Estimating the melt fraction of magma reservoirs using MELTS and magnetotellurics

D. Cordell[1], S. Naif[2], J. Troch[3], and C. Huber[4]
[1]Georgia Institute of Technology, dcordell6@gatech.edu
[2]Georgia Institute of Technology, snaif@gatech.edu
[3]Smithsonian Institution National Museum of Natural History, trochj@si.edu
[4]Brown University, christian_huber@brown.edu

SUMMARY

Magnetotelluric data image the bulk resistivity of the subsurface which can be used to infer magma reservoir conditions beneath volcanoes. The bulk resistivity of magma depends primarily on the melt volume fraction, temperature, and dissolved water content. These variables are coupled via thermodynamic phase equilibria and saturation relationships yet mixing relations for bulk resistivity implicitly treat them as independent. Here, we use a parameterization of the rhyolite-MELTS thermodynamic modelling software to constrain relationships between melt fraction, temperature, dissolved water content and bulk resistivity for rhyolitic magmas. This method results in magnetotelluric interpretations which are (1) thermodynamically consistent, (2) independent of assumptions of temperature and water content derived from past eruptive episodes, and (3) able to investigate saturated melts containing crystal, melt, and volatile (i.e. aqueous fluid) phases. The utility of the method is demonstrated with three case studies of silicic systems at Mono Basin, Newberry Volcano, and the Laguna del Maule Volcanic Field (LdMVF). The moderately-conductive feature at Mono Basin can be explained by under-saturated partial melt (6-15 vol%) at <775°C, indicating relatively stable magma storage conditions since the last eruption. However, the relatively resistive feature at Newberry Volcano requires lower temperatures (<750°C) than previous estimates, suggesting that the system is saturated and has cooled since the last eruption (or that previous interpretations at 850°C are significantly out of equilibrium). The highly conductive feature at the LdMVF cannot be explained by saturated or under-saturated melt and requires additional non-magmatic conductive phases. These results demonstrate the potential of this new method to reduce uncertainty in magma storage parameters derived from magnetotelluric data and highlight the need for additional coupling strategies between petrology, geophysics, and thermo-mechanical models to better understand magmatic systems.

Keywords: magnetotellurics, MELTS, petrology, magma reservoir, volcano geophysics