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Chemical weathering of monsoonal eastern China: implications from major elements of topsoil

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ABSTRACT

Major element compositions of 36 bulk samples and 41 clay samples, which were obtained from 47 topsoils collected in monsoonal eastern China, were investigated with conventional wet chemistry and X-ray fluorescence (XRF) spectrometry, respectively. Based on major element analyses, the mobility of major elements and latitudinal distributions of SiO_2/Al_2O_3 ratio, chemical index of alteration (CIA), chemical index of weathering (CIW) and weathering index of Parker (WIP) were analyzed. Meanwhile, the suitability of these chemical weathering indices to topsoils in monsoonal eastern China and its controls were discussed.

These investigations indicate that Na, K, Ca, Mg, and Si are relatively depleted, while Mn, P, Fe and Ti are relatively enriched in topsoils of the study area by comparison with their contents in the upper continent crust (UCC), and that alkali metal (Na, K) and alkaline earth metal (Ca, Mg) elements are generally easier to be depleted from their parent materials than other major elements during chemical weathering. The latitudinal distributions of CIA, CIW and WIP show that they are suitable to both bulk and clay samples, but SiO_2/Al_2O_3 is only suitable to clay samples, not suitable in bulk ones. All these investigations indicate a significant dependence of grain-size in major element abundance and latitudinal distributions of SiO_2/Al_2O_3, CIA, CIW and WIP, but parent rock type has little effect on them, except its impact on the latitudinal distribution of WIP in clay samples. The significant grain-size dependence probably indicates the presence of unaltered minerals in bulk samples, thus we suggest that clay samples are more suitable to investigating chemical weathering of sediments on continents than bulk samples. The trivial effect of parent rock type probably indicates a relatively uniform chemical weathering on various parent rocks. Correlation analyses indicate that climate is the dominant control of chemical weathering of topsoils in the study area, and the significant latitude effect indicated by the spatial distributions of chemical weathering indices actually reflect the climate control on chemical weathering of topsoils.

Chemical weathering indices actually reflect the integrated weathering history in the study area. Besides the dominant control of climate, other factors like tectonics, parent rock, biology, landform and soil depth and age might also have some effect on the chemical weathering of topsoils in the study area, which needs further research.

1. Introduction

Chemical weathering is an important surface process of the earth and related to many environmental changes caused by interactions and feedbacks among atmosphere, lithosphere, hydrosphere and biosphere. It has long been a research focus in geosciences because of its significance in the earth surface evolution (Nesbitt and Young, 1982; Allen et al., 2001; Chen et al., 2001; Minasny and McBratney, 2001; Dixon et al., 2009), global carbon cycle (Berner et al., 1983; Volk, 1987; Raymo et al., 1988; Brady, 1991; Berner, 1992, 1995; Amiotte Suchet and Probst, 1993; Kump et al., 2000), pedogenisis (Jackson and Sherman, 1953; Sverdrup and Warfvinge, 1988; Minasny and McBratney, 2001; Yoo et al., 2007), and civil engineering (Dearman et al., 1978; Steward and Cripps, 1983; Fookes et al., 1988; Lan et al., 2003).

Persistent investigations on the controls of chemical weathering have contributed a lot to our understanding on the links between chemical weathering and its controlling factors, such as tectonics (geological settings and topographical conditions) (Raymo et al.,

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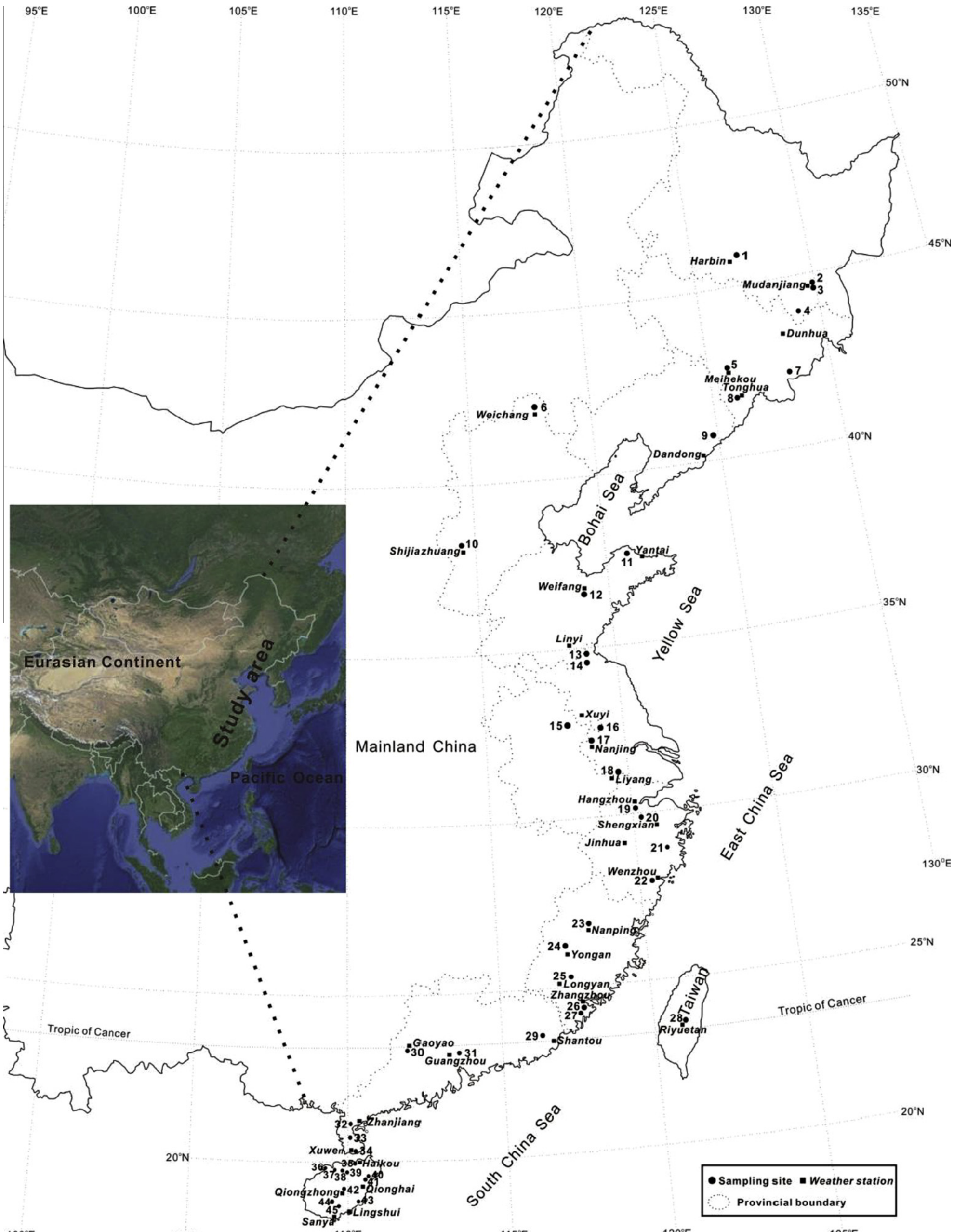

Fig. 1. A sketch map of the study area with sampling sites and weather stations.

1988; Drever and Zobrist, 1992; Raymo and Ruddiman, 1992; Berner and Berner, 1997; Riebe et al., 2001; Jacobson et al., 2003; West et al., 2005; Liu et al., 2007a,b; Moore et al., 2013); provenance (or lithology of source rock) (Sawyer, 1986; Nesbitt and Wilson, 1992; Le Pera et al., 2001; Dessert et al., 2003; Price and Velbel, 2003; Caspari et al., 2006); climate (temperature, precipitation and runoff) (Velbel, 1993; Brady and Carroll, 1994; White and Blum, 1995; Riebe et al., 2001, 2004; Yang et al., 2004; Deepthy and Balakrishnan, 2005; Singh et al., 2005; West et al., 2005; Liu et al., 2007a,b; Gislason et al., 2008; Gabet et al., 2010; Li and Yang, 2010); vegetation (Berner, 1992; Drever, 1994; Gislason et al., 1996); time (Grantham and Velbel, 1988; Taylor and Blum, 1995; Gislason et al., 1996; White and Brantley, 2003); and even human activities (Motuzova and Hong Van, 1999; Chetelat et al., 2008). Although much work has been done, controversies still remain on the controlling mechanisms of chemical weathering, especially of silicate rocks (Stallard, 1995; Yang et al., 2004; West et al., 2005; Li and Yang, 2010; Willenbring and von Blanckenburg, 2010; Moore et al., 2013). Some conventional views about chemical weathering have even been challenged by new discoveries. For example, the famous “Uplift-Weathering Hypothesis” proposed a tectonic forcing of global cooling in Late Cenozoic, suggesting that the increases in chemical weathering driven by the uplift of the Tibet Plateau during that period may have resulted in the decreases of atmospheric CO_2, thus cooling the Late Cenozoic climate (Raymo and Ruddiman, 1992). A recent investigation questioned the tectonic forcing, however, with evidence on the long-term stability of global erosion and chemical weathering rates during the Late-Cenozoic cooling (Willenbring and von Blanckenburg, 2010). A most recent investigation also concluded that silicate weathering in uplifting mountain ranges does not control long-term climate change, based on Ca isotope analyses of silicate and carbonate