Major episodic increases of continental crustal growth determined from zircon ages of river sands

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In order to better understand continental growth history, we have determined the U-Pb age of about 1500 detrital zircons from river sands in three major rivers in North America and South America, and have estimated the rate of continental growth in order to discuss the linkage between continental growth and the thermal evolution of the mantle. The method for estimating continental growth from the age population of a significant number of detrital zircons in river sands has three advantages; (1) the almost even collection of zircons from sedimentary rocks and granitic basements in the hinterlands of the major rivers, (2) determination of the age of juvenile crust due to the high closure temperature of the U-Pb systematics of zircons, and the removal of the influence of recycling of crustal materials within the continental crust, and (3) direct determination of the age of continental formation.

The age population of zircons in the river sands of the Mississippi River shows 4 peaks at 2.6-2.8, 1.7-1.8, 1.1-1.5 and 0.2-0.5 Ga, the peaks corresponding to periods of major crustal formation of the Ouachita orogenic belt, the Grenville orogenic belt, the Yavapai-Mazatzal orogenic belt and Wyoming province in North America. The areal distribution of each orogenic belt is 11, 20, 33, and 14% respectively, and this agrees with the age population of the zircons. This fact confirms the validity of the calculation of continental formation from the age population of zircons in river sands. In contrast, the age population of zircons in river sands of the Mackenzie and Amazon Rivers displays major peaks at 2.4-2.7, 1.0-1.9 and 0.2 Ga, and at 2.4-2.7, 1.9-2.2 and 1.0-1.5 Ga respectively. However, the age distribution of the surface rocks in the drainage basins of the Mackenzie and Amazon Rivers also comprises widely-distributed young orogenic belts. This discrepancy suggests that the young orogenic belts were formed through recycling of older materials, and that essentially no juvenile continental crusts grew at those times. Our new continental growth curve estimated from the age populations of zircons in the river sands of the Mississippi, Mackenzie and Amazon Rivers indicates continuous growth of continental crust since the Archean and major abrupt increases in the Late Archean and early Proterozoic. The continental growth curve reflects episodic increase of the volume of continental crust at 1.9-2.3 and 2.5-2.8 Ga.

The mantle overturn model provides the best explanation for the episodic growth of the continents. Accordingly, our data suggest that mantle overturn occurred at 1.9-2.3 and 2.5-2.8 Ga. If the mantle temperature were high enough in the Archaean, indicated by geologic records to be ca. 150 K higher than that of modern MORB-source mantle (e.g., Ohta et al., 1996; Komiya, 2003), a consequent higher Rayleigh number than at present would have favored double-layered mantle convection. If this were the case, the upper mantle would have behaved as a stagnant lid. On the other hand, it was also responsible for the production of large quantities of MORB that were later subducted beneath island arcs. The subducted material accumulated on the boundary between the upper and lower mantle, and consequently caused catastrophic downwelling into the lower mantle. The catastrophic sinking of the material induced a new influx of recycled material from the lower mantle, resulting in mantle overturn. As a consequence, superplumes and plumes ascended from the core-mantle boundary and the deep mantle, to give rise to large igneous provinces, flood basalts and oceanic plateaus. Episodic continental growth resulted from the mantle overturn because the influx of hotter and fertile materials from the lower mantle revitalized the upper mantle to produce large quantities of MORB and subsequent sialic continental crust through slab-melting.