Tremendous change of the earth surface system and tectonic setting of salt-lake formation in Yuncheng Basin since 7.1 Ma

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Abstract The Yuncheng salt lake has formed under the setting of stepped subsidence of fault-blocks from the north to the south in Yuncheng Basin. In the phase of red clay accumulation during 7.1—3.6 Ma, the size of palaeo-lake was larger than the present salt lake, and palaeo-monsoon had formed. At 3.6 Ma, the northern basement in the basin raised abruptly due to the radiative effect of Qinghai-Tibet Plateau uplifting, and palaeo-lake was contracting southwards. At ca. 2.6 Ma ancient river flowed into the northern part of the basin. During ca. 2.0—1.9 Ma aerolian effect strengthened and loess started to accumulate on the most part of the basin. Since ca. 1.8—1.0 Ma the subsidence of the lake fault-block has been speeding up abruptly. As under the natural hydrogradient the salt lake received enough groundwater supply, and the rate of loess accumulation in the lake area was lower than that of subsidence of the lake fault-block, the lake could be preserved and becomes the only modern lake on Chinese Loess Plateau. Four large strengthening change records of the monsoon were found in the lake sequence of 5.8—1.9 Ma B.P.

Keywords: Yuncheng salt lake, tremendous change of the earth surface system, loess and lake, palaeomonsoon, palaeolimnology.

On the eastern part of Chinese Loess Plateau, a series of Late Cenozoic lake basins, which lie in the Sanggan——Fen-Wei graben-rift system, from the Sanggan River of Hebei Province at the north, through the Fenhe River of Shanxi Province southwards and ending at the Weihe River of Shaanxi Province southwestwards, had been dried out no later than Late Pleistocene. However, the Yuncheng salt lake has been preserved till now and becomes the only present lake on Loess Plateau. That Fenhe River flows through the most part of Shanxi Province with the NNE-SSW strike, abruptly changes westwards at Houma City situated at the northeast of Yuncheng Basin, and flows into the Yellow River finally, should be related to the raising of the northern basement of the basin.

In order to look inside into the tectonic setting of the formation of Yuncheng salt lake, five drilling holes in the Loess Yuan, Loess Liang, fluvial plain and lake area in the Yuncheng Basin have been studied by using multi-discipline methods, such as lithostratigraphy, magnetostratigraphy, sedimentology, micropalaeontology, and geochemistry. At the same time the palaeo-monsoon records in the lake sequence on the eastern part of Loess Plateau have been found.

1 The setting of topography, geomorphology and tectonism in Yuncheng Basin

The Zhongtiao Mountain lies on the southern and southeastern sides of Yuncheng Basin, and joins Gushan and Jiwangshan mountains in E-W direction and located in the northern part of basin at the northeast of salt lake. Accumulated on Gushan and Jiwangshan mountains, Neogene red clay[1] and Quaternary loess-palaeosoil sequence, which were regarded as dust sediments transported by wind[2], formed the Emeling Loess Yuan. The Sushui River is the main one in the basin at present, it flows from the northeast to the southwest through the basin, and finally into the Yellow River. Under the cutting of the ancient Sushui River, the Mingtiaogang Loess Liang formed at the northeast of Shuitou of Xiaxian County, and the relict Loess Liang and fluvial plain occurred successively southwestward from Shuitou. Under the setting of the relative rising of the northern basement and the subsidence of the foreland area of Zhongtiao Mountain, as well as the natural hydrogradient step, a closed converge lake and swamp area formed from Huangcun Village of Yuncheng City to Dalü Village of Xiaxian County. This area has a length of 60 km and the elevation of water surface in the Yuncheng salt lake is even lower than that of the Yellow River situated on the western side by 10 m.

Based on the geophysical data, it could be inferred that six faults with NNE trend occurred in about 60 km distance. From the line of Linjin-Linyi to the foreland of Zhongtiao Mountain, the thickness of Cenozoic strata increased from 1 km in the north to 5 km in the south. It has been found that Quaternary strata had been controlled by the Emeiling fault on the north side of Linyi County town, the Mingtiaogang fault near Taocun Village, the northern bank fault and the southern bank fault of salt lake. The fault-blocks I—IV in the studied area from the north to the south can be determined (fig. 1). Under the setting of the different movement of fault-blocks in the Yuncheng Basin, total of six geomorphological types had formed, i.e. denudational middle mountain, Loess Yuan, Loess Liang, fluvial plain, lake and piedmont fluvial fan skirt.

2 Stratigraphical units of Late Cenozoic in Yuncheng Basin

Miocene stratum is the earliest Cenozoic sediments outcropping in Yuncheng Basin. From old to new geological age, such stratigraphical units have been found as follows.

(1) Miocene Nantan Formation: Semi-cemented gray-colored sand layers yielding gravel, red-colored and spotted mudstone.

(2) Early Pliocene Jingle Formation: It is mainly consists of dark red, brown-red and bright red-colored mudstone, and occurs occasionally in the margin area of the basin.

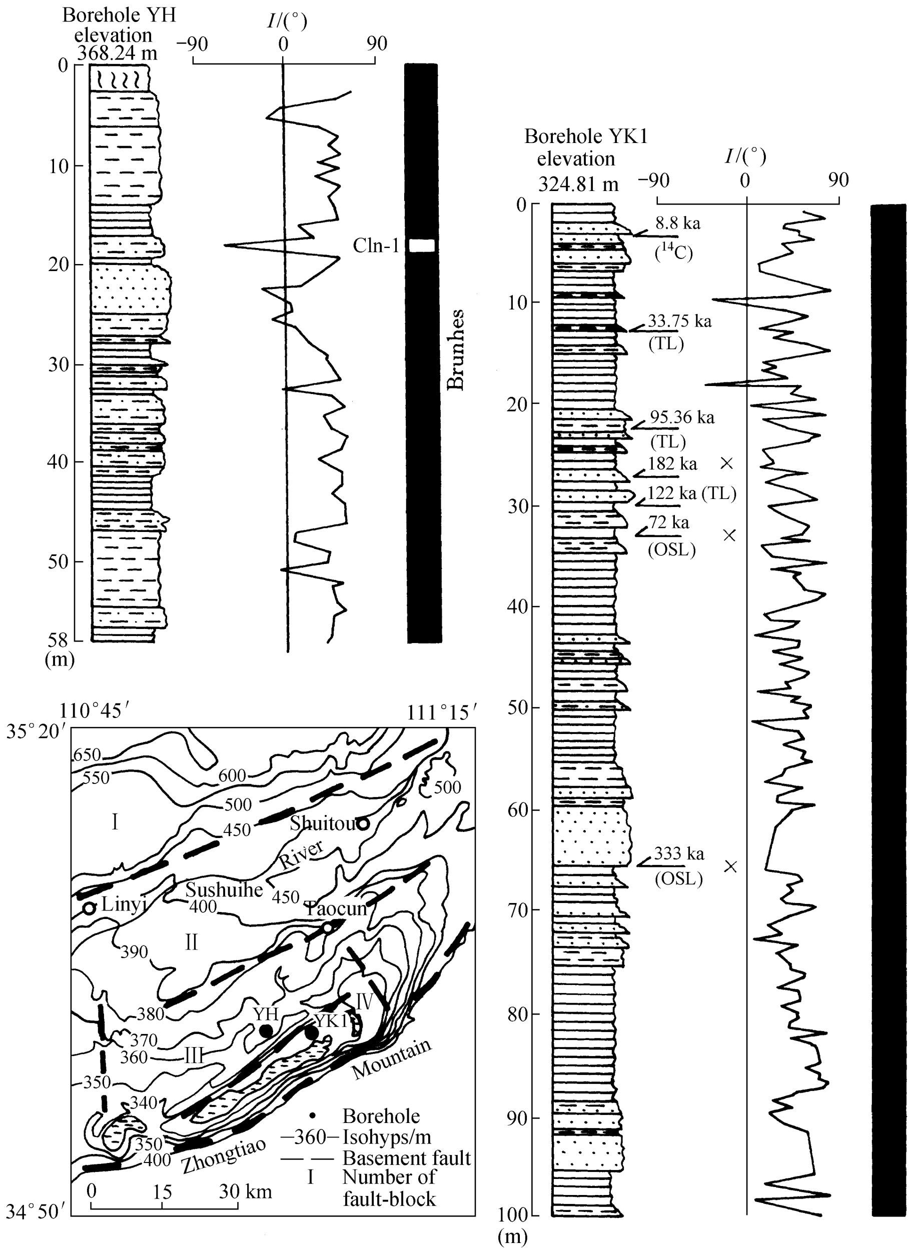

Fig. 1. The magnetostratigraphical correlation between boreholes YH and YK1, and the division of fault-blocks in Yuncheng Basin (legend as shown in fig. 2, the dating data mark × refers to what has been abandoned).

(3) Late Pliocene Youhe Formation (equal to “Green Sanmen Formation”): Gray-green-colored mudstone is dominant and only occurs at Renhe Village of Wenxi County.

(4) Early Pleistocene Sanmen Formation (equal to “Yellow Sanmen Formation”): It is mainly consists of yellow, brown-yellow-colored sand and gravel and silty clay interlayers occur occasionally. From many sites in Wenxi County typical Early Pleistocene mammalian fossils such as *Equus sanmeniensis* have been collected.

(5) Late Early Pleistocene—Late Pleistocene Loess stratum: At many sites the fact of Emeiling Loess Yuan overlying the sand gravel layer of Sanmen formation can be found. At the Mingtiaogang Loess Liang six palaeo-soil layers occur below the elevation of 570 m, the lowest two of these are dated 108.67 ka±9.24 ka and 61.29 ka±5.21 ka respectively by using TL dating method and these should belong to No. S5 palaeo-soil and overlying loess sequence.

(6) Holocene Stratum: From a drilling hole (35°25′00″N, 111°18′00″E, ostiole elevation being 480 m) at Dongzhen Town of Wenxi County, a black clay sample taking from the depths of 11.50—11.70 m was dated 6250±180 a B.P. (^{14}C dating). At drilling hole YK1, situated on the north beach of salt lake, the gray-green-colored clay taking from the depths of 3.05—3.20 m was dated 8880±190 a B.P. There is no sample available to ^{14}C dating at drilling holes in Yuncheng City area. Tracing relict Loess Liang from the north and northeast to the city area, it has been found that the city area should be situated near the bottom of loess stratum or near the top of Sanmen Formation. The reverse polarwander occurring at the sample of 18.20 m from borehole YH situated at city area of Yuncheng, however, might correspond to C1n-1 subchron of 0.493—0.504 Ma (fig. 1). The present paper used the name published in the articles of Cande et al.[3,4]. The sequence at borehole YH generally belongs to early and middle Brunhes polarity chron, its upper stratum might have been erosed out by river. Microbiotas of lake facies also have been found in the borehole. The different subsidence of fault-blocks can be seen from it. The determination of exact fault displacement between fault block III and fault block IV remains to be solved by studying deep drilling hole on fault block III.

3 Study on magnetostratigraphy for standard drilling holes in Yuncheng Basin

Drilling holes P3, P4 and P5 which are located at the northeastern end of salt lake, at the western end of Mingtiaogang Loess Liang and on Emeling Loess Yuan respectively, and boreholes YH and YK1, which are located in city area and on the north beach of the salt lake respectively, have been selected to study magnetostratigraphy. Total headway of these five holes being 1686.43 m and 1647 samples have been collected to measure residual magnetism by using spinner magnetometer. Except that only a few sandy samples were demagnetized under alternating field, the samples were subjected to thermal demagnetization by using U.S. Schostedt TSD-1 thermal sample demagnetizer (each step being 50℃). When most samples were heated to 300—500℃, their magnetic strength attenuated to original 1/10. The samples collected from boreholes P3 and YK1 were heated to upmost 500℃, because the two boreholes are situated at lake littoral zone. The samples collected from the other three drilling holes were heated to upmost 600℃ as the samples have much dust materials, himatite and high magnetism (fig. 2). Magnetic inclinations of some samples at borehole P3 reversed when the temperature raised to 100—200℃, but most samples were still normal polarity. Magnetic inclinations of all samples are close to those of modern Earth magnetic field (50.5°). The locations, curves of magnetic inclination for core samples and palaeomagnetism columns of these drilling holes are shown in figs. 1 and 2.

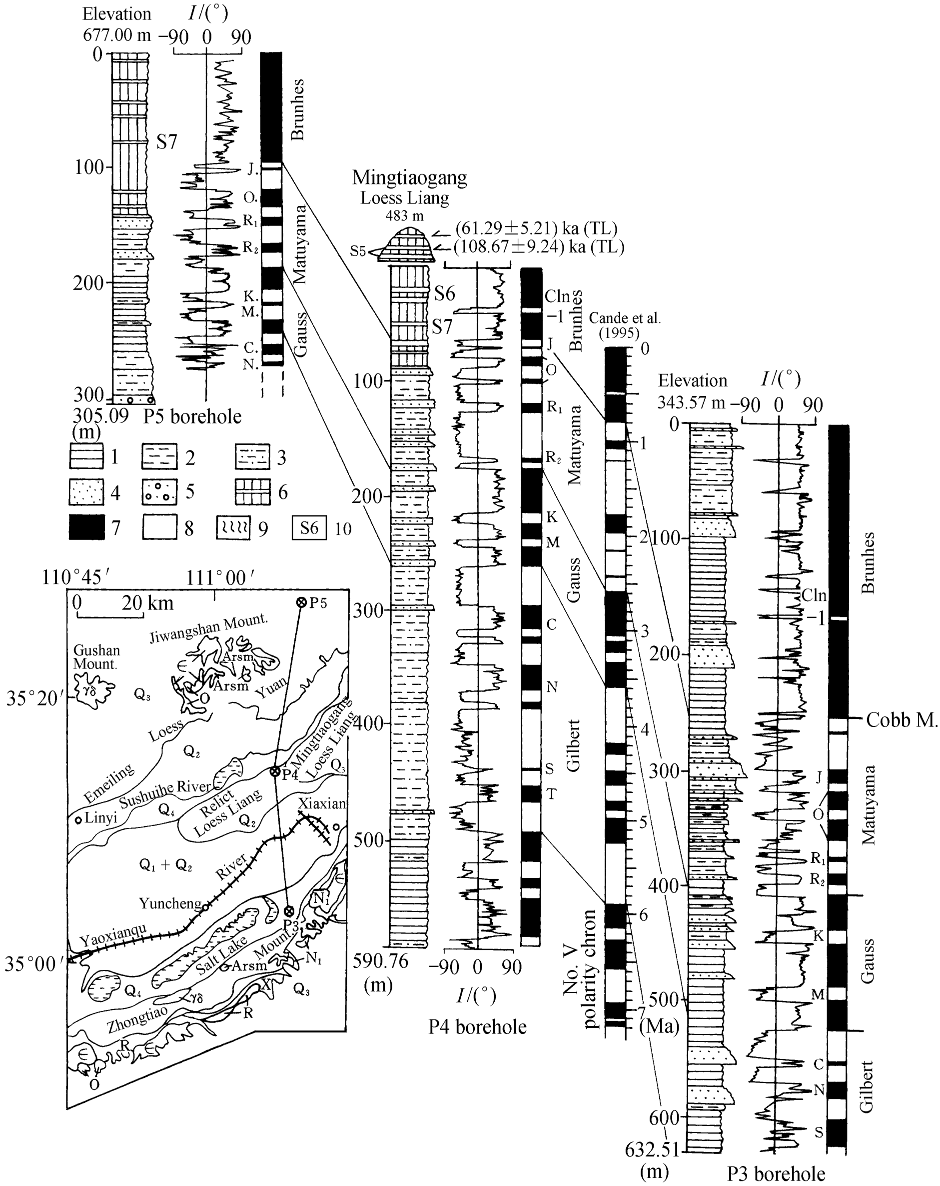

Fig. 2. The geological map of Yuncheng Basin (left lower), the locations, curves of magnetic inclination of core samples and interpretation of palaeomagnetic columns for the deep drilling holes in Yuncheng Basin. Borehole P4, ostiole elevation being 472.50 m. 1, Clay; 2, silty clay; 3, clayey sand; 4, sand; 5, sand and gravel; 6, loess and palaeosoil; 7, normal polarity; 8, reverse polarity; 9, backfill; 10, number of palaeosoil. ⧺, Cannel; ⊗, borehole location. In the left lower figure, Arsm, Sushui Group of Archaeozoic Erathem; X, Xiyanghe Group of Upper Proterozoic Erathem; R, Ruyang Group of Upper Proterozoic Erathem; γδ, granite of Yanshan Stage; ∈, Cambrian System; O, Ordovician System; N_1, Lower Pliocene series.

A total of 267 samples was collected from borehole P5, as the core below the depth of 280 m has been cleavaged, and below this depth no available sample could be collected. At this borehole Brunhes polarity zone occurs at the depths of 0—99 m, Matuyama polarity zone at 99—191 m, Gauss polarity zone at 191—250 m, and the stratum below the depth of 250 m to downgole might be Gilbert polarity zone. The member of 0—143 m is of loess-palaeosoil sequence, and eight kinds of brown-red-colored palaeosoil in 0.41—3.15 m thickness separately occur. The member of 143—196.06 m belongs to Sanmen Formation and two sand layers occur in it. The grain analysis of sandy samples of 177 m and 178 m suggests that these belong to stable river sediments. The sand layer of 180—171 m having coarsing upward grading belongs to abrupt landflood sediment. By collecting one sample per 1 m to analyze microfossil in this borehole, only one sample yields ostracods, i.e. at the sample of 183 m *Candoniella albicans* (50 valves), few *Ilyocypris* spp. and one valve of *Limnocythere ornata* have been found. It suggests that before the sand depositing there was an ephemeral shallow water depression or shallow lake. The member of 195—258 m consists of thick-bedded red and brown-red-colored clay yielding thin-bedded clayey sand. From the depth of 258 m to downgole there are red and brown-red-colored clay, bright brown-red-colored silty clay, bright brown clayey silt, at the bottom gray-yellow-colored sand gravel layer occurs, and gravel and calcareous nodule occur generally in this member. It has been reported that red clay had come into the end of Pliocene[1,5,6]. The red clay at borehole P5 ended near 2.6 Ma B.P.. Two subzones of Réunion have greater thickness, which should relate to the rapid sedimentation of sand layers. Loess accumulation happened before Olduvai subchron, i.e. before 2.0 Ma, which is related to strengthening of wind transportation[7].

At borehole P4 a total of 563 samples was measured. Brunhes polarity zone occurs at the depths of 0—62 m, Matuyama polarity zone at 62—179 m, Gauss polarity zone at 179—260 m, Gilbert polarity zone at 260—490 m, and the stratum below 490 m to downgole belongs to the 5th polarity zone. The stratum of 0—83 m is of loess-palaeosoil sequence and started in Olduvai subzone about 1.9 Ma, and six palaeosoil interlayers occur. The reverse polarwander of 37—41 m which consists of three samples might correspond to C1n-1 subchron. In fig. 2 the west end section of Mingtiaogang and relative TL dating data have been put on borehole P4, meaning that these can be connected. Below loess stratum there are river and relative sediments. At the depths of 85—180 m four river cycles and many subcycles also occur. These belong to point bar and overlying landflood basin sediments, and also belong to Sanmen Formation. Perhaps just as the river activity has more rapid sedimentation, this member has higher sedimentation rate. Maybe because of river oscillation and wash, the Olduvai subzone consists of two parts. Although the sediments of the member of 180—258 m seem to be bright yellow-color, the ostracod assemblage still suggests that this member belongs to lake sediments and should be Youhe Formation. The stratum below the depth of 258 m belongs to red clay and gypsum crystal occurs generally in it, the disssolved salt curve of core samples represents many frequent fluctuations from 5‰—13‰, pH curve is partiality toward sourness, from this depth upwards it drops to less than 1‰ abruptly, pH curve is partiality toward alkali. This shows that since ca.3.60 Ma this place had become a lake of fresh water as river affecting. Since 2.6 Ma the river effect strengthened apparently, the lake sedimentation in this place ended although few ostracods still occur at the bottom of Sanmen Formation.

Brunhes polarity zone starts at the loess in borehole P5 and above the palaeosoil in borehole P4 respectively. In Shanxi Province the tectonic movement has greater activity and this is the reason why this region was unavailable to the stable accumulation of loess[7], so it was only determined that the first palaeosoil above the B/M boundary in the two boreholes could be the S7 palaeosoil.

At borehole P3 a total of 584 samples was collected. Brunhes polarity zone occurs at the depths of 0—254 m, Matuyama polarity zone at 254—409 m, Gauss polarity zone at 409—525 m, below 525 m to downgole it is undrilled out of Gilbert polarity zone. Olduvai subzone may consist of two parts. The greatest negative polarwanders at Brunhes polarity zone mostly belong to turbidity and lake littoral sand, which should be abandoned. It is inferred preliminarily that the negative polarwander in depths of 166—168 m might be C1n-1 subzone.

At borehole YK1 (175 samples), situated on lake littoral zone, two polarwanders with little range are abandoned, one TL dating data collected from sand and two OSL dating data are unavailable logically and also to be abandoned. At borehole YH (58 samples) situated on fluvial plain and also on the north glint of the salt lake, because one clear negative polarwander was regarded as C1n-1 subchron, the sequence above the depth of 19 m at this borehole might have formed since ca.0.50 Ma B.P. (fig. 1). This bank glint should be formed under the fault movement. The satellite photograph represents a fault with NW-SE direction occurring near Dalü Village of Xiaxian County, owing to that the distribution of the shallow salt water also ended near the site, so this fault might be the northeastern boundary of the lake fault-block, and the western boundary of this fault-block lies near Xiaochi Lake.

4 Record of palaeomonsoon and palaeolimnology in Yuncheng Basin

The Yuncheng Basin, situated at the western part of the modern monsoon area, with the land hemi-dry climatic characteristic, has recorded lake palaeomonsoon matching with that preserved by red clay and loess. Because the present Yuncheng salt lake lies close to the Zhongtiao Mountain, under the wind drift from the mountain, and abundant gypsum crystal accumulated on the northern bank of salt lake. In red clay before 3.60 Ma in borehole P4 the gypsum crystal occurred widely and this is the only case in whole rift, so the dissolved salinity in core samples is higher than that of borehole P3. In deep stratum of the later borehole only few samples yield statistic content sporo-pollen (>100 grain/150 g dry sample), and there is no occurrence of subtropic genera; only some samples represent some short phases of pine tree somewhat flourishing and all other samples yield sporo-pollen assemblage of dry vegetation basically. Owing to this, it is inferred that at ca. 6 Ma the Qinling Mountain situated on the south side of Weihe Basin had raised to a relative height to resist the southwestern monsoon and the Yuncheng Basin had dried. The concentrated occurrence of gypsum in borehole P4 is only related to the wind drift from the southeast direction, which may be the southeast monsoon. The fluctuation of salinity curve represented once the change of monsoon strengthening and weakening during 6.10—6.00 Ma. It appears that the palaeomonsoon had formed at ca.7.1 Ma. In addition, *Limnocythere* spp. indicating the permanent water body also occurred at the deep stratum. These suggest that the middle part of the basin had changed itself into lake littoral environment at that time. The environment which is partiality toward sourness seems to be useful to living of euryhaline marine ostracoda, and since

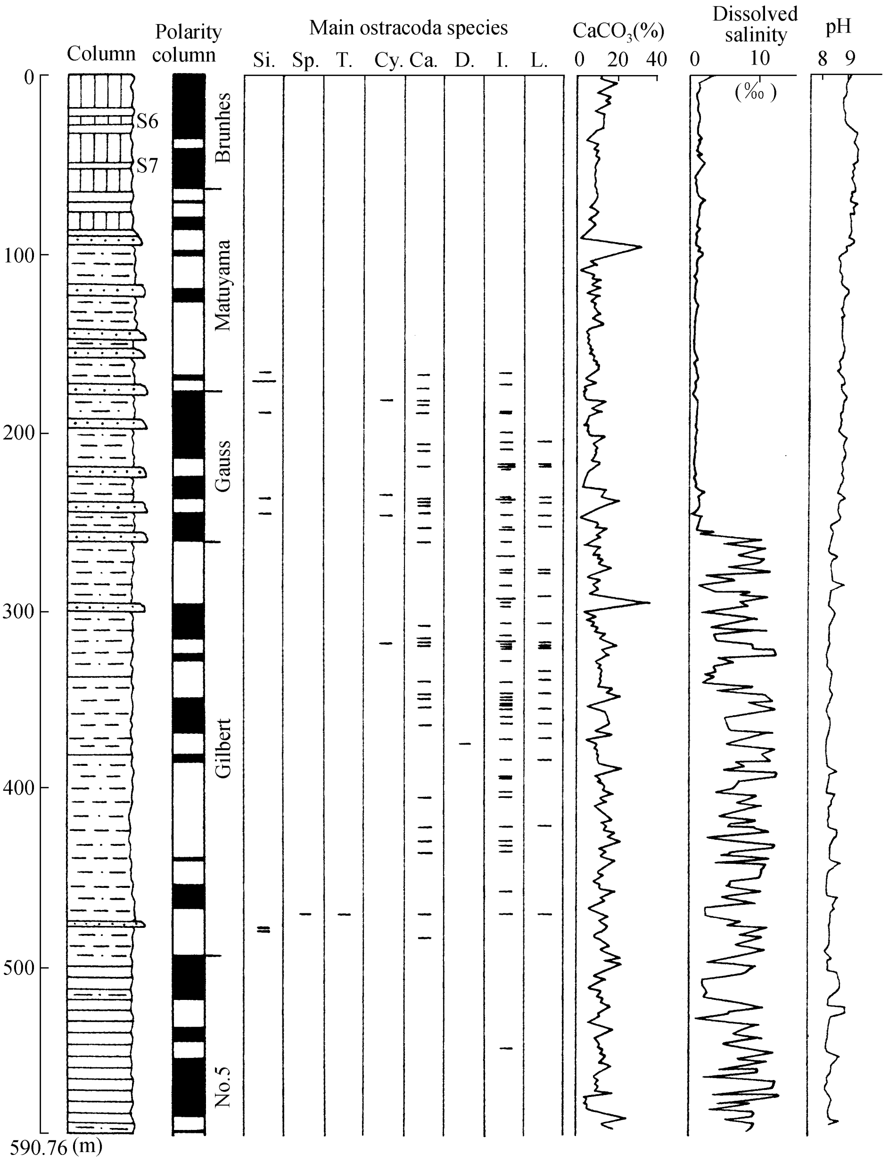

Fig. 3. The content of main ostracods and the curves of $CaCO_3$, dissolved salt content and pH values at borehole P4. Horizon lines under the ostracod names represent the content of ostracod specimen (valves): 1.5mm being 1—10, 2.5 mm being 10—50, 3.5 mm being 50—100. Si, *Sinocytheridea impressa*; Sp, *Spinileberis fruyaensis*; T, *Tanella opima*; Cy, *Cyprideis torosa*; Ca, *Candona* sp.; Ct, *Cytherissa lacustris*; E, *Eucypris inflata*; D, *Darwinula stevensoni*; I, *Ilyocypris* spp.; L, *Limnocythere* spp.

ca. 5.5—5.3 Ma *Sinocytheridea impressa*, *Spinileberis fruyaensis* and *Tanella opima* occurred. The content of $CaCO_3$ of the core samples at borehole P4 is higher than 10% (fig. 3). At borehole P5 the content of $CaCO_3$ is lower than 10% and pH values are higher than 9 generally.

At borehole P3 *Tanella opima* and *Limnocythere* occurred at ca. 4.9 Ma (fig. 4). At Late Gilbert polarity chron, this place and the middle part of the basin all belonged to shallow lake. Similarly, a few valves of typical lake species *Cyprides torosa*, *Limnocythere* spp. associated with fresh

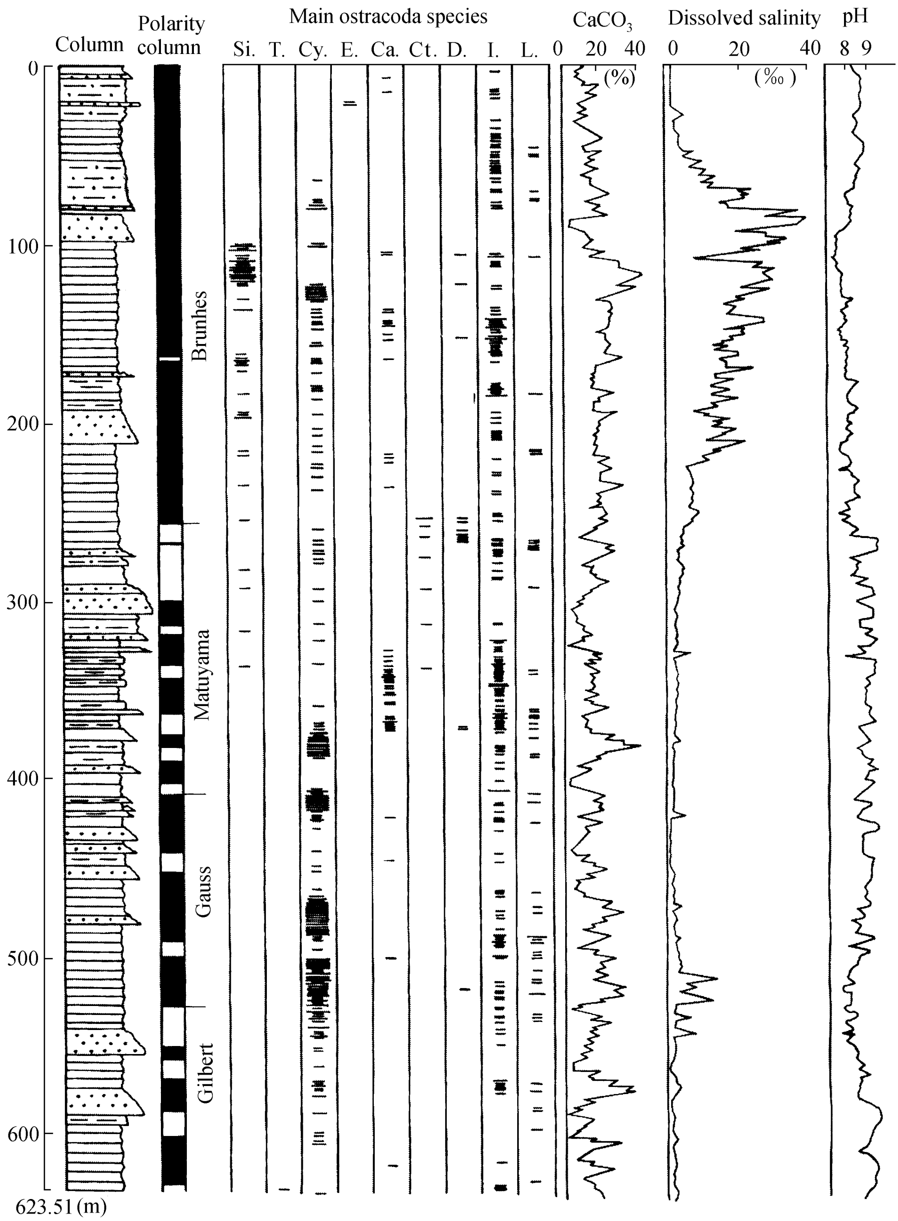

Fig. 4. The content of main ostracods and the curves of $CaCO_3$, dissolved salt content and pH values at borehole P3 (legend and interpretation as shown in fig. 3).

water species *Ilyocypris* spp. in the two boreholes, the salinity of core samples has a rising trend, and pH value is partially toward sourness. These indicate the transform of carbonate type to sulphate-NaCl type of the lake. This time was the inspissational phase of lake.

On Chinese Loess Plateau the member of high $CaCO_3$ content indicates the cold climate[8]. At lake sequence in the North China it had been found that under the dry-cold climate $CaCO_3$ content was higher, on the contrary, under the temperate and wet climate conditions $CaCO_3$ content was lower[9,10]. In a stable lake sequence (such as the lower sequence at borehole P3) the carbonate content, however, seems much more likely to be the function of precipitation/ evaporation, and it is also the record of monsoon change, but not enough to indicate directly the change of temperature.

At borehole P3 clay and silt are the main sediments, their carbonate is all calcite basically. The lake environment in this borehole is favourable to forming carbonate. The pH curve in this borehole represents 2.5 cycles from the partiality toward alkali to partiality toward sourness of lake and the members of high $CaCO_3$ content accord with the enrichment of *Cyprideis torosa*.

Cyprideis torosa is an euryhaline species[11,12], the specimens of this species in the Yuncheng Basin all belong to the smooth valve type of oligohaline. This species has wide distribution on the Northwest China and did not occur in the Late Cenozoic strata on the China continent east to the Sanggan-Fenhe-Weihe rift system. This is also the mark of the ecological differentiation between the west part and east part of China and further indicates that the west part of China had dried long ago. The enrichment member of *Cyprideis torosa* was usually regarded as “brackish water” environment when the associated fresh water species was rare. Comparing to the pH curve it can be seen that these enrichment members correspond to the phase which is partiality toward sourness or the high $CaCO_3$ content member of alkaline lake, representing the inspissational phase of lake, so that the enrichment members of *C. torosa* are regarded as oligohaline water ones. Below the lowest industrial ore layer (elevation being 230 m, corresponding to the depth of 113 m at borehole P3) in the salt lake, at borehole P3 the enrichment of *C. torosa* occurred firstly and afterwards it was replaced by abundant *S. impressa*. It seems that the species with marine genealogy were further available to the partiality toward sourness environment. Owing to the loess accumulation starting from ca.1.9 Ma, it is inferred that the $CaCO_3$ content at the sequence above the depth of 300 m had been affected by loess accumulation. The enrichment members of *C. torosa* below the depth of 361 m were regarded as the evaporation phase of lake, i.e. the strengthening phase of the winter monsoon, among them the members of low carbonate content were the pluvial phases of the summer monsoon strengthening.

Comparing with palaeomagnetic column (each subzone was regarded as uniform sedimentation), main phases of winter monsoon strengthening in the lower sequece of the borehole P3 could be roughly calculated as follows: 3.6—3.3 Ma, 3.20—3.15 Ma, 2.82—2.58 Ma and 2.17—2.14 Ma, among them there are the summer monsoon strengthening phases. At Olduvai subchron (1.95 Ma) as the river predeltaic sand inflowed into the lake, the lake water changed to shallow, and fresh water ostracoda genera *Candona* and *Ilyocypris* continuously occurred. At Cobb Mnt. subchron (1.07—0.99 Ma), with the same reason, the carbonate content dropped, the water dynamic strengthened, and ostracods were rare, afterwards typical lake species *Cytherissa lacustris* and *Darwinula stevensoni* occurred. Since then the loess started to accumulate in all studied areas, and the phase of continuous higher carbonate content also began. At the early and middle phases of Brunhes chron the pH value was relatively low and it indicated that the transforming to sulphate-NaCl type of the palaeo-lake was later than the accumulation of loess. At the depths of 100—110 m the pH values and the $CaCO_3$ content are all the lowest, corresponding to the forming of regional playa.

At the upper part of drilling hole P3, only a gypsum layer of 0.30 m thickness occurs at the depth of 80 m. Because of the effect of the groundwater from neighboring mineral bed migrating downward, long strata represent high salinity. The details of palaeomonsoon records since Brunhes polarity chron will be discussed based on more shallow drilling holes in another paper.

5 Tremendous change of earth surface system in Yuncheng Basin since 7.1 Ma

5.1 Red clay accumulation stage during 7.10—5.90 Ma

The Yuncheng Basin received widely red clay accumulation, oligohaline lake had formed and it situated between modern salt lake and Loess Liang. Palaeomonsoon already occurred.

5.2 Rapid subsidence stage during 5.90—3.60 Ma

The fault-blocks II, III and IV were situated in a rapid subsidence, and from the end of Sidufjall subchron (4.89 Ma) to the end of Cochiti subchron (4.18 Ma) the subsidence of the fault block II was most rapid. At borehole P4 the fact that Cochiti and Nunivak subzones consist of two parts might be related to the turbidity current caused easily by oscillatory subsidence.

5.3 Lake migrating and contracting stage during 3.60—2.58 Ma

At ca. 3.60 Ma, following the diversion of Gilbert/Gauss polarity chrons and the rising of the north basement of the basin, the sedimentary center of the lake was migrating southwards abruptly. On the fault-block II of the middle part of basin the river action strengthened. The tectonic movement in this phase was related to the rising of Loess Plateau, i.e. the radiative effect of the uplifting of the Qinghai-Tibet Plateau. The subsidence rate of the fault-block IV was calculated to be 1.46 times that of the fault-block II and 2.01 times that of the fault-block I respectively. This shows the stepped subsidence among the fault-blocks from the north to the south.

5.4 River action strengthening stage during 2.58—0.78 Ma

Following the diversion of polarity chrons of Gauss/Matuyama chrons, the river action at the northern part was strengthening obviously and the river deposition at the middle part of basin was further quick. At ca. 1.95 Ma, the loess accumulation rate was higher than the river transporting ability and started to accumulate on the northern part, afterwards it advanced quickly into the middle part of the basin. At 2.58 Ma, due to the tectonic movement the river effect occurred in the lake area, the fault-block IV was situated in rapid subsidence at 1.95 Ma and during 1.07—0.99 Ma. The subsidence rate of this fault-block was calculated to be 1.32 times that of the fault-block II and 1.68 times that of the fault-block I respectively.

5.5 Imprecedented rapid subsidence stage of the lake area fault-block since 0.78 Ma

Because the Zhongtiao Mountain raised rapidly, the fault-block IV was situated in a further rapid subsidence. At the same time the loess accumulation still happened on the northern and middle parts of basin, the fault-block III was connected with the fault-block IV during early-middle Brunhes polarity chron, afterwards they separated, and the fault-block IV further subsided. Because the loess accumulation rate was lower than that of tectonic subsidence of the fault-block, under natural hydrogradient the lake area has received enough groundwater and runoff supply, and can be preserved today. The lowest industrial ore layer in the salt lake formed at ca. 0.30 Ma B.P. Apparently, the exploited playa should form very late.

The formation of Mingtiaogang Loess Liang originating from the southern side of the Emeiling Loess Yuan and cut by the ancient Sushui river should happen at Late Pleistocene, at the river valley Late Pleistocene mammalian faunal fossils and aftermentioned some Holocene strata have been found. The fact that loess stratum southwestwards to Mingtiaogang had been erosed out as the hydrodynamic strengthening of ancient Sushui River and other rivers on the southern side of the Loess Liang might relate to the rapidly falling of erosional datum level and possibly rising of the northern part of basin. Because the rivers in the basin all flow into the Yellow River southwestwards, this feature should relate to outflowing of the Yellow River. At the Sanmen Gorge region in Henan Province, based on the dating data for the river terrace it has been concluded that the fact that the Yellow River had flowed out from the ancient Sanmen Lake into the China east plain is related to the tectonic movement happening at ca. 150 ka B.P.[13]. The study on Yuncheng Basin is useful to this inference.

6 Conclusion

The stepped subsidence of fault-blocks from the north to the south in Yuncheng Basin is the tectonic setting for the formation of a closed depression. The abrupt change of river hydrodynamic condition in large area and abrupt migration of the lake sedimentary center are all the representation of tectonic movement. Four eponides records on the tremendous change of the earth's surface system occurred in Yuncheng Basin, in the interval of ca. 4.9—4.2 Ma B.P., 3.6 Ma, 2.6 Ma and ca. 1.8—1.0 Ma B.P. respectively. At the same time, it was recorded that sulfate lake had occurred before 6—7 Ma on the eastern part of Loess Plateau. The change of palaeomonsoon strengthening with large range could cause the transform of lake, and its little change could cause the change of carbonate content in stable lake sequence, and the change of ostracod assemblages matched well these.

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