Geophysical Research Abstracts,
Vol. 11, EGU2009-8038, 2009
EGU General Assembly 2009

Electrical conductivity in a partially molten lower crust from laboratory measurements on xenoliths (El Hoyazo, SE Spain)

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The presence of High Conductive Zones (HCZs) within the lower crust is explained by several mechanisms involving phases as graphite, brines and partial melts, which enhance the conductivity when inteconnected over large distances. In the Internal Betics (Southern Spain) the anomalous HCZ imaged at the bottom of a thinned lower crust (Pous et al., 1999) is combined with low seismic velocities and high heat flow values (Carbonell et al., 1998) supporting the hypothesis that partial melts are present at depths. This is further confirmed by the recovery of restitic lower crustal xenoliths retaining evidence of partial melting (Zeck, 1968). The xenolith also contain up to 2 wt% of graphite which may contribute to the conductivity enhancement.

The present study is focused on the electrical conductivity at high pressure and temperature of four garnet-biotite-sillimanite metapelitic xenoliths collected from the Neogene dacites of El Hoyazo (SE Spain). The paragenesis is represented by garnet + biotite + sillimanite + plagioclase ± cordierite coexisting with graphite and widespread rhyolitic melt as inclusions and interstitial glass (̃10 wt%) (Cesare & Gómez-Pugnaire, 2001). The assemblage developed during regional anatexis at 850-900°C and 500 - 700 MPa (Cesare et al., 1997) and melt was frozen-in during fast uplift.

In order to discriminate the contibution of graphite and melt, assess the effect of their geometrical distribution and infer the influence of the glass rheology to the electrical conductivity, experiments were performed in two gas apparata at sealed and unsealed conditions. In unsealed runs, in fact, the porosity remains open which prevents graphite reconnection. The sealed experiments were conducted in a Paterson Apparatus up to 680°C and 840°C at 100 MPa and to 900°C at 300 MPa, the unsealed ones in an internally heated gas apparatus (IHPV) with Ar as pressure medium up to 950°C and 400 MPa. For each sample three mutually orthogonal cores (X, Y, Z) were drilled parallel to the macroscopic fabric elements to determine the electrical anisotropy: X parallel to lineation and Z normal to foliation.

Two electrodes were placed on the top and the bottom surfaces of the cores in a two pole arrangement in both the Paterson apparatus and the HIPV. In the Paterson apparatus, Nickel electrodes were used together with iron jackets to control the oxygen fugacity and temperature was monitored with one K-type thermocouple soldered on one of the two electrodes. In the IHPV two Platinum discs were connected to Pt and PtRh wires as S-type thermocouples. An authomated impedance spectrometer was used to collect the resistivity values in the range 1-105 Hz.

The Arrhenius plot of the Logarithmic specific conductivity versus the reciprocal absolute temperature, evidence that the electrical properties are remarkably similar in unsealed and sealed runs up to 700°C and linear above 400°C with an activation energy Ea =0.340 ÷ 0.561 eV. At 700°C, in unsealed experiments Ea increases to 1.03 ÷ 1.34 eV and a single impedance arc is observed at every temperature. In sealed experiments, the increment of Ea at 700°C is higher, up to 1.64 eV, and two impedance arcs (along direction X) or three (along Y) are observed. Melting occurs at T>800°C with the production of very tiny spinel + biotite + plagioclase + melt. At 700°C a phase interconnection is achieved which may be related to the glass transition temperature Te of the initial glass.

The laboratory measurements are consistent with the magnetotelluric soundings at temperature of 800-880°C and compatible with the hypothesis that partial melts are present in the Alborán lower crust. This temperature value is important to constraint the actual geotherm in the area.

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