

# Fertilization Potential of Volcanic Ash in Ocean Surface Waters

Paul Frogner (paul@hi.is)<sup>1</sup>, Sigurdur Gíslason (sigrg@raunvis.hi.is)<sup>2</sup> & Niels Óskarsson (niels@norvol.hi.is)<sup>1</sup>

<sup>1</sup> Nordic Volcanological Institute, IS-108 Reykjavík, ICELAND

<sup>2</sup> Science Institute, University of Iceland, Dunhagi 3, 101 Reykjavík, ICELAND

The continuous increase of atmospheric CO<sub>2</sub> (Keeling and Whorf, 1999) stalled following the two largest volcanic aerosol eruptions of this century; Agung, Bali and Pinatubo, Philippines. Since volcanic emission of CO<sub>2</sub> was enormous during these events, there must be an effect on the carbon cycle leading to transient enhanced fixation of atmospheric CO<sub>2</sub>. Sarmiento (1993) suggested iron fertilization and biological fixation of CO<sub>2</sub> in the ocean surface water by volcanic ash from the Pinatubo eruption as a plausible cause.

To test the fertilization potential, pristine volcanic ash from the Hekla 2000 eruption, was dissolved in the laboratory. The Hekla volcano in southern Iceland erupted on February 26, 2000. A plume more than 10-km high formed at the beginning of eruption and ash was carried by winds over northern Iceland towards the North Atlantic Ocean. Most of the ash fell in the interior of Iceland and a maximum thickness of 4-5cm was measured in the sampling area 21km north of Hekla 7 hours after the onset of the eruption (Nordvulk, 2000). Ash was sampled during the ash fall and stored frozen to make sure that the soluble salts did not dissolve and was thereafter freeze-dried.

In the ash plume, volcanic aerosols consisting of acids and water soluble metal salts are adsorbed on the surface of the volcanic ash, consisting of glassy rock (Ragnarsdóttir et al., 1994). When the ash comes in contact with the surface layer of the ocean, the adsorbed aerosol dissolves much faster than the volcanic glass itself, releasing nutrients and trace metals that are rate-determining for growth of biota. To mimic the dissolution of ash particles passing through the photic zone towards the seafloor, the ash was placed as a stationary bed in plug flow-through reactors through which reactant solutions were pumped continuously.

Dissolution of ash in deionized water, artificial seawater and seawater shows that most aerosols adsorbed to glassy particles dissolve within the course of an hour, as seen in high concentrations of major and trace elements. High release of acids in the ash increased the initial release of major and trace elements. An initial pH as low as 2.8 was obtained in both the artificial seawater and the seawater. Substitution of seawater with artificial seawater did not affect initial release for most elements. Release rates of major elements like Si, Fe and Al in the artificial seawater were 50.3, 38.5 and 28.1 μmol g<sup>-1</sup> h<sup>-1</sup> respectively and similar rates 49.5, 37, 0 and 24.7 μmol g<sup>-1</sup> h<sup>-1</sup> were obtained in seawater. In contrast to artificial seawater, pH rapidly increased, from 2.8 to 5.5, after initial (45 minutes) dissolution in seawater due to the buffering capacity (alkalinity = 2.3 meq

/L) of seawater. The artificial seawater pH increased gradually but remained lower than pH 5 during the whole experiment. Decrease in release for most elements with time differed between the artificial seawater and the seawater and e.g. Si release declined by a factor of 7 and 20 respectively after initial dissolution. Furthermore, dissolution in deionized water shows that acid magmatic gases such as HF and HCl are major anion donors of water-soluble compounds adhering to glass particles. This is shown by high initial release of fluoride and chloride.

The North Atlantic Ocean is the largest sink for atmospheric CO<sub>2</sub>, 39%, of the world's oceans mainly due to intense biological drawdown of CO<sub>2</sub> (Takahashi et al., 1999). In large areas of the North Atlantic Ocean phosphate is reduced to near zero values in the first month of spring from uniform concentrations ranging between 0.6 and 1.1 μM during winters (Takahashi et al., 1993). Due to a reduction to near zero values of phosphate in chlorophyll rich areas it is likely that phosphorous limits primary production.

We found that the ash dissolved in seawater initially releases considerable amounts of phosphorous, 1.7 μmol g<sup>-1</sup> h<sup>-1</sup>, but also silica, iron and manganese 49.5, 37.0 and 1.7 μmol g<sup>-1</sup> h<sup>-1</sup> respectively. To reach the highest winter concentrations of phosphorous in the North Atlantic Ocean, it is found that 0.8g ash h<sup>-1</sup> dm<sup>-3</sup> needs to dissolve. Due to the high initial release rate, it is shown that volcanic ash supplies nutrients to ocean surface water that will stimulate biological drawdown of CO<sub>2</sub>.

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