Phanerozoic crustal growth constrained by zircon U-Pb age and Sr-Nd-Hf isotopic evidence from the granitoid rocks in Mongolia

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Mongolia is the largest segment of the Central Asian Orogenic Belt which is formed by accretion of island arcs and subordinate Precambrian microcontinents (Badarch *et al*., 2002). Here we report new U-Pb zircon ages and Sr-Nd-Hf isotopic data of granitoids from four representative areas along one transect from northwestern to southeastern Mongolia (Ider, Erdene, Akhar-Uul and Khanbogd). Zircon U-Pb age data show three distinct age ranges: ca. 538 Ma; 368-290 Ma; and 262–216 Ma, which reveal that: (1) Granitic magmatism in Mongolia was most active during the Carboniferous to Permian; (2) The Cambrian granitoids were emplaced in the Akhar-Uul area in the southern part of Mongolia, although previous studies assumed that the distribution of granitoids young towards the south; (3) The late Permian to Triassic granitoids are mainly located in the central part of the Mongolia (Erdene area). The widespread granitoids indicates accretion and collision processes took place continuously throughout the Phanerozoic. Isotopic data display significant differences along the transects. The Cambrian peraluminous granitoids in the Akhar-Uul area, in the passive continental margin terrane (Badarch *et al*., 2002) show high initial Sr (0.7135 to 0.7244), and low εNd (-8.2 to -8.8) and εHf (-12 to -16). These features suggest that they were derived from sediment source and produced by erosion of old continental crust and were likely emplaced in a forearc environment. Granitoids in the Khanbogd area in an island arc terrane (368 to 290 Ma) show high εNd (+5.3 to +9.9) and εHf (+7.5 to +9.8) whereas those in Ider (350 to 290 Ma), Erdene and Akhar-Uul areas (282 to 213 Ma) that were emplaced in the Precambrian cratonic and Orodvician clastic basin terranes show lower εNd (-2.7 to +4.7) and εHf (-4.1 to +5.5). The depleted isotopic character in the Khanbogd area corresponds to the upper mantle and lower crustal xenoliths included in Cenozoic volcanic rocks, suggesting these granitoids were formed by melting of mafic lower continental crust that was originally formed by mantle-derived magma. Whereas enriched isotopic signatures those in Ider, Erdene and Akhar-Uul areas may be explained by interactions with preexisting old crust where they were emplaced.

Reference

Badarch, G., Cunningham, W.D., Windley, B.F. (2002), *Journal of Asian Earth Sciences* **21** 87-110.

Tracer analyses as a tool to validate the effectiveness of pump-and-treat measures in the field.

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We show that the remediation of a contaminated site, by pump-and-treat, disturbed the groundwater dynamics and lead to mixing of different water components. The remediation impacts on groundwater mixing can be traced by the noble gases ^{3}He and ^{4}He, and by the transient tracers CFCs and SF_6. At the site, chlorinated ethenes as DNAPL lay at the bottom of an aquifer of fluvial sediments, that covers the top of a molassic rock of much older age. Before and after remediation the site was sampled for noble gases, CFCs and SF_6. All these bio-geological conservative tracers indicate a major change in groundwater dynamics although the contamination levels remain the same.

After the remediation, the observed ^{3}He/^{4}He ratios of the local groundwater were lower then the atmospheric value ($1.36*10^{-6}$), whereas before the remediation the ^{3}He/^{4}He ratios were considerably larger. Such distinct change of the He isotopic composition indicates the emanation of isotopically heavy He from the molassic hardrock, most probably through fractures. This let us assume that the DNAPL penetrated into the underlying bedrock, through those fractures that allowed the He to emanate. Such DNAPL impregnation of the bedrock may explain why the remediation measures failed, and would further imply that a DNAPL contamination can hardly be removed, under such conditions, by pump-and-treat methods. Moreover, the abrupt change in the ^{3}He/^{4}He ratio of the local groundwater clearly prove that the remediation measures severely impacted the natural groundwater flow regime.

Other transient tracers, such as CFCs and SF_6, were found to be oversaturated both before and after the remediation. However, the observed change in concentration and relative abundance, again indicate that applied pump-and-treat squemes changed the local hydraulic situation, but did not remove significant amounts of the DNAPL contamination, because the contamination concentration did not decrease in response to the taken measures.