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腾格里沙漠晚更新世湖相沉积介形类及其环境意义

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提　　要

腾格里沙漠晚更新世断头梁剖面分析出介形类7属7种, 分别为 *Limnocythere inopinata*, *Darwinula stevensoni*, *Candona neglecta*, *Cyprideis torosa*, *Ilyocypris gibba*, *Cyclocypris serena*, ?*Neocypridopsis* sp., 其中 *Limnocythere inopinata* 和 *Darwinula stevensoni* 为优势种。根据丰度、分异度及百分含量变化情况, 研究剖面划分出四个介形类组合, 进一步结合年代数据、沉积物及孢粉资料识别出四个气候期。距今约42 000-23 000年间研究区总的气候特征是温暖湿润, 间有几次幅度较小的变冷期; 介形类显示出淡水至中盐水环境, 这一特征持续整个沉积时期, 没有出现干旱期。

关键词　介形类　环境意义　晚更新世　腾格里沙漠

LATE PLEISTOCENE LIMNIC OSTRACODS AND THEIR ENVIRONMENTAL SIGNIFICANCE IN THE TENGGER DESERT, NORTHWEST CHINA*

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Key words　Ostracods, environmental significance, Late Pleistocene, Tengger Desert

Seven ostracod species, namely *Limnocythere inopinata*, *Darwinula stevensoni*, *Candona neglecta*, *Cyprideis torosa*, *Ilyocypris gibba*, *Cyclocypris serena* and ?*Neocypridopsis* sp., have been i-

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dentified from Duantouliang section in the Tengger Desert, Northwest China. *Limnocythere inopinata* and *Darwinula stevensoni* are the dominant species. Four ostracod assemblages have been identified in the light of ostracod abundance, diversity and percentage. Based upon ostracod ecology, chronological data, depositional features and associated pollen, four main environmental stages are observed for the time interval 42 000- 23 000 a B. P., representing a period of generally warm and humid climate, interrupted by several phases of slightly declining temprature. The ostracod fauna indicates fresh-mesohaline environment, which apparently persisted over the entire sedimentation period without any desiccation phases.

Introduction

The Tengger Desert situated in Northwest China, covering an area of 36 700km^2, is the fourth largest desert in China, with more than 400 lakes, large or small, residing in the desert (Zhang *et al.*, 1983). These lakes, which have reacted sensitively to rainfall changes triggered by East Asian monsoons and westerly-induced cyclones, are the terminal sites of endorheic drainage systems of northwestern China. In order to analyze paleoenvironmental changes, this report presents results on late Pleistocene limnic ostracods from Duantouliang section, situated in the northwestern part of the Tengger Desert.

The Tengger Desert extends from western Inner Mongolia to northwestern Gansu province. The desert is bounded on the south by the Qilian Mountains, on the west by the Yabulai Mountain, on the east by the Helan Mountain. Elevations in most part of the area are about 1 000- 1 500m. The dry denuded low mountains and hills of Precambrian and Paleozoic metamorphic and crystalline rocks, with altitudes from 100m to 250m, break up the area into many large or small endorheic basins. The desert are mainly composed of active or semi-active dunes. There are a lot of lakes in it. The Shiyang River, which rises in the Qilian Mountains, with elevation of 4 900m, flows into the desert and becomes the main source of the drainage system of the area. The mean annual temperature and precipitation of the area are > 10℃ and 50- 100mm respectively, and the rainfall is concentrated from July to September. The strong wind has blown throughout the year, and the strong wind and more sand have formed the climatic features of the area. The vegetation, consisting of grass and shrubs, is mainly concentrated in basins, plains, and between dunes where the groundwater level is at the surface. As rare rainfall in spring and rare snowfall in winter, spring rain type, short-day plants are almost completely laking, while summer rain type, annum growth desert herb is comparatively lush in the flora of the area (Ma *et al.*, in press).

Description of Duantouliang Section

Duantouliang section (39°40′N, 103°55′E), with the altitude about 1 266m, is situated in the northwestern Tengger Desert, also in the alluvial basins in front of the Yabulai mountain, and at the end of the western tributary of the Shiyang River. The section is described as follows in order of down to up (Ma *et al.*, in press):

① 370- 353cm reddish-brown, brown-yellow gravel.

② 353- 220cm light brown-yellow, greyish-white clay intercalated with brown silty clay, rich in carbonates.
320- 315cm, ^{14}C age 38 650±170a B. P.
320- 310cm, IRSL age 38 000±100a B. P.
275- 270cm, ^{14}C age 35 020±810a B. P.

③ 220- 135cm clay in interdigitation with silty clay, rich in carbonates. Abundant mollusc fossils beared in silty clay.
155- 150cm, ^{14}C age 26 749±164a B. P.

④ 135- 69cm gravel bearing a small amount of carbonates and rich mollusc fossils.

⑤ 69- 25cm variegated muddy silt with well bedding.

⑥ 25- 0cm reddish-brown gravel bearing rich mollusc fossils.

Ostracod Assemblages

Seven ostracod species, namely *Limnocythere inopinata*, *Darwinula stevensoni*, *Candona neglecta*, *Cyprideis torosa*, *Ilyocypris gibba*, *Cyclocypris serena*, and ? *Neocypridopsis* sp., have been identified from 20 samples of Duantouliang section. It is clear that the fauna diversity is low. *Limnocythere inopinata* and *Darwinula stevensoni* predominate in the assemblages. Ostracods of the section can be divided into four assemblages based upon species abundance and diversity (Fig. 1, Fig. 2) as follows:

Assemblage 1 (370- 320cm)

There are four species, namely *Limnocythere inopinata* (0- 81%, percentage in one sample), *Candona neglecta* (0- 9%), *Cyprideis torosa* (0- 5%), ? *Neocypridopsis* sp. (0- 5%), in the assemblage. The species abundance is rather low, and the amount of *Limnocythere inopinata* which predominates in the assemblage is only 35 valves/10g. No one ostracoda has been found in sample 1 (370- 360cm depth).

Assemblage 2 (320- 220cm)

Darwinula stevensoni first occurs in the assemblage, while the content of this species is low. Still the assemblage is predominated by *Limnocythere inopinata* as in assemblage 1. Four species, namely *Limnocythere inopinata* (82- 99%), *Darwinula stevensoni* (1- 12%), *Candona neglecta* (0- 7%), *Cyprideis torosa* (0- 2%) have been identified.

Assemblage 3 (220- 198cm)

The percentage of *Darwinula stevensoni*, ranging from 32% to 43%, distinctly increases in the assemblage, while the percentage of *Limnocythere inopinata*, ranging from 54% to 63%, decreases. Species composition is the same as in assemblage 2, and the other two species are respectively *Candona neglecta* (3- 5%) and *Cyprideis torosa* (0- 2%).

Assemblage 4 (198- 60cm)

Ilyocypris gibba and *Cyclocypris serena* first occur in the assemblage. Six species, namely

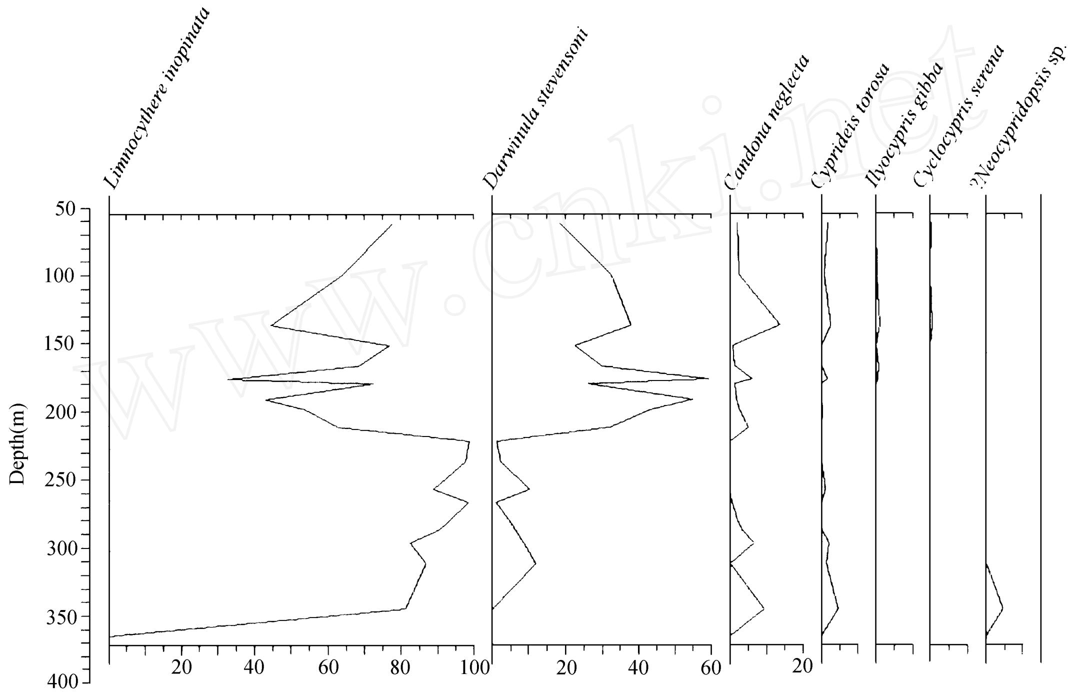

Fig. 1 Ostracoda percentage diagram of Duantouliang Section

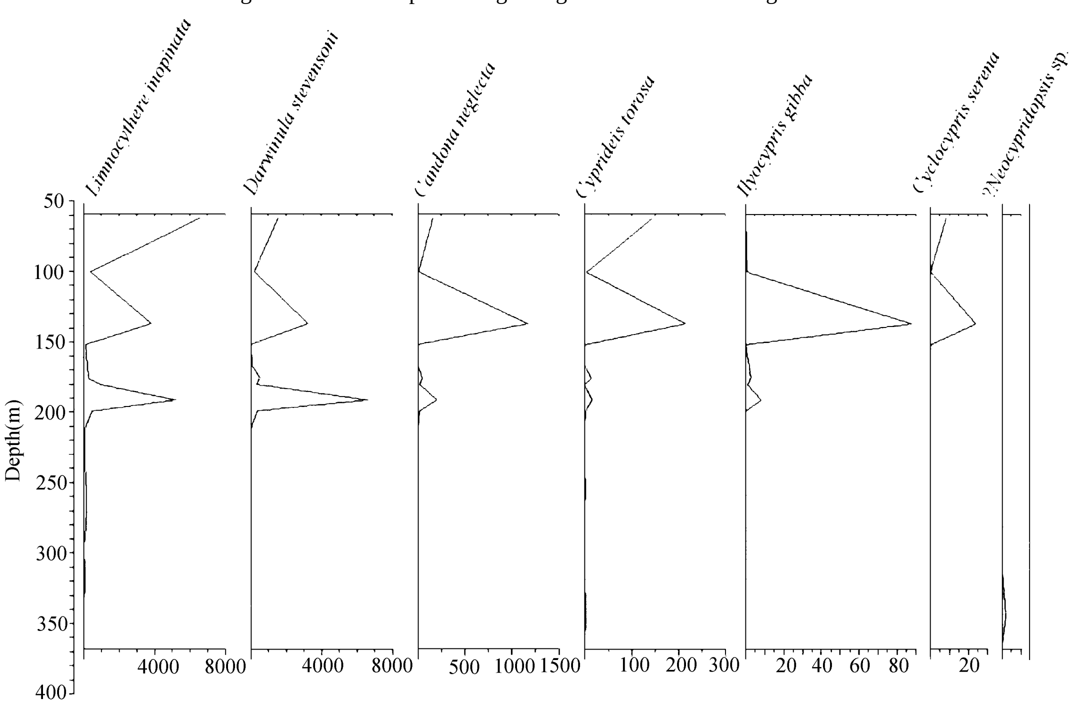

Fig. 2 Ostracoda abundance diagram of Duantouliang Section

Limnocythere inopinata (33-77%), *Darwinula stevensoni* (19-59%), *Candona neglecta* (1-14%), *Cyprideis torosa* (0-3%), *Ilyocypris gibba* (0-1%), *Cyclocypris serena* (0-0.3%) have been identified. Two subassemblages are identified in the assemblage as follows:

Subassemblage 4a (198-174cm)

Three samples have been analyzed, while the percentage of *Darwinula stevensoni* is over 50% in two samples. There are five species in the subassemblage, respectively *Limnocythere inopinata* (33-72%), *Darwinula stevensoni* (26-59%), *Candona neglecta* (1-6%), *Ilyocypris gibba* (0.07-0.3%), *Cyprideis torosa* (0.07-2%).

Subassemblage 4b (174-60cm)

In comparison with subassemblage 4a, the mean percentage of *Darwinula stevensoni* decreases. *Cyclocypris serena* first occurs in the subassemblage. There are six species, respectively *Limnocythere inopinata* (45-77%), *Darwinula stevensoni* (19-38%), *Candona neglecta* (1-14%), *Cyprideis torosa* (0-3%), *Ilyocypris gibba* (0-1%), *Cyclocypris serena* (0-0.3%), in the subassemblage.

Paleoenvironmental Analysis

Ostracods are important microfauna in limnic environment. Plentiful paleoenvironmental information can be gained from their species composition, quantity, structural features and chemical composition. They can be used as good indicators of temperature and salinity.

Ostracods from Duantouliang Section in Tengger Desert are predominated by *Limnocythere inopinata* and *Darwinula stevensoni*. In the lakes of Qaidam Basin, northwestern China, majority of living species of *Limnocythere* dwell on muddy substrates and fossil species of Tertiary are often found in the strata rich in carbonates, and they thrive best in oligo-mesohaline water (Exploration and Development Research Institute *et al.*, 1988). *Limnocythere inopinata* is the dominant species in modern Qinghai Lake in northwestern Tibet, where the salinity ranges from 12% to 13% (Huang, 1984a). In the Eifel highlands between Trier and Bonn (Germany), living *Limnocythere inopinata* occurs in mesotrophic-eutrophic lakes Holzmaar and Schalkenmehrener Marr (Scharf, 1993). The species of *Darwinula* are commonly considered as one kind of ostracods most often found in fresh water (Exploration and Development Research Institute *et al.*, 1988). Occasionally they are also encountered in oligo-mesohaline water (Van Morkhoven, 1963). Tertiary *Darwinula* species from Qaidam Basin are mainly yielded in comparatively low salinity strata, and no one has been found yet in comparatively high salinity, dull colour mudstone strata (Exploration and Development Research Institute *et al.*, 1988). Huang (1984b) described *Darwinula stevensoni* yielded in fine sand of Pliocene Qugou formation in Gonghe Basin, Qinghai province of China. Living *Darwinula stevensoni* has been identified in puddles around Qinghai Lake, while the abundance is rather low (Huang, 1984a). Sars (1928) described this species moved slowly on muddy substrate 2 fathoms deep under water surface at Vensjo in Moss of Norway.

Some other species of the study section, such as *Candona neglecta*, *Cyprideis torosa*, also provide some environmental information. Living species belong to *Candona* mainly live in various fresh water, and some species are encountered in oligo-mesohaline water (Van Morkhoven, 1963). In Qaidam Basin, living *Candona* species are comparatively wide in distribution and rich in quantity in fresh-oligohaline water, no living *Candona* species has been found yet in the water with salinity over 2%, and *Candona neglecta* is the dominant species in the common species of the area (Exploration and Development Research Institute *et al.*, 1988). Living *Candona neglecta* thrives best in the clear and cool freshwater or alkaline lakes with water temperatures 5 ℃- 8 ℃ and luxuriant flora (Li *et al.*, 1991). In lake Mondsee, Austria, *Candona neglecta* is an ubiquitous species living in all types of habitats, from astatic to deep lake and from saline to freshwater (Danielopol *et al.*, 1993). *Cyprideis* is a common worldwide genus since Miocene and prefers to live under salinity comparatively high. It is also an euryhaline and eurythermic genus, such as, the tubercles not developed form of *Cyprideis torosa* are adapted to temperatures of 0 ℃- 30 ℃ and salinities of oligohaline- 120g/l (Exploration and Development Research Institute *et al.*, 1988). *Cyprideis torosa* can live in the 0- 30m depth water (Exploration and Development Research Institute *et al.*, 1988). In China, living *Cyprideis torosa* only distribute in western Qinghai and Xinjiang provinces where sulphate or chloride predominates in chemical composition of water, while it is lack in eastern China where the water chemical composition is predominated by carbonates (Zhao, 1993). The tubercles not developed form of *Cyprideis torosa*, mainly living in river or pond around lake, is the only species of *Cyprideis* found in Recent water of Qaidam Basin, and the percentages in assemblages range from 0.2% to 5.3% (Exploration and Development Research Institute *et al.*, 1988). *Ilyocypris* is commonly found in various fresh water and a few species, such as *Ilyocypris gibba* in oligohaline water. The genus prefers to live under temperature of 10.5 ℃- 20 ℃. Although *Ilyocypris* often scatters in ponds or swamps, it tends to be used as an indicator of fluid water bearing hydrobio and algae. Living *Ilyocypris gibba* has been observed from Qaidam Basin, while the abundance is rather low (Exploration and Development Research Institute *et al.*, 1988). It has been recorded that *Ilyocypris gibba* live mainly in persistent or temporary fluid water with plants and algae in it and water temperature ranges from 4 ℃ to 19.5 ℃ (Li *et al.*, 1991, 1994). The results on ostracods from surface deposits of fifteen recent lakes in Tibet indicate that *Ilyocypris gibba* only appears in lake Yangzhuoyong Co, and the main environmental elements are water temperature 15 ℃ (in August), pH 9.18, salinity 1.781g/l, greyish yellow substrata respectively (Huang *et al.*, 1985, Yang *et al.*, 1982).

Zhao (1993) presents the results on the salinities of 48 living species on the Northern Hemisphere, in which the salinity of *Limnocythere inopinata* is 0.5- 10.69- 25?‰, *Darwinula stevensoni* < 0.5- 15‰, *Candona neglecta* 0.5- 15.7‰, *Cyprideis torosa* 0.4- 150‰, *Cyclocypris serena* 0.714‰.

Based upon ostracod ecological materials above, consulting chronological data, deposits and pollen, it is inferred that four main environmental stages are indicated as follows:

Stage 1 (42 000- 38 000 a B. P.)

The deposits consist of two parts, the lower part gravel and the upper part silty clay. Texture and structure indicate that it is lake sand with local pebble input (Pachur *et al.*, 1995). Ostracods are found in silty clay. The abundance of ostracoda is low and *Limnocythere inopinata* predominates. Ostracoda indicates oligo-mesohaline lake. It is remarkable that the valves of *Limnocythere inopinata* are all female. Recent studies in Europe have shown that this species reproduces only parthenogenetically and is an indicator of summer water temperatures > 8.6℃ (Pachur *et al.*, 1995). It may be inferred that the climatic condition of this period is temperate; this coincides the evidence presented from pollen (Ma *et al.*, in press). Pollen also provide the evidence of moist condition.

Stage 2 (38 000- 31 000 a B. P.)

The occurrence of the common freshwater species *Darwinula stevensoni* reflects that the area of the lake is larger than in stage 1, corresponding to the results inferred from pollen (Ma *et al.*, in press); this may be set off by increased surface runoff caused by decreased evaporation, and pollen indicates moist climatic condition. Still ostracods are dominated by *Limnocythere inopinata*, ostracod assemblage indicates oligohaline-mesohaline water environment. The deposit, being characteristic of rich carbonates, interdigitating with silty sand, is largely lacustrine sediment with dominant local input (Pachur *et al.*, 1995).

During 36 000- 34 000a B. P., the abundance of ostracods is comparatively high and the male *Limnocythere inopinata* occurs; this may be caused by rich cabonates as a result of increased salinity.

Stage 3 (31 000- 30 000a B. P.)

The percentage of *Darwinula stevensoni* in assemblages increases and the content of this species is only second to *Limnocythere inopinata*. And *Darwinula stevensoni* predominates as well as *Limnocythere inopinata*. It is inferred that the lake is larger than that in stage 2. At the same time, ostracod carapaces become large, it seems to imply decreased temperature. Pollen presents evidence of wet and cooling and temperate climatic condition (Ma *et al.*, in press).

Stage 4 (30 000- 23 000a B. P.)

The occurrence of tubercles-bearing *Ilyocypris gibba* seems to indicate comparatively temperate climatic conditions and less salinity water body, while the content of the species is rather low. The lake water may be oligohaline. Stage 4 is established in two steps:

Stage 4a (30 000- 28 000 a B. P.)

The percentage of *Darwinula stevensoni* in two samples of analyzed three samples is over 50%; this indicates rising water levers and the lake is larger than stage 3. Still comparatively large ostracod carapaces implies a cooling. Low evaporation rate or increased snowfall may be the cause of rising water lever during cooling stage. The lake is freshwater.

Stage 4b (28 000- 23 000 a B. P.)

Although the abundances are changeable, the percentages of species are comparatively stable; this suggests less environmental variety. Smaller ostracod carapaces compatible with stage 4a imply comparatively warm water. The occurrence of *Cyclocypris serena* indicates oligohaline water. Decreased percentage of *Darwinula stevensoni* reflects a falling in the water level, this may be caused by increased evaporation rate compatible with stage 4a.

It is worth mentioning that *Limnocythere inopinata* and *Cyprideis torosa* are all without well-developed the tubercles. A number of species, mainly of genera belonging to the Cytherideinae (such as *Cyprideis*, *Cytheridea*, *Cytherissa*) develop typical phenotypic hollow tubercles on lateral surface of their valves when moving to environments of less salinity (Van Morkhoven, 1963). The form of *Limnocythere inopinata* without well-developed tubercles mainly lives in brackish water (Yang, 1986). It is inferred that during 42 000- 23 000a B. P. the water body of palaeolake was comparatively stable and no considerable increase in salinity occurred.

In summary, the period 42 000- 23 000 years ago represented a generally temperate time, interrupted by several phases of slightly declining temperature. The ostracod fauna indicates a fresh-mesohaline lake, which apparently persisted over the entire sedimentation period without any desiccation phases.

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Plate Explanation

All specimens are deposited in Nanjing Institute of Geology and Palaeontology, Academia Sinica.

Plate Ⅰ

1-3. *Limnocythere inopinata* Baird, 1843

1. external view of female left valve, ×60, Cat. No. 128203.
2. external view of female left valve, ×60, Cat. No. 128204.
3. external view of female right valve, ×60, Cat. No. 128205.

4, 5. *Darwinula stevensoni* Brady et Robertson, 1870

4. external view of left valve, ×60, Cat. No. 128206.
5. external view of right valve, ×60, Cat. No. 128207.

6, 7. *Candona neglecta* Sars, 1887

6. external view of right valve, ×50, Cat. No. 128208.
7. external view of right valve, ×50, Cat. No. 128209.

8-10. *Cyprideis torosa* Jones, 1850

8. hinge features of female left valve, ×250, Cat. No. 128210a.
9. internal view of male left valve, ×60, Cat. No. 128210b.
10. external view of male right valve, ×60, Cat. No. 128211.

11. *Cyclocypris serena* Koch, 1837

11. right lateral view of a carapace, ×60, Cat. No. 128212.

12, 13. *Ilyocypris gibba* Ramdohr, 1808

12. external view of right valve, ×50, Cat. No. 128213.
13. external view of left valve, ×50, Cat. No. 128214.

14, 15. ?*Neocypridopsis* sp.

14. internal view of left valve, ×50, Cat. No. 128215a.
15. details of muscle scars, ×300, Cat. No. 128215b.