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Research paper

Crustal growth history of the Korean Peninsula: Constraints from detrital zircon ages in modern river sediments

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ABSTRACT

U-Pb analyses were carried out on detrital zircon grains from major river-mouth sediments draining South Korea to infer provenance characteristics and the crustal growth history of the southern Korean Peninsula, using a laser ablation inductively coupled plasma mass spectrometer (LA-ICP-MS). The Korean Peninsula is located in the East Asian continental margin and mainly comprises three Precambrian massifs and two metamorphic belts in between them. We obtained 515 concordant to slightly discordant zircon ages ranging from ca. 3566 to ca. 48 Ma. Regardless of river-mouth location, predominance of Mesozoic (249–79 Ma) and Paleoproterozoic (2491–1691 Ma) ages with subordinate Archean ages indicates that the zircon ages reflect present exposures of plutonic/metamorphic rocks in the drainage basins of the South Korean rivers and the crustal growth of the southern Korean Peninsula was focused in these two periods. Comparison of detrital zircon-age data between the North and South Korean river sediments reveals that the Paleoproterozoic zircon age distributions of both regions are nearly identical, while the Neoproterozoic–Paleozoic ages exist and the Mesozoic ages are dominant in southern Korean Peninsula. This result suggests that Precambrian terrains in Korea record the similar pre-Mesozoic magmatic history and that the influence of Mesozoic magmatism was mainly focused in South Korea.

1. Introduction

Zircon ($ZrSiO_4$) is an accessory mineral generally rich in felsic igneous rocks. Due to its physical and chemical stability, zircon survives through sedimentary processes such as weathering, erosion, diagenesis, and even recycling with initial information of its source rock and thus its geochemistry includes valuable information for sedimentary provenance. Especially U-Pb isotopic concentration in detrital zircon has been widely analyzed for provenance study (Cawood and Nemchin, 2000; Košler et al., 2002; Amidon et al., 2005; Link et al., 2005; Nemchin and Cawood, 2005) because it provides the age of the source rock and the U-Pb system of a zircon is highly stable as its closure temperature is ~900 °C for typical zircon sizes and crustal cooling rates (Cherniak and Watson, 2000; Moecher and Samson, 2006). Furthermore, U-Pb age analysis on detrital zircons from modern river sediments provides information about provenance characteristics and/or crustal evolution of their drainage basins (Rino et al., 2004; Wu et al., 2007; Morton et al., 2008; Rino et al., 2008; Condie et al., 2009; Yang et al., 2009; Iizuka et al., 2010). A sample of sediment collected at the mouth of a river is assumed to be an aggregate of detritus that originates from all of the different regions of the upstream area. In this case, detrital zircon age distributions enhance our understanding of drainage areas not easily accessible in outcrops and provide information of source rocks without sampling bias.

East Asia consists of the Sino-Korean (North China) and South China blocks in China and the Nangrim, Gyeonggi, and Yeongnam massifs in Korea (Fig. 1A). Crustal growth of the Sino-Korean and South China blocks have been frequently studied by detrital zircon geochronology of modern river sediments in China (Xu et al., 2007; Yang et al., 2007; Rino et al., 2008; Yang et al., 2009; Iizuka et al., 2010 amongst others). Detrital zircon U-Pb ages of the river sediments in the Sino-Korean Block reveal major age groups of 2.6–2.1 Ga, 2.0–1.6 Ga, and 500–140 Ma (Yang et al., 2009), while those of the South China Block are dominated by 3.8–3.2 Ga and

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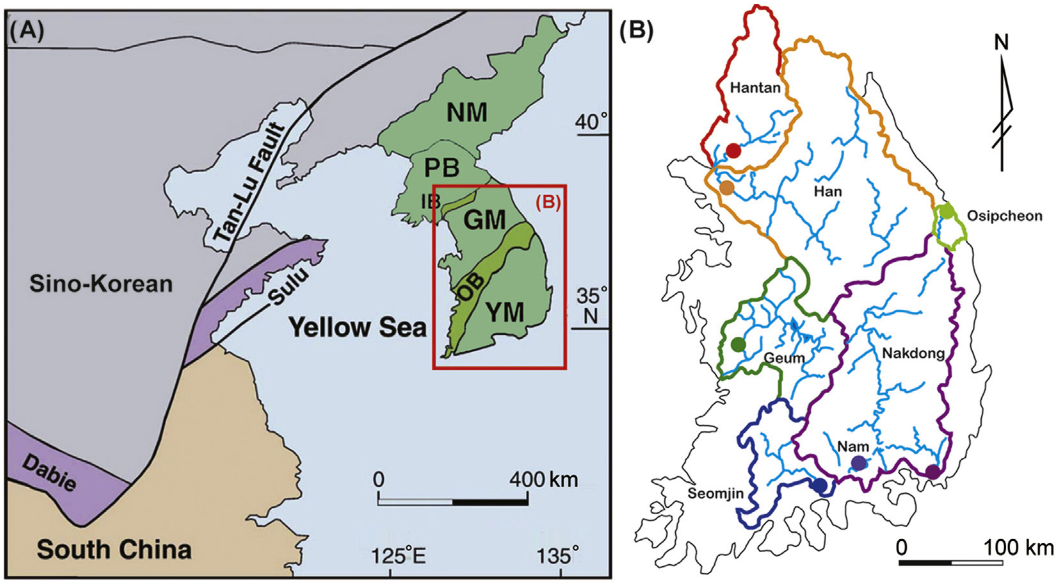

Figure 1. (A) A brief tectonic map of East Asia (modified from Metcalfe, 2006). The boxed area is shown in (B). NM: Nangrim Massif; PB: Pyeongnam Basin; IB: Imjingang Belt; GM: Gyeonggi Massif; OB: Okcheon Belt; YM: Yeongnam Massif. (B) Drainage basins of the major rivers in South Korea. Sample locations are marked with circle.

910–720 Ma (Liu et al., 2008). On the other hand, there is only one report about the detrital zircon ages of modern river sediments in North Korea. Wu et al. (2007) analyzed detrital zircon U-Pb and Hf ages of North Korean river sediments to constrain crustal evolution of North Korea and concluded that the Nangrim massif and Sino-Korean Block were a coherent block since Archean time. However, there is no report of similar studies in South Korea. Hence, here we report detrital zircon U-Pb analytical results of the modern river sediments in South Korea. Purpose of this study is to understand provenance characteristics of modern river sediments in South Korea and to interpret the crustal growth history of the whole Korean Peninsula by comparing and contrasting two Korean river sediments data.

2. Geological setting

The Korean Peninsula comprises three Precambrian massifs from north to south, the Nangrim, Gyeonggi, and Yeongnam massifs, two metamorphic belts (the Imjingang and Okcheon belts), and two sedimentary basins (the Pyeongnam and Gyeongsang basins) with Mesozoic granitoids (Fig. 1A). The Precambrian massifs consist of high-grade gneisses and schists formed mainly during the Archean to Paleoproterozoic (Sagong et al., 2003; Zhao et al., 2006), whereas the western and northern parts of the Gyeonggi massif contain Neoproterozoic to Paleozoic plutonic rocks (Kim et al., 2013, 2015; Park et al., 2014 and references therein). The Imjingang and Okcheon belts separate the Pyeongnam Basin from the Gyeonggi massif, and also the Gyeonggi massif from the Yeongnam massif, respectively. The Imjingang Belt comprises metasedimentary rocks recording high-grade metamorphic events in the late Permian–early Triassic. The depositional age of its protoliths is known as Devonian to early Carboniferous (Park, 1993; Cho et al., 2005). The Okcheon Belt is subdivided into unmetamorphosed to low-grade metamorphosed sedimentary rocks (Taebaeksan Basin) in the northeastern part and low- to medium-grade metasedimentary and metavolcanic rocks in the southwestern part. Depositional age of the basinfill of the Taebaeksan Basin is known to be Neoproterozoic to early Triassic (Cheong, 1987; Lee et al., 2012b, 2016a), while that of the protoliths of the Okcheon Fold Belt to be Neoproterozoic to Permian (Cho et al., 2004; Lim et al., 2005). Mesozoic granitoids are widespread in the whole Korean Peninsula, but are more abundantly distributed in its southern part. They were mainly formed by arc magmatism that sustained throughout the Mesozoic due to the subduction of the Paleo-Pacific plate beneath the East Asian continental margin (Sagong et al., 2005; Kee et al., 2010). In addition, a significant portion of the middle Triassic plutons in the Gyeonggi massif is interpreted to have been formed in association with post-collisional process (Choi et al., 2009; Seo et al., 2010; Kim et al., 2011 amongst others).

The Korean Peninsula is characterized by west-tilting topography with topographic highs (the Taebaek Range) in the eastern part, caused by rifting and the opening of the East Sea (Japan Sea). The Taebaek Range is essentially an N–S trending rift flank and forms a main water divide of the Korean Peninsula. Major rivers in South Korea subdivide the southern Korean Peninsula by their watershed except for the westernmost part of South Korea (Fig. 1B). The Hantan, Han, and Geum rivers flow west, whereas the Seomjin and Nakdong rivers flow south. The Osipcheon River drains the steep eastern flank of the Taebaek Range and flows into the East Sea. South Korean river basins consist mainly of Cretaceous and Jurassic granites and Precambrian gneiss with minor proportions of limestone, schist, volcanic rocks, and phyllites (Lee et al., 1988; Chough et al., 2000).

3. Analytical methods

Medium- to coarse-grained sands were collected from mouths of seven major rivers draining the southern Korean Peninsula (the Hantan, Han, Osipcheon, Geum, Seomjin, Nam, and Nakdong rivers; Fig. 1B). Detrital zircons were extracted from the samples using a conventional heavy mineral separation method. 700 zircon grains, that is 100 zircon grains from each river mouth, were mounted on PFA Teflon sheets. Cathodoluminescence (CL) images of the zircon grains were examined to obtain their internal structures under the scanning electron microscope (JEOL JSM-5400). The U-Pb analyses of the zircon grains were carried out using a laser-ablation inductively coupled plasma mass spectrometer (LA-ICP-MS; Thermo Elemental PlasmaQuad3), housed at the Earthquake Research