May 19th rain triggered lahar originating in the Eyjafjallajökull 2010 volcanic ash. Observation, mapping and granulometric study.

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1: INTRODUCTION

Fig. 1

The explosive eruption of Eyjafjallajökull 2010 started on April 14th. On April 17th the explosive activity was intense, producing tephra of extremely fine ash characteristics. Tephra covered the south flanks of the volcano in a large quantities during the 17th. The tephra fall continued for a month in varying wind directions, however, greatest tephra accumulation was on the south and east flanks of the volcano. After the April 17th event, remobilization of tephra was expected in case of heavy rain. The steep hill-sides south of the volcano were of special concern. However, nature of the lahar onset was surprising, as large areas of the tephra blanket broke loose on relatively gentle slope of the glacier. During the eruption, the low sloping southern flanks were not accessible. However, on the steep hills at the foot of the volcano, many small "miniature-lahars" (Fig 2.) were discovered on May 1st. Observations on water content of fine grained ash layers within the tephra blanket showed an excess of 20-25 wt % .

2: MINI-LAHARS

Fig. 2

3: THE LAHAR EVENT

Fig. 3

The first considerable rain since onset of the eruption occurred the night before May 19th. in the area south of the volcano. The rain was moderate in the lowland, but presumably more intense at higher elevation. All rivers draining the southern slopes of the glacier were overflowed by muddy water. In Svaðbælisá, river that had drained a jökulhlaup in the beginning of the eruption, the flow was richer in volcanic ash and debris; a lahar. The flow occurred in the morning and was described to have the consistency of wet concrete. It reached peak discharge within an hour and was soon diluted by the river and several tributary streams. Fig. 3 is taken after the flow had receded and diluted to muddy streamflow. The photo is overlain by a schematic drawing of the lahar deposit.

4: THE MAPPED DEPOSIT

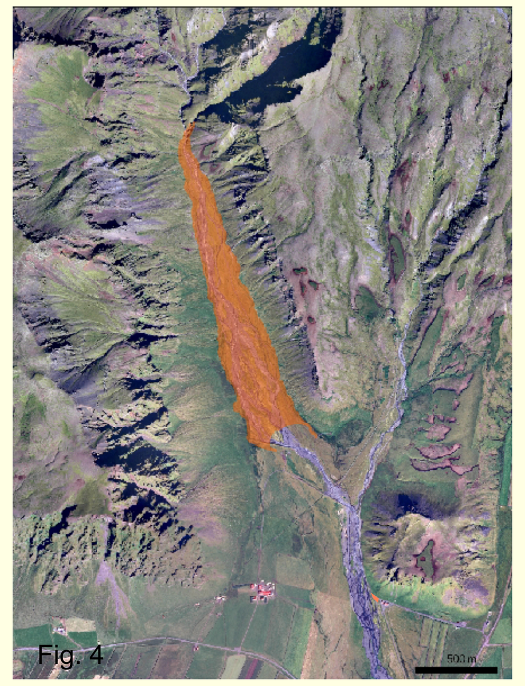


Fig. 4

Fig. 4 shows map of the deposit in the accumulation area of the flow path. The flow was erosive at higher elevation area, whereas the sediment load was deposited at the low elevation river fan. The mapping extends downstream until the flow had been diluted by tributary rivers. From there on, transport of volcanic ash was by suspension to the coast. The boundary of the erosive and accumulative part is at the mouth of a narrow gorge leading from the glacier. The deposit covers approximately 0.4 km^2. The concentrated flow reached roughly 2 km from the onset of sedimentation at the mouth of the gorge. The 350 m wide fan of the small permanent river was covered by 30-45 cm thick deposit. However, thickness of overbanking sediment measured 5-10 cm. Approximate volume of the deposit on this area is 120.000 m^3.

5: ORIGIN OF THE FLOW

Fig. 5

The origin of the flow was first observed on a radar image taken by the Icelandic coast guard aircraft TF-SIF, on May 19th. It shows several sliding areas on the south slopes of the glacier. The red lines represent the outlines of these areas, but the blue one delineates the area later verified to have fed the Svaðbælisá lahar flow. It is proposed that the tephra blanket in this area broke off and slided as a plate directly to the channel carved by the jökulhlaup on 14th of April. A more scattered access to draining rivers may have caused more dilution of ash from the other failed areas, resulting in muddy streamflows in nearby rivers.

6: GRAINSIZES AT THE UPPERMOST FAILURE

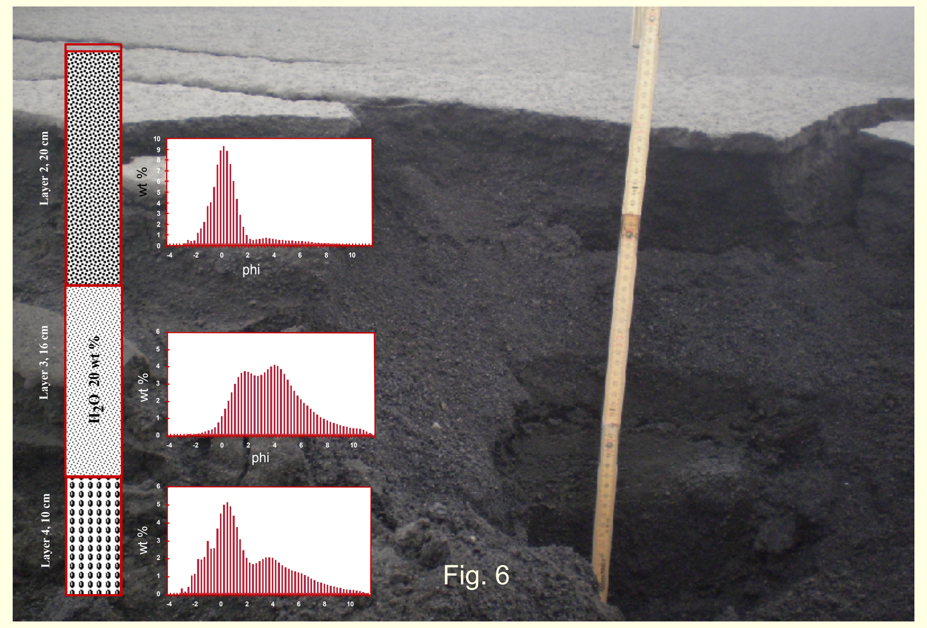


Fig. 6

By inspection of the flank area on May 25th, a 50 cm thick profile at the uppermost limit of the plate failure was revealed. The ash deposit is divided in 3 layers by observation and granulometric characteristics. The bottom layer which contained aggregates up to 2 cm in diameter, shows wide grain size distribution, but the uppermost one is well sorted at about 1 mm mean grain size. Most remarkable is the exclusively fine grained middle layer, which contained about 20 % water by weight. The coarser layer on top was dry, but the middle layer liquefied easily by agitation. This layer retains water by capillary attraction between the grains, due to its extremely fine grained characteristics. Observations during the eruption show that this layer formed in the 17th April explosive phase. It is proposed that the sliding was initiated by liquefaction of the water saturated layer, resulting in transport of more than half of the ash load of the affected area.

7: GRAINSIZES OF THE DEPOSIT

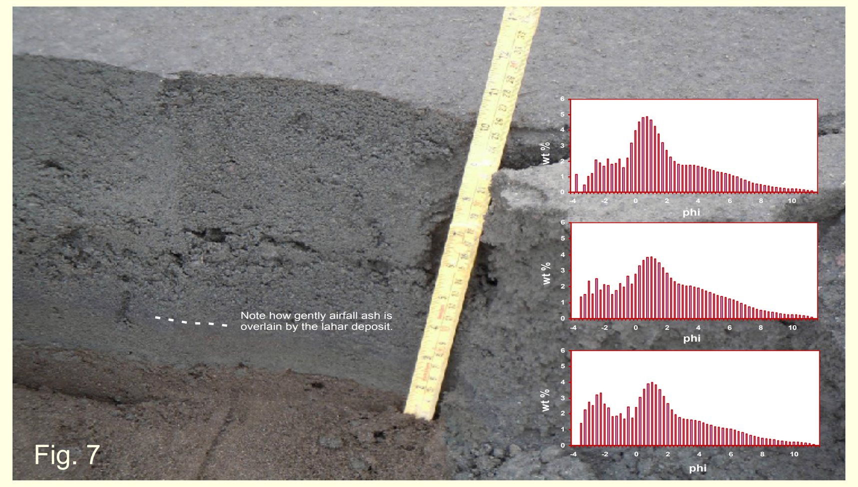
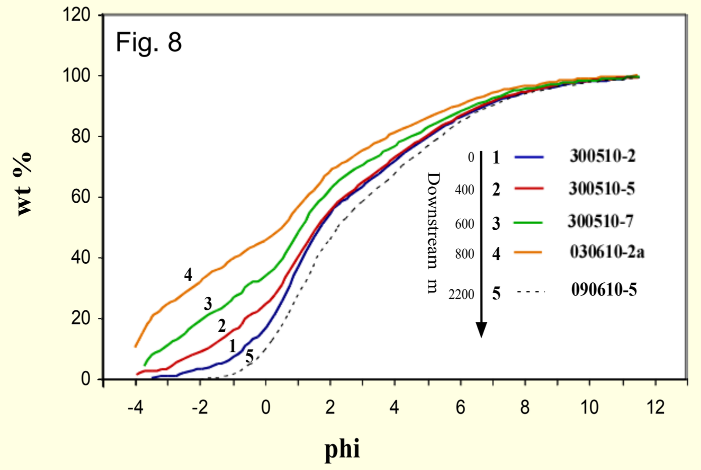


Fig. 7

The deposit is poorly sorted, matrix supported, with no visible lamination or flow structures. The sediment/water ratio and hence the type of lahar flow was determined by grain size analysis of the deposit. The apparent lack of stratification within the deposit and delicate contact with the base ash layer is consistent with a debris flow type, with more than 50-60% sediment by volume (Beverage & Culbertson 1964, Wallance 2000). However, the grain size distribution indicates some accumulation of coarser grains at the bottom. This points to more dilute type of flow referred to as hyperconcentrated flow which is defined by sediment concentration from 20% up to 60%. By comparing grain size distribution columns from the flow and the tephra layer (fig. 6), it is obvious that the largest particles result from incorporation of gravel during the erosive phase of the flow.

8: DOWNSTREAM VARIATION OF THE DEPOSIT



The cumulative curves show increased contribution of the larger grains downstream in the flow sediment. This reflects how the flow gradually lost the competence to carry large clasts very soon after it spread over the river fan. Sample nr 5 was collected as far downstream as undisturbed deposit existed. There, all the gravel and coarse sand has disappeared, thus the sample represents dilution of the hyper-concentrated flow to muddy streamflow.

9: OVERFLOW CHARACTERISTICS

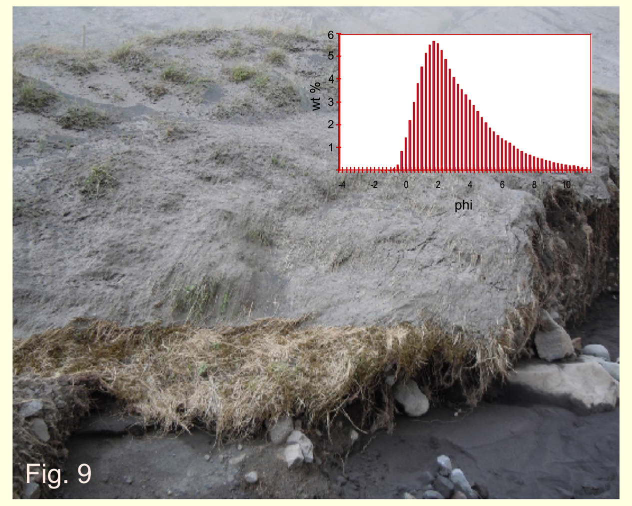


Fig. 9

The waning phase of the flow is expressed in the downhill direction of the suppressed grass of the river banks. The coarsest part of sediment load is settled out in the channel during peak flow. These features correspond to a model of transformation of debris flow to hyperconcentrated flow by selective deposition of coarse particles (Cronin et al, 2000). Water marks from river flood that occurred after the lahar flow deposit had settled, are shown on Fig. 9.

10: CONCLUSION AND FUTURE SCENARIO

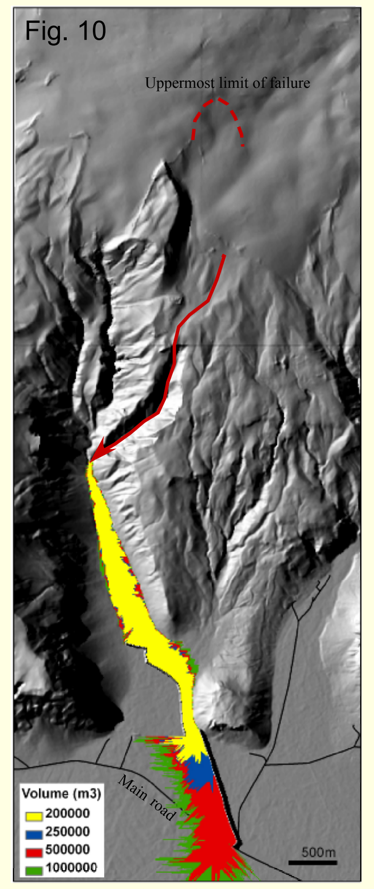


Fig. 10

DEM with 10 m pixel size. © Loftmyndir ehf.

a) The lahar model: Field observation and granulometric analysis indicate that the lahar is best described as an intermediate type between debris flow and hyperconcentrated flow (Castruccio et al., 2000). This denotes that the sediment concentration did not exceed 60% by volume. As the sediment volume measured roughly 120.000 m^3 and it was still wet, 200.000 m^3 of saturated flow seem reasonable to use as an input volume for the LAHARZ program (Shilling 1998, Iverson et al., 1998). That conforms only roughly the measured sediment area (Fig 4, Fig. 10) and exceeds its downstream limits. These discrepancies are easily explained. First, the lateral extension of the sediment area is narrower as calculated by LAHARZ because of the overbank flow observed. Therefore, the downstream extension is overestimated. Secondly, although thickness measurements were not possible all along the flow due to dilution, the 200.000 m^3 LAHARZ model exceeds a site where lahar deposit was detected farthest downstream (Fig 4). Inundation areas of larger volumes up to 1 million m^3 were also calculated in LAHARZ (Fig 10). Flows of this size would destroy farmlands and the main road.

b) The near future: Is a new lahar flow expected in the Eyjafjallajökull area from remobilization of the 2010 tephra? Measurements done on the volume of ash last summer reveal that the catchment area of Svaðbælisá alone was loaded with some 4 million m^3 of ash, half of that is in the ablation area of the lower slope of the glacier. However, conditions that lead to the May 19th "ash avalanche" have changed drastically. Rainy weather in the autumn has formed a network of channels in the tephra layer. That network is gradually transporting the tephra by muddy streams. Presumably such processes will go on in the near future. Nevertheless, generation of concentrated tephra-snow-water lahars after intensive ablation of the glacier in the spring-time, can not be ruled out (Manville et al., 2000). At present this could occur in all channels draining the southern slopes of the glacier. Seasonal lahars originating from the tephra bed covering the southern slopes can be expected for the years to come. However, debris flow initiated by sliding of tephra plates, as occurred on May 19th 2010 is not considered likely.

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