

Volcanic gases and redox biogeochemistry at the Archean-Proterozoic transition

FABRICE GAILLARD¹, BRUNO SCAILLET¹ AND NICHOLAS T. ARNDT²

¹Institut des Sciences de la Terre d'Orléans, CNRS-INSU/Université d'Orléans, 45071, Orléans, France
²ISTerre, Université Joseph Fourier de Grenoble, CNRS, 38400, Saint Martin d'Hères, France.

A major crust-forming event at 2.7 Ga preceded a major change in the chemistry of surface waters on ancient Earth. Formation of a permanently oxygenated atmosphere at 2.45 Ga dramatically affected redox processes in the exosphere, as recorded in the ancient sulphur biogeochemical cycle. The emergence of oxygenic cyanobacteria and changes in composition of volcanic gases are possible triggers of the rise of atmospheric oxygen, but the sequence of these events and the evidence for such changes are debated. In particular, robust geochemical data indicates that the oxidation state of volcanic rocks and their source regions has remained constant since 3.5 Ga.

Using thermodynamic calculations simulating gas-melt equilibria during magma ascent, we show that change in the average pressure of volcanic degassing due to a global decrease in sea level accompanying the growth of the continental crust provides a simple yet robust explanation: Archean volcanic degassing was mostly submarine, occurring under water pressures of 10-100 bar and producing gases with $H_2S/SO_2 > 1$, with low sulphur content. In contrast emergence of the continents in the late Archean led to widespread subaerial volcanism that yielded gases much richer in S and dominated by SO_2 . The transition from H_2S dominated gases at elevated pressure of degassing to SO_2 dominated ones at atmospheric pressure is redox-compensated by a strong H_2 enrichment in the gas.

Archean and early Proterozoic sulphur biogeochemical cycles can be explained by a change in composition of volcanic gases that is unrelated to a change in magmatic source processes but most likely caused by geodynamic and eustatic modifications. The resulting changes in volcanic gas compositions must have impacted on the oxygenation of the atmosphere.

The subduction weathering factory

J. GAILLARDET*, P. LOUVAT*, C. DESSERT AND E. LAJEUNESSE

Institut de Physique du Globe de Paris, UMR 7451, Sorbonne Paris Cité. 75238 PARIS Cedex 05

About 30% of the global consumption of atmospheric CO_2 is due to the weathering reactions involving volcanic rocks. Therefore, volcanic settings are essential to consider both in terms of fluxes and mechanisms of chemical weathering. However few studies have focused on the weathering of volcanic arc islands although it is a key geodynamical setting, for example for the production of continental crust. Most of the degassing of deep CO_2 occurs in subduction zones and subduction volcanism is particularly rich in volatiles, such as sulfuric or chlorhydric acids that are major suppliers of acidity to the earth's surface.

The synthesis of available data on river chemistry in volcanic arc setting and new data from our group on the rivers of lesser Antilles show that the chemical denudation rates are amongst the highest on earth. They range from 10 t/km²/yr to 700 t/km²/yr in the most active regions.

Two dominant mechanisms appear to play the major roles in the subduction zone factory. The first is hydrothermal activity, the second is water runoff; the former being linked to the latter through the water cycle. Hydrothermal activity produces high temperatures and additional acidity in the form of sulfuric, chlorhydric and carbonic acids. Runoff values are generally associated to high precipitation regimes, due to the orographic effect. The orographic effect is temperature-dependent based on the Clausius-Clapeyron relationship.

Due to these two main mechanisms, subduction weathering factory transforms the rocks into sediments at a very high rate and is responsible for high CO_2 consumption rates. Our study suggests that chemical denudation is a significant fraction of the total erosion rate of volcanic arcs and that total erosion rates are in the order of the long-term magmatic eruptive rates.