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The ^{40}K-^{40}Ca chronometer as a tracer of magma sources and crustal contamination

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^{40}K is a long-lived radioactive isotope, which decays to ^{40}Ca with a half-life of 1.25 billion years. Principally, the ^{40}K-^{40}Ca systematics in K-rich igneous rocks and minerals (typical of the Earth's upper continental crust) can serve as a valuable chronometer and tracer of magma sources and mixing. Standard MC-ICP-MS cannot directly measure ^{40}Ca so this method has so far not been used for the ^{40}K-^{40}Ca decay system. In this study, we exploit the capability of the new-generation Nu-Sapphire MC-ICP-MS to also make high precision measurements of ^{40}Ca/^{44}Ca for utilizing the ^{40}K-^{40}Ca chronometer. This instrument features a collision cell that eliminates Ar isobaric interferences on K and Ca isotopes, allowing direct measurements for ^{40}Ca/^{44}Ca with very high precision (<10 ppm) and ~20 ppm relative uncertainty. We present a case study of the late-Permian alkaline igneous suite of the Øyangen Caldera, Oslo Rift, Norway. The basanite, syenite, trachytic-rhyolitic samples exhibit a broad range of fractionated K/Ca (wt.) ratios (0.2 to 43), forming an ideal sample set for ^{40}K-^{40}Ca isochron dating. We quantified the radiogenic ^{40}Ca excess of the individual samples (expressed as $\varepsilon^{40/44}$Ca) relative to the fractionation-corrected terrestrial ^{40}Ca/^{44}Ca ratio and determined the ^{40}K-^{40}Ca isochron age for 19 Øyangen Caldera igneous samples. The age obtained is 265.3 ± 16.3 Ma, consistent with the previous U-Pb ID-TIMS zircon age of 272.7 ± 0.5 Ma. Furthermore, the well-defined intercept on the isochron diagram constrains a common initial ^{40}Ca/^{44}Ca value typical of the mantle ($\varepsilon^{40/44}$Ca ≈ 0). There is no evidence that the primary magma or the evolved magma compositions were contaminated with the metamorphic basement rocks of the Oslo Rift (~1.6 Ga), as they plot along a much steeper slope on the ^{40}K-^{40}Ca diagram. In particular, the ^{40}K-^{40}Ca system is very sensitive to crustal contamination in the highly evolved trachyte and rhyolite magmas as they have very low Ca concentrations. The successful implementation of the ^{40}K-^{40}Ca systematics using high-precision collision-cell MC-ICP-MS Ca isotope measurement warrants more extensive applications for dating and tracing crustal magma sources and mixing.

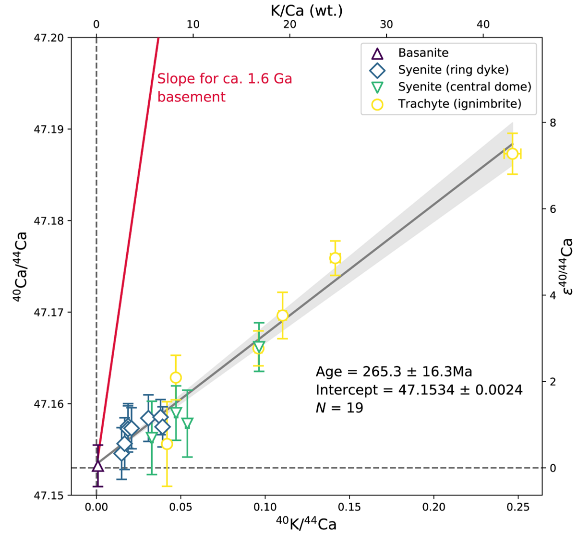

Fig. 1. ^{40}K-^{40}Ca isochron for the Øyangen Caldera igneous rocks. The red line shows the predicted $\varepsilon^{40/44}$Ca compositions of the ~1.6 Ga metamorphic basement rocks in the Oslo Rift.

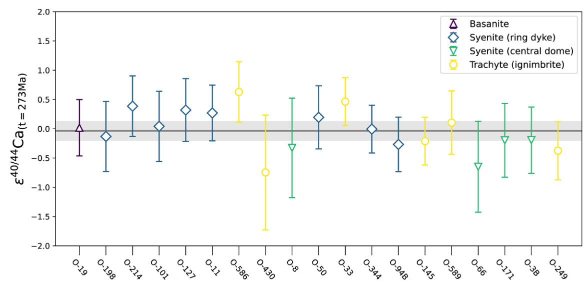

Fig. 2. $\varepsilon^{40/44}Ca_{(t=273 Ma)}$ results show that the Øyangen Caldera magma received no radiogenic ^{40}Ca excess from other sources throughout its differentiation. The grey envelope presents the mean and two standard errors of the sample's $\varepsilon^{40/44}Ca_{(t)}$ values, which are consistent with the typical mantle composition (zero).