The Grímsvötn 2004 eruption produced 0.047 km³ (DRE) of plagioclase-bearing, sparsely porphyritic, basaltic tephra. This study evaluates major oxide and trace element glass compositions, volatile contents and mineral chemistry of the eruption products in order to determine (i) the nature of the shallow crustal storage system beneath Grímsvötn central volcano; (ii) effects of conduit processes on magma fragmentation and eruption style; (iii) the extent of SO₂ and Cl release to the atmosphere during a typical small volume, high frequency englacial basaltic eruption. Melt inclusions hosted in late-growing plagioclase crystals track magmatic degassing and melt evolution within the conduit. New, high-resolution geochemical data from this chemically stratified deposit reflect a history of fractional crystallisation and open-system degassing prior to eruption onset, which resulted in an initial two-phase (volatiles-magma) flow regime in the conduit which later gave way to a homogenous flow regime. Glass inclusions in phenocrysts contain a maximum of 1600 ppm S and 520 ppm Cl, as compared with averages of 815 ppm and 180 ppm, respectively, in matrix glass. Application of the petrologic method indicates that at least 96,000 metric tonnes of SO₂ and 19,000 tonnes of Cl were released to the atmosphere during the G2004 eruption. Component analysis indicates that magma was fragmented at shallow levels by almost exclusively phreatomagmatic mechanisms. The effect of phreatomagmatic quenching and fragmentation was to arrest the degassing process, such that ~45% of the potential magmatic sulphur budget escaped to the atmosphere, compared to a fully degassed equivalent of >70%.