Insects and ecosystem characteristics of the Shuinan Formation in Laiyang Basin

Liu Hongliang¹, Qin Peng¹, Liang Zhihao²

¹Shandong Geological Environment Monitoring, 17 Jingshan Road, Jinan, China
²School of Statistics, Shandong University of Finance and Economics, 7366 Erhuan Dong Road, Jinan, China
365375850@qq.com

Abstract: Since 1923 to 2006 (84 years), many insect fossils have been found and reported from Shuinan Formation in Laiyang basin. The researchers included Grabau, Ping Zhi, Hong Youchong, Zhang Junfeng, Wang Wenli, Yang Jikun, et al. The insect group from Shuinan Formation consist of terrestrial and aquatic insects, most of it is terrestrial insects. Its representative species are: Chironomapteria gregaria, Mesolygaeus laiyangensis, and Copioclava longipoda. By contrast, the era of Shuinan Formation is Early Cretaceous Epoch. According to the statistics, the insect fossils have 12 orders, 67 families, 131 genera and 161 species, thereinto, 5 genera’s familiae incertae sedis. The dominant insects were Diptera, Coleoptera and Hymenoptera, which were obviously different from the present ones. There are four levels of food chain among insects: plants (producers) - primary consumers - level two predators - level three predators. According to fossil insects and the other biology fossils from Shuinan Formation, this paper analyzes the ecological characteristics of the ancient Laiyang basin at the time. It provides the foundation for the protection of insect fossils production in Laiyang basin and the construction of the Cretaceous National Geopark in Laiyang City Shandong Province.

1. Introduction
The paleontological fossils are abundant in the Laiyang Basin, which provides physical evidence for studying the paleogeography, paleoclimate, and paleoecological environment in the geological historical period of the Laiyang Basin. Insect fossils in the Shuinan Formation in the Laiyang Basin are particularly abundant, widely distributed, and diverse. Since 1923, Grabau (collected by Tan Xichou), Bingzhi, Lin Qibin, Hong Youchong, Wang Wenli, Zhang Junfeng, Yang Jikun, Zhang Haihun and other paleontologists have been conducting research on insect fossils in Laiyang. Hong Youchong et al. (1990) systematically studied and summarized the insect fossils of the Shuinan Formation in the Laiyang Basin, describing a total of 8 orders, 41 families, 64 genera, 72 species, and 3 genera of the insect fossils. However, the book describes only the fossil specimens collected during field work from 1986 to 1990. The fossils that have not been collected in the past are not included, which makes the book incomplete collection of insect fossils in Laiyang Basin. After 1990, new insects were successively discovered and described in the Shuinan Formation of Laiyang Basin, and the number of insect fossils continued to increase. In 2010, Zhang Haihun et al. reported that there are 10 orders, about 70 families, and 160 species of insect fossils. According to the collected specimen materials, there are 13 orders, about 80 families, and 300 species. The article does not give specific genera.
For all the above, there are many descriptions of the insects found in the Shuinan Formation in Laiyang Basin. There is no systematic summary. It is necessary and meaningful to summarize them systematically. In this paper, the insect fossils found and reported in the Shuinan Formation of Laiyang Basin are comprehensively collected and sorted, and the ecological characteristics of the insect fossils are further discussed.

2. Geological overview
Laiyang City is located in the east of Shandong Province and in the middle of the Jiaodong Peninsula. Geographical coordinates: 120°31′-120°60′ east longitude, 36°34′1-37°10′ north latitude.

In the stratigraphic division of the whole country, Laiyang is located in the North Hebei stratigraphic area (V) in the Jinji-Luyu stratigraphic area (V4) and the Ludong stratigraphic zone (V411), and the Laiyang-Haiyang stratum. There are mainly Proterozoic, Mesozoic, and Cenozoic strata in the area. The stratigraphic development is the most mesozoic Cretaceous strata, widely distributed and well-developed. It is the most concentrated area of the Cretaceous stratum in Shandong Province, and it is rich in geological heritage. The Cretaceous can be divided into 3 groups and 12 groups, from bottom to top: the Wawuyu Formation, Linsishan Formation, Zhifengzhuang Formation, Shuinan Formation, Longwangzhuang Formation, Qugezhuang Formation, Qingshan of Laiyang Group, Houyi Formation, Bamudi Formation of the Group, Linjiazhuang Formation, Xingezhuang Formation, Hongtuya Formation, and Jingangkou Formation of the Wang Group.

3. Shuinan Formation insect fossil origin
The Laiyang Mesozoic insect fossils are widely distributed in the Laiyang Basin, and their exposed horizons are all in the Laiyang Group Shuinan Formation—Figure 1. There are a large number of insect bodies and a variety of species, especially the preservation of mosquitoes. According to the types and numbers of insects found so far, they can be divided into Tuanwang area and bath shop area.

The origin of insect fossils in the Tuanwang area is mainly distributed in the west and south of Ligezhuang in Tuanwang town; the bathing area is mainly distributed in the area of Maershan in Beibozi Village-Shanqiandian. Houhougou, Maershan in the north of Shanqiandian Railway Bridge, Liusizhuang in Bathing Town, Daming Village in Shanqiandian, Nanwu Village in Longwangzhuang Village, and Shuinan Village. There are many origins, but few species. The first 6 are rich in fossils, especially in the western, south Ligezhuang, and Beibozi of Tuanwang Town, as shown in Figure 1. Insect fossils are produced near ancient rocks.

![Figure 1. Distribution of insect fossils in the Shuinan Formation of the Laiyang Group](image-url)
In Nanwu Village, the fossil layer did not show well. It was exposed in the pit. The lithology was thin gray-green sheet and siltstone.

The fossil point of Shuinan Village is located on the north bank of the northeast river. The lithology is gray-black, gray thin-layer argillaceous limestone, and gray-green thin-layer siltstone.

Liusizhuang, the fossil point is located on a steep ridge near a small river in the southwest of Liusizhuang. The exposed rock layer is a set of gray-green, gray-white, gray-yellow thin siltstone, shale, and thick calcareous sandstone. Produce fish fossils.

Daming Village, Shanqiandian, is located about 300m south of the railway bridge. The Hedongyan quarry has the same lithology as Maler Mountain. Except for insect fossils, fern and cycad fossils are produced.

4. Insect Fossils of Shuinan Formation

There are 162 species of insect fossils reported publicly by the Shuinan Formation in Laiyang Basin. Schizopteryx is a genus discovered and commissioned by Hong Youchong in 1984. The model species Schizopteryx shandongensis is placed in the family Homoptera. Zhang Junfeng revised his classification position in 1991 and placed it in the family Heteroptera. This article recognizes Zhang Wen's classification, and others follow the classification position at the time of publication. Insect fossils in the Shuinan Formation totaled 12 orders, 67 families, 131 genera and 162 species, and the classification position of 6 genera was not determined. See Table 1 for details.

Table 1. List of insect fossils of Shuinan Formation in Laiyang Group

| Order        | Families                | Genera                | Species               | Feeding habits |
|--------------|-------------------------|-----------------------|-----------------------|----------------|
| Odonata      | Aeschnidiidae           | Sinaeschnidia         | S. heishankowensis    | Pred           |
|              | Congqingiidae           | Congqingia            | C. rhora              | Pred           |
| Blattaria    | Mesoblatinidae          | Rhipidoblatina        | R. nanligezhuangensis | Poly           |
|              |                         | Laiyangia             | L. paradoxifomis      | Poly           |
|              |                         |                       | L. delicata           | Poly           |
|              | Sinoblatta              |                      | S. laiyangensis       | Poly           |
| Blattaria    | Longicerciatidae        | Longicercia           | L. mesozoica          | Poly           |
|              |                         |                       | L. rumpens            | Poly           |
| Blattaria    | Pygidicranidae          | Archaeosoma           | A. serratum           | Poly           |
| Orthoptera   | Locustopseidae          | Mesolocustopsis       | M. sinica             | Phyt           |
|              |                         | Pseudoacrida          | P. costata            | Phyt           |
| Orthoptera   | Haglidae                | Laiyangohagla         | Rohdendorf            | Phyt           |
|              | Familiae Incertae       |                       |                       |                |
|              | Sedis                   | Falsirameus           | F. ravus              |                |
| Heteroptera  | Corixidae               | Mesocorixa            | M. nanligezhuangensis | Pred           |
|              |                         | Sigarella              | S. tenuis             | Pred           |
|              |                         | Karataviella          | K. shandongensis      | Pred           |
|              |                         | Corixopsis            | C. tuanwangensis      | Pred           |
|              | Pyrrhocoridae           | Mesopyrrhocoris       | M. fasciata           | Phyt           |
|              | Mesolygaiidae           | Mesolygaeus           | M. laiyangensis       | Pred           |
|              |                         |                       | M. rotundocephalus    | Pred           |
|              |                         | Jiaodianxia           | J. marshanensis       | Pred           |
|              | Schizopteryx            | S. shandongensis      | Pred                  |                |
|              |                         |                       | S. lacustri           |                |
|              | Notonectidae            | Clypostemma           | C. xyphialae          | Pred           |
|              | Anisopinae              | Notonectopsis         | N. sinica             | Phyt           |
|              | Clypostemma             |                       | C. petila             | Phyt           |
|              | Anthocoridae            | Mesanthocoris         | M. brunneus           | Phyt           |
|              | Actinocirciniidae       | Ovicimes              | O. laiyangensis       | Phyt           |
| Heteroptera  | Tettigarcidae           | Sinicicadina          | S. shandongensis      | Sapr+Phyt      |
|              | Mesococcus              |                       | M. lutarius           | Sapr+Phyt      |
| Order          | Families                      | Genera             | Species                        | Feeding habits |
|---------------|-------------------------------|--------------------|--------------------------------|----------------|
|               | M. advenus                    |                    | M. advenus                     | Sapr+Phyt     |
|               | Sinojassus                    | S. brevispinatus   | S. brevispinatus               | Sapr+Phyt     |
|               | Archijassidae                 | Archijassus        | Archijassus                    | Sapr+Phyt     |
|               | Familiae Incertae Sedis      | Cicadoides         | C. orientalis                  | Sapr+Phyt     |
|               |                               |                    | C. shandonggensis              | Sapr+Phyt     |
|               | Oviparosiphidae               | Expansaphis        | E. ovata                       | Phyt          |
|               |                               |                    | E. laticosta                   | Phyt          |
|               |                               | Paroviparosiphum   | P. opimum                      | Phyt          |
|               |                               |                    | P. camptotropum                | Phyt          |
|               |                               | Penaphis           | P. nanlisurezhuangensis        | Phyt          |
|               |                               | Oviparosiphum      | O. latum                       | Phyt          |
|               |                               | Mesoviparosiphum   | M. tuangwangense               | Phyt          |
|               |                               |                    | M. malacum                     | Phyt          |
|               | Sinaphidae                    | Sinaphidum         | S. epichare                    | Phyt          |
|               |                               | Tartaraphis        | T. peregrina                   | Phyt          |
|               | Palaeoaphidae                 | Caudaphis          | C. spinalis                    | Phyt          |
|               |                               |                    | C. lepoteura                   | Phyt          |
|               |                               |                    | C. minulissima                 | Phyt          |
|               | Aphididae                     | Sunaphis           | S. shandonggensis              | Phyt          |
|               |                               |                    | S. laiyangensis                | Phyt          |
|               | Hormaphididae                 | Petiolaphis        | P. laiyangensis                | Phyt          |
|               |                               | Petiolaphioides    | P. shandonggensis              | Phyt          |
| Coleoptera    | Copedidae                     | Forticupes         | F. laiyangensis                | Sapr          |
|               |                               | Fuscicupes         | F. parvus                      | Sapr          |
|               |                               | Picticupes         | P. tuangwangensis              | Sapr          |
|               |                               | Notocupes          | N. ludongensis                 | Sapr          |
|               | Staphylinidae                 | Sinostaphylina     | S. nanlisurezhuangensis        | Sapr          |
|               |                               | Mesostaphylinus    | M. laiyangensis                | Sapr          |
|               |                               |                    | M. fraternus                   | Sapr          |
|               |                               | Laostaphylinus     | L. nigritellus                 | Sapr          |
|               |                               |                    | L. fuscus                      | Sapr          |
|               |                               | Hesternasca        | H. obesa                       | Sapr          |
|               | Coptoclaviidae                | Coptoclava         | C. longipoda                   | Pred          |
|               | Carabidae                     | Cretarabus         | C. medius                      | Sapr          |
|               |                               | Magnirabus         | M. furvus                      | Sapr          |
|               | Carabinae                     | Atirabus           | A. shandonggensis              | Sapr          |
|               |                               |                    | A. tuangwangensis              | Sapr          |
|               | Protoscelidae                 | Protoscelis        | P. tuangwangensis              | Pred          |
|               | Scarabaeidae                  | Proteroscarabaeus  | P. yeni                        | Sapr          |
|               |                               |                    | P. baikensis                   | Sapr          |
|               | Prototrupoides                | Geotrupoides       | G. nodusus                     | Sapr          |
|               | Holocoriboeus                 |                    | H. evitatus                    | Sapr          |
|               | Familiae Incertae Sedis       | Leptocnemus        | Leptocnemus longus             | Phyt          |
|               | Buprestidae                   | Macronotus         | M. tuangwangensis              | Phyt          |
|               | Byrrhidae                     | Jingxidiscus       | J. lusangfenensis              | Phyt          |
|               | Silphidae                     | Sinosilphia        | Sinosilphia punctata           | Phyt          |
|               | Coptoclavidae                 | Coptoclaviscena    | C. grandioculus                | Phyt          |
|               | Nitidulidae                   | Sinosoronia        | S. longiantenna                | Phyt          |
| Diptera       | Trichoceridae                 | Mesotrichocera     | M. laiyangensis                | Phyt          |
|               | Graciliturpulidae             | Graciliturpula     | Graciliturpula asiatica        | Phyt          |
| Order               | Families           | Genera         | Species          | Feeding habits |
|---------------------|--------------------|----------------|------------------|----------------|
| Palaeolimnobiidae   | Palaeolimnobia     | P.laiyangensis| Phyt             |
|                     | Ceuthoneura       | C. dolichoptera| Phyt             |
| Chaoboroidae        | Chironomapteria   | C. gregaria    | Phyt             |
|                     |                    | C.melanura     | Phyt             |
|                     |                    | C. vesca       | Phyt             |
|                     | Mesochaoborus     | M.zhangshanyingensis| Phyt   |
|                     |                    | M.pallens      | Phyt             |
| Asiochaoboridae     | Asiochaoborus     | A. tenuous     | Phyt             |
|                     | Sinochaoborus     | S. divisus     | Phyt             |
|                     | Chaoboropsis      | C. longipedalis| Phyt             |
|                     | Sunochaoborus     | S.laiyangensis| Phyt             |
| Tendipedidae        | Tendipopsis       | T. colorata    | Phyt             |
|                     | Coelochironoma    | C. xantha      | Phyt             |
|                     | Petiolatendipes   | P.shouchangensis| Phyt     |
|                     | Oryctochlus       | O. contiguus   | Phyt             |
|                     | Sinoryctochlus    | S. insolitus   | Phyt             |
| Paratendipedidae    | Paratendipes      | P. laiyangensis| Phyt             |
|                     |                    | P. tuanwangensis| Phyt |
| Sinotendipedidae    | Sinotendipes      | S. tuanwangensis| Phyt |
| Pleciofungivoridea  | Mesopleciofungivora| M. martynovae| Phyt             |
| Eohesperini         | Eohesperinus      | E. latissimus  | Phyt             |
| Parapleciofungivora | P. triangulata    | P. triangulata| Phyt             |
| Pleciomimidae       | Pleciomimella     | Pleciomimella  | Phyt             |
|                     |                    | parva           | Phyt             |
|                     |                    | P. ? Longiradiata| Phyt |
|                     |                    | P. perbella     | Phyt             |
| Aortomiina          | A. shandongensis  | P. laiyangensis| Phyt             |
| Mimallactoneura    | M. laiyangensis   | P. laiyangensis| Phyt             |
| Eopleciidae         | Gansuplecia       | G. triporata   | Phyt             |
| Protopleciidae      | Protopleciidae    | P. orientalis  | Phyt             |
| Sunoplecia          | S. curvata        | P. curvata     | Phyt             |
| Pseudoplecia        | P. ovata          | P. ovata       | Phyt             |
| Familae Incertae    | Meconeura         | M. petrefacta  | Phyt             |
| Sedis               |                    |                |                  |
| Platypezidae        | Sinolesta         | S. lata        | Para+Pred        |
| Palaeoptera         | P. laiyangensis   | P. laiyangensis| Para+Pred        |
| Mesopetia           | M.tuanwangensis   | M.tuanwangensis| Para+Pred        |
| Lithoptera          | L. hirsuta        | L. hirsuta     | Para+Pred        |
| Pseudopetia         | P. grandis        | P. grandis     | Para+Pred        |
| Rhyphidae           | Mesobrachyopteryx | M. shandongensis| Pred |
| Nemestrinidae       | Sinonemestrinus   | S. tuanwangensis| Pred |
| Rhagionidae         | Mesorhagiophryne  | M. robusta     | Pred             |
|                     |                     | M. incert      | Pred             |
| Scelerhagio         | S.mecomastigus    | S. mecocomastigus| Pred  |
| Palaeostriomyidae   | Stratiomyopsis    | S. robusta     | Pred             |
|                     | Mesostratiomyia   | M.laiyangensis | Pred             |
| Silvidae            | Archisolva        | A. cupressa    | Pred             |
| Protomphralidae     | Mesomphrale       | M.asiatica     | Pred             |
| Order | Families | Genera | Species | Feeding habits |
|-------|----------|--------|---------|---------------|
|       | Plecofungivoridae | Mesoplectofungivora | M. martynovae | Pred |
|       | | | Eohesperinus | Pred |
| Hymenoptera | Apidae | Palaepis | P. beiboziensis | Phyt |
| | Megalyridae | Stemmodaster | S. celata | Para+Pred |
| | Ichneumonidae | Polychorella | P. magicus | Para+Pred |
| | | Tanychorea | T. sinensis | Para+Pred |
| | Familiae Incertae Sedis | Oligoneuroides | O. huadongensis | Para+Pred |
| | Mutilidae | Mesomutilla | M. aptera | Para+Pred |
| | Scoliidae | Cretaproscolia | C. asiatica | Para+Pred |
| | | Cretoscolia | C. formosa | Para+Pred |
| | Pelecinitidae | Sinopelecinitus | S. hierus | Para+Pred |
| | | | S. daspletis | Para+Pred |
| | Allopecinitus | A. terpnius | Para+Pred |
| | Heloridae | Laiyanghelorus | L. erynnus | Para+Pred |
| | | Otilia | O. ectemnia | Para+Pred |
| | Gasteruptiidae | Mesepipolises | M. nanligezhuangica | Para+Pred |
| | | Humryssus | H. laiyangensis | Para+Pred |
| | | | H. specialis | Para+Pred |
| | | | H. vulgatus | Para+Pred |
| | | | H. cancellatusa | Para+Pred |
| | | | H. ocultissimus | Para+Pred |
| | | | H. leucus | Para+Pred |
| | Praeaulicidae | Sinowestratia | S. communicata | Para+Pred |
| | Tenthredinoidae | Palaeathalia | P. laiyangensis | Phyt |
| | Baissodidae | Palaeathalia | M. venulosus | Pred |
| | | Shangdondongodes | S. lithodes | Pred |
| | | | S. necrodes | Pred |
| | | Eubaissoodes | E. s completus | Pred |
| | | Calobaissoodes | C. strigosus | Pred |
| | Trichoptera | Tuanwangica | T. aethoneura | Phyt |
| | Neuroptera | Allopteridae | Allopterus | A. luianus | Pred |
| | | Chrysopidae | Drakochrysa | D. sinica | Pred |
| | | Raphidiptera | Huaxiaraphidiae | H. shandongensis | Pred |

Notes: Phyt, phytophagous; Pred, predaceous; Poly, polyphagous; Sapr, saprophagous; Para, parasitism

5. Insect habitat and food habits analysis

5.1 Odonata
Odonata, a semi-perverted insect, goes through the egg stage→the juvenile stage→the (emergence) adult stage. It is generally large in size, with long and narrow wings. Larvae (larvae) are commonly known as leeches, which develop in the water and prey on tadpoles or other small animals. Sometimes they cannibalize. Adults generally fly to catch flying insects in ponds or rivers. In addition to large numbers of mosquitoes and flies, some can also eat butterflies, moths and bees.

The important medium for dragonfly reproduction is water. Its eggs are to be laid in water. Before hatching and growing of eggs and becoming a formal dragonfly, it was carried out in water, so they depended on water. Caused his habit of loving water. Chemical nature is one nature or partial nature. Juveniles and adults are predatory and water-loving.
5.2 **Blattaria**
Magpies, commonly known as cockroaches, are gradual insects. Most species live in wild mangrove forests. They like to choose warm, humid, food-rich, and multi-gap places to live. These are the 4 basic conditions for their breeding. Cockroaches are omnivorous insects and have a wide range of food. Foods that are fragrant, sweet, and oily can also feed on spoiled organic matter, even killing animals. Hungry but not thirsty, has a tendency to wet, and can be eaten when food is poor. Diversity is polymorphism.

5.3 **Lepidoptera**
Lepidoptera, commonly known as pupa, gradual insects, mostly distributed in tropical and subtropical regions, and less temperate. The order is medium and small insects. Most omnivorous, feeding on animal carcasses and decaying organic matter, and partly phytophagous. Changeability is changeability.

5.4 **Orthoptera**
Orthoptera, Pseudosidae, and Singidae, are analyzed by the epiphytic tadpole habits, tadpoles, terrestrial insects, gradual state, living on plants, and most of the phytophagous phagocytosis. Chemical nature is one nature or two natures.

5.5 **Heteroptera**
Heteroptera, gradient insect. Most terrestrial, a few species aquatic, unisexual or polymorphic. Most terrestrial salamanders live on the leaves of plants and feed on sap to feed on them. Aquatic species are predatory.

Insects found in the Shuinan Formation include Amaranthaceae, Amaranthaceae, Middle Amaranthaceae, Amaranthaceae, Sorbusaceae, Puccinidae

The Amaranthaceae and Yangyangidae are aquatic species and predatory.

As a family of fossils, the midge family is classified as the general branch of the family Lepidoptera. The aquatic organism is analyzed as a predatory species based on the analysis of the feeding habits of the current family. Because the worm is small, it can only catch smaller insects or tiny animals.

Rhododendronaceae, terrestrial, phytophagous; Antheridae, terrestrial, predatory.
According to its morphological characteristics, it is ovate and has long antennae. It should be terrestrial and herbivorous.

5.6 **Homoptera**
Homoptera, gradual state, all herbivorous insects. A total of 8 fossils were found, including the family Aphididae, Leafhopper, Paleophytidae, Ovidae, Aphididae, Archaeidae, Aphididae, and Aphididae.

Analysis was based on the existing Cicidae, Leafhopper and Aphididae.

Cicadaceae, larger individuals, mainly live in the woods and suck the sap of plant roots. Chemical nature is mostly partial nature.

Leafhopper family, small, mainly feeding on plant leaves. Chemical nature is mostly partial nature.

Aphididae, small, miniature, live on and feed on leaves, shoots, inflorescences or shoots. Diversity is polymorphism, and multiple people can occur for dozens of generations in a year.

5.7 **Coleoptera**
Coleoptera found 12 fossils. Ornithopodidae, Cryptopteridae, Schizophylidae, Carapaceae, Protopodidae, Searabidae, Gidicidae, Maruidae, Burialidae, Acanthaceae, Crustacea, Pseudomonidae Coccinellidae.

Coleoptera, fully metamorphic, partially metamorphic. The food habits are complex, most of them are herbivorous, few predatory, saprophytic (fecal, cadaveric), and parasitic.
Adults of the Olympidae family live in dead wood or dead stems of live trees, feeding on fungi. Larvae occur in rotten wood and are herbivorous (fungiform). Cryptoptera, rotten plants and rotten animals, manure, fungi, omnivorous. Scarabidae, fecal feeding, feeding on rotting plants, animal carcasses, and part of the herbivorous feeding. Carabidae, prey on small insects. Protothecidae, fossil species, belongs to the carapaceae, predatory. Chitinidae, herbivorous. Maruidae, predatory. Burial insectidae, carnivorous. According to the available information, the foods of the spiny carapaceae, crustaceae, pseudococcinidae, and cleft crustaceae are unclear, but most of the coleoptera are phytophagous, and the phytophagous is very likely.

5.8 Diptera
A total of 19 families of fossils were found in Diptera. Trichoceridae, Trichoplusidae, Trigonidae, Anophelesidae, Anopheles, Asia, Chironomidae, Quasi-chididae, Chironomididae, Pleurotus Family, Epiphycotidae, Protochaetidae, Anophelesidae, Pseudocercopidae, Ranunculaceae, Polygonaceae, Paleohydrasceae, Asteraceae. Mosquitoes, flies and pupae were mainly found, but no pupae were found.

Diptera, completely changeable, polymorphism, larvae are footless or pupae. The larvae of the horned horned mosquitoes and the larvae of the horned mosquitoes are analyzed and analyzed by the living mosquitoes and larvae. The larvae are aquatic, semi-aquatic, and the feeding habits are complex. Archaeopteryx family, analysis of living biogas, larvae aquatic. Adults are mostly plant-eating.

Anophelesidae and Asian anophelesidae are analyzed by living anopheles. The larvae are aquatic and are one of the main benthic organisms. They are herbivorous or saprophytic, and the adults are mostly herbivorous.

Based on the analysis of the existing Chironomidae, Chironomidae, Chironomididae, China, the larvae are one of the main benthic organisms. The organic debris on the bottom of the water plays an important role in the mineralization of organic matter. Larvae are also food for fish and play an important role in ecology. Adults rarely eat or consume sugary plant juices.

Pleurotus spp. Is an analysis of living mosquitoes, terrestrial larvae, edible fungi or plant rhizomes, adult phytophagous, individual species predator small insects.

The nymphaeidae, genus mosquitoidea, and protochaetacea are analyzed by the living mosquitoidae. The larvae feed on the plant roots and rotten plants. Adults are common around the flowers.

Anophelesidae, larval parasitic, adult predatory.

Pseudocercopidae, Long-beared Ranunculaceae, Fossilidae, analysis of the characteristics of pupae, larvae aquatic, predatory, adult blood-sucking or predation.

Polygonidae, larva aquatic, predatory.

The paleo Hydrocephalus and Muliaceae belong to the general family of Hydrocephalus. Based on the analysis of the live leeches and wood maggots, the larvae are predatory or phytophagous, and the adult predatory.

5.9 Hymenoptera
Hymenoptera found a total of 11 families of fossils, Apidae, Apisidae, Apisidae, Aphiidae, Apiceae, Bumblebee, Apisidae, Aphiidae Gastropodidae, Leaf bee family, Baisa bee family.

Hymenoptera, fully metamorphic insect, terrestrial. Divided into broad-crusted order and sub-crusted order, larvae of the broad-capped order are phytophagous. Hymenoptera is mostly predatory or parasitic, and is an important natural enemy and pollinating insect. Only a few are herbivorous, mainly flower and plant juice.

Melidae, larvae are fed by adults and are phytophagous and are important pollinators, hi pollen and nectar.
Long-tailed bee family, Myridae, Fly-winged bee family, Long-bellied bee family, Stem-bellied bee family, original gastroidae, larvae parasite, adult predatory. It mainly parasitizes other insects and arthropods.

Formicidae, larval parasites, adult predators. Larvae are mainly parasitic to other bees.

Bumblebee, larvae ectoparasite, adult predatory.

Leaf bee family, phytophagous, young shoots and leaves on plants, feeding on leaves.

Baisaeidae, fossil family, is classified as the mud bee family, presumably similar to the living mud bee family, predatory, larvae are captured by adult insects to feed other larvae.

5.10 Hairy order
A total of fossils have been found in Trichoptera of Trichoptera. Complete metamorphosis, larvae aquatic, narrow ecological tolerance, feeding on aquatic organisms and microorganisms, is the main food source of fish. Adults suck nectar and juice.

5.11 Arthropoda
There are two families of fossils in the arthropoda, grass family, Hemeroideae, and analysis of phagophagous traits by the living grass family.

Completely perverted, terrestrial. Most adults and larvae mainly prey on aphids, mites, tadpoles and lepidoptera, coleoptera eggs and larvae, while some adults feed on pollen and nectar. Classified as predatory.

5.12 Secretary
Viperidae, completely metamorphic, mainly living in mountainous areas, larvae live under conifer bark, prey on other insects, and adults are also predatory.

6. Preliminary Ecosystem Analysis

6.1 Insect food chain of the Shuinan Formation
The food chain is a process in which chemical energy stored in organic matter in the ecosystem is transmitted in the ecosystem. In layman's terms, various organisms are closely related to each other through a series of relationships between eating and being eaten. This sequence of organisms related to each other in terms of food nutrition is ecologically called the food chain.

Based on the analysis of the feeding habits of insects in each family, the food chain analysis is shown in Figure 2.

The insect food chain of the Shuinan Formation can be divided into 4 levels.

Green plants (producers)→phytophagous insects, saprophytic insects, omnivorous insects (primary consumers)→secondary predators→tertiary predators.

The food chain of aquatic insects is relatively clear, plant debris enters the water, and microorganisms multiply, forming a basic food source. Chironomapteria gregaria and C. vesca have a large number of individuals. They are the main primary consumers and the main suppliers of aquatic animal proteins. They feed on plant debris and microorganisms with rock mosquitoes and caterpillar larvae, occupying the position of primary consumers. Various carnivorous salamanders, such as Laiyang middle salamander Mesolygaeus laiyangensis and Shandong open-winged salamander Schizopteryx shandongensis feed on larvae of the Chironomapteria genus, occupying the position of second-rate consumers.

Cooptoclava longipoda has a distinctly large worm body, strong catching forefoot, and slushy middle and hind feet that can swim fast, and it is likely to feed on various magpies, especially Mesolygaeus laiyangensis. In modern lakes, large swimming-type predatory beetles are often pests of the fish farming industry, and they may prey on a variety of juveniles, which may feed on Chironomapteria larvae. Odonata may be the same as Cooptoclava longipoda, but the possibility of
predation is not ruled out. Long-legged cleft beetle and Odonata dominate the tertiary consumer of aquatic insects.

The food chain of terrestrial insects is long and complicated due to the presence of parasitic insects and carrion insects (cadaveric insects).

For example, there are predator relationships among junior predators, such as: Coleoptera, Protothecidae, Maruidae, Arthropoda, Amphidoptera→Bee Bee, Thin Bee, Bumblebee, Baisaidae→Antidae. These parasitic insects can be parasitic on plant-eating Coleoptera insects, and they are secondary consumers. If they are parasitic on predatory insects, they are tertiary consumers.

The existence of omnivorous and carrionic insects complicates the food chain. The predator's energy enters the omnivores and carrion after its excretion or death, and then flows upward through predation.

6.2 Analysis of paleoecological environment of the Shuinan Formation

From the above data, we can roughly restore the ecological environment of the Laiyang Basin in the Shuinan Formation.

At that time, the Laiyang Basin was a huge freshwater lake with a deep and calm water, and the finely divided and sorted Shuinan Formation strata were deposited. The bottom of the lake is deep and rich in organic matter, presenting a reducing environment, which is conducive to the preservation of insect fossils.

We can infer the terrain and climate at that time by combining the distribution of fossil origin, stratum outcropping and richness of insect fossils. The Laiyang Basin is a huge lake with mountains in the north of Qixia, and Jingshan Island is located in the center of the lake. The climate is warm and humid, with plants flourishing on land. Margins and wetlands are distributed on the edge of Laiyang Lake and the edge of the island, which prosper aquatic insects. Plants on land flourish, providing habitat and food sources for terrestrial insects. No lepidopteran insects were found, and angiosperms were absent or rare.

7. conclusion

(1) The Shuinan Formation in Laiyang Basin is rich in insects, and the species of terrestrial insects are significantly larger than that of aquatic insects, while the aquatic insect fossils are significantly richer than those of terrestrial insects, indicating that the Shuinan Formation of Laiyang Basin should be mainly a shallow lake sedimentary environment. Short-haul transportation and aquatic insects deposited in the lake, forming mixed buried fossil groups. (2) There are many types of terrestrial insects, indicating that terrestrial vegetation should be flourishing at that time, which can provide insects with habitat and food sources. (3) No lepidopteran insects were found in the fossils of the insects. It can be presumed that the angiosperms were absent or rare. (4) A complex food chain formed between the insects of the Shuinan Formation in the Laiyang Basin. We indicate that the ecosystem was stable at that time. And it is speculated that the ecological environment after the Shuinan Formation has changed significantly with no insect fossils were found above the Shuinan Formation. Combined that the stratum Volcanic rocks developed on Shuinan Formation, we presume that the changes of ecological environment in Shuinan Formation were affected by volcanic eruption.
Figure 2. Relationship between insect food chains in the Shuinan Formation (right side aquatic)

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