The 2011-2012 submarine eruption of volatile-rich magma at El Hierro, Canary Islands

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From October 2011 to March 2012 a submarine eruption took place 2 km south of El Hierro, the youngest and westernmost of the Canary Islands. The eruption produced buoyant, gas-filled “lava balloons” that sporadically rose from 100-300 m depth below sea level to the ocean surface and were sampled. Here we report ion microprobe measurements of the volatile element concentrations (CO2, H2O, S, F, Cl) of basanite matrix glass and basanite to phonotephrite melt inclusions trapped in olivine and Fe-Ti oxide phenocrysts collected from the glassy lava samples. The results reveal the volatile-rich nature and degassing history of the 2011-2012 magma. Whereas matrix glasses contain 70-710 ppm CO2, 0.4-0.9 wt.% H2O, 410-1030 ppm S, 1540-1790 ppm F and 850-1010 ppm Cl, melt inclusions show much greater ranges extending to high concentrations. Carbon dioxide concentrations in melt inclusions exhibit extreme variations from <50 to 13700 ppm, with 50% of values above 2000 ppm CO2. Most melt inclusions have dissolved water contents in the range 0.5-1.5 wt.%, but values of up to 3 wt.% are observed. Sulphur ranges from 320 to 5580 ppm and is positively correlated with H2O. Fluorine and chlorine vary from 860 to 2110 ppm and 610 to 1370 ppm, respectively. These volatile concentrations are among the highest ever measured for ocean island magmas. The high CO2 and H2O contents require high entrapment pressures (>200 MPa) for most melt inclusions, in agreement with fluid inclusion and clinopyroxene-melt barometry as well as with syn-eruptive seismicity. This suggests that the volatile-rich nature of the El Hierro magma was inherited from the mantle source. Intense shallow level degassing probably led to powerful submarine Strombolian explosions at El Hierro, as indicated by strong bubbling at the ocean surface. First-order calculations, using an eruptive volume of 329 million m3 (converted to 160-260 million m3 DRE assuming 20-50% porosity) determined from high-resolution bathymetric surveys (Rivera et al., 2013) and assuming 1 wt.% CO2 and 5000 ppm S total degassing, indicate that the El Hierro eruption could have released roughly 4-6 Tg CO2 and 2-3 Tg S to the hydrosphere and atmosphere. However, the formation of abundant sulphide globules associated with magnetite and clinopyroxene phenocrysts may have provided a sink for much of the sulphur. A positive correlation between $S^{6+}/\Sigma S$, as measured by the peak shift method, and S concentration in melt inclusions suggests that a reduction in the oxidation state of the magma during sulphur degassing, possibly aided by extensive magnetite crystallisation, could have caused saturation with a sulphide liquid. Our findings thus have far-reaching implications for the dynamics of the 2011-2012 El Hierro eruption, the volatile-rich nature and degassing of Canarian and other mafic alkaline magmas, and the nature of the mantle source beneath the Canary Islands.