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Provenance tracing of Nd isotopes of sandstorm in Harbin, Heilongjiang province and analysis of its tracks

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Abstract

The present study analyzed sandstorms in Harbin, a city in Heilongjiang province in northeastern part of China. Based on the available ground observation data from meteorological stations in Harbin from 1961 to 2010, investigation was conducted for temporal and spatial distribution characteristics and weather conditions. 48 samples of dust collected from two sites were studied in laboratory. By testing the major and trace elements in samples collected, along with Nd isotope content, the component characteristics of these samples was determined. Annual change in law of sandstorm occurrence was found. Increase in occurrence of dust and sand was particularly obvious since 21st century. Occurrence of sandstorm frequency in different seasons was not same. It was high during spring and fall while low during summer and winter. Occurrence of sandstorm in Harbin was potentially related to direction of strong-wind, and winds from southwest was predominant; Horqin sandy land and Otindag sandy land was deemed as far-forth mass source, and the farmland and desertification area around Harbin was near-source.

Key words

Harbin, Nd isotopic tracing, Sandstorm

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Introduction

Sandstorm is a common and devastating weather phenomenon that frequently occur during spring in the northern region of China (Gao *et al.*, 2012; Lin *et al.*, 2012). In recent decades, sand and dust storms have been attracting people's attention due to its significant influence on the global climate and environment (Tegen and Fung, 2012). Many methods were applied to study the provenance of sandstorm, such as analysis of particle size, mineralogical composition, element geochemistry and isotope tracing and so on." (Wang *et al.*, 2008; Yang *et al.*, 2012b; Zhou and Zhang, 2003). Isotope tracing is used for analyzing isotope residue of samples. Thus, globally isotope tracing method is deemed of great importance in current research. Kanayama *et al.* (2002) applied Sr isotope to track down the potential provenances of sandstorm weather in Japan. Similarly, Sun (2002) used Sr isotope to study whether Huangtu Plateau, Tarim Basin, Qaidam Basin and Junggar Basin were effective provenance zones of sandstorm. Godfrey (2002) employed the method of Pb isotope tracing to discuss the source of abyssal red clay in central North Pacific. Grousset *et al.* (2003) carried out a comparative reasearch on Sr-Nd isotopes of sediments in Sahara areas and discussed its source, claiming that the dominant wind regime that has been influencing this place is interstade pleniglacial. Li *et al.* (2009) compared Sr-Nd isotope in loess, dust in current environment and potential provenances, and discovered that the northern part of Tibetan Plateau was the provenance of loess in loess Plateau. The distribution characteristics of lead isotope in dust source areas in Northern China and significance of isotope tracing had been discussed (Li, 2007), which proved that lead isotope was a useful tracer in determining the provenance of dust in Chinese Loess, glacial dust in Greenland Ice Core and sediments in North Pacific.

Sandstorms are widely distributed in the northern part of China, forming an arcuate zone extending from northwestern districts through Northern region of China to the western part of northeast China. Places where frequency of sand and dust is high includes the Tarim Basin, Dunhuang—Hexi Corridor—Ningxia Plain—Shanbei Line——Alxa-Plateau in Inner Mongolia—Hetao

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Plain and Erdos Plateau (Ma, 2003). However, the northeastern part of China which is adjacent to the Northern Desert and sand lands has been influenced by sandstorms. Therefore, floating dust and sand are two typical types of sandstorm prevailing in Northeast China. In recent five years, desertification resulting from agricultural exploitation and sand lands along the river banks has also become a source of sandstorm. A large amount of researches have been conducted to study the sandstorm in Harbin in Heilongjiang province. Since 2002, research results related to this topic has been published, and most of them are primarily focused on the features of dustfall and provenance of sand using collected data of a single sandstorm or weather information (Rao *et al.*, 2006; Xie *et al.*, 2006; Xie *et al.*, 2009; Zhang *et al.*, 2004; Zhang *et al.*, 2002). Thus, provenances consist of proximal sources and distal source, for the reason that the size curves for the composition of dustfall is complicated, and reveals the bimodal and trimodal distribution(Yang *et al.*, 2012a). Till date no research on the provenance of isotope in sandstorm has been reported.

The spatial and temporal distribution and characteristics of weather conditions of sandstorms occurred in past fifty years have systematically been summarized, based on the weather data from the Harbin Meteorological Bureau. The source of sandstorm in Harbin was also discussed by analysing Nd isotope in samples collected from Shuangcheng and Hulan district. The present study can provide scientific evidence on forming mechanism and provenances of sandstorm and offers support and help to develop the ecological protection in Northeast China.

Materials and Methods

Harbin is located in 125°42'~130°10'E, 44°04'~46°40'N, in the southern part of Heilongjiang province. Harben is the capital of Heilongjiang and biggest city in northeast of China. It is the center of politics, economics, culture and transportation. The research area, is located in the southeast of Songnen Plain, altitude of which descends from the southeastern part to northwestern part. According to the topographic. The geomorphic units in the research area are mainly hills, hill lands, high plateau and river valleys (Fig. 1).

The covering strata are Quaternary, which produce sediments of 30 m to 100 m. The main sentiments are made up of rocks and clay in lakes and rivers, which act as potential provenance of sandstorm.

In recent years, wetland around the research area has been facing degradation crisis due to the impact of economy development. Reasons for these environmental crises are as follows: Firstly, original natural channels for run-off were deterred by human activities such as expansion and development of cities. Particularly, building residence and roads around the city in recent years, which made it difficult for the forming of natural lakes. Secondly, the impact was escalated by other human activities, such as reclaiming lands, digging pools to raise fish, catching animals and birds, digging sand and building architectures without permission. Thirdly, illegal mining changed the soil structure of this area.

Firstly, weather data about sandstorms in Harbin from the Harbin Meteorological Station was collected and then a comprehensive analysis was done.

Dust filtering device TH-1000II is highly precise on timing and measurement with stable flow and easy to operate. It is ideal for dust collection because the efficiency of data collection is constant. Thus, two dust filtering devices-TH-1000II were placed in Shuangcheng in southwest Harbin and Hulan district in northeast Harbin, respectively. And the quantitative paper produced by WHATMAN Company was chosen as filter membrane for collecting samples in sandstorms during sand blowing days.

Nd-Sr isotope was frequently used for tracing the source of winds and was of highest study degree. At the present stage, on the basis of study of source of winds, A large number of statistics of isotopes were accumulated and many experiments were conducted. However, Sr isotope was easily influenced by change in condition of ground surface, and its sensitivity to provenance was not as high as Nd isotope. Sr isotope could be used as a good provenance indicator unless pretreatment of sample was good enough. Consequently, the present study chose Nd isotopes as provenance indicator for studying sandstorms in the research area.

Nd isotope geochemical test was accomplished on TRITON isotope ratio spectrometer by the Key Laboratory of University of Geosciences (Wuhan). The sample dissolution method applied in the experiment of isotopes ^{143}Nd/^{144}Nd was as follows: sample was dissolved in a sealed bomb made of PTFE. SiO_2 was dissolved in 3ml mixed acid of HF+HNO_3 on electric hot plate at a relatively low temperature. Further, 3ml mixture of HF and HNO_3 was added in the bomb. The bomb was sealed tightly and put in an oven at 190ºC for 48 hrs, till the sample was completely dissolved. Then AG50´8 cation positive ion resin column and LN resin was used for Sm-Nd separation. The background value of whole process was: Sm=3×10^{-11}, Nd=1.2×10^{-10}. ^{143}Nd/^{144}Nd ratio of the sample was standardized by ^{146}Nd/^{144}Nd=0.721900. The measured value of standard sample (BCR-2) was ^{143}Nd/^{144}Nd ratio=0.512643± 0.000015(2δ). The standard value measured by the instrument was JNdi-1 ^{143}Nd/^{144}Nd=0.512116±8.

Results and Discussion

According to curve provided by the Harbin Meteorological Station on the accumulated days of blowing sand, sand-dust

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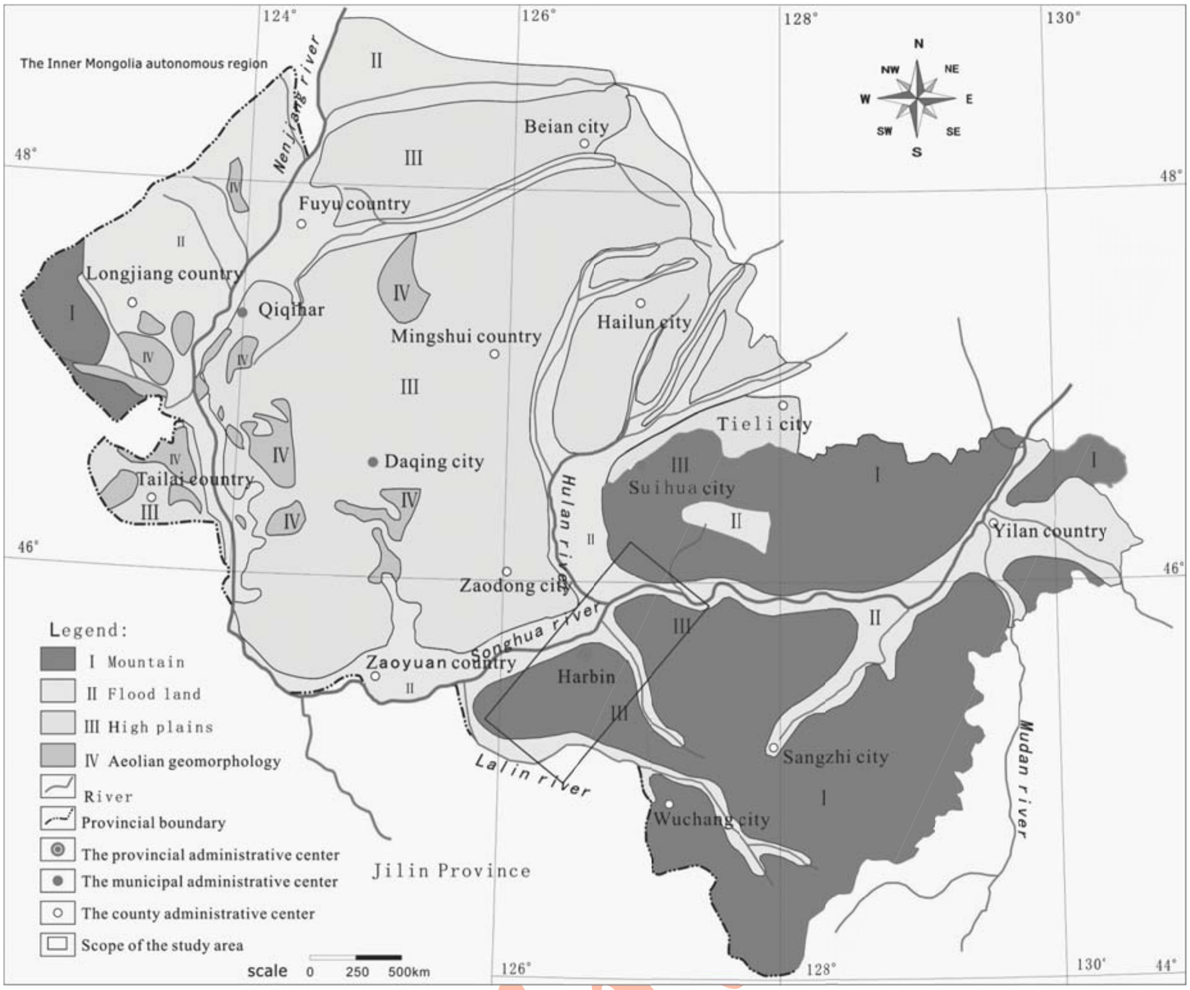

Fig. 1 : Geotectonic setting and schematic map of the research area and nearby cities

storm and strong wind in Harbin from 1961 to 2010 (Fig. 2), a clear seasonal change of sandstorm was observed. Sandstorm mainly occured during spring, but rarely in autumn or winter, and seldom in summer (Yang *et al.*, 2012b). It occurred 285 times in spring from 1961 to 2010, accounting for 85.07% of the total number, while only 16 times in winter, accounting for 4.78%, 18 times in autumn, accounting for 6.37%, and the rest occurred in summer, most of which in June.

The seasonal distribution of sandstorms was positively correlated with the seasonal change of number of windy days (Fig. 2). In spring, cold wave took place frequently along with strong winds and sharp fall in temperature. The average air speed was highest within a year. So the winds offered driving force for sandstorms. Meanwhile, the temperature rose on the whole and the ground began to thaw, which loosened the soil, offering material source for sandstorm. Thus, incidence of sandstorms was highest in spring, which was consistent with the conclusions obtained by previous researches (Gun and Pang, 2003; Wu *et al.*, 2011; Yang *et al.*, 2012a; Zhang *et al.*, 2010). In summers, sandstorm rarely occured because the area was well covered by vegetation and rain fall was abundant (Yang *et al.*, 2012a). While in winters, sandstorm seldom occurred, for the types of sandstorm were almost floating dust.

According to the records of the Municipal Meteorological Station of Harbin, from 1961 to 2010, the number of days with sandstorm was 335, among which number of days with sand blowing was 291, number of days with sandstorm (narrow sense) was 44 (Fig.3), however in last 10 years sandstroms were rare. (Fig.3).

From Fig. 3, shows that sandstorms occured most frequently in 1970s, followed by less frequents in 1960s and in

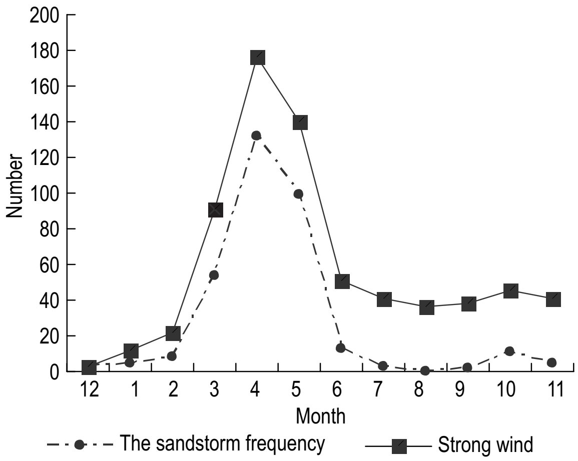

Fig. 2 : Month versus cumulative number of sandstorm days (broad sense) and strong-wind days from meteorological stations in Harbin during 1961-2010, respectively

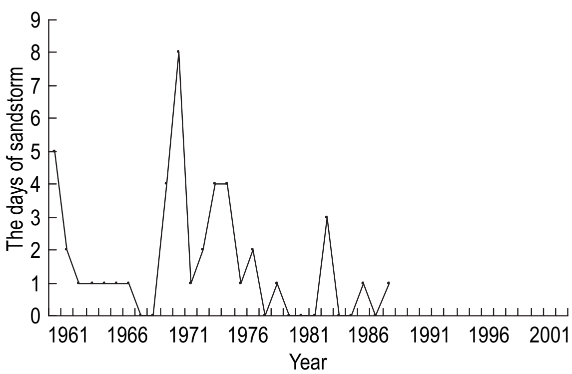

Fig. 3 : The number of days with sandstorms (narrow sense) from Harbin meteorological station during 1961-2010

1980s sandstorms reduced significantly, and in 1990s and 2000s sandstorms were minimum. This rule was consistent with the law of activity of East Asian Monsoon. In 1970s, the East Asia Monsoon was active. While in 1980s and 1990s, it was very weak (Huang *et al.*, 2008). According to related researches (Bai and Zhao, 2012; Luo, 2000), the East Asian Monsoon was strong in La Nina years. In 21st century, La Nina was predominant and reached peak in 2000. After 1988, sandstorms never took place in Harbin in narrow sense (Fig.3). As the main types of sandstorm were sand blowing and floating dust (Yang *et al.*, 2012a). In total 48 isotope samples were analyzed and the results of isotope analyses are summarized in Table.1.

$^{143}Nd/^{144}Nd$ ratio for different kinds of rock and mineral was not same. As compared with element composition, these values did not change much during their migration. Thus, Nd isotope is widely used in tracing the material source and migration path(Liu *et al.*, 2014; Spiegel *et al.*, 2002; Zhao *et al.*, 2009; Zhu *et al.*, 1998).

The ratio was rarely influenced by particle size and chemical weathering. It was correlated to the isotope characteristics of source rocks. Introducing a coefficient εNd(0) to compare the initial n(^{143}Nd)/n(^{144}Nd) ratio in igneous rock and metamorphic rock with n(^{143}Nd)/n(^{144}Nd) ratio of CHUR(Chrodritic Uniform Reservoir) when it came into being. Difference between them was little. So it is necessary and reasonable to introduce coefficient ε, which is given below :

$$\varepsilon Nd(0) = \left[\frac{(^{143}Nd/^{144}Nd)_{measured}}{(^{143}Nd/^{144}Nd)^{0}_{CHUR}} - 1\right] \times 10^{4}$$

In the formula, $[n(^{143}Nd)/\ n(^{144}Nd)]_{measured}$ is the value measured in the experiment, $[n(^{143}Nd)/\ n(^{144}Nd)]^{0}_{CHUR}$ is the modern value of CHUR(0.512638). Using the above, formula value for two regions; Shuangcheng εNd(0) = -6.3205 and Hulan district εNd(0)=-4.2915 were computed.

According to the results obtained, value of εNd(0) of fallen dust samples between -6.6 and -6.4 in Shuangcheng was consistent with that of εNd(0) in Khorchin Sandy Land(Goldstein *et al.*, 1984; Jahn *et al.*, 2001; Liu *et al.*, 1994; Nakano *et al.*, 2004). Yet the values of εNd(0) in other regions differed highly with this value and the distance between Shuangcheng and other region was too far away. Thus, Horqin Sandy Land in Inner Mongolia was the main source of sand and dust in Harbin.

According to analysis on both occurrence regularity of sandstorm and isotope tracing, it was concluded that sediments of sandstorm in Harbin were mixture of sands from proximal provenances and distal ones. The southwest (Horqin Sand Land—Shuangcheng— Harbin City) consisted of two types of provenances: proximal provenance (Horqin Sand Land) and distal ones (agricultural lands and sand lands along Lalin River). The northeast (Hulan District—Harbin City) consisted of only proximal provenances, namely agricultural lands and desertification areas in Hulan district. Dust-sand weather was closely related to richness of sand in source region. Various kinds of sand in source region had different impact on sandstorm weather. Generally, sand in central areas of desert was coarse. Even if it brought sandstorm, it would be impossible for the storm to travel long distance due to weight of sand. The most extensive provenances of sandstorm were usually located in the transitional zone from desert to prairie. Ecosystem was fragile in these areas (Fan *et al.*, 2004; Wu and Nan, 2002), where soil erosion was severe and vegetation was sparse. Besides, it was easy for fine sand to move and travel long distance to low lands, forming influential sandstorm (Liu *et al.*, 2013). Therefore, the provenances of sandstorms were vulnerable ecological regions at the edge of desert, but not the quicksand areas in desert heartland. This conclusion can provide evidences for government and society units in taking actions to prevent sandstorms and improve the environment in Harbin and adjoining areas. Meantwhile, the present research also pointed out the main area that needs more attention.

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Table 1 : The measured value of ^{143}Nd/^{144}Nd isotope

Sample number	^{143}Nd/^{144}Nd	2ä(10^{-6})
DA001-1	0.512296	3
DA004-1	0.512367	3
DA010-1	0.512315	4
DA014-1	0.512461	4
DA041-1	0.512222	6
DA045-1	0.512377	4
DA067-1	0.512358	2
DA093-1	0.512315	4
DA103-1	0.512488	3
DA108-1	0.512385	5
DA152-1	0.512392	4
DB015-1	0.512389	4
DB022-1	0.512477	4
DB023-2	0.512464	4
DB026-1	0.512454	3
DB048-1	0.512354	1
DB048-2	0.519711	25
DB057-1	0.514245	9
DA002-1	0.512399	3
DA012-2	0.512386	3
DA023-1	0.512243	3
DA076-1	0.512384	3
DA081-1	0.512315	3
DA160-1	0.512346	2
DB010-1	0.512393	3
DB013-1	0.512414	4
DB021-1	0.512514	3
DB031-1	0.512478	5
DB084-11	0.512368	3
DB095-1	0.512558	5
HL03	0.512299	3
HL06	0.51234	3
HL16	0.512355	3
HL18	0.512297	3
HL22	0.512296	4
HL22	0.512296	4
HL23	0.512328	3
HL25	0.512331	3
SC19	0.512352	3
SC21	0.512308	3
SC28	0.512357	2
SC29	0.512363	2
SC03	0.51233	4
SC04	0.512269	2
SC05	0.512401	3
SC08	0.512371	3
SC09	0.512331	3
SC11	0.512366	2
H01	0.512321	3

The research area, Shuangcheng, was influenced by proximal source marterials, and the environmental conditions of this area was worse than that in Central Harbin and Hulan district. The primary cause was proximal provenances had a continuous impact on the region and were more influential than distal ones. As compared with sandstorm caused by distal provenances, proximal sandstorm had five characteristics. First, the grain of sand was fine and uniform. Second, it could be blown into the air. Third, it could stay for relatively longer time in air. Fourth, it could be carried over a long distance. Fifth, the main form of dustfall was wet deposition (Fang *et al.*, 2012; Hu, 2001). Thus considerable attention of people can be gained and government can be urged to take action against this challenge. In future, sandstorms in Harbin and northeast plain require further research.

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