding to the late Permian [19, 20].

3. Data analyses and Results

At the beginning of the Triassic period, the area of the United Pangea reached its peak. Due to the very limited extent of sea intrusion, the arid climate zone is widely distributed. Therefore, a large number of salinous ointment deposits in the continental red layer and marine strata are formed. In the early and middle Triassic period, the Chinese region was bounded by the Qinling-Kunlun Mountains, showing the topography of the northern mainland of the South China Sea. It was not until the late Triassic that the South China Plate was joined together with the North China [19].

In the early and middle Triassic, the waters of the South China Plate that inherited the Permian continued to receive marine sedimentation. This was followed by large-scale retreat in the late Middle Triassic, with shallow sea retreats to the pre-Qiangui and Longmen Mountains, while the climate of the Late Triassic was characterized by sea-land interchange coal-bearing sediments or continental sediments [19]. The Permian North China Plate is linked to the Tarim Plate and the Siberian-Mongolian Plate, forming a huge northern Chinese ancient land[19].

We counted 10 items, but the data showed that the data of 4 items were relatively complete and had a clear trend (Table 1). The specific performance is:

Table 1 . Permian-Triassic insect diversity revealed by fossils from China

Protorthoptera	Blattoidea	Hemipteia	Mecoptera	Age	Straton (Formation)	Region (Province)	References
		1 genus		C2-P1	Xiazhuang	Beijing	Huang et.al., 2018 [21]
		2 genus		P2	Yinping	Anhui	Fu et.al.,2021 [22]
2 genus	6 genus			P2	Shanxi	Shanxi	Gu et.al., 2014
1 genus	1 genus			P2	Shihezi	Henan	Gu et.al., 2014
1 genus				P2	Gufeng	Anhui	Gu et.al.,2014
	2 genus			P3	Xuanwei	Yunnan Guizhou	Gu et.al., 2014
				P3	Longtan	Anhui Jiangsu	Gu et.al., 2014
6 genus	1 genus			T1	Tupo	Ningxia	Gu et.al.,2014
			3 Family 4 species	T2	Tongchuan	Shannxi	Sun et.al., 2007 [23]
		8 genus	5 genus	T2	Tongchuan	Shannxi	Zhao, 2020 [18]

Proto-Orthoptera distributed 2 genera, 1 genus and 1 genus in Shanxi, Henan and Anhui in the middle of the North Permian period, respectively, and 6 genera in Ningxia in the early Triassic period, which showed that the overall performance was that the Permian had a decreasing trend, but the diversity of the early Triassic suddenly increased significantly. It is not distributed in South China (Fig. 1).

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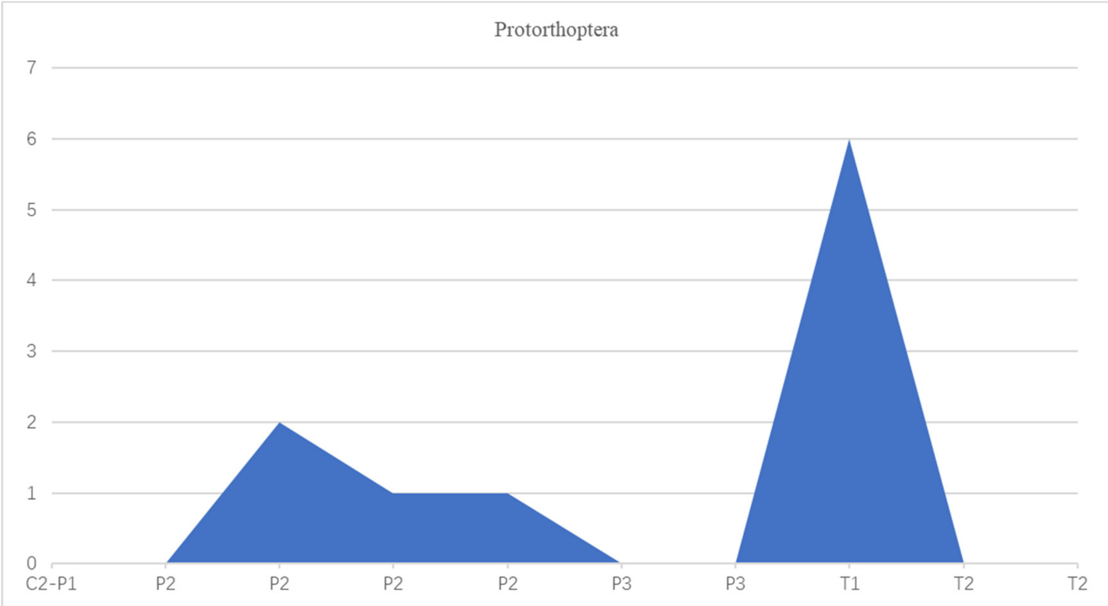

Fig 1 . Protorthoptera diversity from China in Permian-Triassic

There were 6 genera and 1 genus in Shanxi and Henan in the middle of the Permian of the order Blattoidea, 1 genus in Yunnan in the late Triassic period, and 1 genus in Ningxia in the early Triassic period. The overall performance is that the middle of the Permian suddenly turned from prosperity to decline, and there was a slight recovery in the late Permian (Fig. 2).

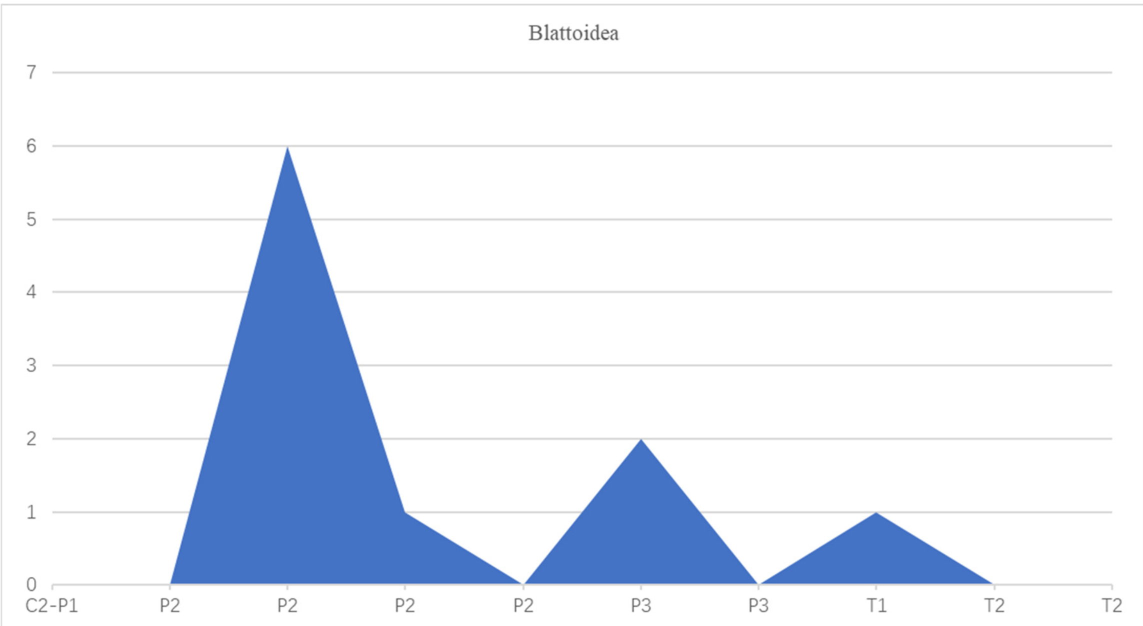

Fig 2 . Blattoidea diversity from China in Permian-Triassic

In the middle of the Hemiptera, 1 genus and 2 species were distributed in Beijing and Anhui, respectively, and 8 genera were distributed in Shaanxi in the middle of the Triassic (Fig. 3).

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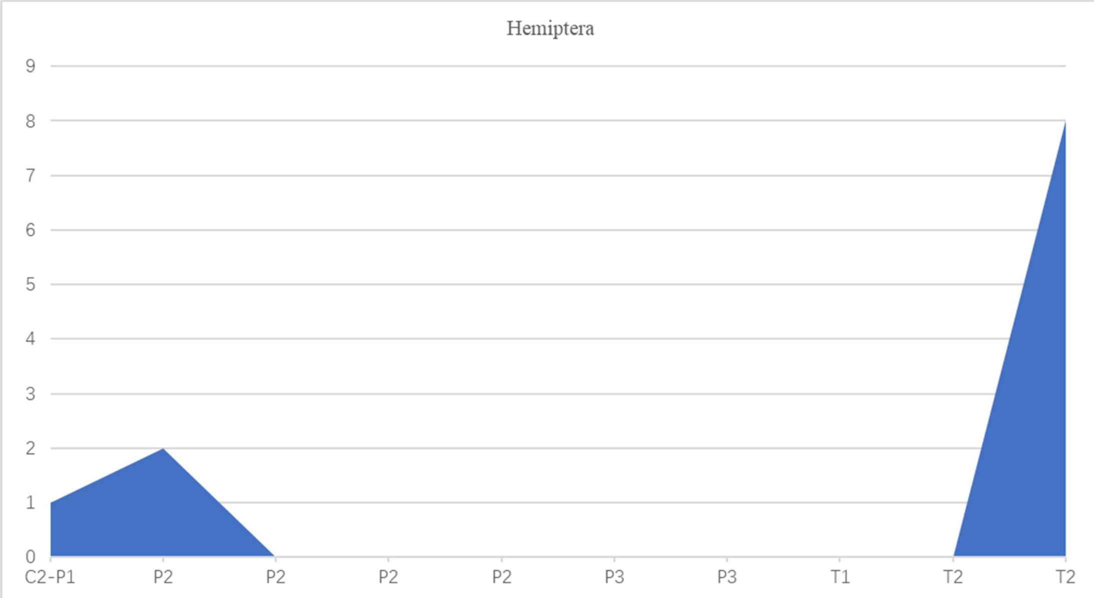

Fig 3 . Hemiptera diversity from China in Permian-Triassic

A total of 3 families, 5 genera and 4 species were distributed in Shaanxi in the mid-Triassic of the order Mecoptera, and 1 family and 1 species in Xinjiang in the middle of the Triassic (Fig. 4).

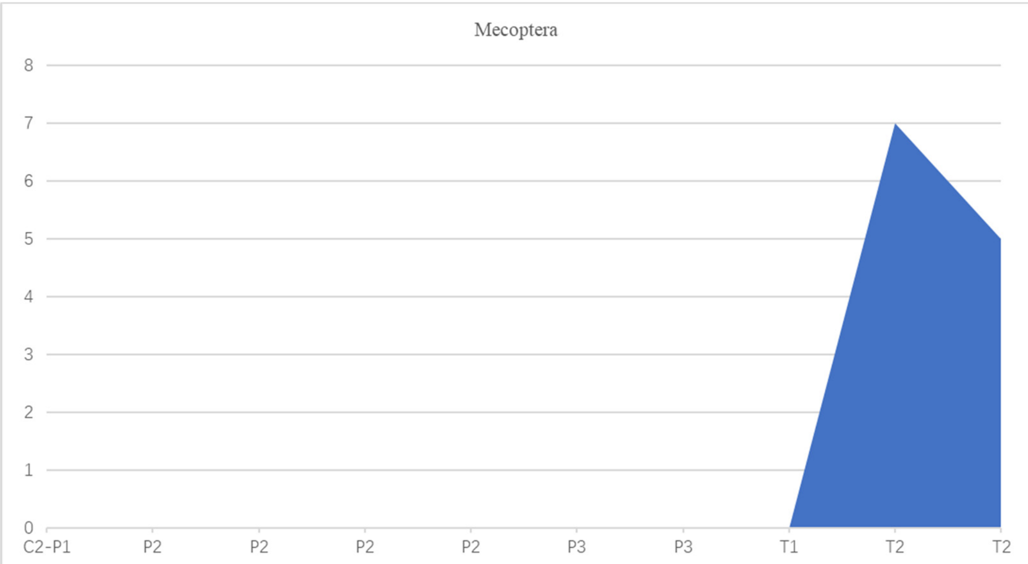

Fig 4 . Mecoptera diversity from China in Permian-Triassic

During the Permian to Triassic periods, all 4 orders flourished after the mass extinction, with differences in the length of recovery time: Protoptoptera and Hemiptera had considerable differentiation in the late Permian, and more divergence after the mass extinction; The order Cockroach diverged extensively during the Permian period, decayed after the mass extinction, but flourished after the restoration of the entire Triassic to this day; The order Mecoptera emerged after the mass extinction and flourished until the Cretaceous period.

4. Discussion

The number of Protoptoptera species may not be affected by mass extinction without decreasing, possibly because food sources are not affected by environmental changes, and competition for the same niche is weakened and can quickly adapt to environmental changes.

Blattoidea flourished in the early and middle Permian period, although the number decreased sharply after the mass extinction, but it was not completely extinct, after a period of recovery and flourished to this day, may be because of tenacious vitality, many food sources, individuals are easy to hide, very adaptable.

There are not many fossil records of Hemiptera's mid-Permian period, and its numbers have increased sharply and become prosperous after the mass extinction; It may be because the new generation of vegetation after the mass extinction provided it with a suitable food source and habitat, allowing it to multiply and differentiate in large quantities.

The order Mecoptera was also inconspicuous during the Permian, but flourished more than Hemiptera in the mid-Triassic , peaking in the middle of the Jurassic Period and then declining slightly. Probably because of the abundance of food, the extinction of natural predators, and the emergence of new predators after the evolution of time. Protoptoptera is an extinct order that is believed to be the ancestor of many living insects and is the earliest winged insect. The order Mecoptera, Hemiptera and Blattoidea are probably all evolved from the order Protoptera. Their feeding relationship is relatively simple, eating only plant leaves, and food competition alone is not enough to cause extinction effects on other orders.

The order Blattoidea is related to the order Mantis, Protoptoptera, and the ecological feeding relationship between the order Blattoidea and other orders has many intersections due to the wide range of food in the order Cockroach. After the mass extinction, although the number of Blattoidea decreased sharply, it was not completely extinct, and after a period of recovery, it has flourished to this day, indicating that it is affected by environmental changes. The cockroach, commonly known as cockroaches, has long been considered a species with tenacious vitality. They are flat, omnivorous and extremely adaptable. The origin of the order Cockroach dates back to the Middle Carboniferous Period and is one of the oldest insects in history.

The feeding relationship between the suborder Wax Cicada and other destinations is not much involved and may decrease due to environmental changes. Most of the hemiptera insects mentioned in this article are the suborder Wax Cicada, and the earliest fossil records date back to the Late Permian. Plant-feeding, it sucks plant sap with a spike-sucking mouthpiece.

The family Scorpion is related to the Protoptera and Diptera, but its feeding habits are rare, unable to affect other orders, and less affected by environmental changes. The insects of the order Longptera are mostly Scorpionaceae, the adults are small and scavenging, and their body morphological characteristics are between the order Longptera and Diptera, which is an important intermediate species in the evolution of insects of the order Mecoptera.

The table shows that the four orders that survived the mass extinction were characterized by strong adaptability, small insect bodies, and low ecological niches, and did not have predators who were at their peak. The energy needed for each individual to survive is small and readily available, which presumably will be decisive for them to survive the mass extinction.

At the time of the mass extinction, some of the living insect orders did not appear, and only a few orders of insects at that time survived the mass extinction, and the four orders with the most obvious data mentioned in this article are the most obvious. During the mass extinction, a large number of plants died, causing large herbivores to lose their food source and then die. Carnivorous insects mostly have the habit of hunting only live animals and thus lose their food source. Instead, the carcass became food for the scavenger-eating Scorpions of the order Mecoptera, and the individuals who survived acid rain and dust gradually grew. As large trees decay, dwarf shrubs and herbs with low thresholds for survival have lost their competitors and have been able to absorb large amounts of inorganic salt, organic matter and other nutrients and grow widely. Cockroaches and Protoptoptera feed on plant leaves, and wax cicada suborder sucks sap from the xylem of shrubs.

So we think the impact of volcanic activity that led to the mass extinction on terrestrial ecosystems is equally enormous. Since the plates merged to form a pantic, the impact of large-scale volcanic eruptions on terrestrial ecosystems was holistic. Large ferns were replaced by gymnosperms, and vegetation on land underwent major alterations. Large insects and carnivorous insects have died out in large numbers, and small plant-eating and omnivorous insects have risen. Terrestrial ecosystems at the end of the Permian and the early Triassic were very different.

5. Conclusion

This paper found that during the Permian and Triassic periods, the genus diversity of the proto-orthoptera decreased after the mass extinction, presumably because the original species diverged and new insect orders appeared; The Blattoidea (cockroach) showed a brief trend of extinction after the mass extinction, but soon returned to prosperity; Hemiptera's population was less affected by mass extinctions, with only minor fluctuations in diversity and subsequent prosperity beyond the Permian; The order Mecoptera is speculated to be an emerging species of the Triassic, evolved from pre-existing ancient winged insects and was more adaptable to the environment at that time. Specific trend changes for the above four purposes may be affected by volcanic activity. Volcanic eruptions have led to changes in the dominant vegetation species and distribution zones, so some insects with short feeding intervals, large amounts of energy (Lepidoptera), narrow feeding ranges, poor resistance to harmful substances (Lepidoptera, Hymenoptera), and long growth cycles have quickly disappeared. Insect diversification can reflect changes in terrestrial ecology, providing a reliable example of changes in our current climate environment: scientists can predict the possible ecological impact of global warming through previous records, and take preventive measures to prevent the mass extinction of species again.

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