

## 高温マグマプロセス解明に向けたジルコンウラン系列年代測定法の再編 Reconstruction of zircon U-series dating for investigation of high-temperature magma process

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Zircon U–Pb age data for the samples of the Quaternary period can provide key information to unveil the high-temperature cooling history of magmas and also to define chronological constraints for the tephras as an important chronostratigraphic marker horizons (Schmitt, 2011). Independent of the analytical difficulty associated with measuring small amount of radiogenic Pb, to obtain accurate crystallization ages from young zircon, it is necessary to correct for the effect of initial disequilibria caused by intermediate nuclides in the  $^{238}\text{U}$  and  $^{235}\text{U}$  decay series (i.e.,  $^{230}\text{Th}$  and  $^{231}\text{Pa}$ ) (Wendt and Carl, 1985). Common Pb contribution is also non-negligible in the case of Quaternary zircon dating. To correct these effects, the modified correction method using the  $^{207}\text{Pb}$  has been proposed (Sakata et al., 2017; Sakata, 2018). In this approach, estimating the magnitude of disequilibria from Th/U and Pa/U partitioning in zircon–melt system is highly required. However, it is widely recognized that Th and U could have been heterogeneously distributed in the magma and, more importantly, that  $(\text{Th}/\text{U})_{\text{melt}}$  could change with time due to the crystallization of U–Th-bearing minerals within the melts (Amelin and Zaitsev, 2002). These factors make it difficult to estimate the  $(\text{Th}/\text{U})_{\text{melt}}$  and  $(\text{Pa}/\text{U})_{\text{melt}}$  at the time and site of zircon crystallization. Faced with this, another approach can be applied. As a second approach,  $^{238}\text{U}$ – $^{230}\text{Th}$  dating method is widely used for young zircon dating as well. In this method, however, it is also difficult to discern the potential multi-stage crystallization history of a single crystal if, for example, Th/U in the melt is variable (Boehnke et al., 2016). Therefore, more rigorous dating method is highly desired for revealing the history of magmas before eruption. In this study, we would like to return to the principle of U- and Th-decay series, and reconstruct a better dating method which overcomes the aforesaid problems.

After deforming the formula in Wendt and Carl (1985), which represents relationship among the numbers of atoms in  $^{238}\text{U}$ -decay series, we have introduced a new equation associated with zircon crystallization age, which including information about  $^{232}\text{Th}$ -decay series and common Pb. In equation 1, the ' $t$ ' denotes zircon crystallization age, and ' $c$ ' and ' $m$ ' represent common Pb and measured isotopic ratios, respectively. This indicates that accurate crystallization age can be derived by measuring isotopic ratios in equation 1 without depending on uncertain estimation of Th/U and Pa/U partitioning in zircon–melt system.

We also provide analytical technique for this method using laser ablation-ICP tandem quadrupole mass spectrometry (LA-ICP-MS/MS). To measure  $^{230}\text{Th}/^{238}\text{U}$  in zircon accurately by LA-ICP-MS, great care must be taken for abundance sensitivity and polyatomic interferences due to the existence of tailing from  $^{232}\text{Th}$  mass peak and  $\text{Zr}_2\text{O}_3^+$  (Guillong et al., 2015). With the present LA-ICP-MS/MS technique, high abundance sensitivity of better than <0.3 ppb can be achieved, and thus the possible interferences from polyatomic ions can be successfully removed. Several reference zircon samples were used to evaluate the reliability of the measurement of  $^{230}\text{Th}/^{238}\text{U}$  and other isotopic ratios in equation 1. The resulting values showed good agreement with the reference values. In this presentation, we would like to demonstrate first application of new dating method to Quaternary zircon samples, and discuss its effectiveness for magma process

study.

## References

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$$\begin{aligned} \left( \frac{{}^{206}\text{Pb}}{{}^{238}\text{U}} \right)_m &= e^{\lambda_{238}t} - 1 + \left\{ \left( \frac{{}^{230}\text{Th}}{{}^{238}\text{U}} \right)_m - \frac{\lambda_{238}}{\lambda_{230}} \right\} \left\{ e^{\lambda_{230}t} - \frac{\lambda_{226}}{\lambda_{226} - \lambda_{230}} + \frac{\lambda_{230}}{\lambda_{226} - \lambda_{230}} e^{(\lambda_{230} - \lambda_{226})t} \right\} \\ &+ \frac{\lambda_{238}}{\lambda_{226}} e^{\lambda_{238}t} (e^{-\lambda_{226}t} - 1) + \left( \frac{{}^{232}\text{Th}}{{}^{238}\text{U}} \right)_m \left( \frac{{}^{206}\text{Pb}}{{}^{208}\text{Pb}} \right)_c \left\{ \left( \frac{{}^{208}\text{Pb}}{{}^{232}\text{Th}} \right)_m - e^{\lambda_{232}t} + 1 \right\} \end{aligned} \quad (1)$$