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Pulsating activity during the 2010 summit eruption of Eyjafjallajökull: Correlation of eruptive style, plume height, deformation, seismicity, earthquake tremor and chemical evolution of eruptive products

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The 2010 summit eruption of Eyjafjallajökull is divided into four phases: i) the first powerful phase lasting from 14-17 April with a strong component of phreatomagmatic explosive activity, sending ash plumes to Europe ii) a second phase lasting for 15 days and marked by substantial reduction in vigour of the activity featuring weak magmatic (Vulcanian) explosions with minor tephra production and lava emission, iii) a third phase with renewed vigour and Vulcanian-like explosions sending ash plumes again in over Europe, and iv) a final phase marked by steady decline in eruption intensity until the end of continuous activity on 22 May. Minor explosive activity was also observed on 4-8 June.

Geodetic data show the summit eruption was associated with gradual contraction of a source, distinct from the pre-eruptive inflation sources. For the initial 10-days of the summit eruption, a deflating sill source under the summit at about 5 km depth can explain the observed deformation. However, for later stages of the eruption the source geometry appears to evolve (change with time). Also, the rate of deflation did not change in a regular manner. These changes can be attributed to inflow of new magma into the deflating source during the eruption, at the same time as outflow occurred to the surface. This is consistent with seismicity pattern during the eruption and geochemical variation in the eruptive products.

Earthquake locations strongly indicate transport of deeper rooted magma towards the modelled inflation source, also identified as a seismic gap between 3 and 5 km depth. After drop in seismic activity following the initial days of the eruption, then activity renewed on 3 May when deep earthquakes were recorded near the crust-mantle boundary. Activity gradually shallowed during the next days but similar deep activity was also detected 11 May and 15 May. This renewed deep seismic activity was in all cases followed by an increase in plume height and a 3-10 fold increase in magma discharge. Deflation of the volcano during the eruption, indicative of pressure decrease, proceeded at variable rate during the eruption. This pattern was perturbed during few days in early May when deflation slowed and temporarily changed to inflation, with inflow exceeding outflow. Furthermore, there is also a large difference in the estimated volume of eruptive products (0.17 km3 DRE) and the overall volume contraction of the deflation source (about 0.03 km3 DRE).

Mechanically mixed magma emitted during the explosive eruption shows increasing MgO in the basaltic end-member with time, which upon injection mingled with more evolved melt just prior to and during the eruption. The characteristic mixing time is hours to days. The most marked change occurred during revival of intense explosive activity in early May with clear evidence for a primitive basaltic component (i.e. olivine w/Fo80) in the predominantly trachyandesitic magma.

Seismic tremor shows a complex relation to the amount of inferred magmatic flow; large amplitude tremor occurred during the phase of predominant lava production, but low amplitude tremor during explosive phases.

We conclude that variable input of basaltic magma into more evolved magma source under the summit area contributed to the variable activity during the eruption, and in particular to the revival in eruptive activity in early May.