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The Godtifonn avalanche

The group also had the chance to visit the Godtifonn avalanche track located about 25 km west of Stryn. 1 ½ years previously, a huge avalanche event released and impacted one of the most important transnational roads connecting eastern and western Norway. The name "Godtifonn" indicates an avalanche breaking during "good times" in the sense of bright weather conditions. In this region, blue sky weather conditions are often related to easterly winds leading to snow redistribution into the huge release area (Fig.2). The avalanche has a frequency of 5-10 years but normally smaller than the last event.

The Event

On the 16th of February 2005 at about 10:30h a huge avalanche was triggered. The night before there had been strong easterly winds. It was cold, clear weather with an east wind at the summits at the time of the avalanche. Records speak of an event of comparable size in the late 1970s.

The dust cloud and flying debris affected the RV15 road. Several cars were caught up in the cloud, but only one was seriously damaged. This car was turned over several times on the road and the bodywork was dented by flying debris.

No people were injured. The other cars were left standing in 20-30 cm of avalanche deposit and the road was blocked by trees and rocks. The telephone line near the road was broken. On the counter slope the whole forest in the main direction was broken.

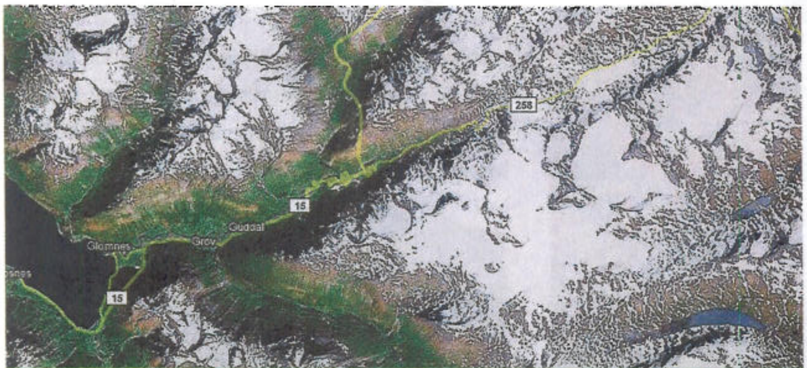

Fig. 1: Location of the Godtifonn avalanche

Seeing the run out area of the Godtifonn avalanche for the first time normally causes disbelief that an avalanche would be able to distribute the rocks over the whole area as can be observed. But two observations make it quite clear, that only the avalanche can be the reason for this phenomenon. First, in the area of the distributed rocks, a birch forest was also destroyed. The main impact direction of the avalanche is cleared witnessed by the forest and is in very good congruence with the area in which the distributed rock particles can be observed. Secondly, the translocated rock is clearly different from all other rocks which can be found in the counter slope in terms of surface condition and shape. All transported rocks have a perfectly clean surface, with no moss or grass and they have a perfectly smooth and rounded surface as typically found in river or torrent beds. Fig.2 shows the group during the field survey.

Fig. 2: Distribution of rock particles with impressing size on the counter slope. The particles are either fully rounded or partly broken. The shape and surface properties rise the assumption that the avalanche translocated the single objects from the torrent bed.

The release area

Fig. 3: Godtifonn release area. The arrow indicates the easterly wind direction leading to additional snow by redistribution.

Figure 3 was taken a few days after the event, but now the clear fracture line or Stauchwall can be observed and delineated. The release area therefore has been determined by using the information of Krister Kristensen who was flying by helicopter over the area a few days after the event and by analyzing the inclination map derived from the Dem. Fig.4 outlines the spatial distribution of the inclination classes. The area is very flat thus leading to a very low frequent release behavior. The very upper and lower part has steepness even less than 25 ° which is a generally accepted as a criterion. In the middle the steepness has values between 25° and 35°. For the simulations the release area has been determined as outlined in Figure 4.

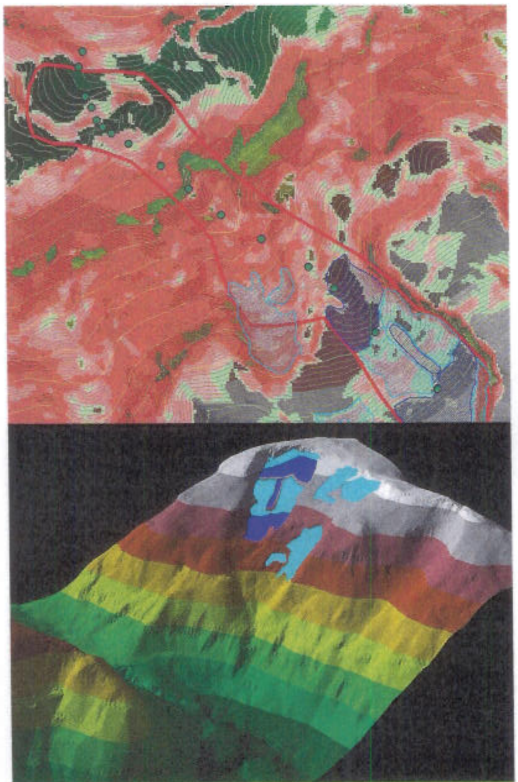

Fig. 4: Inclination classes in the release area. Right: the blue boundaries show the release areas determined for the dynamic simulations. Left: 3D overview of the release area.

The track

The Godtifonn avalanche track, with an inclination of 31.3°, is medium steep but parts of it are nearly vertical as can be seen in Fig.5 and Fig. 6. The channeling effect (horizontal curvature) is not very pronounced but given for the whole track. In the lowest part, the track flattens leading to a "rounded" longitudinal profile enabling the avalanche to rise on the counter slope with full energy.

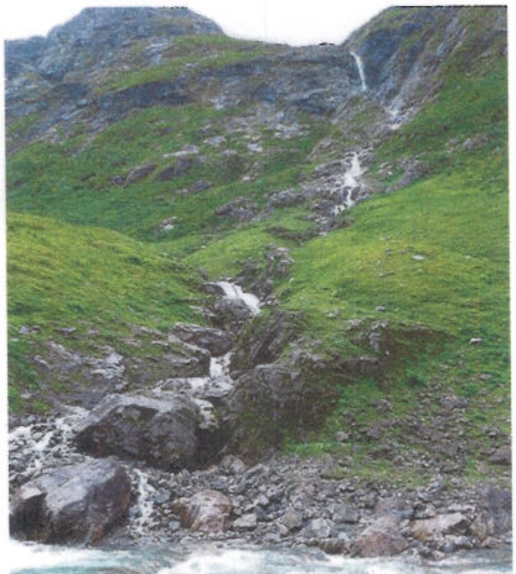

Fig. 5: Track of the Godtifonn avalanche

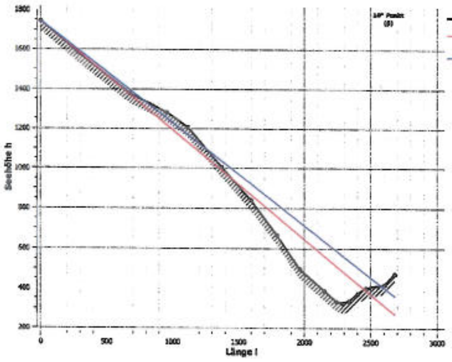

Fig. 6: Godtifonn release area. The arrow indicates the easterly wind direction leading to additional snow by redistribution.

Simulations with the dynamic models

The dynamic calculations have been carried out with ELBA+ and SamosAT. The calculations have the character of a first attempt. In order to facilitate the comparison of the results, the same initial conditions have been used. The release height was set at 1.71 [m] giving a release volume of 239213 m³ with a density of 300 kg/m³. For the friction parameter standard values were applied. Many interesting comparisons between ELBA and SAMOS and sensitivity analyses could be worked out on this event, but for this report the "standard" calculations should meet the demand. Fig. 7 outlines the distribution of the calculated avalanche. The results have satisfying congruence both in the spatial extension and the calculated velocity. The quality of the simulations also slightly limited by the DEM, which has a high generalized character.

Velocity profiles

The avalanche front speed calculated with Samos AT and ELBA+ develops differently along the track.

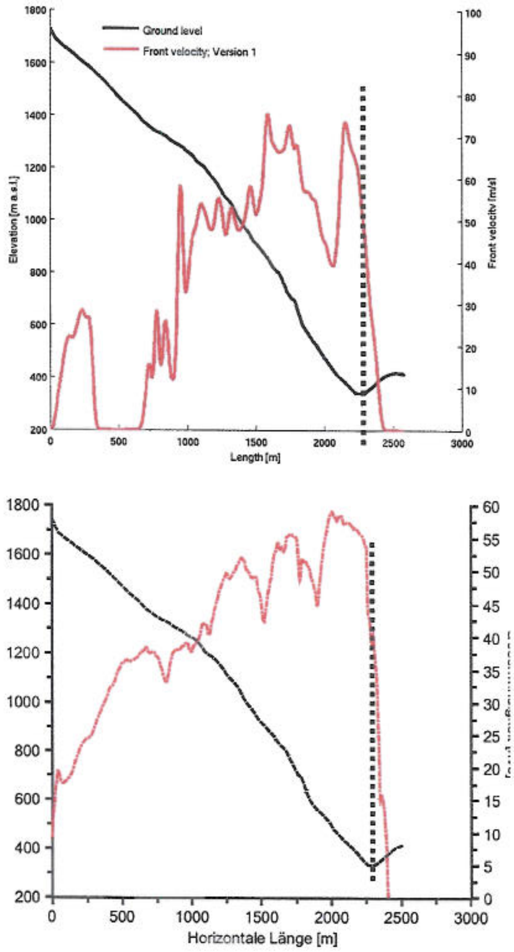

Fig. 7: Velocity profiles of Samos simulation (top) and ELBA+ simulation (bottom)

Preliminary interpretations

Basically there are two methods of interpreting the distribution of the stones in a physical way. One method would be to compare the driving forces F_f with all withholding forces F_w. F_w has to be broken down into three components:

i) F_a: the force to accelerate the particle,

ii) F_h: to hoist the mass particle against gravity,

iii) F_r: Friction forces due to gliding or other collisions.

Yet, for the sake of simplicity, the choice was for the more straightforward approach of comparing the turbulent drag forces F_d with the driving forces F_f. The driving forces can easily be derived by m*a of the single rock particles with m: mass and a: acceleration. The drag of obstacles in a turbulent fluid again can easily be achieved by $F_d = A\ \rho\ v^2 /2\ C_w$ with A: cross sectional area of the single particle, ρ density, v: velocity (of the current) and Cw: empirical resistance factor.

The driving forces have to meet the drag forces if the particles are starting to move. In this way of "back calculation" low drag forces would indicate that the avalanche has not enough power to move the block. The interesting feature of this simple threshold approach is that it enables rough analyses on the relation between deposition, fluid velocity, density and particle size.

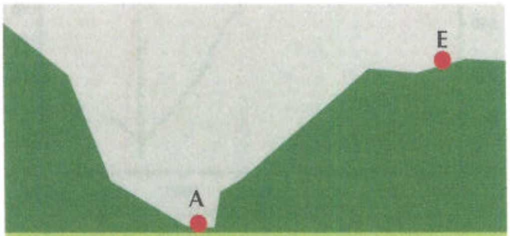

Fig. 8: Schematic outline of the track

The avalanche calculations with the numerical models delivered front velocities between 40 -50 m/s. The initial avalanche speed at the beginning of the counter slope was therefore determined at 45 m/s for the analyses (A in Fig. 7). At a height of 90 m above ground (deepest point of the valley) the last block has been observed and also the influences to forest disappear. Therefore the maximum height of the event on the counter slope has been fixed at 90 m (E in Fig. 8).

During the field inspection, there was a discussion as to whether this impressive event follows the behavior of an explosion or the stones have been moved by the "avalanche fluid". Despite the "explosion impression" in the field, the distribution of the single rocks clearly indicates the translocation of the particles being caused by a viscous transport medium. With increasing block size, drag force must increase and subsequently the deposition has to start earlier in relation to smaller particles. When passing the valley the avalanche added new rocks from the torrent bed (in addition to the particles already entrained in the track). It will be hard to determine the velocity of the various single particles at point [A], but nevertheless the sorting effect can be clearly observed.

The velocity distribution of the avalanche from [A] to [E] differs in the two dynamic models and should be tested in detail for further applications. Therefore again a simplification has been made by assuming a linear velocity decrease between 45 m/s in point [A] and 0 m/s in point [E]. With this assumption a first estimation of F_f and F_d can be made by using the values:

A: cross sectional area of the observed block,

ρ: 50 kg/m³ (assuming that this very fast current should have low density),

C_w: 0.7 (typically from 0.4 to 1),

v: velocity of the avalanche calculated for every deposition point.

It is worth mentioning that F_f only depends on the mass and acceleration (in fact deceleration) whereas Fd depends on much more uncertain parameters like density or even the C_w value (which is uncertain especially in relation to the fluid type „avalanche", not following a Newtonian behavior).

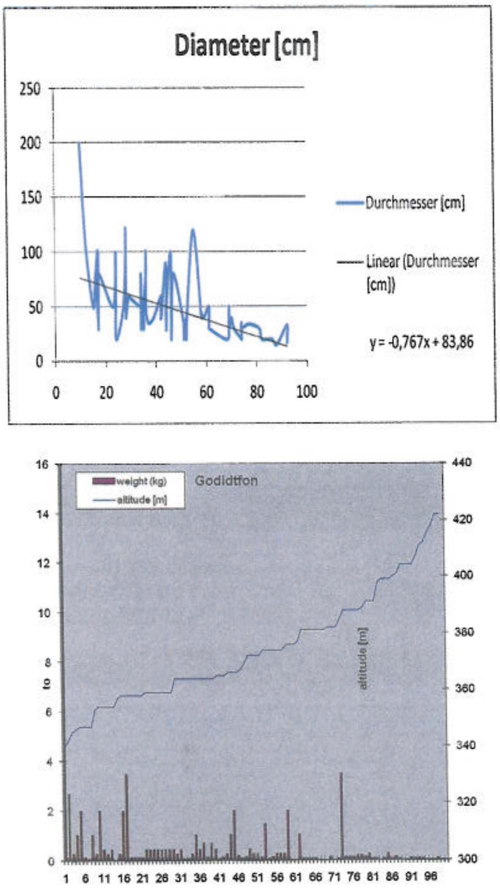

Fig. 9: Distribution of the transported rock particles over the counter slope. Top: clear decrease of rock size with increasing altitude. Bottom: frequency of deposited particles; a single block with a mass of 3.5 to has been moved 70m up.

The first tests with an avalanche density of 50 kg/m³ resulted in drag forces which have been much too low in relation to the driving forces. Values varying between 5-20% of the need drag. By increasing the density to 250 or 400 kg/m³ and also increasing the Cw value to 0.8 the results become more valuable. With a density of 250 kg/m³ the drag forces for all observed blocks increased to in average 60% of all Ff values. But by increasing the average density of the avalanche up to 400 kg/m³ the difference decreases to only +6%. Thus an avalanche with the supposed velocity and a density of 400 kg/m³ would be able to move the blocks as observed. Fig. 9 outlines also that there are obviously single blocks which do not follow this positive general trend. As indicated by the peaks in Fig. 9 the biggest blocks of the various levels still would not be impacted by sufficient forces to be moved. Further studies on this point would be very interesting. As a first interpretation the similarity with e.g. debris flow would attempt to explain this phenomenon by interacting and collisional forces of the smaller particles.

Further analyses using also RADAR and other particle velocity information will be carried out for this very interesting avalanche event.

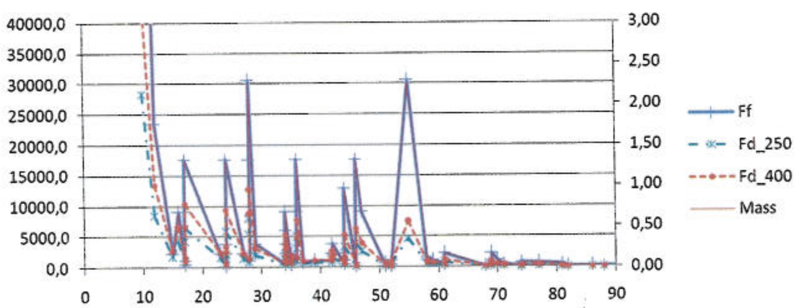

Fig. 10: Derived drag forces for all deposited blocks assuming a linear velocity decrease. Left axis - Ff: driving force; Fd: drag forces with varied density. Right axis: weight of the single blocks [to].

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