Crustal CO_2 liberation at Merapi, Indonesia: An earthquake trigger?

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On May 26th, 2006, the magnitude 6.4 Yogyakarta earthquake occurred along a splay of the Opak River Fault system, with hypocentres at 10-15km depth [1]. Prior to 2006, variation of fumarole carbon isotope ratios was limited ($\triangle\delta^{13}C_{2001\text{-}2004}$ = 0.5‰ ± 0.3l) with an average baseline value of -4.1‰ ±0.2 (vs, PDB). This value is typical of subduction zones [2]. Carbon dioxide collected after the earthquake showed a dramatic increase from the baseline to $\delta^{13}C$ = –2.4‰. In 2007 and 2008, $\delta^{13}C$ values returned to background levels. This rise coincided with an increase in eruptive intensity and volcano seismicity by a factor of 3-5 for several weeks after the earthquake [1]. High carbon isotope gas values, such as those observed in 2006, are not produced by decompression- or fractionation induced degassing in either open or closed system mode [3], suggesting an addition of CO_2 from a non-magmatic, high-$\delta^{13}C$ source. The increase in $\delta^{13}C$ in 2006, its transient duration, the crustal depth of the earthquake hypocentres, and the link with eruptive and seismic intensity are all consistent with addition of CO_2 from mid- to upper-crustal depths. Such additions of crustal CO_2 to subduction zone baseline fluxes may modify volatile budgets of ascending magmas at Merapi considerably [4]. Therefore, CO_2 liberation from long-term crustal storage reservoirs, such as the thick limestone basement underneath Merapi, may be a process that is triggered and/or amplified by external mechanisms such as seismic events. We thus envisage a chain of events whereby earthquake and volcano interact in a positive feedback loop. We conclude that crustal volatiles intensify ongoing eruptions and that late-stage volatile addition may potentially trigger explosive eruptions independently of magmatic recharge and fractionation processes and may even be a key factor in promoting regional seismic activity.

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Noble gases as tracers to determine the effective diffusivity in the sediment porewater of Lake Hallwil

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Noble-gas concentrations in surface waters and sediment porewater are often found at atmospheric equilibrium according to the local temperature and salinity conditions prevailing in water body during gas partitioning with the atmosphere. As noble gases are chemically inert, deviations of the measured noble-gas concentrations from the expected solubility equilibrium concentrations can be interpreted in terms of physical transport processess.

Since 1985 an artificial aeration system is installed at the bottom of Lake Hallwil, a medium-sized eutrophic lake in Switzerland, to foster the water circulation and to prevent anoxic conditions in its hypolimnion. Starting from 2002 the aeration system has been enhanced in order to inject oxygen-enriched gas into the water body during the summer period. The enrichment in oxygen is achieved by pumping atmospheric air through large volumes of molecular sieves. The same process is also responsible for a significant enrichment in light noble-gas species (i. e, He, Ne, and Ar) in the injected gas phase.

The small bubbles injected at low pumping rates during summer completely dissolve into the water column producing a characteristical noble-gas excess pattern. This noble-gas excess is expected to diffuse from the water column into the sediments. Therefore, noble gases have the potential to be used directly as tracers to determine the effective diffusivity of solutes in the sediment pore space under quasi-natural conditions and to allow to quantify the overall injected gas / O_2 mass over large time scales.

In this work we present noble-gas concentrations measured in the water column and in the sediment porewater of Lake Hallwil over the last five years. Based on these data we modelled the diffusive transport of He, Ne, and Ar in the sediment column to quantify diffusive transport and the O_2 injection into Lake Hallwil.