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Geomorphological investigation on snow-avalanche impact on slopes in the Fnjóskadalur and Bleiksmýrardalur valleys, North Iceland

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1. Introduction

The geomorphological impact of snow avalanches in Iceland has been recently underlined. Especially, investigation in Northwestern and Northern Iceland highlight their strong effect on Icelandic slopes (Sæmundsson, 2000a, 2000b, 2000c; Decaulne, 2001; Decaulne and Sæmundsson, 2004, 2005; Sæmundsson and Decaulne, 2005; Sæmundsson, 2005). In particular, the latter results underline the role of debris transport by snow avalanches for colluvial cone development. The Fnjóskadalur - Bleiksmýrardalur areas display strong evidence of this phenomenon.

The valleys are located few kilometres east from the fjord Eyjafjörður, in central North Iceland (figure 1). Fnjóskadalur is a 40 km long valley, oriented from SE to N, with maximum elevation between

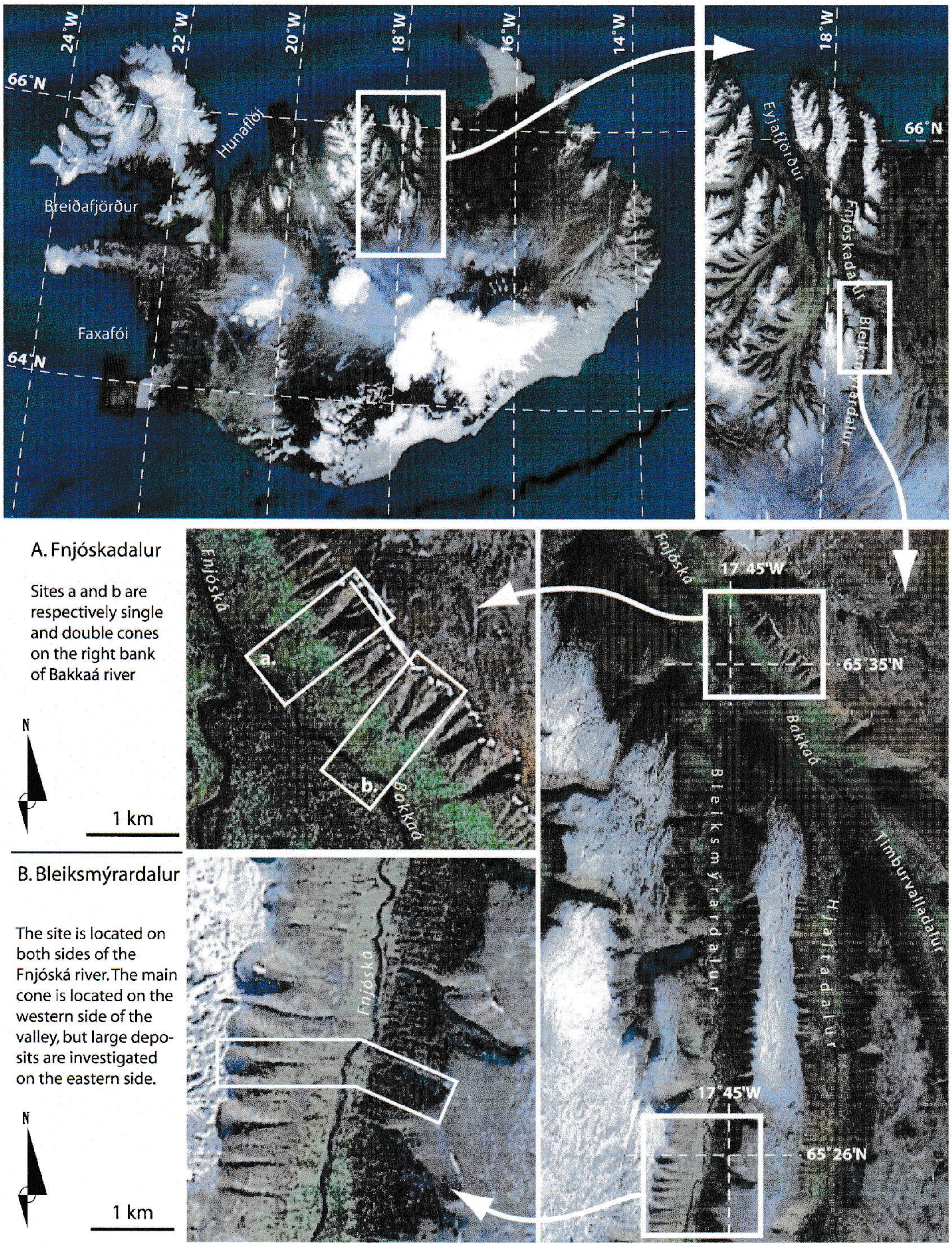

Figure 1. Location of the study area (source: EarthSat & DigitalGlobe from Google Earth 2005).

900 m and 960 m. The river Fnjóská that flows around 180-200 m in the upper part, drains the valley. Bleiksmýrardalur, a 90 km valley oriented S-N, is the upper catchement of the river Fnjóská; the maximum elevation of mountains is over 1000 m and the valley floor runs around 360 m in the studied area.

The bedrock belongs in the valley to the Upper Tertiary period, and consists into basic and intermediate extrusive rocks with intercalated sediments, older than 3.3 m.y., while the upper part of the mountains belongs to Upper Pliocene and Lower Pleistocene (0.8 – 3.3 m.y.) (Jóhannesson and Sæmundsson, 1998).

The Fnjóskadalur - Bleiksmýrardalur valleys offer several favourable circumstances for snow-avalanche impact studies: (1) the valley is still largely unpopulated and remote from human activities, at least in its upper southern ranges; therefore geomorphic evidence of different processes acting on slopes are preserved, while they are removed in the surroundings of most of the coastal communities threaten by snow avalanches (especially those field evidence concerning the maximal runout distances), (2) the Fnjóskadalur slopes are birch wooded (bushes and trees of *Betula pubescens*), offering a rare dendrogeomorphological opportunity in Iceland.

Two sites have been selected in the Fnjóskadalur valley, and one in the Bleiksmýrardalur valley.

2. The Fnjóskadalur area

2.1. Presentation

The investigated colluvial cones in the Fnjóskadalur valley are located on the right bank of the Bakkaá River, just uphill its confluence with the Fnjóská river (figure 1). The northern cone developed down a large gully carved into the western face of the mountain (figure 2a). The apex of the cone is at 315 m a.s.l., and its distal part is around 200 m a.s.l. The cone is largely covered with birch trees and bushes, whose stem diameter varies from 1 cm to more than 15 cm. Snow avalanches and debris flows affect the cone surface. The southern site consists in two coalescent cones that came from two individual gullies (figure 2b). The apexes of the cones are located around 310 m a.s.l., and the distal part in both cases lays around 200 m a.s.l.

In this site, investigation includes geomorphological observations, vegetal recognition, and dendrogeomorphological analysis.

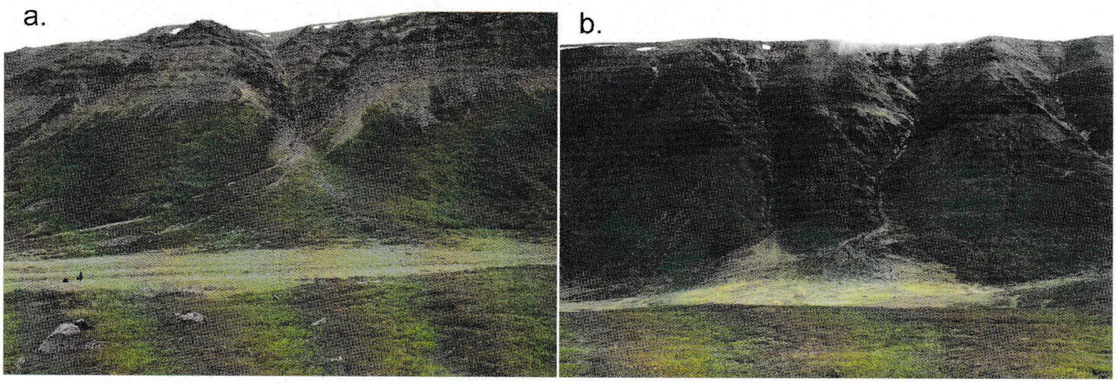

Figure 2. The Fnjóskadalur sites, a. the single cone, in the northern part of the investigated area (snow-avalanche transported boulders in the foreground), and b. the double cones in the southern part (Photos: Þorsteinn Sæmundsson, August 2004).

2.2. Geomorphology

Geomorphological investigation of the two sites reveal the presence of numerous source areas for snow avalanches, as huge amounts of snow can accumulate both at the top of the summit plateaux, and within the more or less large indentations that cut the headwall, which is 500 m high (figure 3). Most of these indentations are moreover the source areas of debris flows. Northerly and easterly winds encourage snow accumulations at the top of the leeward slope, and snow cornices on the ridge crest. In the study sites, the snow-avalanche paths include three well-defined parts on each unit: (1) the carved headwall acts as the starting zone, (2) the track crosses the gully, the cone and (3) the runout zone includes the distal part of the cone and continues over the flat land up to 200 m down the cone (figure 4).

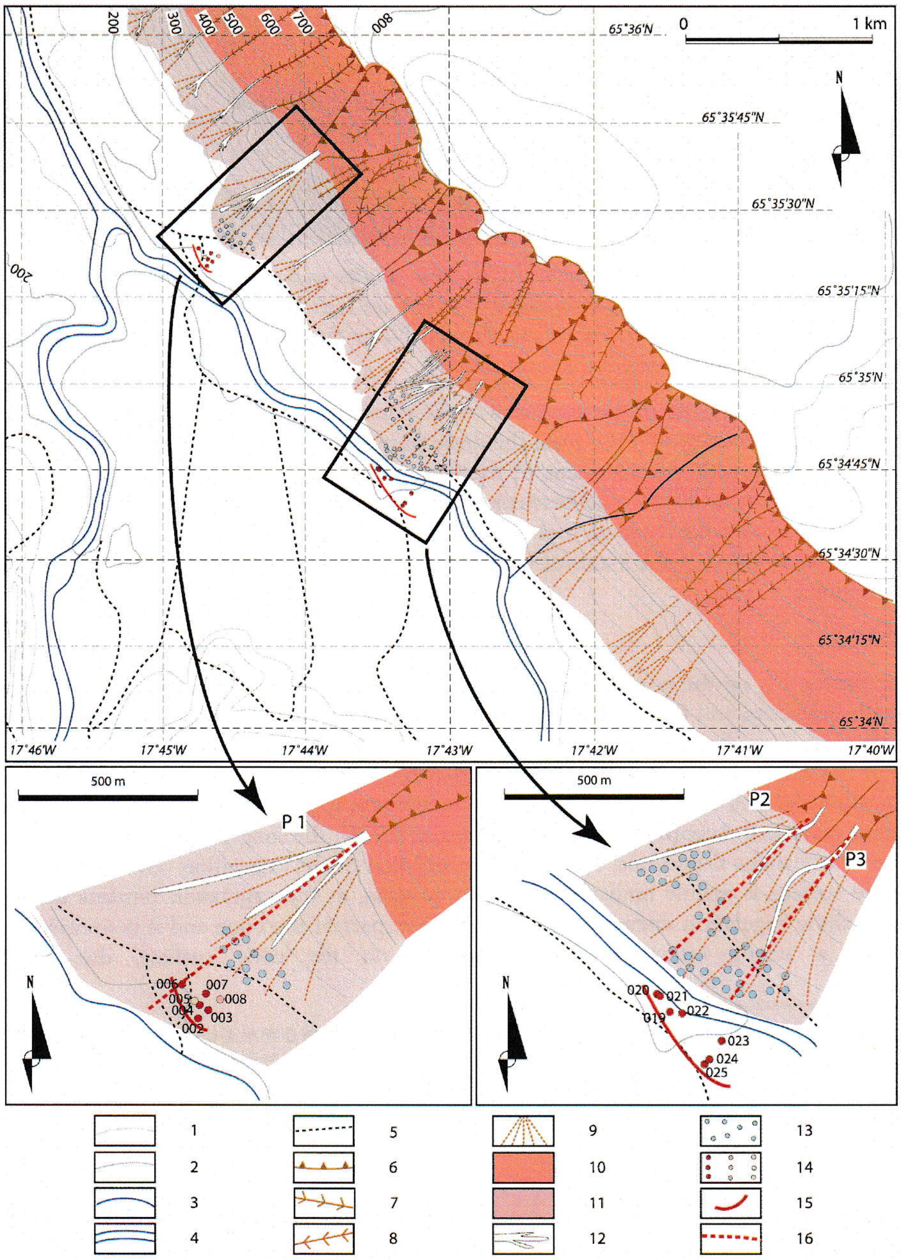

Figure 3. Geomorphological map of the Fnjóskadalur area. 1: Contour line 20 m; 2: Contour line 100 m; 3: Brooks; 4: River; 5: Trails, tracks; 6: Rockwall scarp; 7: Rocky outcrop; 8: Chute; 9: Talus cone; 10: Rockwall; 11: Talus; 12: Debris flows; 13: Snow-avalanche boulders; 14: Extreme runout distance of snow-avalanche boulders: old boulders, medium age boulders and new boulders; 15: Minimal recognised extreme runout distance of snow avalanches; 16: Longitudinal slope profiles (P1, P2, P3).

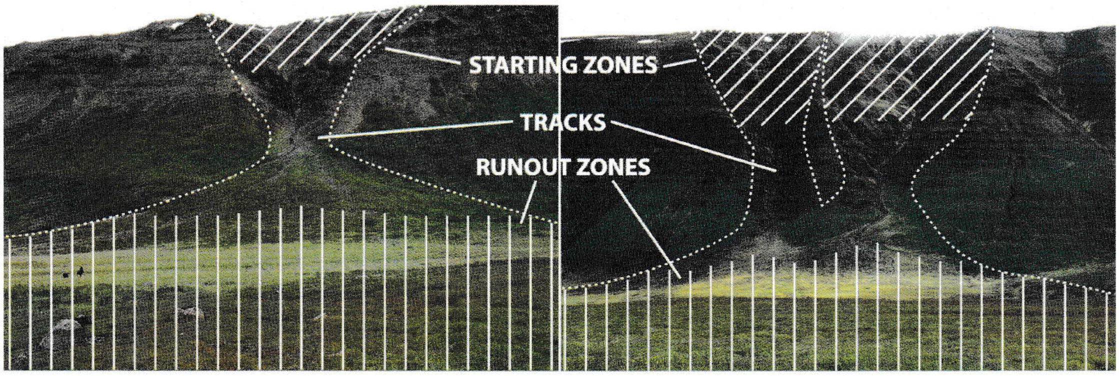

Figure 4. Snow-avalanche paths in the areas of single and double cones in the Fnjóskadalur valley.

Figure 5. Quantitative investigation in the main axis of the cones. a: slope angle measurements; b: measure of the divergence of the long axis of the rock material with the main axis of the slope and vegetation relative coverage on and between rock fragments; c: measurements of the vegetation coverage and diversity. Notice the numerous and large snow-avalanche transported boulders on c. (photos: Þorsteinn Sæmundsson, August 2004).

Long profiles were measured in the main axis of the cones (see location on figure 3), using a tape and a Suunto inclinometer (accuracy = 0.5°), from the distal part to the apex one. The slope angle (figure 5a), the divergence of boulders with the main axis of the cone, i.e. parallel, oblique or perpendicular (figure 5b), relative vegetation cover on blocks and between blocks at each station, i.e. every 10 m, and the vegetation diversity were measured using a square metre grid (figure 5c) at ground level at several locations along the profiles. As visible on figure 5, the a-axis of the debris deposits is changeable, and large fragments (a-axis > 50 cm) are frequent.

2.2.1. Cone 1

The long profile P1, on the northern cone (figure 6), shows a strong concavity. The toe of the cone lies on very gentle gradients, and the external boundary of the cone is quite difficult to find; this is the same for the two other cones studied in the Fnjóskadalur area. Therefore, the C index[1] remains low when taking into account the whole profile (= 0.44), the distal part of the profile being very smooth with slight micro-topographical changes. A significant break in the slope angle appears at segment no. 17, the upslope part having higher gradients. According to Blikra & Nemec (1998), the long profile, with a marked concavity, reveals a snow-avalanche dominated cone. The appreciation of the vegetation cover between rocks shows that the cone surface is mainly undisturbed by any process, as the vegetation remains dense; only some sparse places show vegetation disturbance in the medium part of the cone and it is necessary to reach the apex to see a strong effect of slope dynamics on the cone surface, due to both snow

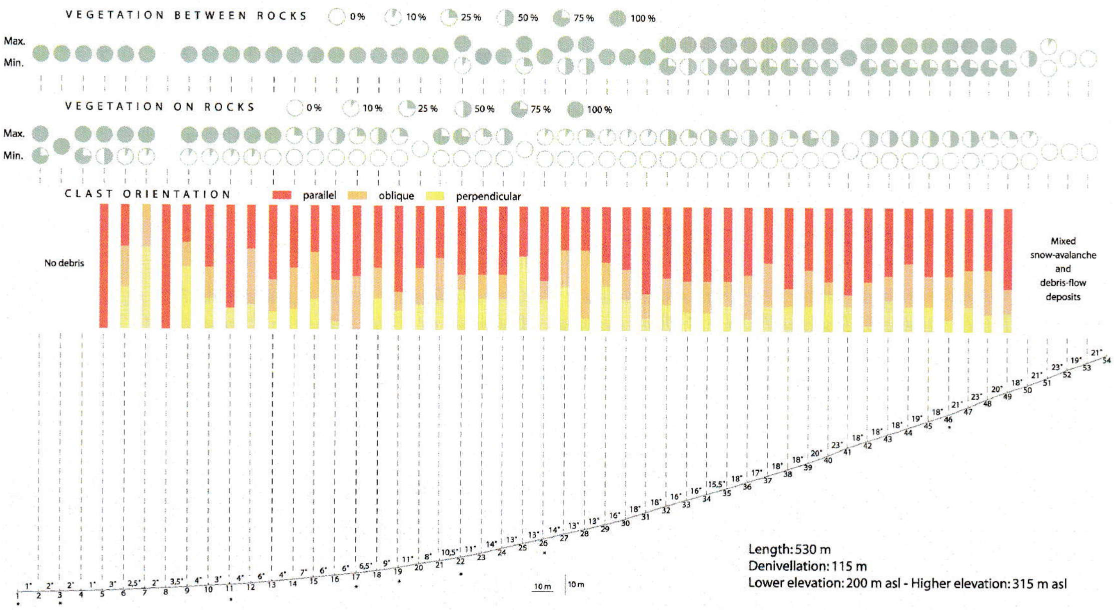

Figure 6. Longitudinal profile P1, in Fnjóskadalur, highlighting the concave profile of the talus, the strong parallel orientation of rocks deposits and the low disturbance of the cone surface, providing evidence of recent snow-avalanche activity. The asterisks under the topographical profile figure the location of vegetation analysis at ground level with the square metre grid.

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[1] The index "C" expresses the distal concavity of the talus slope. This is the sum of slope angle differences between successive segments in the distal zone divided by the number of segments. For a 30 segment slope profile, the index C = [Σ(α10-α09)…+…(α02-α01)]/10 (Jomelli, 1999). The distal concavity gets stronger when C value is going far from 0.

avalanches and debris flows. In contrast, the low vegetation cover on deposited material underlines an important supply in fresh rock debris, obviously provided by snow avalanches instead that by debris flows, as the slope surface is only slightly affected. The orientation of the clasts shows a strong parallel divergence of their a-axis with the main angle of the colluvial cone. This parallel orientation of clasts is an evidence for the snow-avalanche dominance all over this slope, especially in the distal zone. Moreover, the minimal extreme runout distance of snow avalanches were recognised through the position of snow-avalanche transported boulders (figure 3). At the toe of the first cone, the boulders were found more than 150 m downslope from the point β, i.e. the location where the slope reach 10° from where snow avalanches decelerate, and the runout angle α from the external boulder is 20° (Bakkehøi *et al*, 1983). Therefore, the maximum runout angle of the snow avalanches from this path is lower than 20°.

The vegetation survey of this cone, at ground level, underlines an irregular diversity of species along the slope profile, the more numerous species being observed in the median part of the cone (table 1 and annex 1). Vascular plants are of course the most represented, but pioneers plants (such as *Silene acaulis*) are absent or poorly represented. This remark supports the previous observation that geomorphic processes acting on slopes do almost not perturb the cone surface in another way than supplying debris, i.e. the snow cover protects the low vegetation. Thus, transport and deposition processes are more significant than erosive ones. The diversity index D is uneven over the slope and is therefore not very representative on this kind of well-vegetated slope.

Table 1. Vegetation coverage and diversity on the single cone, site 1, along the longitudinal transect P1, at stations 1, 3, 11, 17, 19, 22, 26 and 46. List of recognized vascular plants, occurrence and spatial distribution is given in annex 1.

	1	3	11	17	19	22	26	46
coverage								
vascular plants	79	81	83	89	85	90	92	75
mosses	3	4	1	2	0	0	0	0
lichens	0	0	0	0	0	0	0	0
dead organic material	18	15	12	5	11	10	6	23
minerogenic	0	0	4	4	4	0	2	2
total coverage	**82**	**85**	**84**	**91**	**85**	**90**	**92**	**75**
diversity								
Simpsons D value[2]	0,62	0,794	0,801	0,804	0,786	0,691	0,807	0,699

2.2.2. Cone 2

The long transect P2, measured on the northern cone of the double cone site, shows a concave profile (figure 7) with a C index = 0.31 and an extended toe. Most of the debris fragments are very fresh, being only partially covered with vegetation (mostly lichens) in the median part of the slope. In the distal part, fresh fragments juxtapose older ones, which have a 75 % vegetation cover (mosses and lichens). The proximal part of the cone is exclusively covered with fresh debris. The vegetation cover between rocks is quite even all over the slope, and only the upper part of the cone shows signs of disturbance, with continuous debris supply and movements due to snow avalanches and debris flows (and rockfall occasionally) that hinder vegetation to develop. As shown on figure 3, snow avalanches from this path are extremely powerful, transporting large boulders that have been deposited on the left bank of the river Bakkaá, i.e. more than 220 m from the point β, giving a α angle = 21°, measured from the furthest boulder (the snow avalanches may therefore reach a further distance).

Perched boulders or debris coating on the surface of larger boulders, as well as impacts on boulders by transported rock fragments (figure 8) are also evidence of snow-avalanche activity on cones.

2.2.3. Cone 3

The third cone, the southern one of the coalescent group, shows a general concave profile, despite a C index = 0.44. The surface of this cone presents several accidents, with frequent convex forms (figure 9), even in the distal part. This is due to debris-flow landforms that disturb the long profile. At the apex, an important debris supply is responsible for the marked convexity. Once again, debris flows are involved in the creation of such a profile. Nevertheless, the clast orientation along the profile gives evidence of dominant snow-avalanche activity on this cone, as deposited fragments are mainly oriented parallel to the main axis of the cone. Moreover, the vegetation on the cone is poorly disturbed, indicating that most of the transport and deposition processes occur while the vegetation of the cone surface is protected. This is an-

[2] The diversity is calculated as the Simpsons D index = 1-Σf^2 where f is the frequency of the plant [f=(number of hits of plant of this species)/(total number of hits of plants)].

other evidence for snow-avalanche activity, together with the large number of debris fragments on the cone.

The relative age of deposits, known with the help of vegetation cover on rock fragments, is quite singular on this cone: fresh boulders are found all over the slope except in the distal part, where older boulders with 75% or 100% of their surface covered with lichen, mosses or grass dominate. But exclusively fresh snow-avalanche transported boulders have been observed on the opposite bank of the Bakkaá River at the extremity of the snow-avalanche path. Thus, recent snow avalanches were extremely powerful and had an exceptionnal runout distance, transporting boulders along a 700-800 m path, and depositing boulders more than 300 m further the point β, giving a maximal α angle = 20°, measured from the furthest boulder (the snow avalanches may therefore reach a further distance, then the true α angle should be lower than 20°).

The vegetation at ground level on this cone presents similarities with the survey on cone 1. A higher number of plants, thus a higher diversity, are observed at each measured station, even if the coverage is more or less the same, except in the lower apical part, where it is only 47%. The proximity of debris-flow features probably explains this low vegetation cover at this location.

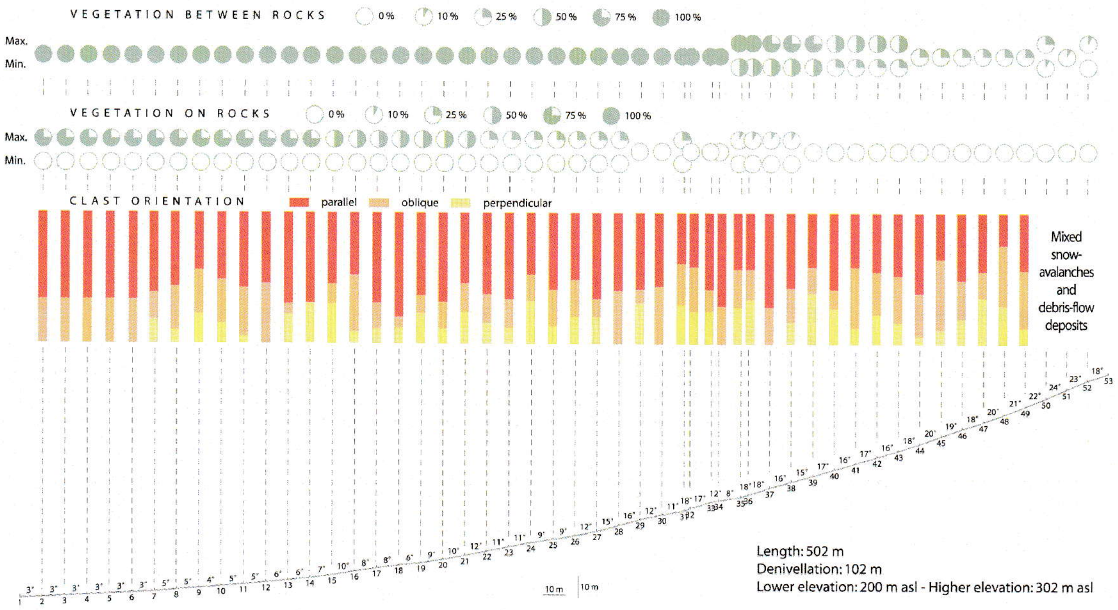

Figure 7. Longitudinal profile P2, in Fnjóskadalur, highlighting the concave profile of the talus, the strong parallel orientation of rocks deposits and the low disturbance of the cone surface down the apex zone. Old boulders, covered with lichens and/or mosses, are only found in the distal zone, mixed with fresh ones, providing evidence of recent snow-avalanche activity.

Figure 8. Perched boulders and coated impacted boulders provide evidence for snow-avalanche activity (Photo: Þorsteinn Sæmundsson, August 2004).

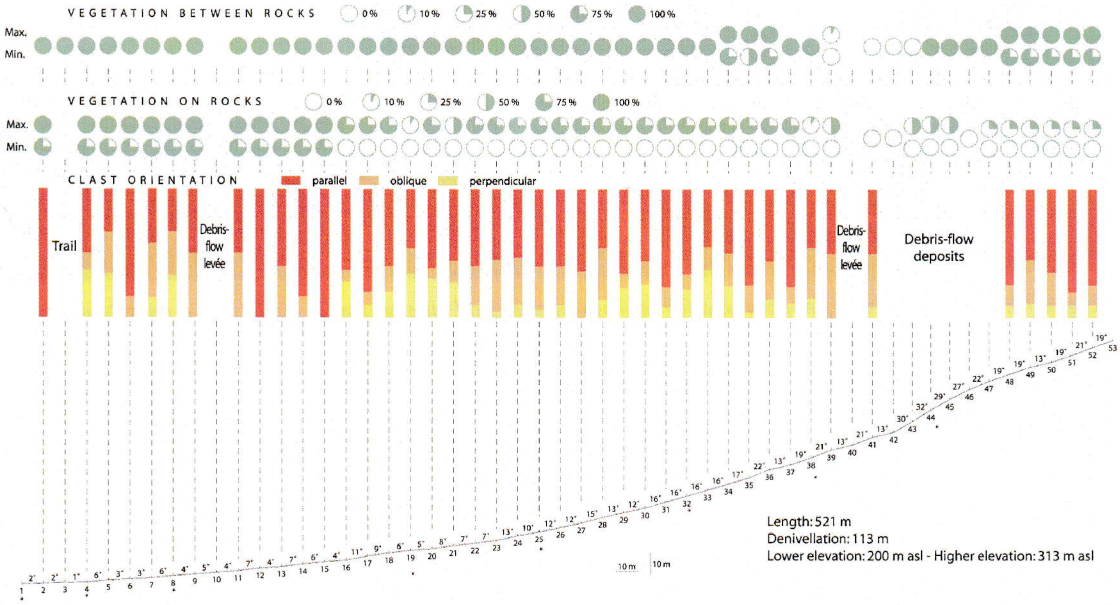

Figure 9. Longitudinal profile P3, in Fnjóskadalur, highlighting the concave profile of the talus, the high debris supply in the apical zone, marking a strong convex profile, the parallel orientation of rocks deposits in all zones of the talus, and the low disturbance of the cone surface, even in the apex zone (except from debris-flow deposits). The oldest boulders are found in the distal zone. The asterisks figure the location of vegetation measurements at ground level with the square metre grid.

Table 2. Vegetation coverage and diversity on the southern cone in site 2, along the longitudinal transect P3, at stations 1, 4, 8, 19, 25, 32, 38 and 46. List of recognized vascular plants is given in annex 2.

	1	4	8	19	25	32	38	44
coverage								
vascular plants	79	81	83	89	85	90	92	75
mosses	3	4	1	2	0	0	0	0
lichens	0	0	0	0	0	0	0	0
dead organic material	18	15	12	5	11	10	6	23
minerogenic	0	0	4	4	4	0	2	2
total coverage	**82**	**85**	**84**	**91**	**85**	**90**	**92**	**75**
diversity								
Simpsons D value	0,62	0,794	0,801	0,804	0,786	0,691	0,807	0,699

2.3. Dendrogeomorphology

Dendrogeomorphology is a branch of dendrochronology. It consists into using the stem characteristics to provide information on spatial and temporal aspects of earth surface processes over annual to centennial time scales. The wooded areas of talus and colluvial cones in Fnjóskadalur are favourable for applying this technique. Therefore, birches at different stage of evolution were studied on the three cones, the aim being to highlight the main snow-avalanche paths and its lateral spreading on the cones. Here we present the results from investigation dealing with trunk size and damage evidence on trees. The size of the tree refers to the maximum diameter of its trunk, while damage on trees are classified into four groups: trees (1) that are significantly tilted (figure 10a); (2) trees that present scar(s) (figure 10b); (3) trees that present decapitation (figure 10c), and (4) trees without any evidence of disturbance. Trees presenting scars are always tilted in the study area, and trees with decapitations offer both evidence of tilting and scars.

2.3.1. Cone 1

A large part of the cone is wooded, but thickness of tree trunk is highly variable. Figure 11a shows that the largest trees are found preferentially at the external boundaries of the cone and within its lower parts. The maximum diameter measured on birch does not exceed 20 cm. Smaller trees and bushes are found in the main axis in the upper parts of the cone. This tree-size distribution was expected, as processes acting on slopes are more active in the apex - upper median part, in the main axis of the cone, instead that at its periphery or far downslope. The southern part of the cone, i.e. south from the brook, seems to be more affected than the northern part, with smaller trees found at lower altitudes.

Figure 10. Evidence of tree deformation used for dendrogeomorphological investigation: a. tilt; b: scar; c: decapitation (photos: Armelle Decaulne, August 2005).

Table 3. Characteristics of sampled trees on cone 1, Fnjóskadalur.

tree characteristics	# of trees	%
undisturbed trees	54	12
trees tilted	116	25
tilted trees with scars	216	46
tilted trees with scars and decapitation	79	17
total	465	100

On this cone, 465 trees were observed and were exactly located with GPS. Most of them present a pronounced tilt feature, and trees with tilt and scars are the most numerous. Tilted trees with both scars and decapitation are more seldom (table 3). Undisturbed trees are not well represented. Therefore, deformations are widespread on this cone, indicating a frequent snow-avalanche activity.

The distribution of damage on trees (figure 11b) supports the previously observed asymmetry of the geomorphic dynamics on this talus cone, as the area covered by tilted and scared trees is more extended in the southern part of the cone that is the northern one, and undisturbed trees are more numerous in the northern part than in the southern one. Therefore, it seems that the preferentially path followed by snow avalanches is in the southern part of the cone. A secondary track follows the brook, tilting and impacting trees with rocks. An unexpected spatial distribution of decapitate tilted trees with scars appear on figure 11b: these heavily damaged trees were mostly expected in the upper parts, while they are scarcely found both in the median and distal parts. The explanation belongs probably to the size of trees, as thin trunks can easily bend; therefore, decapitation will be found where trees are larger, and preferentially within the axis of the less frequent snow avalanches, as repetitious snow avalanches will be unfavourable to the growth of large tree. Finding of decapitate trees even in the distal part of the cone underlines the destructive potential of snow avalanches, even far from the starting zone. Furthermore, the

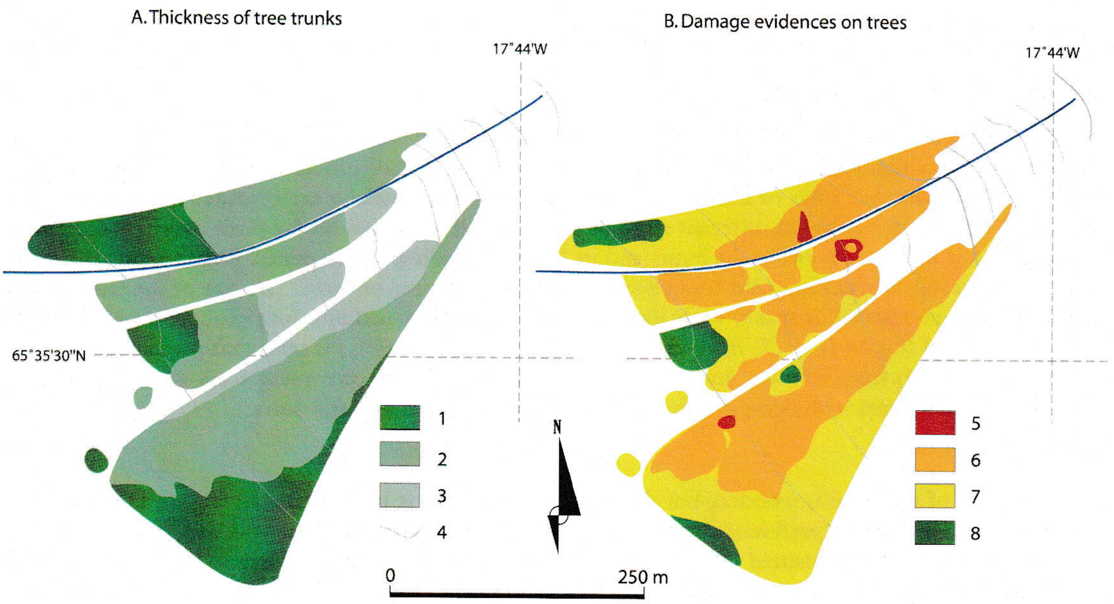

Figure 11. Dendrogeomorphological results on cone 1, Fnjóskadalur. A: Thickness of tree trunks (1: Ø > 12 cm; 2: 5 cm < Ø < 12 cm; 3: Ø < 5 cm; 4: elevation lines = 20 m). B: Damage evidence on trees (5: Trees showing tilting, scars and decapitation; 6: Trees with tilting and scars; 7: Tilted trees; 8: Undisturbed trees).

Figure 12. Isolated broken trunks of largest trees on cone 1 (photos: Armelle Decaulne, August 2005).

location within the main path of undisturbed trees or of only tilted trees shows that the impact of snow avalanches is selective along the path.

The strong tilt of trees and the main represented trunk diameter from 5 to 12 cm, associated with the low number of broken trunks (figure 12a and b) indicate that (1) the lateral spreading of snow avalanches cover the whole cone, (2) the main paths cover the areas where tilted trees with scars are observed, (3) the avalanche frequency is high enough to impede most of the trees to grow straight, and (4) tree tilt avoid the trunk to be broken by the snow-avalanche pressure (i.e. trees grow with recurrent snow-avalanche activity).

2.3.2. Cones 2 & 3

The cones 2 and 3 are densely wooded on their external boundaries, and in the upper median and apical parts of the cones. A large part of both cone surfaces is deprived of wooded vegetation. Respectively 644 and 775 trees were sampled (table 4). Large trees (trunk diameter > 12 cm) are seldom and only seen at the cone limits. The smaller trees are located in the upper parts of the cone, or at lower altitude within the main path (figure 13a). All trees are tilted, and most of them present scars (table 4). The location of decapitate tilted trees with scars underline the paths of the most frequent snow avalanches.

Table 4. Characteristics of sampled trees on cone 2 and cone 3, Fnjóskadalur.

	cone 2		cone 3	
tree characteristics	# of trees	%	# of trees	%
undisturbed trees	0	0	0	0
trees tilted	211	33	191	25
tilted trees with scars	187	29	503	65
tilted trees with scars and decapitation	246	38	81	10
total	644	100	775	100

On cone 2, the path on the southern part of the cone is the most common one, and the path following the brook channel (also a debris-flow channel) is the secondary path; the biggest damage on trees are found in the apical part of the cone (figure 13b). Here, even small trees shows decapitation evidence, underlining the devastating efficiency of snow avalanches on this cone. The presence of large trees in the mid-part of the cone (figure 13a) reveals the location of lower snow-avalanche frequency, even if these trees are tilted and are bearing scars.

On cone 3, only fewer severe damage on trees are observed (table 4 and figure 13b), and the trees present mostly tilting and scars. We observe that snow-avalanche impact on trees could be selective, damaging seriously trees far in the path, while damage in the upper part are less severe.

The lateral spreading of snow avalanches is large on both cones, as no trunk seems to be undisturbed. Nevertheless, snow avalanches originating from neighbouring starting-zones could inflict some of the damage at the cone limits, especially in the low median and distal parts.

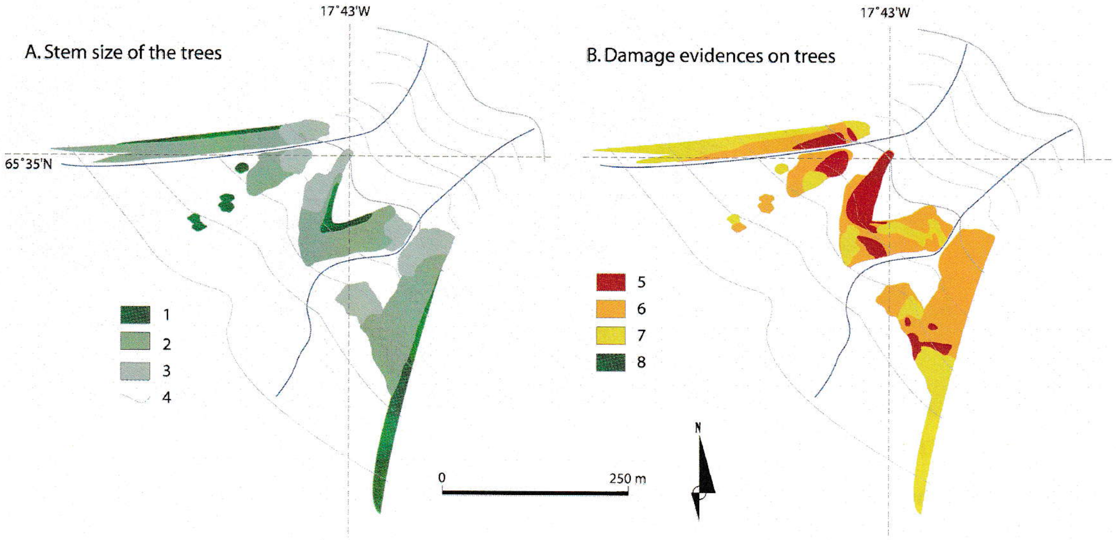

Figure 13. Dendrogeomorphological results on cones 2 and 3, Fnjóskadalur. A: Thickness of tree trunks (1: Ø > 12 cm; 2: 5 cm < Ø < 12 cm; 3: Ø < 5 cm; 4: elevation lines = 20 m). B: Damage evidence on trees (5: Trees showing tilting, scars and decapitation; 6: Trees with tilting and scars; 7: Tilted trees; 8: Undisturbed trees).

3. The Bleiksmýrardalur area

3.1. Presentation

The investigated area in the Bleiksmýrardalur valley is located on both banks of the Fnjóská River (figure 1). On the western bank of the river is the main gully followed with a colluvial cone that has been cut by the river in its distal part (figure 14a). On the eastern bank is a small gully with a poorly developed talus, which joins the distal part of the western cone (figure 14b). The apex of the cone is at 480 m a.s.l., and its distal part is around 370 m a.s.l. Snow avalanches and debris flows affect the surface of the western cone. The vegetation consists into high latitude heath; dominant plants are recapitulated in annex 3.

Figure 14. The Bleiksmýrardalur study area: a. the western site and its well developed colluvial cone cut by the Fnjóská River in its distal part; b. the eastern gully (Photos: Þorsteinn Sæmundsson, August 2004).

3.2. Geomorphology

The western slope of the Bleiksmýrardalur valley is a favourable source area for snow avalanches in the investigated part, as huge amounts of snow can accumulate both at the top of the summit plateaux, and within the more or less large indentations that cut the headwall (figure 15). Thus, the western slope is more favourable than the eastern one. Most of these indentations are also the source areas of debris flows. Westerly winds encourage snow accumulations at the top of the leeward slope, and snow cornices on the ridge crest. The runout zone of snow avalanches originating from this gully cross the Fnjóská River and terminates on the flat land at the toe of the opposite slope.

The long profile of the valley bottom was measured from the top of the apex of the eastern cone to the apex of the western one (figure 16), using the methods explained in paragraph 2.2. The talus distribution appears asymmetric in this part of the valley, with a steeper eastern slope and higher elevation on the

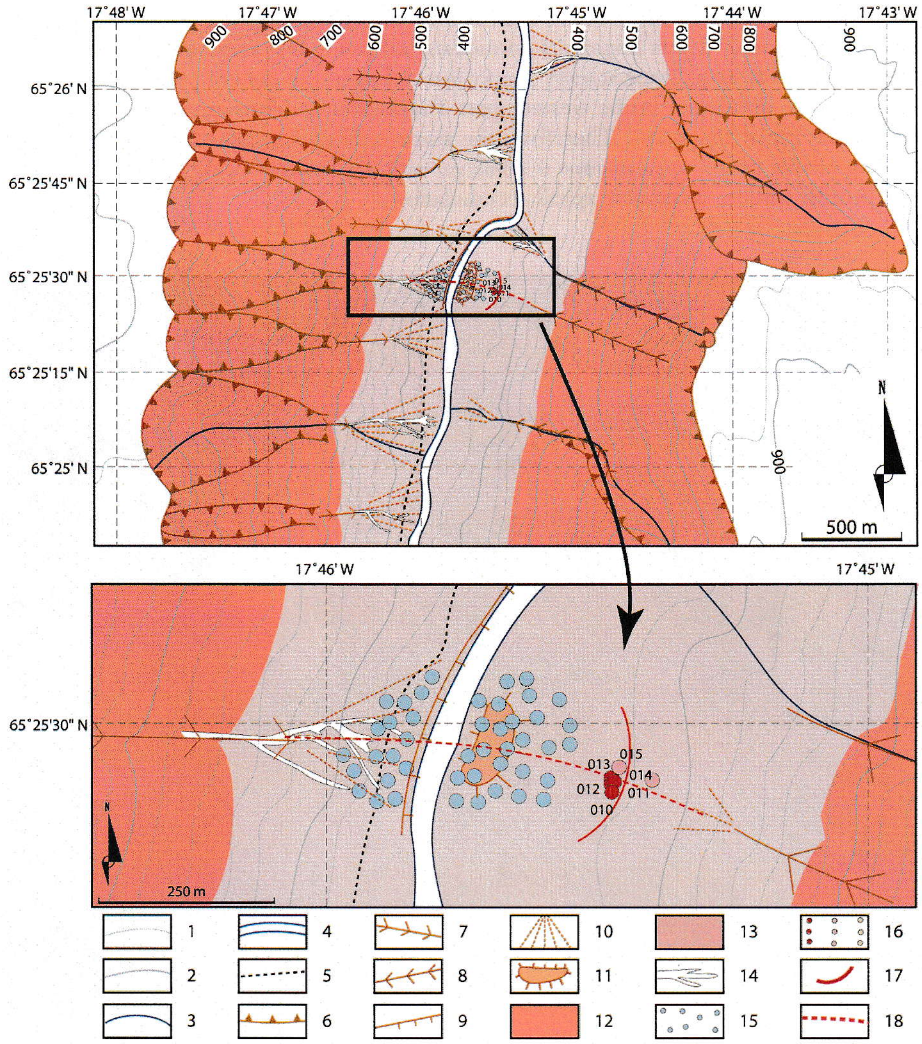

Figure 15: Geomorphological map of the Bleiksmýrardalur investigated area. 1: Contour line 20 m; 2: Contour line 100 m; 3: Brooks; 4: River; 5: Trail; 6: Rockwall scarp; 7: Rocky outcrop; 8: Chute; 9: Escarpment; 10: Talus cone; 11: Accumulation landform; 12: Rockwall; 13: Talus; 14: Debris flows; 15: Snow-avalanche boulders; 16: Extreme runout distance of snow-avalanche boulders: old boulders, medium age boulders and new boulders; 17: Minimal recognised extreme runout distance of snow avalanches; 18: Longitudinal slope profiles.

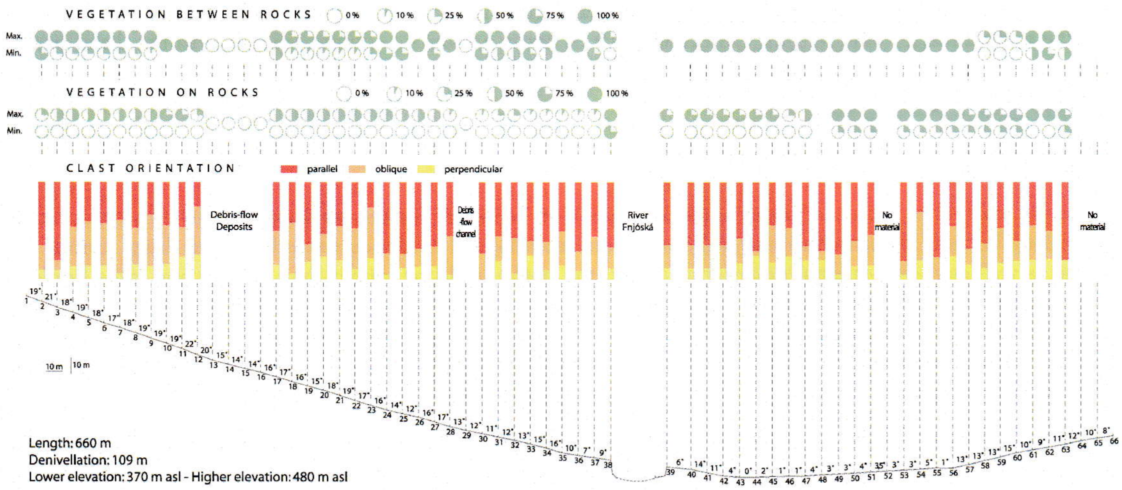

Figure 16. Topographical long profile, clast orientation and vegetation cover on and between rocks in the Bleiksmýrardalur site.

western part. The distal part of the western cone is located on the eastern bank of the river. In the distal parts, parallel orientation of debris fragments dominates, indicating that snow-avalanche activity is the main deposition process in the area. Slope activity supply less debris in the eastern part than in the western part, and the talus is more developed in the western part. Furthermore, debris are more seldom in the eastern part, and especially fresh fragments. Therefore, the slope activity is assumed to be lower on the eastern slope. The long profile of the western cone is concave, with a C index = 0.66. The slope gradient is regular all along the profile, without noticeable apical accumulation.

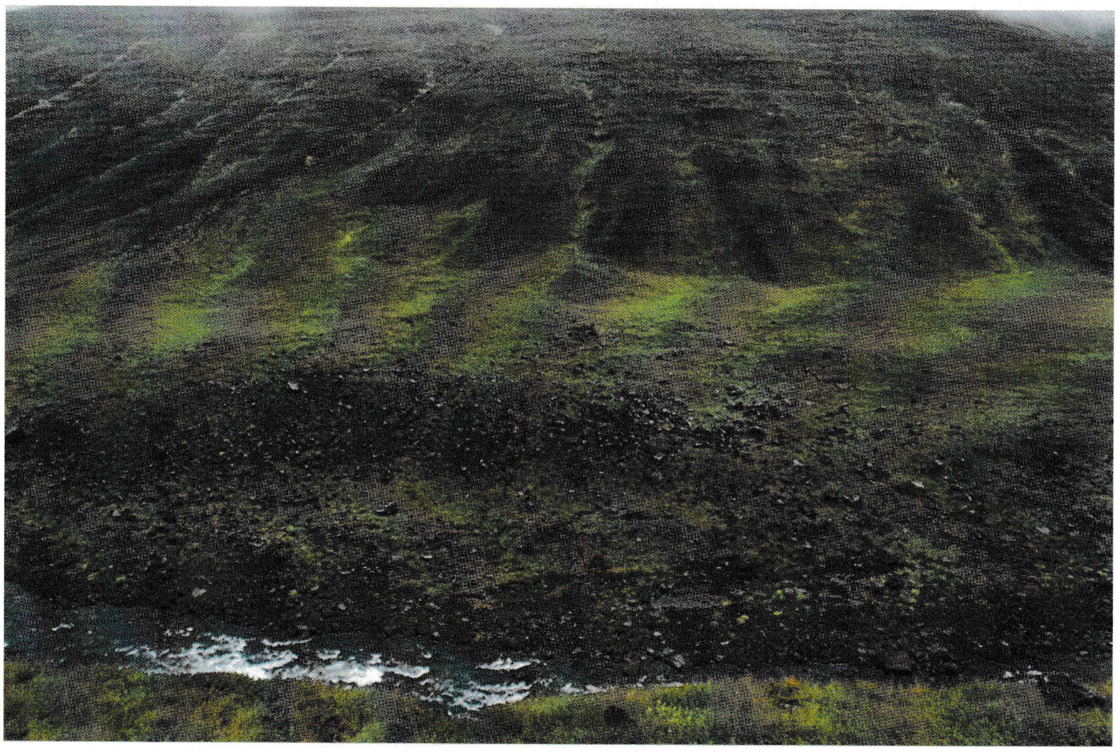

Figure 17: The snow-avalanche boulder accumulation, forming the distal part of the main cone, cut by the river Fnjóská. The furthest boulders originating from the western slope are seen in the mid-part of the picture, stopping at the toe of the small cone from the eastern gully (photo: Þorsteinn Sæmundsson, August 2004).

A large debris accumulation has been built by snow-avalanche transported boulders on the eastern bank of the Fnjóská River (figure 17). Therefore, the river is not an obstacle for snow avalanches; in contrary, the western bank acts as a springboard that gives more impetus to transported boulders as there is less friction with the ground. Snow-avalanche boulders, indicating the maximal runout distance of snow avalanches, are observed about 200 m from the river (figure 15), on the eastern bank. The path of the avalanche is then longer than 475 m. Other evidence of snow-avalanche activity are found in the distal part of the western cone, on the eastern bank of the river. Especially, coated boulders, balanced and perched boulders are frequent.

4. Concluding remarks and further work

Snow avalanches are an efficient transport agent on Icelandic slopes, as illustrated by this study in the Fnjóskadalur and Bleiksmýrardalur valleys. Geomorphological evidence underline their long runout distance as well as their potential destructive effect: the paths could be longer than 700 m, and large boulders are transported further than 200 m from the β point, while snow-avalanche spreading covers the full width of the cones. This is of major implications not only from a geomorphic point of view, but for risk assessment and land-planning too, illustrating the potential damage inflected by snow avalanches and snow-avalanches transported boulders in inhabited areas, even at a large distance from the slope.

Further work is suitable in this area to get a better knowledge of talus cone development, thus of snow-avalanche frequency and magnitude. Fabric analysis would help to understand the material organisation within the cone; tephrochronology will help to know the rhythm evolution of talus slope during the Holocene, and suitable profile has been observed in cone 1, Fnjóskadalur. Dendrogeomorphology methods have not yet been fully applied in the Fnjóskadalur valley; especially shrub and tree disturbance examined through stem disc and trunk drill, and dendro-inclinometry will reveal more information on slope dynamics during the last centuries.

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Appendix 1 – Low vegetation on cone 1 along P1 long profile.

	Fnjóskadalur P1							
	# of hits at each station along the slope profile							
	1	**3**	**11**	**17**	**19**	**22**	**26**	**46**
vascular plants								
Achillea millefolia	-	-	1	-	-	*	-	-
Agrostis sp.	4	20	11	6	1	3	1	24
Alchemilla alpina	-	-	-	8	5	1	8	-
Anthoxanthum odoratum	-	8	22	4	1	8	1	4
Arctostaphylos uva-ursi	-	-	-	2	10	*	6	-
Betula nana	-	-	*	33	24	45	35	30
Betula pubescens	-	-	-	-	-	19	*	-
Bistorta vivipara	-	*	*	*	1	-	*	-
Carex sp.	6	5	7	-	-	-	-	-
Carex sp. Long	-	-	-	-	-	-	-	1
Deschampsia cespitosa	13	20	23	-	1	-	-	14
Deschampsia flexuosa	-	-	-	-	1	5	4	-
Dryas octopetala	-	-	-	-	2	3	12	-
Empetrum nigrum	-	-	-	15	7	2	10	-
Equisetum arvense	-	-	-	2	*	-	*	-
Equisetum sp.-	-	-	-	-	-	-	-	2
Festuca sp.	-	-	-	-	1	-	-	-
Galium normanii	-	-	-	2	-	-	*	-
Galium verum	3	-	5	13	1	1	-	*
Juncus arcticus	-	3	-	-	-	-	-	-
Kobresia myosyroides	48	24	14	-	-	2	2	-
Luzula multiflora	4	*	*	*	*	*	-	-
Ranunculus acris	-	1	-	-	-	-	-	-
Selaginella selaginoides	*	-	*	*	*	-	2	-
Taraxacum sp.	-	-	-	-	1	*	1	-
Thalictrum alpinum	1	-	-	1	-	-	-	-
Thymus praecox	-	-	-	2	1	*	4	-
Vaccinium myrtillus	-	-	-	-	-	-	2	-
Vaccinium uliginosum	-	-	-	1	28	1	4	-
mosses	3	4	1	2	-	-	-	-
lichens	-	-	-	-	-	-	-	-
non organic	18	15	16	9	15	10	8	25
total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
counts								
vascular plants sðecies	7	7	7	12	45	11	14	6
total # of species	9	8	7	13	15	11	14	6
coverage								
vascular plants	79	81	83	89	85	90	92	75
mosses	3	4	1	2	0	0	0	0
lichens	0	0	0	0	0	0	0	0
dead organic material	18	15	12	5	11	10	6	23
minerogenic	0	0	4	4	4	0	2	2
total coverage	**82**	**85**	**84**	**91**	**85**	**90**	**92**	**75**
diversity								
Simpsons D value	0,62	0,794	0,801	0,804	0,786	0,691	0,807	0,699

* means that the plant was seen within the grid but not met at the counting point.

Appendix 2 – Low vegetation on cone 3 along P3 long profile.

	Fnjóskadalur P3							
	Station # on longitudinal slope profile							
	1	**4**	**8**	**19**	**25**	**32**	**38**	**44**
vascular plants								
Achillea millefolia	-	-	1	1	*	-	-	-
Agrostis sp.	-	9	19	7	4	*	5	5
Alchemilla alpina	-	-	-	14	11	-	21	-
Anthoxanthum odoratum	1	1	3	15	2	*	-	-
Arctostaphylos uva-ursi	29	-	-	5	5	23	23	3
Betula nana	4	-	14		5	6	-	-
Brotrychuim lunaria	-	-	-	-	1	-	*	-
Calluna vulgaris	6	-	-	-	-	-	-	-
Carex bigelowii	2	3	1	6	1	-	-	-
Carex sp. Long	2	8	5	-	-	-	-	-
cerastuim sp.	-	-	-	-	-	-	2	*
Deschampsia cespitosa	-	9	4	*	-	-	-	-
Deschampsia flexuosa	5	29	35	22	9	8	7	-
Dryas octopetala	-	-	-	-	-	-	-	29
Empetrum nigrum	9	-	-	4	30	7	4	-
Equisetum sp.-	1	-	-	1	3	-	3	1
Galium normanii	-	2	*	1	2	1	1	-
Galium verum	1	2	3	1	2	3	7	*
Hierochloe odorata	-	-	2	-	-	-	-	-
Kobresia myosyroides	-	-	-	-	5	*	-	-
Luzula multiflora	1	3	1	2	-	-	2	-
Potentilla crantzii	-	-	-	-	1	-	-	-
Taraxacum sp.	-	*	*	*	-	-	1	-
Thalictrum alpinum	4	*	*	-	1	*	-	-
Thymus praecox	-	-	-	-	2	1	1	9
Vaccinium uliginosum	14	-	-	*	-	37	-	-
Viola sp.	-	-	-	1	*	-	-	-
mosses	1	*	-	-	-	-	4	-
lichens	20	34	12	19	16	14	19	53
non organic	20	34	12	19	16	14	19	53
total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
counts								
vascular plants sðecies	13	9	11	13	16	8	12	5
total # of species	14	9	10	12	16	8	14	5
coverage								
vascular plants	79	66	88	80	84	86	77	47
mosses	1	0	0	0	0	0	4	0
lichens	0	0	0	0	0	0	0	0
dead organic material	20	34	12	15	13	14	6	20
minerogenic	0	0	0	5	3	0	13	33
total coverage	**80**	**66**	**88**	**80**	**84**	**86**	**81**	**47**
diversity								
Simpsons D value	0,809	0,749	0,761	0,838	0,827	0,722	0,827	0,567

* means that the plant was seen within the grid but not met at the counting point.

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