

## Intraplate volcanism due to small-scale convection – A 3D-numerical study

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Although most of the intraplate volcanism in ocean basins is expressed in linear chains, not all of those can be attributed to a stationary hotspot. Many ridges show erratic age-progressions (e.g. Musicians, Magellan seamounts) or span more than thousand kilometers in a couple of million years (e.g. Line Islands, Pukapuka ridges). Cracking of the lithosphere and small-scale convection have been invoked to account for this type of volcanism. The former presumes a partially molten asthenosphere, whereas the latter has not yet been tested and validated in a numerical model.

In the Earth's uppermost mantle SSC is likely to develop due to instabilities of the thickened thermal boundary layer below mature oceanic lithosphere. It is characterized by convective rolls aligned by plate motion. Their onset is earlier (i.e. beneath younger and thinner lithosphere) for lower mantle viscosity (e.g. for hot or wet mantle) or adjacent to lateral inhomogeneities. In these cases, partial melt potentially emerges in the upwellings of SSC. This changes the compositional buoyancy owing to melt retention and additional depletion of the residue. Therefore, it promotes upwelling and allows for further melting. This self-energizing mechanism is able to sustain melt production in a once partially molten layer for a couple of million years.

In order to dynamically test the SSC hypothesis for intraplate volcanism, we take the step towards fully thermo-chemical 3D-numerical models of SSC. This is, we analyze a set of models at low mantle viscosities and varying temperatures, which provide insight into the interaction of SSC and melting. Therein, we explore the 3D-patterns of melt associated with SSC, the amounts and shapes of volcanism. We also incorporate small thermal anomalies that locally reduce the onset age of SSC.

Volcanism is predicted to evolve synchronously in a region of hundreds of kilometers after onset of SSC. Therefore, age progressions of ridges are not required to be monotonous anymore. The amount of volcanism is highly dependent on mantle viscosity. For ambient temperatures (1350 °C) viscosities have to be low ( $1.3 \cdot 10^{19}$  Pa·s) and volcanism forms on 30 Ma old lithosphere. For elevated temperatures (1400 °C) viscosities can be higher ( $2 \cdot 10^{19}$  Pa·s) and volcanism still forms on 50 Ma old lithosphere. Lateral thermal anomalies further increase viscosities required and are able to focus volcanism.

## Stochastic modeling of surface roughness evolution during mineral dissolution

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Mineral dissolution rates are typically normalized by the surface area of the dissolving mineral. Any dissolution reaction, however, must cause the surface of the dissolving solid to change. It is, therefore, possible that surface area is a dynamic variable during mineral dissolution. In particular, surface roughness may evolve over time and, in order to interpret mineral dissolution rates, it is important to know whether a steady-state surface roughness exists and how this steady-state roughness might respond to variables that control dissolution rate such as dissolution reaction mechanism, solid defect density, and free energy of reaction ( $\Delta G_{rxn}$ ).

Mineral dissolution and, by extension, surface evolution may be treated, theoretically, as a chemical kinetics phenomenon by parsing the surface into reactive sites. Unfortunately, the basic assumption of random collisions needed to formulate classical rate equations is inapplicable for surface evolution where site-site interactions are subject to geometric constraints. To address this problem, we have developed a 2-dimensional Ising model of dissolution and precipitation. In this model, the solid is represented by all spin-up lattice sites and reactions are represented by flipping the spin at a site with probability (per unit time) determined by the number of spin-up (or, occupied) nearest neighbors. By varying the functional relationship between reaction probability and the number occupied nearest neighbors, we simulated a variety of reaction mechanisms as well as the effects of  $\Delta G_{rxn}$ . By introducing spatial heterogeneity into the reaction probabilities we simulated the effects of defects in the solid. Simulations were performed with a variable time dynamic Monte-Carlo algorithm with reaction sites found with bisection of the surface.

Our simulations indicate that a unique steady-state surface roughness exists over a broad range of dissolution mechanisms. Carefully chosen defect structures were found to generate periodic surface roughness behavior which was, however, accompanied by periodicity in the net reaction rate indicating that the intrinsic reactivity of the surface was unaffected by defects. Surface roughness as a function of  $\Delta G_{rxn}$  was found to be highly sensitive to the precipitation mechanism even when the net dissolution rate as a function of  $\Delta G_{rxn}$  was relatively constant. Our results also shed insight into the existence of an inflection point in dissolution rate vs.  $\Delta G_{rxn}$ . Results will be discussed in terms of relative step nucleation and retreat rates.