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Entangling the Thermal History, CMB temperature, Adiabatic Gradient and Viscosity Structure of the Mantle with the Thermal and Dynamic Requirements for Upper Mantle Melting

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Our understanding of the Earth's interior can be improved by modeling the petrology and geodynamics of the mantle. This approach allows us to compute several features that can be independently compared with petrological and geophysical observations which ultimately provide a validation for the whole procedure.

Melting in the upper mantle is the end-product of several dynamic and petrological processes. The description of these processes is usually based on simplifying assumptions. However, it is possible to develop a more realistic approach that considers the complex interplay among the petrological and dynamical aspects. Here we present a multistage numerical procedure to characterize the thermal and dynamic conditions of the mantle that ultimately control the melting process as a function of time and space during mantle upwelling. (1): A parameterized mantle convection model is used in conjunction with a thermodynamic approach and an optimized mineralogically dependent viscosity model to determine the thermal history of the mantle from top to bottom using several constraints such as the melting temperature requirement to generate komatiite magmatism in the Archean and plume melting in more recent time. (2): The viscosity and the thermodynamic models and the thermal state at the CMB from the thermal history study are then applied to model the geodynamic evolution of a thermal plume. (3): The thermal and dynamic evolution at shallow depth (but below the mantle solidus) is then used to constrain the melting process which is investigated using a coupled two-phase flow model and a thermodynamic formulation for melt. The whole procedure illustrates the interconnection among a wide range of factors, such as thermal history, CMB temperature, mantle viscosity, thermal structure of plumes, evolution and composition of melt.

Here stage (3) is applied to the case of melting under a moving plate (e.g. Hawaii). In particular it is shown how the thermal and dynamic interaction of the plume with the lithosphere affects the melt distribution and composition and how it is related to the various stages of magma emplacement. Bathymetry/topography appears to be correlated with the thermal erosion of the lithosphere. A source component of melt detected by the model is clearly provided by the lithospheric mantle. One important observation for hot spot magmatism is that volcanism and emplacement of melt on the surface can take place much later and at some lateral distance from the vertical location where melting originally started. This concept applies for the development of tholeiitic basalts but also for pyroxenites that, even though are associated to post-shield events, they may have actually formed in an earlier stage. Magma permeability plays a crucial role on the characterization of the extent of the melt production and local abundance because it affects the melt transport and the chemical variations of the residual solid.