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The Fate and Environmental Consequences of Reduced gas Mixtures Resulting from Magmatic Intrusion into Carbonaceous Rocks

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Recent developments on the impacts of Large Igneous Provinces on climate changes and extinction rates emphasize the fundamental role of country rocks in gas emissions. Contact metamorphism of country rocks intruded by sills and dikes of mafic melts can be particularly important due to their long exposure to high temperatures. When the host rocks are composed of carbonates, sulphates, salts, or organic-compounds such as bituminous shales or coals, their heating can inject into the atmosphere a quantity of volatiles that greatly exceeds the amount delivered by purely magmatic degassing. We focus here on the interaction between magma and carbonaceous rocks. Recent studies have estimated the gas released by contact metamorphism of bituminous shales in the Karoo Province; we calculate the composition of the volcanic gases which results on this interaction, taking into account the magmatic contribution too. We then present an evaluation of the fate of such gases during their diffusion in the atmosphere.

The modelling of the composition of the modified volcanic gases is based on gas-melt thermodynamic calculations that take into account S-H-O-C gaseous species at temperatures and pressures in equilibrium with basaltic liquids. We simulate the incorporation into the gas-melt system of organic compounds as CH or CH2, depending on the maturity of the carbonaceous rocks (coal or oil). Addition of C and H has a dramatic effect on the amount and the redox state of the gas in equilibrium with the basalt. With the incorporation of only 0.2 wt% CH, the gas composition changes from CO2-H2O dominated (typical of basaltic gases on Earth), to CO-H2 dominated (a strongly reduced mixture, which resembles Martian volcanic gases). Addition of more than 0.2 wt% CH can trigger graphite saturation, such as reported in few locations where carbonaceous rocks have been ingested by basalts. In the famous Disko Island location, for example, we calculate that an incorporation of 1 wt% CH led to saturation in metal iron.

These "modified" volcanic gases are injected into the atmosphere at a rate directly proportional to the eruption rates and then disseminated. Using a 3D atmospheric algorithm coupling convective dynamics and chemistry, we model the expansion of the gas at a continental scale. Our simulations show that, at reasonable gas emission rates, no significant oxidation of CO occurs because the OH-radical concentration is strongly reduced due to the large concentration of CO and H2. This allows the gas to propagate faraway from the emission centre. The lateral propagation of the gas is significant at the scale of a continent within 2 weeks, which might reveal a new mechanism for mass extinctions.