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ESR dating of tephra with quartz: inconsistency between signals

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Determining the age of tephra is important for reconstructing the history of environmental change during the Quaternary epoch. To this end, we consider dating of quartz using the electron spin resonance (ESR) method. Quartz was first found to be useful for ESR dating of fault gouge while the mineral was also used for dating of tephra, heated flints, and sediments.

The first investigation pertaining to ESR dating of tephra using quartz was published using the Al center (a hole trapped at Al site replacing Si). Subsequently, several other successful results on tephra have been reported (e.g. Imai and Shimokawa, et al., 1988, Imai et al., 1992, Toyoda et al., 1995, and Yokoyama et al., 2004). Buhay et al. (1992) reported that the ESR age (45-49 ka) of a tephra from New Zealand is consistent with the 14C age (42-44) within statistical errors.

However, in other studies, systematic discrepancies were observed between the ages obtained using the Al center and Ti-Li center (an electron trapped at a Ti atom replacing Si, accompanying a Li ion as a charge compensator). Toyoda et al. (2006) systematically investigated the ESR and RTL (red thermoluminescence) ages of tephra with a known age range of 30 to 900 ka, and found that ESR dating has problems in obtaining equivalent doses. Using the same dose rate, the RTL ages were consistent with the expected ages while the ESR based results were inconsistent and involved lage scatter in data. The scatter in ESR ages was found to increase with age. Toyoda et al. (2009) proposed a new protocol, the multiple-aliquot regenerative-additive dose method, which provides equivalent doses estimates with smaller errors than the traditional additive dose method. In the present paper, we have analyzed the same Nm-Sb tephra and A-Fm tephra and Ft to check the reproducibility of dating results and to test if known doses can be recovered using the multiple-aliquot regenerative-additive dose procedure.

The age obtained from Ti-H center is consistent with the age reference for Nm-Sb while the ones from Al and Ti-Li center overestimate. The ages obtained from Al and Ti-H center are consistent with the age reference for A-Fm while the ones from Ti-Li center overestimate. The dose recovery test indicates that the equivalent dose estimate based on the Ti-H center of Nm-Sb and A-Fm agrees within error of the expected dose (370 Gy). We consider the dose recovery test to be a useful procedure for choosing the signal appropriate for dating.

Keywords: quartz, ESR, dating, tephra