LIPs and climate change

FRANCIS A. MACDONALD[1], ROBIN WORDSWORTH[1], NICHOLAS SWANSON-HYSELL[2]

[1]Harvard EPS, 20 Oxford St. Cambridge, MA 02138, fmacdon@fas.harvard.edu, rwordsworth@seas.harvard.edu
[2]University of California, Berkeley, CA 94720, swanson-hysell@berkeley.edu

Large igneous provinces (LIPs) cause climate change on different timescales by altering planetary albedo, greenhouse forcing, and surface weatherability. On multi-annual to centennial timescales, LIPs form fire fountains that drive turbulent, volatile-rich convective plumes with heights >15 km. Individual eruptions can drive cooling with an increase in planetary albedo from the conversion of volcanic SO_2/H_2S emissions to tropospheric and stratospheric sulfate aerosols. Aerosols have the maxiumum radiative effect when erupted at low latitude, and are more likely to penetrate the stratosphere when the background climate is cold. Once a volcanic eruption begins, a positive feedback may occur: surface cooling by aerosols lowers the tropopause height, making it easier for subsequent eruptions to penetrate the tropopause and recharge the aerosol content of the stratosphere. If an eruption series associated with a LIP does not send a planet into a Snowball Earth, then the climate should return to the pre-eruption state on a relatively short timescale.

Recent geochronology has demonstrated that in many LIPs the bulk of magmatism occurs in <1 Myr, and warming due to greenhouse gas emissions should occur on a similar timescale. The amount of outgassed CO_2 depends on the volatile content of the melt and the wall rocks. Once eruption rates have waned to a background level, the climate system should return to the pre-eruption state on the timescale of the ocean carbon cycle, ~10-100 kyr.

On timescales >1 Myr, continental flood basalts may increase planetary weatherability leading to lower steady-sate CO_2 levels through silicate weathering. Given that mafic rocks are highly soluble, in the warm, wet, tropics emplacement of LIPs at low latitude should have a great effect on increasing weatherability. For some LIPs, uplift associated with the thermal bouyancy of the plume could enhance the exposure of fresh basalt available for chemical weathering. However, LIPs that occur in association with continental rifting may subside and be buried under sediment limiting their effect on weatherability. Here we analyze the Neoproterozoic to present record of LIPs in the context of timing, paleolatitude, background climate, wall rock composition, and tectonic setting, and assess the degree to which LIPs may have driven climate change.