

(三) 山旺研究

SHANWANG RESEARCH

A Study on Miocene Shanwang Formation, Linqu, Shandong, China —with a Brief Review of Research History in This Locality

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Abstract At first, this paper gives a brief review of early research history in the study area, especially on the details of first discovery of this locality by C. C. Young. Secondly, the geological setting of the Xiejiahe basin is briefly discussed, and the Miocene stratigraphic sequences are described in detail. Thirdly, the sedimentary environments are analyzed and the status of paleoecological study is estimated, based on the analysis of different fossil assemblages, it is proved that the Xiejiahe basin was in a humid and warm climate during the Miocene period, associated with some volcanic activities. At last, a comparison among the Clarkia basin, Idaho, USA, Steinheim crater, Germany and study area (Shanwang) is made, the similarities and differences of three areas above are discussed in this paper.

Key words Shanwang formation, Miocene, Xiejiahe basin, Paleoecology

The Xiejiahe basin, with an area of about 1 km², is located about 22 km east to the Linqu County, Shandong Province, China (roughly within N36°33', E118°44'), where the famous Shanwang Formation is well developed. After the first geological work in 1935, C. C. Young named "Shanwang Series" in 1936, called it as "the book of ten thousand volumes" (Young, 1936b). From then on, C. C. Young, T. L. Tchang, Teilhard de Chardin, R. W. Chaney, H. H. Hu, B. V. Skvortzov, V. C. Juan did some researches on mammals, Angiosperms, fish, frog, tadpoles, diatoms and ores, etc^①. These studies founded a basis for accepting the Shanwang Formation as "the book of ten thousand volumes" with lots of beautiful fossils. Many results have been involved in a couple of college textbooks. This locality has become a typical Miocene section in China.

1 Research History

1.1 Ancient records

The first formal record of Shanwang's fossils could be back up to 1896, when the Local Chronicles of Linqu County wrote as: "there are special materials called Wanchuanshoe (the book of ten thousand volumes) in hillside, 2.5 km east of Linshan Hill, these materials are neither mud nor hard rocks, which are easy to get on surface; plane and clean, piled up like pieces of papers, if you split them apart, you could find many forms like insects, fish, beasts and flowers".

In 1935, the new edition for Local Chronicles of Linqu County (vol. 21, no. 22) recorded as follows: "The Yaoshan Hill is in the east of town, yielding poor coals. In the east hillside, there are minerals exposed by a stream side, they are neither mud nor rocks, plane and clean, laminated, there are many lifelike shapes, such as insects, fish, birds, beasts, hills and waters, flowers when splitting them apart. These minerals are easy to break when drying".

① Sun Q G, Li F L *et al.*, 2000. A bilingual bibliography of geological and paleontological studies of Shanwang Formation, Shandong Province, China (1936~2000), this volume pp 272~288

The formal description of Shanwang's fossils in scientific sense was firstly done by C. C. Young. He wrote an article entitled "Memory of Shandong Trip", which was published on the Nature supplement of World Daily on April 12, 1936 (Young, 1936b).

As recorded in that article, C. C. Young did his geological trip with Bie Meinian, around Sishui, Xintai, Shandong in Autumn, 1934. He happened to see some fish and plant fossils from Shanwang Fm at the storing room of Professor Scott, who was a head of Geological Department, Qilu University.

In the Spring of 1935, C. C. Young specially visited Scott for asking the details of the discovery of Shanwang's fossils when he had a short stay in Ji'nan, capital of Shandong. Scott told that these fossils were collected by Paul Bergen in 1909 from the Shanwang village, Xiejiahe, Linqu (Young and Tchang, 1936).

1.2 Discovery

After meeting with Scott, C. C. Young, accompanied by three geological technicians, went to Linqu to do field investigation. C. C. Young stayed in a villager's house in Shanwang Village, which was very near to the fossil location. He and his colleagues found many fossils from exposed shales. In March 1936, C. C. Young finished a geological report for this investigation, and he submitted his paper on fossil frogs and fish to the Bulletin of the Geological Society of China, which was published in June of the same year. In this paper, C. C. Young first set up "Shanwang Series" for the fossil-yielding strata, and he called it as "Wanchuanshoe", it means the book of ten thousand volumes.

Since then, the Shanwang Series attracted much attention among academic circle. Lots of work were carried out by different researchers, such as the investigation on diatomite ores by V. C. Juan in 1936, fossil collection by C. C. Young and R. W. Chaney in 1937, study on diatoms by B. V. Skvortzov in 1937, fossil deers by Teilhard de Chardin in 1938, flora by H. H. Hu and R. W. Chaney in 1940, etc. But almost all of studies had to give up due to the breakthrough of Anti-Japanese War (Yang *et al.*, 1991; Juan, 1937; Young, 1937; Teilhard de Chardin, 1939; Hu and Chaney, 1940).

1.3 From 1950 to 1970s

After the foundation of P. R. China in 1949, the geological study was widely carried out for meeting the needs of resources. In the early of 1950s, some mineral and ore investigations were made for different purposes. The basic geological map was drawn during this period. In the late 1950s, some paleontological and stratigraphical work was done on spore-pollen and mammals. After then, during the periods of geological mapping by Beijing College of Geology in 1958 and diatomite mining, many excellent fossils, such as salamanders, toads, chelonia, bats, mices with furs, insects, huge mammals and birds, etc., were discovered (Sun, 1961; Zhang, 1963).

1.4 Establishment of fossil conservation region

In 1978, an academic symposium on paleontology was held in Linqu, Shandong. Many paleontologists proposed a suggestion for protecting the beautiful and precious fossils in this site. After

then, a formal proposal for establishment of state-level fossil conservation of Shanwang Fossil location was submitted to the State Council by Shandong province, it was approved by the State Council in 1980, so the Shanwang fossil location becomes the first state-level fossil conservation region in China. Since then, extensive studies on Shanwang's fossils have been carried out and many results have been obtained not only on paleontology, but also on paleomagnetism, age dating, volcanics, etc.

1.5 1990s

It is a new step for the study of Shanwang Fm, the multi-disciplinary researches, such as paleoclimate, paleoecology, paleohydrology, taphonomy and paleoenvironment, are paid much attention. In this period, many achievements have been obtained in the study on the ancient vegetation of this area, as well as insect study. Anyway, as a famous fossil resource, there is still much work for us to do in future.

2 Geological setting

2.1 Outline

Tectonically, the Xiejiahe basin of Linqu is located at the east margin of Luxi Platform Anticline, adjacent to the west boundary fault of Tan-Lu Fault, the Luxi Platform Anticline is at the southeastern part of Huabei Platform.

On the crystallized basement of Luxi Platform Anticline, there are Paleozoic cap rocks, but lack of the deposits from the Upper Ordovician to Middle Carboniferous. A series of fault basins at different scales were formed in the Mesozoic and Cenozoic, which were resulted from the activities of local uplifting movement and the Tan-Lu Fault.

The Jurassic coal-measures of Fangzi Fm were deposited in the northeastern part of Xiejiahe basin, which are not exposed on surface. The Lower Cretaceous Qingshan Fm, composed of volcanic agglomerates, breccia and tuffs, is exposed about 20 km southwest to the Xiejiahe basin. The Upper Cretaceous Wangshi Fm, dominated by sandstones, shales and conglomerates, is revealed in the Niushan, about 16 km southwest to the Xiejiahe basin.

The Paleogene Wutu Fm is the coal-bearing clastic rocks, which are exposed in Wutu area, 20 km northeast to the Xiejiahe basin, this Fm yields some vertebrate fossils, belonging to a new Eocene fauna.

Miocene Niushan Fm consists of basalts, glutenite and conglomerate, exposed mainly around the Niushan area (Bureau of Geology and Mineral Resources of Shandong Province, 1991; Tong and Wang, 1993; Young, 1961; Chow and Li, 1963; Cheng, 1961; Yeh, 1962).

2.2 Shanwang Fm in Xiejiahe basin (Fig. 1)

In the past decades, there were many disputes about the Shanwang Fm. Based on the volcanic-sedimentary cycles, it should be subdivided into Niushan, Shanwang and Yaoshan Fms from the bottom to top. Here we give a recent new stratigraphic system based on our own study.

Quaternary, Holocene, outwash and flood plain deposits

Pleistocene: Loess, prismatical joints developed, with glutenite lenses and calcareous nodules, 20 m in thickness, yielding *Camelus* sp. and other freshwater mollusks.

-----Disconformity-----

Yaoshan Fm (Upper Miocene or Pliocene)

β_3^2 Slab joint-developed brown and brownish black thick-bedded alkaline olivine diabases

100 m

N_{g2}^2 Red-purple eruptive brecciated ignimbrite

20 m

β_3^1 Steel-gray alkaline dorgalite with brownish yellow blowhole basalt, with buchnerite inclusions and megacrysts of pyroxene and anorthoclase. 20 ~ 60 m

N_{g2}^1 Grayish yellow-brown basaltic pyroclastic rocks, loosely constructed, well laminated, mainly basaltic pyroclastic and tuffaceous cements, strongly carbonatized 30 ~ 50 m

Shanwang Fm (Middle Miocene)

β_2^8 Steel-gray, massive dense basalt, with olivine phanocrysts and xenocrysts. 3 ~ 11 m

N_{g1}^4 Grayish green, yellowish brown mudstone, shale and calcareous shale, locally with poor coals, yielding vertebrate fossils 2 ~ 20 m

-----Disconformity? -----

β_2^7 Purplish gray blowhole olivine massive basalt, with olivine phanocrysts and xenocrysts, as well as megacrysts of anorthoclase 7 ~ 17 m

N_{g1}^3 Brownish yellow, grayish green mudstone and shale, occasionally with thin-bedded siltstone, yielding animal fossils 10 ~ 25 m

N_{g1}^2 Upper part: Grayish black shale, with phosphorus nodules and two layers of silty mudstone yielding diatoms; middle part: Grayish white, green and brown diatomaceous earth with phosphorus nodules, lamellar beddings developed, micro-beddings clear, with diatomaceous shale; lower part: blackish brown, grayish green clayed shale and grayish white and yellow mudstone, with a few of blackish brown oily shale. Most animal and plant fossils are yielded in this bed. 7 ~ 27 m

N_{g1}^1 Grayish yellow, green and brown basaltic breccia, agglomerate and pyroclastic rocks, loosely constructed, pebble size mixed, bedding unclear 15 ~ 25 m

-----Disconformity-----

“Niushan Fm” (Lower or Middle Miocene), about 180 m thick

β_2^6 Blue brick-colored, snow-flowered basalt, prismatical joints developed, a red weathering crust on the top

β_2^5 Dark gray basalt, tubular blowholes and prismatical joints developed

N_{n2} Grayish brown-brownish yellow tuff-dominated deposited pyroclastic rocks, horizontal beddings developed, strongly carbonatized, with carbonate cemented siltstone lumps

β_2^4 Grayish green basalt, tubular blowholes and prismatical joints developed

N_{n1} Grayish white, yellowish green arkose or conglomerate, with clasts of vertebrate fossils

β_2^2 Dark gray laminated basalt, with mega-crysts of anorthoclase, pyroxene and olivine, as well as greywacke xenoliths, prismatical joints developed, with a red weathering crust on the top

β_2^1 Grayish green massive basalt, interbedded with yellowish green mudstone, prismatical joints developed, with several weathering crusts

β_2^1 Grayish black dorgalite, with brownish gray and gray conglomerate at its bottom, most of pebbles are granite-gneiss

-----Disconformity-----

Underlying Strata: **Taishan Group** (Archeozoic) Granite-gneiss

This stratigraphic column is of some new discoveries compared with previous work (Li, 1991).

Based on many-year field work, the lower basalt (β_2) was totally erupted during the Miocene, its absolute dating is between 18 Ma to 35 Ma. After the end of basalt eruption, the basalt platform underwent a long-term erosion, on which the normal fluvial deposits were formed, i. e., the arkose in "Niushan Fm", which are widely distributed in the Shanwang area. In general, the lithology of this Fm is fining up, sometimes with red clays at its top. In the northwestern area, some poor-preserved huge mammal tooth fossil (possibly belonging to rhinoceros) was discovered in this Fm, the tuffaceous sandstone in this Fm is only exposed in the northeastern hillfoot of Linshan Hill. These deposits were wrongly considered as the Paleogene Guanzhuang Fm in the past.

By now, we still don't know whether the "Niushan Fm" here is equal to the original Niushan Fm in Niushan area, in order to solve this problem, it needs to date the ages of basalts above and below the two "Niushan Fms".

3 Sedimentary environment of Shanwang Fm and paleoecology of Shanwang biota

3.1 Sedimentary environment of Shanwang Fm

The discovery of volcanic agglomerate at the bottom of Shanwang Fm gives evidence that the Xiejiahe basin was an ancient volcanic crater, formed by the Iceland-type volcanos on the basalt platform, because the viscosity of lavas was lower, the volcanic cone high above the surface were not formed in common cases. Since the Xiejiahe crater was just located in the depressed zone of the basalt platform, a maar with a roughly equal elevation of surface was formed due to water catchment of stream runoffs. This maar was semi-enclosed sometimes, so it could maintain a long-term water body within only 1 km² for a large amount of diatoms and fishes, even the lake was located within the subtropic zone at that time. A series of small-scale volcanic activities, indicated by volcanic basaltic chips and bombs in sediments or rumpled structures of diatomaceous earth layers, were taken place in the late Shanwang period. At the final stage, this maar was a marsh environment, the peats were formed in the center of the lake (Yang *et al.*, 1991).

Table 1 Paleoclimate indicated by different floras and faunas in Xiejiahe basin

| Fossil assemblages | Main representatives | Geographic distribution | Paleoclimate |
|--------------------|--|---|--|
| Spore-pollen | <i>Ulmus</i> > 25%, <i>Betula</i> 10%, Pinaceae 23% | Euroasian continent to the north Yangtze River | Joint area between temperate and subtropic zone |
| | <i>Carya</i> 7.4% | Subtropic, Zhejiang, etc | |
| Floras | Dominated by: Betalaceae, Rosaceae, Ulmaceae, Tiliaceae, Salicaceae | Temperate, high-elevated area in subtropic zone | Subtropic zone, evergreen broadleaves, deciduous and mixed forests |
| | Secondary by: <i>Fagus</i> , <i>Liqui-</i> <i>dambar</i> , <i>Hamamelis</i> , <i>Cymno-</i> <i>cladus</i> | Modern corresponding species on- ly in south China | |
| | <i>Cinnamomum</i> | Tropic, subtropic zones in Asian, Oceania | |
| | <i>Ficus</i> | Tropic, subtropic zones | |
| | <i>Sapindus</i> | Yangtze river valley | |
| Insects | <i>Aphana</i> , <i>Mesopeplus</i> , <i>Agrothe-</i> <i>reutes</i> , <i>Yezoceryx</i> , <i>Tiphia</i> , <i>My-</i> <i>oponone</i> , <i>Oecophylla</i> , <i>Plectia</i> , 63% | Similar to modern Oriental region | Subtropic zone |
| | 5% of palaeartic, 32% of mixed and cosmopolitan species | | |
| | <i>Tumecolium humiquise</i> | Related to dense plants | |
| | Kalotermitidae, Blattaria | Humid environments | |
| Diatoms | Dominated by: <i>Melosira islandi-</i> <i>ca</i> , <i>M. distans</i> , <i>M. undulata</i> , <i>Fragilaria virescens</i> , <i>Navicula</i> <i>bacillum</i> , <i>N. plocentula</i> | Cooler water body in north area | Cooler water body |
| | <i>Fragilaria constyuens</i> , <i>F. c.</i> var. <i>venter</i> , <i>F. c.</i> var. <i>trium-</i> <i>dulta</i> , <i>F. pinnata</i> , <i>Achnanthes</i> <i>lanceolata</i> , <i>Stauroneis anceps</i> , <i>S. phoenicentron</i> | Eurythermic water body | |
| | <i>Eunotia bigibba</i> , <i>E. clevei</i> , <i>Navicula amphibala</i> | Puna area | |
| Mammalia | <i>Lagomeryx</i> , <i>Meinia</i> , <i>Plesiacerat-</i> <i>therium</i> and other 20 speices | Marsh area near to forest | Humid subtropic, warm temperate |
| Reptilia | <i>Alligator lucus</i> | Lower reach of Yangtze | Subtropic zone |
| Amphibia | <i>Buffo linguensis</i> , <i>Macropelobates</i> <i>cratus</i> | Southwest area in China | Humid and hot |

3.2 Paleocology of Shanwang biota

The actual taphonomic study has not been widely carried out because most of studied specimens were collected from mining. As we roughly know that the fish fossils are distributed in different horizons and localities, they also are of different types. As for the fossil birds, most of them are preserved in central lake deposits. It is told that some fossil insects still keep their original colors when you reveal them in rocks, but they would be oxidized soon when they expose in air for a little while.

Table 2 Comparison among Xiejiahe basin, China, Clarkia basin, USA and Steinheim, Germany

| Areas | | Clarkia basin, Idaho, USA | Xiejiahe basin, Linqu, China | Steinheim Crater, Germany |
|-----------------------|--------------------------|---|---|--|
| Geography | Type | Broad lake blocked by basalt lavas | Maar formed in depressed area on basalt platform | Impact crater in Jurassic strata |
| | Area | 70 km ² , connected with outside | 1 ~ 2 km ² , connected or disconnected with outside | 5 km ² , isolated from outside water systems |
| | Site | Dense forests and high mountains surrounded | Forest edge or marsh area | Warm and humid environment |
| Depositional features | Thickness | > 100 m | 46 ~ 81 m | > 100 m |
| | Basin edge deposits | Coarse sandstone | Huge-pebble conglomerate, glu-tenite, volcanic agglomerate | Clastic rocks |
| | | | Dominated by massive clastics | |
| | Varves | Extremely well | Excellent | Quite good |
| | Beddings in volcanic ash | 1 ~ 2 mm to 50 ~ 60 cm | | |
| | Horizontal beddings | Stable, extending 100 ~ 200 m | Stable, extending several ten meters | Stable and developed |
| | Other rocks | Mudstone and silty mudstone | Mudstone, shale, silty mudstone, marl | Mudstone, shale |
| Fossil Assemblages | Spore-pollen | Spore-pollen | Spore-pollen | Spore-pollen |
| | Algae | Diatoms, Chrysophyta | Diatoms, Chrysophyta | Diatoms, Ca-alges |
| | Foraminifer | Foraminifer | -- | ? |
| | Sponges | Sponges | Occasionally found | ? |
| | Arthropod | Insects | Insects, ostracods | Insects, ostracods |
| | Fr molluscs | Fr molluscs | | Abundant <i>Planorbis</i> |
| | Trace fossil | -- | Occasionally seen | |
| | Plants | Abundant | Abundant | Abundant |
| | Fish | 3 species 3 in genus | 11 species in 8 genus | 2 species in 1 genus |
| | Other vertebrates | -- | Ammphibia, reptiles, birds (4 species in 4 genus) and mammalia (> 20 species) | Ammphibia, reptiles, birds (15 species) and mammals (> 50 species) |
| Paleotemperature | 15 °C | 13.30 ~ 21 °C | ? | |
| Average annual T | 25 ~ 30 °C | 11.5 °C | ? | |
| Paleoclimate | Warm, humid | Warm, humid | Humid, warm | |

The dark diatomaceous earth layers are commonly alternated with light ones, all them are dominated by planktonic *Melosira islandica* and *M. youngi*. The diatoms in dark ones are short cylindrical, but they are long cylindrical in light ones, by the way, the shell wall thickness and bore numbers of the diatoms are different between in dark and light ones. The water temperature of dark layers is dated as 21 °C by oxygen isotope method, only 14.4 °C for the light ones. It is supposed that the dark diatomaceous layers were formed in Summers and Autumns, when there were sufficient organic matters in lake; and the light ones were formed in Winters and Springs, with lower temperature and organic supply. By the way, the spore-pollen could also provide extra evidence for it, for instance, the percentage of pollens of *Quercus* sp., which were blooming in Summer is higher in dark layers than in light ones, in contrary, the percentage of pollens of *Ulmus* sp., which was

blooming in Spring, is higher in light layers than in dark ones.

Different floras and faunas indicate a same paleoclimatic result for the Xiejiahe basin (Table 1).

In addition, a trace fossil specimen was collected in 1986, which was named as *Shanwangichnus* (Yang Shipu, 1996). Trace fossils could tell us much about the benthic animals and their environments, it needs to do much on it. The fish fossils are dominated by Cyprinidae, most of them were lived near the lake bottom, they fed on diatoms and insects, only one genus in Serranidae of Perciformes was found as the carnivorous fish, it had little influence to other fish because its length is only 11 cm (fish with a length more than 25 cm would be harmful for other fish). According to fish assemblage, it is roughly similar to the environment of modern Yangtze river valley, and the Danioninae is only living in Burma, Thailand and Yunnan of China (Zhou, 1990, 1992; Chen *et al.*, 1999). For ammphiba, there were toads and Pelobatidae which were suitable to terrestrial environments, in addition, there were Rhacophoridae and Hylidae which were fit to live in forests, In general, the ammphibian composition represents a damp and hot, hilly forest environment with streams developed, the characteristics of salamanders, frogs and tadpoles indicate a quiet water environment. For birds, besides Galliformes, there were Anseriforme Natatores represented by Anatidae and Gruiforme wading birds represented by *Youngornis gracilis* (Yeh, 1977, 1980, 1981; Yeh and Sun, 1984). The mammals reflect a damp and hot forest and lake-side marsh, which is similar to that in Steinheim in Germany but different from the Clarkia basin in the USA. One of characteristics of Shanwang's fossil assemblages is lack of invertebrate animals. In Shanwang Fm, only a very few of Ostracods are discovered (Zhen, 1986).

After all, the deposits of Shanwang Fm and its fossil assemblages need to be further studied in future, especially on the relationship between organisms and their environments.

4 Comparison

According to our data, the deposits in the Xiejiahe basin, Shanwang, Shandong, China are some similar to the Miocene deposits in Clarkia basin, Idaho, USA and in Steinheim, Germany, but they have their own characters (Table 2).

From the comparison above, we can find that the Xiejiahe basin is characterized by small area, easy connection with outside, densely surrounding forests, humid and warm climate. The water body in the basin could be connected or disconnected sometimes with other systems. During the deposition period of Shanwang Fm, there were volcanic activities. Because of a small lake area, wave action was not too strong, the huge mammal remains were not easy to be destroyed. But for the preservation of fossil fishes, the situation is different, the poor preservation of larger fishes is common, however, the most of small-body fishes are preserved extremely well. We still do not know why. After all, there are much work to be done on the fossils and their once-living environments in the Xiejiahe basin.

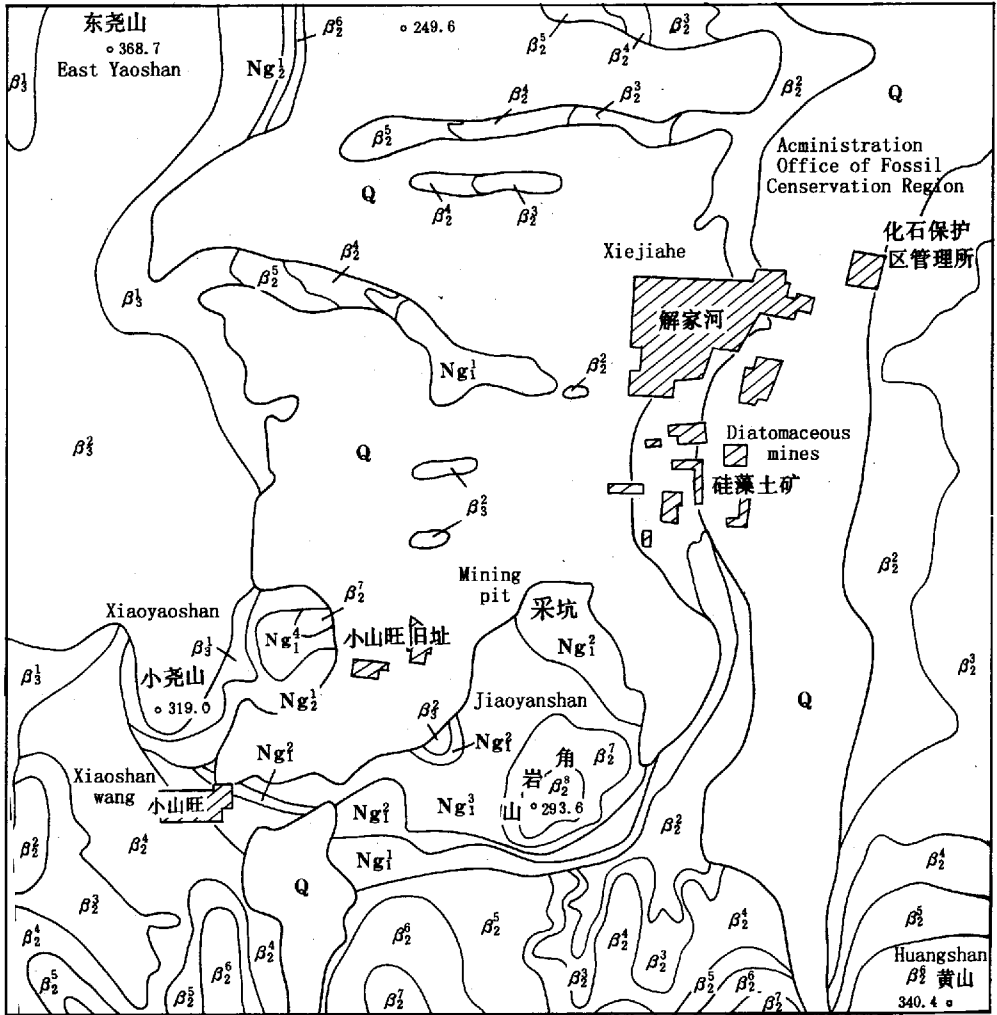


Fig.1 Geological Map of Study Area

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