ELECTRICAL CONDUCTIVITY AND VELOCITY ANOMALIES IN PARTIAL MELTS

T. J. Shankland (Geological Research Group, Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87545)

It is possible to use the theories of aggregates to predict physical properties of partial melts and to interpret high conductivity or low velocity anomalies in the mantle. Electrically a partial melt is regarded as an aggregate of a good conductor, the melt, in a relatively insulating crystalline matrix. Elastically the partial melt is a mixture of low velocity basaltic liquid intermixed with a high velocity crystal phase. Lines of constant conductivity or velocity can be plotted on a graph of temperature vs. melt fractions; when combined with plots of temperature vs. degree of partial melting from experimental petrology, these results can be used to estimate both temperatures and melt fractions in mantle zones having anomalous conductivity or velocity. The results are applicable to a range of tectonic and geothermal features such as Yellowstone or oceanic ridges.

Figure 1 illustrates an application of this approach to the oceanic low-velocity zone (LVZ). Figure 1a depicts the electrical conductivity of a partial melt which is about 0.1 S/m at 100 km depth (Shankland and Waff, 1977). The conductivity data can be satisfied along the approximately hyperbolic curve of possible temperature and melt fractions. The addition of a petrological curve of partial melting (Wyllie, 1971, Fig. 8-20) constrains the permissible temperature range and allows the estimation of the melt fraction. In Figure 1b is a similar plot of a constant shear velocity V_s of the LVZ normalized to V_{so} of the unmelted material according to the saturated crack model of O'Connell and Budiansky (1974). A representative V_s/V_{so} is 0.9. The aspect ratio of crack thickness to diameter has been adjusted to give the same temperature and melt fraction. In this case the data are satisfied by a dominant aspect ratio of .038 at a melt fraction of .034.

While other elastic and electrical models (and eventually experimental data) could have been used, the important point is that plots of temperature vs. melt fraction for a given physical property permit us to obtain information about the temperature, amount, and configuration of existing regions of partial melting. The results can be applied to problems of magma genesis or regional geothermal exploration.

REFERENCES

O'Connell, R. J., and B. Budiansky, 1974, "Seismic Velocities in Dry and Saturated Cracked Solids," J. Geophys. Res., 79, 5412-5426.

Shankland, T. J., and H. S. Waff, 1977, "Partial Melting and Electrical Conductivity Anomalies in the Upper Mantle," J. Geophys. Res., 82, in press.

Wyllie, P. J., 1971, The Dynamic Earth: Textbook in Geosciences, Wiley, New York.

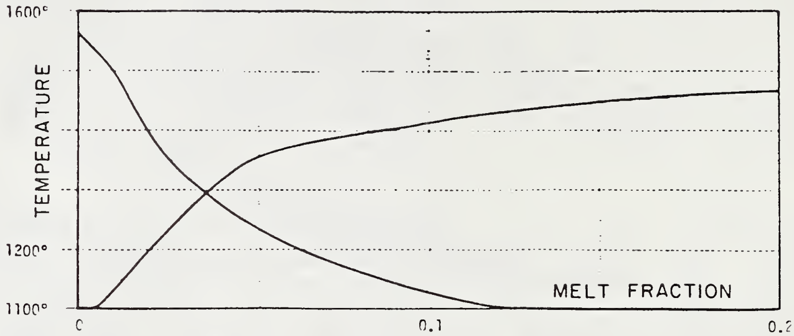

Fig. 1(a). Plots of temperature vs. melt fraction for an effective conductivity of 0.1 S/m and of Wyllie's (1971) peridotite melting curve.

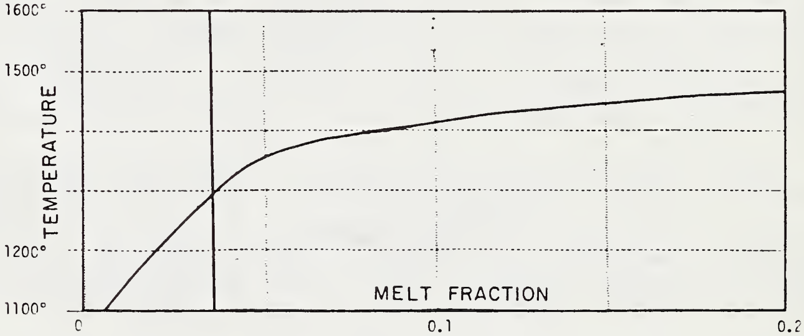

Fig. 1(b). Plots of temperature vs. melt fraction for shear velocity ratio V_S/V_{SO} = 0.9 and of the same peridotite melting curve as in 1(a).