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Report

on

GEOLOGICAL STUDIES OF THE WATERSHED OF THJÓRSÁ

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Gudmundur Kjartansson.

Reykjavík, March 6, 1954

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For four weeks this summer (1953) I made a geological survey for the State Electricity Authority on the upper watershed of Thjórsá, nearly only in uninhabited country. The area is large and there are many places where dams, tunnels and other constructions for electric developments might possibly be undertaken. Sigurdur Thoroddsen, engineer, has pointed such places out to me and marked them on a map with suitable explanations for my guidance. In concert with him, I chose to try to get a general view of the geological formations of the whole area, where developments could be considered, rather than to examine individual damsites to some completion, except those that seem to be of special interest for the area's geology.

The report, that follows, is not only the result of my explorations this summer, I was before fairly well acquainted with a large part of the area.

A. General View

On enclosed map, it is differentiated between the six rock systems, which are of greatest importance at the upper part of Thjórsá, and its tributaries. Those systems listed by age, are:

I. The Hreppar System (Hreppamyndunin)

II. The Palagonite System (Brúngrýtismyndunin)

III. The Thjórsá Lavas (Þjórsárhraun)

IV. Sediments of Lava Dammed Lakes

V. Postglacial Pyroclastic material

VI. Lavas younger than Thjórsá-lavas.

I. The Hreppar System

North-west of the dotted line, which is drawn on the map up along Ytri-Rangá, just east of Kaldakvísl and over the northern part of Thorisvatn, and which I shall call "rockboundary", nearly all the countryrock [1]) is made up by the Hreppar system. Excluded, are only a few tuff hills, just west of Kaldakvísl (e.g. Saudafell and Thveralda), which seem to be only remains of the Palagonite system and lie on top of the Hreppar system.

About the physical characteristics of the Hreppar system I have written before in a report about geological surveys at Gullfoss (sept. 1951), and I refer to that, because this system as a whole is the same at Thjórsá as at Hvítá, only details differ from one place to another, here as there. It should, though, be mentioned that nowhere at Thjórsá have I discovered such a magnificent breccia formation as the one which I named "Brúarhlöd breccia (report of 1951), but rather do the rocklayers at Thjórsá compare to the "Gullfoss-layers".

As I have explained in earlier reports, the rock layers of the Hreppar system are, in general, tight and solid, compared to what exists here in this country.

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[1]) Icel. berggrunnur, a term meaning all kinds of rock which was formed and indurated before the end of the last glaciation.

Furthermore, there is now available valuable experience regarding this rockformation from the development at the Sog river, because all the rock that was excavated there belongs to the Hreppar system, and everywhere in this system similar rocks may be expected. (See, though, later about the damsite on Thjórsá at the mouth of Svartá).

II. The Palagonite system

South and east of the "rockboundary" along Rangá and Thorisvatn, the Palagonite system starts, and a large change is found both in landscape and in kinds of rock.

The main kinds of rock in this system are two: palagonite rock, which is much more common and forms nearly alone whole mountains and mountain ranges, and pillow-lava, which is in some places in thick layers in the palagonite rock.

These are very questionable rocks from a technical standpoint, because they are both very leaky and seem not firm, (especially the tuff), but no experience is available about hydro-developments in palagonite areas.

By far the greatest part of the palagonite rock is originally tuff, i.e. pyroclastic material (volcanic gravel, ash and pumice) which has solidified under pressure and cementation into a rather loose, brownish rock.[1]) The rock is, in many places, bedded, and the layers do often dip in the same direction and almost to the same degree as the surface of the earth. In many places the palagonite rock

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[1]) Icel: brúngrýti.

shows slide planes which are formed by the upper layer being pushed forward over the under layer (by glacial pressure while the rock was not hardened). Both the boundary between layers and the slide faults are now, in general, so well cemented that the rock does not much rather cleave along them than in other directions. On the other hand, the layers weather differently.

All palagonite rock is finely porous and absorbs water, which falls on it. In much rain, puddles can form for awhile on palagonite rocks. But most of them disappear in a few hours, even if one puts a cover over them to prevent evaporation.

On flat ground and in the long and narrow passes between mountains in the palagonite area a solid rock is not often seen - except where there is young lava. Most of the depressions into the country rock are covered by loose, volcanic (pyroclastic) gravel, which will be discussed later, and which is not less porous than the palagonite rock and the pillow-lavas in the mountains. In the palagonite area there is, therefore, hardly any watertight type of rock, and it is also a typical dry area. (More later, V).

The two geological systems, the Hreppar system and the palagonite-formation, which now have been discussed, form the countryrock, "the firm solid rock", the bottom of which is nowhere to be seen in this part of the country. It was fully formed some time before the end of the last glaciation. The younger, i.e. recent, geological formations, which later were laid down on top of the country rock, remain to be discussed. But there is one layer, in between which must not be forgotten, although I do not find it possible to show it

on the map at this time. This is the moraine from the end of the last glaciation. I have described this moraine in a previous report (1949 p. 4-7 and it will not be repeated here). The moraines ("the gravel plains") play a much greater role on the surface of the Hreppar system than on the palagonite system. But one must have in mind, that a layer of moraine may be expected in the depressions and on the plains of the palagonite area next over the palagonite-rock, although the younger layers of lava and pumice conceal it in very moist places.

III. Thjórsá-lavas.

Lavas, erupted in postglacial times, cover the greatest part of the plains between mountains east of the rock-boundary line, but they have also spread over large areas west of this line, especially down in the inhabited areas. By far, the most of these lavas are the so-called Thjórsá-lavas, which are easily recognizable by large white dots of felspar, and only these lavas are of importance with regard to conditions for hydro-developments.

The Thjórsá-lavas have been erupted from a volcanic zone a few kilometers wide, which lies from Frostastadavatn (vatn = lake) in a straight direction, north-east along the ridge and the western slope of Vatnaöldur to Ljósufjöll and possibly still further into the wilderness.

One of the older Thjórsá-lavas, - likely the very oldest one - has flowed all the way to the sea. At Laugardælar and other places in the Flói district, it has been drilled through and its thickness has been found to be about

20 meters. Shortly above the farm Galtalækur in Land district two of the younger Thjórsá-lavas end in steep edges on top of the old and the largest one, and at Tungnaá, east of Sigalda there can be seen four layers of lava, one on top of the other - and it is, though, likely that they are more numerous, but the lowest ones conpletely covered.

The Thjórsá-lavas look old and they lie in under most, or all, post-glacial lavas, which they meet, among those the Hekla-lavas. Still, their age can hardly be more than 5-7 thousand years, because the sea had fully receeded from the low-land before one of the oldest of those lavas flowed over the districts Skeid and Flói.

These lavas have occupied and filled the old beds of the large rivers - Tungnaá below Svartikrókur and Thjórsá below the mouth of Tungnaá - and the rivers now, either flow on top of the lavas or follow one of their edges. The present beds of the rivers are, therefore, due to their youth, in general, shallow and in some place hardly at all cut down.

The lavas are, of course, porous and through their cracks must flow much water, which otherwise would flow in the rivers. In stretches where the rivers have cut the least down, the ground water level slopes obviously away from the rivers, so that water disappears from them and becomes ground-water. Some of this reappears down in the river bed, but some is lost to the river completely and flows either underground all the way to the sea or reappears in springs outside of the watershed, especially in sources of Ytri Rangá

and in district of Land.

The last mentioned conclusions are mostly based on measurements of temperature, which I have made of springs in various places around the country and not the least in the area which is being discussed. By those measurements, I pretend to have discovered that from underneath areas, where streams and rivers seep into the earth and disappear, abnormally warm springs issue. In other words: ground water which has seeped from rivers is warmer that the other, which is formed directly from rain and snow. For instance, the springs on the western river-bank in Rangárbotnar are 1 - 2°C warmer that those on the eastern bank. This indicates that the water in the first mentioned springs has, previously flowed on the surface in the river bed of Thjórsá, Tungnaá or Helliskvísl. Also, the springs in Landssveit are warmer that those found in other areas in the same elevation, and some of this water flows into Rangá. I think it is likely that nearly half of the water of Rangá is a leakage from the first mentioned rivers, especially Thjórsá.

It is obvious that seepage and, thus, loss of water from the rivers is increased, if their surface is raised by dams. It would, also, be increased much more than in proportion to the increase in pressure, caused by the raising of the water, because the reservoirs would flow over areas of lava, which are much more permeable than the river bed itself, which has been tightened, to a certain extent, by the glacial silt from the river. The progress of Helliskvísl, after it was forced out of its river bed by an eruption in Lambafit in 1913, is instructive as to how glacial water tightens its

river bed (See: Úr sögu Helliskvíslar, Náttúrufræðingurinn, 1953).

IV. Sediments of Lava-Dammed Lakes

The edges of the Thjórsá-lavas, in some places, cross old river beds. In all those places, the rivers have for some time formed lakes above the lava dams. But they have, soon, filled them by their sediment, and in some cases these lakes have to a certain extent been drained out by the rivers cutting through the lava dams. The sediments which now fill the lake basin are mostly silt and sand, both of them unhardened and very weak foundations for dams.

The uppermost lake basin is the river bed of Tungnaá, stretching from the south-western end of Vatnaöldur and, at least, far inland on the east side of Snjóöldufjallgardur (Snjóöldu = mountain range), but it reaches possibly much further. Here, at the S.W. end of Vatnaöldur, Tungnaá flows west crossing the eruptive zone from which the Thjórsá-lavas issued. At least two, but likely more lava flows, have here flowed in the river bed and, to a certain extent, they have been erupted from its bottom and they have dammed up the river. There is hardly any doubt that the total thickness of those lavas amounts to tens of meters, and it is quite possible that they are more than 100 meters thick. Now this lake is filled and replaced by a plain of mud and quicksand. Only in previous sharp inlets from the lake still unfilled lakes remain (see map).

The next basin of a previous lake is where Blautakvísl flows into Tungnaá just north of Vesturbjallar. The river

has now completely drained it out by cutting through the tuff threshold at the northern end of Sigalda (see damsite 10). It seems, though, to have completed filling it up before, but by draining it out, the river has eroded down again and carried away much of the lake sediment, so that it is now only left in sand and clay terraces along the roots of the hills north of the basin.

The third lake of this kind was above where the Thjórsá and Tungnaá meet and stretched from there more than 10 km. up along the valley of Thjórsá between Búdarháls and Fitjaskógar. The Thjórsá-lavas, which here are not fewer than three, have barred the mouth of this valley, but below they followed the old river bed of Thjórsá all the way to the ocean, and raised the river equal to their thickness (50-100 meters east of Sandafell ??). This lake is very little drained out, because Thjórsá has cut itself down very little at the upper-most part of the lava dam, but the lake is completely filled by sediment.

Small lakes of this type have been formed at the mouth of the Thjórsár-dalur, but the lowest lake bed and one of the larger ones is between the districts Skeid and Holt. It lies at the eastern edge of the lava, which here consists only of one flow, and it stretches from Krókur up to above Kaldárholt. The lake basin is completely filled, but drained only very slightly. It is now nearly all sand flats which are completely flooded in large floods.

Finally, Hvítá and its tributaries have formed very extensive lakes at the northern edge of the lava on the lowland. About that, I refer to my earlier report (Sept.-Oct.,

1949, pgs. 19-23, sketch IV).

V. Postglacial Pyroclastic Material

The area of this formation coincides nearly with the palagonite area, as it covers, there, large plains and valleys between the mountains. Such a landscape is called "vikrar". The pumice reaches the greatest thickness in Vatnaöldur, more than 300 meters, but it becomes thinner and more discontinuous in the north-west, so that on that side, its limits become unclear. When it approaches Thorisvatn, the layer of pumice becomes so scattered, that it can hardly be shown on a map with such a small scale as the map enclosed with this report. It is though, possible that in this area there are in bowls piles of pumice which may be some tens of meters thick.

The pyroclastic material has obviously been erupted from Vatnaöldur and from its nearest neighbourhood. The Vatnaöldur is a ridge shaped volcano, which lies in the direction north-east to south-west, as other mountain ranges in the palagonite area. But Vatnaöldur is the youngest of those mountains, postglacial, and differs from the others in that their material is not hardened. The most voluminous material of this mountains ridge is black pumice, but besides that, there are in some places frothy scoria clots, which have, in a few places, formed small streams of lava. Mixed in the pumice, are scattered rock fragments of various sizes, originated from the countryrock, which the eruptions have broken through. Most of these fragments are of hard and compact basalt, similar to the basalts of the Hreppar system, but surprisingly few are of tuff. Some of these fragments are of a rock type which, by the unaided eye, can not be

distinguished from a Thjórsá-lava, and this indicates, that before the eruptions in Vatnaöldur branches of those lavas stretched east to those areas, where the ridge shaped volcano later was piled up.

The pumice from Vatnaöldur has filled up valleys and drowned mountains. It covers, among other things, most of the craters from which the Thjórsá-lavas were erupted. Only a few of them stick out of the pumice north and west of the mountain ridge on the southern bank of Tungnaá. From Vatnaöldur to Thorisvatn the pumice covers nearly all flat ground, but on hills and on steep slopes it has often been removed by wind erosion. In all this area, one may expect the pumice to amount to tens of meters in passes and in valleys between the tuff ridges. In some places one sees, though, lava peaks cropping out of pumice, and it is always Thjórsá-lava (f.i. Karl and Kerling). Undoubtedly, there is Thjórsá-lava in more places than where it is seen. It is not likely that there is pumice again under the lava, but rather that the lava overlies immediately the country rock or the glacial sediment, which then again lies on the country rock.

The loose volcanic gravel, which now has been discussed, is, of course, one of the most pervious of all kinds of rock. When, in addition, the country rock which lies under it is also pervious it is no wonder that the area east of the rockboundary (see map) is, typical dry area. The underlined term is defined in my article Íslenzkar vatnsfallategundir ("Icelandic Types of Rivers", Náttúrufr. 1945, pg. 113) and will not be discussed further, here.

In this dry area, the slope of the ground water level is very small and, in general, this level is very far down,

especially in hills and mountains, because, there, it is only very slightly bent upwards. Springs and streams are very unusual in the palagonite areas and only occur in the deepest depressions. Still many of its deep valleys go down below the surface of the ground water. But, in those, there are ponds and lakes, by far, most of which have no outlet on the surface and the height of their water level varies depending on the season and weather. At the edges of the dry area - that is at the rockboundary - there are in many places, springs with much water and they form typical "linda"-rivers [1]), as Thórisós, the rivers in Thóristungur, and Ytri-Rangá. Rivers of the same type are also formed in the deepest valleys within the palagonite formation, in those that are not closed by a rock threshold. Such is Vatnakvísl, which flows from the Veidivötn area to Tungnaá, and Blautakvísl, which flows into Tungnaá west of Thóristindur.

V. Lavas Younger than the Thjórsá-lavas.

On the map there are shown some lavas, which are younger than the Thjórsá-lavas. Those are mostly some northmost stretches of the Hekla-lavas, but also a long and narrow lava field along a young looking volcanic fissure in the area of Veidivötn. Others, are too small to be possible to show on the map, e.g. in the eastern slope of Vatnaöldur and at Veidivötn. None of those small lavas reach to the areas where developments are most likely contemplated.

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1) A type of rivers, defined loc. cit.

B. Different Localities

Possible damsites and reservoirs are numbered as on the map.

1. Damsite at Thjórsá at the mouth of Svartá

Thjórsá flows, here, wide between up to 10 meters high gravel banks. Judged by the current the bottom seems to be fairly even, and it becomes steeper downstream. In the same direction, the river gorge becomes somewhat deeper and its banks become steeper, so that not far downstream from Svartá the gravel slope is replaced by a steep rock wall. Above the junction of the two rivers, firm rock can not be seen in the river bed, but at the junction, the rock appears lowest in the banks above the water level and the river seems to flow on flat rock. Still further downstream the rockwalls start. All are these various types of sediments, mostly a clay with scattered pebbles (undoubtedly moraine) and a sandstone. Both, and, though, especially the sandstone, are rather loose, but have different degrees of looseness in different places. Some of the sand is too loose to be termed sand-stone. In various places in the cliffs on both sides of the river, the sand is not the least cemented and it is no denser than usual in gravel pits in postglacial river gravel. These parts of the rock are obviously both pervious and weak against water pressure, as indicated by the fact, that certain sections of the cliff which consist of the loose sand have, to a great extent, been excavated and are thus mostly to be found in caverns and inlets. But, as these zones of weakness in the rock seem to be of limited sizes and to be isolated from each other

by sounder rock, they may be harmless. But they are questionable and their spreading needs a much closer investigation, as by drilling.

Because of the rock in this gully of Thjórsá being poorly hardened, I thought this, at first sight, to be a late moraine overlying the country rock. This is not so. Further down the river, this formation disappears under a basalt layer, and there, one also finds basaltic injections into the formation. This is, therefore, a part of the country rock itself, probably belonging to the youngest (the uppermost) rock layers in the Hreppar system. But in no other place, have I found such soft rocks in that system.

On both sides of Thjórsá, at the mouth of Sandá, there are undulating morain landscape with scattered large erratic boulders. At the proposed damsite the country rock is nowhere seen except in the river bed, so one may expect that the hills are all moraine, and that it is even thicker than their hight. About such formations, I refer to what I have written before about the proposed damsite at the head of Hvítá at Hvítárvatn. (Report from 1949).

2. A Tunnel under Nordlingaalda

Nordlingaalda is nearly completely covered by moraine, and one sees there, nowhere, a rock cropping out close to where the tunnel would be. But a few kilometers further north on this hill, a few basalt peaks sticks out of the gravel. The structure of this basalt indicates that it was originally injected as dikes or veins into tuff and was later laid bare by denudation. More things indicate that

the hill is composed of some type of tuff, and it is probably firm and watertight as in a gully of Kisa west of the hill.

3. Damsite on Kisa and in Miklulækjarbotnar

West of Nordlingaalda, flows the river Kisa in a tuff gully, and the rock is, in many places uncovered, both on its sides and on its bottom. All this rock looks to me as being solid looking and tight, and, also, old looking (belonging to the Hreppar system) and with considerable basaltic injections in the form of dikes or vains. Probably the country rock is of this type between Kisa and Miklulækjarbotnar, but in this part, it is very much covered by moraine, and in Miklulækjarbotnar, I saw nowhere an outcrop of the country rock. But approaching Fellakvísl, the basaltic country rock takes over and it lies in many places, uncovered along the east side of that river.

4. Damsite on Dalsá North-East of Öræfahnúkur

The hills on both sides of the river are basaltic. But down in the river bed, the river flows over banks of coarse rock material with great boulder in it, and one sees there no solid rock on a large section. Probably there is a thick and relatively firm moraine under the loose gravel on the river bed.

5. Tunnel from the Dam over Dalsá under Öræfahnúkur and Helgavatn down to Fossárdrög

Öræfahnúkur and an unnamed peak 2½ km. south-west from it, are composed of indurated sediments elsewhere, the country-rock is, for this distance, a firm and solid basalt

rock, which lies in thick, nearly horizontal layers with little or no intercalations of other rocks. The sediments in the peaks seem to me, clearly, to lie on top of these basaltic layers, and not to reach nearly far enough down to touch a tunnel which would be in a 600 meters elevation. Yet, I can not fully discard the other possibility that the sediments lie under the basalt and project up through it, only in the peaks. But even so, one should be able to escape the sediments by placing the tunnel ½ - 1 km. west of the peaks. No doubt, one can, by further investigation, find the contact between the basalt and the sediments uncovered and, thus, definitely decide which one of the formations is on the top. Helgavatn is shallow and, supposedly, dries up sometime in late summer. It is, though, possible that underneath - and even in more low spots on this way - there are deep basins into the country-rock filled with moraine. The existence of this lake, and others of the same kind, proves the imperviosity of the country rock.

6. Various Damsites on Fossá and Stóra-Laxá

Regarding the damsite on Fossá west of the southern part of Lambafell and north of Fossheidi and over Stóra-Laxá above or below Geldingatangi, it is of greatest importance, that there is underneath everywhere, a dense and solid basaltic country rock (the Hreppar system), and I have no reason to describe every place individually, as I have explored them rather casually. It is possible that it is, in some places, rather deep down to the rock surface and especially does it seem so to me at the upper damsite on Stóra-Laxá, where the river seems to have deposited con-

siderable sand banks. It seems that the tunnel from Stóra-Laxá south-east to Fossölduver would all lie in the basalt, which has been spoken of before.

7. Damsite on Fossá below Fossölduver and Tunnel through Fossalda.

All the way from Fossölduver down to Háifoss, the river Fossá flows over no deposits but on solid basalt rock. This is still the same basalt formation which is discussed in 5. and 6.

Fossalda has three types of rock formations, all of which belong, though, to the Hreppar system. One lies on top of the other and the contacts seem to be horizontal. Lowest, there are different types of tuff, which look old and solid. It can only be seen on those sides of the mountain which face the valleys Fossárdalur and Thjórsárdalur. The tuff reaches somewhat more than half way up the cliff, over which Háifoss falls. In the slope of Fossárdalur, there are large injections of rhyolite into the tuff. On top of the tuff lies the same basalt formation which forms the whole country rock along Fossá and all the way west over Stóra-Laxá. The rhyolite injections do not seem to reach up into this thick slab of basalt. Finally, the top of fossalda, that is above 580-600 meters elevation, is again, tuff.
A tunnel from Fossölduver through Fossalda in 400-500 meter elevation and to the mouth of Fossárdalur would, therefore, probably be in basalt all the way.

8. Damsite on Tungnaá south of Vatnaöldur

In this area, more specific just above Hófsvad (Gudmundur Jónasson's automobile crossing), Tungnaá hits a rock bottom for the first time after winding through quicksand plains in a filled up lake bed for more than 40 kilometers (see IV). This flat rock is the lava dam itself, which formed the lagoon.

As mentioned before, the dam is composed of Thjórsá-lavas, and it is to be expected that they are a few in number, one on top of the other. They have been erupted in this neighbourhood and are here, therefore, somewhat more slaggy and porous than where they have flowed a long distance. The lavas are, though, hardly any more pervious here than in other places, because they must have been fairly well tightened by having damed up glacial water for thousands of years. This holds, though, only for the lava on the bottom of the river bed and other places under ground water level. But, if one were to dam the river here and raise its surface by 35 meters, the dam would have to reach a few kilometers up on the southern bank of the river, where the glacial water has never been able to tighten the lava. In that part, the lava is so covered by pumice that rockhills and peaks are only seen now and then. North of the river the palagonite rocks project from underneath the pumice cap of Vatnaöldur and the dam would butt against them. But the contact between the tuff and the lava would, here, be a dangerous spot in the foundation. On the contact one may expect loose sand or scree which would be pervious and poorly withstand the water pressure. This suspicion is backed up by the fact that where the river follows this con-

tact - as happens, for instance, just below the crossing - it has cut itself a narrow channel.

If, at this place, there was to be a 35 meter high dam, there would be seepage not only through the foundation of the dam. Undoubtedly, much water would seep from the Veidivötn depression (which then would be a part of the reservoir) west through Vatnaöldur. As pointed out before, that mountain range is composed of postglacial pyroclastic gravel, mostly pumice and some slaggy lava, which both are very porous. Surely, it is possible that drowned palagonite ridges may be hidden under the pumice - like the palagonite rocks which project from the hills at Hófsvad - but nothing indicates that a continuous palagonite core lies under them along their whole length. And even if so, that type of rock is also poorly water proof.

Another section which would leak would be at the southern end of the dam, through pumice, lava, cratermounds and tuff Hills north of Frostastadavatn.

I believe that the leakage west from the reservoir along the 25 km. long distance from the sources of Vatnakvísl to south of Frostastadavatn would amount to all the inflow before the water level had risen 35 meters - or by other words, that it is not possible to make there such a large reservoir.

This opinion of mine is based on two instructive "experiments" which nature herself has made in construction of dams in palagonite and lava areas, That is at Hagavatn and in Lambafit. I have described both before (Report to the State Electricity Authority, 1949, and "Úr Sögu Helliskvíslar" (From the History of Helliskvísl) in Náttúrufr.

1953), and here only the conclusions shall be recapitulated.

1. When a glacier dams up, completely, the outlet of Hagavatn, the water level rises only by 15 meters and the seepage through the rock is, then, equal to the flow which is now in the outlet (Farid River very appr. 10 m^3/sec.). The section of the bank of the lake where it is possible that ground water level slopes away from the lake, when its level is at its highest, is though only 6 km. long.

2. Helliskvísl (flow appr. ½ - 1 m^3/sec.) ended for 15 years in the same lava depression. Then finally it had tightened the lava enough for it to start flowing out of the depression when in flood. The lake has, though, never become deeper than a man's hight nor greater than ½ km^2 in area.

9. Tunnel under Skyggnir in Vatnaöldur north-west to Blautakvísl

On this section, thick loose pyroclastic gravel covers a country rock of palagonite tuff. Furthest west, the tuff (with pillow-lava woven into it) projects out of the gravel on small steep hills. But both, between the tuff hills and on the eastern part of the area, one may expect that the volcanic gravel is very deep down to the country rock and that the rock surface lies below the level of Tungnaá. But, at that depth and further down, one may also expect layers of Thjórsá-lava under the pyroclastic material.

10. Damsite on Tungnaá east of Sigalda

Here, the river has cut itself a narrow gorge, approximately 20 meters deep, through a tuff ridge. The tuff is on both sides and on the bottom. Something would seep from the reservoir through the lava south of Sigalda.

Still one may expect that all this lake basin has tightened somewhat, because, here, there was a lake with glacial water before the tuff ridge was cut through (see IV).

11. Damsite above Hrauneyjafoss and a Tunnel from there to the West.

Here, Tungnaá follows the northern edge of the Thjórsá-lavas, and north of it, there is the palagonite system which I have not investigated at all at this place.

12. Damsite on Kaldakvísl east of Svartárdrög

Kaldakvísl flows here for a long distance in a narrow canyon, approximately 15-20 meter deep, and it is, in most places, very narrow, deep and rapid. The canyon is all cut into tuff. The rock varies somewhat but it is mostly brown tuff, and through it lie dikes and irregular veins of basalt. This tuff seems to be more solid than usual tuff of the palagonite system and it is quite possible that it should be classified with the Hreppar system. (like the tuff in the gorge of Kisa, 3.) On top of the tuff west of the river lies moraine, which in most places has loose gravel on the surface, but it is consolidated into a fairly firm conglomerate in a depth of a few meters, judging by what one can see in ravines.

13. Damsite on Kaldakvísl at the Mouth of Thórisós.

The shallow valley which Kaldakvísl flows along north of Ósöldur is all cut out of the Hreppar system which consists here mostly of basalt. But down in the valley, at the river, there are, though, sedimentary rocks, or more specific conglomerate (and breccia). That rock is fairly

hard and solid, forms f.i. rapids both in the Kaldakvísl and the Thórisós 2 km. above the junction of the rivers. It crops, also, out of the gently sloping gravel plains further out on the tongue between the rivers, and it indicates that the gravel of the plains is not deep. Just below the river junction, a basaltic bottom starts in Kaldakvísl and, there, a narrow basaltic gorge begins, which gets deeper downstream.

The sedimentary rock, which is mentioned above, seems surely to be originally moraine, but it is not clear to me whether it is an intercalation between the basalt layers (and then of similar age as these), or, a much younger moraine which has accumulated down in the valley.

The end of a lavastream with large felspars in it (a "Thjórsá-lava") stretches out the tongue between Kaldakvísl and Thórisós and ends in a definite edge scarcely 2 km. from the tip of the tongue (marked correctly on map Geod. Inst.). As a matter of course, the damsite should be selected in front of the lava edge, and the firmest foundation would probably be obtained at the river junction or a little further down where the basalt picks up from the tuff and the sand plain.

On both sides of Kaldakvísl the country rock is covered by a thick moraine.

14. Damsite on the east side of Hnaus and a Tunnel through Hnaus.

Hnaus is all composed of the Hreppar system and the tunnel would probably lie mostly in basalt. Tungnaá flows

here for a long distance on the joint of this basalt on the north and Thjórsá-lava on the south side. The basalt lies, of course, in under the lava and there is a danger of loose layer at the joint, as usually in similar circumstances.

15. Damsite on Thjórsá and Tungnaá at Sultartangi

On the east side of Sandafell Thjórsá flows in a shallow gully along the lava edge. But Tungnaá comes from the east on top of the lava, which it has hardly at all cut into, but falls from top of it in a low waterfall down into Thjórsá.

Sandafell is all composed of the Hreppar system and at least its lower part is a solid looking basalt. Furthermore, there is a small hill of similar material which projects out of the lavas east of the river junction.

The layers of lava east of Thjórsá are not fewer than three, one on top of the other (see IV). But only the uppermost layer is seen, even in the river bed of Thjórsá. It is though possible, that deep pools and channels cut down through it. The danger of a loose layer at the joint of the lava and the country-rock I consider somewhat less here than in many other places under similar circumstances, because the roots of Sandafell are steep and it is, therefore, likely that the lava flowed there against a bare rock wall. Furthermore, Thjórsá is very swift at the front of Sultartangi, so it must flow on a solid bottom. The Thjórsá-lava in Sultartangi and east of Tungnaá is probably relatively solid and tight, because here Tungnaá has flowed over it in many branches and both tightened it and eradicated faults from its surface. With other things even, it is better to

select such beds of previous or still existing branches of the river for a foundation for a dam.

16. Tunnel from Sultartangi through Sandafell and Stangarfjall west to Fossárdalur, would lie alternately in different sediments and basalt.

About damsites further down Thjórsá and also about a damsite at the outlet of Thórisvatn into Thórisós, it is referred to the report by Dr. Hawkes and myself: Geological Report etc., of which the State Electricity Authority has got a copy.

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Gudmundur Kjartansson

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