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Augite and enstatite pyroxene standards for SIMS oxygen isotope analysis and their application to Merapi volcano, Sunda arc, Indonesia

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Measurement of oxygen isotope ratios in common silicate minerals such as olivine, pyroxene, feldspar, garnet, and quartz is increasingly being performed by Secondary Ion Mass Spectrometry (SIMS). Many mineral groups exhibit solid solution, however, which leads to compositional uncertainty such as in calcic clinopyroxenes [(Ca, Mg, Fe^{2+}, Fe^{3+}, $Al)_2(Si,Al)_2O_6$] and magnesium-iron orthopyroxene [$(Mg,Fe)_2Si_2O_6$]. Variations in mineral chemistry can lead to instrumental mass fractionation (IMF) during SIMS analysis, which must be corrected for using repeated analysis of compositionally similar standards to ensure accurate results. Here we report on new augite and enstatite pyroxene standards sourced from Stromboli, Italy and Webster, North Carolina, USA (Swedish Museum of Natural History mineral collection) in order to widen the current applicability of SIMS to mineral compositions in common igneous rocks. Aliquots of the crystals were analysed independently by laser fluorination (LF) to establish their $\delta^{18}O$ values. Repeated SIMS measurements on randomly oriented fragments of the pyroxene crystals yielded a range in $\delta^{18}O$ less than ±0.21 and 0.29‰ (1σ) for NRM-AG-1 and NRM-EN-2, respectively. The homogeneity tests also verified that the proposed standards do not show any crystallographic orientation bias and that they are sufficiently isotopically homogeneous on the 20 μm scale to be used as routine mineral standards. We tested the utility of our new standards by analysing pyroxene from Merapi volcano, Indonesia. SIMS data for Merapi pyroxene (n = 204 analyses) overlap and exceed the published range of $\delta^{18}O$ values for Merapi pyroxene determined by LF, thus underscoring that 20 μm scale resolution $\delta^{18}O$ analysis can reveal a level of isotopic detail that may be masked by single crystal or whole rock studies. Moreover, the SIMS data display a frequency peak at the 5.5 to 6.0‰ interval, which defines the mantle $\delta^{18}O$ composition beneath Central Java. We conclude that crystal-scale oxygen isotope approaches on pyroxene can deliver a wealth of petrological information, which is now more widely accessible due to improvements in SIMS standardisation.