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An integrated chemical thermodynamics and fluid flow model with applications to mantle geodynamics

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Geodynamic (Gd) continuum flow models have being extensively used to understand chemical and physical processes in the Earth mantle. A severe limitation of Gd modeling is that petrological and mineralogical data are seldom used to constrain the physics of the model itself and the results from the numerical simulations are not easily and directly compared with geochemical observations. The most straightforward approach to improve Gd simulations is to incorporate chemical thermodynamics (Td) in the form of Gibbs free energy minimization with the approximation of the local equilibrium condition. Phases compositions and abundances are then retrieved in space and time. Once these quantities become available, then they can be used to put constraints on the physics of the flow model, making the Td and the Gd parts intimately coupled. Some applications of the method are described in this presentation. 1) We have applied the method to simulate dynamic equilibrium melting processes beneath ridges using a modified version of the Td database developed by Ghiorso et al. (G3, 2003) in combination with a 2-D multiphase flow model where dynamic of melt and mantle are coupled but treated separately. Focusing of melt from off-axis regions toward the surface is mainly obtained through flow at the base of the lithosphere-asthenosphere boundary. The importance of the latent heat of melting and the dissipative stress (momentum exchange between two phases which is controlled by permeability/viscosity ratio) will be emphasized in the presentation. 2) A similar approach is used to simulate melting and plume-lithosphere interaction beneath Hawaii. Asymmetric melt distribution as well as temporal melt separation associated with islands chain volcanism is reproduce by the model. Partial erosion of the base of the lithosphere caused by the increment of heat connected with the plume and melt transport is also observed. Plume evolution and island volcanism in Hawaii are essentially controlled by change

in viscosity from lithosphere to astenosphere region, melt dynamics, mantle/melt density contrast, and the appropriate definition of the Td database (currently CO2/H2O components are not available in the database). 3) Recently there has being rising discussion questioning the existence of plumes and a plume-upwelling mode of mantle flow. We are using the best (and only) self-consistent Td database developed by Saxena (GCA, 1996) for computation of equilibrium assemblages at very high pressure and high temperature to constrain a compressible mantle flow model that includes a self-consistent interaction between mineral phases, composition and mantle physical properties such as density, viscosity and thermal expansion. Viscous dissipation and adiabatic heating are included in the model. Mantle viscosity is modeled following Yamazaki and Karato (Am Min, 2001). Initial results are open for discussion mainly due to the following reasons: a) certain physical properties of minerals at very high pressure are not sufficiently well constrained from experimental measurements b) Td database is restricted to the system Fe-Mg-Si c) intrinsic limitations of 2-D numerical models. Nevertheless we think this is a promising direction for future research.