Volcanogenic acid deposition enhances weathering of Andisols in Nicaragua

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1. Introduction

Sulphur and halogen-rich gas emissions from passively degassing volcanoes can generate important dry- and wet-deposited fluxes of SO_2, H_2SO_4, HCl and HF locally and regionally. Such volcanogenic depositions may represent significant inputs of acids to soils located downwind.. Here we investigate the influence of a persistent tropospheric volcanic gas plume on the weathering degree and acidification of Vitric and Eutric Andisols developed on basaltic parent materials. We contrast soils collected from the same sites in 2001 and 2017.

2. Study site and Soil Analysis

Masaya volcano (E = 560 m a.s.l., Nicaragua) has been degassing continuously since 1993 (**Fig. 1**). The volcano currently emits *ca.* 700, 230 and 25 Mg d^{-1} of SO_2, HCl and HF, respectively. We collected soil samples along two transects located 5 (VI soils) and 15 (EU soils) km downwind of the volcano (**Fig. 2**). Previous works showed that both the VI and are Andisols, but the former are less weathered than the latter[1,2]. The VI and EU sites receive heavy SO_2+HCl-rich dry depositions, equivalent to proton fluxes of *ca.* 7.3-9.1 and 5.5-7.3 mol m^{-2} yr^{-1}, respectively[3]. The soils were characterised for various physico-chemical properties in the laboratory.

Figure 1 Masaya volcano and its gas plume. Note the gas-impacted vegetation

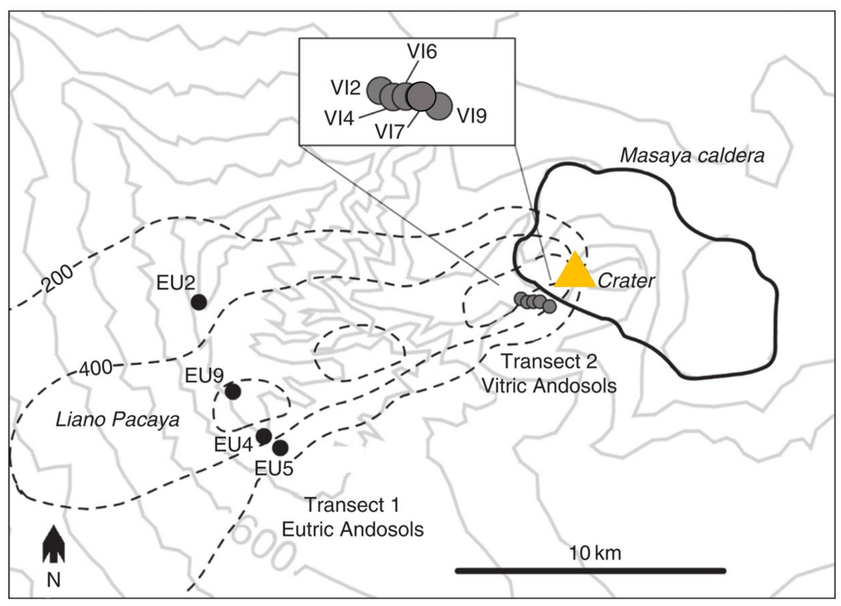

Figure 2. Spatial pattern of proton deposition fluxes (mmol m^{-2} d^{-1}) as measured in 1999 downwind of Masaya volcano[3]

3. Results and Discussion

All the surface soils display lower total reserve in bases contents in 2017 compared to 2001 (**Figs. 3a-b**). In parallel, the base saturation % decreases (**Figs. 3c-d**) and the exchangeable acidity (approximated by $\Delta pH_{(H2O-KCl)}$) increases (**Figs. 3e-f**) in 2017; the effect is more pronounced in the EU soils. The contents of amorphous/poorly crystalline minerals (allophanes and ferrihydrite) did not vary significantly between 2001 and 2017 (not shown). Similarly, no clear trend in sulphate retention could be inferred **(Figs. 3g-h)**.

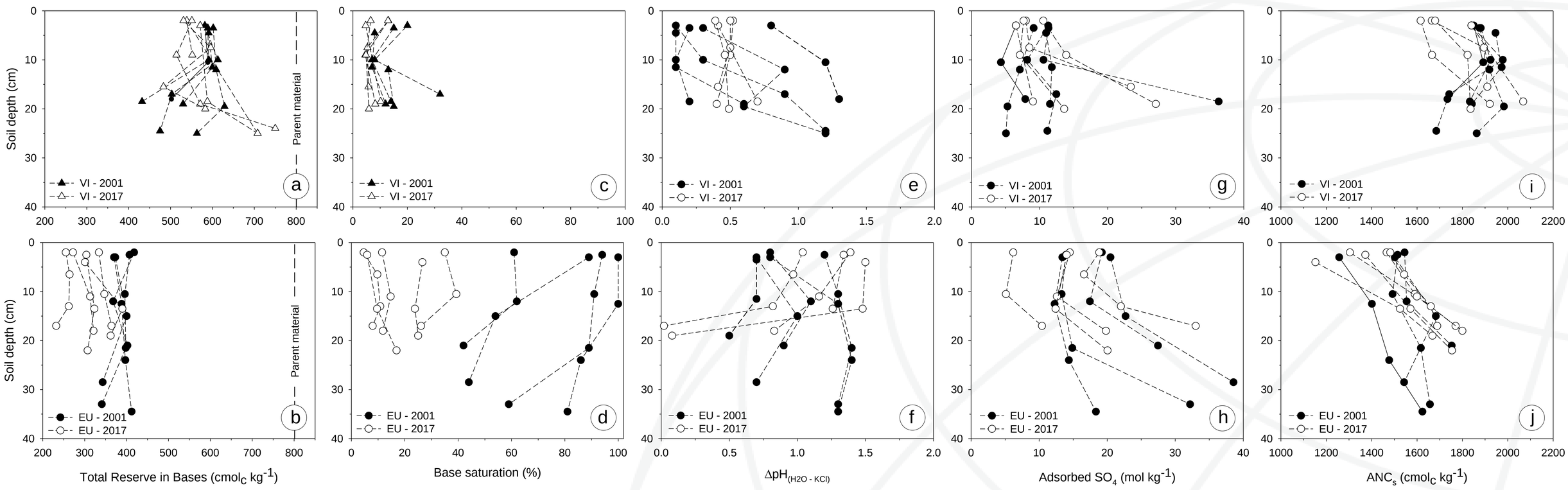

Figure 3 Total reserve in bases, base Saturation %, $\Delta pH_{(H2O-KCl)}$) , adsorbed sulphate concentration and acid neutralizing capacity (ANC(s)) of the VI and EU soils.

The results suggest that 16 years of continuous volcanogenic acid deposition have increased weathering in both the VI and EU Andisols. This is accompanied by a lowering of their acid neutralizing capacity (ANC(s)) (**Figs. 3i-j**). ANC(s) decreases by leaching of the base cations and through desilicification. Inorganic sulphate retention in the soils may have reached its maximum. We calculated very high rates of proton neutralization of *ca.* 13.1 and 4.4 mol m^{-2} yr^{-1} in the surface horizons of the VI (15 cm) and EU (20 cm) Andisols, respectively. This compares reasonably well with the volcanic SO_2+HCl-derived fluxes of protons of *ca.* 7.3-9.1 and 5.5-7.3 mol m^{-2} yr^{-1} brought to the VI and EU sites, respectively, *via* dry deposition[3].

4. Conclusion

We argue that heavy volcanogenic acid deposition at Masaya volcano enhances weathering and decreases the ANC(s) of the Andisols located downwind. Our study has potentially relevant ramifications for discussing the environmental effects of immense and sustained degassing during flood basalt eruptions.

References [1] Delmelle et al. (2003) Env Poll 26:445-457; [2] Delfosse et al. (2005) Eur J Soil Sci 56:113-125 ; [3] Delmelle et al. (2001) Env Sci & Tech 7:1289-1293