The contribution of limiting nutrients to the ocean from the 1991 eruption of Mount Pinatubo

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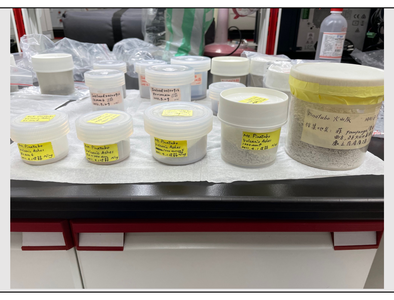
Background and Motivation

The 1991 eruption of Mount Pinatubo was the second-largest volcanic event in the 20th century, producing a bulk tephra volume of 5.5km^3, with a Volcanic Explosivity Index (VEI) of 6(1). This eruption lowered the global CO_2 concentration by 2 ppm! It was proposed to be attributed to the effect of surface ocean fertilization from the release of limiting nutrients from the tephra(2).

Previous studies suggested that volcanic ashes could enhance biological fixation of atmospheric CO_2(3), due to the significant input of bioavailable major and minor nutrients(4,5,6). However, to the best of our knowledge, no study has reported and estimated the contribution of the limiting nutrients to the ocean, particularly P and Fe, from the 1991 eruption. Therefore, this study attempts to quantify Mt. Pinatubo's limiting nutrient contribution.

Samples

Sample image (photographed on 2022/07/19)	
Sample name	Mt. Pinatubo volcanic ashes
Location	Philippines N15^{O}18'15'', E120^{O}51'33''
Collection date	1991/07/06
Sorting date	2011/04/01

Samples are sorted into respective sizes. <50um, 50-200um, 200-1000um, >1000um

Method

- The samples were collected by Prof. Shu-Chen Pai of Institute of Oceanography, National Taiwan University
- Sample sizes are validated using Scanning Electron Microscope (SEM)
- Energy Dispersive Spectroscopy (EDS) is used for mineralogical analysis of samples.
- Sample's bulk element concentration is obtained by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) using total digestion procedure(7).
- To simulate tephra's instant dissolution in seawater, ultrapure water leaching method is used(7).

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Results and Discussion

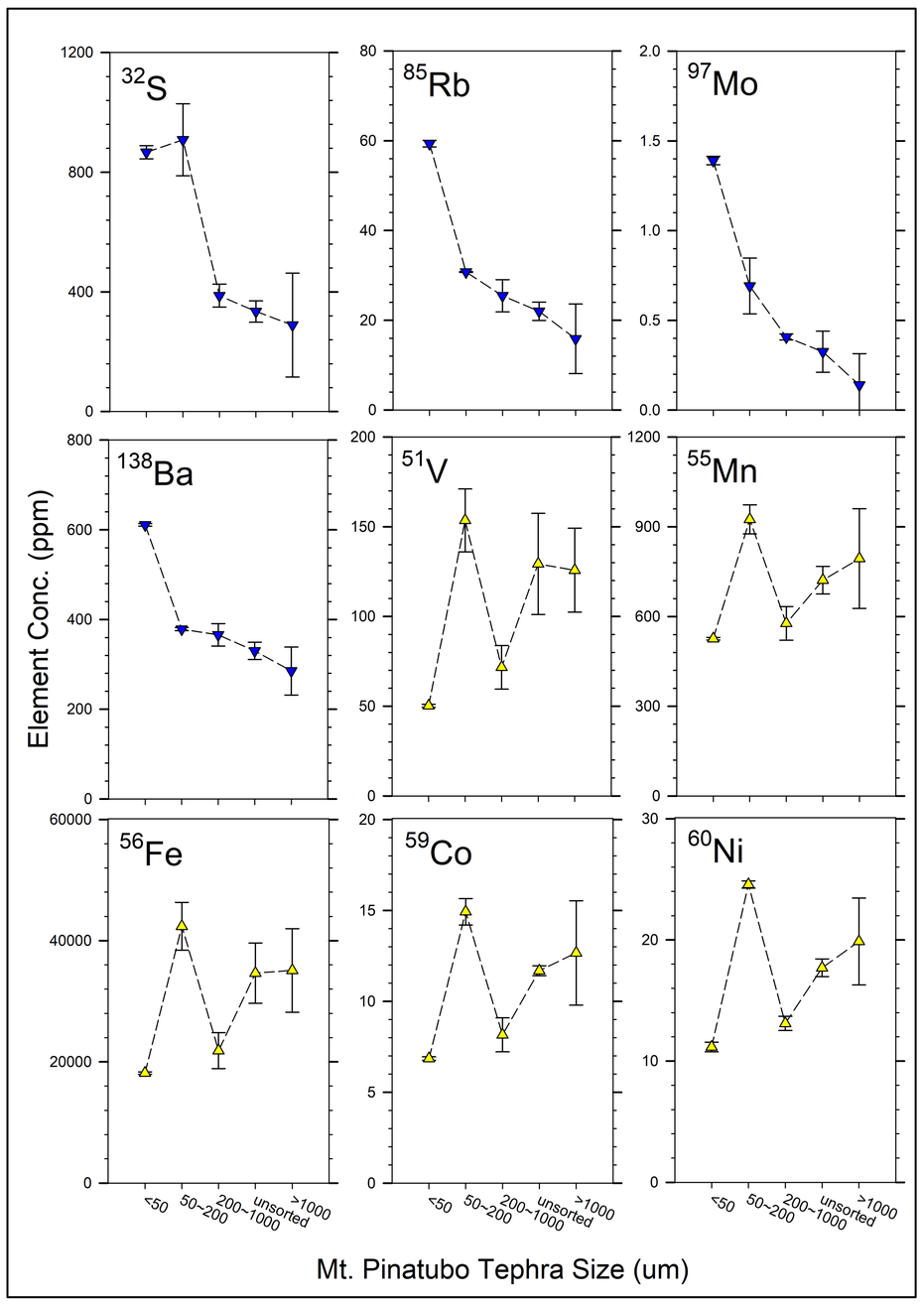

Figure 1. A Selection of Bulk Element Concentration in Different Size Fractions

- Shown Fig. 1, the elements in blue exhibits a negative trend, proposed to be the effect of adsorption onto tephra favoring small size (high surface area to volume ratio). S, Rb, and Ba's low melting point to volcanic eruptions (up to 1200 ^{O}C) results in readily adsorption. The reason behind a negative trend of Mo is uncertain.
- Fe and P, two limiting nutrients, are critical factors influencing phytoplankton growth in the ocean. The estimated contribution of dissolvable Fe and P from the eruption are 10^{10} and 10^9 mole, respectively, which theoretically would result in 10^{15} and 10^{11} mole of CO_2 uptake, respectively.
- Fig. 2 shows increased occurrence of iron oxide in size 50-200um, supporting ^{56}Fe data in Fig. 1. This could be explained by crystal's preferred size stabilization. Hematite (Fe_2O_3), Ilmenite ($FeTiO_3$) and Pyrite (FeS_2) are also found in greater abundance in size 50-200um.

Oxygen by stoichiometry (Normalized), All results in compound%

Spectrum	Na	Al	Si	S	Ca	Fe	Total
Spectrum 1		1.14	2.82	1.08	1.15	93.82	100
Spectrum 2	0.77	30.28	68		0.96		100
Spectrum 3	1.98	5.33	16.77	1.73	1.47	72.72	100

Spectrum	Na	Mg	Al	Si	K	Ca	Fe	Total
Spectrum 1		2.05	1.5	3.22			93.2	100
Spectrum 2			12.49	74.3	7.27	5.92		100
Spectrum 3	2.69		12.48	79.3	3.88	1.65		100

Spectrum	Mg	Al	Si	Ti	Fe	Total
Spectrum 1		1.89	3.02	3.77	91.32	100
Spectrum 2	2.14	4.19	7.17	4.68	81.81	100
Spectrum 3		11.4	49.71		38.85	100

Figure 2. Mineral composition analysis on size 50~200um using SEM and EDS

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