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Correction of initial-disequilibrium on U-Th-Pb system for Accurate Zircon Dating

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During recent years, the improvement of analysing technique provides a more precision in case of dating Quaternary zircons. Major analytical problems associated with age determination of the young zircons are (1) the analytical difficulty to measure extremely low Pb/U and Pb/Th ratios (e.g., ^{206}Pb/^{238}U $<$0.0001), and (2) initial-disequilibrium in the U-Th-Pb decay systems through the crystallization of zircon in source magma. The ability to measure isotope ratios with high-dynamic ranges could be improved by the suppressor device for ion counting systems in the ICPMS instrument, in which the gain of the ion counting could be changed during the fast mass scanning, and the resulting precision and accuracy for the Pb/U and Pb/Th ratio measurements was be dramatically improved. However, correction of the initial-disequilibrium is highly desired to obtain reliable age data for young ($<$1Ma) zircons. Because of the different distribution coefficient ($D_{zircon/magma}$) between U and Th, isotope equilibrium was disturbed at the crystallization of zircons in source magma. Among the uranium series decay products, the initial disequilibrium of ^{230}Th can become a major source of systematic error in the resulting ages. To evaluate and correct the contribution of the initial disequilibrium on ^{230}Th, the ratio of the distribution coefficient for Th and U ($f_{Th/U}$ =D^{Th}/D^{U}) must be defined [2]. To achieve this, we have determined both the ^{238}U-^{206}Pb and ^{232}Th-^{208}Pb ages were obtained for three tephra zircon samples collected from Kirigamine rhyolite, Bishop tuff and Toga pumice (^{40}Ar-^{39}Ar ages are 0.945 $\pm$ 0.005 Ma, 0.7589 $\pm$ 0.0036 Ma, and 0.42 $\pm$ 0.01 Ma reported by [3], [4], and [5], respectively) using a LA-ICPMS. The resulting ^{232}Th-^{208}Pb ages were 0.938 $\pm$ 0.026 Ma (Kirigamine), 0.757 $\pm$ 0.008 Ma (Bishop), and 0.428 $\pm$ 0.004 Ma (Toga), respectively, demonstrating that the resulting ages were consistent with the previously reported values. The $f_{Th/U}$ values could be calculated based on the measured ^{206}Pb/^{238}U ratio and the resulting ^{232}Th-^{208}Pb ages, and the calculated $f_{Th/U}$ values were 0.50 $\pm$ 0.26 for Kirigamine, 0.51 $\pm$ 0.10 for Bishop, and 0.55 $\pm$ 0.07 for Toga zircons. The resulting three $f_{Th/U}$ values agreed well within the analytical uncertainties. The disequilibrium-corrected ^{238}U-^{206}Pb age can be calculated under the assumption that the $f_{Th/U}$ value did not vary significantly among the zircons. To evaluate this, we have measured the ^{238}U-^{206}Pb and ^{232}Th-^{208}Pb ages for zircons from Sanbekisuki tephra [6]. The $f_{Th/U}$ values used for the correction was based on the weighted mean of three $f_{Th/U}$ values obtained here ($f_{Th/U}$ = 0.53 $\pm$ 0.05). The corrected ^{238}U-^{206}Pb age was 86.2 $\pm$ 2.1 ka, which agreed with the ^{232}Th-^{208}Pb age (90.1 $\pm$ 2.6 ka) within the analytical uncertainties. It should be noted that the ^{238}U-^{206}Pb dating after the correction of the initial disequilibrium can provide accurate and precise chronological information. To evaluate the reliability of the present correction technique for the U-Pb dating, we have developed a pseudo concordia diagram (plot of ^{206}Pb/^{238}U ratio against the ^{208}Pb/^{232}Th ratio). In this diagram, most of the U-Th-Pb isotope data fall close to a concordia curve, suggesting that the Sanbekisuki zircon did not suffered from significant Pb-loss. In conclusion, we can construct more accurate and effective dating tool based on the U-Th-Pb decay systems based on the $f_{Th/U}$ value defined in this study, especially, for the young zircons.

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