SOME GEOLOGICAL PROBLEMS INVOLVED IN THE HYDRO-ELECTRIC DEVELOPMENT OF THE JÖKULSÁ Á FJÖLLUM, ICELAND

A Report to The State Electricity Authority

by

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The State Electricity Authority Reykjavik, January 1959

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CONTENTS

SUMMARY

The following paper deals with some of the main geological problems involved in the hydro-electric development of the glacier river Jökulsá á Fjöllum. The paper is based on the author's geological studies in the Jökulsá and Mývatn areas in the 1950ies.

One of the main geological problem met with in these areas is the risk of leakage from proposed storage lakes, both through post-glacial lava flows and through the bedrock. In order to elucidate this problem the author outlines briefly the geological history of the Jökulsá area (mainly the area between Mývatn and Jökulsá).

The drainage area of Jökulsá is mainly situated within the Palagonite tuff area and the main types of rock met with are: 1) interglacial basalt (dolerite) lavabeds with intercalated sedimentary layers. 2) subglacially formed palagonite tuffs and breccias. 3) postglacial lava flows. These types of rocks are shortly described and their genesis discussed. The Late glacial and Postglacial sediments are also described and a special attention is drawn to a 5 km long esker (Photos fig. 1-6), the Grænalág esker, situated SE of Eilífsvatn and ab. 9 km from the proposed damsite at Selfoss. The gravel and sand of this esker and another smaller esker farther eastwards will probably be the chief source of material for concrete aggregate needed for a dam at Selfoss.

A striking feature of the Jökulsá area, especially W of Jökulsá, is the great number of N-S running faults, joints, grabens and lavaproducing fissures. The main graben systems are shown on Pl. I. The age relation between the crater rows and grabens is discussed.

The geology of the area N of Skógarmannafjöll, which forms the water divide between Jökulsá and Laxá, was especially studied with regard to the risk of leakage from a storage area E of that divide. The divide area is covered by postglacial lavaflows and the author tries to answer the question whether or not there are many lava flows superimposed one on another in this area. He also tries to establish the age of the lavaflows and to estimate roughly their total thickness. The risk of leakage is discussed without leading to any definite conclusion. Pl. II is a geological map of this water divide area and Pl. V a tentative E-W profile through the area.

The possibility of forming a storage area by the erection of dams farther westwards, between Hvannfell and Lúdent and between Lúdent, Strandarholt and Námafjall, is also discussed from a geological point of view and a geological map of the area is presented (Pl. III).

A long chapter is dedicated to a more close study of the geology of the Dettifoss area. The bedrock units met with there, both the basalt (dolerite) layers and the sedimentary layers are described one for one both geologically and from an engineering

standpoint, and so are also the bedrock units in the immediate vicinity of the waterfalls Réttarfoss and Vígabergsfoss. Pl. VI is a geological map of the Dettifoss area and Pls. VII-XI are geological sections through the Jökulsá Canyon.

Studies of tephra layers (volcanic ash layers) in soil profiles (Pl. XII) have thrown a new light on the age and genesis of Ásbyrgi and the northernmost part of the Jökulsá Canyon. The famous Ásbyrgi is not, as formerly assumed, a tectonic depression but an erosional feature. It is a former river bed of Jökulsá (cf. the map on Pl. XIII). And the tephrochronological studies reveal that Jökulsá has flowed through Ásbyrgi until about 2 500 years ago and consequently it must have eroded the northernmost part of the Jökulsá Canyon during the last 2 500 years. The author´s studies lead him to the conclusion that a tunnel from Réttarfoss to an outlet near Vestara Land would probably have to be lined to a considerable degree to make it resistant enough against erosion.

The risk of leakage through the bedrock from a planned storage area S of Selfoss is considered. Such a leakage is mainly to be expected along the N-S running graben systems. Numerous springs in Hólmatungur and near the mouth of Hafragil show that the risk of such a leakage exists and the author stresses the necessity of measuring the discharge of these springs. He does not think it likely that the leakage will increase catastrophically after the formation of a storage lake.

The geology of the proposed damsite at Núpaskot and Miðfell is shortly discussed and the geology of the damsites is shown somewhat schematized on Pls. XIV and XV.

The last chapter deals with the risk of glacier bursts (Icel. jökulhlaups) in Jökulsá á Fjöllum. Such glacier bursts are known to have occurred in the late 17th and early 18th centuries, the last big one in Aug. 1729. The author´s rough estimate is that none of the floods had a discharge higher than 15 000 m^3/sec and that the total run off in one day has hardly been higher than 1 km^3 in any of these hlaups.

INTRODUCTION

The following account is mainly limited to the geology and geological history of those parts of the drainage area of Jökulsá á Fjöllum, that are of interest in connection with the harnessing of the river. It deals mainly with the geology of projected or possible dam-sites, and storage areas such as the Dettifoss-Selfoss area, the Jökulsá Canyon, dam-sites at Núpaskot and between Lambafjall and Miðfjöll and the resulting storage area (designated Storage Area II in the following) and the big storage area (Storage Area I) that would result from a high dam at Selfoss. The geology of the last named area is of special interest with regard to the risk of leakage of the storage water from that area.

THE GEOLOGICAL HISTORY OF THE JÖKULSÁ AREA

In the following an attempt will be made to outline briefly the geological history of the Jökulsá area mainly limited to those parts that are mentioned in the introduction.

The drainage area of Jökulsá á Fjöllum is on the whole situated within the young volcanic (pleistocene and postglacial) belt that extends from coast to coast from northernmost Melrakkaslétta to Eyjafjöll. We find here mainly 3 types of rock:

A. Interglacial dolerites.
B. Subglacially formed palagonite tuffs and breccias.
C. Postglacial basalt-lava flows.

INTERGLACIAL ROCKS

Where postglacial lava has not been poured out the bedrock of the Jökulsá area between the tuff ridges consists mainly of doleritic lava flows. So does for instance the riverbed of Jökulsá between Hrossaborg and Axarfjörður. Most of the doleritic lavaflows visible in the area belong certainly to the Last Interglacial (Riss-Würm or Sangamon) that according to most geologists lasted from ab. 180 000 to ab. 120 000 years before the present, but which according to some recent theories, is considerably younger (150 000 - 80 000). Only in the Jökulsá Canyon one finds lavabeds that may belong to the last but one Interglacial (Mindel-Riss or Yarmouth). The sources of the dolerite beds are, at least partly, interglacial shield volcanoes such as Grjótháls W of Dettifoss, but some of the flows may be flows from fissures. The dolerites at Jökulsá are on the whole a little more finegrained than the Reykjavík dolerite. Intercalated between the dolerite beds are sedimentary layers of different origin, such as tephra layers, wind- and water transported material and rock weathered in situ. The lithification of these sediments is on the whole little advanced and thus their permeability is rather high.

SUBGLACIAL VOLCANIC ROCKS

During the Last Glacial (Würm or Wisconsin) that lasted from ab. 120 000 to ab. 20 000 years before the present (acc. to some recent theories from ab. 80 000 - ab. 12 000), the volcanic activity of the Last Interglacial continued, but because of the influence of the covering inland ice this activity produced other type of products and resulted in other landforms than the interglacial volcanism. The landforms built up by this volcanism are mainly of two types :

1. Long ridges and cone-rows built up mainly of palagonite tuffs, breccias and globular basalt.

2. Tablemountains, i.e. more or less esodiametric socles of palagonite tuffs, breccias and globular basalt, capped by basalt lava flows.

The ridges are the results of subglacial linear eruptions and correspond to the postglacial crater rows such as Þrengsla-borgir, - Lúdentsborgir or the Laki crater row. The difference is that while the subaerial fissure eruptions mainly produce lava the subglacial ones mainly produced different types of palagonite breccias with lava nodules and occasionally beds of pillow lava.

When studying the postglacial linear eruptions in Iceland, e.g. in the Mývatn area, we find that one and the same fissure very seldom pours out lava more than once. This does not always mean that a long fissure was formed in its entire length in a single eruption, only that each part of the fissure has erupted only once (Hekla is the most famous exception). The same seems to have been the case with at least most of the subglacial fissure eruptions. Many of the subglacial ridges, such as Austari-Skógarmannafjöll, the cone row between Möðrudalur and Víðidalur, and Jarlhettur, are in the author's opinion monegenetic. Other ridges, such as Námafjall, are clearly built up by eruptions from two or more fissures running parallel and near each other. It is most likely that they did not erupt at the same time and each of them only once.

The socles of the tablemountains are built up mainly in the same way as the tuff ridges, but according to an explanation first suggested by G. Kjartansson (1943) as an alternative hypothesis to Recks tectonic theory, and later detailed independently by Mathews (1947) and van Bemmelen and Rutten (1955), the lavaflows that cap the tuff socles were formed when the socles had been built up so high that the lava eruptions were no longer subglacial or subaqvatic but subaeric. For details of this explanation, which the author fully accepts in principle, although not in all details as presented by van Bemmelen-Rutten, it is sufficient to refer to the comprehensive work: Tablemountains in Northern Iceland (Leiden 1955).
The tablemountains are thus mainly constructive and not tectonic as assumed by Reck, Nielsen and many other geologists.
They are the result of central eruptions and in the author's opinion their uniform chemical composition suggests that they are not the result of mixed central eruptions and thus do not correspond to postglacially active volcanoes such as Öræfajökull

and Snæfellsjökull, that presumably are fed by more or less isolated magma pockets. They are most likely directly corresponding to the postglacial shield volcanoes such as Trölladyngja and Kollótta dyngja, and are, like the tuff ridges and the postglacial crater rows, fed by a rather deep lying, uniform basalt magma. Their height corresponds roughly to that of the postglacial shield volcanoes and has an upper limit above which the magma table could not be raised. The explanation why the ridges did not reach a comparable height is simply the above mentioned fact that each fissure erupted only once.

POSTGLACIAL ROCKS

The volcanic activity that built up the tablemountains and tuffbreccia ridges of the Ódáðahraun area during the Würm Glacial has continued without interuption into the Postglacial Time. One proof of this are the Dalfjall-Námafjall ridges. There it is really difficult to state where the subglacial activity ends and the postglacial one begins. And the postglacial building up of shieldvolcanoes are, as said before, a direct continuation of the activity that built up the tablemountains. The postglacial fissures and shield volcanoes have both produced extensive lava flows within the area in question. Tephrochronological studies show, however, that the shield volcanic activity has ceased at least 3 000 years before the present while the youngest lava fissure, Nýjuborgir in Sveinagjá, erupted in 1875. The postglacial lava flows will be closer dealt with in later chapters.

Besides the lava producing volcanoes, explosion volcanoes, or volcanoes of Hverfjall type are found between Mývatn and Jökulsá. The youngest of these volcanoes is undoubtedly Hverfjall that has been proved to be younger than the light tephra layer H_3 [1] and thus hardly more than 2 500 years old.

Lúdent is considerably older than H_5 and probably very early

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1) In a previous paper, Laxárgljúfur and Laxárhraun, the author has dealt with the light rhyolitic tephra layers that occur in soil profiles in N and NE Iceland and illustrated how useful they are for geological datings. It is sufficient to refer to this paper, adding that since that paper was published three of the prehistoric Hekla layers, i.e. H_3, H_4 and H_5 have been dated with the C^{14} method.

The age of H_5 (dated by the Carbon-14 Dating Laboratory in Copenhagen) is

	6320 ± 190	years
	6510 ± 250	"
Av.	6410 ± 170	years

The age of H_4 (dated by the same laboratory) is

	4000 ± 150	years
	3650 ± 150	"
Av.	3830 ± 120	years

The age of H_3 (dated by the Geochronometric Laboratory in Yale) is 2712 ± 130 years.

postglacial. The same is the case with Hrossaborg. T. Einarsson was the first one to express the opinion that this volcano has been overridden and eroded by the inland ice. The present author has in his paper on Laxárgljúfur expressed the opinion that Hrossaborg was formed during the Alleröd Time (ab. 12 000 - ab. 10 800 before the present). On closer study he has found that its E and W flanks have also been eroded by rivers the beds of which are clearly visible on aerial photos. It is most likely that these rivers were meltwater rivers from the receding inland ice.

POSTGLACIAL SEDIMENTS

The late glacial and postglacial sediments that cover the bedrock of the area dealt with in this paper are mainly glacial and glacifluvial. Along Jökulsá especially on its E side, the ground moraine or glacial drift (till) has been washed away, but the main part of the Mývatn-Jökulsá area that is not covered by postglacial lava has a rather thick cover of glacial drift that certainly is to be found also beneath the postglacial lava. On the whole the drift is rich in big angular blocks. This seems to be typical for drift on dolerite (cf. the Reykjavík area). Typical glacial drift of this type may be seen on both sides of the Grímsstaðir-Reykjahlíð road W of the Jökulsá bridge. Presumably the lavaflows farther west rest on the same type of drift.

Between Lake Eilífsvatn and the Dettifoss area extends a broad belt of terminal moraines and glacifluvial deposits indicating a stagnation of the inland ice retreat. In the paper on Laxárgljúfur and Laxárhraun the author showed that during the Alleröd Period (ab. 12 000 - ab. 10 800 before the present) the inland ice receded from the Mývatn area and accordingly also from the plains between Mývatn and Jökulsá. During the following period, the cold Second Dryas Period, lasting from ab. 10 800 to ab. 10 000 before the present, the ice advanced again and became stationary for hundreds of years, and during this stage of stagnation which the author has named the Hólkot Stage the above mentioned deposits were formed. They belong to the same stage as the terminal moraines and comes running obliquely across Reykjadalur between Breiðamýri and Laugar, and the system of moraines and sandur plains between Reykjahlíð and Hlíðarfjall.

At the end of the Second Dryas Period the climate became rather suddenly warmer and the icefront began receding again and then seems to have dammed up a lake in the triangle between Hágöng, Eilífur and Grjóthals. At its maximum this lake may have covered a considerable area SE of the present Eilífsvatn i.e. the present Grænalág, including the basin of the present lake. There are, however, no signs of it having had an outlet towards NNW, between Eilífur and Hrútafjöll, but the bed of such an outlet might now be covered by postglacial lava. Presumably the lake had its outlet towards E, between the ice margin and Grjóthals.

THE GRÆNALÁG ESKER

An interesting remnant of this lake is an esker (swedish "rullstensås") SE of Eilífsvatn (cf. map on Pl. I). This is by far the longest esker the author has seen in Iceland, where eskers on the whole are rare. (It may be mentioned here that in Aðaldalur the autoroad between Höskuldsstaðir and Hólkot follows a typical esker with dead ice lakes on both sides). The esker SE of Eilífsvatn (in the following named the Grænalág esker) runs from a point about 1.2 km SE of the lake towards SE through Grænalág and the graben between Vestari Brekka and Austari Brekka and is at least 5 km in length (Figs. 1-3). In the graben between Austari Brekka and Vestari Brekka it reaches its max. relative height, about 15 m, and is there more than 20 m broad at the base, its crest covered by head-size blocks and coarse gravel. Further NW-wards the esker is sinuous in a typical way (Figs. 3 and 5) and the material on its surface is a rather fine gravel with coarse sand beneath (Fig. 3). Presumably its inner structure is that of an ordinary esker. A considerably smaller esker is situated a short distance W of the Sveinar graben, (cf. the map on Pl. I). This esker is possibly an engorged esker (swedish "slukås"). A typical section of an esker may be studied on the right side of the autoroad when driving from Reykjahlíð towards Grímsstaðir in Mývatnssveit. It is situated a short distance NE of Reynihlíð. This section (Fig. 4 and 6) shows the typical crossbedding and stratification of the material and a tendency of the material of the sides to lie parallel to the side slopes.

The most common mode of origin of eskers is in tunnels at the base of a nearly stagnant glacier. Usually these tunnels are parallel to the latest direction of the glacier flow. In these tunnels meltwater streams flowed under hydrostatic pressure and emerged in water at the glacier margin, depositing their load of sand and gravel outside the tunnel. Presumably the downstream parts of the eskers were built first and they were then gradually extended in the upstream direction. The Grænalág esker was probably formed when the inland ice receded towards S from its position during the Hólkot Stage. A tunnel river then emerged in the abovementioned ice dammed lake. At that time the pass between Eilífur and Hágöng was possibly blocked by local glaciation.

Where eskers are common, such as in Fennoscandia and Canada, they are the chief sources of material for road surfacing and concrete aggregate. Often their material is excellent for these purposes. The occurrence of such a big esker at a distance of only about 9 km from a dam site at Selfoss may therefore be of a great economic value. A closer study of the Grænalág esker, both of its constituents and its extension and volume is therefore necessary. What has been said here is mainly to point out the existence of this esker.

As already mentioned a belt of moraines and glacifluvial deposits stretches from Eilífsvatn eastwards towards Dettifoss. It is possible that suitable material for concrete filling may be found within this belt, besides in the eskers. The surface layer of the moraines near Dettifoss is rich in big blocks. Further study will reveal the type of the moraine, whether it is clayish, sandy etc. It gives the impression of being on the whole hardened and rather difficult to work.

DIASTROPHISM AND TECTONIC FEATURES

One of the most striking features of the northern part of the Ódáðahraun area (including the Mývatn area) and its continuation towards N is the very great number of N-S running faults, fissures and graben strips.

On the map on Pl. I have been drawn the main systems of grabens in the Mývatn-Jökulsá area, E of the water divide. These are: The Austari Brekka - Vestari Brekka graben or Kræðuborgir graben, the Sveinar graben, Sveinagjá graben and Fjallagjá graben. West of this graben system is one big system of faults and grabens that runs from the Mývatn area over Leirhnúkur and Gjástykki to Kelduhverfi.

Characteristic for these grabens is the small width in relation to the length of the graben system. Fissures and fault lines with a distance of few hundred metres may run parallel tens of kilometres. The vertical displacement seldom exceeds 20 m and is usually 5-15 m. The Sveinar graben is at least 30 km in length but its average width is only 0.6 km and the vertical displacement 2-20 m. The Austari Brekka - Vestari Brekka graben is 1.5-2.0 km wide. Within the main faults that outline a graben the down-faulted area is often split up by many parallel rifts. These are not shown on the map. Between the grabens, one also finds long rifts without displacement running parallel to the grabens. One such rift (not shown on the map) is W of the Sveinar graben. Some grabens are partly limited by step faults.

THE AGE RELATION BETWEEN GRABENS AND CRATER ROWS

When studying the map on Pl. I we find that each of the graben system contains one and more crater rows. Within the Kræðuborgir graben are the big Kræðuborgir crater row (cf. also the map on Pl. II) and farther N, SE of Grænavatn, the tiny Grænalág crater row. Within the Sveinar graben is (partly) the Sveinar-Kvensöðull crater row, probably the longest one in Iceland, and the Rauðuborgir crater row. Within the Sveinagjá graben system are the Nýjahraun craters of 1875 and the miniature crater row E of Dettifoss. Also in the Fjallagjá graben there are craters.

When trying to find the age of the grabens it is of importance to study the time relation between them and the lava flows produced by the crater rows within them as the age of these lava flows can often be roughly determined - in some cases even quite exactly - by means of tephrochronology or in other ways, for instance by C^{14} dating, in case the lava has flowed over vegetation-covered ground.

With regard to the crater rows and their lavaflows in relation to the grabens we have mainly three types of sections of the grabens as shown on Pl. IV.

Type a: Such a section means that either no crater row has been formed within the graben or that its lava does not cover the graben in its entire length. Grabens without a crater row are found in the Mývatn area, for instance N of Lake Sandvatn and some of the grabens between Sveinagjá and Jökulsá are of the same type. More common is, however, that a crater row found within a graben does not follow that graben in its entire length and its lavaflows cover only a part of the graben. So is for instance the graben between Austari Brekka and Vestari Brekka a continuation towards N of a graben system that extends southwards over Vestari Skógarmannafjöll. Within that graben is the Kræðuborgir crater row, but the lava from that crater row covers only the southernmost part of the graben between Austari Brekka and Vestari Brekka. A section through that graben farther N would thus be of type a.

Type b: In this case the course of the lava flow has obviously been directed by the graben and the graben must thus have existed when the lava flowed through the section. In that case the graben must either be older than the eruption or have been formed during the eruption, but before the lava covered the section, that is, it may have existed before the eruption started and must have existed before it ended although it may have deepened after the eruption had ceased. Judging from descriptions of eye witnesses the Sveinagjá graben did partly exist before the 1875-eruption and was partly formed during that eruption. The famous Laki crater row from 1873 is at least partly (N of Mt. Laki, acc. to photos taken by G. Kjartansson from Laki and aerial photos taken by the author) within a shallow graben that seems to have been formed during the eruption.

Type c: In this case the graben was formed or at least deepened either during or after the eruption.

In my opinion most of the grabens containing crater rows have formed or at least deepened in connection with the formation of these crater rows and as a result of their eruptions (mainly outpouring of lava). They may thus be classified as linear collapse calderas corresponding to the more or less circular collapse calderas formed in connection with many of the eruptions from shield volcanoes. But it seems also clear that some of the grabens now containing crater rows existed, at least partly, before the fissures within them opened and poured out lava. We can take as an example the longest of the crater rows (or row of crater rows), the Randarhólar-Sveinar row, that has a length of at least 30 km. W of Jökulsá it follows the abovementioned Sveinar graben, that runs in nearly straight N-S direction from Hafragil to Rauðuborgir. Within the graben are the crater rows Rauðuborgir, Sveinar, Ytri-Sveinar and the craters at Hafragil (Hafragil itself follows the western fault of this graben). On the eastern side of Jökulsá Canyon the graben continues in the same direction and runs through Sauðafell. But the Randarhólar - Kvensöðull crater row on the E side of

Jökulsá, that is a direct continuation of the crater row on the W side, does not follow the graben but has a more easterly direction, or towards NNE. It seems most probable that the Sveinar graben existed before the fissure eruption started and that the eruption started in the fissure E of Jökulsá. That fissure was then gradually prolonged towards SSW until it met the graben, from where it changed direction and followed the graben towards S. The graben so to say captured the eruption fissure. But we have also a clear evidence of the graben having deepened considerably after the beginning of the fissure eruption as, both E of Hafragil and S of the jeep track that crosses the graben farther south, transversal sections of the graben are of the c-type on Pl. IV. This deepening was in all probability connected with the eruption. E of Jökulsá, at Randarhólar, the author has measured soil profiles on the lava produced by the crater row. This lava is so much older than H_4 that its minimum age is hardly less than 6 000 years and it may be a lot higher. Thus it seems most likely that the fault lines of the Sveinar graben-system have not been active for at least 6 000 years.

As to the age of the Kræðuborgir graben-system it is, at least partly, older than the lavafield Búrfellshraun (outpoured from Kræðuborgir), that is ab. 2 000 years old (cf. next chapter), but this graben-system is also, at least partly, younger than the above mentioned Grænalág esker, as the fault lines have effected the esker after its formation. Consequently this graben-system was partly formed later than 10 000 years and earlier than 2 000 years before the present.

Nothing can as yet be said with certainty about the age of the Fjallagjá graben system, but in the authors opinion it is likely that it is, like Hrossaborg, early postglacial. Hrossaborg is, however, not situated within this graben, but just E of it.
The youngest diastrophism in the area between Mývatn and Jökulsá is connected with the 1875-eruption of Sveinagjá. We don´t know of any other dislocations E of Námafjall-Hágöng in historical time, and as far as we know the dislocations connected with the Sveinagjá eruption did not affect any other graben-system. The small craters E of Selfoss are probably in the same graben-system as Sveinagjá but these craters are probably old.

THE GEOLOGY OF THE WATER-DIVIDE AREA N OF SKÓGARMANNAFJÖLL

One of the questions, and one of the most serious, that have arisen in connection with the planned harnessing of Jökulsá and forming of a great storage lake S of a dam near Selfoss is: How high can the level of that storage lake be raised without risk of the water escaping to the Mývatn area over the water divide between Jökulsá and Laxá where this divide is at its lowest. According to the topographical maps available the surface divide runs from Vestari Skógarmannafjöll towards NNE, following the Kræðuborgir crater row. The height figures on the water divide area differ on the Danish Geodetic Institute maps and the more recent U.S. Army Map Service maps, being considerably lower on the american maps, but to find out which figures are more correct is a geodetic problem beyond the scope of this paper. If there were no risk of leakage in the divide area the question of the highest possible storage lake level would be merely a topographical one. But actually the divide area is covered by postglacial lava in a zone reaching about 7 km northwards from Skógarmannafjöll. It was therefore considered necessary to study this area geologically. The question that must be answered is: How thick is the postglacial lava in the water divide area. This again leads to the question. Is the area covered by a single lava flow or by many flows superimposed one on another? The types of lava and the age of the flows are also of importance when discussing the risk of leakage.

The geological map of this area which accompanies this paper (Pl. II) is topographically based on the U.S. A.M.S. maps (sheets 6023 I - 6023 IV, Scale 1:50 000). The geology is based on the authors field studies, and the study of aerial photos. Some of the photos used were taken by the U.S. Air Force during the war and used for their topographical maps of the area. They were also used by van Bemmelen and M. Rutten for a geological photo-interpretation of the Ódáðahraun area, and the resulting map is published in their book on the table-mountains (Scale 1:200 000). This interesting map is rather incomplete as regards the area included in the author's map, and in some places incorrect as the american photos of this particular area are not very satisfactory. However, their map has been of some use. Besides the author has had access to some excellent aerial photos taken by Á. Böðvarsson (of the Icelandic Government Surveying Department). They do not however cover the SW part of the area, but that part of the map does not matter much from the point of view of studying the leakage problem.

The author's map is certainly far from correct in detail but it ought to be considerably more reliable than older maps.

THE GEOLOGICAL HISTORY OF THE WATER DIVIDE AREA

The geological history of the area included in the map on Pl. II is typical for most of the Mývatn-Jökulsá area. A brief outline of this history is therefore called for here.

Interglacial rocks are met with only on the N-most and NE-most part of the mapped area. They are dolerites covered by glacial drift, the thickness of which has not been measured but seems to be the normal one for the Mývatn-Jökulsá Area. The glacial drift covered dolerite is in all probability found under the postglacial lava cover on the plain and the drift may be somewhat thicker in the lowest part of the divide area than in the higher areas where it is now visible. The palagonitic areas on the map date back to the Last (Würm) Interglacial. Here we have one typical tablemountain, Búrfell, with lava cover and a circular summit crater. Short E of Búrfell is a long system of tuff ridges, Vestari Skógarmannafjöll, the topography of which indicates that they are composite, i.e. built up by two parallel running fissures. The two tuff breccia peaks protruding from the shield volcanic lavas a short distance N of the summit crater of Ketildyngja are probably built up on the same two fissures that built up Vestari Skógarmannafjöll, and the two ridges WNW of Taglabunga are on the eastern fissure. Austari Skógarmannafjöll are a single fissure ridge.

Outside the above mentioned tuff ridges, the palagonite tuff protrudes the dolerite lavas in few small spots. One such is visible S of the auto road between Austari Brekka and the Sveinar graben.

The oldest postglacial lava flows in the mapped ared are found SE of Austari Brekka. The author has not studied this area sufficiently to be able to discern between the individual flows that may be found there. Presumably the oldest flow is from the Rauðuborgir crater row, that belongs to the Randarhólar - Sveinar system and is thus in all probability more than 6 000 years old. But at least the SE part of the lava area E of the Sveinagjá lava is younger than the Rauðuborgir lava and comes either from Ketildyngja or some volcano farther towards SE. All these flows are mainly helluhraun (pahoe-hoe). How far westwards beneath the Kræðuborgir lava this flow does extend cannot be decided by field observations only. We don´t know with certainty the location of the sublava water divide. Presumably this water divide was not at all marked, as the terrain is so flat. The author´s guess is that this divide is to be found between Kræðuborgir and Rauðuborgir (cf. Pl. V) and that the Rauðuborgir lava does not extend much farther west than to this divide. But this lava flow is not the only one that may be expected underneath the Kræðuborgir lava (Búrfellshraun). From the shield volcano Ketildyngja enormous lavaflows have been poured out, the most extensive one being the flow a branch of which covers the area W of Búrfell. This lavaflow has been dealt with in the author´s paper Laxárgljúfur and Laxárhraun and is called Older Laxárhraun (Older Laxá lava). Another branch of this lava has flowed towards NW, down Seljahjallagil and spread over the Mývatn area (cf. map on Pl. III) and then flowed northwards through Laxárdalur and Aðaldalur to Skjálfandi. This flow is definitely considerably older than H_3 but a little younger than H_4. Its age is thus about 3 500 years. A broad stream of this lava has flowed towards N between Hvannfell and Búrfell (cf. map on Pl. III). We do not know how far northwards this stream extends but it is certain that it does nowhere emerge from underneath the margins of Búrfellshraun, which rather points against it having spread over a big area now covered by Búrfellshraun. The older Laxá lava is mainly helluhraun. Judging from the tephra layers in its soil cover the oldest lava that has flowed northwards between Austari and Vestari Skógarmannafjöll is also a branch of the same flow. It may possibly have joined the stream between Búrfell and Hvannfell somewhere N of Vestari Skógarmannafjöll, but in the author´s opinion it more likely did not.

Later two lava flows have followed the same valley between the two Skógarmannafjöll. The sources of these flows are Taglabunga and (or) Skuggadyngja, two parasite domes on the north flank of Ketildyngja (like Kilauea on Mauna Loa). Both these flows are thin and their extension underneath Búrfellshraun is in all probability very limited.

The extensive lava field Búrfellshraun has its source in the crater row Kræðuborgir, situated within a graben system that is a continuation towards S of the graben between Vestari Brekka and Austari Brekka and continues southwards through Vestari Skógarmannafjöll. Some of the craters are very big and the crater row has poured out a very great amount of lava. The eastern part of the flow (E of the crater row) is helluhraun, very even, so that it is rather easy to drive a jeep over it. The margin towards east is diffuse. The lava increases in thickness towards the crater row. E of the two southernmost of the main craters, big areas have collapsed and are surrounded by vertical walls, 5-7 m high. The lowest height figures on the american maps of this area refer to the bottom of these collapsed areas. Farther SE are small sinkholes up to 8 m deep. On the continuation towards N of the faultline that runs along Vestari Skógarmannafjöll are some features that look like craters on the aerial photos and are shown as such on the map on Pl. II. The author doesn't think that any lava was emitted from these craters and is not even certain if these features should be interpreted as craters. W of the Kræðuborgir crater row the Búrfell lava has a much more uneven surface than E of the row. Between Fálkaklettur and Kræðuborgir it is, however, mainly helluhraun although split by many rifts, farther westwards it gradually becomes more and more blocklava (apalhraun). Búrfellshraun is certainly younger than H3 and certainly prehistoric. A comparison between soil profiles on this lava and on Younger Laxárhraun - the age of which is very near 2 000 years according to Carbon^{14} datings - indicates that these two extensive lava flows are of about the same age. Consequently the age of Búrfellshraun is not far from 2 000 years.

The youngest lavaflow on the mapped area is the Sveinagjá lava flow or Nýjahraun from 1875. As previously hinted at this flow is interesting as being the only flow of this area the formation of which has been described by eye witnesses. The author refers to Thoroddsens compilation of these descriptions in Die Geschichte der isländischen Vulkane, pp. 230-240. The contemporary descriptions are more thoroughly related in Ó. Jónsson: Ódáðahraun II, pp. 246 ff. These descriptions prove i.a. that the eruption fissure gradually increased in length during the eruption. The crater row B on the map on Pl. II started erupting on Febr. 18th, the northernmost crater row (A) on March 19th and the craters C on April 4th. It is also of interest to note that the Sveinagjá eruption coincided with eruption in Askja 45 km farther south and during the same eruption smoke was emitted from the fissures in Gjástykki. Thus a zone about 100 km in length was activated at the same time.

Let us again turn to the cardinal question from the point of view of those who are interested in raising the storage water level south of the Selfoss dam as high as possible: How thick is the lava cover of the water divide area and how permeable. As to the first part of this question we state that at least three big lava flows may have reached that zone. Pl. V is a tentative schematic E-W section through the water divide area, but it must be stressed that we do not know the location of the water divide area and probably the divide is rather diffuse and may really be a rather broad zone. The thickness of the lava in the critical part of the water divide area, viz. the lowest part of that area, above which leakage could be expected, can be tentatively estimated at 15 $\pm$ 5 m, and this is of course only a very rough guess.

It is really impossible to tell how much water would leak through the lava and be drained to Mývatn if the storage level was raised above the sublava water divide. Nowhere in the lava covered area is the ground water level visible, not even in the deepest sinkholes, and no springs are found at the W margin of Búrfellshraun, as that margin rests on lava that also lets water through.

In the author's opinion it is possible that the leakage through the lava from a storage area E of the water divide to the Mývatn area might not prove serious, even if the storage lake level were raised let us say 5-10 m above the sub lava water divide. The experience from the Laxá Canyon rather supports this possibility. But at the same time it must be stressed that there is a risk that the leakage might prove serious. How great that risk is the author simply can not tell. As the northern-most part of the lava cover N of Skógarmannafjöll is probably rather thin. The line along which the lava would have to be tightened by grouting in case of serious leakage is hardly more than 3.5 km in length and may even prove shorter.

ON THE POSSIBILITY OF BUILDING STORAGE DAMS W OF THE WATER DIVIDE

Considering the risk of leakage through the lava covering the water divide area N of Skógarmannafjöll the question has arisen whether there is any possibility of stopping water flow to the Mývatn area by building dams approximately as shown on the map on Pl. III. Topographically this does not look impossible and therefore it was found desirable to present a geological map of this area too. This map is mainly based on the author's studies in this area in the early 1950's. The tephralayers made it possible to establish the sequence of the lava flows and determine their approximate age. On the map on Pl. III those flows, that are of about the same age or older than H_5, viz. 6 500 years or more, have been designated with small open rings. The flow shown with big open rings is the Older Laxárhraun, approx. age 3 500 years. Shaded (with dash lines) are flows younger than H_3, viz. younger than 2700 years. Historical flows are black. The two small tightly dotted lava flows just N of Lúdent are exceptional in being rather acid. They are both more than 5 000 years old.

Before the postglacial volcanic activity started in this area the surface water from the area now covered by Búrfellshraun W of the sublava water divide has flowed to the Mývatn basin somewhere between Strandarholt and northernmost Hvannfell, probably about midway between. Then the volcanic activity began. In its first stage the explosion crater Lúdent was formed and the pass between Strandarholt and Hvannfell was divided in two. Shortly after the formation of the lavaflows, that are designated by small open rings on the map, began. They were produced by series of fissure eruptions, we don't know how many. The lava is predominantly helluhraun and the flows are probably thin. Somewhat later, but certainly before the deposition of H_4, the crater Hraunbunga just N of Lúdent and the two small lavaflows flanking that crater were formed.

About 2000 years ago the fissures Þrengslaborgir - Lúdentsborgir opened and poured out an enormous lava flow, the Younger Laxá lava, that covers most of the Older Laxá lava and also the lavas between Lúdent and Strandarholt. At about the same time the lavafield Búrfellshraun was poured out from Kræðuborgir and reached the pass between Lúdentshæðir and Hvannfell.

In order to stop water flowing westwards between Námafjall and Hvannfell it would be necessary to build dams between Hvannfell and Lúdentshæðir (1 on the map on Pl. III), Hraunbunga and Strandarholt (2) and Strandarholt and Beinihryggur (3). If the lava flows were impermeable this would be well worth considering. The geological problem is how thick the lava cover on the dam sites is as one has to tighten (grout) that lava down to the bedrock. 1. Between Hvannfell and Lúdent there is a distance of about 1.5 km. There we have at least two lava flows, viz. Búrfellshraun, which is here mainly of apalhraun type, and beneath it at least one helluhraun flow. Besides it is possible that the Older Laxá lava is intercalated between Búrfellshraun, and the "old" helluhraun lava. The Laxá lava however emerges nowhere from underneath the Búrfell lava and the author regards it as likely that it was dammed up by the old lava E of the dam site as it is drawn on the map on Pl. III.

The thickness of Búrfellshraun at the dam site is roughly estimated about 10 m. The underlying helluhraun is probably thinner. The total thickness of lava can be roughly estimated 10-15 m.

2. The distance between Hraunbunga and Strandarholt is about 1 km. There we have at least two lava flows, viz. a branch of the younger Laxá lava from Lúdentsborgir, mainly of helluhraun type and at least one older flow. The younger Laxá lava is rather thin here, probably 6-8 m but how thick the underlying flow or flows are the author doesn't know. A very rough guess at the total thickness of lava at damsite 2 is 10-15 m.

3. Beneath dam 3 there is only one flow and a very thin one, hardly more than about 3 m in thickness.

In the area between dams 1 and 2, are the abovementioned volcanoes Lúdent and Hraunbunga. The tuff layers that build up Lúdent and the ridge SE of that volcano may let some water through, but in the author's opinion, that leakage would not be of any importance.

To the disadvantages of damming a storage lake so far westward as indicated here must be added that the stored lake would drown the lowermost part of the solfatara area E of Námafjall.

THE GEOLOGY OF THE DETTIFOSS AREA

In the following the riverbed and canyon of Jökulsá from about one km above Selfoss to just below Hafragilsfoss and a belt about 2 km broad on each side of the river is called the Dettifoss area. C.K. Willey (of the Harza Engineering Company, Chicago) has written a report on this area, and much of the geological information on this area, that is found in his report was given to him verbally by the author during our reconnaisance together. Consequently there is not much to be added regarding the geological units as such and in the following they will, for the sake of convenience, be designated, in the same way as by Willey. His words will also be quoted to some extent when describing single units. But first a short general description of the area shall be given (cf. the map Pl. VI).

As already mentioned the bedrock in this area is composed of doleritic lava beds with intercalated sedimentary layers. The dolerite layers are almost horizontal (dipping a little northwards) and have a tendency to solidify into a coarse vertical columnar structure which facilitates the formation of vertical canyon walls.

The canyon of Jökulsá between Selfoss and Hafragilsfoss has mainly been eroded in postglacial time. Details of the history of the canyon will not be entered into here, but attention should be drawn to how much influenced by the diastrophism the erosion has been. Before finding its present bed that is directed by the tectonic N-S lines, as evident when studying the present Dettifoss and Selfoss, the river has followed several other parallel lines of weakness and formed such features as Hafragil, that follows the W limit of the Sveinar graben, and the shorter canyon midway between Hafragil and Dettifoss.
In early Postglacial Time and at time when the river carried more water than now, because of the melting of the receding inland ice, it has washed away most of the originally thick cover of glacial drift and other moraines on both sides of the river, especially on the E side, and left the moraine undisturbed only on the highest ridges (cf. Pl. VII, Section II). Such ridges are e.g. found along the E side of the Sveinar graben W of Dettifoss, and there the moraine cover seems to be 6-8 m thick in places. The moraine-cover may also have been that thick in the graben W of these ridges but at least in the northernmost part of it, near Hafragil, this moraine has been washed away before the lava was poured out, but farther south a moraine layer may be expected beneath the lava.

A notable event in the postglacial history of the Dettifoss area was the eruption of the Sveinar-Kvensöðull fissure that crosses the present Jökulsá canyon just N of Hafragilsfoss (Fig. 7) and from there continues in NNE direction on the E side of the canyon. The crater row is shown in its entire length on the map on Pl. I. The lava has flowed from the fissure at various places but nowhere in big volume, and as far as can been seen this lava is everywhere pahoehoe lava and the lavabeds thin. The extension of the lava flow is also shown approximately on map on Pl. I and a part of it more detailed on the map on Pl. VI, but especially E of the canyon the mapping of the lava is far from accurate. As will be seen on the map on Pl. VI the lava does not cover entirely the bottom of the graben S of Hafragil. A small apron of this lava, which has originated in the fissure W of the present canyon is now found E of the river about 400 m N of Dettifoss (cf. Pl. VII). Certainly the canyon did not exist W of that apron when it was poured out, and probably it did not at that time extend as far south as the place where the fissure crosses the canyon, at least it must then have been much narrower at that place than now, otherwise we can not explain the craters situated on the very rim of the canyon on both sides (Fig. 7). The erosion of the river since the fissure erupted, has - on the E side of the canyon - exposed the feeder channel of the crater row down to the water level of the river (Figs. 9 and 10). From ab. 20 m beneath the bottom of the crater and downwards the channel is filled by a ab. 6 m thick dyke of dense columnar basalt (horizontal columns). Upwards the channel widens and there we have the columnar basalt of rosette structure gradually emerging into slaggy lava and higher up to scoriæ.

It is obvious that in the Dettifoss area the Sveinar graben has deepened considerably since the lava from the fissure was consolidated, as the lava is cut through by faults showing vertial displacements of some metres. Probably this happened near the end of the eruption or shortly after.

The tiny crater row on the E side of Jökulsá E of Selfoss, has previously been mentioned. The lava is of helluhraun type and has formed a very thin sheet.

As to the age of these two lava flows we only know that the minimum age of the lava from the Sveinar fissure E of Jökulsá is hardly less than 6 000 years, and it may well be several thousand years older. Probably the lava E of Selfoss is also very old.

THE BEDROCK UNITS IN THE DETTIFOSS AREA

Unit A. Some of the highest ridges between the river and the autoroad on the E side are capped by this layer. It also covers a considerable part of the area W of the cataracts S of Selfoss and forms the bottom of the old riverbed found there (cf. Pl. VII, Section I). Probably still another layer (A_0) is superimposed on this layer beneath the moraine cover of the ridges bordering the E side of the Sveinar graben, as assumed in Section II.

Unit A consists of a rahter fine grained dolerite that does not show any pronounced tendency to jointing or columnar structure. It rests directly on unit B without any sediment between.

Unit B is a massively jointed grey dolerite extending from about elevation 340-318 m. The columns are up to nearly 3 m across and frequently they are 2 m across. The surface exposure of this layer is characteristically light grey in colour. Its contact with the underlying unit C is very tight and nowhere where the author has been able to look at that contact has any sediment or a scoracieous contact been found. Upon the whole the layer is very uniform and dense but because of the above mentioned columnar structure and a horizontal jointing it has not been resistent to stream erosion. This erosion has plucked out many large blocks which are dispersed generally over the present surface exposure. Unit B forms the rapids of the river about 0.5 km upstream from Selfoss.

"Insofar as bearing strength is conserned, unit B will be very satisfactory for any height of concrete dam possibly to be considered. Where freshly exposed no excavation except for the removal of plucked or loose blocks will be required before placing concrete there on. It will, because of its jointed nature, permit excessive leakage when subjected to the head of water behind a dam and cement grouting will be required for cut-off purposes under all structures and, perhaps, for some distance beyond. This grouting would need to extend down to unit C throughout. Almost any consideration of a dam to utilize the head at Selfoss and Dettifoss would almost certainly be founded dominantly on Unit B". (Willey.)

Unit C extends from about elevation 318 to 307 m. It forms the waterfall Selfoss (Fig. 11) and the floor of the abandoned river bed between Hafragil and the canyon N of Dettifoss. This unit is easy to identify as it is rich in small felspar phenocrysts (diam. 2-5 mm). In its uppermost part it is vesicular and its surface looks so fresh (cf. Fig. 12), that when the author first saw it exposed he took it for postglacial lava. Clearly it has been covered by Unit B before any weathering or erosion had changed its surface. It rests unconformably on Unit D (cf. Fig. 13) and its thickness thus varies from place to place. It thins out towards N and the author has not observed it N of Hafragil. It is massively jointed columnarly and has also a tendency to horizontal jointing in the middle (cf. Fig. 13). It seems to be very resistant to erosion.

"From the engineering standpoint, Unit C is an exceptionally competent rock for load bearing, for watertightness and for tunneling". (Willey.)

Unit D is a sedimentary or sedentary layer that varies much both in thickness and structure. Where it is thickest, about 6 m, due W and E of Dettifoss (Figs. 14, 15 and 17) it is a breccia of angular blocks, that are not scoracious. They are up to more than 0.5 m in diam. and the layer is without any stratification and poorly cemented. On the whole it gets thinner towards S, but thickens locally (cf. Fig. 13). NW and E of Dettifoss it is seen to be capped by a 20 cm thick layer of black volcanic sand (Fig. 15). The undercutting and collapse of Unit C has formed Selfoss.

"From an engineering standpoint the principal defect of Unit D is its great permeability. However, no springs were observed issuing from it which probably attests to the great degree of unpermeability of Unit C. It is not now expected that it would be a factor in permitting leakage from any reservoir constructed upstream. It is not likely to be seriously waterbearing where encountered in any underground excavations, but would need to be sealed wherever any water conductor would pass through it". (Willey.)

Units E and F extend from about elevation 302 to 255 m . Together these units form Dettifoss because of the undercutting of unit G. E and F are of about the same thickness (E somewhat thicker) and consist of grey columnar dolerite. Unit E has in some places one indistinct interflow contact and Unit F has a distinct one (cf. Fig. 16). Between E and F are in some places lenses of intercalated breccia up to about 1 m thick. "From an engineering standpoint, both units are highly competent rock". (Willey.)

Unit G is a sedimentary layer. It extends from about elevation 255 to 245 metres at Dettifoss but as it rests on an eroded dolerite layer it varies in thickness. As seen on Fig. 21, taken on the W side of Jökulsá N of Dettifoss it consists of stratified material, mainly coarse sand and fine gravel but the uppermost part is coarse gravel. Like Unit D it is weakly cemented and seems to be very permeable and to be the main aqvifier in this part of the canyon. Small springs issue from it S of Hafragilsfoss and bigger ones N of that waterfall (cf. later).

"Any water conductor which crosses this layer would require sealing" (Willey).

Unit H extends from about elevation 245 to 230 m. It is a rather compact dolerite layer without a conspicuous tendency to columnar jointing. It is in close contact with Unit I (cf. Pl.VIII).

Unit I forms Hafragilsfoss and extends from about elevation 230 to 205 metres. It is a columnar dolerite of very much the same type as Unit F and shows also one distinct interflow contact. "Generally this formation can be considered a highly competent rock from the engineering standpoint" (Willey).

The contact zone between Unit I and the underlying unit, which is probably a breccia, is obviously pervious and feeds considerable springs on both sides of the river.

It is right to point out that sections I-III are somewhat schematic insofar as the units are not so even in thickness as shown there. Thus G varies a lot in thickness as seen on Figs. 13 and 18, and the underlying layer H is also rather uneven, as its surface is eroded. Between sections I and II a thin basalt layer is found intercalated between units B and C on the W side of Jökulsá, a short distance S of Dettifoss. It seems to have a very limited extension and may represent the end of a lava tongue coming from W.

A tunnel going from a dam site S of Selfoss to an outlet a short distance N of Hafragilsfoss would probably have to be lined to some extent or at least where it cuts through sedimentary layers, as these layers are hardly cemented enough to be resistant against erosion.

THE RÉTTARFOSS-VÍGABERGSFOSS AREA

From Hafragilsfoss Jökulsá flows 7.5 km northwards through a narrow canyon of about the same type as shown on the section III on Pl. VIII, a short distance N of that waterfall. The canyon walls are steep and built up of dolerite-layers. About 0.5 km south of Réttarfoss the canyon changes into a narrow, U-shaped valley which gradually enwidens northwards. Along the sides of the valley run terraces at different hights, showing that formerly this valley has been partly filled up by the deposits of Jökulsá (cf. the chapter on the Age and Genesis of the Jökulsá Canyon). Near the present river bed the bedrock is however laid bare. Section IV on Pl. IX is measured near a probable damsite S of Réttarfoss, section V (Pl. X) at Réttarfoss and section VI (Pl. X) immediately N of Vígabergsfoss. The rock units in these sections have not been correlated with certainty with the units in section III (Pl. VIII), at Hafragilsfoss, there being probably 2-3 basalt layers between unit J at Hafragilsfoss and the uppermost layer shown on section IV. This is however of no significance from the engineering point of view.

Unit X (M in Willey's report)forms the famous Vígaberg at Vígabergsfoss and the perpendicular rockwall extending from Vígabergsfoss to Réttarfoss on the E side of the river. This unit is a dark basalt; its lower part consisting of very regular vertical columns, the upper part is also jointed, forming beautiful rosettes. The upper part of this layer is rather compact and the permeability is probably low. The springs at the contact with the underlying units are no proof against this, as unit X is probably intrusive and of limited extension so that the water in the springs need not have penetrated through that layer. This layer is, in the author's opinion, probably younger than the formation of the Jökulsá valley. At Vígaberg it rests directly on

Unit T (N in Willey's report) a thick layer of grey, hard tillite, extending from elevation about 180 m to about 162 m. "From an engineering point of view the tillite is very satisfactory for bearing strength, tunneling and water tightness" (Willey). At Réttarfoss there are two basaltlayers (R and S in section IV, Pl. IX) between X and T. Layer R is characterized by a tendency to horizontal jointing, but the vertical jointing in it is not marked. Layer S is rather thin and is more markedly vertical jointed than R.

The waterfall Réttarfoss, which is of a similar type as Selfoss, although lower, is formed partly by layer S and partly by the tillite layer, which is not quite as resistent to the erosion as layer S but resistant enough to form a waterfall at Vígaberg where it rests on

Unit U, a layer which is exposed in the gorge N of Vígabergsfoss, where it consists partly of basalt globe breccia and partly of pillow lava. A short distance S of Vígabergsfoss it is capped by a bluish gray tuff of rather a loose consistence.

As to the bedrock in section IV (Pl. IX), at the probable damsite S of Réttarfoss, it must be stressed that the section presented here is mainly based on extrapolation from sections V and VI (Pl. X). It may be regarded as highly probable that the river flows here on unit S and presumably that layer is rather thin in that section. It is also very likely although not absolutely certain, that the tillite layer extends to this section but its thickness there is only a guess. Whether layer U is also found there is more questionable, but the author considers it likely.

On the E side of the river between Réttarfoss and Vígabergsfoss there is as beforesaid a considerable leakage on the contact between Unit X and the underlaying units, mostly where it rests directly on the tillite. There is also some leakage through the contact between layer S and the tillite, which is highly impermeable.

Much bigger are the springs issuing higher up on the valley slopes on both sides of the river, especially on the western side, in Hólmatungur, where the biggest springs really form small rivers. The aquifier of the main springline is not exposed but probably it is layer J in section III (Pl. VIII) (cf. the chapter on Leakage through the bedrock). The main springline in Hólmatungur and on the opposite site of the valley, in Forvöð, is at so high a level that it ought to be possible to direct at least some of the springs into a reservoir south of Réttarfoss.

THE AGE AND GENESIS OF JÖKULSÁRGLJÚFUR A TEPHROCHRONOLOGICAL STUDY

By Jökulsárgljúfur, the Jökulsá Canyon, is usually meant the canyon of the glacier river Jökulsá á Fjöllum between Selfoss and the place where the river leaves its gorge a short distance N of Vestara-Land and flows out to the sandur plain of Axarfjörður-Kelduhverfi. The total length of this "canyon" is 30 km. With its many beautiful rock formations, mainly of columnar lava, such as Hljóðaklettar (Fig. 28) and Vígaberg, and with its mighty falls of brownish glacier water contrasting with the clear bluish water in the many springs issuing from the slopes, and with its sheltered spots of luxuriant vegetations (Hólmatungur, Forvöð) Jökulsárgljúfur presents some of nature's most magnificent sceneries in Iceland.

Only a part of Jökulsárgljúfur is a canyon in the strict sence. Morphologically we can distinguish between three main parts. The southernmost part, 9.5 km in length, and extending from Selfoss to about 0.5 km S of Réttarfoss is a real canyon (cf. the sections II and III, Pl. VII and VIII), narrow and with steep walls and clearly formed mainly by the erosion of running water. The middle part, from 0.5 km S of Réttarfoss to Hljóðaklettar, is a more or less U-shaped valley with boulder and gravel terraces at different heights on both sides. The length of this valley is 9.0 km. It is obviously formed, at least partly, by glacier erosion, but the present bed of the river on its bottom is mostly small and in some places cut down in the bedrock, forming a second canyon.

The northernmost part of Jökulsárgljúfur is again a real canyon, of a similar type, although still narrower, than between Hafragilsfoss and Réttarfoss. Its total length is about 11.5 km. Section VII (Pl. XI) is from the northernmost part of this canyon, WNW of the farm Vestara-Land.

It has already been mentioned that at least the southernmost part of the canyon S of Réttarfoss, viz. the part S of the Sveinar crater-row, is in all probability younger than the formation of this crater-row and thus evidently of postglacial age and hardly older than ab. 8 000 years. As to the middle part of Jökulsárgljúfur its U-shaped profile is obviously due to glacial erosion. The author's present opinion - not yet sufficiently founded - is that a broad U-shaped valley, open towards N, existed here at the end of the last but one glaciation (Riss or Iowan). During the Riss-Würm Interglacial lavaflows, mainly from W, filled up the northern part of that valley and partly filled the bottom of its southern part and covered the morains left there by the Riss-ice (Layer T in sections IV-VI, Pl. IX-X). Some of these flows may have come from fissures E of the present valley.

In order to elucidate the postglacial development let us now turn for a while to another remarkable landscape feature in this area.

ÁSBYRGI

In the author's school geography it was stated that "Ásbyrgi in Kelduhverfi is a beautiful and peculiar horseshoe-shaped tectonic depression". This statement is in reality only half truth. With its vertical rockwalls rising higher and higher as one advances southwards, until they reach a height of about 100 metres, with the high rocky "island" (Eyjan) in the middle and with luxuriant vegetation and the small pond in its southernmost end Ásbyrgi is indeed both beautiful and peculiar, but it is neither horseshoe-shaped nor is it a tectonic depression. It is obviously the result of the erosion by running water and the source of that water is Jökulsá á Fjöllum. In other words, it is a former bed of that river. The "floor" of Ásbyrgi is everywhere covered by big waterrounded boulders of the same type and size as one finds in the present bed of Jökulsá on the stretch between Hljóðaklettar and Vestara-Land. The slope of the "floor" of Ásbyrgi between its mouth and southern end is about 1 m per 500 m or about that of the present Jökulsá on the first 5 km after it leaves its gorge at Vestara-Land. The slope of the river in the northern part of that gorge is about 1 : 300. Thus the slope of the floor of Ásbyrgi is about the same as one would expect if it was an old bed of the

Jökulsá river. This riverbed can be followed from Ásbyrgi southwards to the present canyon of Jökulsá, E of Rauðhólar. Most of this riverbed is shallow. At Kvíar it has formed waterfalls, 6-8 m high. A short distance S of Ásbyrgi it has divided into two main flows. The western-most has been by far the biggest and has eroded channels 10-15 m wide and 6-8 m deep before plunging down the precipitous rockwall, thus forming the biggest waterfall in Iceland. At the base of this fall it has eroded a wide plunge hole, at least 12 m deep, now partly filled by a pond, Byrgistjörn. A smaller plunge hole with a small pond is also found at the base of the eastern waterfall. Further it should be noted that Ásbyrgi is not the only "fossil" riverbed in this area. Between it and the present canyon of Jökulsá a branch of that river has formed a narrow but rather deep gorge that terminates in Ástjörn, a deep pond with steep rock-walls on its eastern and western side. Had this gorge been deepened and enwidened farther it would, together with the present Jökulsá canyon, have formed a second Ásbyrgi, with an "island". On the E side of Jökulsá there is the canyon of Landá that obviously has not been formed by that tiny river but by a branch of Jökulsá.

It may be regarded as nearly certain that all these old riverbeds are partly formed along preexisting tectonic N-S lines as are parts of the present Jökulsá canyon. On the areial photos such a line is seen a short distance W of Ásbyrgi.

THE AGE OF THE "FOSSIL" RIVERBEDS

Having stated that without doubt Ásbyrgi is an old riverbed the question arises: when was it eroded. A priori it would seem most likely that it happened in early Postglacial Time and that during most of the Postglacial Time Jökulsá has been confined to its present bed. Yet a study of the tephra layers in Ásbyrgi and adjacent area gave the rather unexpected result that hardly more than 2 500 years have passed since Jökulsá left Ásbyrgi. In 1951 the author measured a lot of soil profiles on the "floor" of Ásbyrgi and on Eyjan and on the rockwalls, near their edge, and also in the old riverbed S of Ásbyrgi. Some of these profiles are shown on Pl. XII and their location on Pl. XIII. They reveal that everywhere on the "floor" the soil cover is thin and only 2-3 black tephra layers are found there, the thickest one being the layer the author has designated as "a" in former papers and that layer is definitely younger than the rhyolitic Öræfajökull layer of 1362, but not younger than 1570 (cf. S. Thorarinsson: The Öræfajökull Eruption of 1362. Reykjavík 1958) and the same thickness of soil cover and the same tephralayers are found in the old riverbed between Ásbyrgi and the Jökulsá Canyon. But on Eyjan and on the rockwalls, further on both sides of the riverbed S of Ásbyrgi and on a rock ridge in the riverbed, rising some metres above it, the soil cover is much thicker and there are found the rhyolitic Hekla layers H_3 and H_4 and probably also H_5. This means that they contain the entire postglacial soil cover in this area, while the formation of soil in the old riverbed S of Ásbyrgi and in Ásbyrgi itself did not start until after the formation of layer

H_3 that was deposited about 2 700 years ago.

The author's first thought when finding this was that the canyon might have been dammed up temporarily by the formation of the Rauðhólar crater row, that has crossed the Jökulsá Canyon S of Kvíar and later has been cut through by the river which has washed away the outer, slaggy and scoracious cover of most of the craters - except the northernmost ones, Rauðhólar themselves - leaving only their cores of beautifully jointed basalt rock, the famous Hljóðaklettar. But a soil section measured on the slope of the biggest of the Rauðhólar showed that this crater-row is at least 8 000 years old (cf. Pl. XII). Further investigations have shown that in Jökulsárgljúfur S of Hljóðaklettar the soil cover is thin up to a height corresponding roughly to the col between the canyon and the riverbed S of Ásbyrgi (about 150 m above S. L.) but above that height it is thicker and contains the light Hekla layers. Even at Forvöð one does not find the Hekla layers in the soil until one arrives above the middle of the valley slopes. S of Réttarfoss layers H_3 and H_4 are found on the highest terrace at about 230 m height (cf. section IV, Pl. IX), but not beneath 200 m:s height. Furthermore it has been stated that at Vestara-Land the soil cover is thin and without light layers on a rock terrace at about 100 m hight that has been eroded by Jökulsá whereas a little higher up the soil contains this layers (cf. Fig. 31 and section VII, Pl. XI).

From the tephrochronological studies it seems inevitable to draw the conclusion that the northernmost 10 km of the Jökulsá canyon were mainly formed by erosion during the last 2 500 years or so. Possibly, although not likely, the river there found a former canyon (pre-Würm) filled up by glacial drift, but it should also be taken into consideration that the rock on this stretch is easily eroded as it consists of thin lavabeds with rather thick layers of badly cemented conglomerate layers between (cf. Fig. 30). As the river must during this erosion period have transported a great quantity of gravel and boulders from the valley-part of Jökulsárgljúfur its erosional power has probably been very great. Taking also this in consideration it seems most likely that the canyon was mainly cut through pleistocene basalt (dolerite) layers and intercalated sediment layers during the last 2 500 years.

From an engineering point of view we may draw the conclusion that as this canyon could be eroded in such short time at least the northern half of a tunnel from Réttarfoss to the outlet of the Jökulsá canyon would probably have to be lined with concrete to a considerable degree because of the risk of erosion.

THE RISK OF LEAKAGE THROUGH THE PLEISTOCENE BEDROCK FROM THE STORAGE AREA S OF SELFOSS

In a previous chapter the risk of leakage from this area towards W through the postglacial lavabeds has been discussed. But the planning of a great storage area S of a dam at Selfoss also involves the problem of leakage through the pleistocene bedrock. As previously mentioned this bedrock consists mainly of interglacial dolerite beds, separated by sedimentary layers, some of which are described in the chapter on the Dettifoss area. Much of the storage area is without a permanent surface drainage. The only lake within the area, Eilífsvatn, is without a permanent outlet drainage. Only during the main snow melting period in the spring is it drained through an outlet towards E, but rivulets, especially from the Hágöng massif, flow permanently into the lake. Consequently the lake must have some drainage through the bedrock. When the author visited this lake on Aug. 23rd 1957 the water level was 1.65 m below the highest level it had reached the previous spring. A study of the hydrography of this lake, including measurements of the discharge of the rivulets feeding it and the changes in the height of its water level are highly desirable, as they might increase our scanty knowledge of the permeability of the bedrock of the storage area.

When trying to estimate the possibility of leakage from the planned storage area S of Selfoss a special attention should be paid to the springs in the Jökulsá canyon that possibly or probably are partly fed by water from the storage area. On the map on Pl. I the location of some of these springs is shown schematically by arrows. We find that these springs are mainly limited to two areas. The southernmost one is in the close vicinity of Hafragilsfoss and a short distance downward from that waterfall. The main aquifier is here the sedimentary layer (unit) G. At least two springs (both of them roughly estimated less than 20 l/sec) issue from this layer in the E wall of the canyon opposite the mouth of Hafragil. On the W side there are at least four springs, they are, on the whole, larger than on the E side; none of them however has discharge exceeding 50 l/sec (this is a very rough guess as the author has only studied them at a great distance through fieldglasses).

The main spring area in the Jökulsá canyon is in the vicinity of Vígabergsfoss, in Hólmatungur, on the W side of the river. There small springfed rivers are found. Considerable springfed brooks are also found on the E side of the river, near Vígabergsfoss.

It seems to me obvious that the springs in the Hafragilsfoss and Vígabergsfoss areas are connected with the fault-graben-fissure systems that have been described in a previous chapter. The springs at Hafragilsfoss are connected with the Sveinar system, and the Hólmatungur springs mainly with the Kræðuborgir graben system. It may be added that from underneath the lavaflows in the W part of Kelduhverfi issue many springs that are connected with a big fault and graben system W of the water divide between Jökulsá and Laxá, viz. the Gjástykki-Leirhnúkur system.

In the author's opinion we may draw the conclusion that the doleritic bedrock obviously lets some water through, on the whole probably more than the palagonite bed rock; that the main aquifers are the contacts of the doleritic lavabeds and the sedimentary layers between some of these beds and that the subterranean course of the drained water is directed by the N-S running fault lines and the feeder dykes of the crater rows together with the slight dipping of most of the dolerite beds towards N. We may assume that the feeder dykes are more or less impervious to water and thus form an obstacle to sub-surface drainage towards W and E. Therefore, any considerable leakage from the Selfoss storage area towards W to the Mývatn area beneath the postglacial lava is not to be expected, whereas the risk of leakage through the bedrock towards N must be taken seriously into consideration. Whether Eilífsvatn is drained towards W to the Gjástykki system or towards E to the Kræðu-borgir system cannot be told with certainty but it is more likely that it is drained towards E, and that water should thus issue in Hólmatungur. What must be done as soon as possible is to measure the discharge of all the main springs in the Hafragils-foss and Vígabergsfoss areas and also their temperature. When knowing the total discharge of the springs in each area and knowing roughly the precipitation (it is desirable to put up a rain sampler within the storage area) it might be possible to calculate roughly how much of the water of this springs can be counted for by precipitation in the areas N of the planned storage area, and whether or not one has to reckon with some part of it coming from the storage area.

Even if we could state with any probability that some of the water of these springs comes from the planned storage area (some of the springwater in the Hafragilsfoss area certainly does) it will of course be very difficult to estimate how much the leakage would increase after the formation of a storage lake. Almost certainly it will increase, but personally I doubt that it will increase very much. It may also be regarded as pretty certain that the initial leakage after the formation of the storage lake will gradually decrease because of tightening of the leakage channels by the sediment in the glacial water, but how fast this decreasing will be the author dares not estimate.

THE DAMSITES AT NÚPASKOT AND MIÐFELL

In connection with the hydro-electric development of Jökulsá á Fjöllum it has been discussed to dam up a big water reservoir in the Möðrudalur area. This is possible by building two dams; at Núpaskot and between Lambafjöll and Miðfell. These dams connect a series of tuff ridges that border the northernmost part of the storage area. These ridges were probably formed during the Last Glacial and consist mostly of a rather homogenous, fine-grained palagonite tuff. Here and there one finds pillow lava e.g. in Núpaskot and Ferjufjall. The author is of the opinion that there is hardly any risk of so serious a leakage through these ridges that it would hazard a damming project, but if the storage area is dammed very high up there might possibly also be some risk of leakage through the lava S of Fremstafell. As to the geology of the damsites it is shown somewhat schematized in sections VIII and IX, Pl. XIV and XV. At both damsites the valley floor is covered with postglacial sand and gravels the thickness of which is not known. A rough guess is that the thickness lies between 2 and 6 metres, but this ought to be determined either by drilling or by geophysical methods or both.

The northernmost dam, crossing Skarðsá at Núpaskot a short distance above the junction of this river with Jökulsá, connects a smooth slope of a palagonite tuff ridge on the southern site with a steep rock wall on the northern site (cf. Fig. 32). The northern part of the cliff on the eastern side of Skarðsá consists mainly of pillow lava although not of the most typical type. The same type of pillow lava is found in the southernmost part of Ferjuás on the western side of Jökulsá. This lava is easily eroded and has in all probability rather great permeability for water. The southern part of the cliff east of Skarðsá consists of a beautiful columnar basalt, probably intrusive, in the subglacial palagonite tuff. From an engineering point of view this lava should be very satisfactory both for tunnel driving and as an abutment and the columns fit so tightly to each other that the author does not think there is any risk of leakage through this rock.

As shown on section VIII, Pl. XIV, a tongue of postglacial lava rests on the gravel on the western side of Skarðsá. This is the end of a lava flow coming from south. The author has only studied this lava in fieldglasses from the other side of Skarðsá. It seems to be a rather thin flow but would probably require grouting under the dam to assure watertightness.

The northern slope of the palagonite tuff ridge that would form the southern abutment of the dam is covered by a layer of scree and some ground moraine the thickness of which has not been studied but is hardly more than about 2 m. The second dam site, between Lambafjöll and the northernmost hill of Miðfell, is of similar type as that at Núpaskot except for that both abutments of the dam consist of palagonite tuff. The postglacial cover of glacial drift and scree material is mostly less than 2 m in thickness. Also here is a lava flow on one side of the river, this lava has come from north and does not extend quite through the pass so that the dam would not necessarily have to rest on it. How thick the layer of alluvial material is beneath this lava and the lava at Skarðsá can only be determined by drilling or by geophysical methods. Presumably it is about the same as in the riverbed.

To sum up: There are in the author's opinion hardly any serious geological problems involved in the planning of a reservoir in the Möðrudalur area. The problem where to get sand and gravel, fit for the building of the dams, has not yet been satisfactorily solved, but it ought to be possible to find suitable gravel and even sand somewhere in the area between Möðrudalur and Núpaskot in some of the river terraces found in this area.

GLACIER BURSTS IN JÖKULSÁ Á FJÖLLUM

One of the problems that must be faced when planning a hydro electric development of the glacier rivers in Iceland are the glacier bursts that occur in many of them. These glacier bursts (icel. jökulhlaup) are floods that are mainly of two types with regard to their origin. They may be caused by the drainage of ice dammed lakes (glacilimnogen or limnoglacial hlaup). The biggest hlaups in Iceland of this type are those caused by the drainage of Grænalón at Skeiðarárjökull. The other type and the more disastrous one is caused by subglacial volcanic activity (volcanogen or volcano-glacial) either by intermittent melting of ice in connection with subglacial eruptions (Öræfajökull, Katla) or by a continuous melting of ice caused by subglacial solfatera activity. The storage of water in the Grímsvötn depression is to a considerable degree caused by solfatera activity. The discharge graphs of volcanogen and glacilimnogen glacier bursts show a close resemblance (cf. Figs. 8-10 in S. Thorarinsson: Some New Aspects on the Grímsvötn Problem, and the logarithmic diagram in S. Thorarinsson: The Jökulhlaup from Katla, in Jökull 1947). The drainage mechanism of these two types of hlaups thus seems to be essentially the same, a raising of the damming ice barrier when the water pressure has become sufficiently high, and then the water forces its way underneath so that the stored water is drained off. Usually the drainage is slow at first, accelerates to an ephemeral maximum and then rapidly decreases. The maximum discharge of a Skeiðarárhlaup is estimated at 4-5 x 10^4 m^3/sec, that of a Kötluhlaup to more than 10^5 m^3/sec. The max. discharge during a Grænalónhlaup (glacilimnogen) is about 6 000 m^3/sec. The main bulk of the water in a Skeiðarárhlaup is drained off in about 4 days, that of a Kötluhlaup in less than one day and that of a Grænalónhlaup in about 5 days. Comparison between different jökulhlaups in Iceland shows, that the bigger the vertical difference, between the surface of the stored water and the outlet of the hlaup at the glacier margin, is in relation to the horizontal distance the hlaup has to force its way under the ice, the bigger is, ceteris paribus, the maximum discharge of the hlaup compared with the total volume of discharged water. This explains i.a. the very great maximum discharge of the Kötluhlaups.

Let us then turn to Jökulsá á Fjöllum. In an earlier paper (Jökulhlaup og eldgos á Jökulvatnssvæði Jökulsár á Fjöllum = Glacier bursts and volcanic eruptions within the ice covered drainage area of Jökulsá á Fjöllum, Náttúrufræðingurinn 1950: 113-133) the author has gathered the available information about hlaups that have occurred in Jökulsá á Fjöllum. As this river flows far from human habitation during most of its course between Vatnajökull and its outlet in the ocean, most of the information available is connected with damage caused by the hlaups in the two settlements the river passes, viz. Axarfjörður and Kelduhverfi, and we know nothing about the behaviour of these floods farther south.

The glacier bursts in Jökulsá of which pretty reliable knowledge is available, although in very few cases some doubt exists, are the following:

About	1490	Time of year uncertain
	1655	In spring or early winter
	1684	In early November
	1711/12	During the winter
	(1716)	September or October
	1717	Early in September
	1726	Late winter and spring
	1729	In August

To this may be added, that in December 1902 and in June 1903 there occurred floods in Jökulsá. They were, however, much smaller than most of the above mentioned and were not certainly glacier bursts.

As to what has caused the glacier bursts in Jökulsá they were in all probability nearly all a result of subglacial volcanic activity in Vatnajökull, in the Kverkfjöll area or (and) under Dyngjujökull, and thus of the same nature as the hlaups from Katla. We may conclude from the descriptions that none of them was big enough to cover both the sandur plains of Axarfjörður and Kelduhverfi at the same time. The big burst of 1784 mainly flooded the westernpart of the area, that of 1711/12 the eastern part and the 1729-glacier burst again the western part. Presumably the maximum discharge of these hlaups was considerably smaller than that of a big Skeiðarárhlaup. In the author´s opinion it is unlikely that any of the floods recorded had a maximum discharge higher than 15 000 m^3/sec and probably they were of so short a duration that the total volume of water discharged never has been more than 1.0 to 1.5 km^3. The total run off in one day through the Dettifoss area has hardly been higher than 1 km^3 in any of these hlaups.

By a closer examination of the floods in Jökulsá at least two of them, i.e. those of 1717 and 1729, both among the biggest ones, occur at the time of year which rules out the possibility of an ice bar. Moreover the fact that four of these floods (1684, 1716, 1717, 1726) can be proved without doubt to have coincided with volcanic activity in Vatnajökull, can hardly be accidental. It is also an interesting fact that all the great floods in Jökulsá known to have occurred in historical time are concentrated within a short period (1655-1729) and the later part of that period coincides with the period of volcanic activity in the Mývatn district.

It has formerly been assumed that a damming up of Jökulsá by an ice bar at Ferjuás might cause a big hlaup. On a closer study the author does not consider that likely to happen.

It is difficult to tell how big the glacier bursts in Jökulsá can be. From the vague descriptions we possess of these bursts and with the available knowledge of the havoc they have wrought, and especially by studying how near the present river bed in the Jökulsá Canyon the soil cover extends and how old that soil cover is (here the tephra layers are of help) one might possibly gain some further information about the maximum discharge of the above mentioned hlaups. In this connection it may be mentioned that the light rhyolitic pumice from the Askja eruption of 1875 floated by Jökulsá shows how high the water of that river has been raised since 1875 or during the last 83 years. Where the river profile can be well defined such as a short distance S of Réttarfoss, where the pumice is found on the riverbanks the max. discharge of the river since 1875 could be roughly calculated.

As to the risk of big hlaups occuring again in Jökulsá it should be pointed out that, as said before, all the big hlaups in historical time (with a possible exception of the hlaup ab. 1490 that may have been rather big although not one of the biggest) occurred within a very limited period. Whereas two hlaups from the Katla area and at least ten hlaups from Grímsvötn can be expected every century, many centuries may pass before volcanic activity causes a big glacier burst in Jökulsá á Fjöllum.

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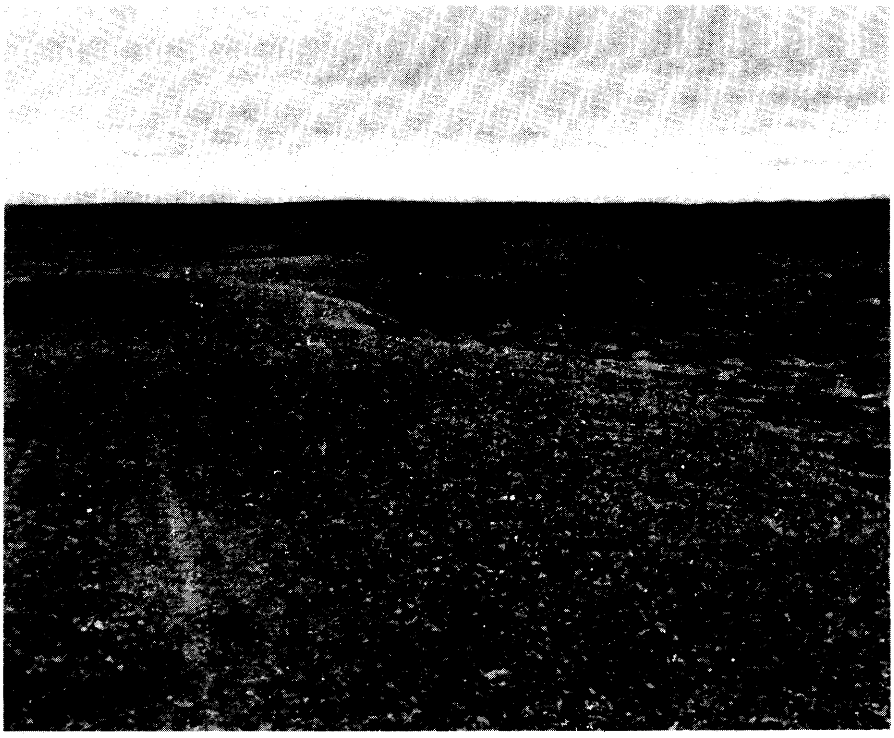
Fig. 1

Fig. 2



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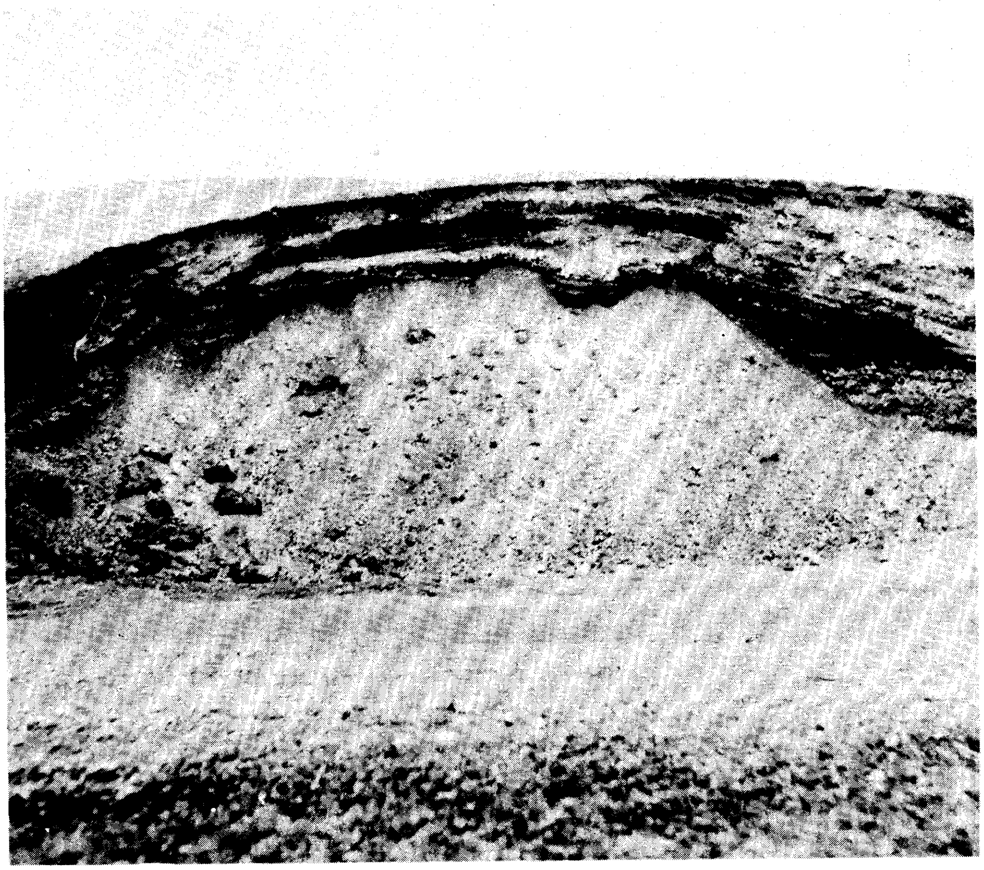

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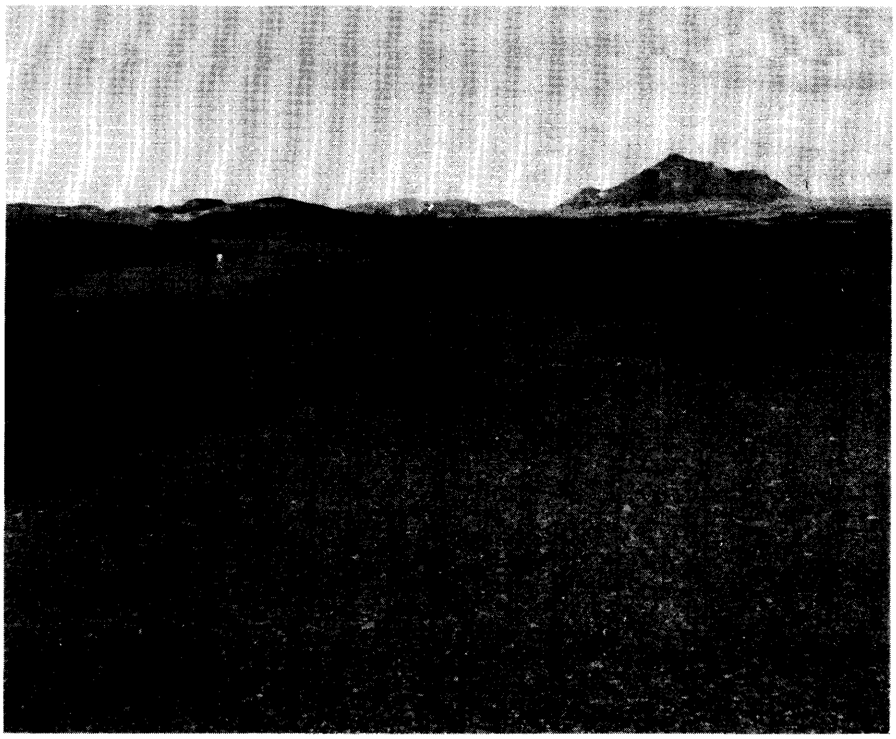

Fig. 5

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Fig. 7

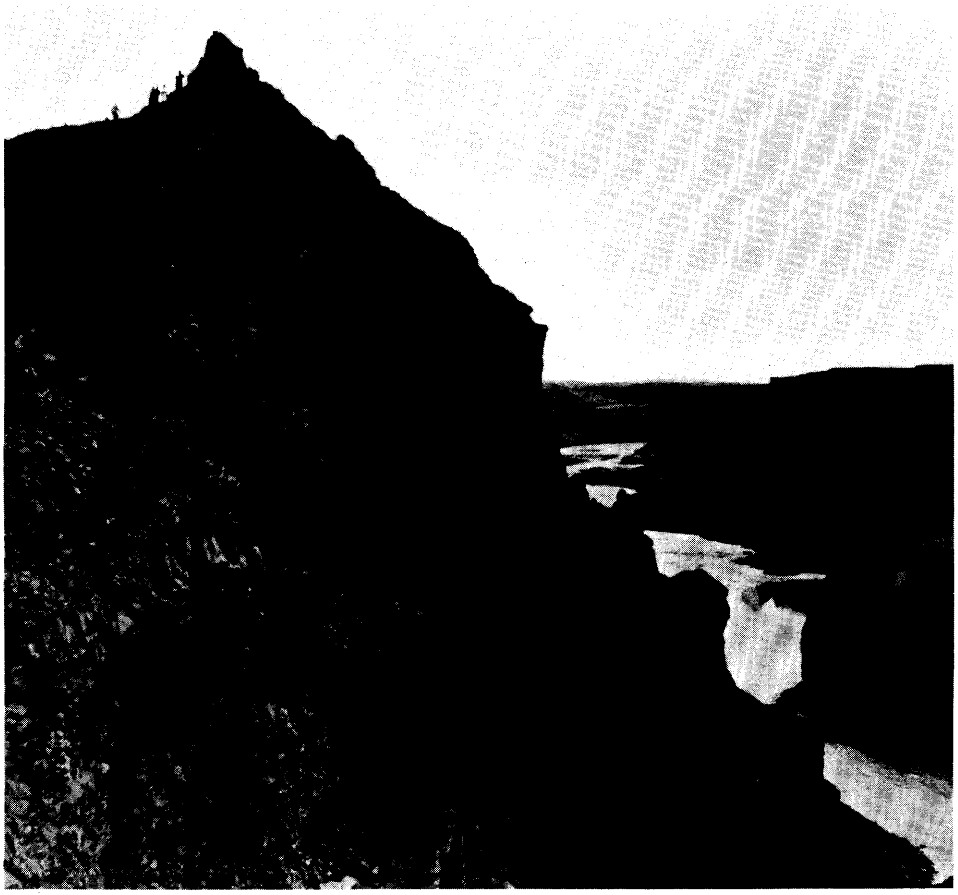


Fig. 8

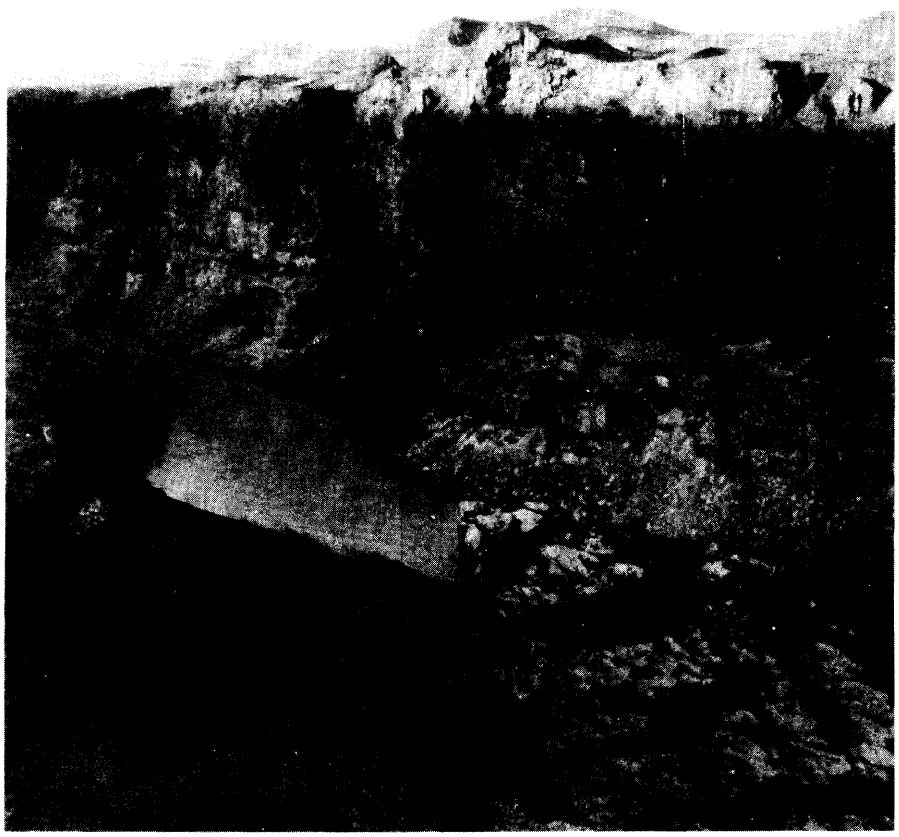


Fig. 9

Fig. 10

B B

C C

Fig. 11

B

C

Fig. 12

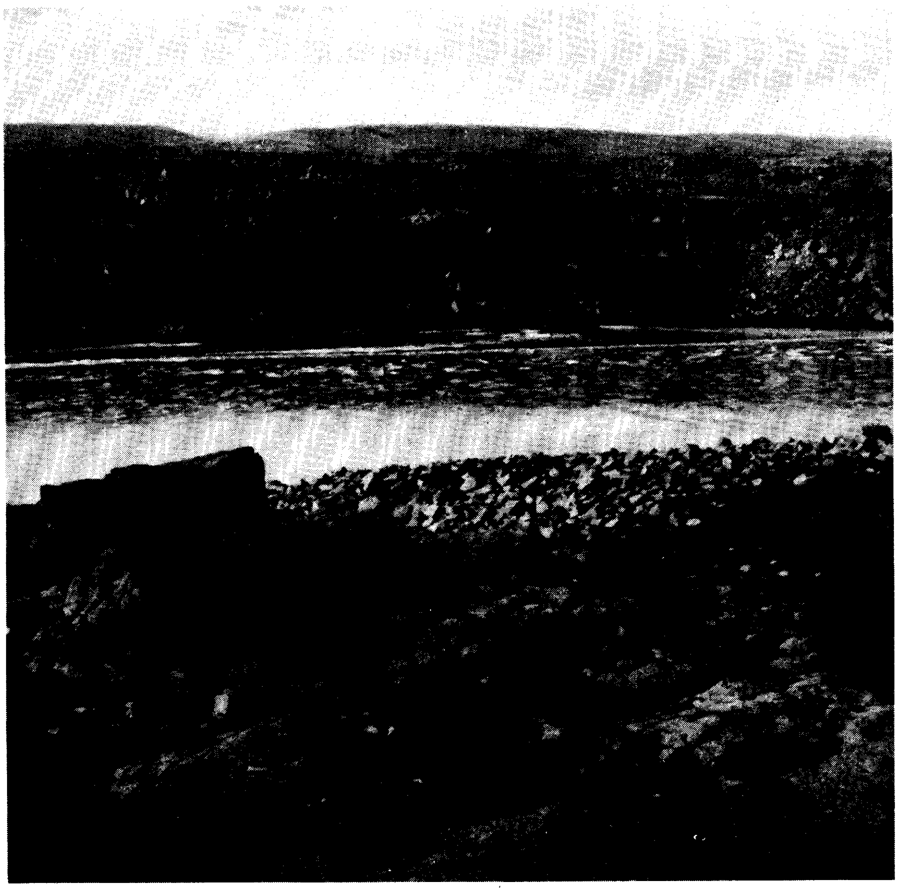


Fig. 13.

Fig. 14

Fig. 15

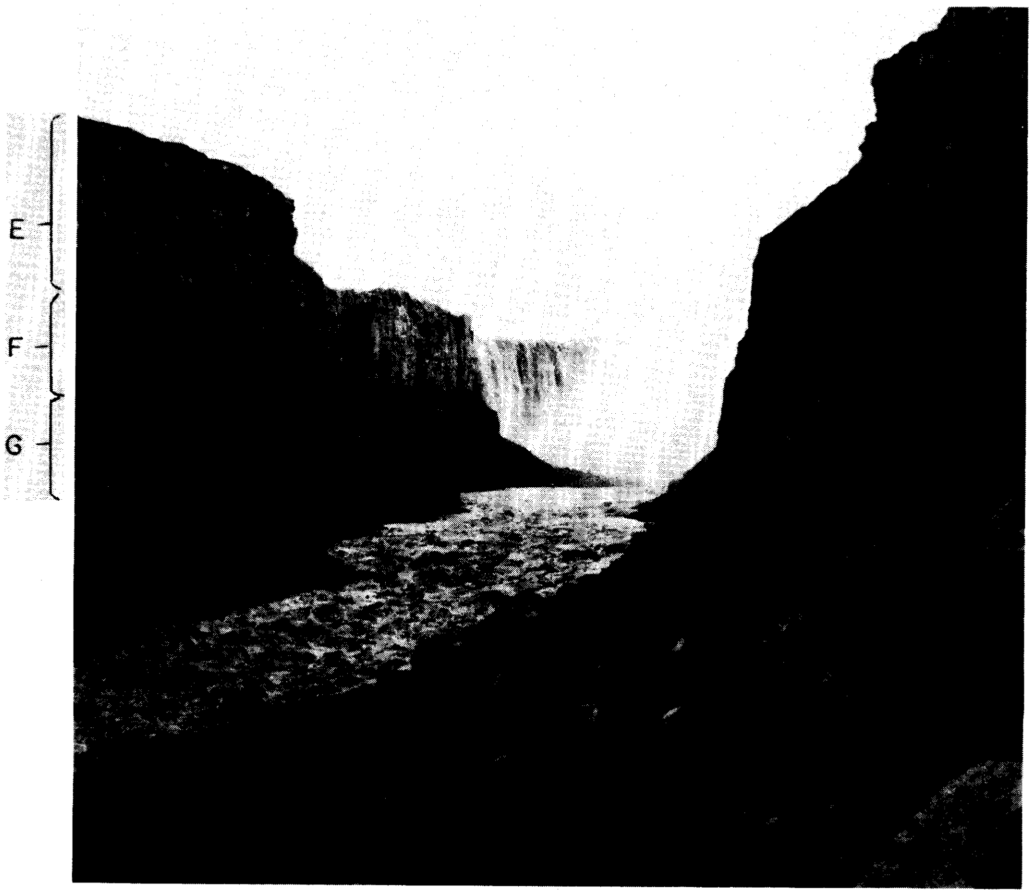


Fig. 16

C

← Volcanic sand

D

Fig. 17

E

F

G

Fig. 18

Fig. 19

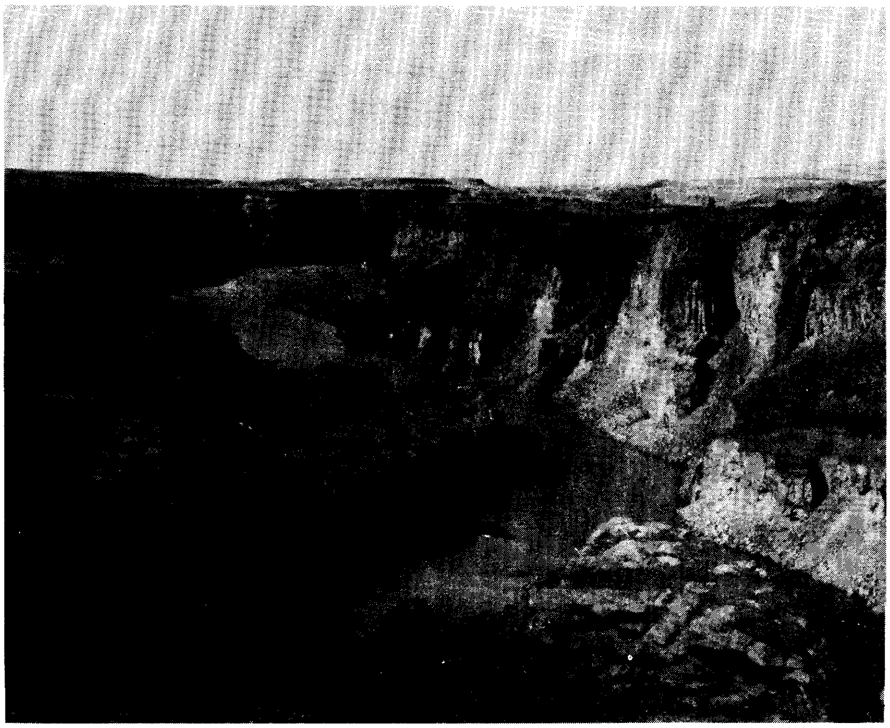


Fig. 20

Fig 21

Fig 22

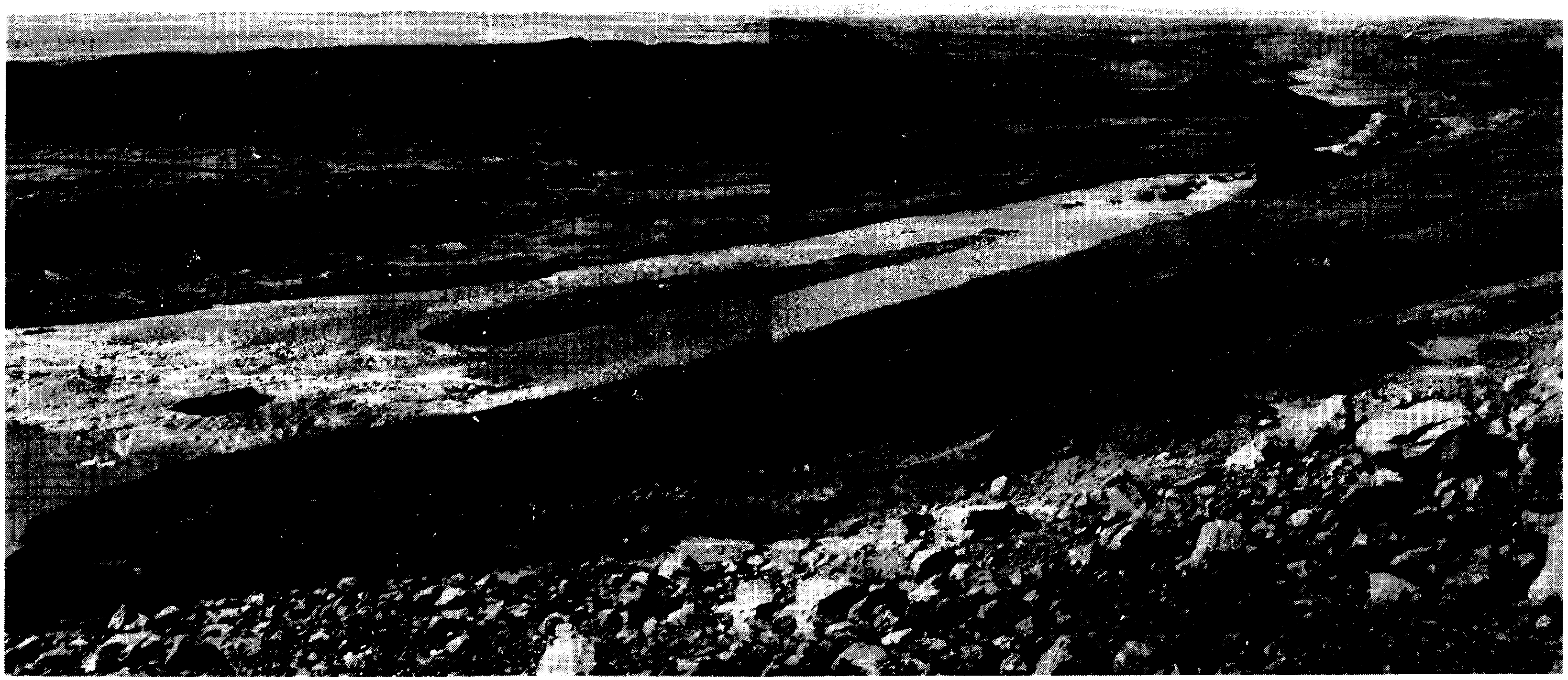


Fig. 23

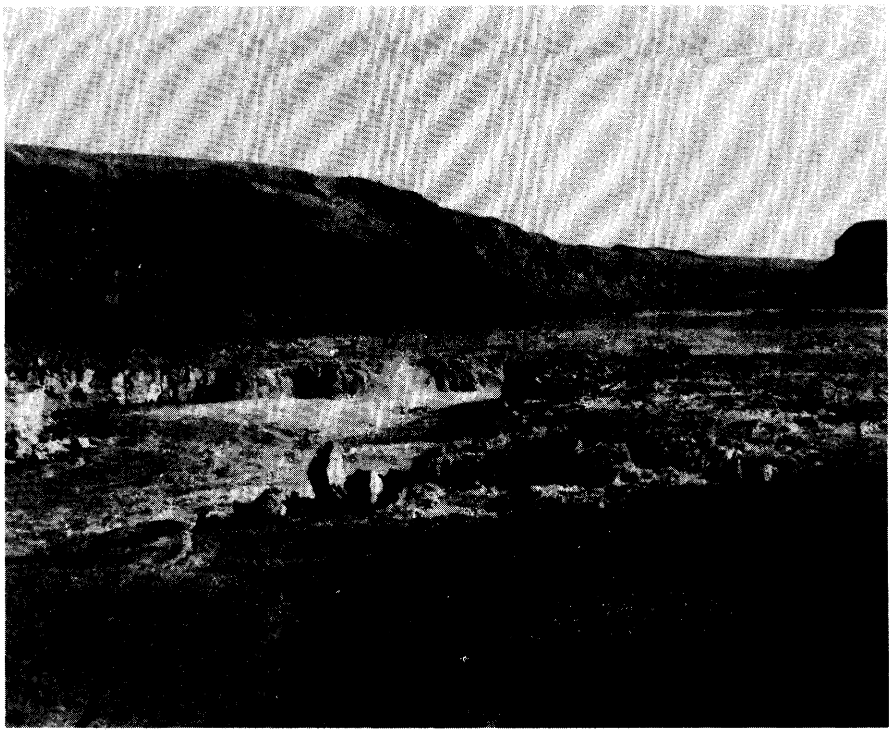


Fig. 24

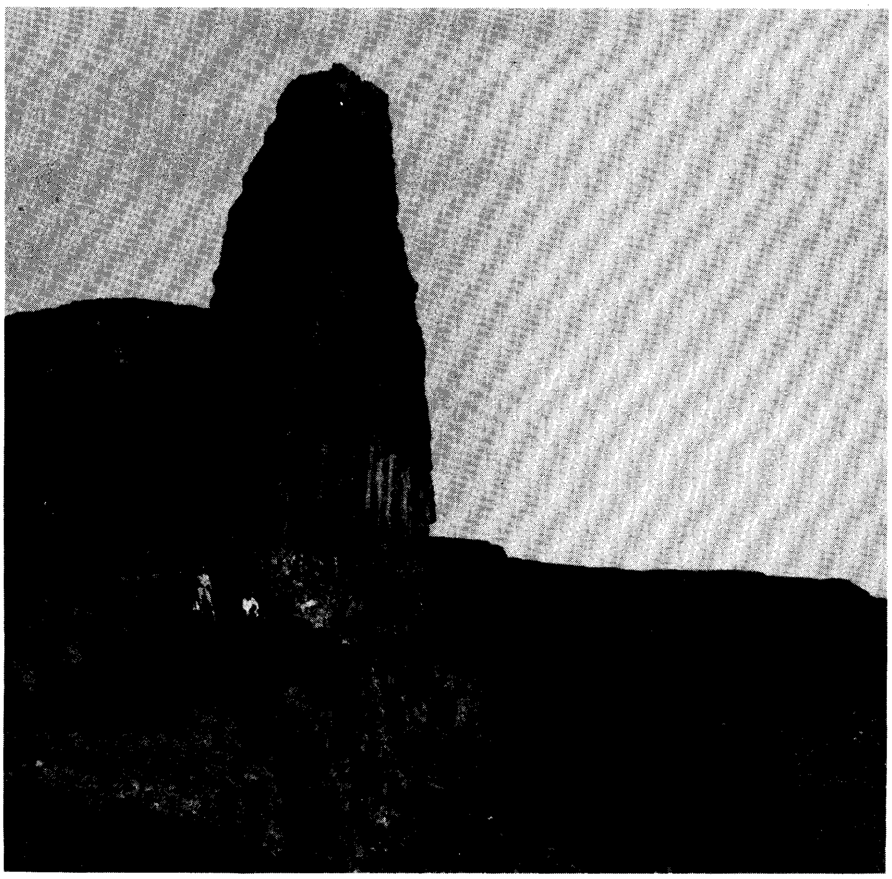


Fig. 25

Fig. 26

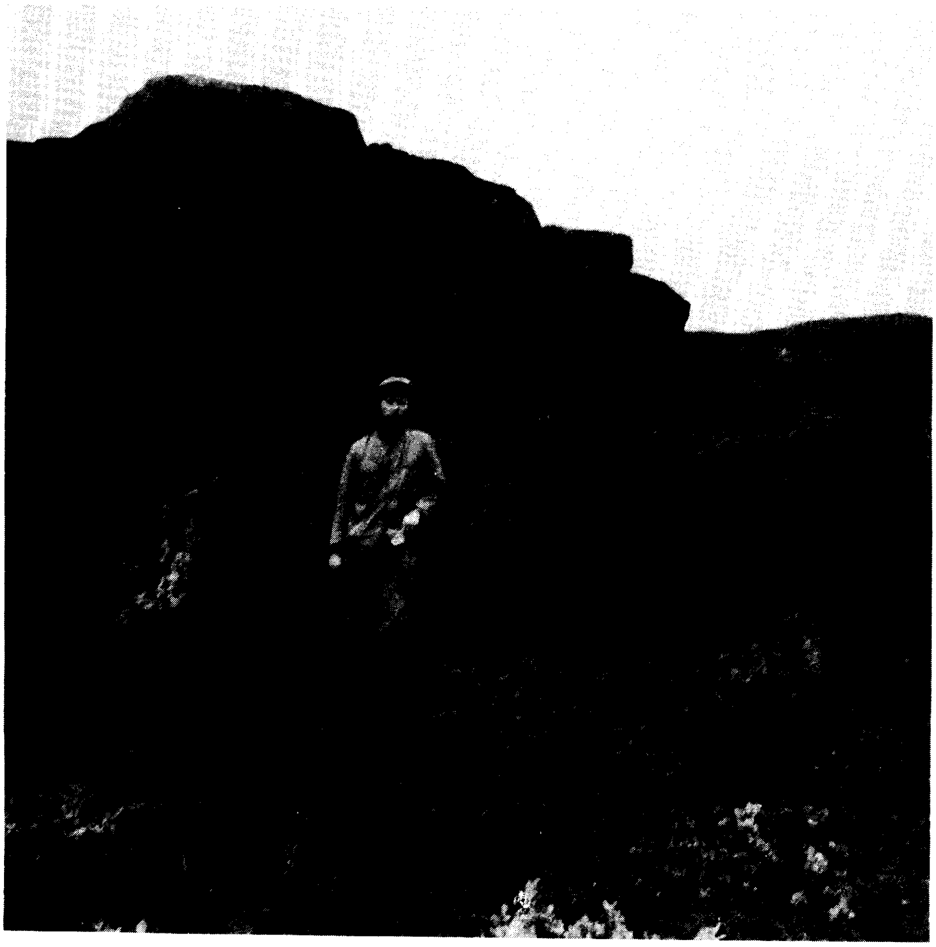


Fig. 27

Fig. 28

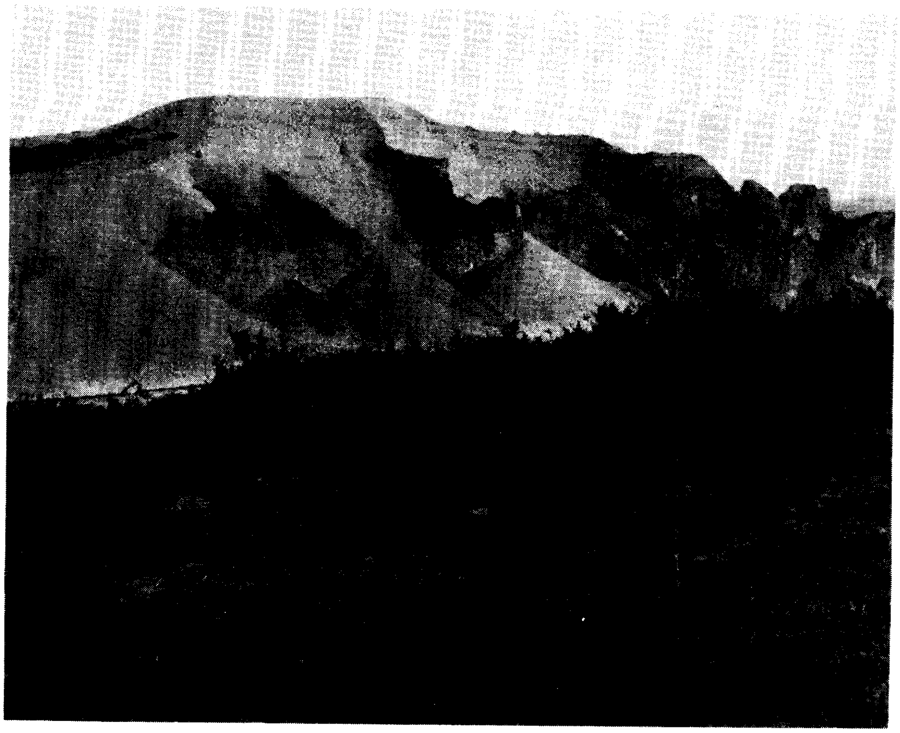


Fig. 29

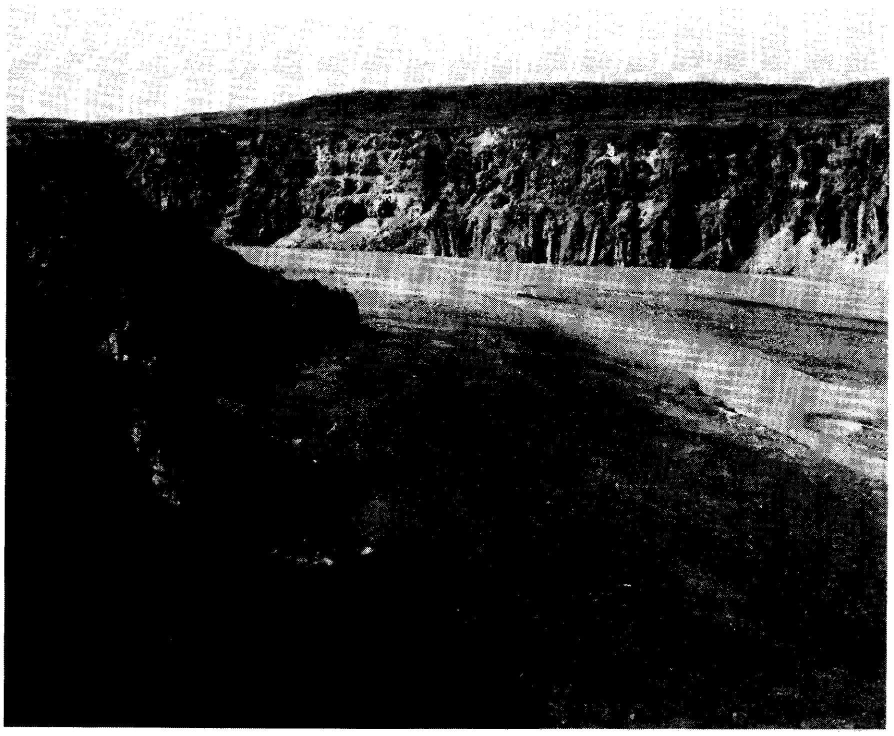


Fig. 30

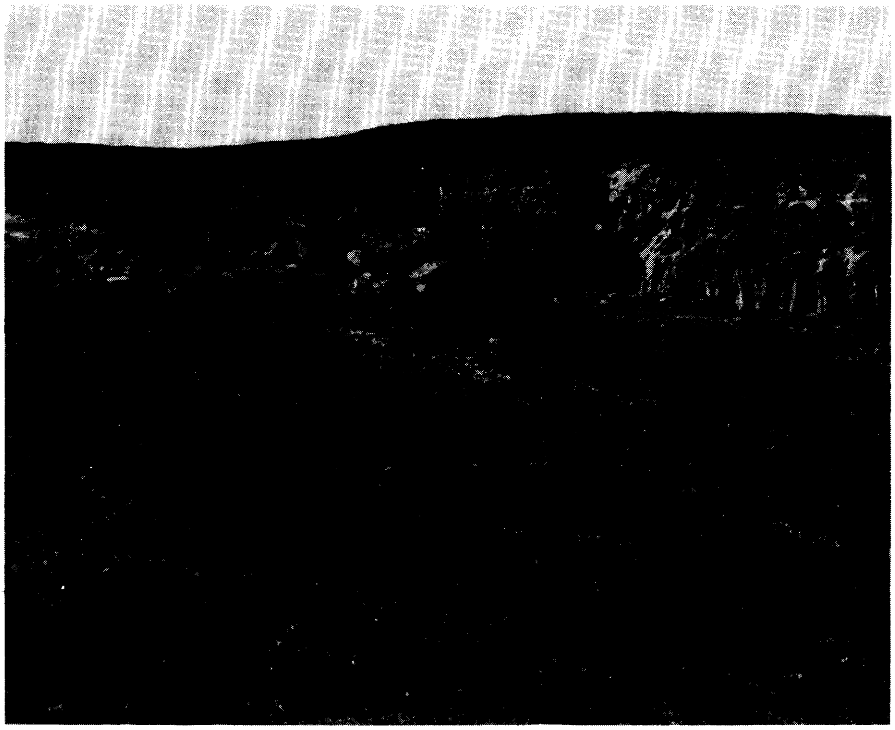


Fig. 31

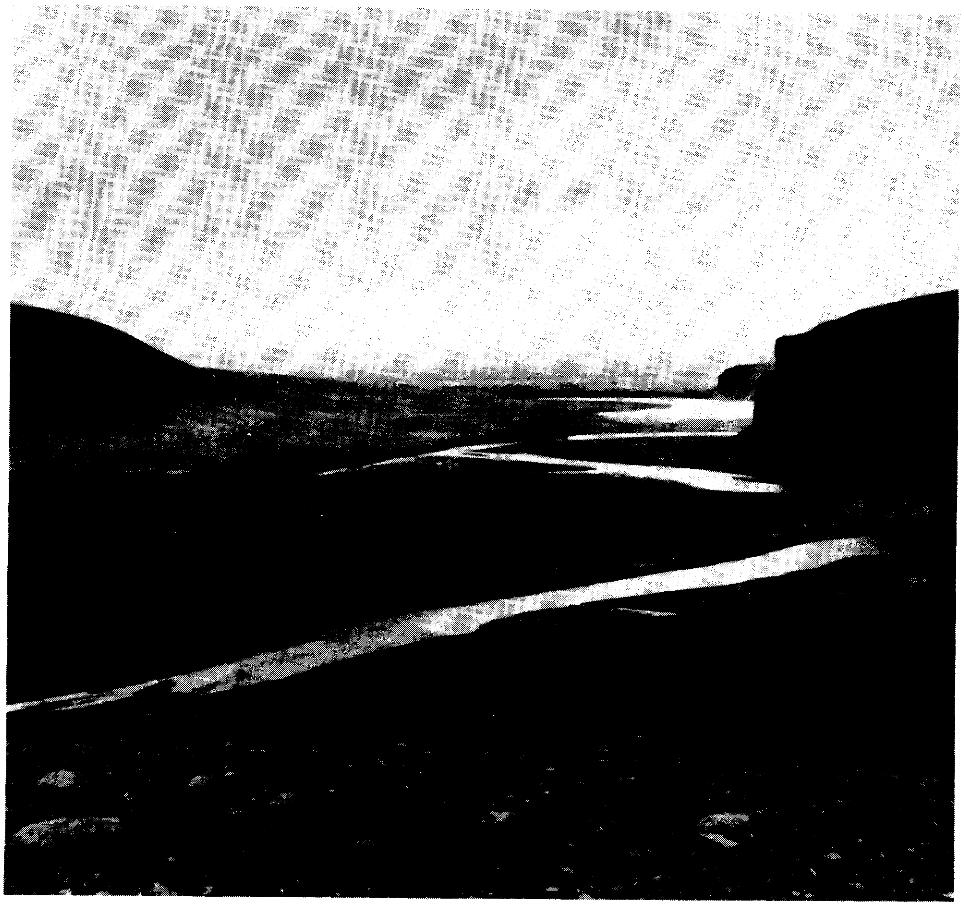
S  N

Fig. 32

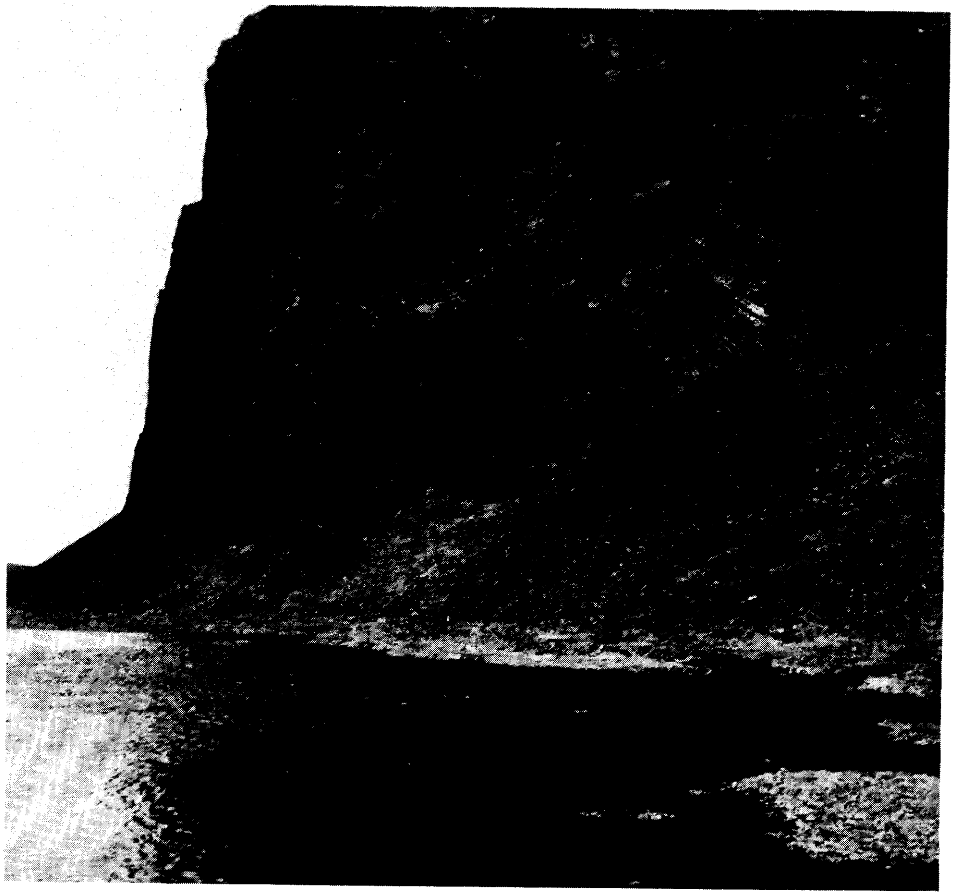


Fig. 33.

Fig. 34

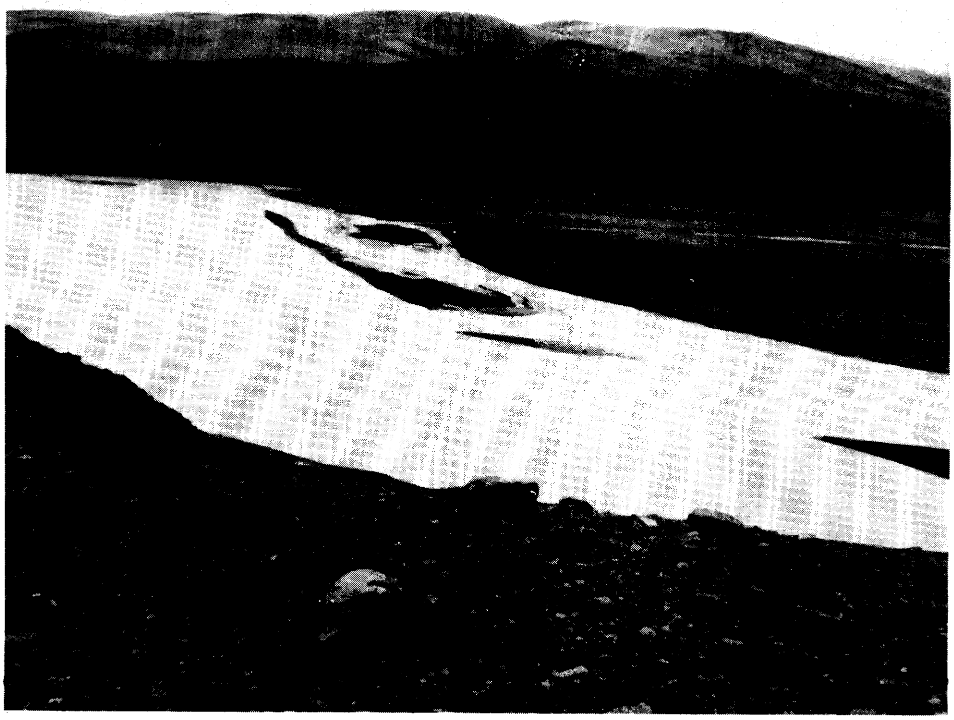
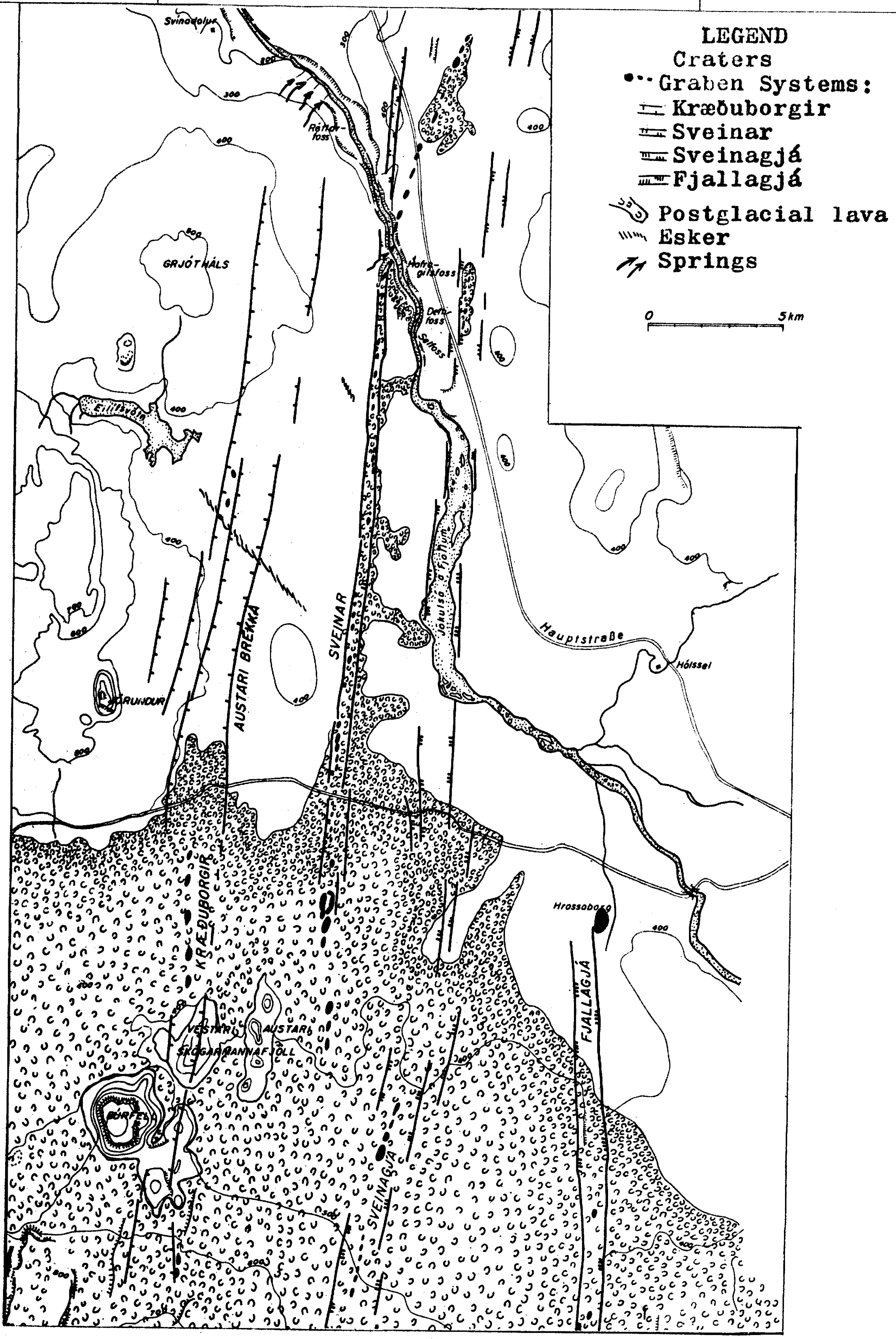
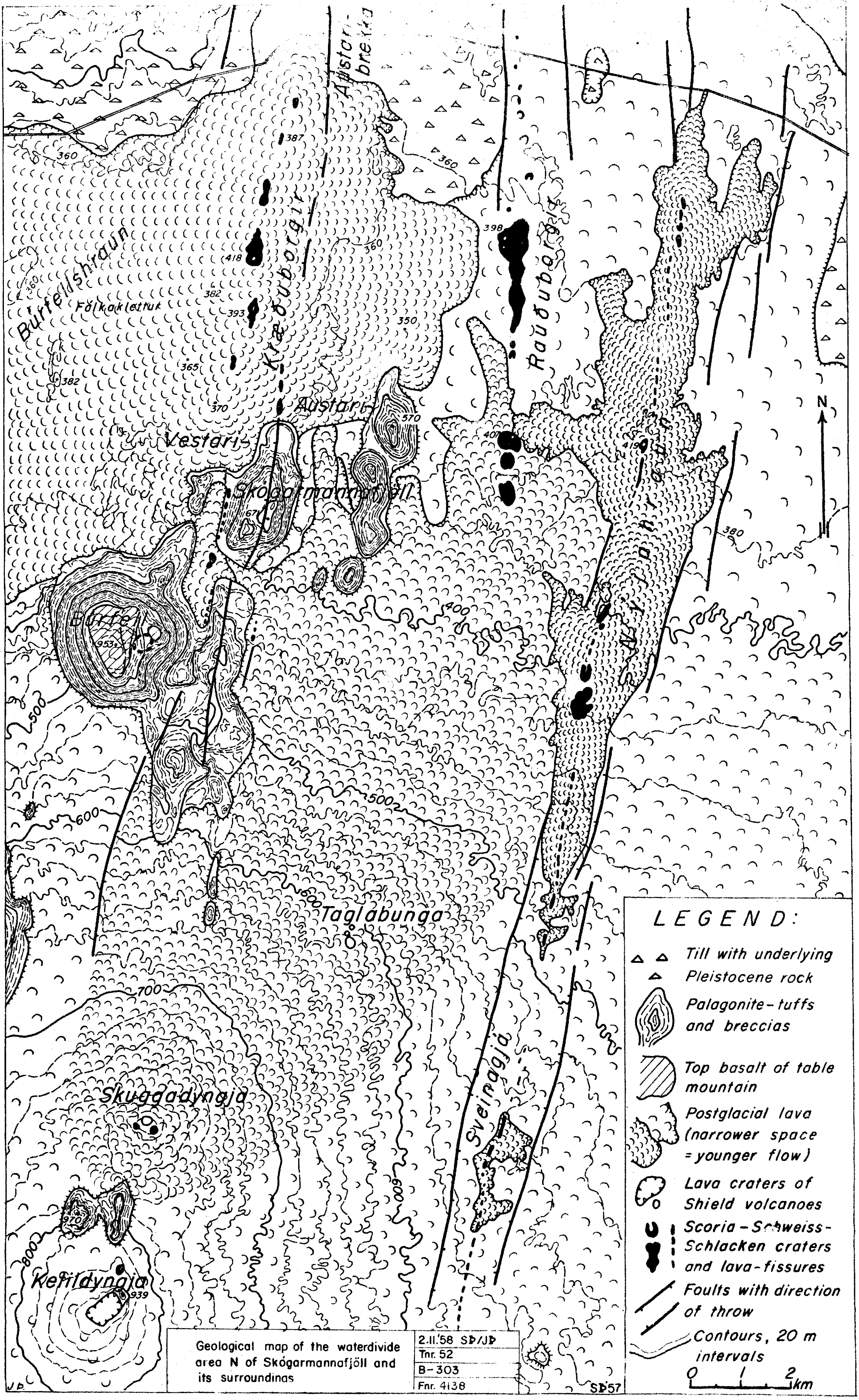


Fig. 35

Plate 1	**Faults fissures and craterrows in the Jökulsá area.**	2.11.'58 SÞ/PJ Tnr. 48 B-3o3 Fnr. 4118





Austari-breKKa
Búrfellshraun
Fálkaklettur
Kræðuborgir
Rauðuborgir
Austari-
Vestari-
Skógarmannafjöll
Búrfell
Taglabunga
Skuggadyngja
Ketildyngja
Sveinagjá
N
LEGEND:
Till with underlying Pleistocene rock
Palagonite-tuffs and breccias
Top basalt of table mountain
Postglacial lava (narrower space = younger flow)
Lava craters of Shield volcanoes
Scoria - Schweiss-Schlacken craters and lava-fissures
Faults with direction of throw
Contours, 20 m intervals
0 1 2 km
Geological map of the waterdivide area N of Skógarmannafjöll and its surroundings
2.II.58 SÞ/JÞ
Tnr. 52
B-303
Fnr. 4138
SÞ57
JÞ

Plate III	Geological map of the area between Námafjall and Hvannfell	2.11.'58 S.Þ./P.J. TNR 53 B-303 FNR 4139

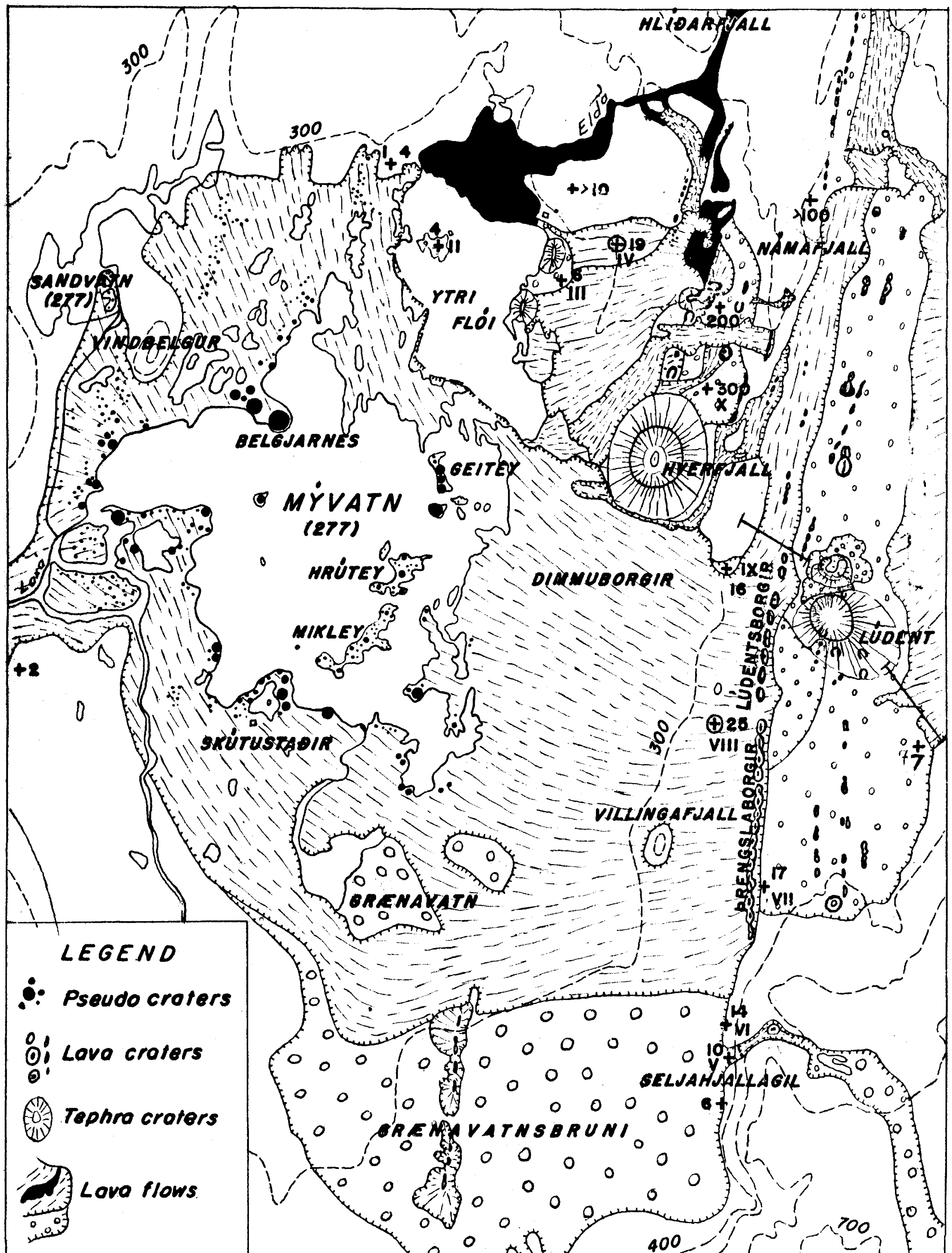


Plate IV	Three types of graben section between Mývatn and Jökulsá.	1.11.58. S.Þ. / P.J.
		TNR. 46
		B– 303
		FNR. 4103

Explanations in text.

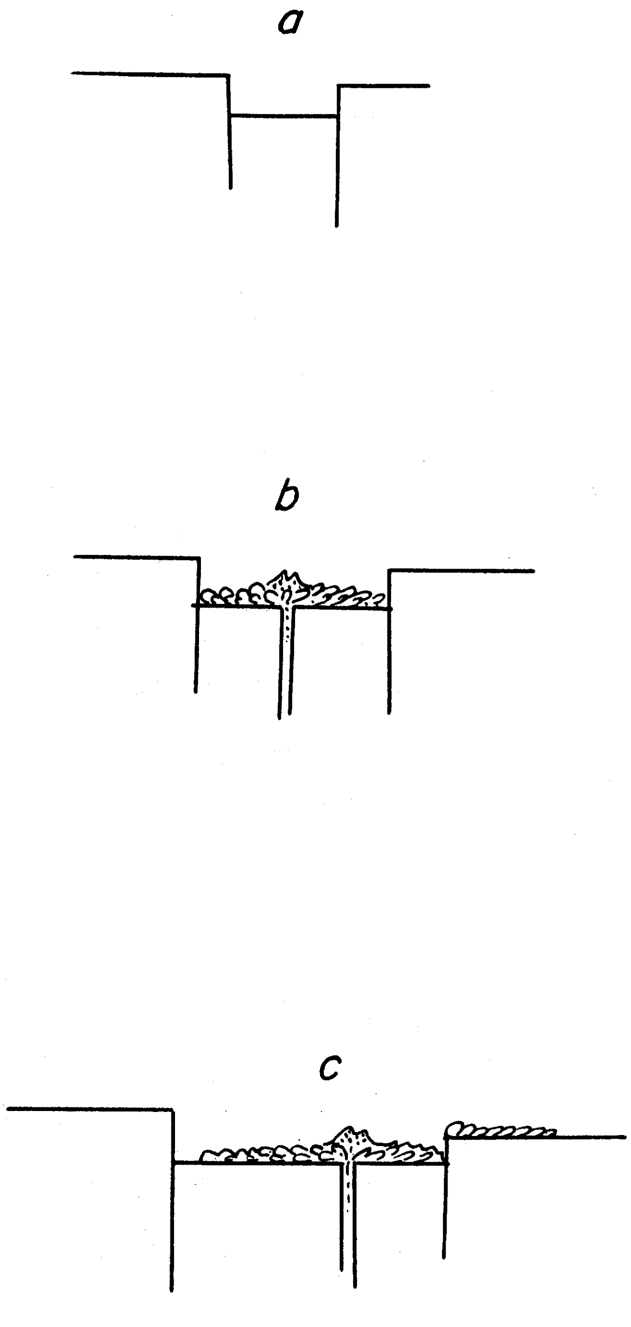
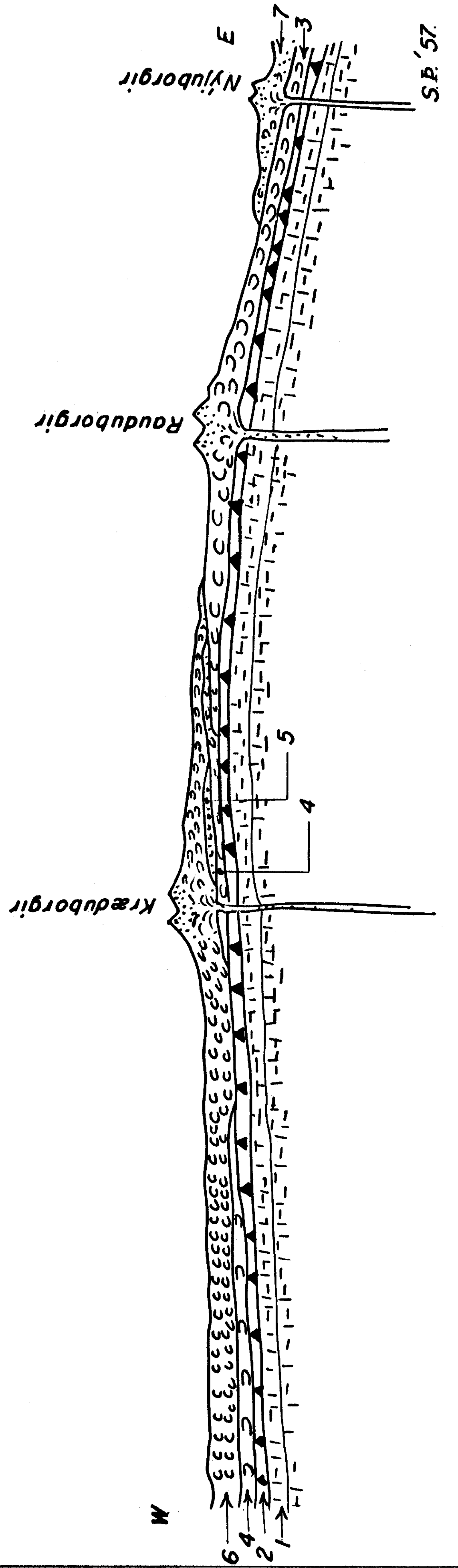


Plate V	Schematic W–E section through the water-divide area N of Skógarmanna-fjöll.	2.11.'58. S.B./P.J.	
		TNR.	45
		B.	303
		FNR.	4102



1: Bedrock (dolerite). 2: Glacial drift. 3: Lava flow from Rauduborgir. 4: Lava flow from Ketildyngja (Older Laxá lava). 5: Lava flow from Taglabunga. 6: Lava flow from Kræduborgir (Búrfellshraun). 7: Lava flow from Nýjuborgir (Sveinagjá).

Height scale is greatly exaggerated.

Plate VI	Geological map of the Dettifoss area.	2.11 58 SÞ/PJ
		Tnr. 47
		B - 3o3
		Fnr. 4117

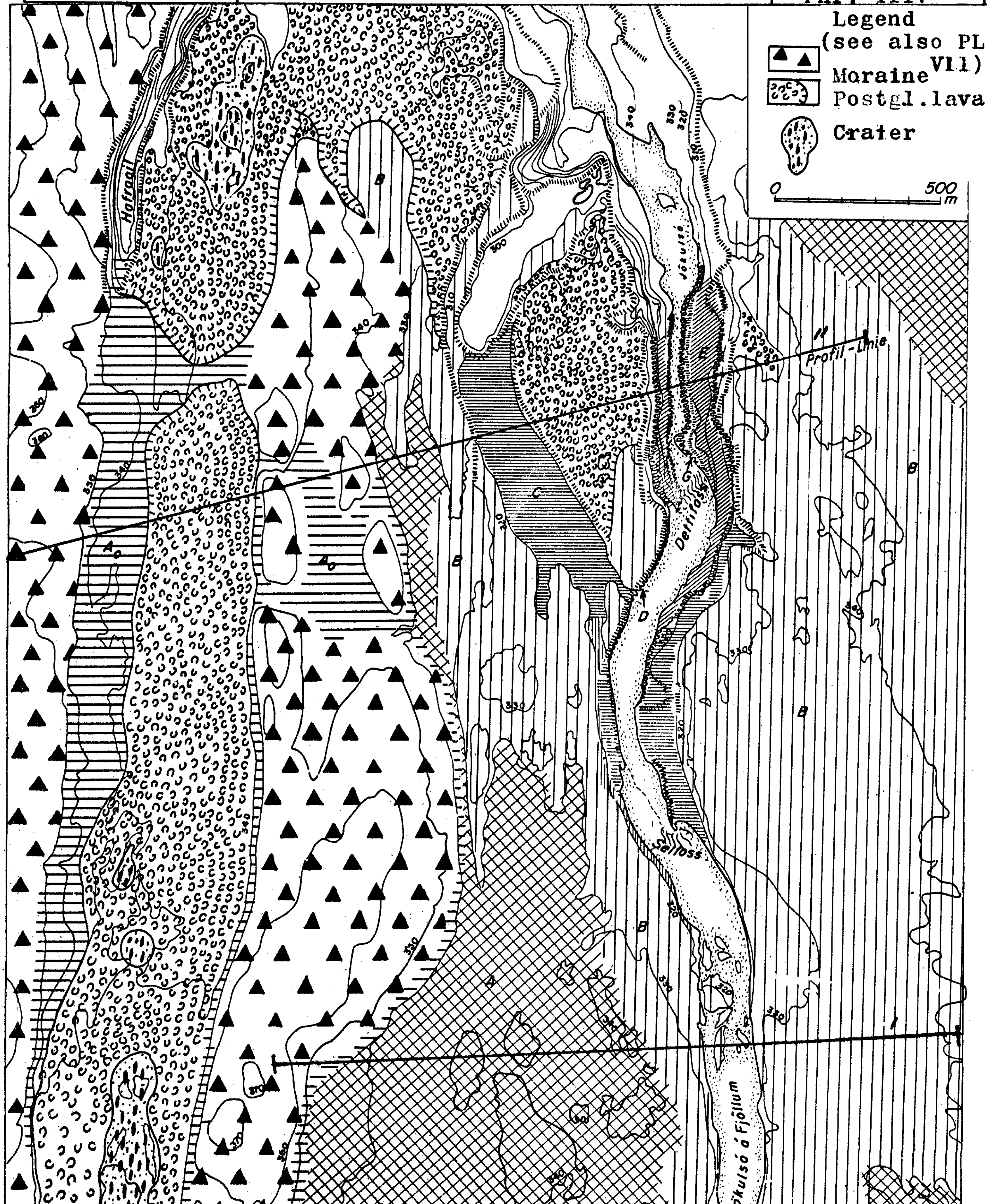


Plate VII (to be continued) Section I	Geological section through the river bed of Jökulsá at the proposed dam site S. of Selfoss.	2.11.'58. S.P./P.J. TNR. 37 B– 303 FNR. 4094

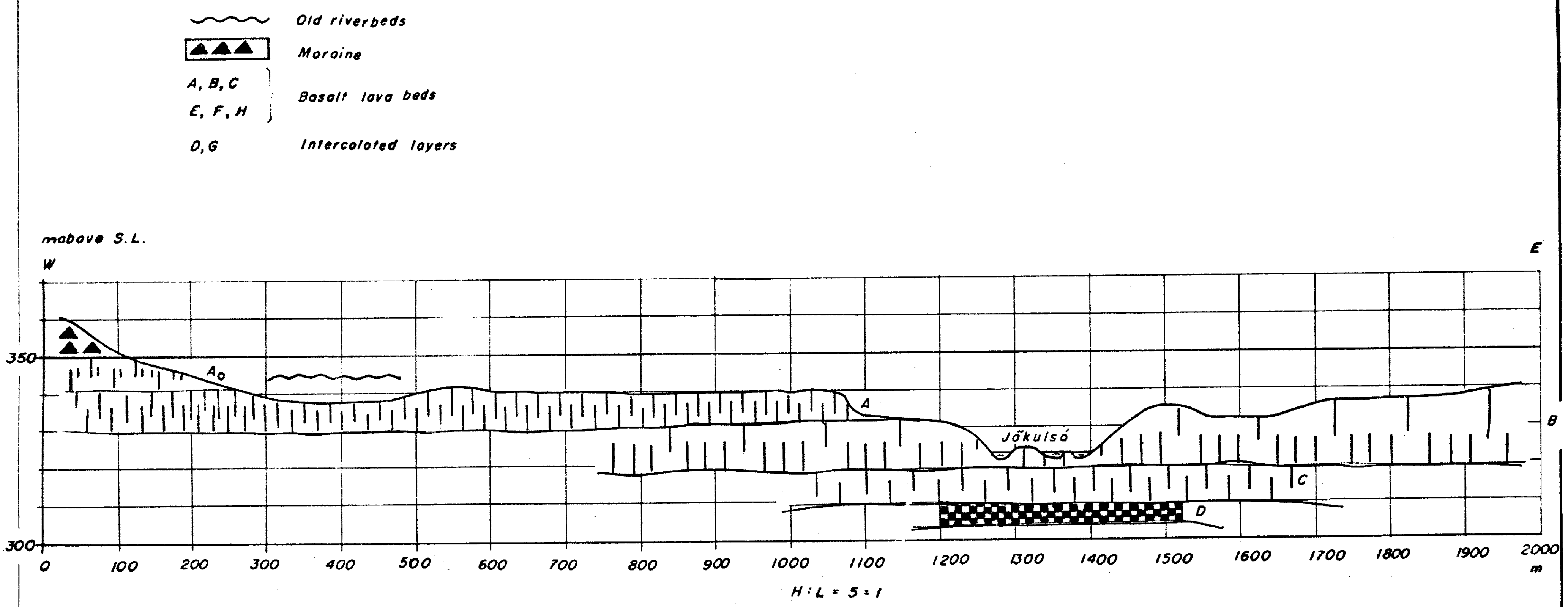


Plate VII (continued) Section II	Geological section through the Jökulsá Canyon a short distance N of Dettifoss	I.II.'58. SÞ/PJ Tnr. 38 B – 303 Fnr. 4095

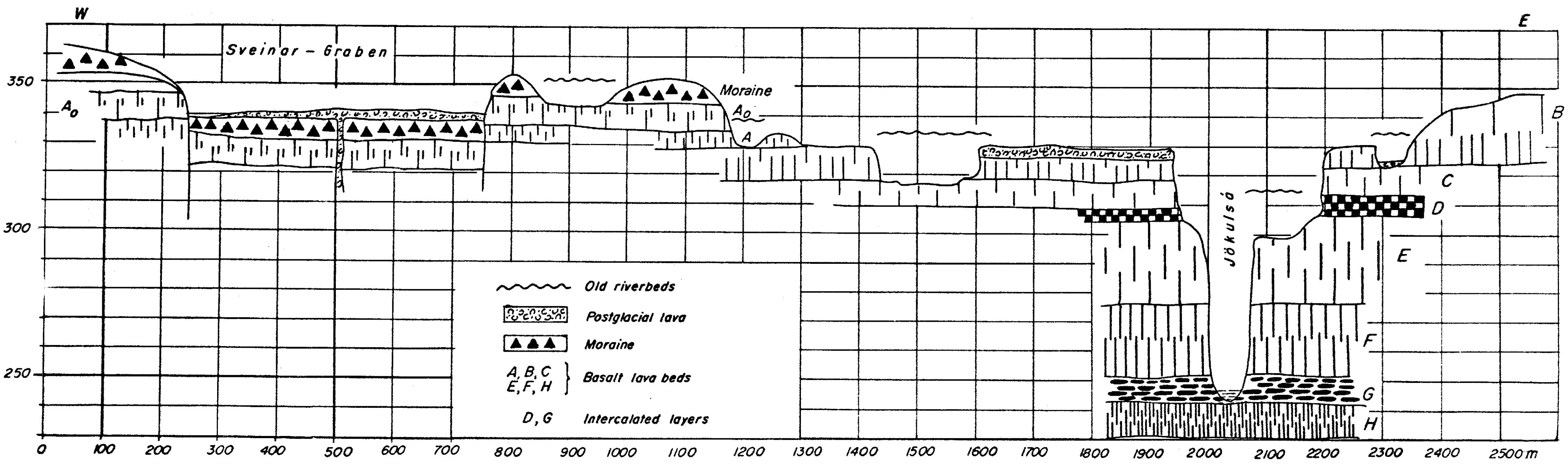


Plate VII Section III	Geological section through the Jökulsá Canyon a short distance N of Hafragilsfoss	2.11.'58 SÞ/PJ Tnr. 37 B-303 FNR. 4097

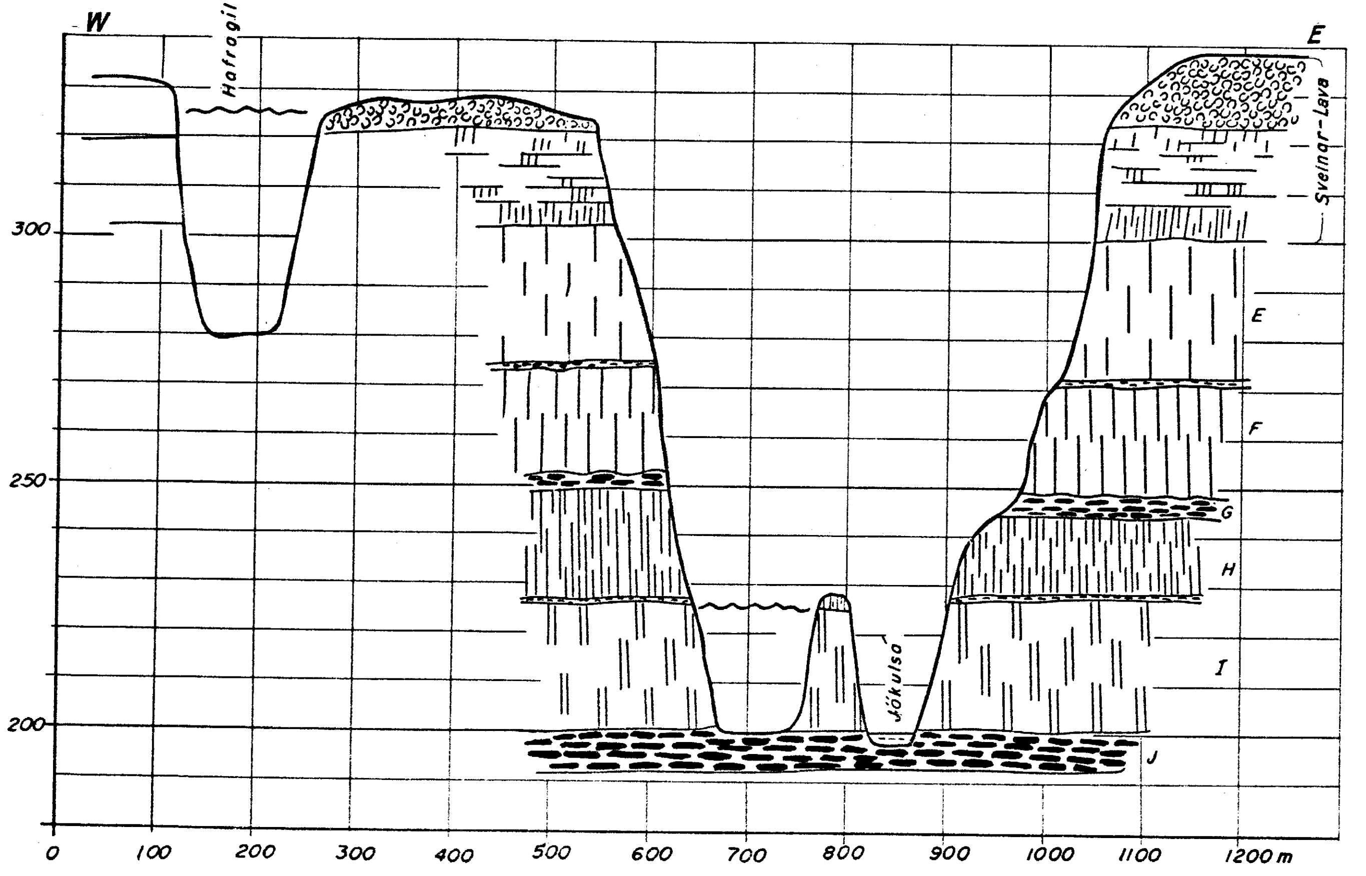


Plate IX Section IV	Geological section of the proposed damsite S of Réttarfoss.	2.11.'58. S.Þ. / P.J. TNR. 40 B – 303 FNR. 4097

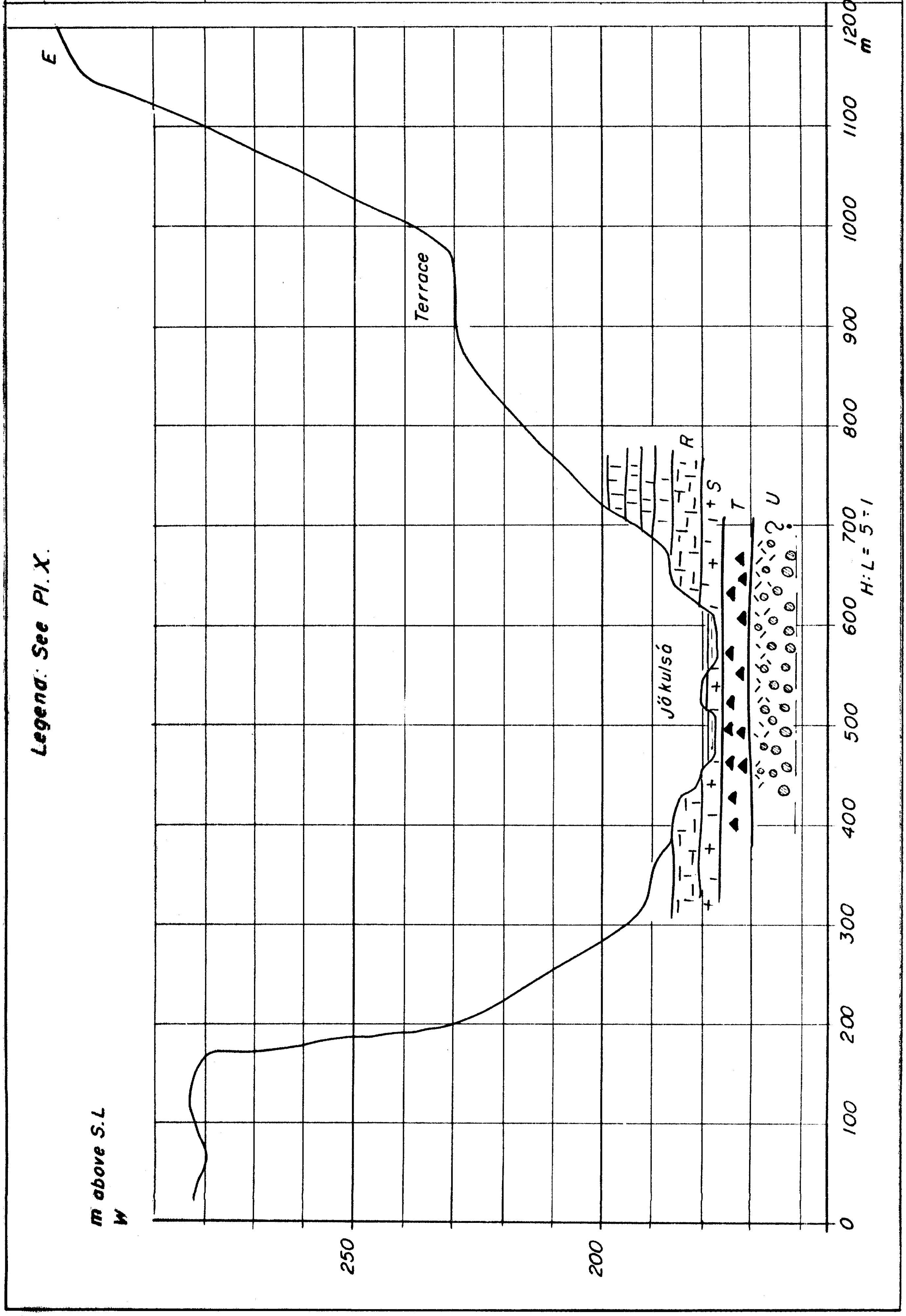


Plate X (to be continued)	Map showing section IV — VI	24.11.'58. S.Þ./P.J.
		TNR. 50
		BNR.- 303
Scale 1:10 000.		FNR. 4127

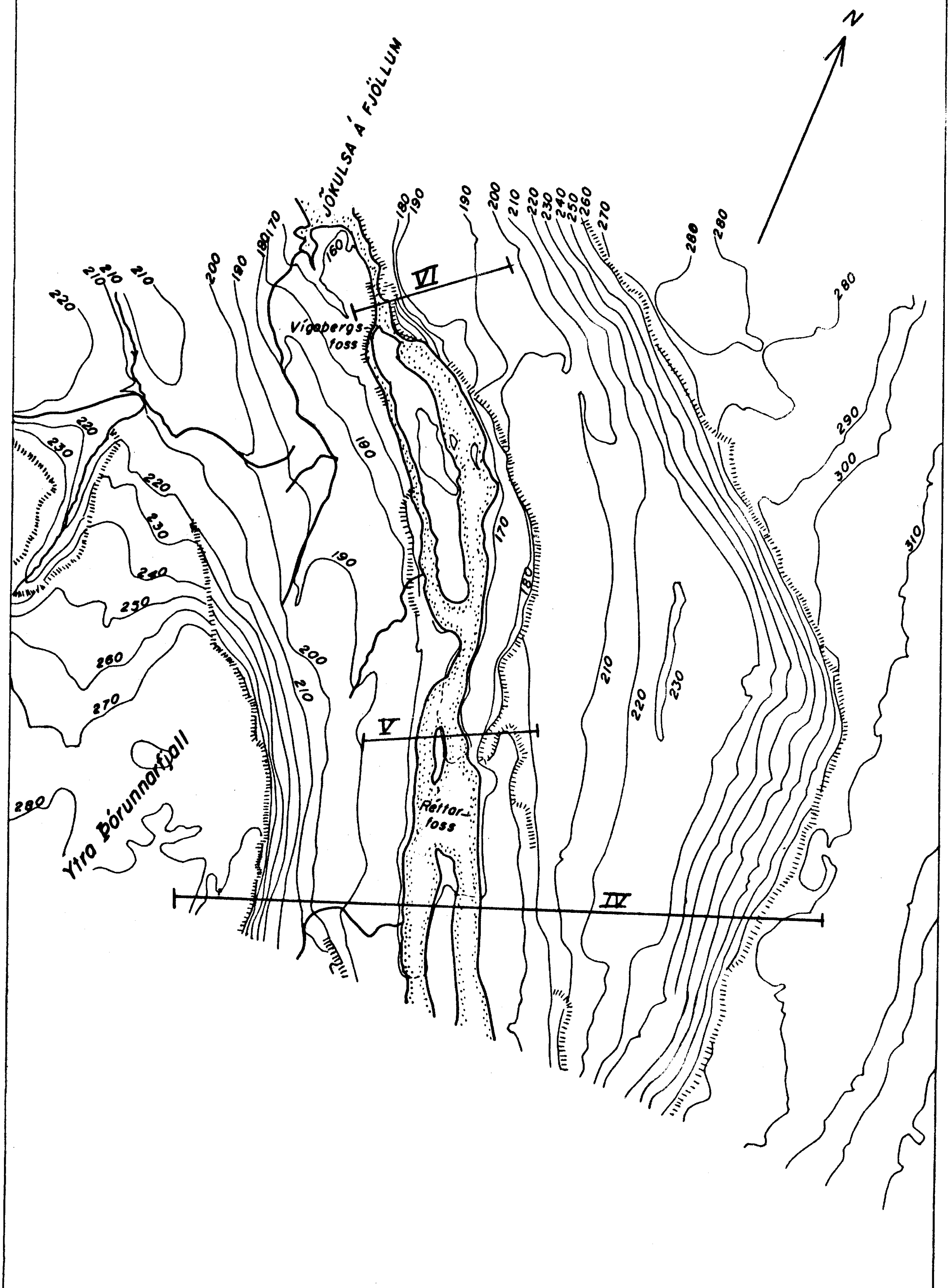


Plate X (continued) Section V and VI	Geological section at Réttarfoss and Vigabergsfoss	1.11.'58 SÞ/PJ.
		Tnr. 41
		B – 303
		Fnr. 4098

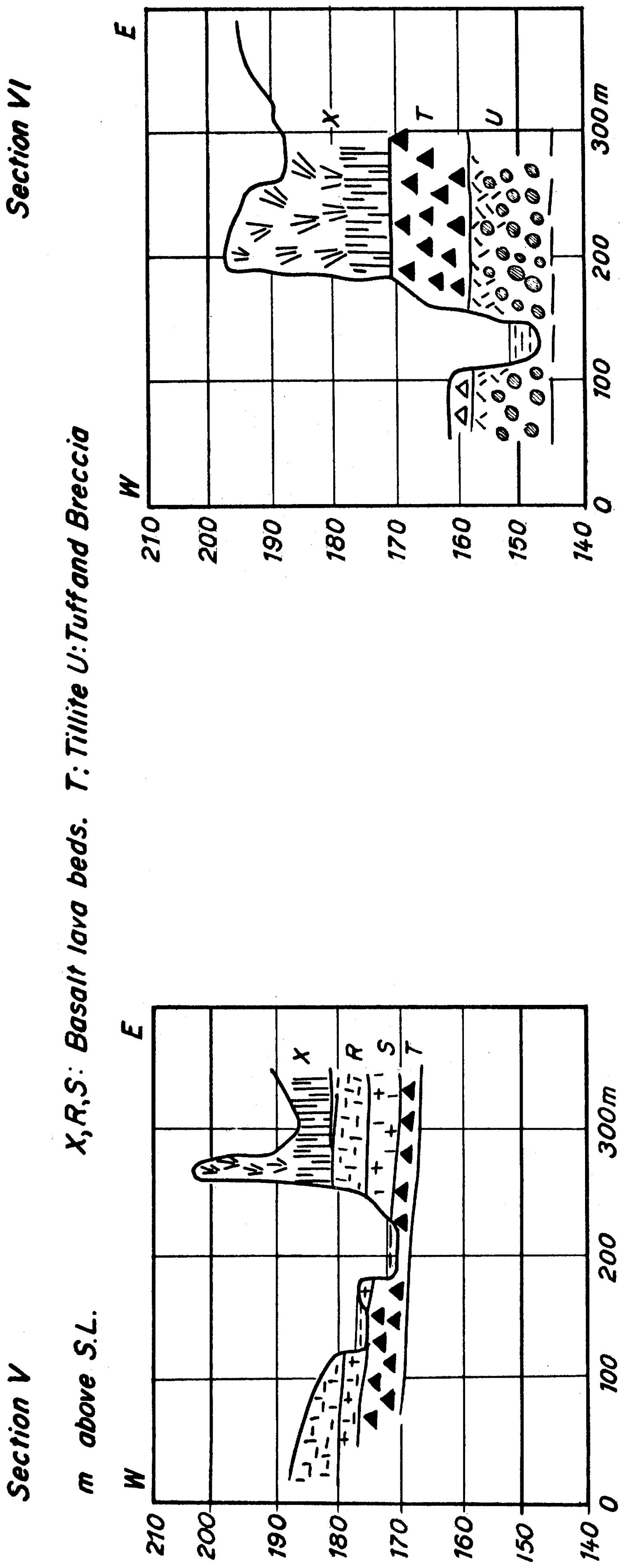


Plate XI Section VII	Geological section through the Jökulsá at Vestara - Land	1.11.'58 SÞ/PJ Tnr. 42 B-303 Fnr. 4099

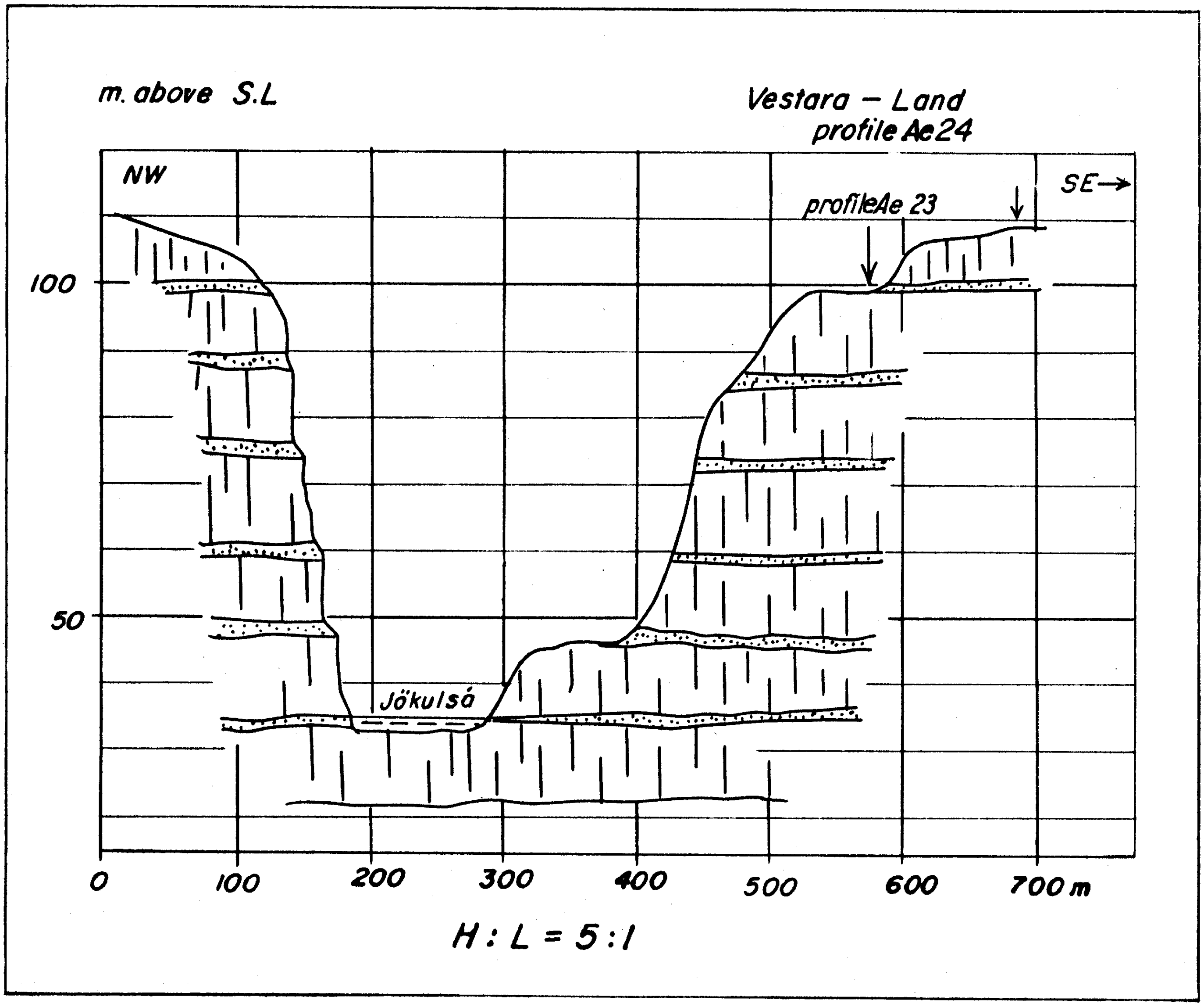
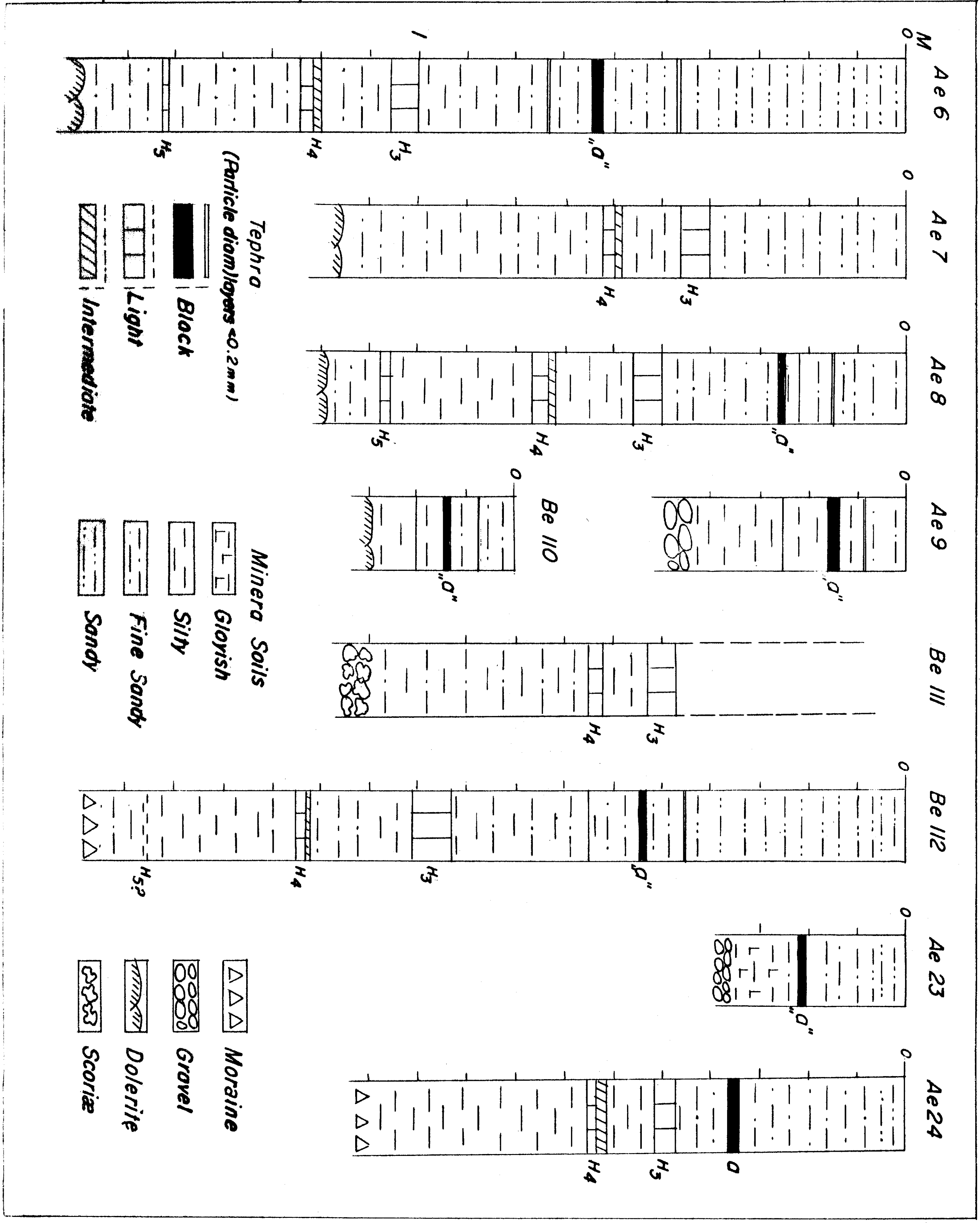


Plate XII	Soil profiles from the Ásbyrgi - Jökulsá area	2.11.'58 SÞ/PJ
		Tnr.51
		B-303
		Fnr. 4128



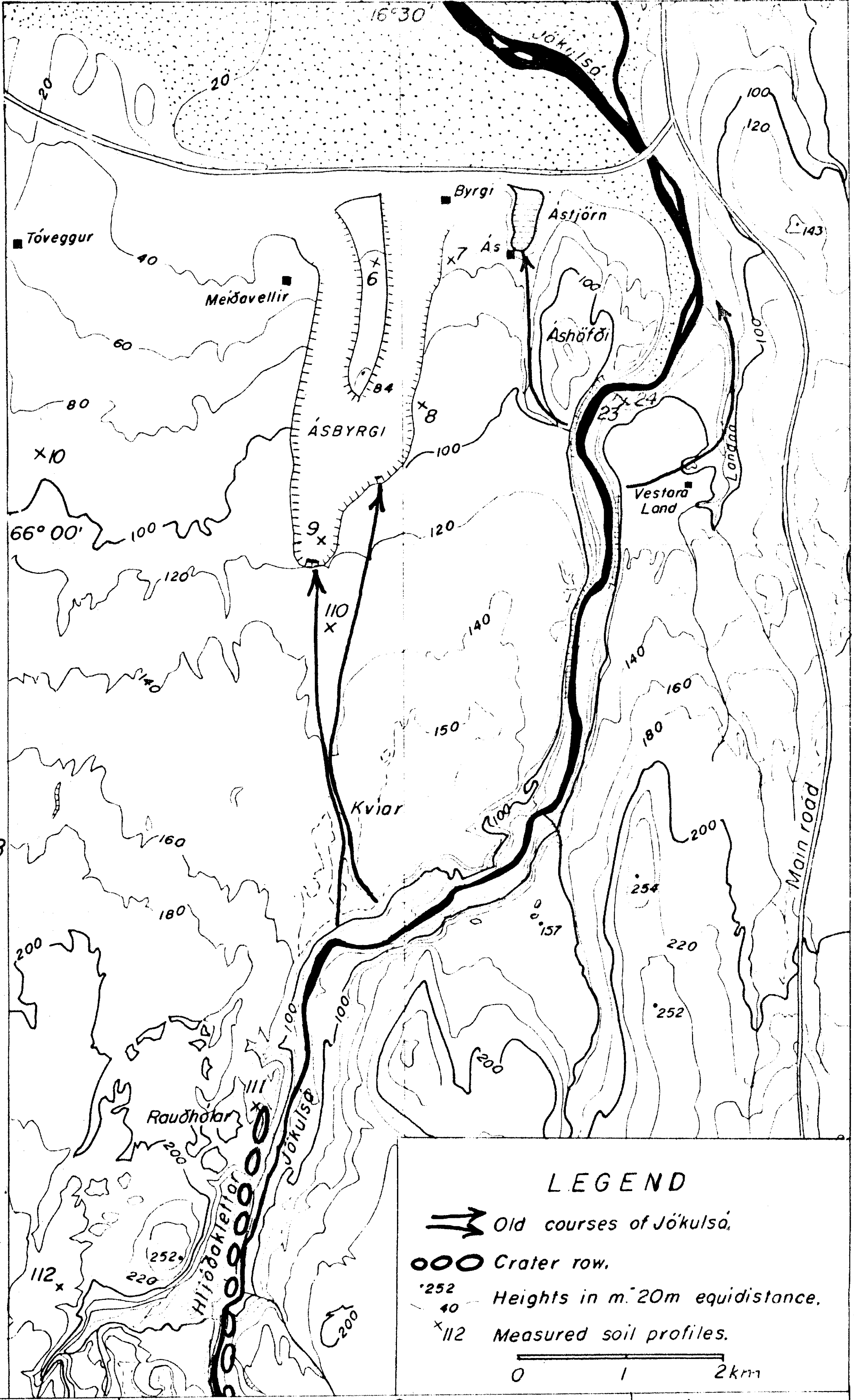


Plate XIII	Topographical map of Ásbyrgi and the northermost part of the Jokulsá-Canyon.	2.11.'58. SP/PJ.
		TNR. 49
		B-303
		FNR. 4119

Plate XIV Section VIII	Geological section at Núpaskot.	1. 11.'58. S.P. / P.J TNR. 43 B – 303 FNR. 4100

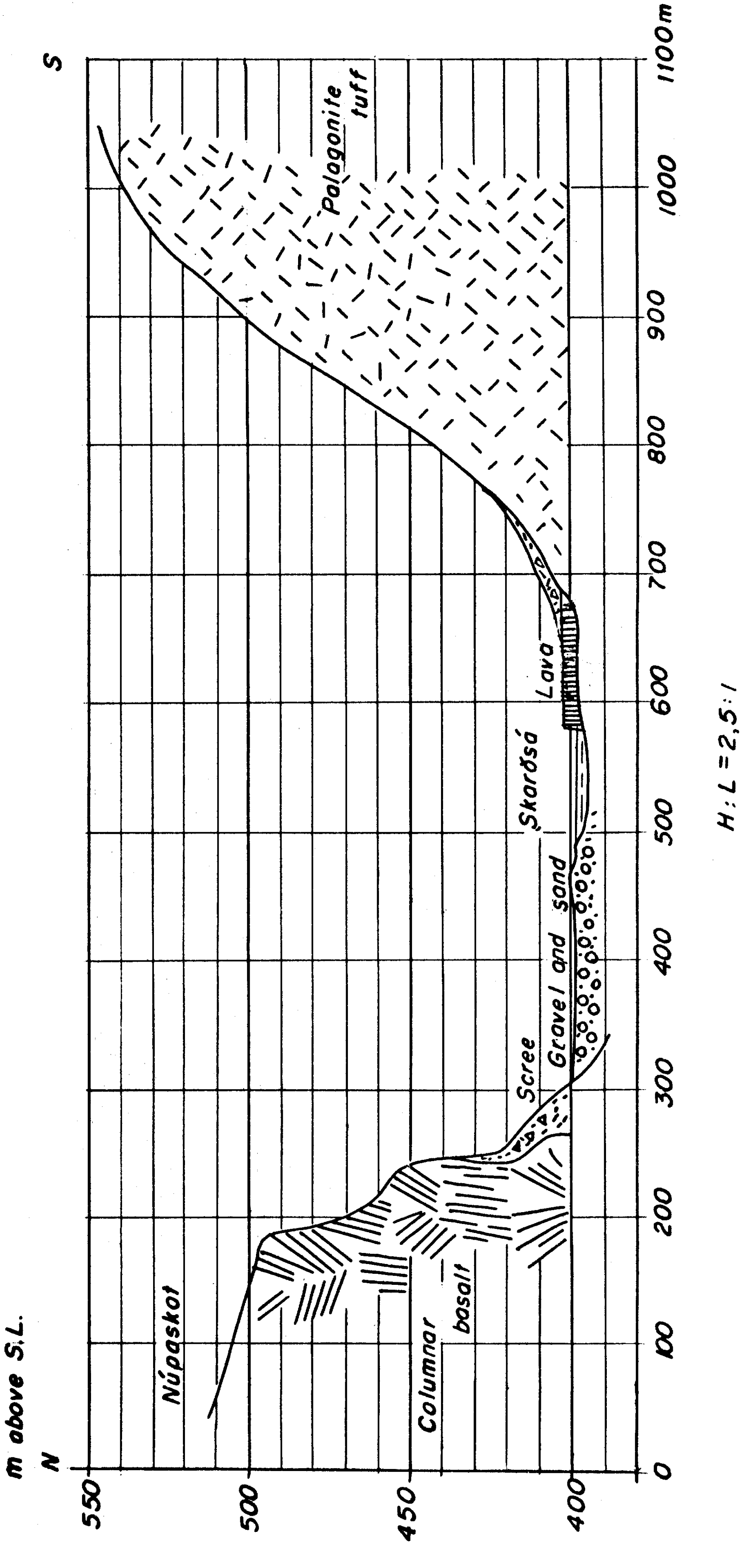


Plate XV Section IX	Geological section between Miðfell and Lambafjöll .	1. 11.'58. S.Þ./ P.J. TNR. 44 B- 303 FNR. 4101