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Considering bioactivity in modelling continental growth and the Earth's evolution

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The complexity of planetary evolution increases with the number of interacting reservoirs. On Earth, even the biosphere is speculated to interact with the interior. It has been argued (e.g., Rosing et al. 2006; Sleep et al, 2012) that the formation of continents could be a consequence of bioactivity harvesting solar energy through photosynthesis to help build the continents and that the mantle should carry a chemical biosignature. Through plate tectonics, the surface biosphere can impact deep subduction zone processes and the interior of the Earth. Subducted sediments are particularly important, because they influence the Earth's interior in several ways, and in turn are strongly influenced by the Earth's biosphere. In our model, we use the assumption that a thick sedimentary layer of low permeability on top of the subducting oceanic crust, caused by a biologically enhanced weathering rate, can suppress shallow dewatering. This in turn leads to greater availability of water in the source region of andesitic partial melt, resulting in an enhanced rate of continental production and regassing rate into the mantle. Our model includes (i) mantle convection, (ii) continental erosion and production, and (iii) mantle water degassing at mid-ocean ridges and regassing at subduction zones. The mantle viscosity of our model depends on (i) the mantle water concentration and (ii) the mantle temperature, whose time dependency is given by radioactive decay of isotopes in the Earth's mantle. Boundary layer theory yields the speed of convection and the water outgassing rate of the Earth's mantle.

Our results indicate that present day values of continental surface area and water content of the Earth's mantle represent an attractor in a phase plane spanned by both parameters. We show that the biologic enhancement of the continental erosion rate is important for the system to reach this fixed point. An abiotic Earth tends to reach an alternative stable fixed point with a smaller continental surface area and dryer mantle. The origin and evolution of life on Earth might be responsible for the rise of continents 3.5 billion years ago.

References

[1] N. H. Sleep et al., Annu. Rev. Earth Planet. Sci. 40, 277-300, 2012

[2] M. T. Rosing et al., Paleo3 232, 90-113, 2006