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In-situ HPHT-studies of partial melting of basalt by means of complex electrical conductivity and energy dispersive X-Ray diffraction data

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In volcanic areas partial melts may be the cause for observed lateral and vertical oriented electrical conductivity anomalies. Melt distribution depends on size and form of the magma chamber and the feeder dykes; the conductivity contrast between melt and solid rock exceeds more than one order in magnitude even at elevated temperatures $>$600˚C. The specific conductance of a melt depends on chemical and thermodynamic parameters like pressure, temperature, oxygen-fugacity and compo-sition of the melt. As melt and surrounding solid rocks are generally not in equilibrium, the chemistry of the melt, and thus its conductance, is additionally influenced by exchange reactions and their kinetics. In laboratory experiments it was found that melt first is formed in triple junctions and along grain boundaries; above roughly 10% of melt fraction, an interconnected network can be assumed, at least 20 vol% of melt are sufficient to explain high conductivity in volcanic areas.

In this study we followed partial melting of labradorite and basalt under in-situ p,T-conditions by means of impedance spectroscopy (IS) and energy dispersive X-ray diffraction experiments (EDX). The labradorite samples were of 35 and 50% albite content and acted as a model substance due to their well known thermodynamic properties. Chemical and mineralogical composition of the basalt were analysed by microprobe and XRD resulting in 75% plagioclase and 22% augite plus an amorphous phase $<$ 3 %. The basalt samples came from craters Brulant and Sery at Piton de la Fournaise, France. Temperature dependencies of complex conductivity of labradorite and basalt were measured in the temperature range 400^o C up to 1400^o at frequencies ranging from 1 kHz up to 100 kHz. Pressure was kept constant at 0.3 GPa. Redox reactions of Fe^{2+} into Fe^{3+} can increase the electrical conductivity, thus the experiments were conducted in reducing atmosphere. Stationary conditions for each variation in temperature were reached in less than 20 hours at low temperatures ($< 800^o$ C) and less than 1 hour at high temperature conditions ($>1000^o$C). Above the solidus, melt is formed and causes significant changes of dielectric properties even if present only in small amounts and isolated in pockets. The higher mobility of charge carriers in the melt causes both, shorter time constants of polarisations and an increase in conductivity. The polarisations increased the refined model capacitor of an electrical equivalent circuit model:1.5 orders in magnitude (1300˚C to 1450˚C) for labradorite and 2.5 orders in magnitude for basalt (1000˚C to 1260˚C) wrer found, while the impedance was decreased by about 2 orders of magnitude (labradorite) and by 2.5 orders of magnitude (basalt) when an interconnected melt-film along grain boundaries was formed. Activation energies for labradorite and basalt increased from 0.98 eV to 5.29 eV and 0.99 eV to 3.86 eV respectively, when the solidus was crossed.

In-situ X-Ray EDX-experiments were conducted at the synchrotron radiation source at the HASYLAB, DESY, Hamburg, Germany using a multi-anvil device of MAX80 geometry. Cylindrical samples of 3 mm in diameter and height were used. Temperature was controlled using a PtRh thermocouple in connection with a Eurotherm regulator; pressure was calibrated against the line shifts of NaCl. Partial melting of basalt was detected at temperatures $>$ 1050˚C. Melt fraction was increased from $<$ 3% at temperatures $<$ 1030˚C up to $>$ 60% at a temperature of 1200˚C calculated on the basis of changes of the peak to background intensity ratio. Similar results were obtained on labradorite where melting started at a temperature of 1300˚C, the position of the solidus (50% ab); while at temperatures higher than liquidus conditions the sample was totally molten. Melt fraction increased from 0 up to 100% between solidus and liquidus. This correlates with the changes in dielectric properties measured at identical temperatures. The results of the EDX and IS were independently confirmed by optical analysis of thin sections of quenched samples.

These laboratory data of conductivity changes due to partial melting allows to interpret surface geoelectrical measurements in more detail and can be used for model calculations of the electrical properties of partially molten volcanic rocks.