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Influence of temperature, pressure, and chemical composition on the electrical conductivity of granite

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Abstract

The electrical conductivities of granites with different chemical compositions [X_A = (Na_2O + K_2O + CaO)/SiO_2 = 0.10, 0.13, 0.14, and 0.16 in weight percent] were measured at 623–1173 K and 0.5 GPa in a multi-anvil high-pressure apparatus using a Solartron-1260 Impedance/Gain Phase analyzer within a frequency range of 10^{-1}–10^6 Hz. The conductivity of the granite sample with X_A = 0.13 was also measured at 0.5–1.5 GPa. The results indicate that pressure has a very weak influence on the electrical conductivity in the stability field of granite, whereas increases in temperature and the value of X_A produce dramatic increases in the electrical conductivity. For the granite samples with X_A = 0.16 and 0.13, the activation enthalpies are 1.0 eV above 773 K and 0.5 eV below 773 K, suggesting that impurity conduction is the dominant conduction mechanism in the lower-temperature region. For the granites with X_A = 0.14 and 0.10, the activation enthalpy is 1.0 eV over the whole temperature range, suggesting that only one conduction mechanism dominates the conductivity. Based on the value of activation enthalpy (~1.0 eV) and the dependence of electrical conductivity and activation enthalpy on X_A at high temperatures, we propose that intrinsic conduction is the dominant conduction mechanism in all samples, and that K^+, Na^+, and Ca^{2+} in feldspar are the probable charge carriers controlling the conductivity. All conductivity data at high temperatures can be fitted to the general formula

$$\sigma = \sigma_0 X_A^{\alpha} \exp\left(-\frac{\Delta H_0 + \beta X_A^{\gamma}}{kT}\right)$$

where σ_0 is the pre-exponential factor; α, β, and γ are constants; ΔH_0 is the activation enthalpy at very small values of X_A; k is the Boltzmann constant; and T is the temperature. The present results suggest that the granite with various chemical compositions is unable to account for the high conductivity anomalies under stable mid- to lower-crust and southern Tibet.

Keywords: Electrical conductivity, granite, composition, temperature