Wind erosion at the dry-up bottom of Aiby Lake

—— A case study on the source of air dust

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Abstract Clay-rich deposits are usually considered as hard materials to be eroded by wind. Data from both surface monitoring and field survey at the dry-up bottom of Aiby Lake present that clay-rich lacustrine deposits are easily broken down and eroded away by wind in the seasonal alternation process under the natural arid environment, and are the significant source of air dust. The surface of the clay-rich deposits is broken and softened by the freezing-and-thawing action in winter season and/or by salt and alkali action with precipitation. Impact of wind-input particles and plow of plant branches with wind force drive the clay-rich sediments moving. Wind picks up the clay pebbles and repeats the impaction further-ward onto the dry-up surface. Tremendous fine materials, including soft salts, are contributed to air dust, and transported in long distance.

Keywords: wind erosion, source of air dust, Aiby Lake.

The source of air dust is one of key questions on the mechanism of dust storm and control of the hazard. There are various kinds of source area in the arid zone, including sandy deserts, farmlands and other bared surfaces. But the dry-up lake bottom was not significantly mentioned as the source of air dust. Since late 1970s Jinghe Town (fig.1) about 300 km west of Urumqi has been frequently attacked by dust storms. First the dust was considered from the farmlands. Since the dust on grass and plant leaves always made animals sick after they ate the plants, on the power lines frequently made short-cut events, and on the railway seriously made the steel decay, the composition of the dust attracted us to find the source[1].

Clay-rich sediments usually are considered as hard deposits to be picked up by wind blow[2]. Laboratory studies have also had the data supporting the conclusion[3]. But the fine particles are so easy to be kept in the air and to be brought away for long distance transportation[4,5]. That means once the clay particles are driven into air, they are more important to affect the atmospheric environment and have much broader negative influence than silt and fine sand. Therefore, we need to understand what changes the dry-up lake bottom, which is composed of clay-rich sediments, has after it been exposed to air, how the surface is broken down, and how the materials are driven away by wind blow.

In the arid zone there many lakes have shrunk in the large range, including Aral Sea, Lake Balkash, Lake Alar, Aiby Lake, Aiding Lake. And others even dry out, such as Lop Nur, Manas

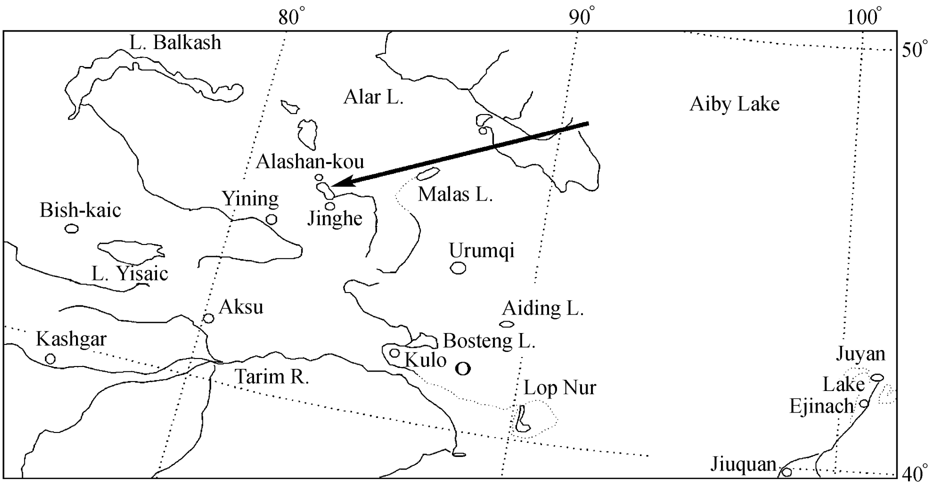

Fig. 1. Index map of Aiby Lake.

Lake and Juyan Lake. Broad lake bottoms have been exposed to the air for many years. Most of the exposed area are actually deflated by wind blow. Only eroded depth varies from place to place.

Aiby Lake is just located at the leeward of the Alashankou wind gap. Strong and frequent eolain action is sufficient at the dry-up lake bottom and makes typical processes of wind erosion on clay-rich sediments. This study shows that the dry-up lake bottom is an important source area of the air dust and aerosol.

1 Method and results

1.1 Field survey

1.1.1 Wind erosion evidence. We first visited the lake bottom from Alashankou side in the autumn of 1994. Wind erosion had already occurred at the margin zone for about 100 — 200 m wide from the last shoreline (a gravel bar). Wind inputting materials had gotten on the margin zone, and a few places are covered with flooding materials. But the dry-out lake bottom was once merged temporally in the short term before our visit (by spring flooding or other reason). The wind inputting materials covered surface was hard to step on. But inner part of the bottom surface was too soft to take a walk. Later the place has been surveyed every year. Since 1996 wind inputting materials have reached about 1000—1250 m away from the last shoreline at the margin zone. Wind erosion trenches presented, and yang yardan landforms were formed. The deepest trench was measured at 980 m away from the gravel bar (fig. 2(c)), which was 36 cm related to the top of a yardan (very much close to the original lacustrine sediment surface). The inner part has become hard enough to walk on. And the lacustrine sediment surface has been deflated down by wind blow, but the depth has become much shallow.

Not all the eroded sediments (mainly clay and silt) are carried away by wind as air dust. Most of the materials broken from the lacustrine sediments become fragments in coarse sand to fine gravel size (from 0.5 to 5 mm in diameter), and are driven forward by wind on the ground. In 1997 the clay fragments accumulated as dunes at the zone from 2760—4280 m away from the gravel bar (fig. 2(c)). After this zone the wind eroded surface was very even flat.

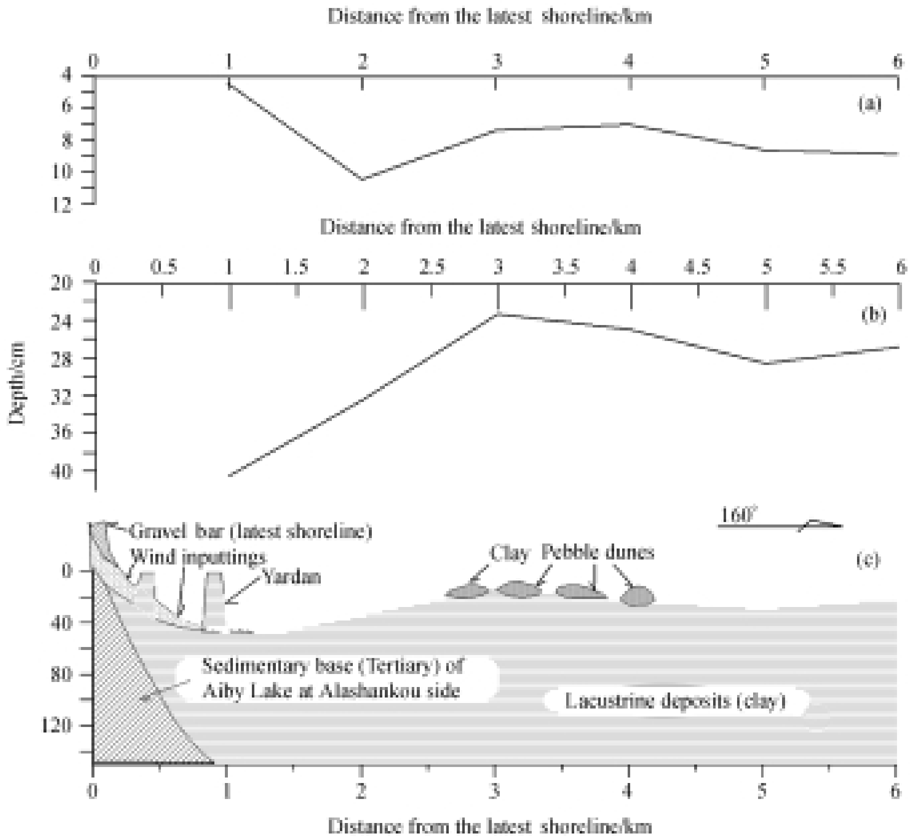

Fig. 2. Variation of wind erosion amount at the dry-out bottom of Aiby Lake. (a) showing one-year amount of wind erosion based on the data observed from April 1998 to Nov. 1999, (b) Presenting the approximate total amount of the surface deflation. (c) Cross-section along the monitoring line.

The surface of wind inputting coverage at the margin seems no more deflation after the surface has been replaced. Wind inputting materials and flooding alluvium accumulate at the zone, and make surface growing up. The wind inputting materials are composed mainly of coarse sands (about 45%) and gravels (about 28%). A certain amount of lacustrine sediments has been mixed with the wind inputting materials. The largest gravel input by wind is about 20 cm in diameter. It should be pushed in by wind in sliding or/and rolling status. But most of particles smaller than 4 mm could get into the bottom in jump way, and hit the surface.

1.1.2 Collecting samples. In order to understand and compare or correlate the properties of sediments, various types of deposits were sampled for laboratory study. The samples were mainly for mechanical and chemical analysis, especially to distinguish the soft salt components. Three kinds of deposits were sampled. One was the lacustrine sediments, second was the wind inputting materials, and third was deposits of the air dust at the surrounding place. Both the lacustrine sediments and the wind inputting materials were sampled at two layers. One was at about 1-cm-thick surface layer, and the second was sampled at 10 cm from the surface. Large particles were measured on the field.

Dust samples were collected in a container with natural deposition. The containers were set at 7.5 or 8.0 m from the ground surface to minimize the local dust influence. But at Alashankou Meteorological Station the containers were set at the half meter and 1-m-high place since the land surface is fully paved with gravels. After one-year collection, enough dust deposits had been gotten at most sites for analysis. But the samples at Alashankou Meteorological Station were only coarse sand and pebbles. The largest pebble collected in the container at half meter was about 4 mm.

1.2 Surface monitoring

In order to measure the amount of deflation of the dry-up lake bottom 30-cm-long steel sticks were buried into the lacustrine sediments. Totally 12 sites were selected to monitor the changes of the surface. The sites were specially located at the strong eolain action zone on purpose, and together made up 3 monitoring lines. One was at the north side of the dry-up bottom in the S-N direction. The other 2 were at the Alashankou side and extended toward the southeast according with the prevailing wind. Four sticks were buried at the corners of a 2 m × 2 m square at each site. Each stick was only left 5 cm above the ground surface. And then the sticks were measured in every 3 months. After 16 months of monitoring all the sites were merged with the increase of lake water in the winter of 1999.

During the monitoring term a maximum deflation measured is 18.9 cm for the 16 months at the site about 2000 m away from the gravel bar, and the minimum is only 1.28 cm at the site just next to the wind inputting coverage zone about 1 km away from the gravel bar.

The monitoring result presents that the surface deflation took place at about 1 km away from the last shoreline. The strongest erosion occurred at the zone from 2.5 to 2.5 km. It weakened to 4 km, then got stronger again (fig. 2(a)).

1.3 Lab study

1.3.1 Grain size. Mechanical composition of the sediments was analyzed with Malvern2000 laser size instrument. The instrument can identify particles from 0.02 to 2000 μm continuously. Anyhow, the data were output in 100 grades (fig. 3). Distributions of the grain size are very alike from each other between the lake deposits and the dust deposits. Clay materials are more than 30%, silt more than 40%, and sand less than 15%. But the dust samples obviously show that a large amount of clay and fine silt is not deposited in the vicinity of the source region. About 10%—15% clay and more fine silt have been brought away. On the other hand, the proportion of the coarse silt has been enriched in the dust samples.

1.3.2 Soft salts. Soft salts are certainly enriched at the surface of the dry-up lake bottom. At most places there are about 12%—28% of total soft salts in the top layer about 0.5—10 cm thick. Underneath the top layer total soft salts are rapidly reduced. At about 25 cm or deeper the salts are getting even 6.5%—8.5%.

The total soft salt of the dust varies with seasonal change. Usually the dust contains a very high percentage of total soft salts in spring, and gets lower content in summer. In the spring of 1998 the dust at Jinghe was gray white, and contained 43.12% total soft salts. The soft salt contents of the dust are co-relatable with the lacustrine sediments.

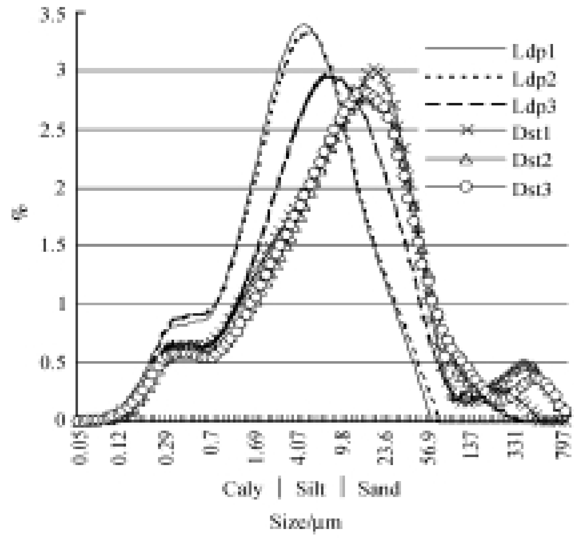

Fig. 3. Grain size distribution curves of Aiby Lake deposits and dust deposits at the vicinity. Ldp1— Ldp3, Surface sediment samples from different places of the dry-out lake bottom; Dst1—Dst3, dust deposit samples from Jinghe, Bole and Tuotuo.

2 Discussion

2.1 Breakdown of the clay-rich deposits

2.1.1 Wind condition at Alashankou. Alashankou is one of wind gaps where the wind entries the Junggar Basin. Wind blow is very strong and very frequent (fig. 4(a), (b)). There are 163 windy days per year on average in the last 40 years records, and maximum velocity gets about 55 m/s (Apr. 13, 1977). Strong wind is mainly distributed in dry season. It makes wind erosion on the dry-up lake bottom much more active. In addition, the frequent wind also has a great influence on the high evaporation, dries up the surface soil moisture at the bottom, and makes the clay-rich sediments fragile.

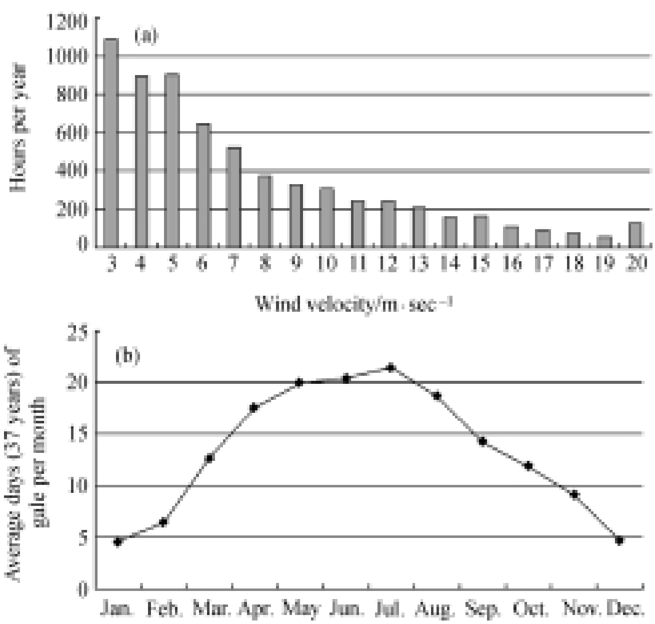

Fig. 4. Wind condition recorded at the Alashankou Meteorological Station. (a) The strength classified in terms of wind velocity and their annual frequency. (b) The annual distribution of strong wind.

2.1.2 Freezing-and-thawing action and salt-alkali action. Seasonal freezing-and-thawing action is very active at the dry-up lake bottom. The days of temperature getting down below zero are more than half a year. During the winter season a thin snow layer at the bottom melts for several times. Until early or middle spring the surface is always with a soft layer about 5—10 cm thick, which is softened by needle ice. The soft layer is with no difficulty to be eroded by wind. The winter freezing-and-thawing action softens the surface layer of the clay-rich sediments, and makes wind erosion very strong in later April to early May.

The lacustrine deposits are rich not only in clay but also in soft salts and alkali. Dissolving and re-crystallization of the soft salts at the surface layer are very active under the exchanging with ground moisture and the high evaporation capacity at the dry-up bottom. Even the frequent shower of the precipitation makes soft salt action much more active. The soft salt action breaks up the surface of the clay-rich sediment to make small wind tunnels on the surface.

2.1.3 Hit of the wind inputting materials. The wind is so strong that tremendous sands, gravels and plant branches are blown into the dry-up bottom area every year. The wind inputting materials hit the surface of the clay-rich sediments, break the deposits into fragments, and drive the clay deposit fragments moving while they jump into the area. Plant branches even break the surface, and drive clays moving by plowing at a lower wind speed.

2.2 Wind erosion at the dry-up bottom of Aiby Lake

Wind erosion started many years ago (probably in later 1970s) at the margin after the bottom was exposed to air and dried. But the very outside margin was covered with wind inputting materials later soon. And then the strongest erosion zone migrated toward the inner part. Fig. 2 shows that the strongest zone was at the zone between 800 and 1500 m away from the gravel bar before 1998, but it moved to the zone between 1500 and 2600 m during 1998 to 1999.

At the strongest erosion zone tremendous clay fragments are formed. Part of them is not carried away, and accumulates at the zone between 2760 and 4280 m, and lowers down the eroding ratio. After this zone the eroding ratio increases again. When the clay-rich sediments are broken down, clay fragments in various size are formed, and become very active agents in the wind erosion process by jumping on the surface with windblown force.

Most part of the dry-up lake bottom has been under the wind erosion process (fig. 5) even when the clay-rich sediments are not perfectly dried up. Very large amounts of eroded materials in pebble and sand size shift on the ground in jumping and/or rolling way. They are re-deposited into the swampland. But still tremendous silt and clay are picked up into air, and carried away by wind.

2.3 Contribution of the dry-up lake bottom to air dust

Dust collected in the vicinity of Aiby Lake presents a close relationship with the lacustrine sediments in properties of both mechanical and chemical composition. Occurrence of the dust storms in the leeward has a negative relationship with the area of water surface of the lake (fig. 6). It indicated that the formation of the dust storm is related to the dry-up of the lake bottom. People in Jinghe Town at about 65 km leeward critically suffer the salty dust from the dry-up lake bottom. During the period from 1998 to 1999, there was dust deposited for about 300 t/km^2 per year according to the data collected at Jinghe Meteorological Station.

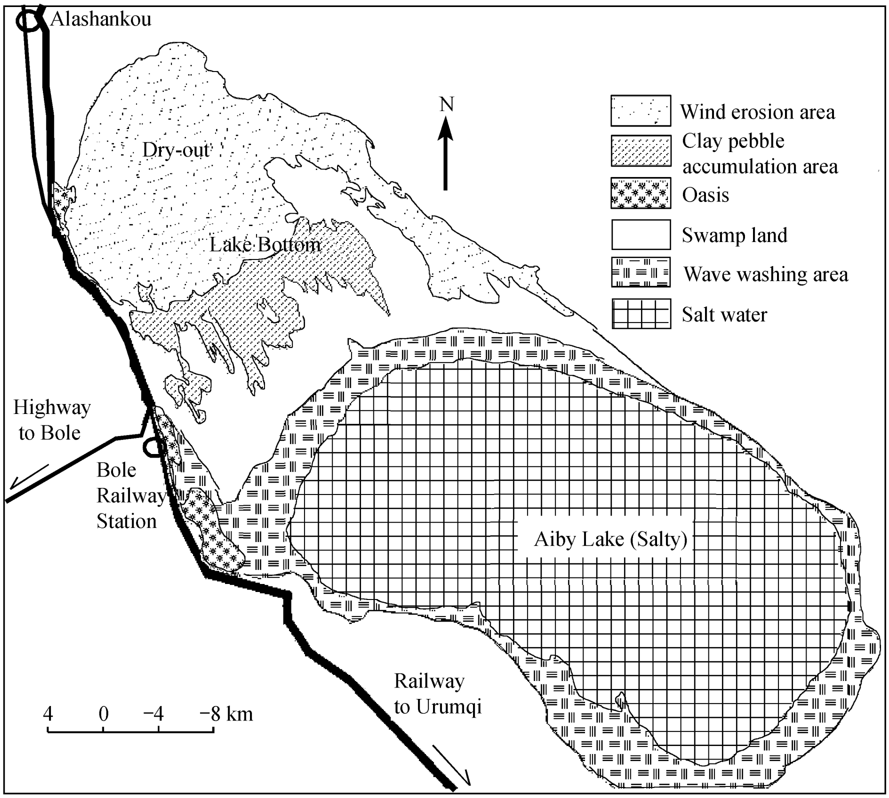

Fig. 5. Map showing the area of Aiby Lake and wind erosion.

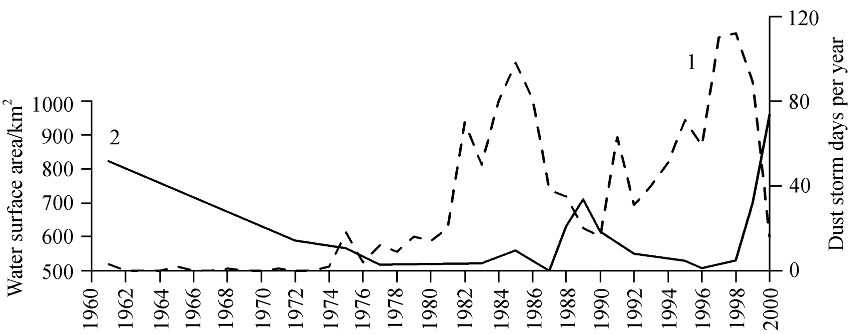

Fig. 6. Relation between the dust storm event at Jinghe and the area of water surface of Aiby Lake. 1, A curve of annual dust storm events at Jinghe from 1960 to 2000; 2, showing the changes of the water surface of Aiby Lake during the same period.

By comparing the mechanical composition of the dust with the lake deposits, there is a large amount of clay and silt not deposited in this region, but they have been carried away further. Stability of solid materials in the air mainly depends on the size of the particles and the air condition. Lacustrine sediments are just supplying particles with the suitable size for air dust in long distance transportation. They certainly contribute a significant amount of minerals, soft salt and others to air dust or/and aerosol.

Dry-up lake bottoms are one of the important source regions of air dust although there are only 117 km^2 of the dry-up bottom under the wind erosion process at present. In the arid region there are many exposed lake bottoms and other bared clay-rich sediments. Yardan landforms are found at all dry-out lake bottoms and other muddy or clay-rich sediments.

3 Summery

(1) Wind erosion at the dry-up lake bottom of arid land is obviously strong, especially at the margin where tremendous wind inputting materials make impaction. The fast erosion zone migrates away leeward from the margin with the advance of wind inputting cover. The rate of erosion reduces leeward with an increase of the distance from the last shoreline on the bottom. Clay-rich sediment pebbles broken from the lacustrine deposits are active agents to drive more clay materials moving in the inner part of the bottom by jumping on the dry-out lake bottom.

(2) Seasonal and daily freezing-and-thawing action is very helpful to softening the clay-rich sediments. Minimum precipitation and sub-surface moisture make the soft salts and alkali in the sediments very active on the surface layer. Once the hard surface is broken up and softened all the year around, it is not difficult for it to be eroded by wind.

(3) Dust collected in the vicinity presents the properties of the lacustrine sediments. The dry-up lake bottom supplies suitable particles for air dust. And a more important fact is that a large amount of clay and fine silt is not deposited in the local region. In other words, a certain amount of clay and fine silt is keeping in the air for long distance transportation.

(4) Most of the fragments broken from the lacustrine sediments are in sandy and pebble size, and move on the ground in jumping or rolling ways. Large part of them is re-deposited into swampland of Aiby Lake. But during the movement they produce a great amount of air dust, including fine grains, soft salts and alkali, and are blown away.

(5) Aiby Lake is only a case. The dry-up and bared lake bottoms with clay-rich sediments are plenty in arid land. Materials from the dry-up lake bottom are a very important source of air dust.

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