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Volcanic gas geochemical monitoring of the 2021 Tajogaite eruption (La Palma, Canary Island) reveals a CO_2-rich source for alkaline ocean island volcanism

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Intra-plate alkaline oceanic island volcanoes are believed to erupt some of the most CO_2-rich mafic magmas on Earth. However, eruptions at such volcanoes are relatively infrequent relative to more regularly erupting arc volcanoes and, consequently, few have been characterized instrumentally for their gas emissions. In the Canary islands (eastern Atlantic ocean), a CO_2-rich mantle source has been inferred from melt inclusion analysis of erupted basanites, but no historical eruption in the archipelago had yet been studied instrumentally to explicitly link these petrological constraints to the corresponding high-temperature volcanic gas emissions until the 2021 Tajogaite eruption of the Cumbre Vieja volcanic system, La Palma. This eruption presented an unprecedented opportunity to measure the composition of gases emitted from an eruptive alkaline mafic system, using a combination of ground-based and UAS-borne Multi-GAS instruments and Open Path Fourier Transform Infra-Red spectrometers. A key feature of this eruption was the existence of multiple, closely-spaced vents erupting simultaneously yet exhibiting contrasting eruptive styles and degassing mechanisms. Our observations capture a systematic compositional contrast between the explosive upper vents (having CO_2/SO_2 ratios >> 30) and the lower spattering/effusive flank vents (having CO_2/SO_2 ratios < 10 and as low as 0.05). We reproduce this distinctive CO_2 fractionation pattern with a degassing model, initialized at P-T-X-redox conditions relevant to La Palma. By scaling the vent-specific gas compositions to mass eruption rates from both vent types, and in combination with SO_2 flux results obtained from satellite-based (TROPOMI) observations and melt inclusion record of parental melt sulfur contents, we estimate that the 2021 Tajogaite eruption released as much as ~5400 kg s^{-1} CO_2 to the atmosphere - far greater than any previously reported volcanic CO_2 flux measurement to date. Further, we reconstruct the primary CO_2 content in the parental (undegassed) Cumbre Vieja basanite to be between 3 and 5 wt. %, amongst the highest CO_2 contents yet calculated from syn-eruptive analyses of volcanic gas emissions. Taken together, these observations highlight the exceptionally CO_2-rich nature of the magma feeding the 2021 Tajogaite eruption, with implications for the volatile budgets and environmental impacts of intra-plate alkaline volcanism more broadly throughout Earth's history.