EPSC Abstracts
Vol. 5, EPSC2010-174, 2010
European Planetary Science Congress 2010


# Surface to interior interactions on the evolving Earth

**J. Dyke** (1), F. Gans (2) and A. Kleidon (1)
(1) Max Planck Institut für Biogeochemie; Jena, Germany (jdyke@bgc-jena.mpg.de)

## Abstract

The Earth can be regarded as a planetary heat engine in that there is a significant temperature gradient between the hot interior and colder surface. As heat flows over this gradient it can do work. It may be assumed that geological processes entirely determine the power generated by this system. However, Vernadsky described life as the geologic force [Vernadsky, 1926], while Lovelock noted the role of life in driving the Earth's atmospheric composition to a unique state of thermodynamic disequilibrium [Lovelock, 1968]. Rather than surface processes being entirely driven by interior processes, we explore the hypothesis that the Earth is a complex, co-evolving, non-equilibrium system in which the surface can affect the interior. Here, we use these notions in conjunction with thermodynamics to quantify biotic activity as a driving force for geologic processes. Specifically, we explore the hypothesis that biologically-mediated processes operating on the surface of the Earth, such as the increase of weathering of continental crust, affect interior processes such as mantle convection and have therefore shaped the evolution of the whole Earth system beyond its surface and atmosphere.

We set up three simple models of mantle convection, oceanic crust recycling and continental crust recycling. We describe these models in terms of non-equilibrium thermodynamics in which the generation and dissipation of gradients is central to driving their dynamics and that such dynamics can be affected by their boundary conditions. Via the proposed principle of Maximum Entropy Production (MEP) [Kleidon and Lorenz, 2005] we use these models to quantify the maximum power that is involved in these processes. The assumption that these processes operate at maximum levels of generation and dissipation of free energy (and so MEP) lead to reasonable predictions of core temperature, sea floor spreading rates, and continental crust thickness. With a set of sensitivity simulations we then show how these models interact through the boundary conditions at the mantle-crust and oceanic-continental crust interfaces. We set up a work budget of the Earth's interior to compare the maximum power estimates that drive interior processes to the power that is associated with biotic activity. We estimate that the maximum power involved in mantle convection is 12TW, oceanic crust cycling is 28TW, and continental uplift is less than 1TW while surface life generates 250TW of chemical free energy.

By utilizing only a small fraction of the generated free chemical energy for geochemical transformations at the surface, life has the potential to substantially affect interior processes, and so the whole Earth system. This study can be seen as consonant with [Rosing et al., 2006] which proposed that life was significantly responsible for the formation of continental crust. We plan to extend our model by considering atmospheric and oceanic chemistry and so more exactly quantify the effects of the emergence and evolution of life on the Earth system.

## References

[Kleidon and Lorenz, 2005] Kleidon, A. and Lorenz, R. D. (2005). *Non-Equilibrium Thermodynamics and the Production of Entropy: Life, Earth, and Beyond*. Springer, Berlin.

[Lovelock, 1968] Lovelock, J. E. (1968). A physical basis for life detection experiment. *Nature*, 207:568–570.

[Rosing et al., 2006] Rosing, M., Bird, D., Sleep, N., Glassley, W., and Albarede, F. (2006). The rise of continents: An essay on the geologic consequences of photosynthesis. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 232(2):99–113.

[Vernadsky, 1926] Vernadsky, V. I. (1926). *The Biosphere*. Copernicus, New York, English translation, 1998.