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Did North Atlantic Igneous Province igneous sills trigger or maintain Paleocene Eocene Thermal Maximum global warming?

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Igneous sills of the North Atlantic Igneous Province (NAIP) were intruded into organic-rich sediments, generating methane and carbon dioxide by thermal maturation. These greenhouse gases escaped to the ocean and atmosphere through hydrothermal vents above the sills that have been observed on seismic reflection data and by drilling. It has been suggested that the NAIP sills provided a significant component of the greenhouse gases that forced warming during the Paleocene Eocene Thermal Maximum (PETM). Here we consider whether methane released by NAIP sills could have triggered, as well as maintained, the PETM warming. Warming resulting from the PETM trigger began a few thousand years before the major upheaval in the carbon cycle that was associated with the PETM itself. Recent organic geochemical investigations have suggested that methane was involved in the trigger. Since the lifetime of methane in the atmosphere was approximately one decade during the Paleocene, the triggering methane pulse probably contained on the order of 100 Gt or more of carbon and was probably released in a period of c. 10 years or less.

We use recent field observations of fluidized country rocks around sills to speculate on a model for sill emplacement, greenhouse gas generation and escape. The observation of fluidized sediments associated with lobe and finger structures along inward-dipping sections of many sills suggests that these sill rims propagated laterally by fluidizing a restricted volume of country rock, allowing the magma to advance into the fluidized region as a viscous fingering front. At this stage, the fluidized region was not connected to the surface by a conduit, so greenhouse gases could not escape rapidly. Eventually, as the sill rim propagated laterally and upward, a hydrothermal conduit was initiated and propagated rapidly upward to the surface. This model, based on field observations implies that the gases which initially escaped up the hydrothermal conduit were supplied from a region surrounding the sill rim, rather than the strata above and below the sill that correspond to its thermal aureole. The maximum volume of gas that escaped rapidly, within a decade of the time of conduit formation, is therefore proportional to the circumference rather than surface area of the sill. This consideration suggests that individual NAIP hydrothermal vents probably could not have delivered a sufficiently large gas volume to trigger the PETM. Instead, a large component of the methane and carbon dioxide generated by thermal maturation adjacent to each sill would have seeped up the conduit over a much longer period closer to a century in duration. The observation that many NAIP vents are topped by mounds rather than craters is consistent with this interpretation. We therefore suggest that the greenhouse gases vented above NAIP sills helped maintain the PETM warming but an additional mechanism is required to explain the initiation of this event.

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