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The Postglacial Big Landslides in Iceland Illustrated by Stereographs

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1. Introduction

Purpose Under the term of "landslide", one will imagine a superficial, narrow landslide recently caused by the seepage of water, whereas the postglacial big landslides in Iceland have some hundred meters width, height and thickness, and they are attributed to the big earthquakes at that age. A similar landslide is found at Mt. Binevenagh (384 m, "N. Ire" in Pl. I), north-east of Londonderry, North-Ireland, which together with Iceland, Spitsbergen, etc., belongs to the "Brito-Arctic Plateau Basalt Region".

The introduction of these past landslides will lead us to a more fundamental recognition of the present one geomorphologically, climatologically and dynamically.

Method The author got and read two studies[1,2] on the big landslide in Iceland, but the most comprehensive ones[3,4], which are in Icelandic, have not come to his hand despite all his effort to obtain them. He is afraid that the following description may have been touched in them[3,4] already, but he eagerly wishes to report the slides by the text, by a quantitative table, especially by several stereographs. He would also like to insist upon the hypothesis that the sand-spit-like topography in fjörd was caused by a big landslide from the fjörd cliff.

Definition Now, the proper use of the term "landslide" should be determined as C. F. S. Sharpe has done[5]. But only "landslide" is used here because slides are not so clear for the author as they were observed from the bus or the ship, and as the landslides were very old.

Stereoscope To see the stereographs shown by the letter a and b in the plates, the two convex lens type stereoscope is the best, but the naked eye method is also recommendable.

Acknowledgement The author would like to express his hearty thanks to Dr. S. Thorarinsson who offered him a lot of literature and

convinience during his seven weeks stay in Iceland. He is also indebted to the institution of Research Abroad in Hôsei University.

2. Summary of Dr. S. Thorarinsson's treatises[1,2]

The first big slump met with on the road from Reykjavik to Mývatn has broken away from the mountain Hraunsnefsöxl near Hredavatn in Nordurárdalur. (Hr. in Fig. 1) The next is the biggest postglacial rockslide in Iceland of Vatnsdalshólar at the mouth of the Vatnsdalur valley. (1 in Fig. 1. 1 in Pl. I) The slumped rock covers an area of about 6 km^2. This great rock mass, containing both basalt and rhyolite, has broken away from the mountain Vatnsdalsfjall and fallen towards the west. (cf. 1 m in Pl. I) The blocks have formed a great number of conical mounds. According to an old saying, one of the three "innumerable things" in Iceland. The age of Vatnsdalshólar is hardly more than about 10,000 years.

The third one is found on the almost entire eastern side of the Langidalur valley (La. in Fig. 1) and the biggest of the slumps, about 2 km broad, is the northernmost one. This slump has left a great scar in Langadalsfjall. The endmoraine-like front of the rockmass is visible

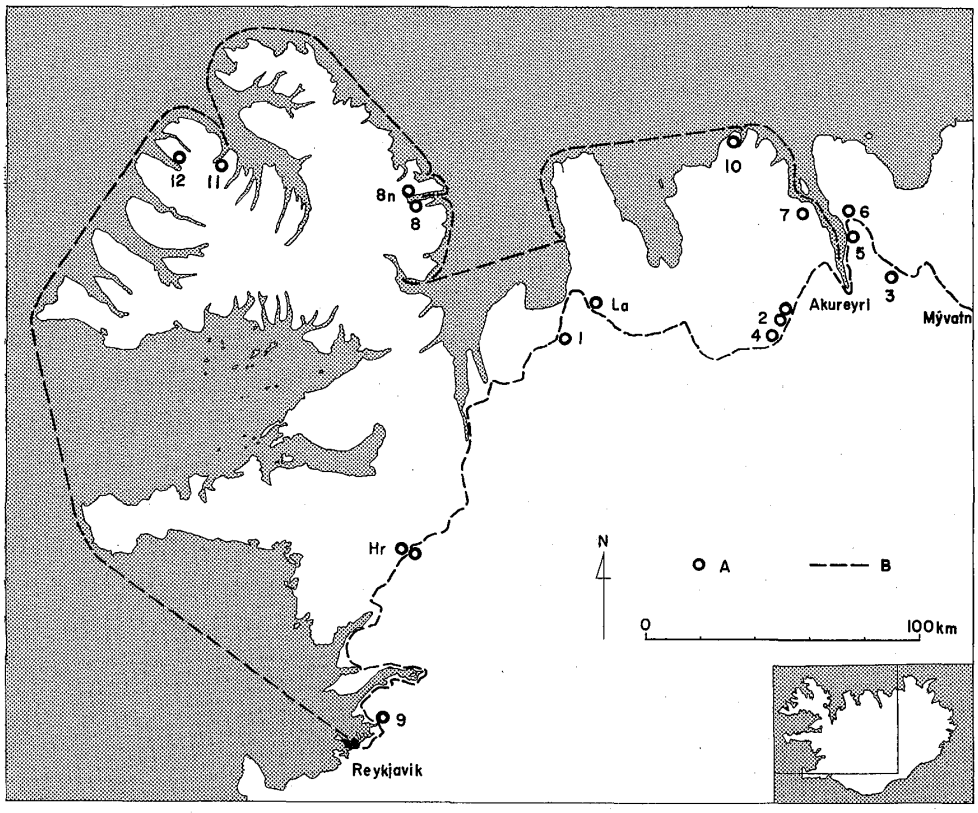

Fig. 1. The location of the big landslides in the north-west Iceland.
A : Location. Numerals correspond to those in the text and plates.
B : Author's route.

on the opposite side of the valley, about 70 m above its bottom.

The fourth group of slumps is in the beautifully U-shaped Öxnadalur valley. The biggest is Hraun (2 in Fig. 1. 2, 2 m in Pl. I), a magnificent slump which literally has split Mt. Háafjall, leaving precipitous rock walls ending upwards in a row of pinnacles, the highest of which is the famous Hraundrangi. Smaller but conspicuous slumps are farther south in the valley, such as Varmavatnshólar (4 in Pl. II). The scars of such slumps may resemble glacial cirques with moraines in front. A typical example of a cirque-like scar is Stórutjarnarskál in Ljósavatnsskard. (3 in Fig. 1. 3 m, stereo 3a, 3b in Pl. I)

The big slumps in Iceland are mainly confined to the valley of the plateau basalt areas. Tephrochronological studies and studies of the age relation between the landslides and gravel terraces in the

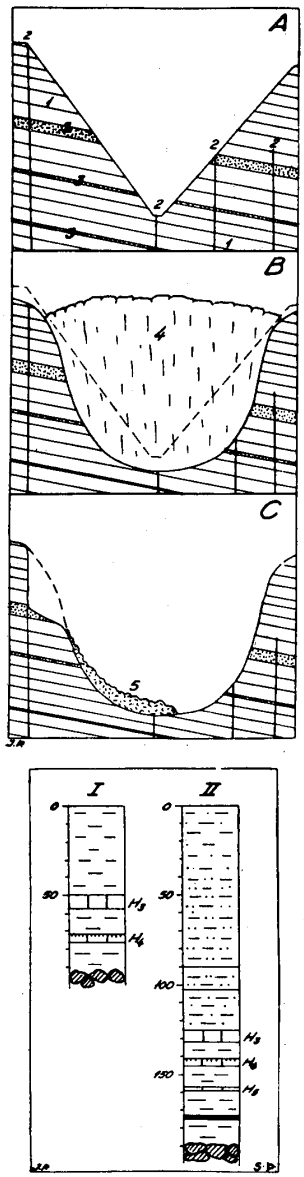

Fig. 2. Diagram showing schematically the formation of a slump in a valley within the basalt area. 1: basalt beds, 2: dykes, 3: sedimentary layers, 4: ice, 5: rockslide or slump. (upper)

Soil section from the rockslide opposite Hraun in Öxnadalur (I) and from the rockslide Leyningshólar in Eyjafjördur (II). H_3–H_5: rhyolitic tephra layers from Hekla. (Lower)

(Both after S. Thorarinsson)

valley indicate that most of the slumps are of late-glacial or early postglacial age.

They have been caused mainly by the oversteeping (cf. p. 90) of the valley sides by glacier erosion and their formation was probably facilitated by frequent earthquakes at the time when the glacial-isostatic land upheaval was at its fastest, which was more than 9,000 years ago. The geological structure of the valley sides has also played a role. Fig. 2 shows schematically the formation of a slump in a valley within the plateau basalt area and explains why such slumps and slides often are formed only on one side of the valley in these areas. The explanation of the numerals in Fig. 2 is as follows:

1: basalt beds, 2: dykes, 3: sedimentary layers, 4: ice, 5: rockslide or slump. (upper)

H_3—H_5: rhyolitic tephra layers from Hekla. (lower)

Within the area of Pleistocene Palagonite series big slumps are not so common as within the basalt areas, but smaller slumps and rockslides are frequent. Slumpings in connection with earthquakes are still frequent within these areas. Besides the slump, debris slides are very common in the valley within the basalt areas at present as the result of an exceptionally heavy rainfall. The destruction of the birch wood on the valley slopes in Iceland has led to increased sliding of the soil cover since the arrival of man.

3. Eight unknown landslides observed by the author

"Unknown" means only that these landslides are not reported in the studies[1,2]; he is not sure whether these landslides are reported or not in the studies[3,4] and others. These landslides were observed by the author on his journey during September 17th-21st, 1964, under the guidance of the above mentioned literature[1,2]. His route was: Reykjavik —Akureyri—Mývatn—Akureyri—(North-west sea route)—Reykjavik. In each of the maps are two white converging lines and their meeting point indicates the place where the corresponding photograph was taken.

Landslide No. 5 (cf. 5a, 5b, 5c and 5m in Pl. II)

This is located on the west side of Mt. Yztuvikurfjall (606 m) on the east coast of Eyjafjördur, 18 km north of Akureyri. The landslide took place with about 1200 m width, with about 700 m thickness and its fallen detritus flowed to the west to make a semi-cone of about 1 km radius. There are some low sea-cliffs formed already around the semi-cone. Plate II-5c, taken from the north, illustrates this semi-cone in its middle right, residual cliff after the landslide in the left upper white part. This cliff will also be a position of the estimated fault running from south to north in the direction of Eyjafjördur. The

dark slope in the foreground will be a part of the old cliff of the U-valley, judging from the scattered roche-moutonée, but, this dark slope does not continue smoothly to the top part of the U-valley, and it makes a questionable terrace.

Plates 5a and 5b were taken towards the east from the author's ship about 3 km off the coast, which will illustrate, when stereoscoped, a steep basalt cliff, gentle debris flow, a slight development of talus and a questionable somewhat inclined terrace of middle height, which is partly broken by this landslide. The latter two characteristics will have a relation with the same topography of the next landslide No. 6 as a probable results of fault activity.

Landslide No. 6 (cf. 6a, 6b and 6m in Pl. II)

The map 6m continues to the upper edge of the map 5m with a slight gap. In the map 6m, a cliff of dense contour runs north about 3.5 km from the letter G of Gerdafjall. This line will be a continuation of the estimated fault line mentioned above and also the residual cliff of the landslide. The stereographs 6a and 6b, taken from the ship about 4 km off, shows a steep basalt cliff, qestionable middle height terrace, semi-bowl like hollow in it, and pudding-like debris topography in that hollow. All these characteristics are common to the landslides No. 5 and No. 6, but hardly seen in other landslides.

Landslide No. 7 (cf. 7 and 7m in Pl. III)

This is located in the north-east slope of Krossahnjúkur (989 m) on the west coast of middle Eyjafjördur. This is not single but plural as are shown in plate 7. This estimated slope before landslide is exceptionally gentle of only 22°, but landslide occured almost every parts of this slope. This characteristic is same as the landslide in Langidalur[2] with the estimated slope of 21°.

Landslide No. 8 (cf. 8a, 8b, 8c, 8d, 8n and 8m in Pl. III)

Early on the morning of 18th September, the author found big landslides on the south and north coasts of Reykjarfjördur, the east part of the huge north-western peninsula in Iceland. Southern one was not covered with snow yet and he could examine so many large boulders in the debris comparing their size with the electric pile. The principal points of the stereographs 8a, 8b are as follows: 1) the development of talus is well on the right half, but is poor on the left, which is largely covered with slided debris. 2) The volume of debris seems too large compared the cliff's height. If it is so, the origin of debris will be questionable. Plate III-8d was taken to the south-west, showing dimly the north edge of Mt. Háafell (783 m) whose east valley Háafellsdalur might be considered as the origin of the questionable debris flow, judging from the map reading. Plate III-8c was taken towards the east, and shows the inclination of the talus on the right, that of the debris

flow on the left. Plate III-8n is the estimated landslide on the north coast entirely covered with snow, which is guessed by the disturbed net pattern of white and gray.

Landslide No. 9 (cf. 9a, 9b and 9m in Pl. IV)

The author became aware of the landslide on the familiar south side of the plateau Esja, after he had come back to Reykjavik from this journey. The stereographs were taken from Reykjavik at a distance of 15 km with about 150 m base line through 100 mm lens. The topography of this landslide is similar to that of Köldukinnarhólar in Langadalsfjall mentioned above[2].

Landslide No. 10 (cf. 10 in Pl. IV and Fig. 3)

This is located immediately to the west of the famous fishing industry village Siglufjördur, north Iceland. In other words, the village is located on the debris flow of the landslide. The hollow between the two mountainsides is the landslide in the photograph 10 in Pl. IV, and the flat place where some chimneys and buildings are seen is not a bottom of U-valley but a debris flow tongue as is shown in Fig. 3.

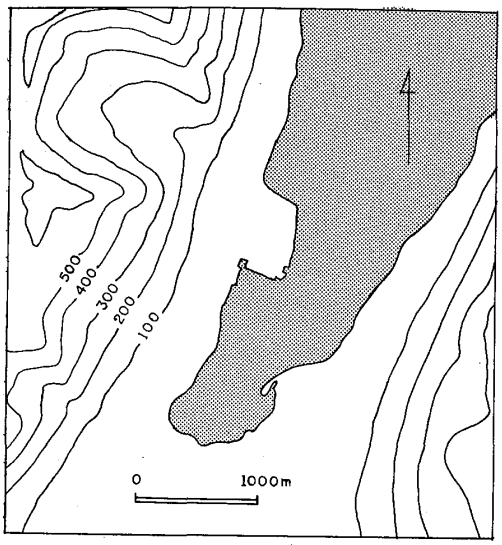

Fig. 3. A topographic map of Siglufjördur showing a big landslide and a flat tongue on its foot.

The mountainsides of Siglufjördur have an interesting asymmetrical gully topography, on which he has written another paper.[6]

Landslide No. 11 (cf. 11 and 11m in Pl. IV)

The co-existence of the landslide No. 10 with the flat tongue in the fjörd guided the author to a solution of his prolonged question why a sand-spit exists in Isafjördur, which is engraved impressively on the 25 krónur banknote. Consulting the photograph 11 taken by A. P. and the map 11 m of 1 : 50,000, he concluded that this sand-spit-like topography will not be a sand-spit but a partly submerged debris flow from a huge hollow of landslide, even if its root is adjacent to the opposite coast of the landslide. This opposition might occur if the velocity of the debris flow were so high.

Landslide No. 12 (cf. 12 and 12m in Pl. IV)

He found a similar topography at Flateyri near Isafjördur. There is a hollow of about 1 km width and depth on the mountainside, and also a sand-spit-like topography on the probable axis of the landslide, as is shown in the map 12m.

More such examples should be collected to establish this hypothesis, and the field survey is also essential, but both are almost impossible for the author now.

4. Several values of landslide elements

To compare these big postglacial landslides with the small one of the present age, the author calculated several elements of landslide tentatively as is shown in Table 1. The meaning of symbols are illustrated in Fig. 4 and as follows:

W: Width, H: Height, T: Thickness, V: Volume = W×H×T, L+T: Total flowing distance, θ: Estimated inclination of the cliff before landslide, read from adjacent contour, θ': Inclination of the slided residual cliff at present, read from

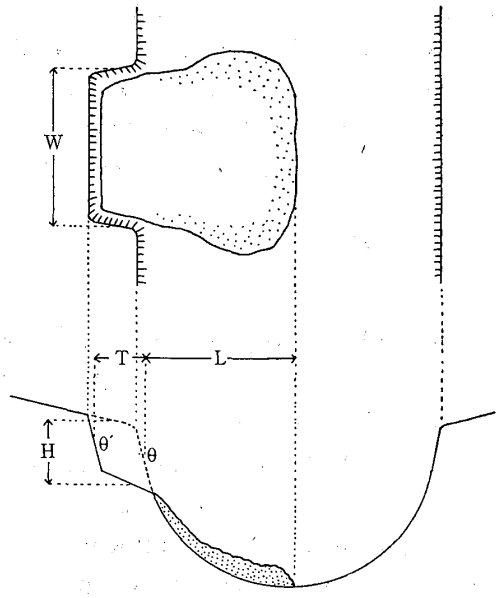

Fig. 4. Definition of some elements of the big landslide.

Table 1. Several values of landslide elements in Iceland.

No. of the landslides		W(km)	H(km)	T(km)	V(km³)	L+T(km)	θ(°)	θ'(°)	map used
1	North	2.1	0.3	0.9	0.57	5.5	37	36	M
	South	1.1	0.3	0.7	0.23	6.2	37	39	10
2		3.5	0.5	0.5	0.88	2.7	39	48	10
3		1.8	0.5	0.7	0.63	2.7	29	36	M
4		—	—	—	—	—	26	—	10
5		1.2	0.4	0.2	0.10	1.7	34	46	M
6		3.4	0.3	—	—	—	22	45	10
7		3.9	0.5	0.3	0.59	1.6	22	45	M
8		1.5	—	—	—	1.0	—	—	25
9		2.6	0.3	0.8	0.62	3.2	34	45	M
10		1.2	0.3	0.9	0.32	2.5	27	34	M
11		1.4	0.3	0.7	0.29	4.5	29	36	5
12		1.6	0.3	1.7	0.82	5.5	34	34	5
La.	North	1.1	0.2	0.3	0.07	3.5	27	31	M
	South	1.5	0.3	0.3	0.14	2.9	21	40	M
Total		27.9	4.5	8.0	5.24	43.5	418	514	
Sample		14	13	12	12	13	14	13	
Mean		1.99	0.35	0.67	0.437	3.35	29.9	39.5	

contour.

5 : 1/50,000 map, 10 : 1/100,000 map, 25 : 1/250,000 map, M : Another 1/50,000 map read in Iceland.

These values show us the enormous scale of the landslide compared with that of the present one, but the unexpected small value of the estimated inclination θ of U-valley cliff before landslide took place may throw doubt upon a word "oversteeping" (P. 86), since there are countless steeper mountains that do not give birth to landslides over the world, even in the basalt region.

5. Summary

1) The author introduced the twelve postglacial big landslides observed by him with five sets of stereographs, twelve photographs, twelve maps and one table.

2) The table consists of seven elements of landslide. Their mean values are as follows :

Width (W) : 1.99 km
Height (H) : 0.35 km
Thickness (T) : 0.67 km
Volume (V) : 0.437 km^3
Flowed distance (L+T) : 3.35 km
Estimated inclination of the cliff before landslide (θ) : 29.9°
Inclination of the slided residual cliff at present (θ') : 39.5°

The unexpected small value of θ will suggest some problems.

3) He infers that the gentle slope, and flat tongue or sand-spit-like morphology in some fjord of Iceland had been formed by these big landslides because of their co-existence, which will be illustrated by Plate IV-10, 11, 11m, 12, 12m and Fig. 3.

Literature

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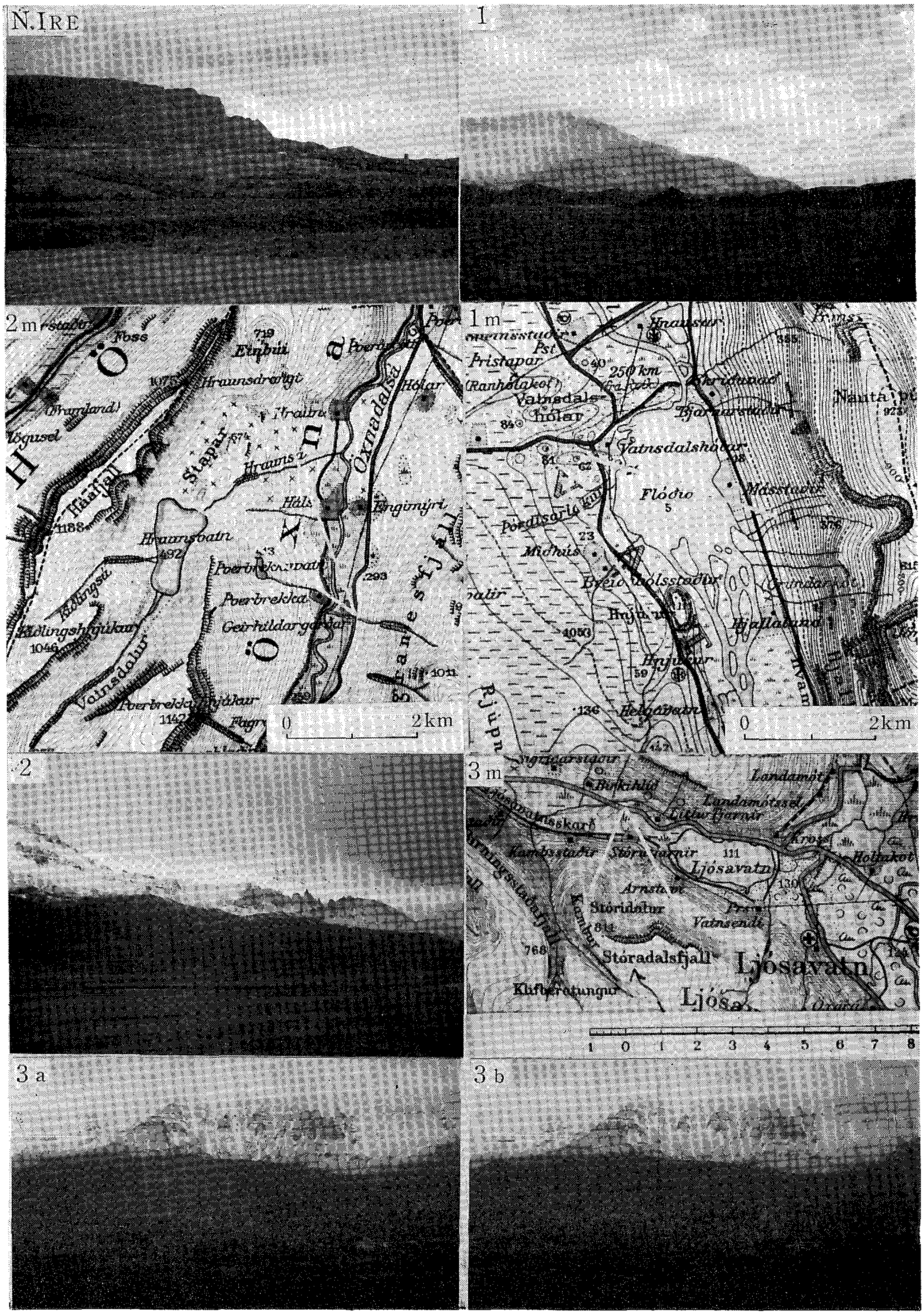
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Vatnsdalur
Vatnsdalshólar
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Másstaðir
Ljósavatn
Stóradalsfjall
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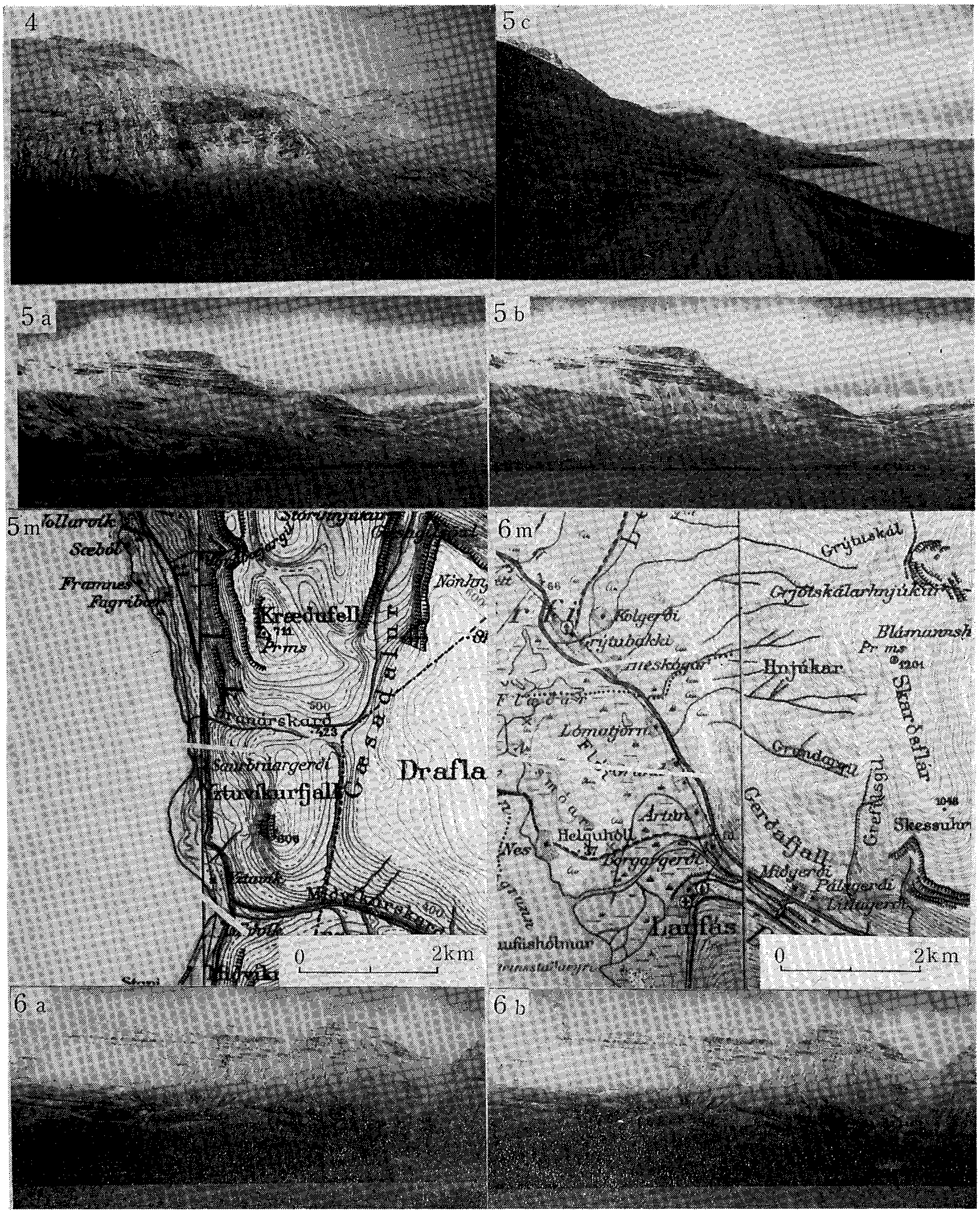
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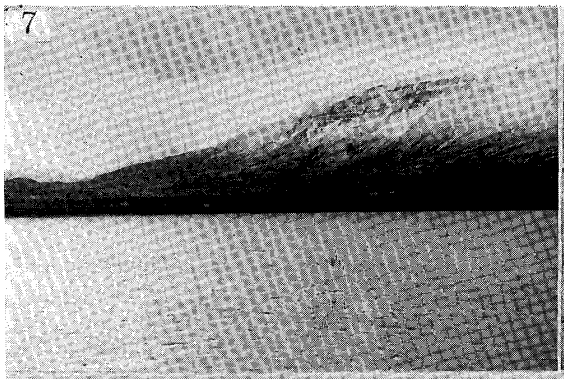
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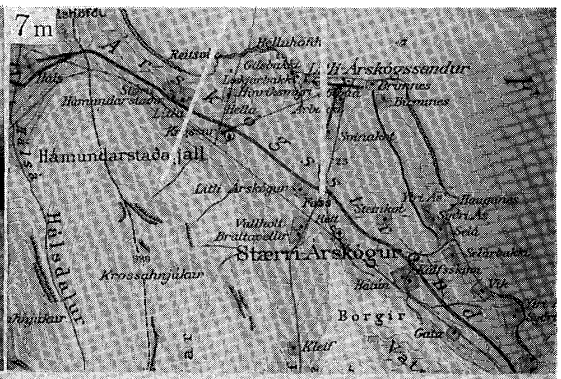
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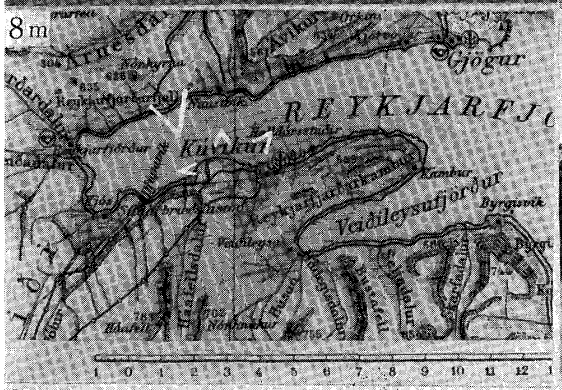
8 m
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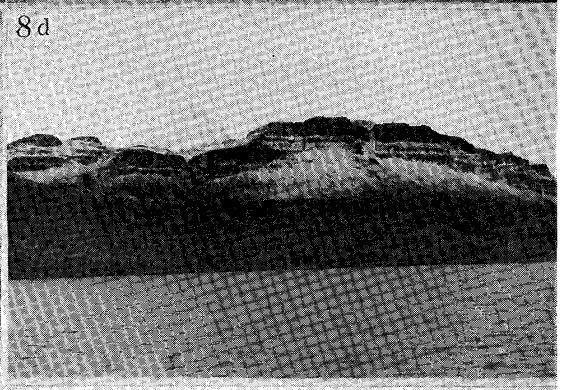
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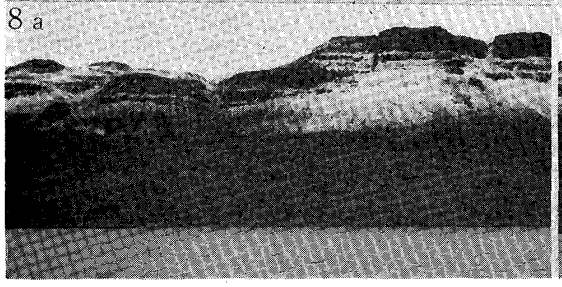
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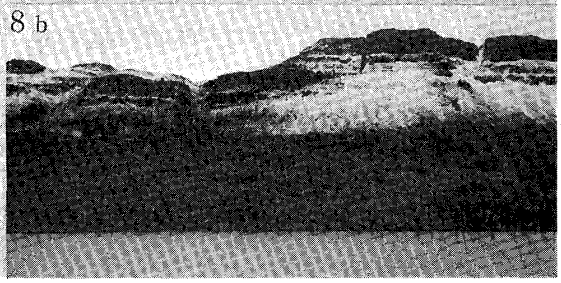
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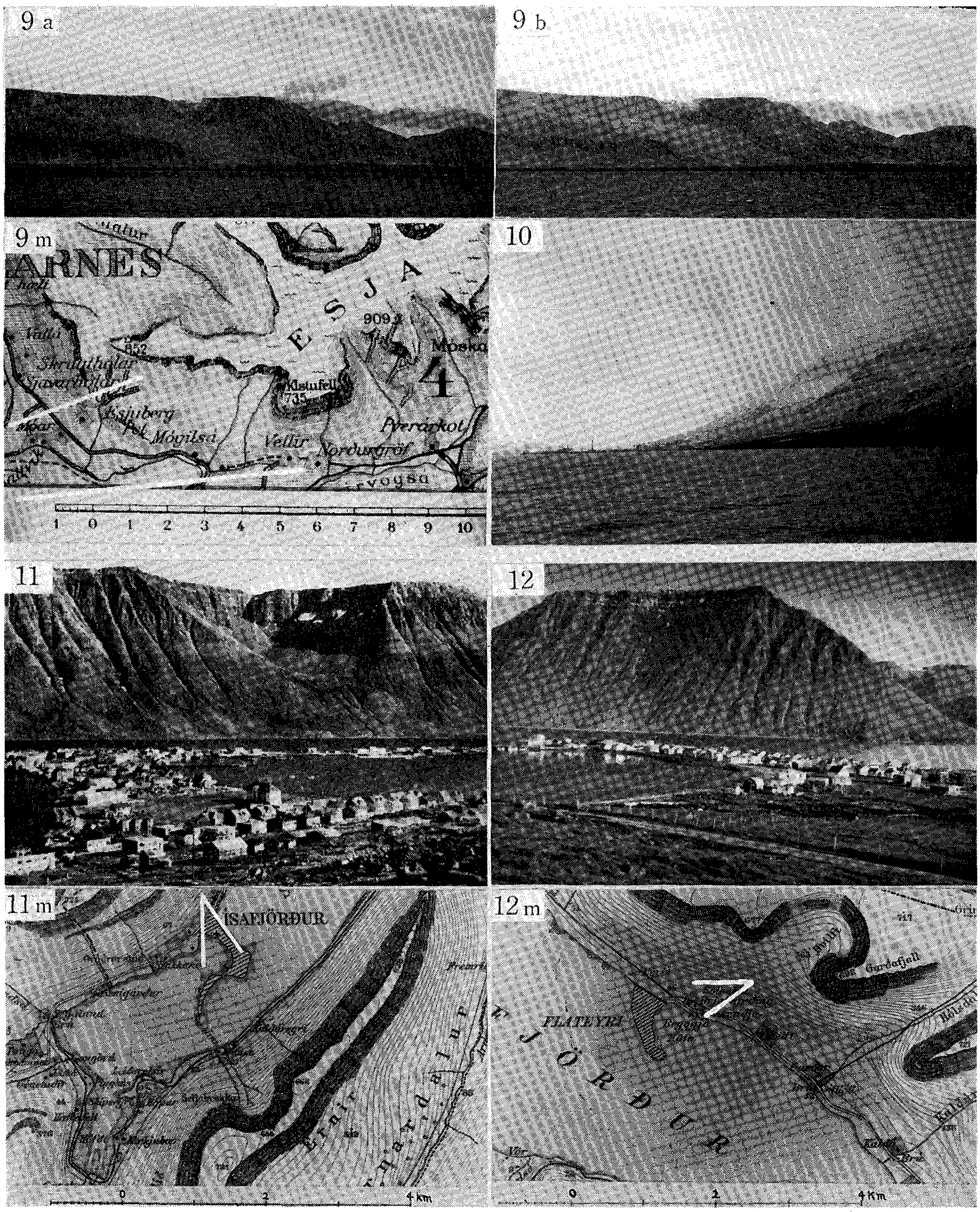
9 a
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