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Lead isotope variability of fine-grained river sediments in Tibetan Plateau water catchments: Implications for geochemical provinces and crustal evolution

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ABSTRACT

The crustal structure of the Tibetan Plateau records the dynamic processes of several terranes that underwent disaggregation, aggregation, and amalgamation. The dynamic evolution of continental crusts is best understood from these three processes. However, the detailed geochemical province division of the Tibetan Plateau and the palaeo-tectonic affinity or evolution of terranes remains unclear. In this paper, the acid-insoluble fraction of fine-grained river sediments from catchments in the whole Tibetan Plateau was measured for lead isotopes and trace elements. This study aims to reveal lead isotopic characteristics, to delineate different lead isotope geochemical provinces, and to trace and uncover the tectonic affinities of various terranes in the Tibetan Plateau. Results show that by weak acid chemical treatment, the characteristics of the Pb isotopes of fine-grained river sediments can be utilized to represent and discriminate geochemical provinces. The characteristics of Pb isotopes enable the identification of different geochemical provinces and the palaeo-affinity of various tectonic units. Constrained by tectonic evolution, the Tibetan Plateau tectonic units can be divided into the following five Pb isotope geochemical provinces: 1) Qilian Terrane; 2) Northern Tibetan Plateau geochemical province, including Eastern Kunlun-Qaidam, Songpan-Ganzi and Eastern Qiangtang Terrane; 3) Northern Lhasa Terrane; 4) Southern Lhasa Terrane, and 5) Himalaya Terrane. In relation to the controversy concerning the palaeo-affinity of the Qilian and Songpan–Ganzi Terranes, the Pb isotopic compositions of fine-grained river sediments suggest that they were much more likely separated from the Yangtze Craton than from the North China Craton. The characteristics of Pb isotopes and trace elements of the Eastern Kunlun–Qaidam and Eastern Qiangtang Terrane show some similarities with the Songpan–Ganzi Terrane, which indicate that they also possibly originated from the disaggregation of the Yangtze Craton. The various partial melting and contamination of the old Himalaya continental crust from radiogenic Pb isotopes and Tethys mantle materials with low radiogenic Pb isotopes caused different Pb isotopes and trace elemental associations in the Southern and Northern Lhasa Terranes. These factors also led to the evolution of the two different geochemical provinces.

1. Introduction

The Tibetan Plateau is the latest amalgamation of crustal blocks through multistage collisions in the Asian continent. The assembled exotic terranes record the complex dynamic processes of disaggregation and amalgamation (Xu et al., 2006). The identification and origin of the individual terranes within Tibet is yet to be fully resolved. The application of lead isotopes is a promising tool to trace the origin of continental fragments, and which we apply in this paper.

Previous studies divided the Chinese continent into four main lead isotopic geochemical provinces: Huaxia, Northeast, North China, and Yangtze (Zhu, 1995). However, the detailed geochemical province divisions for the inland Tibet Plateau, particularly the palaeo-tectonic affinity of its terranes, are still the subject of debate. The Himalaya terrane has been the focus of studies for decades (Yin, 2006), and is widely accepted as mature continental crust within the Tibetan Plateau (Mo et al., 2006; Wu et al., 2010). Gariépy et al. (1985) recorded Pb isotopic data of 80 K-feldspars in 6 granitic belts of Gangdese (Lhasa Terrane) and Himalaya. The results show that the Lhasa and Himalaya Terranes belong to different Pb isotopic provinces. Furthermore, these terranes originated from different portions of Gondwana. Mo et al. (2006) studied the volcanic rocks and granites in the Tibetan Plateau, which revealed different Sr-Nd isotopic characteristics of the northern Tibetan Plateau, Lhasa, and Himalaya; and divided the Tibetan Plateau lithosphere into three geochemical units, namely, the northern Tibetan Plateau geochemical province, the Neo-Tethyan mantle reservoir, and

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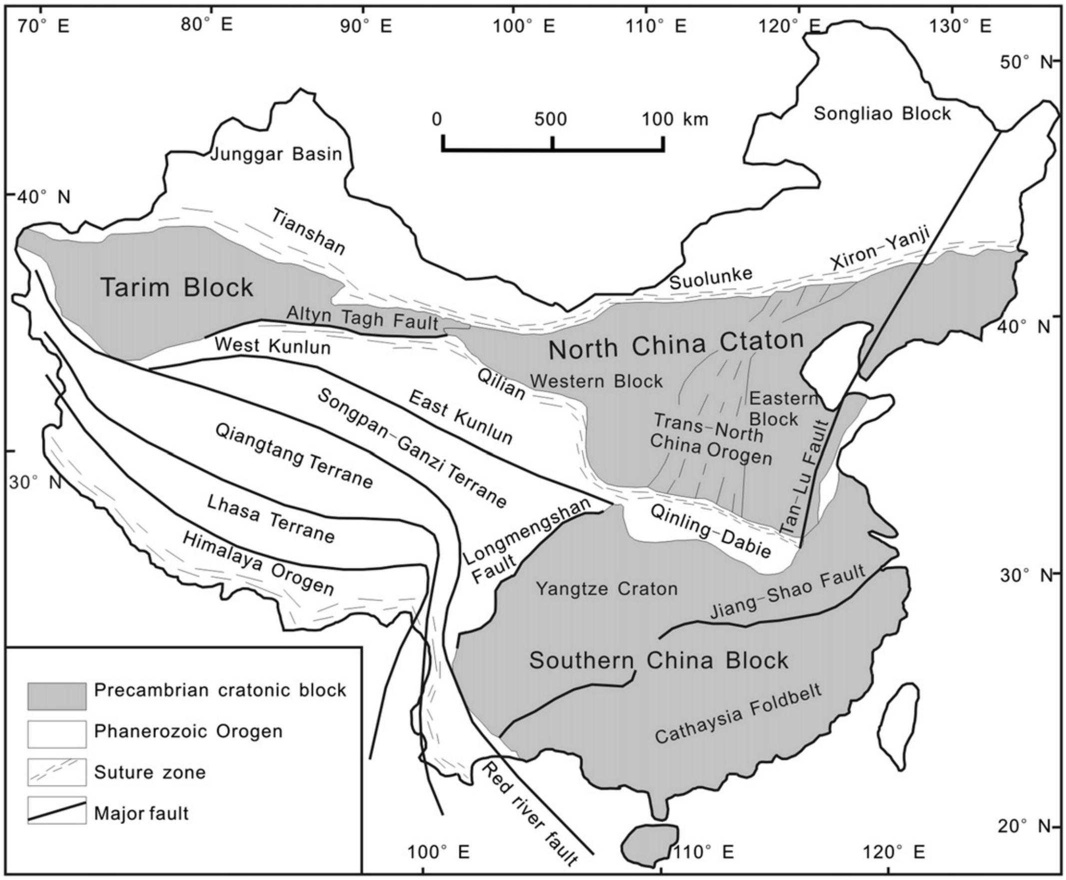

Fig. 1. Map of China showing some major tectonic divisions (modified after Zheng et al., 2013).

the Himalayan continental crust component. Zhao et al. (2007) investigated the Pb isotopic compositions of the volcanic rocks from terranes of the Tibetan Plateau and proposed three units, namely, Tethys mantle (depleted Pb isotopes with lower $^{206-208}Pb/^{204}Pb$), Himalaya continental crust (higher $^{206-208}Pb/^{204}Pb$), and the northern Tibetan Plateau (with intermediate $^{206-208}Pb/^{204}Pb$ ratios). No conclusions were made about the palaeo-tectonic affinity of the terranes or the evolution of the Tibetan Plateau. Some workers interpret the palaeo-tectonic affinity of the Qilian Terrane as being with the North China Craton (Feng and He, 1996; Qiu, 1984; Zuo and Liu, 1987). Others considered that the Qilian Terrane separated from the Yangtze Craton (Tung et al., 2007; Wan et al., 2006; Wu et al., 2010). The following mutually incompatible hypotheses summarize the possible evolution of the Songpan–Ganzi Terrane and its tectonic affinity: 1) A palaeo-tectonic affinity with the Yangtze Craton (Chen et al., 2006; Wu et al., 2010; Xu et al., 2007; Yang et al., 1994); 2) a palaeo-tectonic affinity with the North China Craton (Bruguier et al., 1997); 3) the widely distributed flysch complex of Songpan-Ganzi originates from the Qinling-Dabie Orogen (Nie et al., 1994; Weislogel et al., 2006); 4) the flysch was deposited above an oceanic floor (Şengör, 1987; Yin, 1980; Zhou and Graham, 1995); 5) the flysch was deposited in an backarc basin (Gao, 1990; Gu, 1994); and 6) the flysch is the primitive lithosphere of the Tibetan Plateau which existed before the India-Asia continental collision (Harris et al., 1988; Mo et al., 2006; She et al., 2006).

We seek to resolve the evolution of the Tibetan terranes utilizing lead isotopes of fine grained river sediments. These have been used successfully to recognize geochemical provinces (DePaolo, 1981; Nelson and DePaolo, 1985; Zartman, 1974; Zhu, 1995,), although there are only a few studies for the Tibetan Plateau (Zhao et al., 2007). The available reports are mainly focused on a few outcrops of metamorphic or volcanic rocks. However, integrating data from a variety of bedrock types for different tectonic units is difficult due to such sampling limitation. By contrast, modern river sediments represent erosional products although coarse-grained clastic sediments generally have a short transportation history and commonly originate from a limited area. Fine-grained river sediments have a history of long-distance transportation and are usually derived from a larger region, and can be considered representative of large segments of continental crust from which they derive (Castillo et al., 2008; Chaudhuri et al., 1992; Rao et al., 2006). The use of acetic acid removes secondary minerals derived prior to or during transportation, deposition, and diagenesis. Accordingly, we utilize the acid-insoluble fraction of fine-grained river sediments from catchments covering the whole Tibetan Plateau, and apply Pb isotopes and broad geochemical data to assess the tectonic affinities of its terranes.

2. Tectonic setting of the Tibetan Plateau

The North China Craton (NC), the South China block (comprising Yangtze Craton in the northwest and the Cathaysia block in the southeast) and the Tarim Block are three major tectonic units adjacent to Tibet (Figs. 1 and 2). The South China and the North China Craton coalesced with the formation of the Qinling-Dabie-Sulu ultrahigh pressure metamorphic belt in the Triassic (Ling et al., 2003; Zhang et al., 1995, 1996, 2004; Zhao and Cawood, 2012; Zheng et al., 2012). Between these palaeo-cratons are several micro-terranes whose origins are at question. The formation of micro-terranes from uplifted oceanic basins is unlikely (Xu et al., 2007). It is probable that the micro-terranes have separated from larger continental fragments. Some of the modern micro-terranes that are embedded within China