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Environmental Information Revealed by Sensitive Grain Size Component of Lake Sediments in Longcheng Yardang on the Northeast Edge of Tarim Basin

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Abstract On basis of grade-standard deviation method, two sensitive grain size components (component 1:5.8～10.0μm, component 2:60.3～104.7μm) and a less sensitive grain size component (component 3:15.1μm～22.9μm) were extracted from the samples of the sedimentary age of LX02 profile, which were collected from Longcheng Yardang region on the northeast edge of Tarim Basin. The study discusses the material sources and action forms of different grain size sensitive components, which can be used as an indicator to reveal the regularity of the lake and the intensity of wind-sand activity respectively. The lacustrine transgressive and regressive history of the region has been reconstructed for 72－51ka B.P. by the characteristics of the content of sensitive grain size component 2, and the palaeoclimate information of the sediments was restored, which provided the basis for exploring the distribution law of other environmental factors in lake sediments.This paper is helpful to explore the law of environmental evolution and the history of climate change in arid regions.

1. Introduction

The indicator of lake sediments can reveal the evolution of the basin environment and the important events of human activities, such as river channel change, temporal distribution of lake pollutants, flood and fire, etc (ZHANG Zhenke et al. 1999; Xu Wang et al. 2014; WANG Yonghua et al. 2004). Because of the advantages of sequential continuity, wide distribution and abundant information, lake sediment grain size is extensively used as an indicator in studying the frequency and intensity of wind-sand activities, identifying the transportation of materials and hydrodynamic conditions. It is regarded as the most effective environmental proxy indicator for lake evolution and wind field condition in geologic history (Shen Jiet et al. 2005; Qiang Minruiet et al. 2006). As a consequence of the complexity of sedimentary dynamics and diverse sources of lake sediments in arid and semi-arid regions, the frequency curve of the lake sediment grain size is mostly bimodal or multimodal (Yang Yiet et al. 2015). Formerly, researchers mostly focused on the single grain size parameters of sediment to reveal the sedimentological significance, which other related environmental indicators are needed to analyze and compare with sometimes (Sun Youbinet et al. 2003). In recent years, some experts and scholars have tried to use a variety of mathematical methods to separate the single grain size from the whole sample size parameter, such as function fitting (Sun D et al. 2002), terminal element model (Weltje G J 1997), neural network expert system (Qu Zheng 2001), etc, then further discussed the significance of sedimentology.

The arid region of northwest China is the main source area of the global atmospheric dust (Qiang Minruiet al. 2006), Lop Nur is one of the hot spots in ancient climate and palaeo-environment research, which is in the east of Tarim Basin. Previous studies in this region have been concentrated in Luobei, Luozhong and the Achic Vally (Luo Chaoet et al. 2007; Wang Yonget et al. 2001; Zhu Qinget et al. 2009; Ma Chunmeiet et al. 2008), the related research on Longcheng Yardang region has been relatively rare. In this paper, a standard deviation method was used to extract the grain size components that vary significantly from the sedimentary samples. Through the discussion of the relationship between different grain size components and the sedimentary dynamic environment, the history of lake transgression and regression from 72-51 ka B.P. about Longcheng Yardang region was eventually reconstructed. Such a research can be useful to explore the law of environmental evolution and the history of climate change in arid and semi-arid regions.

2. Research Area

The research area is located in Longcheng Yardang on the northeast edge of Tarim Basin in Xinjiang, deep in central Asia. It is characterized by a typical continental arid desert climate, with cold winters, hot summers, and large difference in temperature between day and night. The mean annual average temperature is 11.6℃, extreme minimum temperature -28℃, and extreme maximum temperature 44℃. Annual precipitation is less than 10mm, and evaporation is greater than 3000mm. This area is full of northeast wind, with an average wind speed of 2～4m/s and maximum wind speed of 17～25m/s.

There are abundant landforms around the research area, including dry lake basin in the south, Kumutak Desert in the southeast, Taklimakan Desert in the west and the Achick Vally in the east. Due to extreme climatic characteristics and special geographical location, this area has become one of China's arid central regions and dust storm source regions.

3. Sample Collection And Time Scale Establishment

The sampling site of LX02 profile is in the fluvial terrace in the south of Longcheng Yardang (as shown in Figure 1), with an altitude of 813m above sea level. This profile is divided into 15 natural sedimentary layers. The stratigraphic lithology is shown in Figure 2.

Sediments within a depth of 5.4m below the ground are the main objects of this research. We collected 93 samples for grain size analysis. To ensure the rationality and reliability of the samples in terms of distribution and quantity, all sample collection met the related requirements of optical dating test and grain size analysis completely. 6 samples were selected as test points from the top 0.18m、1.19m、2.21m、3.10m、3.71m、4.69m respectively for optically stimulated luminescence(OSL) dating. The relationship between the depth of LX02 profile and the age of OSL is shown in Table 1.

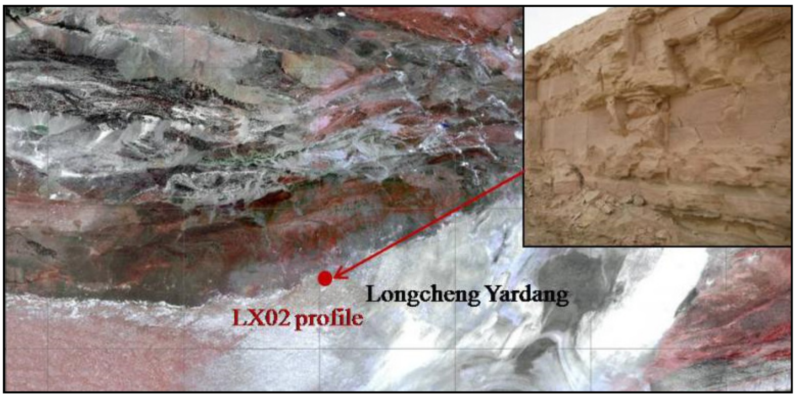

Figure 1. Location of LX02 profile

Table 1. Relationship between the depth of LX02 profile and the age of OSL

Depth/m	0.18	1.19	2.21	3.10	3.71	4.69
Time/ka B.P.	53.1±4.4	56.1±3.2	57.9±3.3	60.5±4.0	67.0±6.0	71.0±3.6

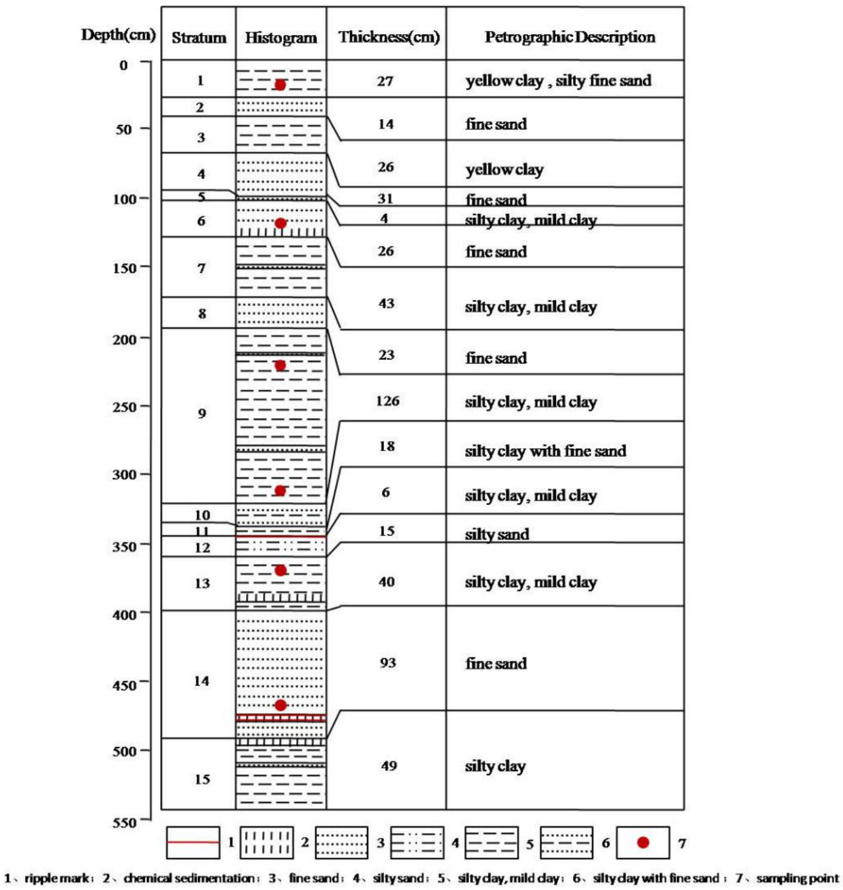

Figure 2. Stratigraphic lithology of LX02 profile

Figure 3 shows the age versus stratigraphic thickness of LX02 profile, which reflects the fluctuation of deposition rate in different depths. As the age goes from far to near, the deposition rate varies from slow to fast: at a depth of 0.18～1.19m, the deposition rate V_1=33.67cm/ka; at a depth of 1.19～2.21m, the deposition rate V_2=56.67cm/ka; at a depth of 2.21～3.10m, the deposition rate V_3=34.23cm/ka; at a depth of 3.10～3.71m, the deposition rate V_4=9.38cm/ka; at a depth of 3.71～4.69m, the deposition rate V_5=24.49cm/ka. In general, the deposition rate of the section is between 9cm/ka and 60cm/ka, which is close to the previous research results (Yung Y Let al. 2008).

According to the speculation, the sedimentary age of LX02 profile in 5.41m depth is about 72.3ka B.P., and the sediment near the ground was in 51.0ka B.P..

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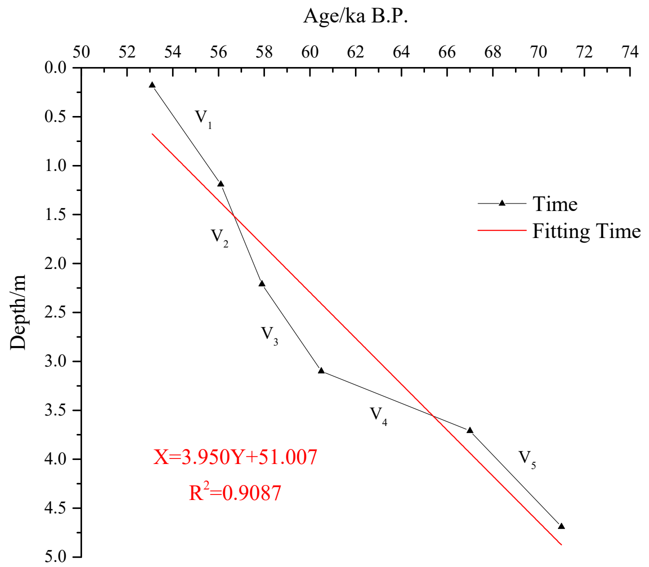

Figure 3. Age versus stratigraphic thickness of LX02 profile

4. Data Analysis

The grain size frequency curve of the sediment was plotted in accordance with the total grain size samples of LX02 profile (Figure 4). As can be noted from Figure 4, different color curves show the distribution of grain size frequency in different depths. The curves are mainly single peak curves or double peak curves, of which the peak value deviation is large, and there are a small number of multi-peak curves with no obvious weak peak as well. Among them, the single peak curve shows that the sediment grain size distribution is concentrated, which reflects a single sedimentary dynamic form, however the double peak and multi-peak curves show that the sedimentary environment is relatively complex. In this case, the mixture of single and double peak curve type may be for the same source mixed in different proportions under multiple sedimentary dynamic effects, also may come from different sources under multiple sedimentary dynamic effects.

In order to further discuss the complex situation of sedimentary environment consisting of various forming factors, the sediment grain size data is analyzed by standard deviation method, and the standard deviation value of LX02 profile is presented in Figure 5. As can be noted from Figure 5, there are two peaks of standard deviation, which are the grain size modes that are sensitive to the changes in sedimentary environment, and the corresponding grain size levels are 5.8～10.0μm and 60.3～104.7μm. There is also an obvious standard deviation valley between the two peaks, with the corresponding grain size range from 15.1μm to 22.9μm, which represents another granularity component that is relatively insensitive to the environment. Based on the distribution range of each component, we calculated the percentage content and average value of the whole section respectively: the percentage of component 1 is 1.54%～35.62%, with an average of 17.03%; the percentage of component 2 is 0.13%～55.72%, with an average of 15.34%; the percentage of component 1 is 0.51%～26.12%, with an average of 13.89%.

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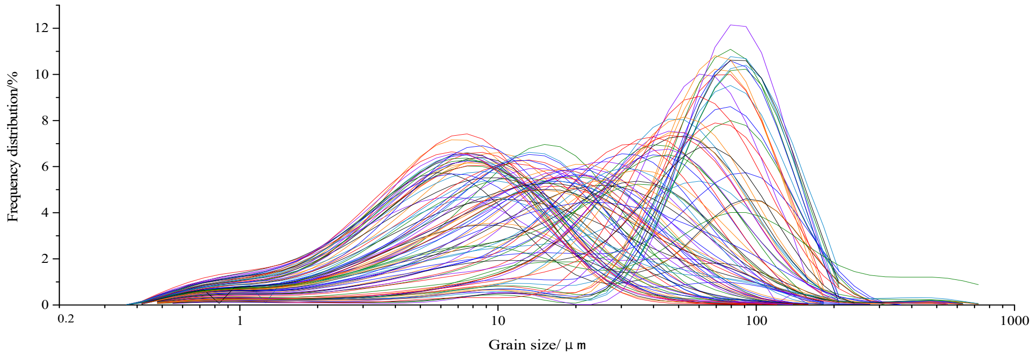

Figure 4. Sediment grain size frequency curve of LX02profile

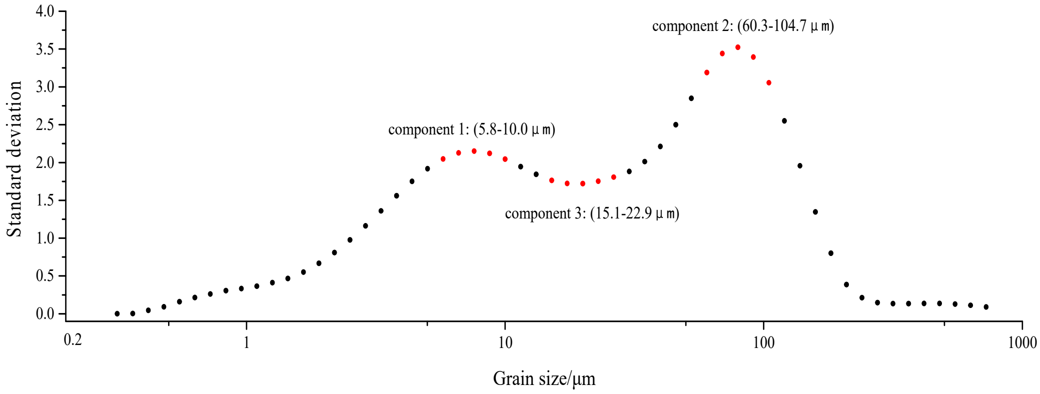

Figure 5. Grain -size classes versus standard deviation value of LX02 profile

Through the comparison between the percentage change trend of the three grain size components (Figure 6) and the correlation analysis between different components (Figure 7, 8, 9): there are significant fluctuations in the three components, and the changes in component 1 and component 2 are reversed, in other words, there is an obvious trade-off between the two components. Differently, the change of component 3 is more complex, which is consistent with component 2 in the depth range of 0.17～0.66m (51.7～53.6 ka B.P.)、2.04～2.34m (59.1～60.3 ka B.P.) and 2.74～3.11m (61.8～63.3 ka B.P.), and is consistent with component 1 in most other depths. It indicates that there is a direct relation between component 1 and component 2, but component 3 is not closely related to the former two.

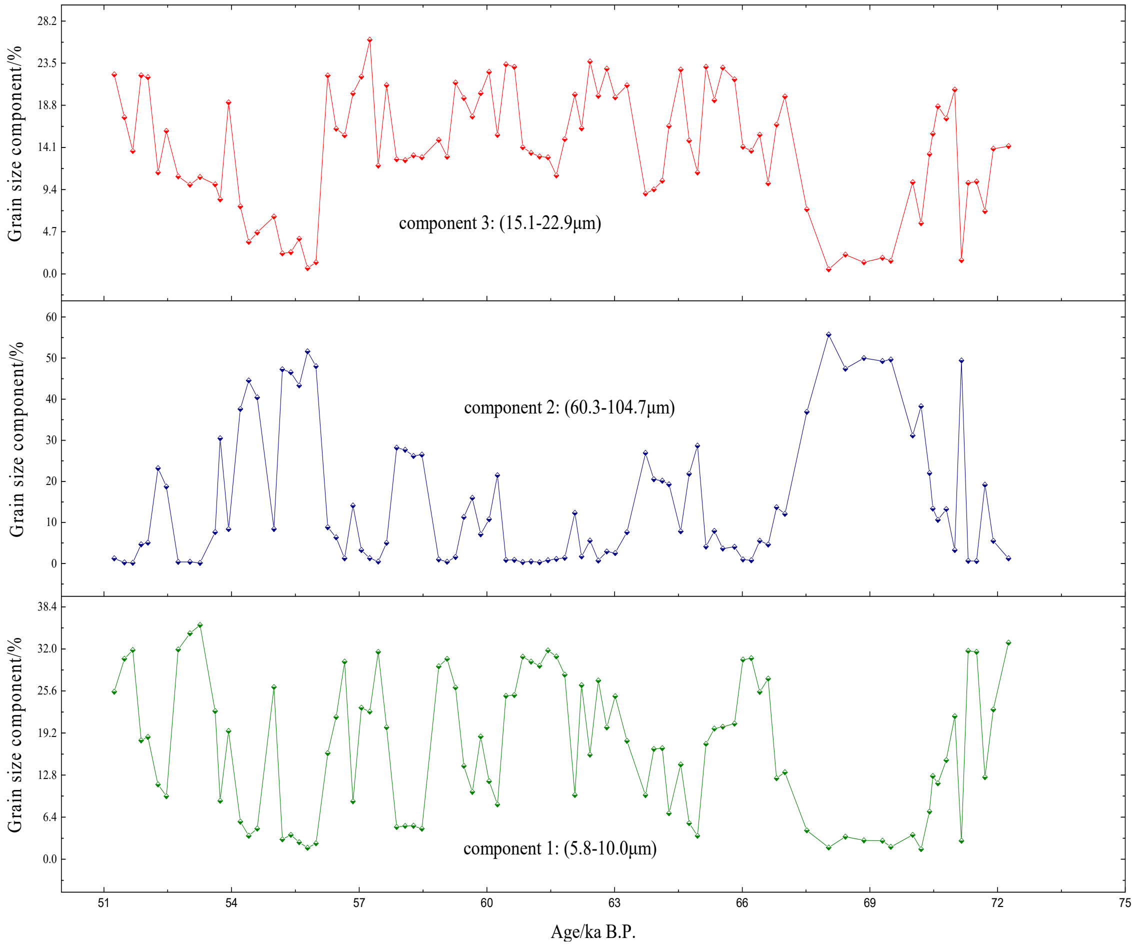

Figure 6. Variations of three grain-size components of LX02 profile

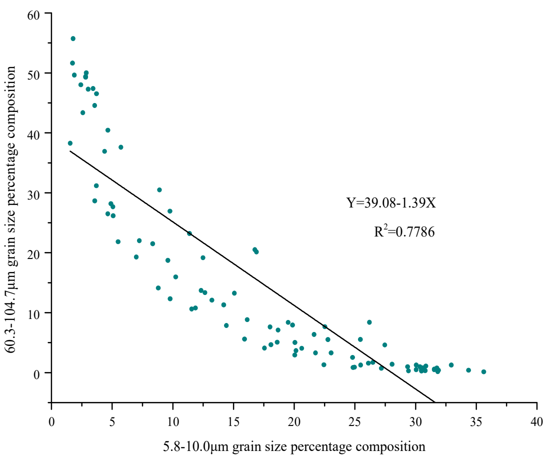

Figure 7. Fitting curve of component 1 and component 2 content change

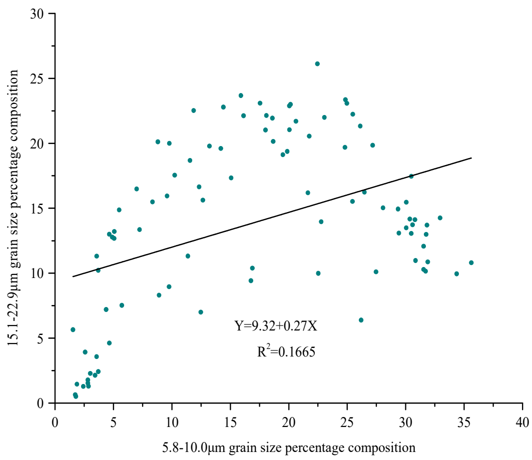

Figure 8. Fitting curve of component 1 and component 3 content change

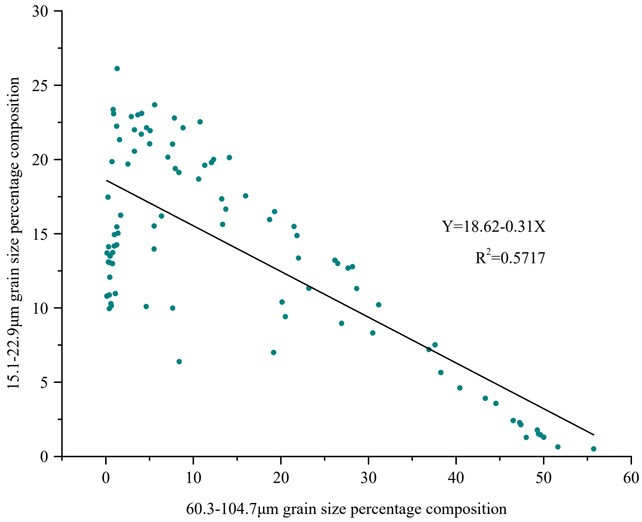

Figure 9. Fitting curve of component 2 and component 3 content change

Given the influence of the surf on the lake shore and the waves of the lake, the grain size of sediments is of an obvious differentiation. Yin zhiqiang et al.(2008), through the study of the multi-component characteristics of the sediments of many lakes, pointed out that the center of the lake was dominated by sediments of ＜10μm, and the closer to the center of the lake, the higher the percentage of this range of grain size is. By inference, component 1 represents the suspended particulates that are separated by the lake hydrodynamic machinery after runoff into the lake, considering the position of LX02 profile in the lake product platform and the grain size of component 1 ranging from 5.8μm to 10.0μm. Since the center of the lake is dominated by the upper and lower elliptical oscillations of water waves, only the smallest particles can hold in suspension with the oscillatory motion, which make the grain size of component 1 finer and of a better separation.

As the distance from the shore decreases, the depth of the water becomes smaller, and the fluctuation of the upper and lower elliptical oscillations gradually decreases, while the effect of surf is gradually enhanced. Under the wash and backflow of the surf, the coarse gravel at the botttom of the lake is lifted by the stronger friction force on the shore. The trend of component part 2 is just the opposite of component 1, and the component grain size is coarser with a poorer sorting characteristics. Accordingly, it can be concluded that component 2 are those coarse gravel sorted out under the strong upward movement of the surf.

In addition, considering the wind-sand effect of the arid and semi-arid regions is very significant, there should be some sand deposition in the sedimentary of the enclosed lake. The result of modern dust precipitation also shows that most of the dust particles in northwest of China are concentrated in 5～63μm.It is speculated that the reason for the relatively small standard deviation of component 3 is the direct settlement of aerosol particles.

As stated previously, there is a significant negative correlation between component 1 and component 2. This suggests that the relative distance of the lake has been fluctuating because of the conversion from cold and dry climate to warm and wet climate over the past 72～51 thousand years, or the opposite. In most of the depth range, component 3 is consistent with component 1, indicating that two geological forces, mainly wind and water, control the composition of the particles in this region. Zhang xiaoye (2001) pointed out that there is a greater connection between the two components of the grain size＞20 μ m and the dust storm or medium-strong dust transport, and 2～20 μ m particles are the result of dust input in normal conditions; He further pointed out that the dust of the last interglacial period was carried out to the loess plateau mostly in an non-dust condition, however, the transport of the glacial dust was mostly completed under the action of dust storm, accompanied by the significant increase of ＞20μm components. This is the main reason that the variation tendency of the component 3 in LX02 profile is the same as that of component 2 in most periods.

To sum up, the amount of grain size sensitive component 1 can be used as an indirect indicator to indicate the extent of the position of LX02 profile near the center of the lake. The higher percentage of component 1 is, the closer the position relatively to the central lake. The amount of grain size sensitive component 2 of LX02 profile sediment content can be an identification of lakeside. The higher percentage of component 2 indicates the position relatively closer to the lakeshore. The grain size less sensitive component 3 is the product of the direct deposition of atmospheric suspended particles in the lake platform, the content of which in the profile can be used as an important basis for judging the strength of wind strength and dust activity in the region.

5. Reconstruct The History of Lake Transgression And Regression

According to the change of the sensitive grain size component 2, the history of the lake transgression and regression in the region of Longcheng Yardang has been reconstructed from 7.2-5.1 ka B.P.. It can be seen from Figure 10 that in the period of 7.2-5.1 ka B.P., it may be affected by the rapid fluctuation of several temperatures in the northern hemisphere, and the fluctuation of component 2 is violent. At least 11 cases with significant increase in content happened in 71.67～71.76 (Number LN1), 71.03～71.26 (Number LN2), 67.08～70.47 (Number LN3), 64.66～65.06 (Number LN4), 63.47～64.38 (Number LN5), 60.14～60.31 (Number LN6), 57.74～58.65 (Number LN7), 55.03～56.22 (Number LN8), 53.99～54.91 (Number LN9), 53.65～53.87 (Number LN10) and 52.16～52.53 (Number LN11) cal ka B.P.. The study period can be divided into three stages:

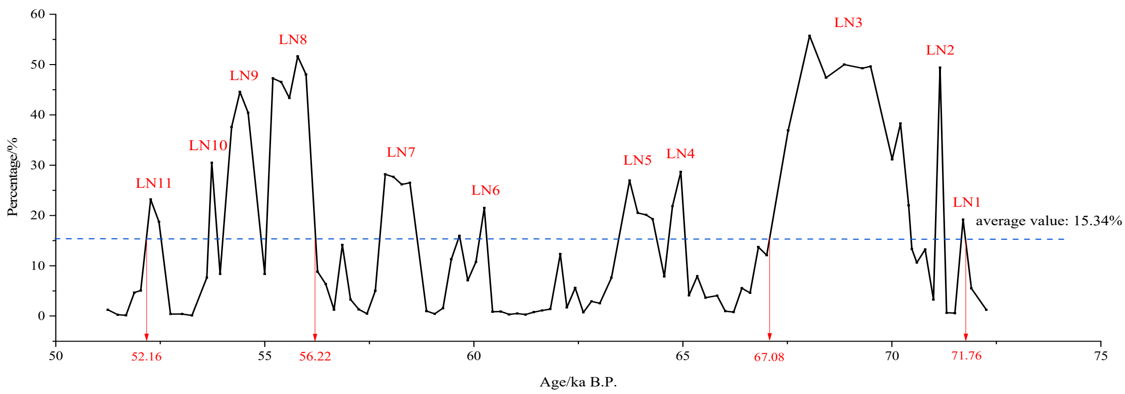

Figure 10. The curve of percentage variation with time of component 2

Stage Ⅰ: 71.76—67.08 ka B.P., early glacial stadial of the last glacial stage (earlier MIS4) (Ni Zhiyunet et al. 2011), the content of component 2 is far higher than the average and other times(later MIS4 and MIS3). The sediment particles in this region are relatively coarser due to reduced supply and dry climate, resulting in an increase in the percentage of component 2. As a comparison, we discussed the palaeoclimate evolution of the region through the analysis of the composition of clay minerals and the quality scores, which proved that this period was cold and dry climate indeed. According to the research of Jing Minchang (Jing Minchang 2004), the eastern part of Qaidam Basin in the early glacial stadial of the last glacial stage period is cold, which is consistent with the results of this study.

Stage Ⅱ: 67.08—56.22 ka B.P., late glacial stadial of the last glacial stage (later MIS4), the content of component 2 is lower than the average profile and other times(later MIS4 and MIS3). There were only four unobtrusive lake reversals, which were consistent with the mid climate in the late winter of MIS4 (Ni Zhiyunet et al. 2011). Through the analysis of the composition of clay minerals and the quality scores, it is proved that this period was warm and wet climate indeed.

Stage Ⅲ: 56.22—52.16 ka B.P., interglacial stadial of the last glacial stage (MIS3), the content of component 2 is mostly higher than the average, but its duration is shorter than earlier MIS4. This stage represents the warming of the climate, but the rise is small, and the climate is dry and cold, in which there were four more outstanding lake withdrawal events. Through the analysis of the composition of clay minerals and the quality scores, it turned out to be a colder and drier climate in this stage.

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