

Acid sulfate alteration of basalts in active geothermal systems, Krísuvík, Iceland

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The Krísuvík field in SW Iceland is an active volcanic geothermal system with surface temperature up to 100°C. It is a vapour dominated system, characterized by intensive acid-sulfate alteration of the surface rocks, active fumaroles, hot-springs and mud-pools. The intensive alteration and leaching of the surface rock is brought on by a sulphuric acid formation by condensation and oxidation of fumarolic vapour rich in volatiles like H₂S with the atmosphere or oxygen rich ground- and surface waters. The alteration pattern can be deviated into four general zones. In the zone of highest steam discharge elemental sulphur dominates the surface, with, anatas, amorphous silica, pyrite and sometimes kaolinite and covellite. In area of lower activity anatas, silica, pyrite and kaolinite are the main alteration products with hematite and goethite being abundant close to the surface. On the sides of the area smectites become the most abundant alteration minerals. Gypsum and anhydrite is found in the area and is believed to be a weathering product of fossil zone of higher activity. The waters are mostly acid with pH between 1.5 and 7.9 caused by elevated SO₄ between 10 and 5066 ppm and are elevated in most metals including Fe (0.05-753 ppm) and Al (0.03-390 ppm) but low in Cl (1.4-17.9 ppm).

Geochemical modelling was used to quantify the processes occurring in the geothermal system, both the gas-water-rock interaction and progressive leaching. The aquifer deep water composition was reconstructed using mineral-buffer reactions and gas geothermometry, and the fluids allowed to boil and separate upon ascent to the surface using both open and closed system boiling. Mixing ratio of the steam, rich in H₂S and CO₂, with surface oxygen was modelled and the subsequent mineral alteration patterns.

Prediction of sub-seafloor gas hydrate inventories by empirical relationships

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We present a combined geochemical-geophysical approach to predict sub-seafloor gas hydrate inventories. In detail, a geochemical transport-reaction model has been applied to quantify the overall formation potential of methane and, hence of gas hydrate, by microbial degradation processes under varying environmental conditions. Model runs have been constrained by field data derived from ODP drill sites located at various continental margins covering different geological and tectonic settings. Organic matter degradation has been calculated using the method of Wallmann et al. (2006) [1]. Based on the site specific model results and an extensive sensitivity study, a simplified transfer-function has been derived that enables the calculation of gas hydrate quantities by 3 easily accessible parameters: the gas hydrate stability field, the sedimentation rate, and the penetration of seawater sulphate in the sediments.

The general validity of the transfer function is demonstrated by comparison to published results from other gas hydrate bearing sites and the function has been used to estimate gas hydrate inventories along 2 seismic lines across the Pacific continental margin offshore Costa Rica. Regional variations of the thermal gradient (depth of the BSR) and the overall sediment thickness along the lines have been derived from post-stack seismic sections. Overall, gas hydrate concentrations range from 0 to 100 g CH₄ per cm² seafloor. The highest amounts of GH are expected at mid-slope depths, where optimal conditions with respect to organic matter input, sediment thickness and stability conditions are met. Integration of gas hydrate concentrations along the profiles yield that about 20 x 10¹² g(CH₄) are stored in gas hydrates on trench-parallel section (normalized to 1 km) of the Central American continental margin, which is well in the range of published data.

[1]Wallmann, K., Aloisi, G., Haeckel, M., Obzhirov, A., Pavlova, G., Tishchenko, P. (2006) Kinetics of organic matter degradation, microbial methane generation, and gas hydrate formation in anoxic marine sediments.- *GCA*, **70**, 3905–3927.