6th International Maar Conference
July 30 - August 3, 2016, Changchun, China

A Guidebook for Pre-conference Field Trip to Aershan-chaihe Volcanic Field

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July 28 – 30, 2016

1 General Information

Transportation

It is the participants' responsibility to arrive at Aershan (Arxan) airport (Figure 1) in the morning of July 28 (the officially scheduled early morning flight from Beijing to Aershan airport on July 28 is OK). The trip starts with assembly at the airport in the morning, and includes a two-night stay in Chaihe town. In the morning of the third day, all the participants leave Chaihe town for Qiqihar train station by bus, then travel to Changchun by high-speed train, and then ride on a shuttle bus to the conference center.

Breakfasts, Lunches, Dinners, Drinks & Snacks

Breakfasts will be provided by either the organizer with box meal or the hotel. Lunches will be arranged in reserved restaurants or be supplied as box lunches during the field trip. Dinners will also be arranged by organizers of the trip. Bottled mineral water, drinks and snacks will be supplied during breaks of the field trip.

Weather & Clothing

In late July, it often rains in the Aershan-Chaihe volcanic field. We recommend that umbrellas/raincoats are necessary items to be carried with you. Long-sleeved shirt is OK for sunny days but jacket is recommended for early morning, night and occasionally raining days. Sneakers and long pants will be OK. T-shirt and short pants are not recommended. Mosquito protect lotion might be needed.

Safety, Insurance & Responsibility

Liability insurance is the responsibility of each individual. Participants should have their own medical coverage. The organizing committee assumes no responsibility for accident, loses, damage, delays, or any modifications to the program arising from unforeseeable circumstances.

Help & Emergency Contact

Whenever helps are needed, the supervisor and guiders can be reached through the following ways.

Dr. Qiang Liu
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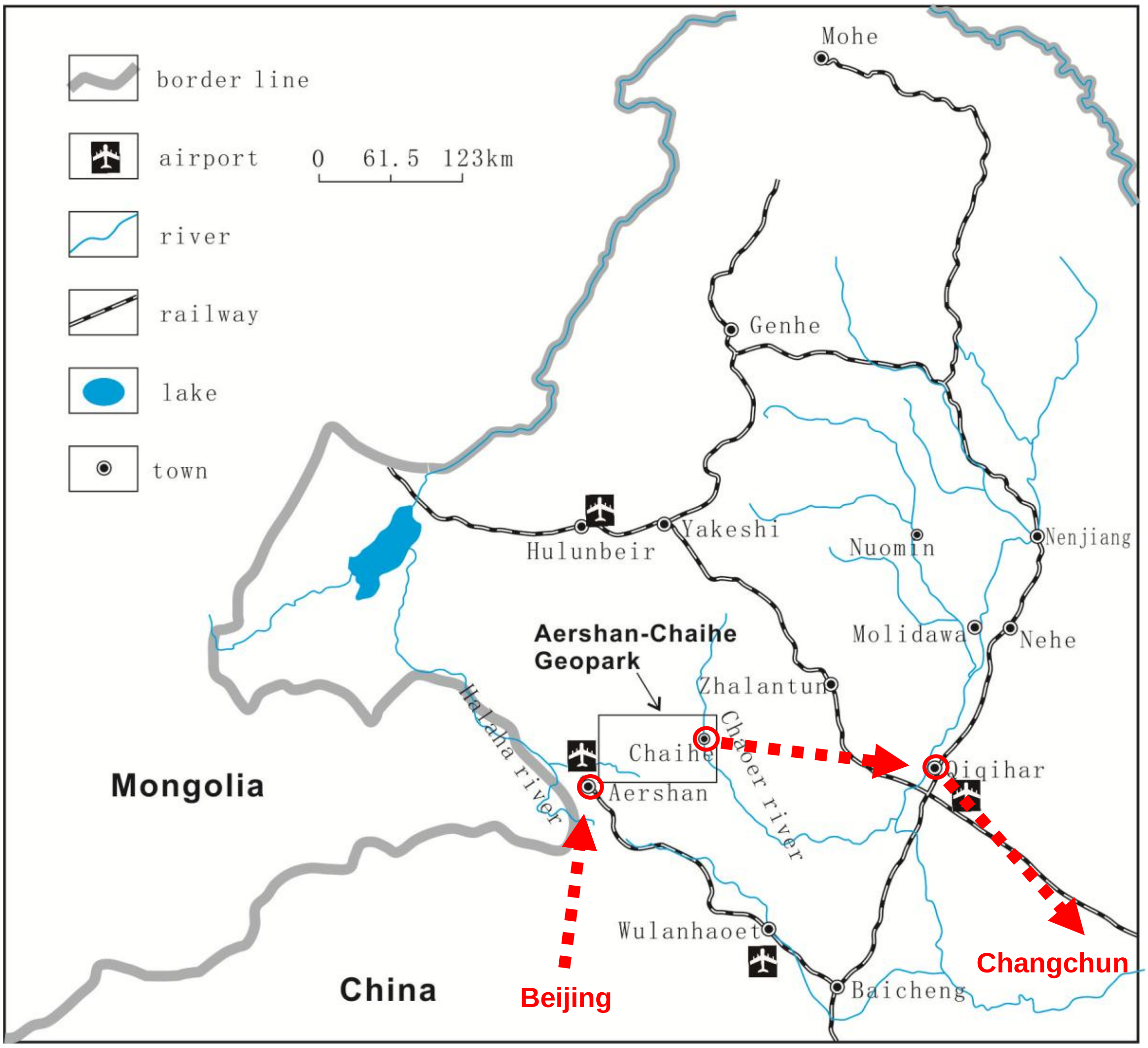

Figure 1. Map showing the location of the Aershan-Chaihe volcanic field/geopark and major travelling route of the trip.

2 Route and Timetable

The whole pre-conference field trip to the Aershan-Chaihe volcanic field is planned from Aershan airport to the conference center in Changchun with a three-day duration of July 28-30.

DAY 1 --- (July 28, 2016, Thursday)

09:40-10:00	Assembly of all the participants at the front of Aershan airport.
10:00-12:00	Bus travel from Aershan to Tianchi Town, then to **Stop 1**: phreatomagmatic eruption deposits—base surge deposits.
12:00-12:30	**Tianchi Service area-Stop 2**: in the course of bus driving, enjoy the road-side view: volcanic landforms –rugged scoria lava landscape, “stony land forest”.
12:30-13:00	**Stop 2**: swarm of tumuli.
13:30-14:30	Lunch in Xing’an Town.
14:30-14:40	**Stop 3**: “turtle rock” and pahoehoe land surface nearby Xing’an town by walk.
14:40-15:30	**Stop 4**: Dujuan lake (lava dammed lake), hornitos.
15:30-17:00	**Stop 5**: Tuofengling crater lake and welded agglomerate; beer/drinks break possible.
17:20-18:00	**Stop 6**: Great Canyon of fragmented basalt.
18:00-19:00	Travel from Tuofengling to Chaihe Town; road side viewing: columnar jointed basaltic mountain.
19:00-19:30	Settle down in the hotel.
19:30	Dinner time.

DAY 2 --- (July 29, 2016, Friday)

08:30-11:30	**Stop 7**: Woniupao volcanic lake; Phreatomagmatic eruption deposits near the lake.
11:30-12:00	**Stop 8**: columnar jointed basalt exposure, “Water-Rock Fresco”.
12:00-13:00	Back in hotel and lunch time.
13:00-14:30	**Stop 9**: site visit of Heixiadong (Black Bear Den) Volcano.
15:00-16:00	Visit of the Chaihe Volcanic Museum and tea/coffee time, then end-up of the day.
17:30	Dinner time.

Alternative:

08:30-13:00	**Stop 10**: visit of Moon Lake; on the road of bus returning to Chaihe for lunch, 10min will be given for watching of Heixiadong volcano (Stop 9) but no time for climbing.
13:00-14:00	Lunch time.
14:00-17:00	**Stop 7**: visit of phreatomagmatic eruption deposits near Woniupao crater lake.
17:00-17:30	**Stop 8**: columnar jointed basalt exposure, “Water-Rock Fresco”.
18:00	Dinner time.

DAY 3 --- (July 30, 2016, Saturday)

06:30-07:00	Breakfast in the hotel.
07:00-11:00	Travel by bus from Chaihe town to Qiqihar train station.
11:00-12:00	Buying train tickets, lunch time.
12:47-16:00	Boarding on Train D30 (Qiqihar-Changchun).
16:20	Boarding on the shuttle bus to the conference center.

3 Regional Geology Outline

The Aershan (Arxan)-Chaihe volcanic field (ACVF)，located in the middle of the Great Xing’an Range, is a Quaternary volcanic field in the north of the North-South Gravity Lineament in eastern China (Figure 2)．34 Quaternary volcanoes scatter in the Halaha River and Chaoer River area, forming a general NE-trending belt. Quaternary volcanic rocks in this area, mainly alkaline basalt, cover an area of ca. 400 km^2. Both magmatic eruptions and phreatomagmatic eruptions are found in this area. The magmatic eruptions formed cinder cones, tephra fallout deposits, and many kinds of lava (e.g. aa lava, pahoehoe lava and block lava). Typical fumarolic cones and lava hillocks are found in the lava flows. The phreatomagmatic eruptions generated typical base surge deposits, which are characterized by parallel bedding and staggered bedding structures of the deposits.

Based on the volcanic field characteristics, in conjunction with geological dating by K-Ar, the Quaternary volcanism in the region occurred in four periods: early Pleistocene, middle Pleistocene, Late Pleistocene and Holocene. Basalts of the Early Pleistocene, mostly mantled by the later volcanic rocks, are distributed in the margin and valleys of the volcanic field. The Middle Pleistocene, the most volcanic-active period in this area, witnessed the formation of more than half of Quaternary volcanoes and lava flow fields. Moderate volcanism occurred in the Late Pleistocene which produced a small amount of volcanic deposits. Volcanic activities are strengthened again in the Holocene Period, characterized by strongly explosive eruptions, widespread lava flow with well-preserved typical lava surface structures.

One of the most remarkable features in the ACVF is the interplay between water and fire, i.e. lava and superficial water. The ACVF is located in the western piedmont of the Great Xing'an Range. Relatively abundant rainfall and low temperature/ low evaporation rate facilitate the development of forest cover in this area. It is just in this very watery environment, volcanoes came up and created spectacular scenes. When ascending magma met shallow aquifers, violent explosive eruptions generated tuff rings and tuff cones. While the lava flow encountered a river, it reshaped the river channel, and some special volcanic scene occurred in the lava flows, such as fumarolic cones/hornitos and lava hillocks/tumuli. Additionally, volcanic activity in this area created many volcanogenic lakes. According to their origins, they are classified into four types: crater lake, maar lake, volcanic dammed lake, and collapse lava lake. Finally, when volcanic eruption subsided, deep water interacted with the underneath magma, making Aershan well-known as a warm springs geopark. In all, two conflicting factors, water and fire, coexisted and worked together, creating a great variety of unique landforms in the Aershan-Chaihe Volcanic field.

For deeper insights into the petrogenesis and magmatic evolution of the ACVF, systematic studies of petrogeochemistry and isotopes for the volcanogenic rocks have been conducted particularly in recent years. Integrated results indicate a quite homogenous composition of all the Quaternary (2.0 Ma-Holocene) volcanic rocks in the ACVF (Figure 3) that resemble MORB source with a low degree partial melting (8-15%) of garnet peridotites mantle, no matter they were erupted from different localities/volcanoes and different ages, thus suggest a same magma source domain for the entire Great Xing'an Range (both west and east flanks). Also, the low SiO_2 content (48.90–51.47wt.%) and low $^{87}Sr/^{86}Sr$ (0.7034–0.7041) and abundant xenoliths (olivine, garnet) suggest a rapid ascending of the magma with little crustal assimilation/contamination. In contrast, Late Miocene (10.5–8.0 Ma, Figure 3) erupted basalts tens of kilometer away from the ACVF are more andesitic, have higher SiO_2 content (55.7–59.2wt.%) and $^{87}Sr/^{86}Sr$ (0.7053–0.7067), and rarely contain xenoliths, all of which imply a slower ascending of the magma and a contribution of crustal contamination, or a different magma source. These changes are possibly in response to the episodic evolution of the geodynamic forcing/ asthenosphere convection occurred in the west Pacific-east Eurasian plate margin after cessation of the Japan Sea spreading.

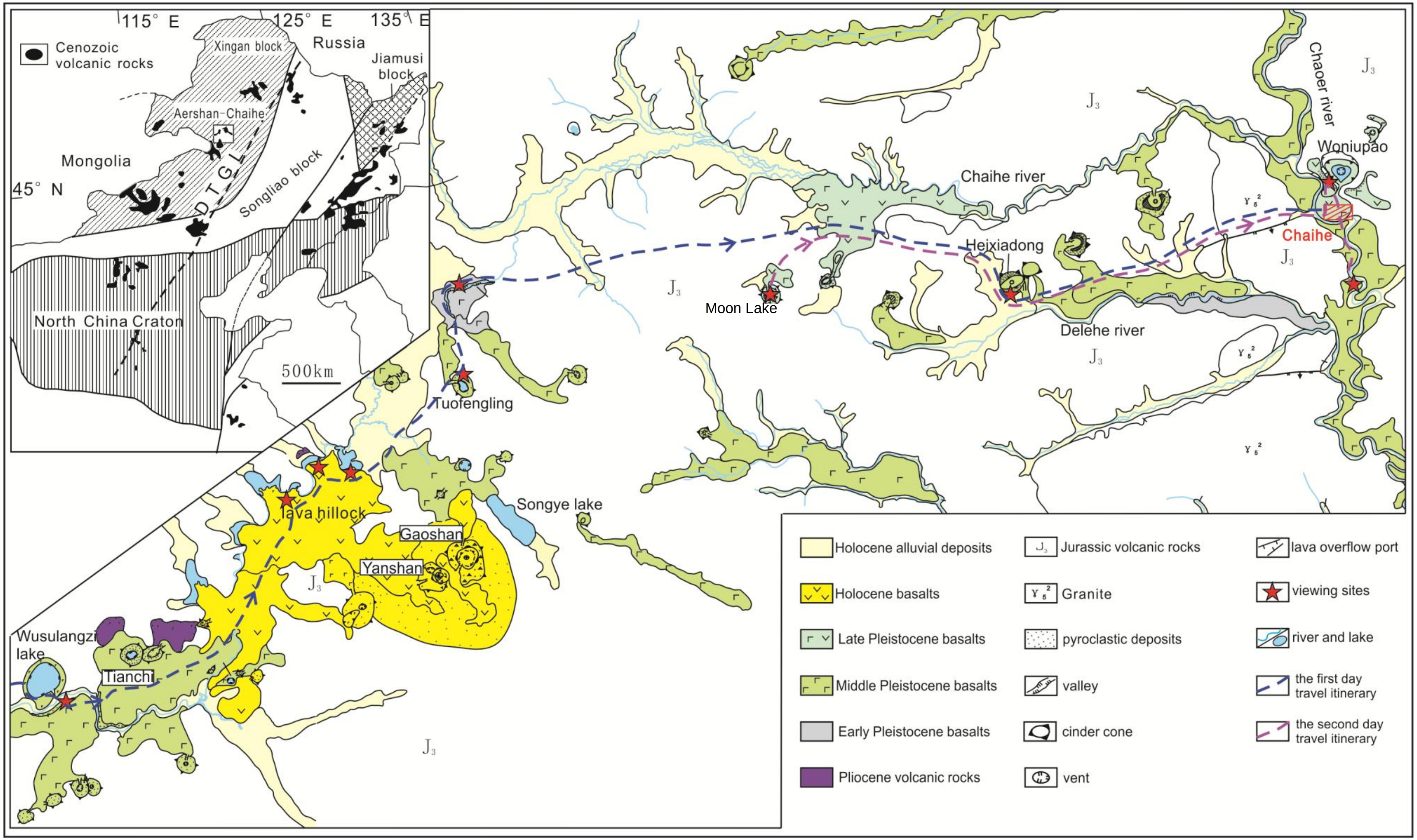

Figure 2. Volcanic geology map of the Aershan-Chaihe volcanic field and the viewing site locations of the trip. For detailed chronological data see Table 1.

Table 1. Chronological data of the Aershan-Chaihe volcanic rocks relevant to the trip.

Sample location*	dating material	age (Ma)	method
Wusulangzi lakeside	basalt	0.45	K-Ar
NonfreezingRiver	basalt over base surge depst	0.587	K-Ar
NonfreezingRiver	basement basalt	6.7	K-Ar
Yanshan	charcoal	0.002	^{14}C
Gaoshan	lava	0.126	K-Ar
Tuofengling	volcanic rock	0.246	K-Ar
Great Canyon	basalt	2.30	K-Ar
Moon Lake	volcanic rock	0.743	K-Ar
SW Woniupao lake	lava	0.162	K-Ar

*the name of the Sampling location can be found in the geology map (Figure 2).

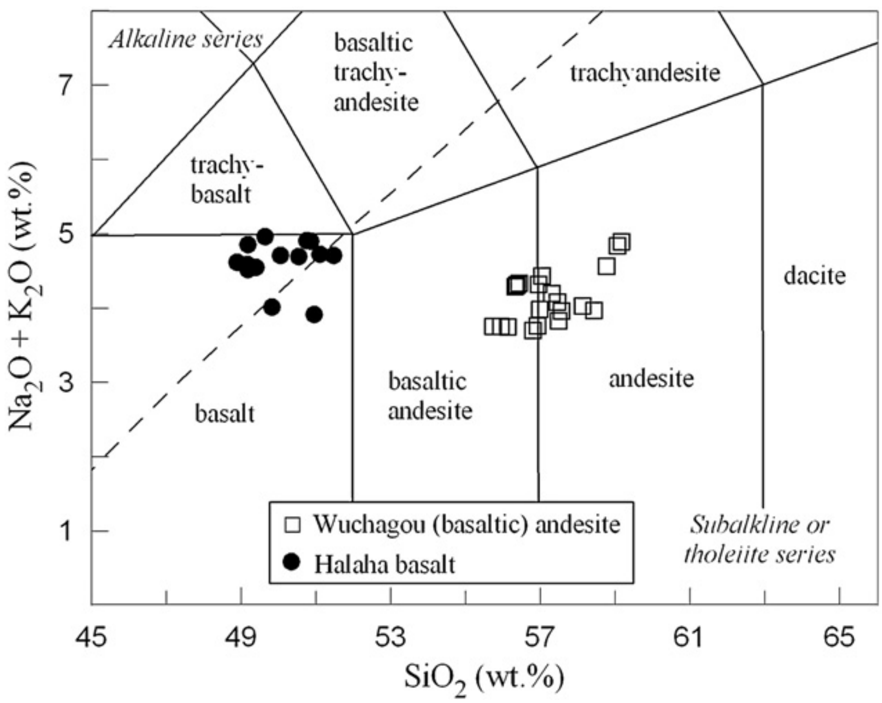

Figure 3.Total alkali vs. SiO_2 diagram for late Cenozoic volcanic rocks in the ACVF (solid circle, 2.0 Ma to the Holocene) and an adjacent volcanic area Wuchagou (open square, 10.5 - 8.0 Ma).

4 Introduction to Viewing Sites

Stop 1: Base surge deposits on the terrace of the Nonfreezing River near Tianchi Town

At this stop, we will see a well exposed phreatomagmatic/ base-surge pyroclastic deposit. Abundant thin parallel beddings and cross-bedding layers occur in the section, and a dense lava layer topped these sediments (Figure 4). These deposits are commonly supposed to be originated from eruption of the Wusulangzi lake, a late-Cenozoic volcanic lake or a residue of an ancient maar, but it is still in debate about the location of the maar vent. The diameter of the lake is about 1400 meters. A series of base-surge deposits sections outcropped on the south of the Wusulangzi lake, but more accurately, on the river terrace of the Halaha river tributary (= Nonfreezing River). There is, however, no strong evidence to link these base surge deposits to the Wusulangzi lake.

Figure 4. Phreatomagmatic deposit on the Nonfreezing river terrace near Wusulangzi lake.

Road side viewing: aa lava flow landform with forest, “Shi Tang Lin”

Along both sides of the road, you can see vast and spectacular landforms of scoria lava with rugged relief, spanning tens of kilometers in length and width and covering hundreds of square kilometers in area (Figure 5). The local people call it “Shi Tang Lin” in Chinese, which means forested stony land/sea, or forested lava platform. There are countless ponds and rugged scoria lava hills/edifices constituting a fantastic volcanic realm. The dominant opinion on the formation of this landscape is that hot lava flew into a wetland where numerous swamps and lakes were widely distributed making vigorous interactions between vaporized water and the lava, and produced irregular shaped scoriae. Because of the very young age of the eruption (2000 years ago), little soil has developed on the lava surface. Today, only larch (*Larix gmelinii*) and dwarf pine (*Pinus pumila*) thrive as the dominant species of the forest. Azalea (*Rhododendron dauricum*) is probably the most notable species of shrubs that blooms with a brilliant pink color in springtime.

Figure 5. Typical aa lava flow surface with mild forest, "Shi Tang Lin".

Stop 2: Tumuli/lava hillocks

Among the scoria lava sea/stony land forest, bunches of tumuli formed another wonderful scene of lava surface, and are easily accessed along a recently constructed tourist track. They are commonly in a round mound shape, a few meters high and 5-10 meters in diameter (Figure 6).

According to K. Németh et al. (in press), the presence of lava tumuli is a good indicator to the zone on the lava flow where the speed of the lava flow was slow enough to generate sufficient lava crust to solidify, and have lava flow inflation to be relatively steady to maintain pressure increase to lift and partially crack the continuously forming crust. Such situations commonly achieved when a lava flow exits from a narrower valley to a confined basinal region where the slow speed decreases by the decrease of the emplacement slope angle, or when the flow course has a sudden change due to some morphological obstacles. However, some research addressed a contribution from interactions of hot lava with ground surface water, and believed that tumuli tend to form in areas where the lava flow entered to a wet, swampy land or to a shallow lake. It is interesting to notice, as we will see, that all the tumuli have a circular shape at their basal margins. Therefore, any solution/hypothesis on the formation of these tumuli should be able to provide a dynamics of the lava flow that is required for the circular shape.

Figure 6. Tumuli/hummocky lava rises in the scoria lava forest of the ACVF.

Stop 3: Turtleback lava/pahoehoe land surface

"Turtle-back" lava surface structure and pahoehoe features are well-preserved and can be observed near the Xing'an (= Hinggan) town (Figure 7). They commonly appear with a smooth surface and with a diameter of 2 to 3 meters. Together with pahoehoe feature, these surface textures indicate a low viscosity of the lava. The surface may contain strips and elongated bubbles in the pahoehoe that were formed by stretching during the lava flowing, which can be used to identify the direction of the lava flow. In the smooth-surfaced lava field, there are numerous rises and pits with irregular shapes, suggesting the presence of some lava flowing passages/tubes underneath the solidified lava crust. On the vertical exposures of the lava pits, there are multiple layers of the lava flow, and their thickness varied from 2 to 10 m. Each of the lava flow unit commonly has a loose-structured surface crust and a dense lower part with rare gas bubbles, which again suggests low viscosity of the lava flow.

Figure 7. Turtleback structured lava surface near the Xing'an Town.

Stop 4: Dujuan lake (lava dammed lake), hornitos/fumarolic cones

On the western side of the Dujuan lake (a lava dammed lake along the Halaha river), a number of hornitos can be observed. They are commonly 1.5-3 m in diameter and about tens of centimeter to 1.5 m in height. Two major types developed in the area. One looks like a small volcano cone with imbricate (layered shingle/rubble) lava crusts (Figure 8, left).There is no obvious pahoehoe outside the hornito, suggesting that the lava melt inside the cone had been largely solidified before the opening of the cone by mild explosion/gas ejection, or due to insufficient pressure to break up the crust of the lava rise. Rather than a cone shape, another type looks like a mini-crater with a pahoehoe fringe ring which is also called fumarolic dish (Figure 8, middle, right), indicating the fluid nature of the lava spilling out the hornito after explosive opening at the top of the hornito.

Lava hornitos are also lava surface forms that are associated with low viscosity basaltic lavas. They form through a small opening on the solidifying lava surface. Through these holes the magmatic pressure fluctuation in the still hot, fluid and moving lava interior can split melt out to the solidified lava crust, gradually forming a lava flow. As the lava pressure accumulated, lava spattering can take place along these cracks. The cracks can form due to the mechanical stress on the solid lava crust caused by the still moving interior of the lava. Another, a popular explanation argues, however, that the formation of hornito is associated with the lava flow emplacement over shallow lakes and swamps due to the sudden steam generation by the heated water from the ground that entrap large pressurized vapor bubbles.

Figure 8. Hornito/fumarolic cone near Dujuan Lake.

Stop 5: Tuofengling volcano, maar/crater lake

The Tuofengling volcano is an elongated scoria cone. The maar/crater lake makes it a well-known scenic spot for the region (Figure 9). The base of the cone is made up of cinders and tuffs but on the top is a spatter cone composed of welded agglomerate. Abundant peridotite xenoliths (a few to tens cm in diameter) are exposed in the agglomerate, showing the fast magma ascending. The Tuofengling crater has a basement of 1000 m in diameter and a tephra ring wall with a maximal height of 204 m. The tephra ring around the crater is in a horse-shoe shape with steep wall in the north side and an opening northwestward. The crater finally evolved into the lake, about 800 m long and 450 m wide. A bathymetric survey indicates that the lake water has a maximum depth of 34 m in the southeastern side, but most part of the lake is less than 20 m deep. According to a recent study, the Tuofengling volcanic rock has a K-Ar age 0.25 Ma (Table 1), younger than the previous claim that the crater formed some 300 thousand years (0.3 Ma) ago.

The Tuofengling volcano is a typical volcanic cone example for the ACVF. More than half of over ten volcanoes in the area have similar volcanic eruption activity to the Tuofengling, i.e. a Strombolian eruption type. One of the distinguishing features of this crater is the elliptical shape, implying a fissure vent of the eruption.

Figure 9. Tuofengling maar/crater lake (quoted from Tian et al., 2009).

Stop 6: Great Volcanic Canyon

The Great (volcanic) Canyon is located on the headstream of the Chaihe river, it is about 11 km long and 30-130 m deep. Fragmented basalt covers entirely the valley slopes and the top of the terrace (Figure 10). There are a number of possibilities about its formation, such as local tectonic faulting, lava flow overlapping an ancient river channel, or collapse of lava flow tubes. Whatever were the mechanisms for the canyon formation, it is very interesting that large scale fragmented lava/basalt landforms is more common in the ACVF than in the other volcanic fields of China. What are the key processes involved in the well-developed fragmentation of basalts in the ACVF remains an open question.

Figure 10. Great Volcanic Canyon in the ACVF.

Stop 7: Woniupao volcano, maar/crater lake, base surge deposits

It is a late-Cenozoic volcanic lake. The pre-Quaternary volcanism made a large crater with a diameter about 2500 m. The latest volcanism in the Quaternary was dominated by phreatomagmatic eruptions in the crater lake (Figure 11). The base-surge deposits covered the area west of the volcano. We will see a series of base-surge sections with different characteristics, showing the transition from proximal-facies to distal-facies tuff deposits sections. Parallel-bedding, cross-bedding and climbing bedding are extremely abundant in these sections. Spinel-peridotite and garnet-peridotite xenoliths have been discovered in these pyroclastics.

Figure 11. Phreatomagmatic pyroclastic deposits outcropped in the Woniupao lake area.

Stop 8: Columnar jointed basalt on the valley cliff of the Chaoer river

On a cliff wall of the Chaoer river valley near Chaihe Town, the Cenozoic basalt with well-developed columnar joints is exposed by fluvial erosion. The jagged relief of the exposure sculptured by the fluvial processes incorporated with the distorted columnar structure of the basalt coupling its mixed colors due to differential alterations of ferrous minerals, presents a distant artistic vision of mural painting (Figure 12). For this, the local people give it a nickname “Water-Rock Fresco”.

Figure 12. Columnar jointed basalt in the Chaoer river valley, “Mural painting of landscape”.

Stop 9: Heixiadong volcano

Heixiadong (Black Bear Den) volcano is a scoria cone located 20 km from Chaihe town, and is famous for its red-brown lava flows and agglomerate beds of lava spatter (Figure 13). Volcanic bombs and blocks are abundant in these lava flows, similar to welded agglomerate. During the eruption, the welded agglomerate near the crater moved down slope onto the melt which was still hot and ductile, and finally formed a clastogenic lava flow.

Figure 13. Heixiadong volcano near Chaihe Town.

Stop 10: Moon Lake, a maar/crater lake

Lake Moon (47°30.360N, 120°51.990E, 1190 m a.s.l.), is a small closed crater lake (Figure 14), 40 km away from Chaihe Town. The volcanic cone was formed in Middle Quaternary (Table 1). The diameter of the lake is 220 m with a maximum water depth of 6.5m. At present, its surroundings are vegetated with dense conifer-deciduous broadleaf mixed forests. With these characteristics, Moon Lake maintained a highly quiescent environment under which a laminated sedimentary sequence developed with little disturbance, thus provides a high resolution record of climate change for the northern margin of the East Asian monsoon regime. In recent years, a great effort has been made on paleoclimatic reconstructions of Moon Lake for the later Quaternary period (see attached copy of the first page of a research paper).

Note: Access of this site requires a long-distance and time-consuming (3 hours back and forth) walk with altitudinal climbing up of 272 m from the parking lot (the elevation of the parking lot is 961 m, and the viewing spot at 1233 m a.s.l.).This site visit is possibly subjected to cancel, depending on the weather, physical strength of the participants, etc. Instead, more viewing sites will be assigned near Chaihe Town. Sea alternative in the “Route and Timetable”.

Figure 14. Moon Lake in the Chaihe volcanic field.

Selected references

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Note:

Some references are presented below with their first pages, instead of listed above.

1000-0569/2008/024(11)-2569-75 *Acta Petrologica Sinica* 岩石学报

大兴安岭哈拉哈河—淖尔河地区第四纪火山活动初步研究*

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Zhao YW, Fan QC, Bai ZD, Sun Q, Li N, Sui JL and Du XX. 2008. Preliminary study on Quaternary volcanoes in the Halaha River and Chaoer River area in Daxing'an Mountain range. ***Acta Petrologica Sinica*****, 24(11):2569 – 2575**

Abstract 28 Quaternary volcanoes, which scattered along a Quaternary NE strike fault, are found in the area of Halaha River and Chaoer River, middle of Daxing'an Mountain Range. Quaternary volcanic rocks in this area, mainly alkaline basalt, cover an area of ca. 1000 km^2. These volcanoes can be divided into two stages: Holocene volcanoes and Pliocene volcanoes. Both magmatic eruptions and phreatomagmatic eruptions are found in this area. The magmatic eruptions form a series of products, including scoria cones, tephra fallout deposits, and many kinds of lava (e.g. aa lava, pahoehoe lava and block lava). Typical fumarolic cones and lava hillocks are found in the lava. The phreatomagmatic eruptions have typical base surge deposits, which are characterized by parallel bedding and staggered bedding. Volcanic activity in this area form many volcanogenic lakes. According to the difference of lake forming, they are divided into four types: Crater lake, maar lake, volcanic dammed lake, collapse lava lake. Two conflict factors, water and fire, coexists harmoniously in the volcanic area, adding a splendid landscape to the Aershan Volcano and Warm Spring National Geopark.
Key words Middle Daxing'an Mountain Range; Quaternary volcanoes; Volcanic geology; Volcanogenic lake

摘 要 大兴安岭中部哈拉哈河—淖尔河地区受基底断裂控制,发育28座第四纪火山,这些火山总体呈北东向带状分布。研究区第四纪火山岩分布面积约1000km^2,岩性主要为碱性玄武岩。根据喷发时代和火山地质特征,这里的火山大体可分为更新世和全新世两期。按照火山作用方式不同,区内火山可分为岩浆成因和射汽岩浆成因两类:前者活动产物主要包括火山碎屑锥、碎屑席、熔岩流,其中发育结壳熔岩、渣状熔岩、块状熔岩,以及喷气锥、熔岩冢等火山地质现象;后者产物主要是射汽岩浆喷发形成的基浪堆积物,其中发育大型平行层理及交错层理。不同的火山作用形成了火山口湖、低平火山口湖、火山堰塞湖和塌陷熔岩湖四种不同规模与形态特征的湖泊,这种水火相容的火山地质现象为阿尔山火山温泉国家地质公园增添了景观。
关键词 大兴安岭中部;第四纪火山;火山地质;火山成因湖泊
中图法分类号 P588.145

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大兴安岭哈拉哈河-绰尔河第四纪火山分期：K-Ar 年代学与火山地质特征*

樊祺诚　赵勇伟　李大明　武颖　隋建立　郑德文
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Fan QC, Zhao YW, Li DM, Wu Y, Sui JL and Zheng DW. 2011. Studies on Quaternary volcanism stages of Halaha river and Chaoer river area in the Great Xing'an Range: Evidence from K-Ar dating and volcanic geology features. *Acta Petrologica Sinica*, 27(10):2827-2832

Abstract　34 Quaternary volcanoes are distributed along a Quaternary NE strike belt in Halaha river and Chaoer river volcanic field. The lava flow, characterized by alkali olivine basalts, cover an area of $400km^2$. Based on studies on the volcanic field characteristics, in conjunction with geological dating by K-Ar, it is identified that the volcanism occurred in four periods: Early Pleistocene, Middle Pleistocene, Late Pleistocene and Holocene. Basalts of Early Pleistocene, mostly mantled by the later volcanic rocks, are distributed in the margin and valleys of the volcanic field. Middle Pleistocene, the most volcanic active period in this area, witnessed the formation of more than half of Quaternary volcanoes and lava spreading. Moderate volcanism occurred in Late Pleistocene which produced a small amount of volcanic deposits. Volcanic activities are strengthened again in Holocene Period, characterized by strongly explosive explosion, widespread lava flow and well-keeping lava landforms features.
Key words　Quaternary volcanoes; Stages; K-Ar dating; Geology features; Halaha river and Chaoer river

摘　要　大兴安岭中部哈拉哈河-绰尔河第四纪火山区分布有34座火山，这些火山总体呈北东向带状分布，火山岩分布面积约 $400km^2$，岩性主要为碱性橄榄玄武岩。根据火山地质特征，结合火山岩 K-Ar 测年结果，哈拉哈河-绰尔河第四纪火山可进一步划分为早、中、晚更新世和全新世4期。早更新世火山岩，由于被后期火山岩覆盖，主要分布于火山区周边和出露在河谷中。中更新世火山活动最强，不论火山数量(27座)还是熔岩流规模都超过该区第四纪火山的一半以上。晚更新世时期火山活动趋弱，火山活动范围缩小，只局限于小范围区域。全新世火山活动又进入新的高峰期，强爆破式喷发和规模宏大的熔岩流，以及保存完好的熔岩流地貌是全新世火山之特点。
关键词　第四纪火山；分期；K-Ar 年龄；地质特征；哈拉哈河-绰尔河
中图法分类号　P588;145;P597.3

我国第四纪火山最主要分布东北和内蒙东部，主要沿松辽盆地东西两侧分布，其东部自北向南有镜泊湖小北湖火山群、长白山火山群、龙岗火山群、宽甸火山群，其西部靠近大兴安岭-太行山重力梯度带及其西侧，从北往南有五大连池-科洛火山群、诺敏河-奎勒河火山群、绰尔河-哈拉哈河火山群、阿巴嘎火山群、达来诺尔火山群、乌兰哈达火山群、大同火山群。长白山天池火山是一座长寿命的巨型复式火山，其他都是由几座乃至上百座短寿命的单成因火山(monogenetic volcano)组成的火山群，大多保留了较好的火山锥和火山地貌特征，是第四纪火山之重要地质标志，其中不少火山活动延续到全新世，保存了完好的火山地质地貌特征，成为我们所关注的活动火山。

大兴安岭第四纪火山主要包括北部诺敏河-奎勒河火山区和南部绰尔河-哈拉哈河火山区，是我国重要的第四纪火

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大兴安岭哈拉哈河-绰尔河第四纪火山岩地幔源区与岩浆成因*

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Zhao YW and Fan QC. 2012. Mantle sources and magma genesis of Quaternary volcanic rocks in the Halaha River and Chaoer River area, Great Xing' an Range. *Acta Petrologica Sinica*, 28(4):1119-1129

Abstract The Halaha River and Chaoer River volcanic field (HC for short), middle of the Great Xing' an Range, is in the north of the North-South Gravity Lineament in eastern China. The volcanic rocks in HC, dominated by alkali olivine basalts in sodium series, is characterized by relative enrichment in large ion lithophile elements and light rare earth elements. The fractionation of rare earth element of the basalts is weak ($(La/Yb)_N = 8 \sim 12$). They resemble alkali basalts in Datong, as shown by trace elements distribution patterns, and generally exhibit OIB-like characteristics. The basalts show nearly homogeneous Sr-Nd-Pb isotopic compostition similar to MORB source and present depleted mantle characteristics ($\varepsilon_{Nd} = 4.8 \sim 5.9$). All data show that bsalts of HC have a garnet lherzolite mantle source, low degree partial melting (8% ~ 15%) in which results in the primitive magma. Crystal fractionation of olivine and pyroxene from the magma is weak and seldom contamination by the crust rocks happens during the magma ascending, which resulting the volcanic rocks with high MgO content (>9%), Ni content ($>200 \times 10^{-6}$) and Mg value (60 ~ 70). Regional extension triggers asthenospheric upwelling, which may lead to the genesis of magma and subsequent volcanism.

Key words Great Xing' an Range; Halaha River and Chaoer River; Quaternary volcanic rocks; Geochemistry; Mantle source; Magma genesis

摘　要　哈拉哈河-绰尔河第四纪火山地处重力梯度带上的大兴安岭中段。火山岩主要类型为钠质系列碱性橄榄玄武岩。火山岩大离子亲石元素和轻稀土元素相对富集，轻重稀土分异程度弱($(La/Yb)_N = 8 \sim 12$)，稀土元素和微量元素配分曲线与大同碱性玄武岩平行，总体上表现出与 OIB 相似的特征。在 Sr-Nd-Pb 同位素组成特征上表现出亏损地幔的特点($\varepsilon_{Nd} = 4.8 \sim 5.9$)，接近 MORB 的源区范围。哈拉哈河-绰尔河第四纪火山岩岩浆由轻稀土富集的石榴子石二辉橄榄岩低程度(8% ~ 15%)部分熔融产生，火山岩高 MgO(>9%)、Ni($>200 \times 10^{-6}$)和 $Mg^{\#}$(60 ~ 70)，表明它们是较原始的岩浆，岩浆上升过程经历了橄榄石和辉石为主的弱分离结晶作用，没有受到地壳物质明显混染。区域伸展作用引发软流圈地幔上涌是哈拉哈河-绰尔河第四纪火山的岩浆成因。

关键词　大兴安岭；哈拉哈河-绰尔河；第四纪火山岩；地球化学；地幔源区；岩浆成因
中图法分类号　P588.145；P542.5

1　引言

哈拉哈河-绰尔河地区位于大兴安岭中段西麓，大兴安岭-太行山重力梯度带西侧，本世纪以来因其火山潜在活动性逐渐引起地质界的关注(白志达等，2005；赵勇伟等，2008；赵勇伟和樊祺诚，2010，2011；樊祺诚等，2008，2011)。该火山区与重力梯度带南部的大同第四纪火山区遥相呼应，但构造位置上它们分别属于兴蒙造山带内部和华北克拉通北缘。因此，研究哈拉哈河-绰尔河地区火山岩有助于我们加深

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Late Cenozoic magmatic transitions in the central Great Xing'an Range, Northeast China: Geochemical and isotopic constraints on petrogenesis

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ABSTRACT

The Wuchagou and Halaha volcanic fields are located in the central Great Xing'an Range, Northeast China, cover an area of ~1400 km^2 in China, and continue westward into Mongolia. These regions provide an important opportunity to study temporal changes in magma source regions accompanying the evolution of geodynamic-processes. Late Miocene (10.5–8.0 Ma) volcanic rocks from the Wuchagou volcanic field are composed of basaltic andesite and andesite. The characteristics of these rocks include a high concentration of Si (SiO_2 = 55.7–59.2 wt.%), a pronounced negative Nb—Ta anomaly, and a slightly LREE enriched pattern with $(La/Yb)_N$ ratios varying from 2.1 to 6.9. They have Sr and Nd isotopic compositions indicative of long-term incompatible element enrichment ($^{87}Sr/^{86}Sr$ = 0.7053–0.7067, $^{143}Nd/^{144}Nd$ = 0.5118 to 0.5122), with a trend toward the EM1 component. Their isotopic compositions can also be described as Dupal-like, but with less-radiogenic Pb isotopic ratios ($^{206}Pb/^{204}Pb$ = 16.99–17.83, $^{207}Pb/^{204}Pb$ = 15.46–15.52, $^{208}Pb/^{204}Pb$ = 37.42–37.91). Quaternary (2.0 Ma to Holocene) lavas from the Halaha volcanic field consist of alkali olivine basalt and olivine tholeiite, which show alkalic affinities and are characterised by ocean island basalt-like REE and trace element patterns, typical of an intraplate sodic basalt composition. The low $^{87}Sr/^{86}Sr$ (0.7034–0.7041), high $^{143}Nd/^{144}Nd$ (0.5128 to 0.5130), and moderately radiogenic $^{206}Pb/^{204}Pb$ (18.39–18.55), $^{207}Pb/^{204}Pb$ (15.54–5.55), and $^{208}Pb/^{204}Pb$ (38.32–38.47) ratios are similar to those of most late Cenozoic basalts of South China and the Abaga region, Inner Mongolia. The different melt compositions between the volcanic rocks of the two volcanic fields are most likely due to changes in geodynamic processes and magma sources. A possible scenario for the genesis of these volcanic rocks is that Wuchagou andesitic magma formed by high degrees of partial melting of the subcontinental lithospheric mantle with some lower-crust contamination as a result of the thermal reactivation of the continental lithosphere by shallow-level rifting following the cessation of the Japan Sea opening. During the Quaternary, extensive volcanism resumed, with eruptions along deep rifting systems in the Halaha volcanic field, which might have been related to the geodynamic forcing of the continuous piling up and upward thickening of the stagnant subducted Pacific slab beneath Northeast China. Basaltic magmas of this stage were primarily produced by melting of convecting asthenosphere. Using the batch melting of a hypothetical LREE-enriched mantle source in the garnet stability field proposed by Xu et al. (2005), we estimated that the Halaha basalts could be generated from 9 to 14% of partial melting of garnet peridotites.

1. Introduction

In contrast to oceanic basalt, continental basalts must pass through the thick continental crust and subcontinental lithospheric mantle (SCLM) prior to eruption. Therefore, they always have a wide spectrum of origins and compositions. Trace-element and isotopic heterogeneities exhibited by continental basalts are thought to reflect the compositional diversity of the mantle materials from which they were derived. In the past two decades, there have been marked differences between the existing tectono-magmatic models that attempt to explain the generation of within-plate continental basalts. For instance, they are thought to be derived from mantle plumes (Campbell and Griffiths, 1990), partial melting of the SCLM (Gallagher and Hawkesworth, 1992) or convective asthenosphere (Choi et al., 2006), lithosphere–asthenosphere interactions (Chung et al., 1994), oceanic crust–lithospheric mantle interactions (Zhang et al., 2009), and melting of recycled oceanic crust and mantle peridotites in the asthenosphere (Xu et al., 2012).

Since the Cenozoic Era, intraplate volcanism related to continental rifting has prevailed in the passive continental margin of China. One of the widely distributed regions of Cenozoic volcanic rocks surrounds

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RESEARCH ARTICLE

Vegetation and Climate Change during the Last Deglaciation in the Great Khingan Mountain, Northeastern China

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Abstract

The Great Khingan Mountain range, Northeast China, is located on the northern limit of modern East Asian Summer Monsoon (EASM) and thus highly sensitive to the extension of the EASM from glacial to interglacial modes. Here, we present a high-resolution pollen record covering the last glacial maximum and the early Holocene from a closed crater Lake Moon to reconstruct vegetation history during the glacial-interglacial transition and thus register the evolution of the EASM during the last deglaciation. The vegetation history has gone through distinct changes from subalpine meadow in the last glacial maximum to dry steppe dominated by *Artemisia* from 20.3 to 17.4 ka BP, subalpine meadow dominated by Cyperaceae and *Artemisia* between 17.4 and 14.4 ka BP, and forest steppe dominated by *Betula* and *Artemisia* after 14.4 ka BP. The pollen-based temperature index demonstrates a gradual warming trend started at around 20.3 ka BP with interruptions of several brief events. Two cold conditions occurred around at 17.2–16.6 ka BP and 12.8–11.8 ka BP, temporally correlating to the Henrich 1 and the Younger Dryas events respectively, 1and abrupt warming events occurred around at 14.4 ka BP and 11.8 ka BP, probably relevant to the beginning of the Bølling-Allerød stages and the Holocene. The pollen-based moisture proxy shows distinct drought condition during the last glacial maximum (20.3–18.0 ka BP) and the Younger Dryas. The climate history based on pollen record of Lake Moon suggests that the regional temperature variability was coherent with the classical climate in the North Atlantic, implying the dominance of the high latitude processes on the EASM evolution from the Last Glacial Maximum (LGM) to early Holocene. The local humidity variability was influenced by the EASM limitedly before the Bølling-Allerød warming, which is mainly controlled by the summer rainfall due to the EASM front covering the Northeast China after that.

Introduction

The last deglaciation is of great interest, because the climate in the Northern Hemisphere has gone through several distinct changes such as the LGM, Heinrich stadial 1 (H 1), the Bølling-