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Provenance of loess material and formation of loess deposits on the Chinese Loess Plateau

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Abstract

Results of a multiple, isotopic, chemical and mineralogical analysis of loess from the three northwestern inland basins (the Junggar Basin, the Tarim Basin and the Qaidam Basin) and the Loess Plateau region of China are summarized. They suggest a qualification of the conventional views that the three northwestern basins were the important source areas of the Loess Plateau and that the sand deserts were the primary single source of the Chinese loess. It is argued that the gobi (stony desert) in southern Mongolia and the adjoining gobi and sand deserts (the Badain Jaran Desert, Tengger Desert, Ulan Buh Desert, Hobq Desert and Mu Us Desert) in China, rather than the three inland basins, are the dominant source areas of the Loess Plateau. However, although these gobi and sand deserts are regarded as the main source regions, they serve as dust and silt holding areas rather than dominant producers. The mountain processes (including glacial grinding, frost weathering, salt weathering, tectonic processes, and some fluvial comminution) in the Gobi Altay Mts., Hangayn Mts. and the Qilian Mts. have played an important role in producing the vast amounts of loess-sized material for forming the Loess Plateau.

Keywords: loess; provenance; geochemistry; mineralogy; Gobi Desert; sand deserts; Loess Plateau

1. Introduction

Loess and loess-like deposits of Pleistocene age are widespread, covering about 10% of the Earth's land surface [1], with the thickest and most extensive loess occurring on the Chinese Loess Plateau. It is now accepted that particular geological, geomorphological and climatic conditions in central and eastern Asia have led to substantial transportation and accumulation of eolian dust in northern China [2]. So far, the age, pedostratigraphy and climatic implications of Chinese loess have been well studied, and the loess–soil sequences have been correlated with the cyclic climatic changes recorded in marine sediments [3–5].

However, many issues, including origin, transport pathways and source areas of the Chinese loess, still remain controversial. As stated by Lyell [6] "the more that I have studied the subject, the more difficult I have found it to form a satisfactory theory", and even now, the following questions can be at least raised.

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1. Although a desert origin of the Chinese loess was first reported by Richthofen [7], there is still much debate on the formation mechanisms of loess-sized materials [8–20]. In fact, the formation mechanisms of the silt-size particles may not be the same in different geomorphological units of China [21].
2. The east Asia monsoon systems and the westerlies have long been regarded as the dominant wind regimes for dust transportation in central Asia [4,22]. However, the dust entrainment and transport systems are more complicated than expected, since frontal systems and the Mongolia cyclone can be actively involved in the dust entrainment [2,23], whereas near-surface winds and the westerlies are responsible for dust transport. It is still not clear what wind systems are responsible for dust transportation and deposition in the proximal region (e.g., the Loess Plateau) and in the distal regions (e.g., the remote North Pacific). Also, what are the different effects of high-level and near-surface wind transportation on the accretion of dust in different regions?
3. Although a desert source of Chinese loess was first proposed by Obruchev [24], different opinions do exist. For example, Liu [4] pointed out that the gobi and sand deserts near the northern Loess Plateau as well as in the northwestern inland basins (e.g., the Junggar Basin and the Tarim Basin) are the source regions of the plateau. Bowler et al. [25] argued that the Qaidam Basin has been an important dust source for the Loess Plateau during the geological past. Liu et al. [26] proposed that the loess deposits on the Loess Plateau may have a source region in the Tarim Basin but clearly not in the northern Tianshan Mts. Derbyshire et al. [2] concluded that the huge piedmont alluvial fans along the northern Qilian Mts. were the main sources for the loess deposits in the western Loess Plateau. The existence of such debates makes it necessary to reconsider the provenance of loess material on the Loess Plateau.

In order to evaluate some of these ideas and, in particular, to explore the origin and provenance of loess distributed in different geomorphological units of China, extensive field expeditions in the desert and loess regions have been completed in recent years.

In a previous paper [21], the author discussed the distribution, age, origin and provenance of loess in the high mountain regions (the Tianshan and the Kunlun ranges). In this contribution, the isotopic, chemical and mineralogical properties of loess in the Qaidam Basin and the Loess Plateau are also reported. Combined with geomorphological and modern dust storm information, this paper will extend the discussion on the origin and provenance of Chinese loess as well as dust transport associated with different wind systems.

2. Materials and methods

Previous studies have shown that both the grain size and thickness of the Malan loess, deposited during the last glacial period, decrease southeasterly throughout the Loess Plateau, implying the Chinese loess was transported by northwesterly winds [27]. The gobi (stony desert) and sand deserts in the surrounding regions and in the northwestern three inland basins (Junggar, Tarim and Qaidam, Fig. 1) have been proposed as the most important potential sources of the Loess Plateau [4]. One way to test this view is to compare the chemical, isotopic and mineralogical composition of the loess sediments derived from the three large basins with that of the loess from the Loess Plateau.

To this end, we took loess samples from the plateau as well as from the three inland basins (Fig. 1). Loess consists of a wide range of particle sizes from clay to silt, and the loess in different regions has different granulometric composition. Therefore, in order to avoid the effects of particle size on the geochemical and mineralogical contents, only the <20 μm fraction was used, pipetting according to Stokes' Law. This differs from the previous geochemical studies of Chinese loess, in which bulk samples were used [26,28,29]. The advantages of our approach are: (i) only dust particles finer than 20 μm can be transported in long-term suspension over a great altitudinal range and long distances [30]; and (ii) the contri-

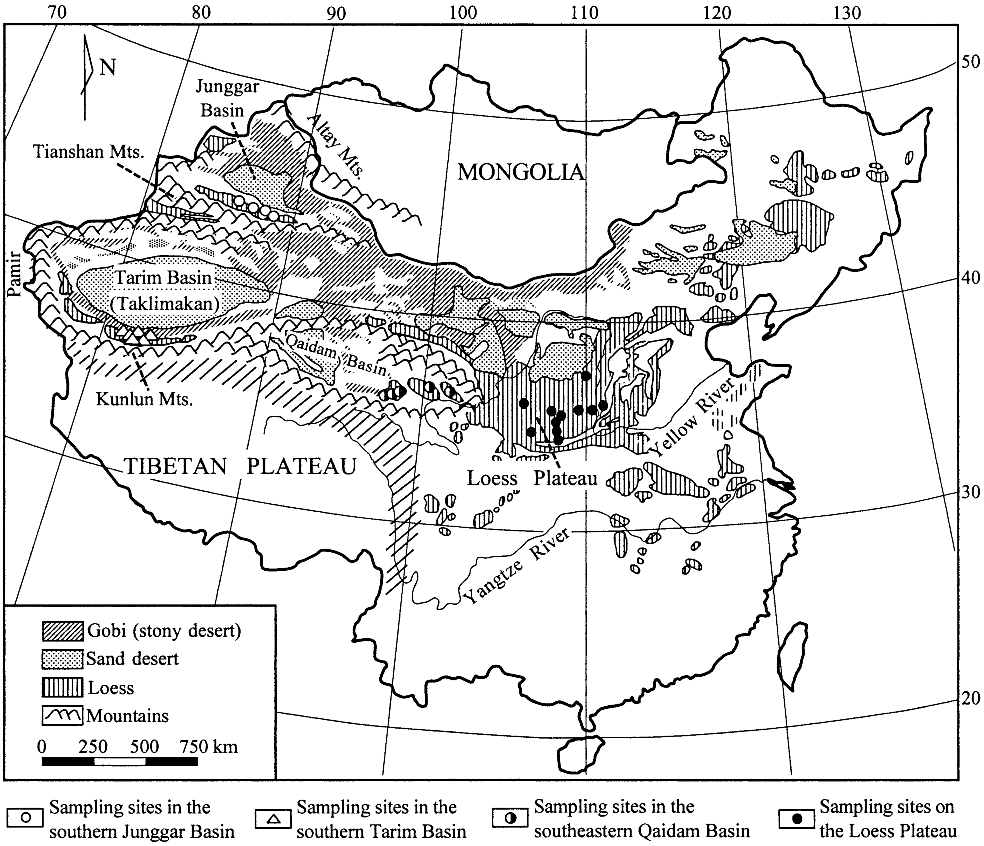

Fig. 1. Map showing the mountain, gobi, sand desert and loess distribution and the sampling sites in China. Note that the loess, derived from the three inland basins (Junggar, Tarim and Qaidam), transported by near-surface wind, mainly accumulates on the windward slopes of the downwind mountains.

bution of coarse particles mainly derived from local loess deposition sites to the geochemical and mineralogical composition can be greatly decreased.

In this study, the Sr isotope ratios were analyzed on a VG 354 mass spectrometer in the Institute of Geology and Geophysics, CAS. The measured Sr isotopic ratios were normalized to $^{86}Sr/^{88}Sr = 0.1194$. The result obtained on the NBS987 Sr standard was $^{87}Sr/^{86}Sr = 0.71026 \pm 2$ (2δ) ($n = 8$) during the measurement period.

Trace element concentrations (including the rare earth elements: REE) were measured on ICP-MS (ELEMENT, Finnigan MAT) in the Institute of Geology and Geophysics, CAS, using a method similar to that described in detail by Ding et al. [31]. We estimated that uncertainties in the analysis were less than $\pm 5\%$.

Mineralogical analyses were obtained by X-ray diffractometer (DMAX 2400). We estimated that the analytical uncertainties were about $\pm 10\%$.

3. Results

3.1. Isotopic results

The Sr isotopic results are given in Fig. 2, expressed as plots of $^{87}Sr/^{86}Sr$ vs. 1/Sr as well as $^{87}Sr/^{86}Sr$ vs. $^{87}Rb/^{86}Sr$, following the methods in other previous Sr isotope studies [29,32–35].

Isotopic data for loess sediments from the liter-

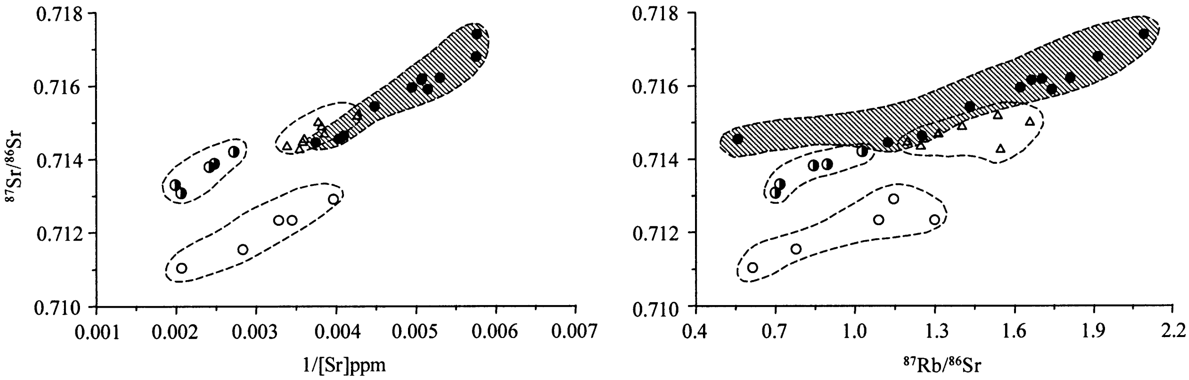

Fig. 2. $^{87}Sr/^{86}Sr$ ratios plotted against 1/[Sr] and $^{87}Rb/^{86}Sr$ of loess samples in the studied regions. Symbols as in Fig. 1.

ature were not used (e.g., [26,29,36,37]) because the analyses were made on bulk samples. Fig. 2 shows: (i) among the samples of different geographic units, loess derived from the Junggar Basin has the lowest values of $^{87}Sr/^{86}Sr$, whereas samples from the plateau have the highest $^{87}Sr/^{86}Sr$ values; (ii) both of the plots ($^{87}Sr/^{86}Sr$ vs. 1/Sr and $^{87}Sr/^{86}Sr$ vs. $^{87}Rb/^{86}Sr$) show geographical distinctions in isotopic ratios, implying different source regions of the loess samples from the Loess Plateau and the three inland basins.

3.2. *Trace element chemistry*

REE and other trace elements of the samples were analyzed. For the loess deposits, because they are derived from various kinds of rocks and are generally well mixed during the entrainment and transport, the REE patterns are quite uniform. This is especially the case for the selected fraction of < 20 μm. Thus, the REE patterns were not adopted in this study. However, the REE ratios are effective in tracing loess provenance. Fig. 3 shows that the Loess Plateau samples have the highest values of Eu/Yb and Eu/Eu*, and both the Ce/Yb vs. Eu/Yb and the LREE/HREE vs. Eu/Eu* show important geographic distinctions and thus support the use of REE ratios as indicators of loess provenance [28,29].

Aside from the REE, other trace elements and their ratios can also provide important information on the provenance compositions as indicated by previous studies [28,38]. Plots of the trace element compositions and/or their ratios indicate that samples from different regions fall into four fields (Fig. 4), highlighting the fact that they are derived from different source regions.

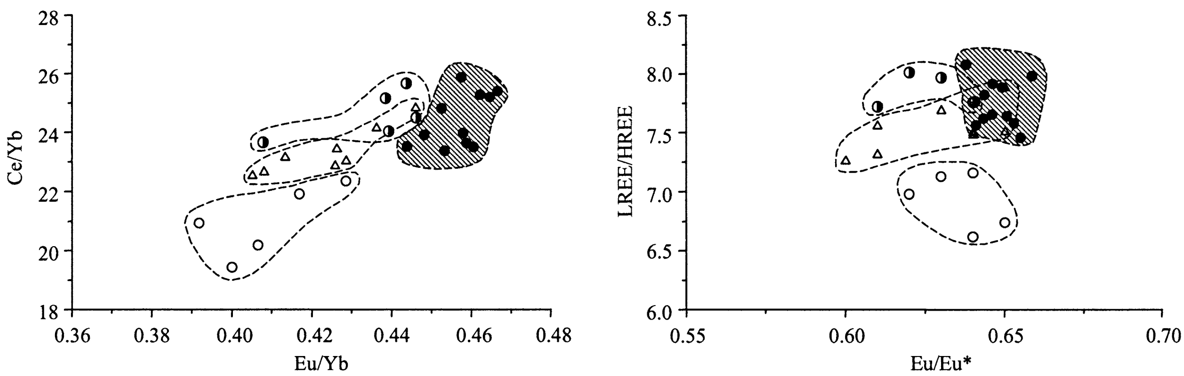

Fig. 3. Ce/Yb vs. Eu/Yb and (LREE/HREE) vs. Eu/Eu* of loess samples in the studied regions. Symbols as in Fig. 1.

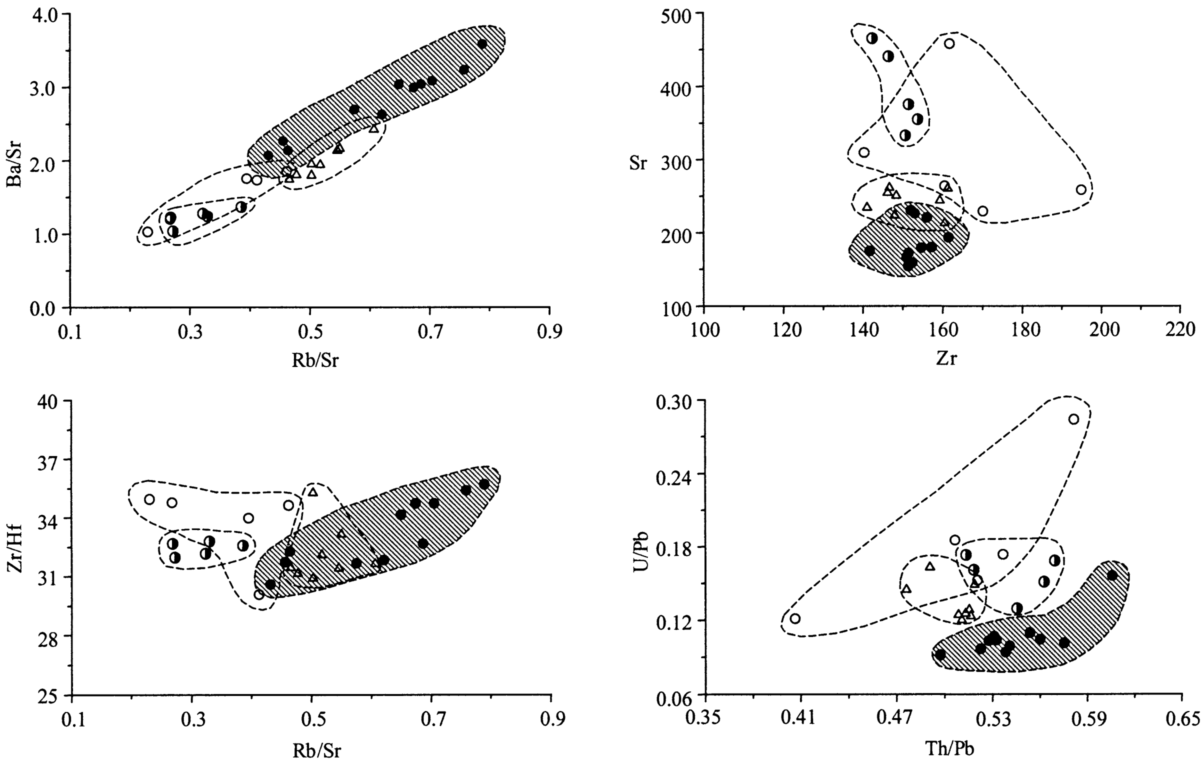

Fig. 4. Plots of Ba/Sr vs. Rb/Sr, Sr vs. Zr, Zr/Hf vs. Rb/Sr, and U/Pb vs. Th/Pb for the loess samples in the studied regions. Symbols as in Fig. 1.

3.3. Mineralogical results

Mineralogical analyses are also commonly used in sediment provenance studies [39,40]. Our results indicate that quartz is the most abundant mineral comprising about 50% in the selected size fraction. Quartz, feldspar, mica and calcite are the main minerals, accounting for more than 90% of the total. Additional minerals include nimite, clinochlore, viitaniemiite, sudoite and orthoclase.

The triangular diagram (Fig. 5) showing the content of the three most common minerals indicates that the Loess Plateau loess has the highest quartz content compared to samples from the other three regions. In this diagram, samples from the Loess Plateau region fall into a separate field, clearly indicating that the loess on the plateau is not derived from the three inland basins. This mineralogical result is consistent with that of the isotopic and chemical studies.

4. Discussion

4.1. Provenance of loess material on the Loess Plateau

The multiple, independent isotopic, chemical and mineralogical traces indicate that the loess samples from the four regions fall into four distinct fields, implying different provenances. Thus, although the three inland basins are upwind of the Loess Plateau, the loess on the plateau is not derived from these basins. Therefore the question now arises, what is the provenance of the Loess Plateau sediments?

Combined with field geomorphological investigation and modern meteorological data, the author concludes that the provenance of loess deposits on the Loess Plateau is the gobi in southern Mongolia and the adjoining gobi and sand deserts (the Badain Jaran Desert, Tengger Desert, Ulan Buh Desert, Hobq Desert and Mu

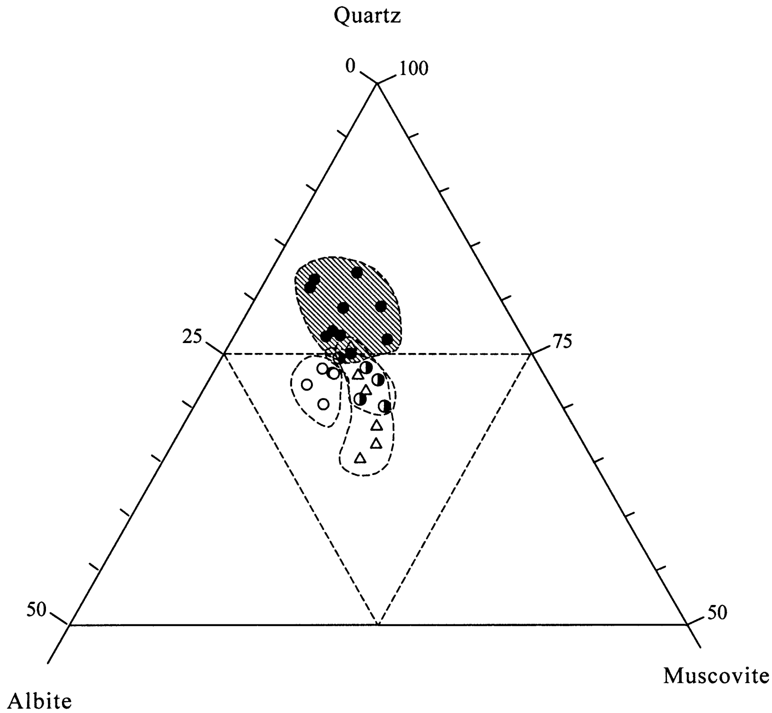

Fig. 5. Diagram of the mineralogical composition of loess in different regions. Symbols as in Fig. 1.

Us Desert) in China, as indicated by Fig. 6. This is supported by three lines of evidence.

1. The prevailing winds in the above gobi and sand deserts are northwesterly, so that they are upwind of the Loess Plateau, and this is the basis for linking the plateau with the mentioned gobi and sand deserts.
2. The gobi and sand deserts are either connected or not far from the plateau region, and there are no high mountains in the dust pathways. All of these geographic features favor dust transport from the above gobi and sand deserts to the Loess Plateau.
3. Statistical data of the moderate and heavy dust storm events (persisting for longer than 2 days and with entrained dust transported medium and long distances) in the spring seasons of the years 1960–1999 also clearly indicate that the above gobi and sand desert region is subject to the most frequent dust storm outbreaks in China ([23], Fig. 7).

4.2. Why is the dust derived from the three inland basins not the main source of the Loess Plateau?

First, Fig. 6 indicates that the prevailing near-surface wind in the Junggar Basin is northwesterly. Dust entrained from this basin is deposited on the piedmont slopes of the northern Tianshan Mts. [14,21]. The upper limit of the loess distribution of 2400 m above sea level (asl) is much lower than the average elevation of about 4000 m of the northern Tianshan Mts. downwind. Thus, dust derived from the Junggar Desert cannot be easily transported out of the basin and to the Loess Plateau region. Moreover, the dust storm data indicate that the Junggar Basin is not a frequent dust storm outbreak region in China (Fig. 7).

Second, although the prevailing near-surface wind in the Qaidam Basin is northwesterly, dust entrained from the gobi, sand deserts and yardangs in this basin contributes little to the main body of the Loess Plateau. The evidence for this

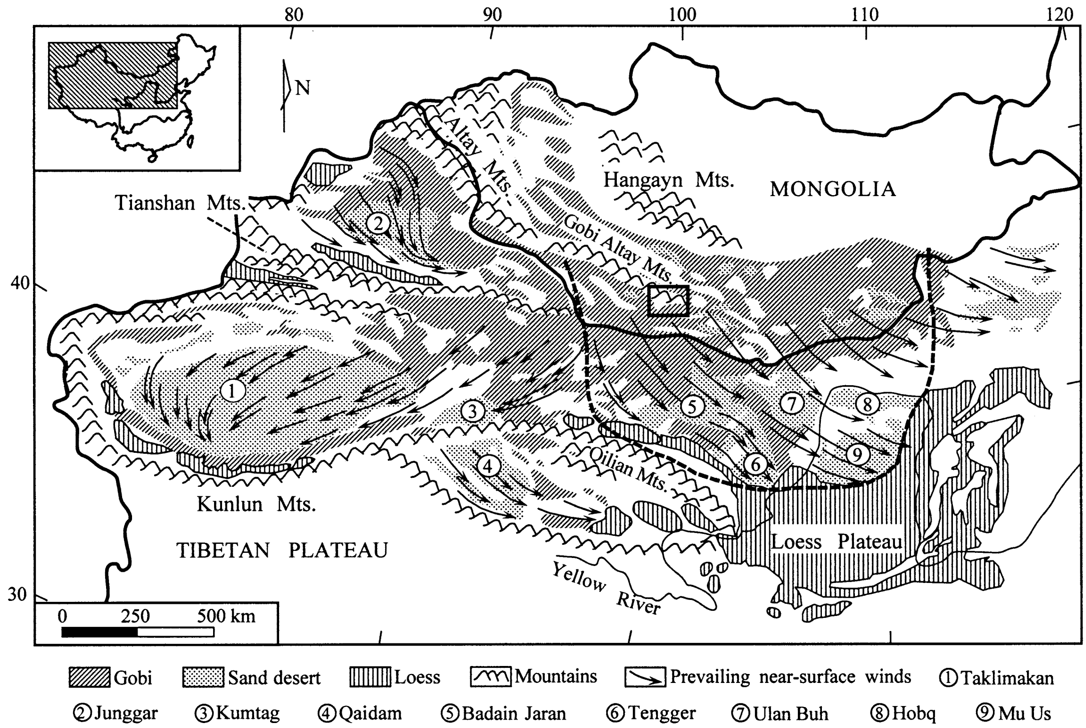

Fig. 6. Map showing the near-surface wind directions (arrow) based on dune orientation in the studied regions. Area circled by dashed line indicates the source region of the Loess Plateau. Rectangle labeled is area shown in Fig. 9.

is as follows: (i) Qaidam Basin is surrounded by high mountains, and dust entrained from this basin is impeded by the downwind extensive high mountains (with elevation > 4000 m asl); (ii) field investigations indicated that dust was mainly accumulated in the southeastern piedmont areas of the basin; and (iii) modern dust storm data also indicate that the Qaidam Basin is not among the high frequency dust storm regions (Fig. 7). This view is consistent with the argument of Pye and Zhou [41], but is different from the view of Bowler et al. [25] who suggested that the Qaidam Basin has been an important dust source of the Loess Plateau region.

Third, the near-surface wind in the Tarim Basin is northeasterly (Fig. 6, with the exception of the western margins). However, areas to the north, west, and south of the Taklimakan Desert are surrounded by high mountains (average elevation > 5000 m); an open area exists only in the east margin (see Fig. 6). Under the easterly winds, dust at an elevation of < 5000 m cannot move out of this desert, but accumulates in the northern windward slopes of the Kunlun Mts. (Figs. 6 and 8a). Thus, dust transported by the near-surface winds from the Taklimakan Desert is not the source of the Loess Plateau. However, the atmospheric circulation in the Tarim Basin is more complicated then in the other basins. Dust from the Taklimakan Desert can be also entrained to elevations > 5000 m and then transported by the westerly jet stream for long distance (Fig. 8a and b). A case study of a dust storm on May 18, 1986, indicates that the effective cause was a coupling of a cold high-pressure cell over the northeastern Taklimakan Desert with a warm low-pressure cell over the northern Tibetan Plateau (Fig. 8b), causing strongly rising airflow [23]. The 500 hPa isobaric surfaces indicate that dust, entrained to an elevation of > 5000 m, moved north and northwestward, ultimately reaching 50°N, where the dust was transported by the westerly jet stream (Fig. 8b) to the remote Pacific.

Although dust transported by the westerly jet

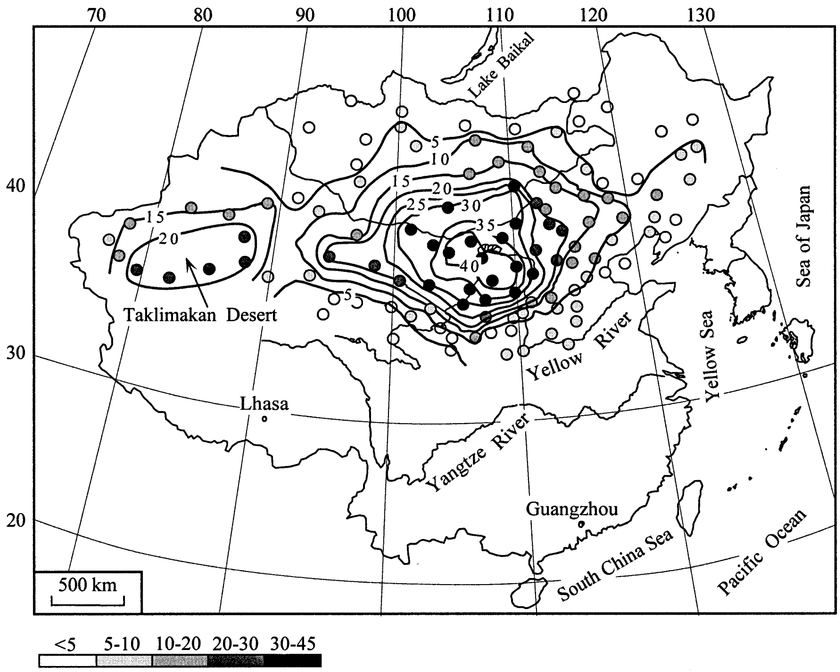

Fig. 7. The spatial distribution of dust storms expressed as the times of dust storm events (shown as contour lines) observed in each meteorological station during the spring seasons of 1960–1999. Noting the two dominant source regions in China and its surrounding regions [23].

stream, entrained from the Taklimakan Desert, can be moved out of the Tarim Basin, they are not the sources of the Loess Plateau. This view is not consistent with the previous argument that the loess on the Loess Plateau may have a source region in the Tarim Basin [26]. Because whenever the dust is entrained to an elevation of > 5000 m and transported by the westerly jet stream, the fine dust is not easily deposited in the proximal region (e.g., the Loess Plateau) but transported to

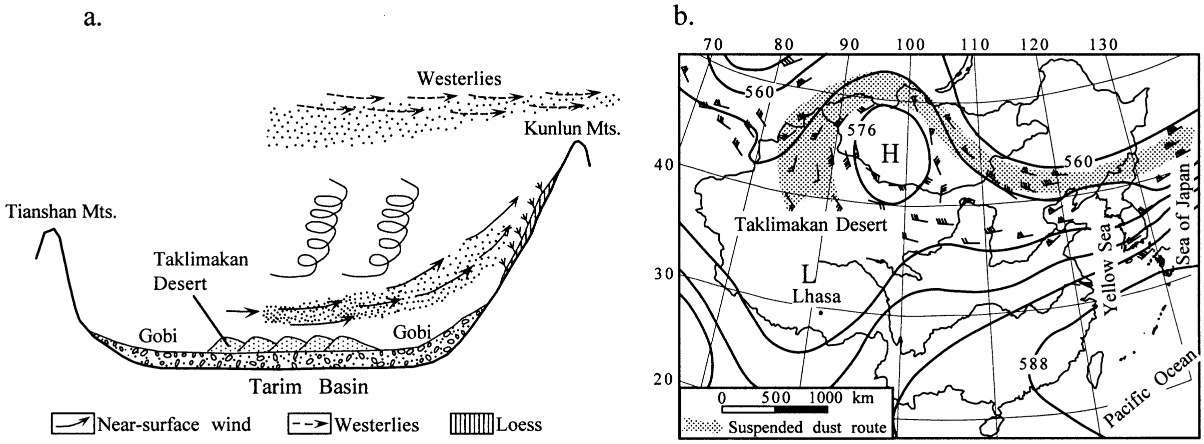

Fig. 8. (a) Conceptual model for the provenance, transportation and deposition of eolian dust entrained from the Taklimakan Desert, and (b) the isobaric surface at 500 hPa on May 18, 1986, showing the pathway of the westerly jet stream transport dust entrained from the Taklimakan Desert.

the Pacific. This can be demonstrated by the meteorological observations on the dust storm on May 18, 1986, which indicated that during this dust storm there was no observed dust fall in the Loess Plateau, though satellite images of this dust storm clearly indicated that the dust entrained from the Taklimakan Desert first moved northwestward over Lake Balkhash, then veered eastward over Lake Baikal and northeastern China, ultimately reaching the Pacific Ocean [42].

4.3. Potential role of mountain processes in the Gobi Altay Mts., the Hangayn Mts. and the Qilian Mts. on the production of the loess-sized materials

Although the gobi and sand deserts in southern Mongolia and the adjoining region of China are regarded as the main source regions of the Loess Plateau, these gobi and sand deserts, to some extent, serve as dust and silt-holding areas rather than dominant producers.

So far, there have been many opinions for the silt-size particle production including glacial grinding [8], frost weathering [43], salt weathering [13,44], eolian abrasion [45], and fluvial comminution [46]. In China, a desert origin of the loess-sized materials has long been proposed since the pioneering work of Obruchev [24]. However, this prevailing opinion has been questioned by Smalley and Vita-Finzi [47], Smalley [9,10,48], Pye [15], Derbyshire et al. [2]. Smalley and Vita-Finzi [47] suggested that there were no specifically desert processes, which could produce the vast amounts of silt required to form a large loess deposit. Derbyshire et al. [2] concluded that materials constituting the piedmont alluvial fans along the Qilian Mts. are important sources of the loess in the western Loess Plateau.

The high mountains in Asia (named as 'High Asia' by Smalley [10]) and the associated mountain processes (including glacial grinding, cryonival breakage, salt weathering, tectonic processes, and some fluvial comminution) have played an important role in producing the vast amounts of loess-sized material. In a previous paper [21], the author concluded that formation of loess in the windward slopes of the northern Tianshan and Kunlun ranges was associated with the wind sorting on the piedmont alluvial deposits generated by glacial grinding and tectonic-induced relief denudation processes. In fact, the formation of the gobi in southern Mongolia and the adjoining gobi and sand deserts in China is also dominantly associated with the mountain processes. The geographic zonation of the distributions of gobi, desert and loess from northwest to southeast are mainly the result of wind sorting on the piedmont alluvial fans in the large and high Gobi Altay Mts., Hangayn Mts. and the Qilian Mts. (see Fig. 6), especially when we consider the following facts.

1. Elevations of the Gobi Altay, Hangayn and Qilian mountains range from about 2500 m to about 5500 m asl. The high elevation gives rise to extreme climatic conditions, favoring the freeze-thaw cycles and frost weathering process, leading to the physical weathering of rocks in the surrounding regions.
2. The high relief and steep gradients give rise to high potential energy of the melting water and other ephemeral river systems. A large amount of clastic material distributed in mountain valleys and the instable slopes can be outwashed and transported either to the piedmont region forming alluvial fans or to the insides of the lowland basins. The multispectral Landsat Thematic Mapper (TM) image clearly indicates that a series of huge alluvial fans is distributed along the piedmont areas of the Gobi Altay Mts. (Fig. 9). The zoning distribution characteristics of the gobi, desert and loess are the result of wind-sorting of these materials.
3. High Asia lies in an active neo-tectonic zone, and the energy release further favors rock denudation and river down-cutting in the above mountain regions and thus the production of loess-sized material.
4. A case study of the sediments of the northern Qilian Mts. indicated that the silt fraction of dune and sand plain samples in the adjoining areas are minor compared to the volumes present on the surface of the piedmont alluvial fans [2], further confirming the great contribution of the piedmont alluvial deposits to the downwind loess deposition.

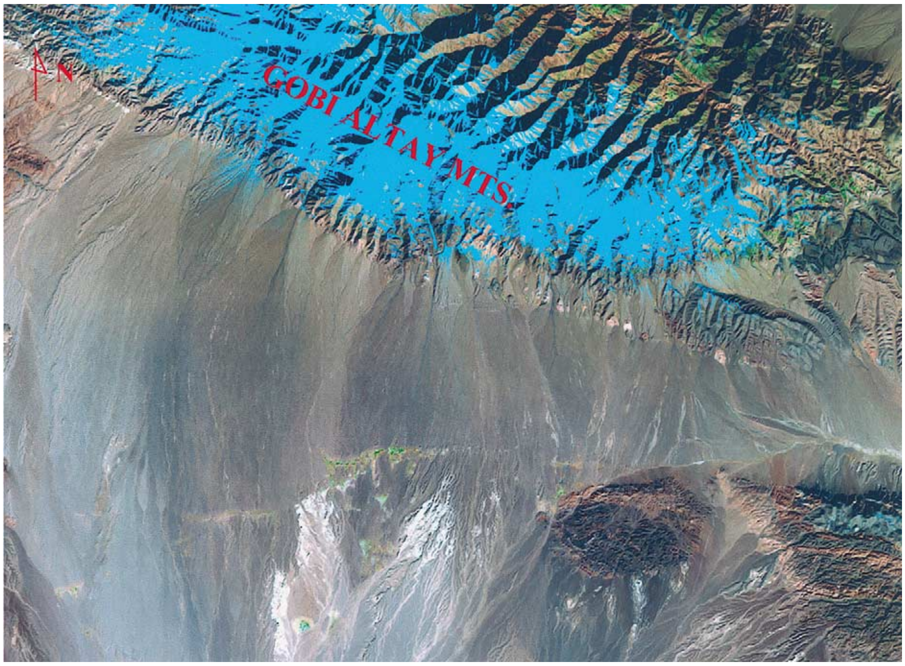

Fig. 9. Landsat TM image (October 20, 2000) showing the landscape in Gobi Altay Mts., southern Mongolia. Note the huge alluvial fans in the piedmont regions, which are the important sources of the silt-size particles transported to the Loess Plateau. See Fig. 6 for location.

Of course, the production of the vast amount of silt-sized particles forming the Loess Plateau is not only associated with the above mountain processes, the alluvial sediments of the Yellow River [2,41] and the eolian abrasion process in the sand deserts can be also minor sources of the Loess Plateau. Here, it is worthy to stress that not only the loess formation in the high mountain regions of western China but also in the plateau region is associated with the mountain processes in High Asia. In this sense, the concept of 'mountain loess' (Smalley [9]) can be more suitably used than 'desert' loess in China.

4.4. *Different pathways, transport distances, contributions, and climatic effects of dust entrained from China and southern Mongolia*

The frontal systems and the Mongolia Cyclone are the most active wind systems for dust storm outbreaks in China [2,23,49,50]. The entrained dust is either transported by the near-surface winds (usually below 2500 m asl) or by the westerlies (above 5000 m asl). The eolian dust from different source regions has different pathways, transport distances, contributions and climatic effects.

As proposed by Yaalon [51], eolian dust can be divided into three kinds: local dust, medium distance dust and long distance dust. In China, the eolian dust entrained from the Junggar and Qaidam basins is transported by near-surface winds. Influenced by the high topography, they are not easily transported out of the basins but mainly accumulated in the windward slopes of the downwind mountains. They are typical local dust. For the Tarim Basin, dust transported by the northeasterly near-surface winds is also local dust, accumulated in the windward slopes of the Kunlun Mts. (see Fig. 8b). However, dust in the Tarim Basin can be also entrained to elevation of >5000 m, then transported by the westerly jet stream for long distance (e.g., 5000 km or even more, Fig. 10). These long distance transported dust materials are important sources of deep-sea airborne materials in the Pacific Ocean.

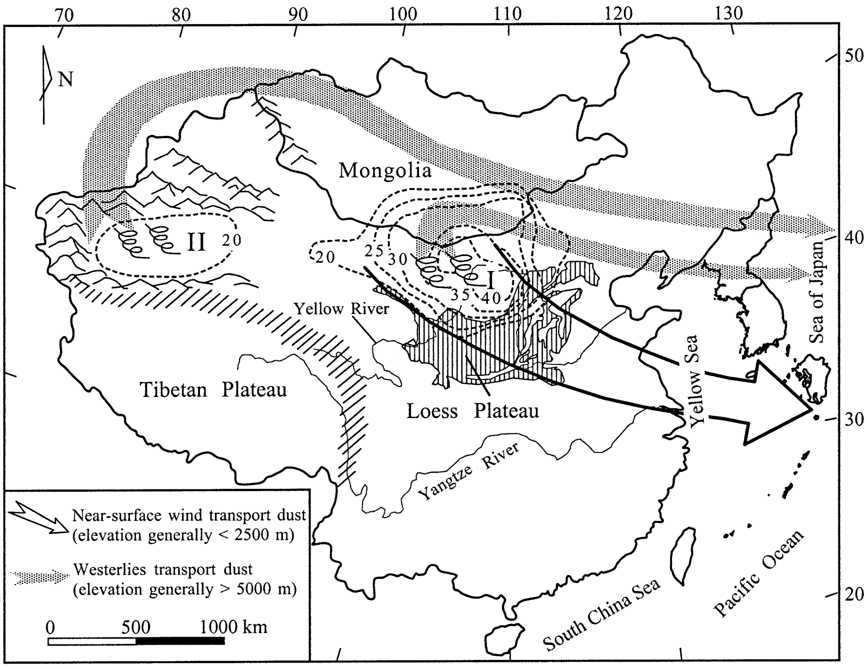

Fig. 10. Map showing the pathways of dust entrained from the two dominant dust source regions of China. Dashed contour lines indicate the times of dust storm events during the spring season of 1960–1999. Area I is the gobi in southern Mongolia as well as the adjoining gobi and sand deserts in China; Area II is the Taklimakan Desert.

Dust entrained from the gobi in southern Mongolia as well as the adjoining gobi and sand deserts in China has two distinct transport modes. In most cases (about 90%, Sun et al. [23]) they are transported by the near-surface winds, but they can be also transported by the westerly jet stream (Fig. 10). Dust transported by the two different wind systems has quite different contributions to the proximal and distal regions (Fig. 10).

First, unlike the situation in the inland basins, there are no high and huge topographic obstacles (except some sparsely distributed small mountains) between the above gobi/sand deserts and the Loess Plateau, mountains with elevations of about 2000–2500 m mainly occur in the southern and eastern Loess Plateau. This specific geomorphological feature highly favors the near-surface dust transportation, and this is the main reason for the formation of the vast and thick loess deposits in the Loess Plateau. In fact, although there are mountains in the southern and eastern plateau, the discontinuity and the limited elevations cannot effectively impede the dust transport to southeastern China and the near Pacific. These near-surface wind transported dust materials from the above gobi and sand deserts are thus medium distance dust, with a transport distance ranging from 500 to about 3000 km. A study of the dust storm of April 14–17, 1998, clearly indicated that the source region was the gobi in Mongolia and adjoining gobi and sand deserts in China, and the dust transported and accumulated (mainly as wet deposition) in the Loess Plateau, southeastern China and the near Pacific (Fig. 11a). This can be also demonstrated by the satellite images of the same dust storm (Fig. 11c, Perkins [52]).

Second, dust entrained from the above gobi and sand deserts in Mongolia and China can be also transported by the westerlies after entrainment to elevations of >5000 m (Fig. 10). In this case, they are not the sources of the proximal Loess Plateau but important sources of the distal deep-sea sediments in the Pacific. Study of the

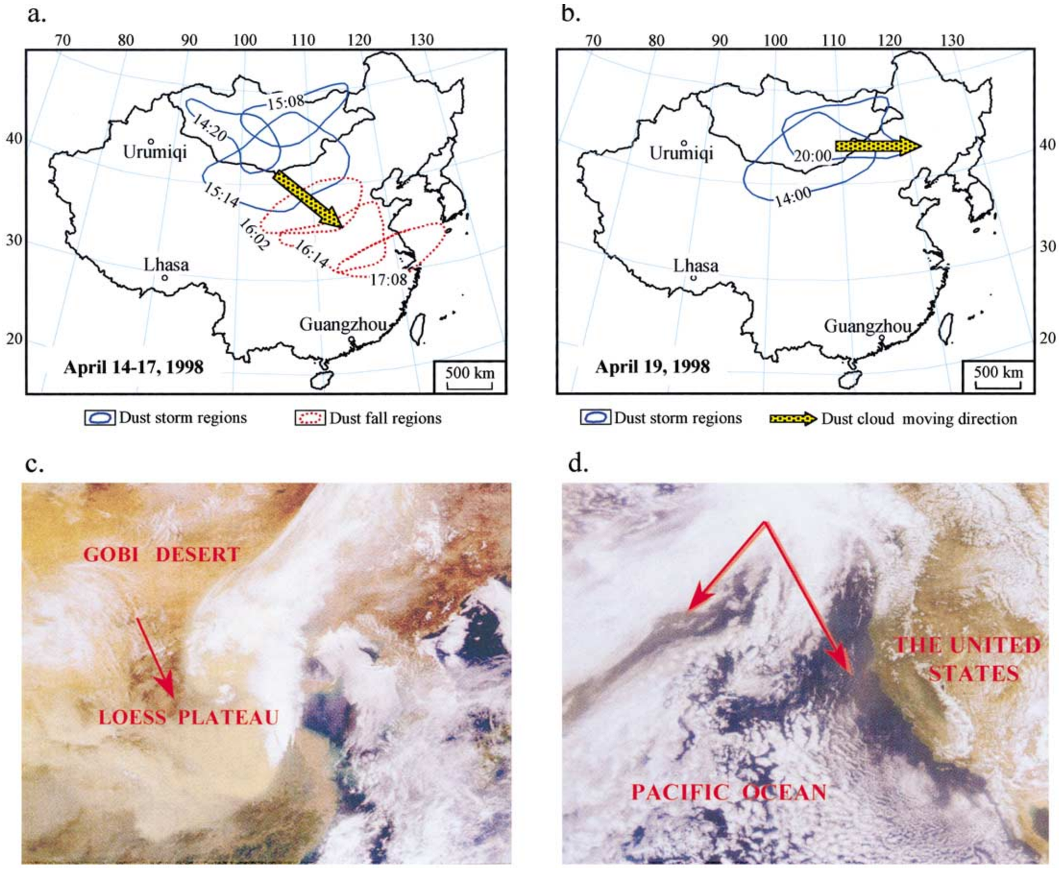

Fig. 11. (a) and (b) are daily boundaries of the dust storm and/or dust fall compiled from surface weather maps during the dust event of April 14–16, 1998 and the subsequent dust event of April 19, 1998. Note that there was no observed dust fall in the Loess Plateau during the latter dust storm event. (c) and (d) are the corresponding satellite images of the above two dust storms [52]. Note that the dust storm of April 14–16, 1998 originated from the gobi in Mongolia as well as the gobi and sand deserts in China (dust transported by near-surface winds) and sent a massive cloud of yellow dust southeastward to the Loess Plateau and southeastern China (c). However, the dust cloud on April 19 originated from the same region but was transported by westerlies across the Pacific and reached the western coast of North America (arrows) after about one week (d).

dust storm event on April 19, 1998, indicated that the source region was also the gobi and sand deserts in Mongolia and the adjoining China (Fig. 11b). However, these westerlies-transported dust was not accumulated in the proximal region (e.g., the Loess Plateau), because there is no observed dust fall occurring in China (Fig. 11b) which is quite different from the dust storm of April 14–17, 1998 (Fig. 11a). Studies on the satellite images clearly indicated that the dust transported by the westerlies moved to the Pacific Ocean and even passed over this ocean to the western coast regions of the United States after about 7 days (Fig. 11d, Perkins [52]). In this case, dust entrained from the gobi in Mongolia and the adjoining gobi and sand deserts in China is long distance dust (with the transport distance can be up to 12,000 km or even more).

There are differences in both the contributions and the climatic effects of eolian dust transported by different wind systems. Local and medium distance dust is transported by near-surface winds; the low elevation and short persistence duration in the air is not favorable for affecting the solar radiation in the atmosphere. However, the westerlies-transported fine mineral dust (usually < 10 μm) can be transported not only for long distances but also can be suspended in the atmosphere for a long period. Tsoar and Pye [30] argued that the very fine mineral aerosols could persist for several months or longer in the atmosphere. These long distance eolian dusts not only contribute greatly to the Pacific, but also have the potential of affecting global climate by influencing the radiative balance of the atmosphere.

5. Conclusion

Although Chinese loess studies have been in the scientific literature for a long period, the origin and provenance of loess materials in different geomorphological units still remains controversial. For the most extensive and the thickest loess deposits on the well-known Loess Plateau, a desert origin and a vast provenance (including the gobi and sand deserts in the nearby region and those in the three northwestern inland basins (the Junggar Basin, the Tarim Basin, and the Qaidam Basin)) had been proposed. However, the isotopic, chemical and mineralogical characteristics of loess derived from the three basins are quite different from that of the Loess Plateau samples, suggesting that these basins are not the source areas of loess deposits on the plateau. Here, the author suggests a qualification of the conventional views that the three northwestern basins were the important provenance of the Loess Plateau and the sand deserts were the primary single source of the Chinese loess.

It is argued that the gobi in the southern Mongolia and the adjoining gobi and sand deserts (including the Badain Jaran Desert, Tengger Desert, Ulan Buh Desert, Hobq Desert and Mu Us Desert) in China are the source areas for the Loess Plateau. However, although these gobi and sand deserts are regarded as the main source regions, they serve as dust and silt holding areas rather than dominant producers. Mountain processes (including glacial grinding, frost weathering, salt weathering, tectonic processes, and some fluvial comminution) in the Gobi Altay Mts., Hangayn Mts. and the Qilian Mts. have played an important role in producing the vast amounts of loess-sized material for forming the Loess Plateau. In contrast, the alluvial sediments of the Yellow River and eolian abrasion processes in the sand deserts can be only minor sources for the plateau. The zonation of gobi, sand desert and loess from northwest to southeast, is largely the results of wind sorting of the huge alluvial deposits from the above high mountain regions.

Dust entrained from different geomorphological units of China has different contributions to the proximal and distal regions. Dust derived from the Junggar and Qaidam basins is transported by near-surface winds, and thus mainly accumulates on the windward slopes of the local mountains (local dust). For the Tarim Basin, dust can be transported not only by the near-surface winds (accumulated in the windward slopes of the Kunlun Mts., known as local dust), but also by the westerlies whenever the dust is entrained to an elevation of > 5000 m asl. In the latter case, dust from the Tarim Basin (the Taklimakan Desert) can be transported out of the basin and ultimately to the remote Pacific (long distance dust). In most cases, dust entrained from the gobi in Mongolia and adjoining gobi and sand deserts in China is transported by near-surface winds to the plateau region, southeastern China and the near Pacific, serving as medium distance dust. Occasionally (about 10%), the entrained dust from the above gobi and sand deserts can be transported by the westerlies to the remote Pacific Ocean and even to the United States (long-distance dust).

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