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The sedimentary impact of jökulhlaups of contrasting rheology generated by the April 2010, Eyjafjallajökull eruption

Andy Russell (1), Rob Duller (2), Andy Large (1), Anne-Sophie Mériaux (1), Matthew Roberts (3), Stuart Dunning (4), Qiuhua Liang (5), Jonathan Carrivick (6), Fiona Tweed (7), and Málfríður Ómarsdóttir (8)

(1) Newcastle University, Earth Surface Processes Research Group, Geography, Politics & Sociology, Newcastle upon Tyne, United Kingdom (andy.russell@ncl.ac.uk), (2) Department of Earth Science and Engineering, Imperial College London, South Kensington, SW7 2AZ, UK (r.duller@imperial.ac.uk), (3) Monitoring and Forecast Division, Icelandic Meteorological Office, Bústaðavegur 9, Reykjavík, IS-150, Iceland, (4) Division of Geography, University of Northumbria, Ellison Building Room D214, Ellison Place, Newcastle Upon Tyne, NE1 8ST, (5) School of Civil Engineering & Geosciences, Cassie Building, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK, (6) School of Geography, University of Leeds, West Yorkshire, LS2 9JT, UK, (7) Geography, Faculty of Sciences, Staffordshire University, College Road, Stoke-on-Trent, Staffordshire, ST4 2DE, UK, (8) University of Iceland

On April 14 (at 01:15 GMT) an explosive subglacial eruption started beneath the 2.5 km-wide summit caldera of Eyjafjallajökull, Iceland. Within hours, the eruption melted through 200 m of the ice cap and became fully phreatic, producing a 11 km-high volcanic plume. By 07:00 GMT rapid melting of the ice cap generated jökulhlaups that cascaded from Gígjökull and down Núpakotsdalur on the northern and southern flanks of Eyjafjallajökull, respectively. The initial jökulhlaup from Gígjökull reached peak discharge in the Markarfljót 5 hours later damaging Iceland's ring road near the Markarfljót bridge. Subsequent increases in eruption intensity generated repeated jökulhlaups from Gígjökull that inundated the Markarfljót. A second jökulhlaup from Gígjökull was witnessed on an over flight at 18:55 GMT on April 15, prompting the immediate evacuation of the population within the entire Markarfljót area. This jökulhlaup was observed to contain a large amount of ice and sediment, and was characterised by a viscous, smooth-surfaced, lobate flow front and a more turbulent fluid flow body suggesting that the frontal wave of this jökulhlaup was hyperconcentrated. This paper presents the results of fieldwork undertaken in April and July 2010 to determine the sedimentary impact of the April 14 and 15 jökulhlaups within the Gígjökull basin and Markarfljót River system.

April 14 jökulhlaup deposits are all located below a well-defined wash limit consisting of woody debris and silt. Deposits typically consist of poorly-sorted sands and gravels arranged as large-scale bars. Downstream of the mouth of the Gígjökull lake basin, the April 14 jökulhlaup only slightly reworked vegetated surfaces and arranged pre-existing sandur material into boulder clusters and localised deposits. All of these sedimentary features are consistent with deposition from a turbulent, Newtonian flow.

In contrast, sedimentary and geomorphic features generated by the April 15 jökulhlaup could be traced downstream to the mouth of the Markarfljót. Associated deposits are represented as a very poorly sorted mélange of primary volcanic eruption products, fragmented glacier ice, soil, vegetation, and boulders. The deposit shows no evidence of internal structure. The surface of this ice-rich deposit is irregular, which also demonstrates evidence for localised channel bank erosion and run-ups to higher elevations within the Gígjökull basin. At ca. 200 m immediately to the west of the exit to the Gígjökull basin, the downstream margin of the deposit exhibits a distinctive lobate morphology, and blankets the April 14 deposits. The April 15 mélange was locally less extensive than the April 15 jökulhlaup surface, allowing the two deposits to be differentiated clearly. Within the April 15 deposits, networks of dendritic channels were observed with flow directions towards the lobe margins. These channels contained horizontally-bedded, well-sorted sand to fine-gravel sized sediment. Sub-metre scale chute channels indicate dewatering of the surrounding deposits. The April 15 jökulhlaup deposits are consistent with a non-Newtonian rheology possessing high momentum and capable of rafting large boulders.

The April 14 and 15 jökulhlaups had very different geomorphic and sedimentary impacts, reflecting their radically different rheologies. Ice-rich deposits, such as those deposited during the April 15 jökulhlaup, have only been inferred from the sedimentary record and have not been observed during volcanic eruptions in Iceland. The variability of jökulhlaup characteristics and impacts resulting from the same volcanic eruption represents a challenge for the interpretation of the sedimentary record as well as the management of volcano-glacial hazards.