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Weathering and S cycle in volcanic watersheds analogous to Mars

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There is significant disagreement about whether chemical weathering participated in formation of aqueous sulfate (SO_4^{2-}) on early Mars, when liquid water was present on its surface. Previous geochemical models mainly focused on volcanic sulfur (S) degassing and atmospheric deposition via acid rainfall. Generally, it is unclear if chemical weathering of S-rich mineralization present in volcanic bedrock might have been an important source of aqueous SO_4^{2-} on Mars. This is because sulfur (S) concentrations of many bedrock S minerals (sulfide, elemental S) cannot be directly measured by most orbital and robotic instruments sent to Mars. Chemical weathering via sulfide oxidation is an important process contributing to dissolution of rocks and formation of aqueous SO_4^{2-} on Earth. Therefore, we selected the watershed of Valles Caldera, New Mexico to better constrain the quantities (fluxes) of SO_4^{2-} from chemical weathering compared to direct oxidation of hydrothermal (H_2S) gases and atmospheric deposition.

Our results at Valles show that the SO_4^{2-} contributions from different sources significantly vary between dry and wet seasons. In the dry season, the aqueous SO_4^{2-} flux from bedrock weathering, mainly sulfide oxidation with minor inputs from sulfate mineral dissolution, appears to be the highest (~7.1 metric tons/month; ~81% of total flux) with minor SO_4^{2-} contributions from atmospheric deposition (~1.3 metric tons/month; ~15%) and hydrothermal H_2S gas emission (0.4 metric tons/month; ~4%). Conversely, in the wet season bedrock weathering leads to SO_4^{2-} fluxes of ~4.1 metric tons/month (~34%) and gas emission of ~6.1 metric tons/month (51%) compared to smaller inputs from atmospheric deposition (~1.8 metric tons/month; ~15%). Our results show that the amount (flux) of SO_4^{2-} transported in the aqueous systems of active terrestrial volcanoes appears to be mainly controlled by the volume of water interacting with a particular S reservoir. The SO_4^{2-} fluxes from chemical weathering only slightly varied between investigated wet and dry seasons. However, oxidation of H_2S from hydrothermal emission was more effective, raising SO_4^{2-} fluxes in surface water under wet conditions. We demonstrate that in addition to hydrothermal H_2S emissions, chemical weathering should be included in geochemical source-to-sink models of sulfur cycles on Mars, particularly when assuming prevailing dry surface conditions in the past.