Grain size distribution of quartz isolated from Chinese loess/paleosol

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Abstract Grain size distribution of bulk loess-paleosol and quartz chemically extracted from the loess/paleosol shows that mean size of the bulk samples is always finer than that of the quartz. The original aeolian depositions have been modified to various degrees by post-depositional weathering and pedogenic processes. The grain size distribution of the isolated quartz should be close to that of the primary aeolian sediment because the chemical pretreatment excludes secondary produced minerals. Therefore, the grain size of the quartz may be considered to more clearly reflect the variations of winter monsoon intensity.

Keywords: **loess/paleosol, quartz, grain size distribution.**

Loess and paleosols in north China are the products of aeolian sedimentary process involving weathering and pedogenic processes to various degrees[1]. The grain size of bulk samples has been regarded as an approximate measure of intensity of East Asia winter monsoon[2]. Quartz is a major component of the loess-paleosol accumulation, reaching a content of 48%—65%. Owing to its chemical and physical resistance, the grain size of the quartz has been regarded as a more reliable proxy index of the winter monsoon intensity[3—5]. However, comparison of the grain size composition between the bulk loess/paleosol and the quartz has not been reported. In this study, a 4-m loess-paleosol section in the south of the Chinese Loess Plateau was sampled in order to examine the grain size distribution of the quartz and the bulk loess-paleosols, and to document the effect of weathering and pedogenic processes on primary aeolian sediment.

1 Quartz isolation and grain size analysis

Bulk samples were collected from the loess-paleosol profile at Lingtai. All the bulk samples weighing 2 g were boiled with 30% hydroxgen peroxide (H_2O_2) to remove organic matter and with 10% hydrochloric acid (HCl) to remove carbonates and iron oxides. The monomineralic quartz is concentrated by dissolving the clay with potassium pyrosulfate ($K_2S_2O_7$) fusion and 30% hydrofluosilicic acid (H_2SiF_6). X-ray analysis of the residual shows that the quartz content is 95% purity, with mica, feldspar and other silicates effectively removed. Scanning electron microscope observation shows that shape and particle size of the quartz has not been changed. At the same time, all the bulk samples were pretreated with the method described by Lu and An[6] for grain size measurement. Both the bulk samples and the quartz were measured for grain size distribution by a Mastersizer S Laser instrument with a 0.015ϕ resolution and a range of 0.05—880 μm.

2 Grain size distribution

Particle size distribution may reflect both primary transport dynamics as well as modification by post-depositional pedogenesis. The grain size distribution of two randomly chosen samples from the loess of the last glacial period and the paleosol of the last interglacial period shows a bias towards the finer, within the range of 0—120 μm (fig. 1). There is a break in the grain size distribution in the bulk loess-paleosol near 10—20 μm, reflecting a bimodal distribution. However, the grain size distribution of the quartz decreases smoothly at around 10 μm, and the distribution of the quartz is unimodal. A small mode between 0—1 μm is also present in the distribution of both the bulk samples and quartz. The small <1 μm fraction may be clay minerals component, the products of pedogenesis. The major difference content in the fine fraction (<1 μm) between the bulk and quartz samples, as well as the difference in the grain size distribution of other size fractions, is because the silicates and chemical materials produced by post-depositional pedogenesis have largely been removed[7].

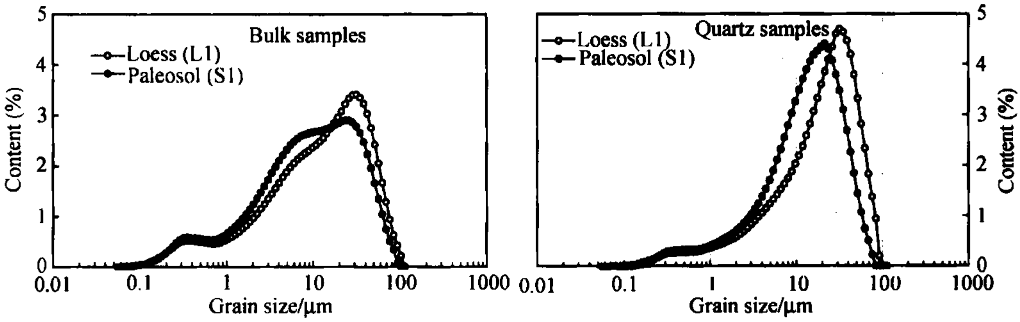

Fig. 1. Comparison of the grain size distribution between the bulk loess/paleosol and the quartz samples.

Table 1 shows the content of clay fraction (<2 μm), ultra-fine silt (2—5 μm), fine silt (5—16 μm), moderate silt (16—30 μm), coarse silt (30—63 μm) and the mean size of the bulk loess-paleosol and quartz samples. Due to the weathering and pedogenic processes, the <5 μm size fraction of the quartz is lower than that of the bulk samples. On the other hand, the 5—30 μm size fraction of the quartz is higher than that of the bulk samples. The content of the >30 μm size fraction of the quartz nearly matches that of the bulk samples. The deviation (table 1) illustrates the difference between the quartz and bulk samples for the same size fraction. This reflects the modification to the original aeolian sediment by pedogenic and weathering processes. For example, the <2 μm fraction content of bulk paleosol is higher than the quartz fraction by 77% but only 51% higher in the loess sample. The larger increase in the fine particles may indicate stronger weathering and pedogenesis process in the paleosol compared to the loess. The mean size of the paleosol is 9% less than the quartz samples, while the mean size of the loess is similar to that of the quartz. Therefore, the change of the grain size fraction proves that the paleosol has been stronger modified by pedogenic processes compared with the loess.

Table 1 Comparison of grain size composition of bulk loess/paleosol samples and quartz

	<2 μm	2—5 μm	5—16 μm	16—30 μm	30—63 μm	Mean/μm	Kurtosis
Loess	14.84%	12.48%	26.99%	22.8%	19.3%	19.38	1.29
Quartz	9.81%	11.54%	30.2%	26.81%	20.05%	19.579	0.294
Deviation	51%	8%	−11%	−15%	−4%	−1%	
Paleosol	16.85%	16.63%	31.51%	19.96%	13.36%	15.228	2.123
Quartz	9.5%	10.6%	37.31%	28.7%	13.17%	16.736	1.373
Deviation	77%	57%	−16%	−30%	1%	−9%	

Deviation = Mean (Qtz) – Mean (Bulk) /Mean (Qtz) × 100%.

3 Discussion

The aeolian sediment has been modified by weathering and pedogenic processes, which were controlled by climatic and bio-geochemical conditions. The chemical weathering of unresistant minerals such as feldspar and mica lead to the formation of the authigenic clay minerals. With the pedogenic processes strengthening, the concentration of the coarse fraction (16—30 μm) would decrease. Conversely, the fine silt and the clay fractions would increase. Grain size modification of the aeolian sediment is revealed by the variation of the coarse (>16 μm) and the finer size fractions (2—16 μm). The grain size distribution between the same bulk and quartz samples demonstrates that the particle fractions have been changed by post-depositional pedogenesis to various degrees. Owing to less modification to the grain size of quartz by pedogenic processes, the gain size of the quartz may closely reveal the variation of the winter monsoon intensity.

The millennial time-scale variability of the East Asian winter monsoon has been previously demonstrated by the grain size variations with both the bulk and quartz samples [4, 5, 8, 9]. Fig. 2 shows

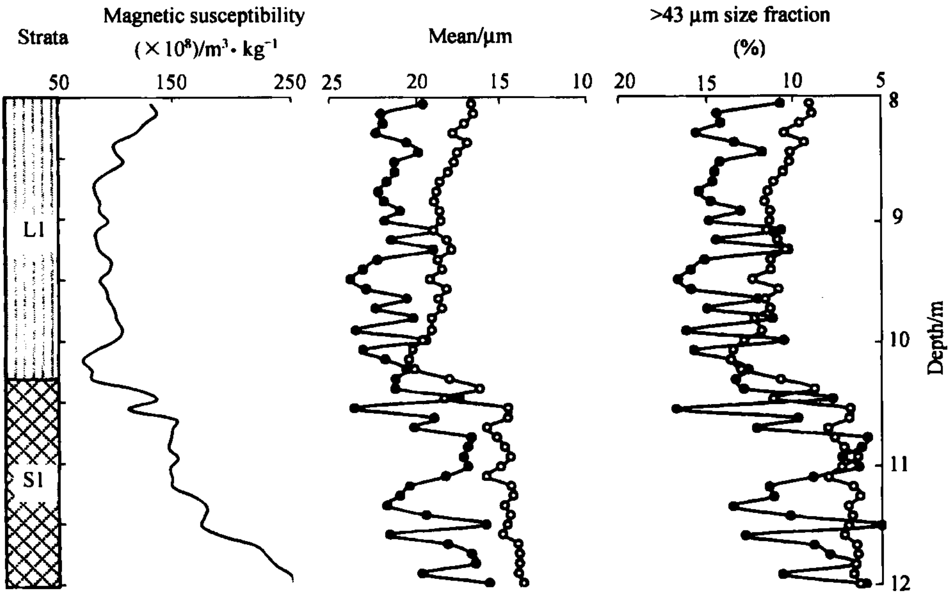

Fig. 2. Grain size variation of the bulk samples (open cycle) and the quartz (solid cycle) samples from the last interglacial paleosol to the last glacial loess.

the grain size of the bulk samples varied with only small amplitude during the last glaciation (L1) and interglaciation (S1) although a clear change takes place in the transition of S1/L1. By comparison, the grain size of the quartz displays large amplitude change during both the last interglaciation and glaciaal phase, but with a small chang during the transition of S1/L1. This is the first detailed comparison of the grain size variations of both of the loess-paleosol and the quartz component isolated from the same specimens, demonstrating that the grain size distribution of the quartz and the loess-paleosol are significantly different. Unresolved aspects of grain size variations (fig. 2) suggest that the implication of grain size distribution of the quartz and the loess/paleosol should be further investigated.

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