Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SCG71-P07 Room:Convention Hall Time:May 21 17:15-18:15

Evolution of the lower crust under southwest Japan constrained from ages of zircon in the xenolith

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The present-day continental crust contains a very large proportion, about 20-70%, of the incompatible elements by mass in the Earth (Rudnick and Fountain, 1995). Therefore, it should have enormous effects on evolution of the Earth both chemically and physically. Although the upper crust has been investigated extensively in terms of its composition, structure, and evolution process, those of the lower crust which extends to 35 km depth on average has been poorly investigated.

The main purpose of this study is to decipher process of formation and evolution of the lower crust, aiming at understanding the evolution of continental crust and the Earth. As a first case study, we try to constrain the evolution process of the lower crust in SW Japan, the Oki-Dogo and Kibi areas, based on zircon ages and geothermometers in the xenoliths.

These two areas are located on the continental margin, and may provide useful insights regarding how the lower crust is formed or destructed associated with subduction.

At Oki-Dogo, peridotite, pyroxinite, gabbro and granulite were found as xenoliths in alkali olivine basalts (Takahashi, 1978) erupted at 3.61Ma (whole rock K-Ar age, Kaneoka et al., 1977). At Kibi, peridotite, pyroxinite and granulite are found as xenoliths in alkali olivine basalts (Iwamori, 1985) erupted at around 9 Ma (Uto, 1989).

To estimate the equilibrium temperature and the U-Pb age of zircon, we sampled gabbros from Oki-Dogo and granulites fromat Kibi, and analyzed them by using EPMA and LA-ICP-MS.

Major constitutent minerals in the gabbros from Oki-Dogo are olivine (ol), clinopyroxene (cpx) and plagioclase (pl), and they have a diameter of 1~2mm. Equilibrium temperature estimated by ol-cpx geothermometer (Loucks, 1996) is approximately 1100^{o}+-50^{o}C. Zircon grains have been obtained from only one gabbro (out of total seven gabbros processed), and are almost anhedral and homogeneous. The total forty grains have been dated to give ages approximately ranging from 2 to 4 Ma, which are broadly the same with that of the host alkali basalt and indicates that zircon grains lost almost all Pb during the magmatic event exceeding the closure temperature for zircon U-Pb dating (i.e., above 900^{o}C).

Major constitutent minerals in the granulite from Kibi quartz, K-feldspar, garnet, kyanite and spinel are the major constituent minerals, and they have a diameter of 500~1000 um. Based on the stability of kyanite and assuming the maximum depth of 30 km based on the present-day Moho depth estimated from the seismic profile (Ito et al., 2010), the equilibrium temperature is constrained to be less than 800^{o}C. Zircons obtained from the granulites are various in shape, exhibiting a wide age range from 420 to 10 Ma. We classified these zircons into igneous and metamorphic origins based on the U/Th ratio, and distinguish the overlapping events recorded in the grains. Bulk rock composition of this granulite from Kibi is aluminous and pelitic (Kushiro, 1987). From these results, we propose a model that a sedimentary material subducted with an oceanic plate, and accreted the material to the continental crust. Then at 28Ma, a part of the Philippine Sea Plate started spreading to create the Shikoku Basin and the spreading ridge had subducted. Because of this, the subduction angle became gentler and accrete more materials and push the formerly accreted sedimentary material further to the rearc region at the same time, accreted prism was metamorphosed by the heat.

In summary, these two examples from Oki-Dogo and Kibi suggest that (1) the lower crust beneath Oki-Dogo were heated by magmatic events that erupt alkali basalts and may reset the U-Pb age of zircon now found in the xenolith, and (2) subducted sedimentary materials can accrete to the lower crust at deep levels, which may be promoted by ridge subduction. Therefore, at this area, a part of lower crust develop independently of the upper crust.

Keywords: Lower Crust, zircon, age, xenolith, southwest Japan