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Trace element degassing patterns and volcanic fluxes to the atmosphere during the 2014 Holuhraun eruption, Iceland

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Trace elements are well known to be volatile at magma temperature and enriched in volcanic gases from active volcanoes worldwide. However, little is known so far regarding their volatility at Icelandic volcanoes, mostly because high temperature volcanic gases are often inaccessible. The 2014 Holuhraun eruption that began on August 29 is characterized by both high extrusion rates of lava and intensive degassing which gives rise to a volcanic plume made of volcanic gases, aerosols and fine solid particles. A unique opportunity to sample the diluted plume at the eruption site was given to us on October 2. Volcanic aerosols were collected on washed PTFE membranes by pumping through the diluted plume for 30 minutes to 1 hour. Reactive gases were simultaneously trapped on impregnated filters, yielding a SO_2/HCl molar ratio at the eruption site of 29-46 and SO_2 concentrations in the diluted plume up to 200 mg/m3 (Haddadi et al., EGU 2015).
PTFE filters were leached in 5 ml of a diluted HNO_3-HF mixture for one week at 90°C. Solutions were subsequently analyzed by ICP-MS using a synthetic reference solution at 10 ppb for external calibration. Both siderophile (Mo, W, Re) and calchophile trace metals (Cu, Zn, As, Se, Cd, In, Sn, Sb, Te, Tl, Pb, Bi) were found to be significantly enriched in the diluted volcanic plume of Holuhraun compared to the background atmosphere in Iceland. Measured concentrations range from less than 0.1 ng/m3 for W up to 400 ng/m3 of Cd. Enrichment factors (EF) relative to Mg, considered as a strictly lithophile element with extremely low volatility, were computed for all analyzed trace metals. The least volatile elements (W, Cu, Zn, Mo, Ag) have EFs in the range 50-300 while the most volatile elements (Cd, Bi, Re, Se, Te) have EFs as high as 10E6. The overall degassing pattern observed at Holuhraun is consistent with those previously reported for other mantle plume related volcanoes like Kilauea (Mather et al., Geochim. Cosmochim. Acta, 2012) and Erta Ale (Zelenski et al., Chem. Geol., 2013). In contrast, it significantly departs from observations at subduction-related volcanoes where Cl-rich gases enhance the volatility of trace metals. Degassing of trace elements at Holuhraun thus appears to be characteristic of hot spot magmatism where gases exhibit high S/Cl ratios.
The volcanic output from the ongoing eruption was estimated by scaling metal-to-SO_2 concentration ratios to the flux of SO_2 ($\sim$1200 kg/s, Gouhier et al., EGU 2015). Daily emissions are in the range 50 g/d (W) – 200 kg/d (Cd), suggesting that the Holuhraun eruption is a major source of pollution to the local environment and atmosphere over Iceland. For instance, from the beginning of the eruptive crisis to the end of 2014, more than 25 tons of highly toxic Cd have been released to the atmosphere. Future work should be devoted to study both the plume dispersion and the long-range transport of metallic aerosols in order to check how this can affect populated areas.