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Consequences of a Below Zero Climate on Passive (Sub)Volcanic Volatile Cycling

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Passive volcanic degassing is an important contributor to the (sub)volcanic gas budget, transporting C, S, O, H, halogens and alkalis to the surface in today's climate. Was it the same during extensive glaciations?

Passive degassing occurs through permeable materials or cracks overlying subvolcanic intrusions, and in volcanic provinces at fumaroles, vents, lava lakes/flows, and in solfatara fields. Today, high temperature volcanic gases deposit volatile metals and their compounds, sulfosalts, sulfates (Ca, Na, K ± Fe) and halide salts and may release primary gases and gaseous reaction products. At lower temperatures, modern hydrothermal fluids react with rock and form gas ± silica, ± sulfates (Al), ± sulfides, ± (Fe, Ti, Mn) oxides, ± clay ± sulfur assemblages. In some cases, brine forms, especially when the volcanic system wanes and water is introduced.

Subzero conditions are likely to create significant differences in volatile cycling. Frozen water (ice) may reduce the extent of hydrothermal systems and enhance salt retention. At low temperatures, some volatiles may stall in the crust as they transform to liquids or fluids (e.g., moderate to high pressure) or solids (especially at low pressure) that block permeable pathways. Clues on subvolcanic volatile behavior at subzero conditions come from fluid inclusions that are routinely cooled in the laboratory under pressure inside host minerals. Upon cooling, inclusions form a mixture that may include liquid(s) (e.g., $CO_{2,l}$), vapor(s), ice, salt(s), sulfides, and clathrate(s). Clathrates (gas hydrates) are solid cages of ice that enclose gas, typically CO_2, N_2, H_2S and/or CH_4.

Overall, a subzero climate stabilizes (sub)volcanic volatiles (C, S, O, halogens, alkalis and Ca) in the solid form (e.g., salts and clathrates). Upon warming (and/or depressurization) the salts dissolve and the clathrates break down, releasing their contained elements to the surface. This "flush" of volcanic-derived elements may cause transient oversaturation in the ocean with respect to carbonates, sulfates and halides. Perhaps this process is recorded where glacial deposits (cold) are overlain by "cap carbonates" (warm) with mantle C isotope values, textural evidence for salts, and some trace metal enrichments.