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ORIGINAL ARTICLE

The spatial distribution of trace elements in topsoil from the northern slope of Qomolangma (Everest) in China

Y. L. Zhang · Z. F. Wang · K. L. Luo · M. J. Ding · W. Zhang · X. D. Lin · X. C. Yang

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Abstract The environment of Mt. Qomolangma (Everest) area is of great significance to the global environmental background and environmental change research. However, there are few studies on the content and distribution of soil trace elements in the area. About 130 soil samples were collected nearby the Rongbuk valley at the northern slope of the Qomolangma from 4,400 to 6,600 m elevations. Nine soil trace elements, Cr, Zn, Sr, Pb, Ni, Co, Cd, Mn, Cu, were analyzed with ICP-AES (inductively coupled plasma atom emission spectrometry). The results showed that soil trace elements content increased with altitude; the content of the Cd in this area was very high, which was 5.8 times of the average content of Chinese soil. There was a noticeable change point for soil trace elements content at the altitude of 5,800 m, and the content of Cd increased abruptly above 5,800 m. This point was just located at the boundary of two types of rocks. The Late Precambrian-Neoproterozoic granite–gneiss and metacryst migmatized interbedded with marble located below 5,800 m; black-dark slate and marl of Cambrian located above 5,800 m (including 5,800 m), the geochemical characteristic of different rocks was the main factors controlling the soil trace elements content in the northern slope of Qomolangma Mountain.

Keywords Qomolangma (Everest) · Soil trace elements · Neoproterozoic granite–gneiss and migmatite interbeded with marble · The Lower Cambrian black slate and marl

Y. L. Zhang (✉) · Z. F. Wang (✉) · K. L. Luo · M. J. Ding · W. Zhang · X. C. Yang
Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS), Beijing 100101, People's Republic of China
e-mail: zhangyl@igsnrr.ac.cn

Z. F. Wang
e-mail: wangzf@igsnrr.ac.cn

Y. L. Zhang · X. D. Lin
Institute of Tibetan Plateau Research (ITP), CAS, Beijing 100085, People's Republic of China

Z. F. Wang · M. J. Ding · W. Zhang · X. D. Lin · X. C. Yang
Graduates School of Chinese Academy of Sciences, Beijing 100049, People's Republic of China

Introduction

Qomolangma (Everest)—the world's highest peak, standing in the middle of the Himalayas, is of great importance to study the world environmental backgrounds and their change for its unique natural conditions, height and complex tectonic geology in the world.

The environmental state of Qomolangma area can indicate global environmental change (Gao et al. 1996; Zhou 2000), for it retains its natural condition without strong human disturbance. Soil trace elements content is one of the fundamental factors to reflect the natural environmental change. To study the soil trace elements content and distribution would be helpful to know the environmental background of the Qomolangma area, to monitor the environmental change and to anticipate the global environmental change.

There are few special reports on soil trace elements in the northern slope of Qomolangma. One of representative researches was the scientific expedition undertaken by the Chinese Academy of Sciences during 1966–1968. The results showed that except for B, the average content of soil trace elements (V, Cr, Mo, Mn, Cu, Zn, Co and Ni) in Qomolangma area was below the world soil average content (the reports on the Qomolangma scientific exploitation-physical geography 1975). On this basis, Zhang et al. (1985) discussed the spatial distribution characteristics of soil Cd and Pb content in the area and thought that soil cadmium and lead content were dependent on their content in their parent material (parent rocks). However, only four soil samples were analyzed and no systematical research in the northern slope of Qomolangma was carried out because the expedition was to study the general content and distribution of soil trace elements in the entire Qomolangma area (from south of the Yarlung Zangbo River to the national boundary). Moreover, the test accuracy was limited due to technical constraints at that time. From then on, no special research was carried out to study the soil trace elements. Therefore, the content and distribution of the soil trace elements in the northern slope of Qomolangma Mount in detail in recent years was still not known. As there are more and more climbing expeditions in Mt. Qomolangma year after year, which affects the soil environment consequentially, it is important to capture the background content and distribution of soil trace elements to compare with the effect on soil trace elements content of the human activities.

In this study, 130 samples are collected within the elevation 4,400–6,600 m in the northern slope of Qomolangma. Soil trace elements content is measured by means of ICP-AES, to discuss the content and distribution pattern of the soil trace elements, and illustrate their source of content differences in the northern slope of Qomolangma.

Materials and methods

Study area

The study area is located in the town of Zhaxizong in Tinggri County of the Tibet Autonomous Region in China (as Fig. 1). Tinggri County belongs to the semi-arid plateau with temperate monsoon climate zone, with great differences in temperature between day and night, arid climate, long sunlight time, little rainfall and big evaporation. In this area, the annual average temperature is 0.7°C, and the average difference in temperature is 22.9°C between day and night, annual precipitation equals 319 mm, the average annual evaporation is 2527.3 mm, and the annual mean wind speed is 4.4 m/s (Rongbulk Temple). In Tinggri County, the average altitude of lake plains is 4,500 m, and the mountain area is above 5,000 m. Zhaxizong lies in Peng-Qu River valley, which is alluvial plain and tilted topography.

Alpine grassland vegetation, with shrub interspersing, is the main type vegetation in the study area. No vegetation is found above the altitude 5,750 m near the sampling points during investigation time, and there are no artificial farming activities around all sampling points. The soil there, is very primitive and skeletal with thin layer in the study area, and the average content of gravel larger than 2 mm was about 40%.

The study area in Qomolangma lies across two geotectonic units (Pan et al. 2002) (as Fig. 2), the south part is the high Himalayan crystallization belt unit, which is mainly an outcrop of the Precambrian period crystalline

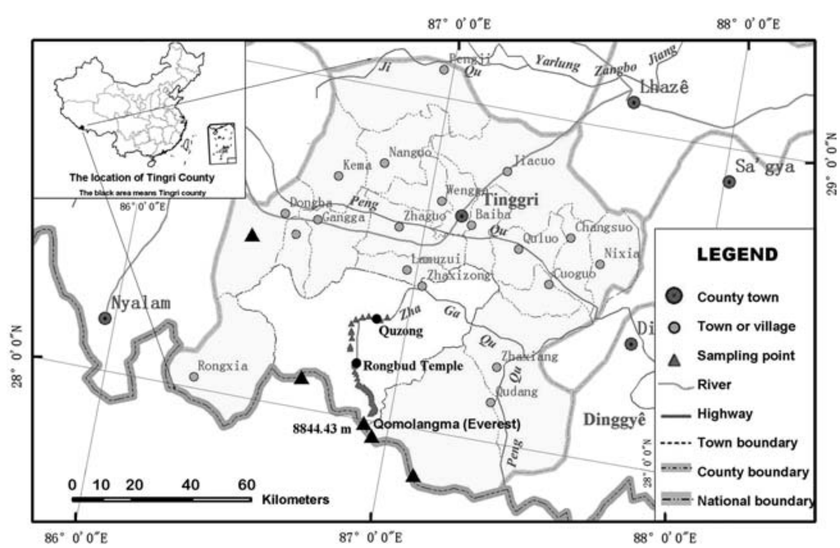
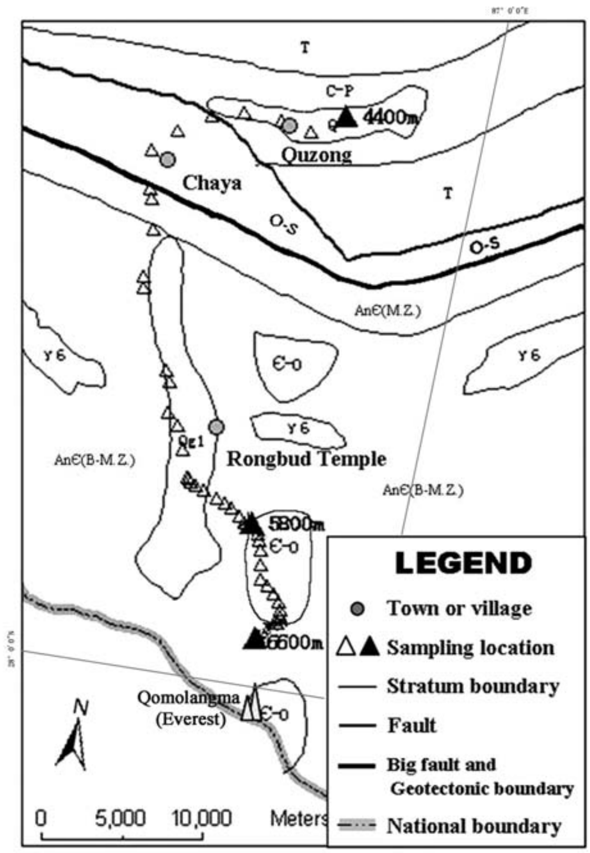


Fig. 1 The location of the study area



T: Trias; **Q**: Quaternary; **γ 6**: Granodiorite;
C-P: Carboniferous-Permian; **Qg1**: Quaternary glacial deposit;
O-S: Ordovician-Silurian period; **AnЄ(M.Z.)**: Muscovite belt;
Є-O: Cambrain- Ordovician; **AnЄ(B-M.Z.)**: Two-mica belt;
According to the geological map of Qomolangma area drawn by the Tibet Exploitation of CAS in Sept. 1968(1:1 000 000)

Fig. 2 The geological map of the northern slope of Qomolangma

rocks and Cambrian–Ordovician stratum (Xiang et al. 1999); the North is the North Himalayan Tethys sediment folds belt which consists of Carboniferous-Permian system carbonate rock, Triassic sand shale and limestone layers, and entered former Department of the Cambrian period and Cambrian–Ordovician stratum area after crossing two tectonic boundaries.

Sampling and analysis

The study was carried out as one part of the fourth large-scale Qomolangma investigations taken by Chinese Academy of Sciences. Three surface soil (10 cm thickness) samples were collected with wooden shovel, packed with cloth bags separately, every 50 m in vertical gradient, from the altitude of 4,400 m near the village Quzong, along the Rongbuk valley (the upstream of Zhaga Qu), through the bottom of the Middle Rongbuk glacier, then turn into East Rongbuk glacier valley to the high altitude of 6,600 m. The geographical co-ordinates and vegetation conditions were recorded simultaneously. In total 130 soil samples were collected in the northern slope of Qomolangma from 1, April 2005 to 20, April 2005 for the three samples in 5,000 m and 2 samples in 4,700 m and 5,200 m were lost in transportation.

About 20 g air-dry soil was taken from each soil sample, after which the gravels larger than 2 mm and vegetation roots were removed with a 2 mm-nylon-sieve. Each sample was skived with agate mills and all passed through the 100 mesh-nylon-sieve (0.150 mm). These soil samples were analyzed in the Laboratory of Analytical and Testing Center in Beijing Normal University. Nine soil trace elements (Cr, Zn, Sr, Pb, Ni, Co, Cd, Mn, and Cu) content was measured by inductively coupled plasma-atomic emission spectrometry (ICP-AES), after high-pressure digestion with H_2SO_4, HNO_3, and HF (Yu et al. 2001).

For quality control in chemical analysis, the standard reference materials GBW 07401 (GSS-1, soil, China, Chinese Standard Sample Study Center, Chinese Academy of Measurement Sciences) were randomly analyzed with each batch of soil samples. The relative standard deviation was 10% and the detection limit was 10^{-9}.

Results and discussion

As can be seen from Fig. 3, soil trace elements content increased with the altitude rising in the study area. The contents of Cr, Co, Cd increasing trends are the most evident (as Fig. 3).

There was an obvious change for the most soil elements at the altitude of 5,800 m; trace elements content suddenly rises in the area above 5,800 m altitude; the change of content of Cd is most obvious. The average Cd content between 5,800 and 6,600 m is 3.6 times to that of the soil collected from 4,400 to 5,750 m, other elements average content above 5,800 m were also much higher than that of below 5,800 m.

As can be seen from the Fig. 4, above 5,800 m, the soil Cu, Mn, Ni, and Cr contents were close to the average contents of Chinese soil and the Tibet Autonomous Region soil (China Environmental Monitoring terminus, Chinese soil background values of elements 1990), but the soil contents of these four elements below 5,800 m were far lower than the average contents. On the contrary, the soil Cd, Pb, Sr and Zn contents below 5,800 m were close to the average content of Chinese soil or Tibet soil, but the average contents of these four

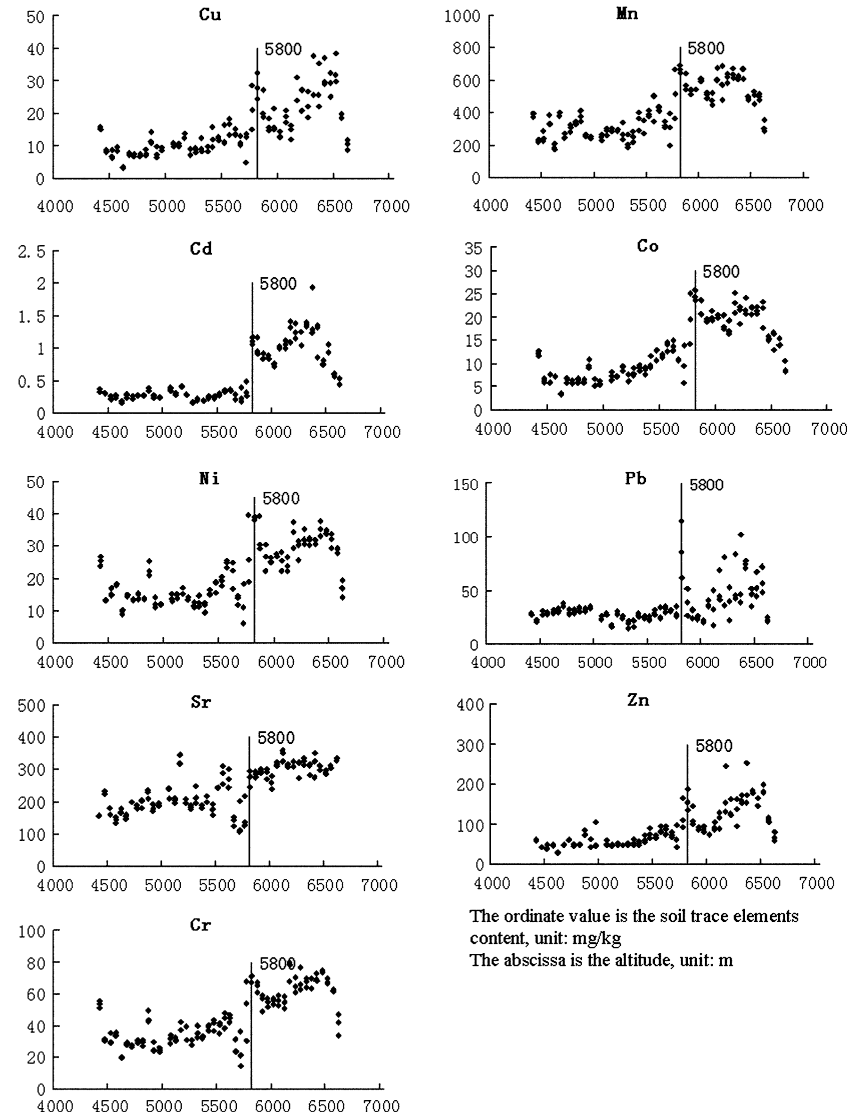


Fig. 3 Spatial distributions of soil trace elements

elements and Co above 5,800 m were far higher than the average contents (as Fig. 4).

As a whole, the average content of Cu, Mn, Ni, Cr in the soil of Rongbuk valley in Qomolangma northern slope between altitude 4,400 and 6,600 m is lower than that in the Tibet Autonomous Region soil, and is also lower than national average levels. Among them, the content of Cu is only 68% of the national average content. Cd, Pb, Sr, Zn content is higher than the average levels of Chinese soil and Tibetan soil. In particularly, the Cd content is 5.8 times of the national average level. The average Co content is equal to the average contents of national and Tibetan soil.

The vertical distance between the sample points of the altitude of 5,750 and 5,800 m is 50 m, and horizontal distance between them is 340 m. Although the two group points were so near, their contents of soil trace elements are so different.

There is little human activity in the northern slope and even no traces of human cultivation in the study area. The soil is still in a relatively primitive state, affected or controlled mainly by natural factors. The physical crack is the dominating process for the soil forming. Therefore, the difference of parent material could be the main reason causing the difference in soil trace elements content.

In the field survey, a boundary of rocks was found at the altitude between 5,750 and 5,800 m (as Fig. 2). They are Neoproterozoic (Precambrian) granite–gneiss and migmatite interbedded with marble below the 5,800 m and black-dark slate and marl of Cambrian above 5,800 m (including 5,800 m), Parent rocks of lower part is the Lower Cambrian black shale (slate and marl), and upper part above 6,500 m perhaps belong to Rouqie Group of Cambrian (Xiang et al. 1999).

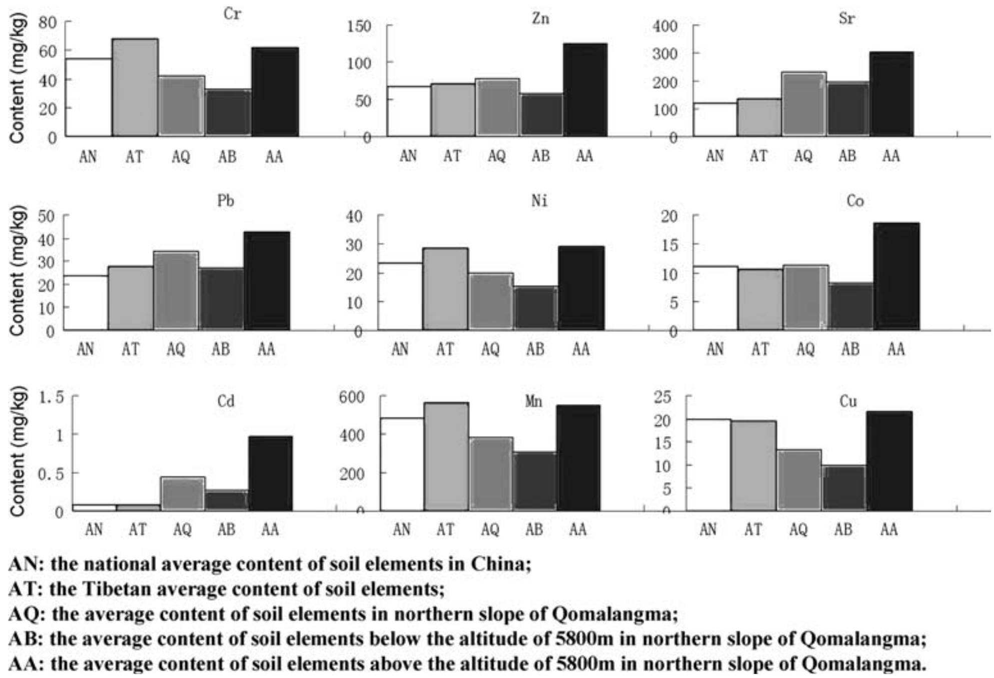


Fig. 4 Comparison of average content of soil elements in different area

The trace element content and geochemical characteristics of the different age's rocks are different (Zhou et al. 2003). The Neoproterozoic granite–gneiss and migmatite interbedded with marble has a lower content of trace metal element, and the Cambrian, especially the Lower Cambrian black shale is rich in the trace metal element (Fan et al. 1981; Horan et al. 1994; Luo et al. 2004). Some trace elements, such as Ni, Cu, Pb, Zn, Cd et al., highly enriched in the Lower Cambrian black shale in Guizhou-Hunan provinces, southwest China (Li et al. 2000), in the Yangtze Platform (Luo et al. 1999; Fan et al. 1981), in Tarim Basin, northwest of China (Yu et al. 2005), and in Hunan, South China (Pan et al. 2004). Therefore, the different ages and types of rocks, with the different trace element content and geochemical characteristics control the content of soil trace elements in the northern slope of the Qomolangma Mountain. More geological background works need to be done.

Conclusion

The content of soil trace elements increases with the elevation increasing in the Rongbuk valley of Qomolangma Mount northern slope range from altitude of 4,400 m to 6,600 m. The average content of Cd in soil is the 5.8 times than that of the national average. Most of trace elements contents suddenly rise from the altitude of 5,800 m. There is a sudden turning point of trace elements content in 5,800 m, which was caused by the difference original geochemical characteristics of different bedrocks.

Till now, there is no study on strata sequence in the northern slope of Qomolangma in detail and even not any fossil reports in the area. Based on the rock type and strata sequence we distinguish the strata units. The further study can focus on the relationship between soil trace elements content and the corresponding elemental content of the bedrocks, and their control mechanisms.

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