Do $^{226}$Ra-$^{230}$Th Isochrons Provide Realistic Crystallization Ages?

SIMS, Kenneth W. W.1; PICHAT, Sylvain2; REAGAN, Mark3; DUNBAR, Nelia4; KYLE, Philip4; SAWYER, Georgina5; GAUTHIER, Pierre J.6; BICHERT-TOFT, Janne2
1. Dept of Geology and Geophysics, University of Wyoming, WY 82071/USA
2. Laboratoire de Sciences de la Terre, Ecole normale superieure de Lyon/France
3. Department of Geoscience, University of Iowa Iowa City, IA 52242/USA
4. N.M.B.G/E&ES Department, New Mexico Tech. Socorro, NM, 87801/USA
5. Cambridge University, Cambridge/United Kingdom
6. Laboratoire Magmas et Volcans, CNRS, CLERMONT-FERRAND 63000/France
ksims7@uwyo.edu

In this contribution we investigate the timescales of melt evolution and crystal growth in the Mt Erebus magmatic system using measurements of $^{238}$U-$^{230}$Th-$^{226}$Ra-$^{210}$Pb-$^{210}$Po and $^{232}$Th-$^{228}$Ra-$^{228}$Th. Our sample suite consists of 22 historic bombs, ranging from 1972-2005; and 5 anorthoclase megacrysts separated from historic bombs for the years 1984, 1989, 1993, 2004, 2005. These samples $^{258}$U-$^{230}$Th and $^{232}$Th-$^{226}$Ra are significant and uniform over the 36 year historical record. The anorthoclase megacrysts and phonolite glass show complimentary $^{226}$Ra/$^{230}$Th disquilibria. In all samples, $^{210}$Pb/$^{226}$Ra are in secular equilibrium for both phases. For the phonolite glass $^{238}$Ra/$^{222}$Th is in equilibrium, whereas in the anorthoclase megacrysts $^{238}$Ra/$^{222}$Th is significantly greater than unity. For the 2005 bomb, whose eruption date is known explicitly, $^{210}$Po was not completely degassed. In-situ ion probe measurements of Ba and Th in the anorthoclase and phonolite glass show that our anortholase and phonolite glass separates are pure with regard to $^{226}$Ra/$^{230}$Th systematics. Instantaneous crystal fractionation, with long magma residence time (> 100 years, < 3 kyrs, depending on $D_{Ba}/D_{Ra}$), can account for the $^{238}$U-$^{230}$Th-$^{226}$Ra-$^{210}$Pb systematics. However, the significant $^{238}$Ra/$^{232}$Th disequilibria in the anorthoclase megacrysts preclude this simple interpretation. To account for this apparent discrepancy we have developed a continuous crystallization model, which incorporates both nuclide in-growth and decay during crystallization. Our model can successfully reproduce all of the measured $^{238}$U- and $^{232}$Th- decay series disequilibria. More importantly, this model shows
that when the timescale of crystallization is comparable to the half-life of $^{226}$Ra, the simple $^{230}$Th-$^{230}$Ra isochron techniques typically used in most U-series studies likely provide erroneous ages.