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Study of the Response of *Tamarix* Cone Sedimentary Veins to Climatic and Environmental Elements in Arid Zones

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Abstract: In order to perfect and popularize the method of using *Tamarix* cone sedimentary veins to reconstruct the climatic and environmental element sequences in arid zones, this paper has summarized the author's and relevant scholars' research progresses in this study area. In the area with modern strong wind-sandy action, the clear *Tamarix* cone sedimentary veins have become an effective dating method, and a paleo-climatic and environmental information carrier. There are clear sedimentary veins within *Tamarix* cones in Lop Nor region that can be used for dating directly. For the age sequence establishment of the *Tamarix* cones with discontinuous clear sedimentary veins, it is necessary to comprehensively use various kinds of dating methods including ^{210}Pbex, ^{137}Cs, and ^{14}C and so on. The parameters of sand material, the content of organic carbon and nitrogen, positive ion, the value of stable hydrogen and oxygen isotopes, as well as the sporo-pollen assemblage contained in *Tamarix* cone sedimentary veins, have sensitive responses to the climatic and environmental change. Although the single climatic and environmental proxy can reflect climatic and environmental change to a certain degree, comprehensively to use multiple proxies contained in *Tamarix* cone sedimentary veins to research the regional climatic and environmental change is more effective and accurate.

Key Words: Climate, Dating, Environment, *Tamarix* cone

1. Introduction

In modern desert regions with strong wind-sandy actions, there are not so many traditional dating materials suitable to establish the high resolution age sequence of sediments in recent hundreds of years, such as tree rings, varved lake sediments, peat bog sediments, historical documents and so on. The specific *Tamarix* cone sedimentary veins, like tree-rings, can not only be used as a means of sedimentary dating with yearly resolution, but are also the effective carriers of paleo-climatic and environmental information in arid zones (Xia *et al*., 2004, 2005a).

The researched results show that the main processing steps are: on the basis of field survey, choose the typical *Tamarix* cones, take out the clear profiles, count the sedimentary veins, sample the sedimentary veins layer by layer, separate and pretreat the sand materials and organic matters of the samples; then by means of the corresponding equipment to measure the grain sizes of the sand materials, the C/N of organic matters, the positive ion contents, the stable isotopes, the pollen assemblage types, etc.; combined the counted sedimentary vein ages with the dating by ^{210}Pbex, ^{137}Cs and ^{14}C and so on of the marker sedimentary layers, establish the age sequences; making use of the observed meteorological and environmental data, establish the correlation model between them and the climatic and environmental proxies, and further reconstruct the changing sequence of temperature, precipitation, wind speed, atmospheric CO_2 concentration, etc.

In this paper, we have summarized the recent progresses in this research area in order to supply references for the relevant researches and the similar arid regions.

2. *Tamarix* and Its Distribution

Around the world, *Tamarix* includes more than 90 species that mainly grow in the old Continental temperate and tropical desert, semi-desert and grassland areas. In China, *Tamarix* includes 18 species and 1 variation. In Xinjiang, *Tamarix* accounts for 84% of the total species number in China, and especially is the richest in the southern Xinjiang (Yin, 2002).

Tamarix chinensis is a kind of deciduous shrub. The *Tamarix* cones distribute in groups in the southern region of Taklimakan Desert, both sides of the rivers such as Tarim River, Hotian River, Keriya River, Cheerchen River and Kongque River etc., as well as the ancient river courses and local lowlands in the desert area (Muhtar *et al*., 2002).

3. Formation and Structure of *Tamarix* Cone

Tamarix cones belong to a kind of shrub-coppice dunes formed by sand materials depositing around *Tamarix* plants in

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extreme arid zones. It is a specific kind of biological landform type in desert environments (Mu, 1993). The typical *Tamarix* cone is in a semi-circle or circular shape with 3-10 m height on the whole, the shape change of which is closely related to *Tamarix* physiological and ecological characteristics and its development stage (Muhtar *et al*., 2002; Li *et al*., 2010).

In the strong windy season of spring and summer, the sand materials carried by wind-sandy flows are obstructed by *Tamarix* plants, around which they land and deposit to form the sand sedimentary layers. In autumn and winter, because the wind speed lowers and the wind-sand actions decrease, the fallen *Tamarix* leaves form the litter layers (Muhtar *et al*., 2002). One sand sedimentary layer and one litter layer constitute a sedimentary vein. The time resolution of such sedimentary veins can reach to an annual level (Xia *et al*., 2004), *i.e*. if the sedimentary veins are clear, they may be counted by the naked eye as a dating method.

As early as the mid 1980s, scholars found that there are as many as 623 layers of *Tamarix* cone sedimentary veins in the Lop Nor region. A later investigation found that in some *Tamarix* cones there are even more sedimentary veins (Xia *et al*., 2004).

4. The Dating of *Tamarix* Cone Sedimentary Veins

About the formed ages of the *Tamarix* cones, as early as 100 years ago, Sven Hedin thought that the *Tamarix* cone can grow 10 m high every one thousand years. Huntington (1907) wrote that "I am sure that the *Tamarix* cones with 50-60 feet height have the grown history of 500-1000 years" (Xia *et al*., 2005b).

The ^{14}C (AMS) age of the 280th layer counted from the surface layer downward (corresponding to 280 a as dated by sedimentary vein dating method) of the sedimentary veins of *Tamarix* cone with 7 m height at the downstream of Damagou in Cele County of Xinjiang is 290±100 a. Based on the information from the archeological studies, the ancient Andier City in Minfeng County of Xinjiang was abandoned about 1000 years ago. In the ancient city gate, there is an 8 m high *Tamarix* cone with 800 layers of *Tamarix* cone sedimentary veins. The sedimentary vein dating method indicates that this *Tamarix* cone was formed about 800 years ago, *i.e*. the cone is formed after the ancient city is abandoned, and therefore, the human activities are stopped. The comparison between the counted results from sedimentary veins and the ^{14}C (AMS) as well as the archeological studies have verified the accuracy of the *Tamarix* cone sedimentary vein dating method (Xia *et al*., 2004).

In Lop Nor region, the dating results by means of *Tamarix* cone sedimentary vein dating method also correspond to the inferred age by ^{137}Cs and $^{210}Pbex$ (Zhao *et al*., 2011a). However, the researched results in the southern region of Taklimakan Desert show that the morphological structures of *Tamarix* cones have significant differences in different concrete positions, and not every *Tamarix* cone has the clear sedimentary veins suitable for dating. For the age sequence establishment of the *Tamarix* cones with discontinuous clear sedimentary veins, it is necessary to comprehensively use various kinds of dating methods including $^{210}Pbex$, ^{137}Cs and ^{14}C and so on. For example, by this method, the age sequences of *Tamarix* cone sedimentary veins at ancient Andier City of 1792-2010 A.D., Andier Meadow of 1600-2010 A.D. and Damagou of 1590-2010 A.D., in the southern region of Taklimakan Desert were established (Wang, 2013).

5. The Response of *Tamarix* Cone Sedimentary Veins to Climate and Environment

The grain-size of sand materials, organic carbon and nitrogen content, positive ion content, stable carbon and hydrogen and oxygen isotope values, as well as sporo-pollen assemblage contained in *Tamarix* cone sedimentary veins in arid zones, record the information of climatic and environmental change.

Zhao *et al*. (2007) revealed that grain-size parameters such as the grain-size, sorting coefficient, skewness value, and kurtosis value of sand materials in every Lop Nor *Tamarix* cone sedimentary vein are relatively consistent. The grain-size distributed curve, and the accumulated probability curve are also similar, which indicate that in about the past 150 years the climate and environment have not experienced dramatic changes. Zhao *et al*. (2011b) also qualitatively analyzed the climatic evolution process in Lop Nor region by means of the correlation between the TOC content, TN content, C/N value of the fallen *Tamarix* leaves, and the temperature and precipitation. Shen *et al*. (2012) found that there is a certain correlation between the change of K^+, Na^+, Ca^{2+} and Mg^{2+} contents in the fallen *Tamarix* leaves and the changes of the local climate, soil salinity, groundwater quality, underground water level, and Lop Nor water area, especially the Tarim River basin's flood in 1958. These are clearly shown in the changes of positive ion contents.

Zhao *et al*. (2011a) previously reconstructed the climatic elements such as the mean relative humidity from August to October, the mean wind speed from April to May, and the mean annual temperature in Lop Nor region since 1839 by means of the high-frequency change of $\delta^{13}C$ sequence of *Tamarix* cone sedimentary veins. The analysis of power spectrum indicates that the quasi-periodic oscillations of 42.0 a,

10.5 a, 8.4 a, 4.0 a, 3.4 a and 2.9 a are involved in the high-frequency information of $\delta^{13}C$ sequence. The quasi -periodic of 10.5 a reflects the active cycle of sunspots around 11 years.

Wang *et al*. (2011) previously reconstructed the climatic element change sequences in the past 160 years on the basis of the data of δD and $\delta^{18}O$. The results show that the variation amplitude of the minimum air temperature in March is less than 1°C. The change of the mean relative humidity from February to April exhibits a certain periodicity, but also exhibits an attenuating trend as a whole. In the time from about the 1930s to 1960s the precipitation in July is very low, but since the 1960s it has been increasing gradually.

Based on the data of the sporo-pollen assemblage of *Tamarix* cone, Wang *et al*. (2010) had divided the climatic change in Lop Nor region into 3 stages. During the period of 1839-1886 A.D. the climate is relatively cold-dry in the whole and has a trend ranging from the cold-dry to the warm-wet. During the period of 1891-1941 A.D., the climate changes alternatively between the cold-wet, the cold-dry and the warm-dry. During the period of 1946-2004 A.D., the climate has changed from the warm-dry to the warm-wet. Since the late 19th century, the pollen concentration has been reduced continuously with the aggravation of human activities.

Although the single climatic and environmental proxy may reflect the climatic and environmental change to a certain degree, it is more effective and accurate for the research on the regional climatic and environmental change to comprehensively use multiple proxies contained in *Tamarix* cone sedimentary veins.

By means of $\delta^{13}C$, C/N value of the fallen *Tamarix* leaves and thickness of the sand layer of *Tamarix* cone sedimentary veins, Xia *et al*. (2005a) qualitatively analyzed the climatic fluctuations in Lop Nor region from 1871 to 2001. He postulates that from 1871 to 1926 the climate is cool and dry, and the wind-sandy action is violent; from 1927 to 1967, it is a little cold and dry, and the fluctuation is obvious; from 1967 to 2002, it is relatively warmer with more precipitation. The climate in Lop Nor region has changed from the relatively dry to the relatively wet in about 100 years.

The contents of TN, K^+ and Na^+ in the fallen leaves of *Tamarix* cones have a positive correlation with the mean temperature from June to August. The values of $\delta^{13}C$ and TOC are negatively correlated with the mean air relative humidity from September to October, and the contents of K^+, Ca^{2+} and Mg^{2+} are positively correlated with it. There is a poor correlation between all the climatic proxies and the total precipitation in the time from June to August in Lop Nor region. Based on the chosen significant correlation factors, Sun *et al*. (2013) reconstructed the mean temperature sequence from June to August, and the mean air relative humidity sequence from September to October. The reconstructed mean temperature sequence in Lop Nor region in the period from June to August in the past 160 years can be divided into four warmer stages and three colder ones. The reconstructed mean precipitation sequence from September to October has three drier stages and three wetter ones, and are divided into the cold-warm and dry-wet climatic periods during the same time.

Making use of the method of correlation analysis, Zhao *et al*. (2012) revealed the correlation between the occurrence of extreme climate events and the extreme data of various environmental proxies including the sand layer thickness, positive ion content, C/N, $\delta^{13}C$, δD and $\delta^{18}O$ of the fallen *Tamarix* leaves and so on, and analyzed the age sequence of the past extreme climatic events and their influencing factors in Lop Nor region during about the past 160 years. The influencing factors on the extreme climatic events mainly include the El Nino phenomenon, the Indian Ocean Monsoon Circulation, and the Westerlies. The Qinghai-Tibet Plateau has also the ability to strengthen or weaken the above factors' effectiveness.

At present, the research of the climatic and environmental change by means of *Tamarix* cones in the southern region of Taklimakan Desert are well underway, and some climatic and environmental proxies such grain-size, C/N, $\delta^{13}C$, sporo-pollen assemblage have been analyzed. The preliminary analyzed results show there is a better correlation between the climatic and environmental proxies and the climatic and environmental elements.

6. The Future Development Trend of *Tamarix* Cone Research

In Lop Nor region, it is necessary to further research the correlations between the growth status of *Tamarix* and the salt water condition in order to: determine the ecological water use, and to provide basic data for ecological restoration measures; to estimate the source of precipitation and their proportion by means of stable hydrogen and oxygen isotopes; and to quantitatively evaluate the degree of land desertification based on the information contained in *Tamarix* cones.

The research focuses on *Tamarix* cone sedimentary veins in the future also include: the universality of generalizing from *Tamarix* cone to other plant cones; the feasibility generalizing from Lop Nor region to other arid regions; and the operability of generalizing from modern plant cones to the old ones.

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