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Holocene Climate Evolution and Neolithic Cultural Evolution Recorded in the Loess Profile in Central Shandong Province, China

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Abstract: The ZQSC loess-paleosol profile was selected to investigate the environmental evolution and its correlation with the development of the Neolithic culture since Holocene in central Shandong Province of China. In the study, grain size, chromaticity, and magnetic parameters were considered as reliable proxies in reconstructing paleoclimate. Besides, the sedimentary age was obtained by ^{14}C dating in Beta laboratory in 2017. The result indicated that the Holocene climate evolution can be divided into three stages: 1) The early Holocene (about 11.5-8.5 ka B.P.). In this period, the climate conditions of the late Last Glaciation were extended, characterized by a dry and cold climate. 2) The middle Holocene (about 8.5-3 ka B.P.). This stage is climatically suitable with the best condition of warmth and humidity. Besides, small fluctuations also existed, in the period of the 4.62-3.784 ka B.P., the climate event was occurred. Besides, numerous pottery shards were discovered in paleosol, corresponding to the occurrence of the transition from the prosperous Longshan culture to the sluggish YueShi culture, potentially related to the sudden temperature drop and the ancient flood event. 3) The late Holocene (about 3.0 ka B.P.-present). The climate condition of this stage was deteriorating steadily. In this period, the 2.948 ka B.P. climate event and buried pottery revealed a great correspondence with the dry and cold events of the Middle Western Zhou Dynasty.

Keywords: Shandong Province, Loess-paleosol, Holocene, Climate Events, Longshan-YueShi

1. Introduction

Loess in China is famous for its wide distribution, continuous deposition, and rich information. It is one of the three pillars of global change research along with deep-sea sediments and polar ice cores. Abundant research achievements of predecessors have made great contributions to this field [1-3]. In recent years, with the deepening of paleoclimate research, the influence of Holocene environmental evolution on the origin and survival of human civilization has attracted much attention. This study also has great significance for the prediction of future environmental change [4].

The combination of natural sedimentary sections and Neolithic cultural remains has been studied deeply in the Loess Plateau and the Yangtze River Basin [5-8]. The Holocene environmental archaeology research in Henan is relatively complete province of China. For example, the study of Peiligang-Yangshao culture in Zhengzhou reveals the temporal and spatial evolution of ancient agriculture and its influencing factors in the middle Holocene in this region [9-10]. The relationship between the Holocene environmental evolution and human activities is also very clear in the Fanjiacheng section in Henan province of China. [11]. In the Yangtze River basin, studies on the relationship between the development of natural environment and the Neolithic culture and human activities in the areas of Zhongqiao Site in Jianghan Plain, Yaojiang-Ningbo Plain, Jianghan-Dongting Basin, and Liyang Plain are more advanced [12-15]. The combination of these natural profiles and cultural remains improves the temporal resolution of the strata, and the inclusion of human civilization into the natural environment system is conducive to further analysis of the relationship between ancient humans, ancient cultures, and environmental evolution.

A large amount of loess was deposited in Shandong Province during the Quaternary Period, which was mainly distributed in the northern part of the central Shandong Mountains and the islands of the Bohai Bay. The loess in this area is mainly derived from the sediment of the Yellow Flood Plain and the exposed dust of the Bohai Bay continental shelf. This is largely controlled by the East Asian monsoon [16]. The Shandong loess, which plays a key role in paleoclimate reconstruction and regional environmental evolution, is located at the link between the northern loess and the southern loess [17-19]. The main area of the Haidai Culture District is Shandong Province, which is also one of the birthplaces of Chinese civilization. The Neolithic culture sequence in this area is Houli-Beixin-Dawenkou-Longshan-YueShi culture, which dates back and forward about 8000 years [20, 21]. Longshan culture (about 4.6-4.0 ka B.P.) is the most prosperous culture in this region, with a high level of development. But it decayed into the primitive YueShi culture in the process of civilization [22].

The factors that influence the progress and decline of human civilization have been controversial in academic circles. The rise and fall of culture are usually explained as the internal factors of human development, such as production technology, social relations, wars, etc. But climate, hydrology, geomorphology, and other environmental factors cannot be ignored [23]. Therefore, we combine the Holocene environmental evolution revealed by loess-paleosol with ancient cultural relics organically and discuss the coupling relationship between the natural environment and cultural development. Also, we hope to explore the Neolithic human-climate-ecosystem interaction. It also refines the historical law and internal mechanism of the evolution of a man-earth system and provides strong support for further coordinating the current man-earth relationship [24].

2. Material and Methods

The study area of Shandong Province is located in the eastern part of China, the lower reaches of the Yellow River, belonging to the North China Plain, and the terrain is mainly plain and hilly; Mid-latitude warm temperate continental monsoon climate. The mean annual temperature (MAT) and mean annual precipitation (MAP) of this section are 12-15°C and 600-800 mm. After field investigation, the Zhangqiu-Shancheng section in the northern piedmont of the central mountain of Shandong was finally selected for research (Figures 1 and 2).

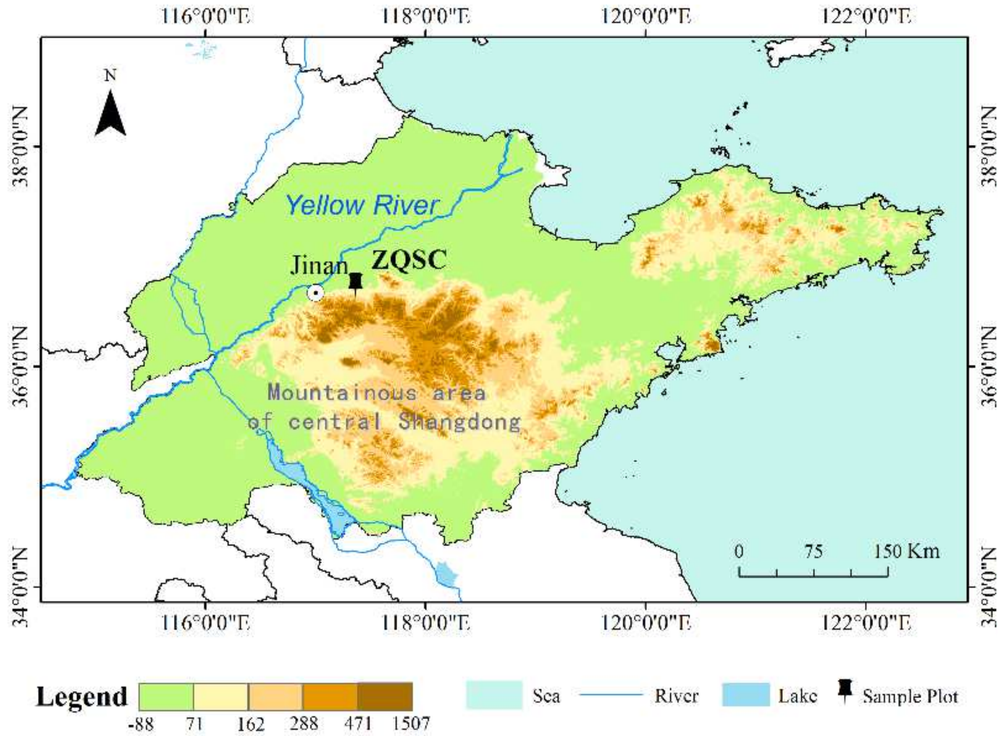

Figure 1. *Schematic map showing the location of the ZQSC profile in central Shandong Province of China.*

ZQSC profile (117° 22'E, 36° 44'N) is located in Jinan City, near the Longshan Cultural Heritage Site, Chengziya. Belonging to the piedmont plain area, the surrounding geological environment is good, no large fault, tectonic active zone, the sedimentary environment is stable. The section was exposed by the earth-taking project of the pottery factory. The top of the section was a cultivated layer, and the exposed part was about 2m thick and the bottom was not seen. The loess-paleosol layer of the section is clear, and the culture layer appears in the middle and upper part of the section (Figure 2). The stratigraphic description is shown in Table 1. We selected the section without ceramic tablets for collection, and continuously sampled from the top to the bottom with an interval of 2.5cm. A total of 68 samples from 0-170cm soil in ZQSC profile were collected for particle size, chroma, and magnetic experiments. Block samples were collected at 30cm and 80cm for the ^{14}C dating test. The sample at 30cm corresponds to the upper part of the cultural relic layer, and the sample at 80cm corresponds to the lower part of the cultural relic layer.

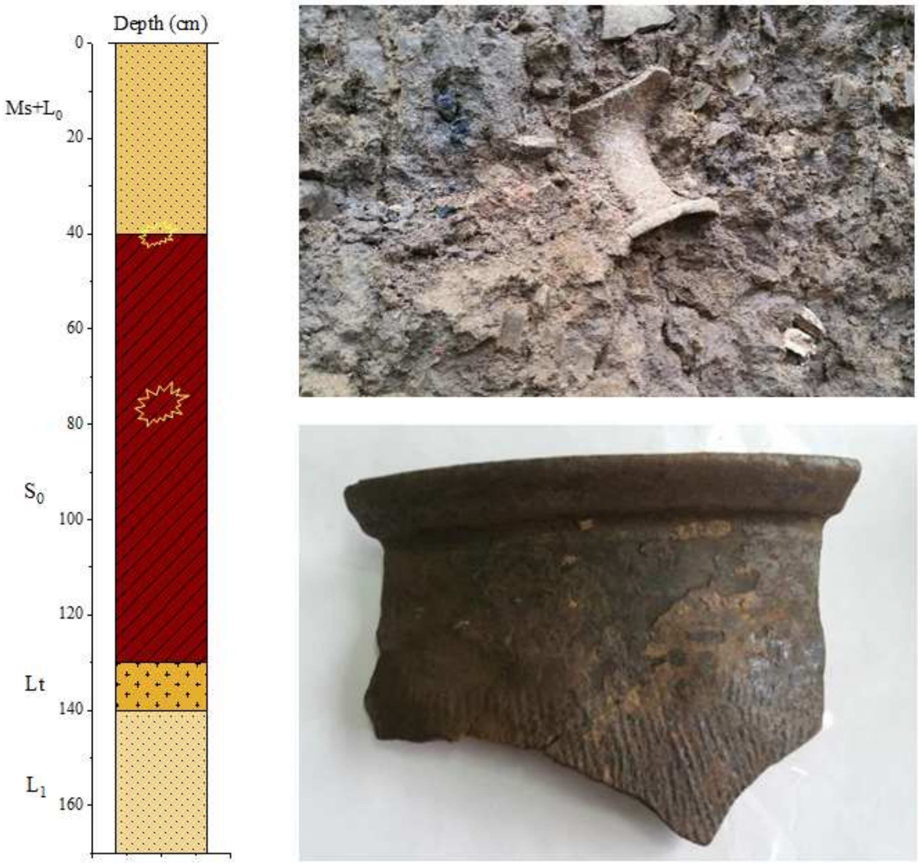

Figure 2. *Formation units of ZQSC and pottery relics.*

Table 1. *Stratigraphic division of ZQSC.*

depth	stratum	Description
0-40cm	Late Holocene topsoil and modern loess ($Ms+L_0$)	Pale yellow clay silty sand, plant root system is rich, loose, and porous, the color deepens upward.
40-130cm	Middle Holocene paleosol (S_0)	Dark brown clayey silty sand, well-developed soil, uniform compact, ribbed block structure is obvious. Gray and cyan ceramics were found at about 40cm, and the ceramics were all fragmented, with a diameter of about 5cm. At about 60-80cm, there were a large number of black and red pottery pieces with corded and basket patterns embedded in the strata, up to 10-15cm in diameter, and mixed with a piece of pottery fragment with a fine neck flask.
130-140cm	Early Holocene loess transitional layer (Lt)	Grayish yellow clayey silty sand, homogeneous granular, dark eluvial intrusions can be seen in many places.
below 140cm	Malan loess in the late last glacial period (L1)	Pale yellow clay silty sand, uniform texture, uniform color.

In this study, ^{14}C dating and cultural relics were used to establish the chronological framework of the section. The grain size, chroma, and magnetic parameters of climate substitution indexes are used to reflect the intensity of soil formation, reveal the climate change, and further explain the coupling relationship between environmental evolution and Neolithic culture.

3. Results

3.1. Chronological Framework

^{14}C dating was tested in Beta laboratory in 2017. Radioactive ^{14}C only exists in the atmosphere and all the carbon-containing substances are in the state of exchange with the atmosphere. Once the material is out of the state of exchange, the radioactivity of ^{14}C will no longer be compensated and will only decline according to the law of decay. This is the principle of ^{14}C chronology [25]. Table 2 shows the ^{14}C age test results of the ZQSC profile. The results of both groups of samples are good and consistent with the field observation strata, which can reveal the soil development age.

Table 2. *Report on AMS ^{14}C dating results.*

profile	sample	weight	location	depth (cm)	age
ZQSC	ZQSC-1	186.5g	(36°44′N, 117°22′E)	30	2530±30yrB.P.
	ZQSC-2	187g		80	4620±30yeB.P.

We sent the 60-80cm and 40cm ceramic pieces in the ZQSC section to the archaeologists of Shandong University for identification. The identification results showed that the pottery pieces at 60-80cm were from Longshan-YueShi culture (4.6-3.5 ka B.P.), and the pottery pieces at 40cm were from Zhou Dynasty (2.996-2.72 ka B.P.) and later. The identification results are consistent with the ^{14}C dating results. Besides, according to the profile deposition rate, we used the time-depth conversion method to interpolate to obtain the ages at 80cm, 60cm, and 30cm respectively (Figure 2). At the same time, according to the international standard age, the time of entering the Holocene in this region is 11.5 ka B.P., and the boundary between the early and middle Holocene is 8.5 ka B.P. The establishment of the stratigraphic age of the section lays a good foundation for the follow-up research.

3.2. Particle Size Analysis

As a proxy of palaeoclimate and palaeo-environment, grain-size has been widely used in aeolian sedimentation research. The variation of grain size of loess-paleosol sequence can explain the variation of wind force and depositional environment for dust transport [3]. As a physical index reflecting the properties of sediments, particle size parameters are not affected by late chemical action and water leaching, indicating good significance. Most of the loess in China is the product of East Asian monsoon and the variation of grain content has regional and global significance. The loess in Shandong is mainly derived from the northern Yellow Flood Plain and the Bohai Bay continental shelf and is also closely related to the East Asian monsoon. Some studies have found that the grain size of loess deposits becomes coarser due to the strengthening of the East Asian winter monsoon and the strengthening of transport capacity, whereas the grain size of loess deposits becomes finer. Sediment grain size is also affected by the summer monsoon. When the intensity of the summer monsoon increases, the regional water, and heat collocation are better, the pedogenesis is stronger, and the corresponding sediment particles are finer. Therefore, the intensity of the East Asian monsoon and the regional paleoclimate can be judged by the grain size of loess [8].

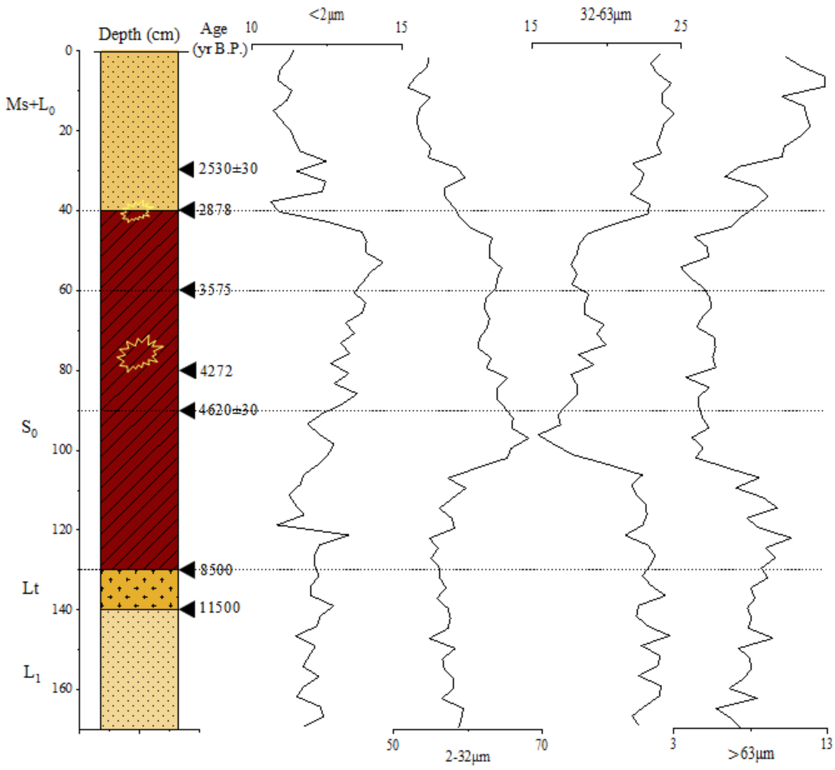

Figure 3. *Curves of grain size for the ZQSC loess-paleosol profile, the cultural relics at 60-80cm are Longshan-YueShi Culture (4.6-3.5 ka B.P.), and the cultural relics at 40cm are the Zhou Dynasty (2.996-2.72 ka B.P.).*

Figure 3 shows the variation curve of particle size components with depth in the ZQSC profile. The loess-paleosol profile is clear and the indexes are different obviously. It is composed of clay (< 2μm), fine silt (2-32μm), coarse silt (32-63μm) and sand (> 63μm). The clay content was 10.605%-14.375%. The content of fine silty sand (fine silty sand, coarse silty sand) ranges from 67.4% to 92.6%, and it is the multiform grain formation, which is a typical aeolian sedimentary characteristic. Coarse and fine silt show anti-phase change. The sand content was the least, with an average of 7.469%. In general, the variation of sediment particles was small during the Late Glacial and Early Holocene, while the variation was large during the Middle and Late Holocene.

3.3. Chroma Result Analysis

Soil color is one of the most striking characteristics of soil, which is closely related to regional climate and environmental changes. Chroma has been widely used in the study of Quaternary environmental evolution in recent years because of its advantages such as high sensitivity, simple operation, and fewer materials [26]. CLELAB color system is one of the main international standard color description and measurement systems. The system uses three parameters (L^*, a^*, b^*) to describe a uniform and continuous color space. L^* represents brightness, a^* represents redness, and b^* represents yellowness [27]. L^* indicates the degree of soil light and shade, which is closely related to the accumulation of organic matter, humus process, and carbonation process [28]. Strong soil formation intensity indicates a high content of organic matter, which is dark in color. a^* and b^* are both quantitative indicators to characterize soil color. a^* is closely related to the content of hematite and magnetite in the soil and increases with the enhancement of soil weathering degree. b^* depends on the content of goethite in the soil and is more closely related to the wetness of the soil.

Figure 4 shows the variation curve of ZQSC profile chromaticity with depth. L* varied from 55.38-67.66 with an average value of 59.88, showing a general decreasing trend from Late Glacial Age to Late Holocene. The curve of a* fluctuates greatly and has obvious change characteristics. However, the value is low, with a range of 3.17-4.6 and an average of 4.02. The overall value of b* is larger than that of a*, with a range of 21.56-24.27 and an average value of 22.98. The changing trend of the curve is similar to that of a*.

3.4. Magnetism Result Analysis

The magnetic minerals carried in sediments are very sensitive to the changes in the sedimentary environment. The magnetic susceptibility of the loess-paleosol sequence recorded the degree of biological weathering (loess-forming intensity) from the side [29]. The variation of magnetic parameters is closely related to sediment provenance, sedimentary environment, climate change, and sedimentary dynamics. At present, magnetism has been widely used as an effective index of regional summer monsoon intensity and precipitation.

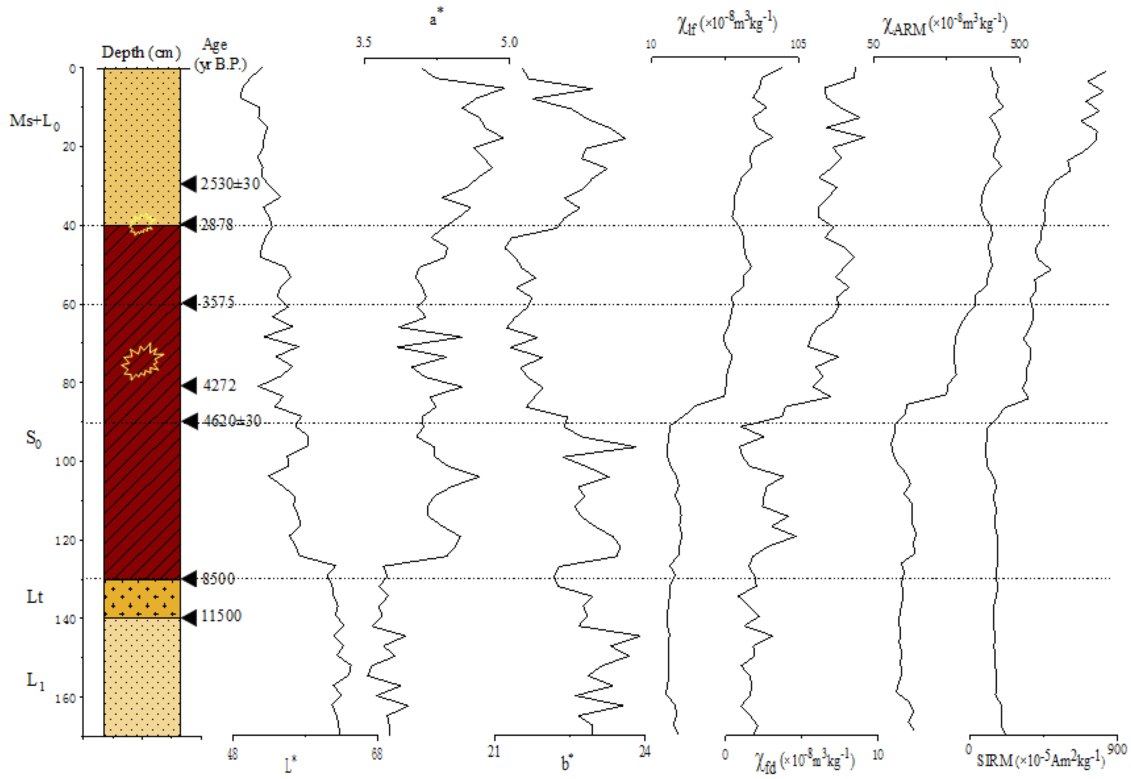

Figure 4. *Curves of color parameters and magnetic parameters for the ZQSC loess-paleosol profile.*

The study of soil magnetism has developed from a simple index of magnetic susceptibility to a comprehensive analysis of multiple magnetic parameters, which greatly promoted the study of loess paleoclimate [30]. It is common to use magnetic susceptibility as a substitute index in the study of loess in Shandong, but magnetic parameters other than magnetic susceptibility are rarely used. Therefore, based on the magnetic susceptibility index (low-frequency magnetic susceptibility χ_{lf}, frequency magnetic susceptibility χ_{fd}) based on Non-hysteretic remanent magnetism of magnetic susceptibility (χ_{ARM}) and saturation isothermal remanent magnetism (SIRM) to the physical and chemical properties of the magnetic susceptibility index reflects profile for them. χ_{lf} and SIRM reaction usually ferrous magnetic mineral content in the soil, χ_{ARM} is of a stable single domain (SSP), the sensitive parameters of ferrous magnetic mineral grains and χ_{fd} main indicator superparamagnetic particles (SP). The two kinds of small magnetic minerals (SSP and SP) are the dominant factors for the change of magnetic susceptibility.

Figure 4 shows the variation curve of ZQSC profile magnetic parameters with depth. The difference between different depths reflects the uneven distribution of magnetic mineral content in the profile. χ_{lf} changes in the range of 19.4×10^{-8}-$94.20\times10^{-8}m^3/kg$, with a mean of $46.64\times10^{-8}m^3/kg$, suggesting that section contains less common magnetic minerals. SIRM curve change trend and χ_{lf} basic consistent, and value are low, it also shows that the profile of magnetic minerals in low mass fraction. The lower χ_{ARM} indicates that the mass fraction of SD particles in the soil layer is low. The changing trend of χ_{fd} which is more sensitive to climate change is the same as that of χ_{lf}, but the fluctuation is more obvious. In general, the variation trend of each parameter is consistent, and there are good positive correlations between χ_{lf} and SIRM, χ_{fd}, and χ_{ARM}. This indicates that the numerical variation of these parameters is mainly affected by the strongly magnetic minerals of fine particles (SP and SSD).

4. Discussion

4.1. Holocene Climate Change in Central Shandong Province

The ZQSC profile shows the significant fluctuation of the climate substitution index, which records the Holocene environmental evolution in central Shandong Province. The bottom of the profile is the Late Glacial Malan Loess, and all indicators show that the climate in this period is dry, cold, and unstable. There is no weakly weathered palaeo-soil layer in L_1, indicating that the influence of summer monsoon in the late Last Glacial Age was very limited.

The early Holocene transitional loess L_t (140-130cm deep at ZQSC profile, about formed in 11.5-8.5 ka B.P.). In general, the grain size of loess is coarser. The content of clay and fine silt was lower, while the content of coarse silt and sand was higher. In the chromaticity parameters, L^* is higher and has a decreasing trend, while a^* and b^* are both lower. The magnetic parameters are all at a low level and the fluctuation range is small. The results showed that the winter monsoon was still strong, the precipitation was less, and the organic matter content in the soil was low. This period continued the cooler climate of the Late Ice Age. However, this layer of soil has a weak pedogenesis phenomenon, suggesting that the East Asian winter monsoon began to weaken and the climate slowly warmed.

The middle Holocene paleosol S_0 (130-40cm deep at ZQSC profile, about formed in 8.5-3 ka B.P.). At paleosol S_0 (130-40cm) In the middle of the Holocene, the chromaticity index responds quickly. At 125cm, L^* decreased rapidly, while a^* and b^* increased rapidly. The grain size parameters also changed, and the fluctuation of fine silt content increased at 120cm, while the fluctuation of coarse silt and sand content decreased. It shows that the climate got rid of the dry and cold environment in the past, and began to develop towards a warm and humid direction. Subsequently, the grain size changed significantly at 110cm. Clayey and fine silt increased rapidly, while coarse silt and sand decreased rapidly. Coarse and fine silty sand are the lowest and highest values in the whole profile. These two indexes show the reverse phase change. At the same time, the chromaticity parameters also make different degrees of response, suggesting that the region entered the Holocene suitable period. However, the magnetic parameters have no significant change compared with the early Holocene, only the χ_{fd} fluctuation is more obvious. But the climate was unstable during the mid-Holocene. The grain size, chroma, and magnetic indexes at 90-60cm all fluctuate to different degrees and last for a long time, suggesting that the winter monsoon force may increase and cold events occur frequently. A large number of pottery fragments of Longshan-YueShi culture buried at 80cm are also direct evidence of climate deterioration events. The magnetic parameters increased sharply at the distance of 90-80cm, which may be related to the environmental deterioration and the evolution of Neolithic culture. All indicators at 50cm in the section indicate that the climate is getting better. The clay reaches the maximum value of the whole profile, and the silt content changes obviously. L^* also showed a slight decrease, while a^* and b^* showed varying degrees of increase. The magnetic parameters are generally higher than those of the early Holocene. The climate of the region tends to deteriorate after a period of favorable conditions. A sudden decrease in the content of clay and fine silt and a sudden increase in coarse silt and sand at 50-40cm suggests that the warm and wet climate of the middle Holocene has ended in this region. Although the climate was not stable in the middle of Holocene, prismatic tight paleosols with a thickness of up to 90cm were developed, indicating a strong peeling-forming process. In the middle of the Holocene, the summer monsoon was strongest, soil formation was strongest, and the climate was warmest and wettest.

The late Holocene topsoil layer and modern loess layer MS and L_0 (40-0cm, about 3.0 ka B.P.-present). The profile enters the late Holocene at 40cm. Coarse silty sand and sand grains fluctuate. The contents of clayey particles, fine silt, a^*, and b^* all fluctuated greatly. L^* is the lowest in the whole profile, indicating that there is a lot of organic matter and humus in the soil, which may be related to the upper tillage layer. The magnetic parameters also fluctuate obviously. All the indicators indicated that the winter monsoon was continuously strengthened and the climate tended to be dry and cold during this period. It was speculated that the monsoon transition occurred in the central part of Shandong Province. A small number of gray and blue fragments were found at 30-40cm, which was identified as cultural relics of the Western Zhou Dynasty. Both historical records and previous studies indicate that the middle and late Zhou Dynasty was a dry and cold period [31, 32].

The variation of the magnetic parameter curve of the ZQSC profile is not consistent with the meaning revealed by other indexes. The sedimentary environment is an important factor affecting the physical and chemical properties of aeolian sediments, such as topography, flowing water, and groundwater. The ZQSC profile is located in the piedmont plain area of the central mountain area of Shandong Province, with low terrain and relatively close to the river, and high groundwater level. Therefore, it may be greatly affected by moisture. Liu et al. made a comparative analysis of the paleoclimatic records of magnetic susceptibility of loess from China, Alaska, and Siberia [33, 34]. They believe that soils have different modes of soil formation under different environments. In the arid oxidizing environment with evaporation greater than precipitation, ferromagnetic minerals such as hematite and magneto hematite are favorable to be generated, and the magnetic susceptibility is positively correlated with the paleoclimate. However, ferromagnetic minerals will be leached and decomposed in a reductive environment with too much humidity, which often leads to the lower magnetic susceptibility of the paleosols than loess, showing a negative correlation with paleoclimate. In the warm and humid Holocene suitable period, this region is likely to be in the reduction environment of high humidity or stagnant water, and the soil is in the intense water activity for a long time, so the maghemite is easy to be dissolved. At the same time, the strong soil formation during the interglacial period also caused the transformation of strongly magnetic hematite to weakly magnetic hematite [35]. It may be an important reason that the magnetic index of the profile cannot correspond to the particle size and chroma index.

4.2. 4.0 ka B.P. Climatic Events and Longshan-YueShi Culture

The fluctuation of climate substitution index and cultural relics at 80-60cm (4.62-3.784 ka B.P.) of the section indicates that the area may be in the range of 4.5-4.0 ka B.P. experienced a climatic event that may have led to the transformation or extinction of the Neolithic culture in the region. The climate fluctuation event around 4.0 ka B.P. in the middle and late Holocene was an important turning point in the development of Neolithic culture in many parts of the world, which was revealed by a variety of paleoclimate records with relatively accurate dating and high resolution [36].

The Longshan Culture (4.6-4.0 ka B.P.) was the most developed cultural stage of the prehistoric culture in Shandong Province [37]. Relics of Longshan culture settlements and active relics are all over the whole region, and the elevation is approaching the sea level from terraces and terraces, the population is growing rapidly, and the production technology has also reached a fairly high level [38]. They were skilled in wheel making, exquisitely crafted egg-shell black pottery and jade, and built many cities. Around 4.0 ka B.P., Longshan culture suddenly decayed into YueShi culture with a low level of civilization. Archaeological evidence shows that the level of development of YueShi culture is much different from that of Longshan culture. All kinds of city sites and settlements were reduced, and eggshell pottery was gone. There is no obvious direct continuity between the culture and the previous stage as if it were newly generated [39]. At the end of the Longshan Culture, the paleo-vegetation and paleo-climate of the upper Shu River had undergone obvious changes, and the cool and dry forest and grassland vegetation appeared [40]. Other scholars also believe that the collapse of Longshan culture is largely related to the abrupt change of climate, and the ancestors of YueShi culture also lived in a relatively dry and cold climate [41, 42].

In the Neolithic Age, the natural environment was the basis for the development of human beings and their cultures. Therefore, environmental change is the fundamental cause of cultural decline or progress [43]. Human beings have no time or ability to fully adapt to the changes in the environment, so they have to migrate to other places to find a new living environment and food sources, and the original culture will rapidly decline or die out [44]. Longshan culture in the lower reaches of the Yellow River experienced a warm and humid environment in the suitable period of Holocene, and the population had enough time to increase and approach the level of resource carrying capacity. Moreover, the resources and environment in the central part of Shandong cannot bear such a huge culture. Although the production technology of the Longshan Culture period was relatively developed, it could not resist the sudden attack. During the climatic transition period, the population and resources in this region broke through the unbalance point, which led to the regression of Longshan culture.

In previous studies, most people believed that the decline of the Neolithic culture around 4.0ka B.P. was related to the paleo-flood events. Five major flood events were recorded in the Jing River Basin, all of which occurred in 4.1-4.0 ka B.P. It is the transition stage from the warm and humid Holocene to the dry and cold late Holocene in this region [43]. The early flourishing civilizations in the middle reaches of the Yangtze River (represented by Qujialing Culture and Shijiahe Culture) were also destroyed by the flood disaster around 4.0 ka B.P. [45]. Flood records around 4.0 ka B.P. were recorded in Huai River Basin, Hai River Basin, and Yellow River Basin, etc. In the field, we also observed a widely distributed and uniform gravel layer in the upper part of the loess profile, confirming that the region experienced a widespread regional flood event in the middle and late Holocene.

The climatic fluctuations experienced in this region during 4.620-3.784 ka B.P. contain the possibility of increasing climatic variability and increasing flood disasters. At least we can conjecture that climate deterioration played a very important role in the succession from Longshan culture to YueShi culture. Precipitation and precipitation variability will increase in the climate transition process, leading to the frequent occurrence of flood events. The flood event may correspond to the dramatic change of climate during the transition from the warm and wet Holocene to the dry and cold late Holocene. The paleo-floods and cooling events occurred suddenly around 4.0 ka B.P., and the magnitude of these events varied but they were all significant in different regions. Although we don't fully understand the mechanism and timing of climate fluctuations, we do know that many parts of the world experienced abrupt changes at roughly the same time. Regional climatic events also indicate that environmental changes had a significant impact on Neolithic culture.

4.3. Late Holocene Climatic Events and Western Zhou Dynasty Culture

The climate fluctuation at 40cm (2.948 ka B.P.) in the profile can be related to the cultural relic layer (identified as the Western Zhou Dynasty (2.996-2.72 ka B.P.)). According to the phenology, Zhu found that China experienced a climate deterioration event in the Western Zhou Dynasty [31]. The general process is a warm period in the early Western Zhou Dynasty, a cold period in the middle Western Zhou Dynasty, and a warm period in the Spring and Autumn Period. The cold and dry conditions in the middle of the Western Zhou Dynasty probably lasted for a century or two. The sub-peak of grain size composition at 50cm of ZQSC profile indicates that the early Zhou Dynasty was still at the end of the Holocene warm period, and the climate was warm and humid. However, with the rapid change of global temperature and the strengthening of the East Asian winter monsoon, the climate began to turn cold and dry in the middle of the Western Zhou Dynasty. The grain size composition in the profile also changes greatly. Especially in the late Western Zhou Dynasty, the climate conditions were very bad, and the dry and cold climate also indirectly led to the demise of the Western Zhou Dynasty [46]. At this time, the fine-grain fraction increased and the coarse grain fraction decreased, indicating that the Spring and Autumn warm period had entered.

Paleoclimate studies in many areas of China have recorded the climate deterioration period of the Western Zhou Dynasty, which was in the boundary of the middle and late Holocene. The geochemical and weathering indices of the Huangqihai H6 section recorded that 3050-2930 ka B.P. was the climate deterioration period of the Western Zhou Dynasty, and 2930-2700 ka B.P. was the dry period of the Western Zhou Dynasty [47]. The Holocene paleofloods stagnant sediments in the Longmen section of the Yellow River also indicate that climate deterioration and flood occurred during 3200-2800 ka B.P. This event can correspond to the transition stage of gas deterioration from the late Shang Dynasty to the early Western Zhou Dynasty in Chinese history [48]. Other parts of the world, such as Antarctic ice core $\delta^{18}O$ and North Atlantic debris deposits, also clearly record abrupt climate events during this period [49-51].

5. Recommendations

In this study, we have done some superficial work on the Holocene climate evolution and the development of ancient culture in central Shandong province. In the future, we hope to have a more comprehensive understanding of the region. For example, in the selection of indicators, we can adopt some chemical weathering indicators, as well as paleo-vegetation and paleo-precipitation indicators. In addition, the dating method can be compared and superimposed with other methods to obtain a more convincing age frame. We can also deepen our understanding of ancient cultural changes and see more clearly the extent to which the environment influenced ancient humans. Finally, we hope to expand the research area and conduct comprehensive research on the whole Shandong Peninsula region.

6. Conclusion

The loess-paleosol deposition of the ZQSC profile in central Shandong reveals the Holocene climate evolution in this region. The early Holocene (about 11.5-8.5 ka B.P.), the East Asian winter monsoon was still strong and continued the dry and cold climate of the Late Glacial Age. The middle Holocene (about 8.5-3 ka B.P.) in this suitable climate period, the combination of water and heat is better. However, the climate was not stable during this period, and there were many abrupt climate events. The late Holocene (about 3.0 ka B.P.-present), the climate is tending to deteriorate.

The combination of natural sections and cultural relics makes the coupling relationship between climate events and Neolithic culture clearer. The climatic fluctuations at 4.62-3.784 ka B.P. and the pottery remains in the section suggest that this region may have experienced the succession from the prosperous Longshan culture to the depressed YueShi culture. The region's population and resources are close to the point of imbalance, unable to resist the back-to-back blows of cooling and flooding. Although the ancestors had a splendid culture and advanced production technology, they eventually went into depression. The climate deterioration event of 2.948 ka B.P. and the pottery remains correspond to the Western Zhou culture. Both historical records and previous studies show that the Western Zhou Dynasty experienced a cold period at 3.0 ka B.P.

Based on the comparison of natural sections and cultural relics, this paper reveals the Holocene climate evolution in central Shandong and its relationship with the Neolithic culture. It is expected to predict the relationship between man and land at that time and enlighten the relationship between population and resources and environment at present.

Due to the objective reasons and the author's knowledge level, there are still some shortcomings, and we look forward to improving them in the follow-up research.

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