Extended abstract No. 306

# PEATLAND ARCHIVES OF HOLOCENE VOLCANIC ERUPTION IN RESPONSE TO CHANGES OF PALEOCLIMATE IN NORTHEAST CHINA

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## SUMMARY

Two layers of Holocene volcanic ash have been discovered in Northeast, China. Combined with the $^{14}C$ dating data of peat cellulose, using the age-depth modeling, the age of tephra layers have been calculated. The analysis of characteristics petrographically and the geochemical composition indicates that one layer of tephra is from the Long-gang volcano group in 2002–1976a B.P. (Calibrated age); another layer of tephra is probably from Towada (Japan) volcanic eruption in 8352±76–9604±80a B.P. (Uncorrected age). Compared volcanic eruption events in $\delta^{18}O$ and $\delta^{13}C$ curves of peat cellulose, the results show that peatland can conserve Holocene widely volcanic eruption events, and these eruptions responded to the minimum temperature and humidity. Therefore, it is a feasible method to analyze the relationship between the climate changes and volcanic eruptions which are recorded in peatland.

KEY WORDS: Peatland; Volcanic eruption; Tephra; Paleoclimate; Northeast China

## INTRODUCTION

Volcanic eruption is one of the important impact factors for Holocene climate change (Simkin and Siebert et al., 1981) just like orbital forcing, solar activity and greenhouse gas. Volcanic ashes and gases have significant impact on climate because they can participate in the atmosphere circulation and change the air composition, even though they can prevent the solar energy into atmosphere (Reginald E., 1981). Research shows that the "parasol effect" can decrease the global average temperature by 0.5 ℃ for a great strong volcanic eruption injected into the stratosphere and covered the whole world during half or one year, and can affect sea surface temperature and El Nino greatly(Li and Sun et al., 1990; Farmer and Cloy et al., 2006). The tephra from a large-scale explosive volcanism of Changbaishan volcano possibly in the 10th century has been found in northern Japan and the Sea of Japan(Machida and Moriwaki et al., 1990). Peatland is normally formed in the Quaternary, especially in the Holocene. As the sediment, it is a particularly good medium for trapping and preserving tephra. When tephra is deposited on the surface of a bog, it is retained and incorporated into the peat mass as the bog grows. Scientists use the climate proxy from peat to estimate past climate conditions and reconstruct paleoenvironment. In recent decades, Scientists obtain a lot of information about paleoclimate proxies from peat land such as plant macrofossils, peat humification, testate amoebae and non-pollen palynomorphs(Chambers and Booth et al., 2011). However, scholars have paid little attention to the volcano ash in peatland, and a minatory of them analyzes the relationship between the climate changes and volcanic eruptions which are recorded in peatland. This paper attempted to explore the relationship between volcano and climate by comparing the volcanic eruptions to climate change which recorded in peatland archives.

## MATERIALS AND METHODS

### Sample site

Jinchuan and Hani peatlands are located in Northeast China (Fig.1), where distribute in a large number of volcanoes, and most volcanoes have erupted in Holocene. The Jinchuan peat is from the largest local dry Maar with the basement elevation 700m and nearly circular area of 0.85 $km^2$. The thickness of peat is 4-5 m in general, while some place can get 10 m. The sand layer is about 4cm thickness, and the depth from ground is 252-255 cm. Hani peatland with depth 10 m is the largest peat deposit in Northeast China, whose development is through Holocene. The sand layer is about 25 cm thickness, and the depth of tephra is 601-625 cm from surface. These two sample sites are typical peatlands, which can be the archives of Holocene volcanic eruptions.

### Extraction of tephra

We use two methods to obtain the tephra from these two different sample sites. The samples from Jinchuan peat were transferred into a plastic beaker, adding 0.1Mol/L NaOH 100 ml, approximately, and placed under a constant temperature about 70 ℃ to disperse so that the humic-acid in peat sample was dissolved. Then most of the plant materials were singled out firstly, and the samples were filtrated by 120 mesh separating two groups of solid parts, while light plant residue seen on and underside the sieve were removed. Light plant residue, solid parts were cleaned with some quantity of dilute HCl to neutralize unnecessary NaOH, followed by repeat clean with de-ionized water, yet there were some plant residue left in samples. Consequently, two groups of samples were baked for 2h at a low temperature (<500 ℃), then two residue were received. The samples from Hani peatland were disaggregated in a large flask with 30ml of $HNO_3$, and then 50 ml of concentrated $H_2SO_4$ were added. A fume extracting hood was secured over the flask, the mixture heated to boiling point and simmered for about

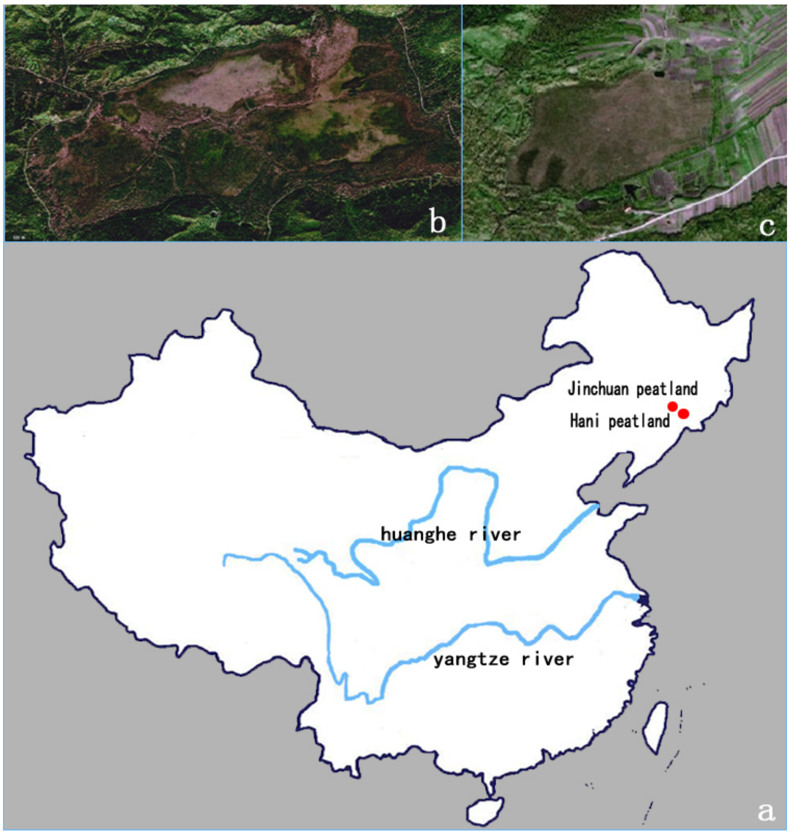



Figure.1 Jinchuan and Hani peatlands. a. Map of China showing the location of Hani and Jinchuan peatlands b. The remote sensing imagine of the Hani peatland (42°13'N, 126°31'E) c. The remote sensing imagine of the Jinchuan peatland (42°20'N, 126°22'E) The remote sensing imagines are from website http://www.tianditu.cn/map/index.jsp

an hour, or until the contents of the flask turned colorless, or pale yellow. After cooling, 500 ml of distilled water was added and allowed to stand for three hours. The liquid and any very fine particles still in suspension were then poured away. The washing process was repeated, then the residue pipetted into small tubes, dried and stored in acetone (Dugmore, 1989). After the processing, the extracted tephra was observed and analyses in microscopes.

## Age-depth modeling

A widely used basic age-depth model is linear interpolation between the dated levels (Bennett, 1994). Scientist summarized that Age-depth models are more ecologically plausible and that take into account likely modes of peat accumulation, include (1) linear accumulation (2) concave curves (3) convex curves and (4) Bayesian models that can include prior information on stratigraphy, accumulation rate and variability, and/or detect outlying dates(BLAAUW and CHRISTEN et al., 2010). We assume that when tephra is deposited on the surface of a bog, it conforms to this model. According to the depth of the tephra layer in peat core, we refer to the $^{14}C$ chronology from Jinchuan and Hani peatlands cellulose(Hong and Jiang et al., 2000;

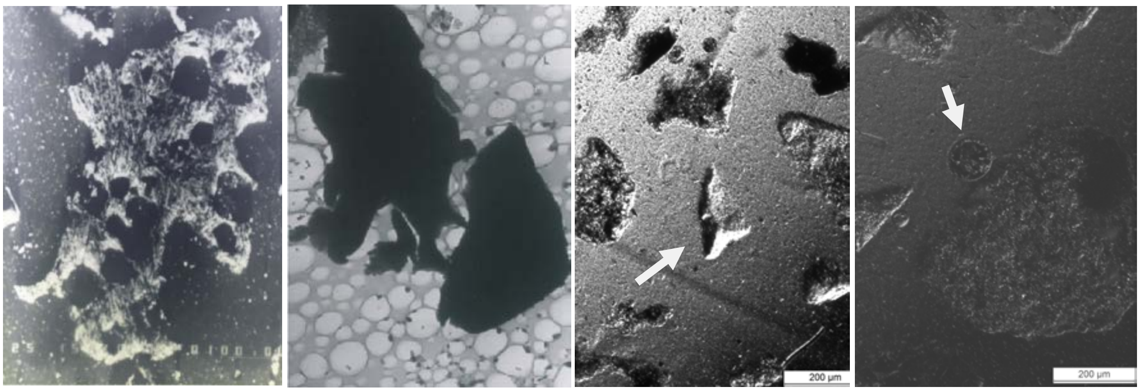
Hong and Wang et al., 2001; Hong and Liu et al., 2009) , and volcanic ash layers have been traced, the age of Jinchuan tephra layer can be calculated to 2002 a B.P.–1976 a B.P. (Calibrated age) and the age of Hani tephra layer is 8352±76 a B.P.–9604±80 a B.P. (Uncorrected age).

RESULTS

These two layers of sand looked like slag with surface bubbles and pits, high porosity, and loose structure, and particle size range was 0.1 to 0.5 mm with irregular edges and corners, observed with optical microscope, electron microscope and polarizing microscope. The sand samples were mainly composed of by the crystal glass and debris, glass debris, the rest were glassy feldspar, pyroxene and ceramic or crystal quartz; and so much volcanic glass was found under electron microscope and polarizing microscope (Figure 2). Therefore, these samples can be identified as tephra.

Jinchuan and Hani peatlands are near to four active volcano groups: Changbaishan volcano, Longgang volcanic group, Wudalianchi volcano group and Jingpohu volcano. Therefore, it was possible that the tephra fell into these peatlands and deposited. We analyzed the geochemical composition of Jinchuan tephra. It shows that the tephra geochemistry from Jinchuan peatland is quite same to the Longgang Jinlongdingzi volcano and come from alkaline basaltic magma, with their content of $SiO_2$ under 55%, same content to $Al_2O_3$ and Fe, so as to $Na_2O$ and $K_2O$, and $Na_2O$ more than $K_2O$(Table 1). We speculated the tephra of Jinchuan came from Longgang volcano group. Based the age-depth modeling we obtain eruption age the of Hani tephra, which is from 8352±76 a B.P.–9604±80 a B.P, but there is no evidence of volcanic eruption in China in this period. We compared this eruption event to the sequence of volcanic eruption from the database of The Global Volcanism Program. Through the indexes such as Distance and Volcanic Explosivety Index, we speculated the 25-cm thick tephra of Hani peatland came from Towada (Japan) volcanic eruption.

A lot of geological evidence reflects the Holocene temperature decrease was closely related to the volcanic eruption, some scientists suggested volcanic eruption was one of main reasons for the last glacial in Holocene(Simkin and Siebert et al., 1981). Comparing a series of East Asia volcanic eruption events in $\delta^{18}O$ and $\delta^{13}C$ curves of peat cellulose from Jinchuan and Hani peatland (Figure.3), we choose 15 volcanic eruption events whose Volcanic Explosivety Index is not less than 4 (When the volcano's VEI reaches 4 and above, that means the tephra can rise up to troposphere and participate in the atmosphere circulation.) and these volcanic eruption events correspond to the minimum points and inflexion of the curves. It seems that these volcanic eruptions indeed affect the local or global climate, making the regional temperature and humidity decreased and forming cold and dry weather, and all these changes can be recorded in peat.




(a) (b) (c) (d)

Figure.2 Petrographically characteristics of tephra. (a), (b) are from Jinchuan peatland; (c), (d) are from Hani peatland; (a) loose structure and obvious pore of crystal glass observed with optical microscope; (b) typical volcanic glass observed with electron microscope.(c) typical volcanic glass shard observed with plane-polarizing microscope.(d) typical vesicular texture observed with plane-polarizing microscope.

Table 1 Chemical compositions of tephra in Jinchuan peatland and Longgang volcano

| Chemical elements | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jinchuan peatland | 50.35 | 3.68 | 15.44 | 12.76 | | 3.97 | 6.71 | 3.73 | 2.73 | | 99.37 |
| Longgang volcano | 46.81 | 2.48 | 16.1 | 9.25 | 0.2 | 7.34 | 8.08 | 3.48 | 2.2 | 0.5 | 97.47 |

## CONCLUSION

Two sections of sand were identified as tephra layers from Jinchuan peatland and Hani peatland in Northeast China, for the gains looked like slag with surface bubbles and pits, high porosity, and loose structure with irregular edges and corners. According to the peat characteristics of uniform deposition, using the age-depth model, volcanic ash layers have been traced, the age of Jinchuan tephra layer can be calculated to 2002 a B.P.–1976 a B.P. (Calibrated age) and the age of Hani tephra layer is 8352±76 a B.P.–9604±80 a B.P. (Uncorrected age). While the tephra geochemistry from Jinchuan peatland was quite same to that of Longgang Jinlongdingzi volcano and came from alkaline basaltic magma, with their content of $SiO_2$ under 55%, same content to $Al_2O_3$ and Fe, so as to $Na_2O$ and $K_2O$, and $Na_2O$ more than $K_2O$. We speculated the tephra of Jinchuan peatland came from Long-gang volcano group. Based the sequence of Holocene volcanic eruptions in Asia which is from The Global Volcanism Program, we speculated the tephra of Hani peatland is probably from Towada (Japan) volcanic eruption.

The sequence of volcanic eruptions has been established in East Asia during Holocene by a series of recorded volcanic eruptions. Comparing these eruption events in carbon and oxygen isotopes curves of Jinchuan and Hani peat cellulose, we found that the neighboring or large scale volcanic eruptions responded to the minimum temperature and humidity. The results show that peatland can conserve Holocene widely volcanic eruption events, and these eruptions can cause the regional climate change, temperature and humidity decrease. Therefore, it is a feasible method to analyze the relationship between the climate changes and volcanic eruptions which are recorded in peatland.

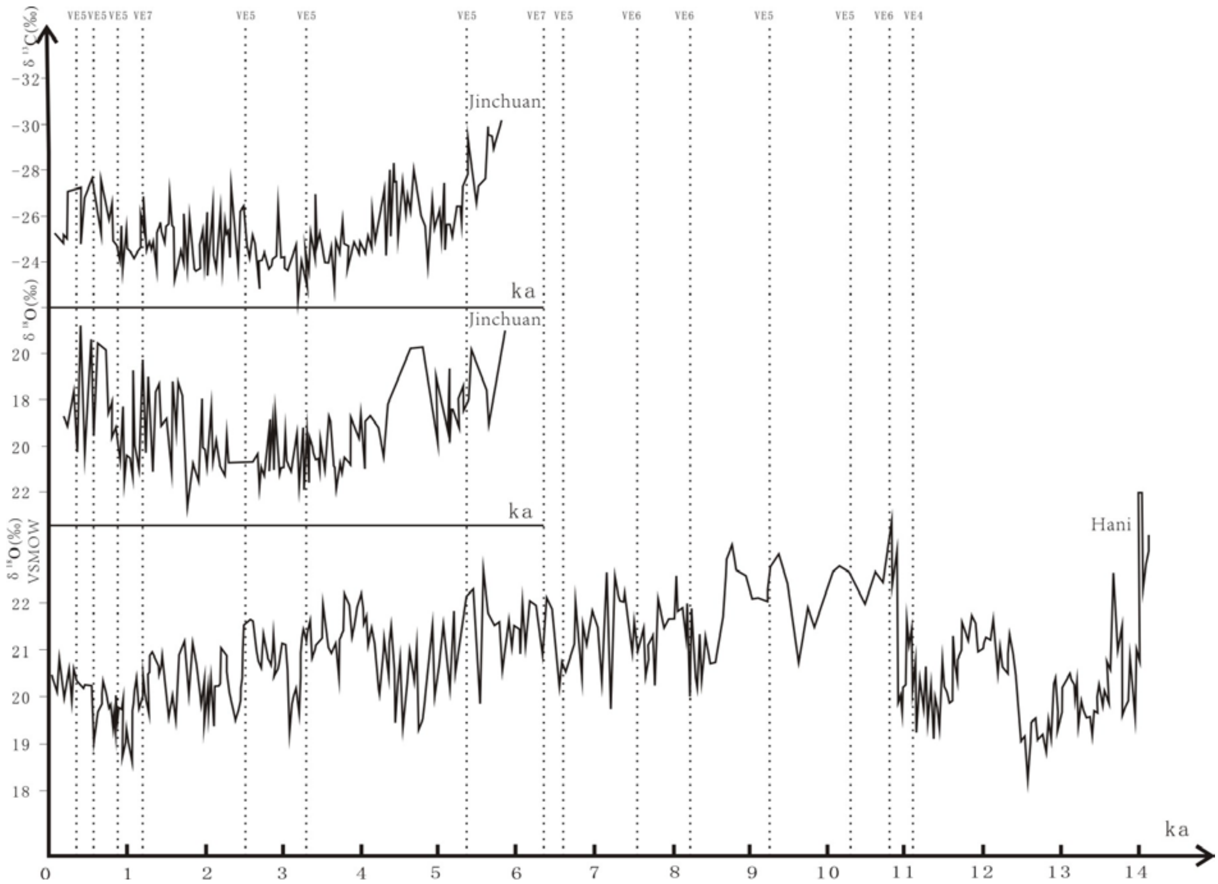



Figure.3 Comparing East Asia volcano eruptions to the δ 18O and δ 13C curves of peat cellulose. The data of volcanic eruption is from Smithsonian Institution, Global Volcanism Program;The $\delta^{18}O$ and $\delta^{13}C$ curves are from references Hong and Jiang et al., 2000; Hong and Wang et al., 2001; Hong and Liu et al., 2009

ACKNOWLEDGEMENTS

This work was financially supported by the National Natural Science foundation of China (Grant No. 41072023).Thank you PhD Jiang Xing-fu from Three Gorges Research Centre for geo-hazard for his helps in Polarizing microscope.

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