ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY
HYDRO POWER DIVISION

FLJÓTSDALUR HYDROELECTRIC PROJECT

ENGINEERING GEOLOGICAL REPORT - POWERHOUSE CAVERN, TAILRACE TUNNEL AND ACCESS TUNNEL

SUMMARY

Prepared for Landsvirkjun

OS-91001/VOD-01 January 1991

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NOTE: In this report the decimal point is used according to the English speaking system, i.e. a point (.), not a comma (,). Example: One million is 1,000,000.00.

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1. INTRODUCTION

This report is a short summary of the results of the engineering geology investigations of the proposed area for the powerhouse cavern and the tailrace and access tunnels of the Fljótsdalur Hydroelectric Project. The report is, to a great extent, based on previous reports (translated or adapted), especially the general geology and stratigraphy.

Most of the field investigations for the powerhouse site were carried out in 1980-81, including all the cored drillholes. In November and December 1990 the drillcores were partly relogged and more measurements carried out, including point load tests and Schmidt hammer tests. This work was done by Birgir Jónsson, Þórólfur H. Hafstað and Árni Hjartarson from Orkustofnun (National Energy Authority) and Ómar Bjarki Smárason from Stapi Geological Services. During this work nineteen samples from boreholes FV-1, 6, 7, 8, 9 and 10 were collected for further laboratory testing at the Building Research Institute, Reykjavík.

2. GENERAL GEOLOGY

Iceland is the largest landmass lying astride a mid-oceanic ridge, i.e. the Mid-Atlantic Ridge which forms the boundry between the Eurasian and North American tectonic plates. The plates drift apart and the gap is filled up with igneous rocks. Iceland consists predominantly of volcanic rocks which have been piled up during the past 20 million years or so, and the oldest rocks found exposed on land are 13-15 million years old cropping out in the far NW and E parts of the country (see Fig. 1). The volcanic rocks are mainly basalts. Rocks of intermediate and acid composition, such as andesites and rhyolites are only found locally in and around central volcanoes. These volcanoes are close to 100, about 25 of which are considered active. The remaining 75 are extinct or dormant (Ref. [7]). Thick sediments are rare in the older parts of the lava pile, but abundant in the Pleistocene rocks that have formed during the last 3 million years. Most of the following is based on the geology chapters in Ref. [1], [2] and [3].

In late Tertiary time, the present East Iceland was situated within the active volcanic zone but has gradually drifted towards the east, at approximately 1 cm/yr. Volcanic activity decreased progressively with increasing drift distance. The accumulative thickness of the basaltic lava pile in East Iceland is about 9 km, and includes a few central volcanoes, which show great variations both in rock types and dip of lava flows.

The total thickness of the exposed lava pile east of Fljótsdalur is about 7-8 km, dipping less than 10° towards west so that the oldest lavas (13 million years old) crop out on the eastern shore. The younger part of the lava pile, outcropping in the Lagarfljót area was formed during the last 6-7 million years. Thin sedimentary interbeds are common between the lava flows.

The approximate relative composition of the bedrock is as follows:

- 80 - 85% basaltic lava flows.
- 10% acid, and intermediate rocks.
- 5 - 10% sedimentary interbeds resulting from erosion and transport of volcanic rocks.

It should be noted that the percentage of sediments in the Fljótsdalur area is much higher than the average values given above.

The average accumulation rate of the lava pile in East Iceland has been in the order of 860 m/M.yrs., whereas the accumulation rate in the Fljótsdalur area seems to have been much lower, or about 360 m/M.yrs.

In late Tertiary time East Iceland was a basaltic plateau with a few central volanoes, forming a low mountain chain stretching NE - SW.

At present, East Iceland is a mountainous area with summits commonly rising up to 1000-1200 m elevation. The retreat of the glaciers left deeply eroded valleys and fjords, as well as the periglacial and postglacial alluvial fills in valleys such as the Fljótsdalur valley.

3. GEOLOGY OF THE FLJÓTSDALUR AREA

The northeast heading Fljótsdalur valley and the lowlands along the Lagarfljót river mark the boundary between the mountainous East Fjords and the 600-800 m high plateau of central East Iceland. Fljótsdalsheiði is the name of the eastern part of the plateau, lying northwest of the upper course of the Fljótsdalur valley.

The river Jökulsá in Fljótsdalur originates at Eyjabakkajökull, an outlet glacier from the Vatnajökull ice cap (see Fig. 2). On the uppermost 10 km of its course, the river runs across a flat plateau at elevation 610 m (the future Eyjabakkar reservoir) after which it starts its steep drop towards the Lagarfljót lake located some 30 km downstream at an elevation of 20 m a.s.l.

The bedrock in the Fljótsdalur area was formed during the last 6.5 million years. It consists of a 1500 m thick sequence of basalt lava flows with consolidated sedimentary interbeds.

The basalts in the Fljótsdalur area have been divided into the three following petrographic types:

- tholeiite basalt
- olivine basalt
- porphyritic basalt

The basalts of Eastern Iceland contain abundant secondary zeolites and other amygdale and joint filling minerals.

Sediments are found in the Fljótsdalur area as interbeds between lava flows and also as thick accumulations filling former valleys.

The nature of the sediments varies with their location within the lava pile. In the lowest part of the pile, most of the sediments are fine grained and tuffaceous; whereas in the upper part of the pile, the sedimentary interbeds indicate cold climate and consist of conglomerates and tillites. The thick sediments are of fluvioglacial origin, mainly conglomerates and sandstones. The accumulation rate of lavas and the average period between eruptions in the Fljótsdalur area has been determined to be about 360 meters per million years and over 20,000 years respectively.

The lava pile of the Fljótsdalur area dips gently towards west. At the powerhouse and tailrace tunnel elevation (ca. 30-60 m a.s.l.), the dip is about 7-8°, decreasing upwards to approximately 4° at the top of the pressure shaft. The lava pile is affected by steep faults and dykes striking in direction 0°N to 15°E. Fault zones are typically 1 to 5 m wide and can consist of crushed rock of low strength, containing some clay minerals. Dykes (basaltic) are usually highly jointed.

The drainage pattern of the Fljótsdalsheiði plateau indicates a rather tight bedrock; this is confirmed by the numerous ponds, lakes and bogs scattered throughout the area. Water seepage in the various layers making up the lava pile is most likely to take place along bedding and tectonic discontinuities.

Some small springs, generally with low discharge rate are known along the steep flanks of Fljótsdalur; most of them issue cold groundwater, low in dissolved solids, whereas a few very small springs (ca. 1 l/s) issue thermal water (10-50°C), medium to high in dissolved solids.

The layered structure of the lava pile and the fact that some joint systems are confined to individual lava flows suggest that several aquifers, more or less independent, exist within the lava pile, separated by tight sedimentary horizons.

In late Tertiary time and during Pleistocene, extensive glaciation took place in Iceland. Ice caps covered the highland plateau and extensive glacial erosion of the underlying bedrock took place, eroding the valleys and fjords, such as the Fljótsdalur valley.

4. MAIN ROCK TYPES

(The following chapter is mostly from Ref. [1]).

4.1 BASALTS

Each lava flow can be divided into three parts as follows:

- **the top scoria (often 10-25% of the total thickness)**
- **the dense crystalline middle part (often 65-85% of the total lava thickness)**
- **the bottom scoria (often 5-10% of the total thickness).**

The top scoria consists most often of scoriaceous and vesicular basalt fragments, with a sandstone matrix. The rock has the appearance of a breccia. In fact, the sandstone has infiltrated into the spaces between the loose scoria fragments; palagonitization later cemented the sandstone and the scoria fragments. The infiltration of sediments into the scoria occurred during the deposition of the sediments; this explains why no such infiltration is present at the bottom of the flows.

The crystalline middle part is a hard dense basalt, light to dark grey in colour. The rock is usually affected by typical columnar jointing resulting from the cooling process of the lava. Other structural characteristics include flow banding, amygdales and joints.

The bottom scoria is most often well consolidated and seldom contains sandstone fillings.

This division of the lava flows can clearly be seen in the borehole logs in Appendix 2. As the top and bottom parts show clearly different engineering properties as compared to the middle part, the term basalt is attributed to the dense middle part of the lava flows and the term scoria to the upper and lower parts of the flows.

Petrographically the basalts are of three types, tholeiite, olivine and porphyritic basalts, but complete transitions exist from one type to another. It therefore follows that the engineering properties of the three types can be very similar.

Petrographic determination in the field may by subject to varying interpretation. Classification of the basalts is based partly on the determination of the amygdale minerals whose composition is very sensitive to small variations in the composition of the rock. There are two basic types, i.e. the tholeiite basalt and the olivine basalt. Each of the two can develop a porphyritic texture, in which case it will be named a porphyritic basalt.

The characteristics of both the tholeiite and olivine basalts are shown in Table 1, adapted from Ref. [1].

TABLE 1. Comparison of typical characteristics of the tholeiite and olivine basalt.

THOLEIITE BASALT	OLIVINE BASALT
Very fine grained	Coarser grained
Free olivine crystals absent	Free olivine crystals visible in handspecimen
Total silica content: 48-50%	Total silica content: 46-48%
Weathered crust; pale brown	Weathered crust; dark brown to deep grey
Spheroidal weathering uncommon	Spheroidal weathering common
Amygdales commonly without zeolites	Amygdales contain zeolites
Well developed flow structures	Less developed structures within flows
Micropores often arranged along subhorizontal surfaces with spacing < 1 cm resulting in faint cleavage	Micropores randomly scattered throughout the rock mass
Scoriaceous part of tholeiite basalt flows: usually 20-30% of the flow thickness	Scoriaceous part of olivine basalt flows: usually 5-15% of the flow thickness
Occurs usually as single lava flows	Forms compound and single lava flows
Average thickness of lava flows: 13 m**	Average thickness of lava flows: 10 m***
Hardness of the dense matrix I to II*	Hardness of the dense matrix: I to II*

*Hardness scale ISRM.

**22 basalt flows in power house and tailrace tunnel elevations.

*** 11 basalt flows in power house and tailrace tunnel elevations.

The porphyritic basalt has the basic characteristics of one of the two types described above with more than 5% modal plagioclase (bytownite) phenocrysts. Phenocrysts of other minerals like olivine and augite may also occur in smaller amounts. When the amount of phenocrysts is above 7-10%, the groundmass is usually of the olivine basalt character.

The average thickness of the porphyritic basalt flows is very similar to that of the other two types.

4.2 SEDIMENTS

Three different types of sediments occur in the lava pile of the Fljótsdalur area:

a) **Basaltic tuffaceous sandstone,** usually palagonitized and well cemented. They normally form interbeds of 2-30 m thickness between the lava flows.

b) **Red tuffaceous sandstone/siltstone,** originated from acidic explosive eruptions and red residual soils. These sediments can contain some clay minerals and alter quickly and crumble when exposed to atmospheric conditions. Sedimentary interbeds of this type are commonly 0.2-3 m thick.

c) **Conglomerate, sandstone and siltstone.** These sediments are found as interbeds of a few cm up to over 100 m in the Fljótsdalur lava pile. They are common in the headrace tunnel route.

These sediments can in many cases be considered almost impervious.

5. ENGINEERING GEOLOGY: POWERHOUSE CAVERN, TAILRACE TUNNEL AND ACCESS TUNNEL

5.1 ROCK SERIES AND TECTONICS

The location of the boreholes and the layout of the underground structures can be seen in Fig. 3. The powerhouse cavern, the access tunnel and most of the tailrace tunnel lie in the lower half of the Marklækur suite (ML), but the outermost 300 m of the tailrace tunnel will lie in the topmost layers of the Hengifossá suite (HF). See figures 4 and 5.

The lower half of the ML suite, which is close to 5 M.yrs. old, consists of rather thin basaltic lavas with sediments of various types. Most of the basalts are tholeiitic, although olivine and porphyritic basalts are also present. The sedimentary layers are mostly tuffs of basaltic to acidic composition, sandstones and conglomerates. Boreholes FV-1, 7, 8 and 9 give good cross sections through the lower half of the ML-suite.

As mentioned in chapter 3, faults, dykes and other tectonic lineations in the powerhouse/tailrace tunnel area have directions that lie between 0°N and 15°E. These lineations, therefore, meet the powerhouse caverns and the tailrace/access tunnels under a favourably large angle, usually 60-70° (see Fig. 3).

Hydraulic fracturing stress measurements were performed in 1981 in borehole FV-1. Seven measurements were made, the deepest one at 504 m depth in the borehole, or approximately 68 m a.s.l., or near the elevation of the roof of the powerhouse cavern (63.7 m a.s.l.). The measured horizontal stress at this depth was very low, or 5.6 (min) to 5.8 (max) MPa. The vertical stress, calculated from the weight of the overlying rock pile, is much higher, or 13.6 MPa. Fig. 7 shows the result of all the measurements. These stress conditions are probably common in Iceland and must be taken into account regarding rock support.

It should be noted that the maximum vertical stress is of the same order as the uniaxial compressive strength of the weaker sedimentary interbeds in the lava pile. At the newly completed road tunnel at Ólafsfjörður in Northen Iceland, new joints appeared in the sedimentary layers, where the stress was highest (>500 m of overlying rock), and some crumbling occurred.

Temperature measurements from 1981 in borehole FV-1, show a temperature of approximately 20°C at proposed tunnel elevation.

5.2 ESTIMATED OCCURRENCE OF DIFFERENT ROCK TYPES

From the borehole logs in Appendix 2, the percentages of the different rock types to be encountered during the underground excavation may be estimated. This is summarized in Table 2.

TABLE 2. Estimated percentages of rock types and number of layers* in the underground excavation.

	Access Tunnel	Tailrace Tunnel	Power-house
Basalt	73%	67%	65%
No. of layers	13 - 20	13 -20	3
Scoria	12%	13%	12%
No. of layers	7 - 10	11 - 16	2
Red Interbeds	1%	1%	8%
No. of layers	6 - 9	6 - 9	2
Other sediments	11%	16%	14%
No. of layers	5 - 7	8 - 12	1
Fault Breccia	<3%	<3%?	1%?
No. of layers	?	?	?
Dykes	?	?	?
No. of layers	5-10?	5-10?	1-2?

*Some layers will probably be encountered more than once in the same tunnel due to tectonic dislocations.

5.3 THE ACCESS AND TAILRACE TUNNELS

Most of what is said here may apply to both the access and tailrace tunnels, as they lie almost parallel to each other. The proposed location of these tunnels can be seen on figure 3, as well as the location of the boreholes from which most of the geological information on the underground structures is based.

Figures 4 and 5 show the assumed geological sections along both tunnel routes. As can be seen from the sections and confirmed above in Table 2, which is based on the borehole logs (see Appendix 2), the most common rock type to be encountered during tunnelling will be basalt. Table 2 shows the percentages of the other rock types expected during the underground excavation. The table shows that the access tunnel will encounter a higher ratio of basalts than the tailrace tunnel because the former lies above an approximately 10 m thick sedimentary layer, which will be present in the outer part of the tailrace tunnel. See figures 4 and 5.

Although the red siltstone/claystone interbeds are probably only 1% of the tunnelling rock, as many as 10 such layers may be present on the tunnelling route and some of these layers might be encountered more than once due to tectonic dislocations. These interbeds can form a plane of weakness, due to their tendency for horizontal parting, even though the layers may be as thin as 5-10 cm. Other observed sediments, such as the coarser sandstone and conglomerates are much stronger rocks. Fault breccias and adjoining broken/crushed rock will require extra support, especially if the fault zone is filled with water. Dykes could increase the water inflow, at least temporarily.

The stratigraphy of the inner part of the tunnels is really only based on borehole FV-1, as borehole FV-2 enters a basaltic dyke at an elevation of 70 m a.s.l., and stays within the dyke for 86 meters, not showing the surrounding stratigraphy for this interval down to -16 m a.s.l., see figures 4 and 5. From -16 m elevation and down to the bottom of the hole it goes alongside the dyke in a fairly disturbed and broken rock, which very likely does not show the typical characteristics of the surrounding rock. Due to the presence of the dyke, the interpolation between borehole FV-1 and the outer holes is not very accurate.

Tables 4, 5 and 6 in chapter 6 show some important geotechnical properties of the different rock types and Appendix 1 contains results of laboratory tests, done in 1980-84 on samples from the tunnelling area.

When tunnelling progresses downdip, in this case westwards, i.e. into the hill, new layers will first appear in the roof of the tunnel. When the weakest siltstone layers, with tendency for horizontal parting and crumbling under high stress, approach the tunnel roof this way, it is neccessary to carry out a careful simultaneous geological inspection/mapping and comparison with logs of the nearest boreholes in order to be prepared for these possible weakness layers. Whenever thought necessary drilling into the roof could be done to locate these possible weakness layers.

5.4 POWERHOUSE CAVERN

The assumed stratigraphy for the cavern can be seen in fig. 6. The geological units have been extrapolated from borehole FV-1 (see Appendix 2), a distance of approximately 230 m. The assumed inclination of the strata from the borehole to the cavern is ca. 7°, which is close to the maximum dip.

There is no reason to expect a great change in the stratigraphic sequence over this distance although the exact elevation of each layer/contact may be offset by a few meters due to inaccuracy in the estimated dip angle. If there are any faults located between FV-1 and the cavern the layers may be displaced by even a few tens of meters compared to Fig. 6, but the investigations so far do not indicate the presence of faults over that distance. However, the stratigraphy at the powerhouse cavern will show itself during the construction of the nearby tunnels.

The roof of the cavern is expected to be within an almost 30 m thick tholeiite basalt layer. This layer has been given a Q-value of 3 in the core log, a rather conservative estimate; a more probable value is 5-6. The possible behaviour of the sedimentary layers under changed stress conditions is discussed in chapter 5.1.

Laboratory tests on samples from layers expected at the powerhouse cavern are listed in Appendix 1. Point load tests from borehole FV-1 can be seen at the beginning of Appendix 2. See also tables 4, 5 and 6 in chapter 6. A report on tests being done on samples from these layers at the Building Research Institute, Reykjavík, is expected in February 1991.

5.5 TAILRACE CANAL AND PORTAL AREA

The overburden at the portal site can be divided into 3 types (fig. 8): Talus (scree), finiglacial gravel terraces and alluvium at the river Jökulsá í Fljótsdal. From fig. 8 it looks as if the portal will be located in a 10-15m thick sedimentary layer, of which the lower two thirds is tuffaceous sandstone of reasonably good tunnelling quality. The top third of the sedimentary layer is red silt/sandstone, which is probably a poor tunnelling rock. Between the red siltstone and the tuffaceous sandstone underneath, there is possibly a 1.5 m thick olivine basalt unit as can be seen in the core log for borehole FV-10 in Appendix 2. On top of the red siltstone there is a 35 m thick olivine basalt.

The thickness of the overburden was investigated with various methods, including seismic soundings, light overburden drills (Cobra soundings) and air percussion drilling down into the bedrock. Apart from the talus, the overburden is mostly sand and gravel with finer soil on top.

6. GEOTECHNICAL PROPERTIES

The bedrock in the tunnelling area has been divided into five different geotechnical units:

1. Basalt
2. Scoriaceous basalt/Scoria
3. Sedimentary rock
4. Fault breccia
5. Basaltic dykes

The sedimentary rocks are subdivided into red interbeds and other sediments.

The technical data in this chapter (mostly from Appendices 1 and 2), is based on measurements and tests on drillcore from the following elevation intervals of the boreholes listed in table 3 here below:

TABLE 3. Elevation intervals of boreholes from which data for Tables 4, 5 and 6 were obtained.

Borehole No	Elevation m a.s.l. from	to	Basalt thickness, m (number of layers)	Scor.bas. thickness, m (number of layers)	Sediment thickness, m (number of layers)
FV-1	121.0	- 66.0	122.7 (15)	24.3 (9)	36.8 (13)
FV-7	94.4	- 0.6	65.8 (5)	18.0 (6)	13.1 (4)
RV-8	169.7	- 0.4	100.0 (12)	48.7 (13)	18.4 (10)
FV-9	101.8	6.4	65.2 (4)	18.5 (5)	101.1 (3)
FV-10	86.4	31.2	47.2 (2)	4.9 (2)	2.5 (2)
Total thickness 596.2 m			400.9 (38)	114.4 (35)	67.8 (32)

Tests on the drill rate index, bit wear index and cutter life index (DRI, BWI and CLI) were carried out in 1990 at the SINTEF Laboratories, Trondheim, Norway. Five samples were tested, four from the head race tunnel route and one from the pressure shaft area. The results of these tests can be seen in Ref [1], Table A-13, page A-25.

6.1 BASALT

Basalt is the most common rock in the area (see Figs. 4 and 5). Some geotechnical properties of the basalts are summarized in Table 4. All values are based on measurements on drillcores from possible tunnelling rocks in boreholes FV-1, 7, 8, 9 and 10. The drillcore from FV-6 was omitted because of the presence of a dyke below elevation 70 m a.s.l. and disturbed rock adjacent to the dyke; see borehole log in Appendix 2.

As mentioned in chapter 4, the three main basalt types in the project area, the tholeiite, olivine and porphyritic basalts, can have similar engineering properties and many of the basalt layers lie somewhere in between the pure types, i.e. almost complete gradation exists between the three main types. Therefore, all the basalts are treated here together as one rock group.

The thickness as well as the RQD's of each basaltic layer were measured in the rock cores. All drillcores from the tunnel elevation were classified using the Norwegian rock mass quality classification system, the Q-system, (Barton et al. 1974). Some minor modifications have been made to the original system in an attempt to adjust it to the geological conditions in Iceland, but practical experience is very limited. The Q-values, therefore, should be looked upon only as a relative measure of the quality of the rock.

The uniaxial strength was measured on intact samples in the laboratory both using the conventional uniaxial test and the point load test. More tests are being carried out at the Building Research Institute, as this report is going into print. The new BRI results should be available in February 1991.

TABLE 4. Some geotechnical properties of the basalt.

	Thickness (m)	RQD (%)	Q (Rock mass quality)	Uniaxial strength (MPa)
Minimum	0.9 m	40	2	77*
Maximum	31.3 m	100	16	441*
Typical	6-12 m	65-85	6-9	170-240
Weighted average	10.6 m	77	8.5	206
No. of measured layers/tests	38 m	38	38	45
Total thickness	400.9 m			

* Only two samples under 100 MPa.

** Only one sample showed over 400 MPa strength and 4 samples over 300 MPa [10].

6.2 SCORIA

The scoriaceous contact breccia (or simply scoria) is usually a rather well cemented mixture of basaltic glass, glassy basalt and crystalline basaltic fragments with sandy silt and clay fillings of varying degree. This rock mechanical unit is found on almost every contact between basalt layers and can usually be divided into top scoria of the lower basalt and bottom scoria of the upper basalt. The thickness of each scoria layer can vary considerably over short distances. A summary of some geotechnical properties of this rock type is given in Table 5.

TABLE 5. Some geotechnical properties of the scoria/scoriaceous basalt.

	Thickness (m)	RQD (%)	Q (Rock mass quality)	Unaixial strength (MPa)
Min	0.5 m	<20	<1	7
Max	10.0 m	100	16	51
Typical	1-4 m	60-90	4-7	15-25
Weighted average	3.3 m	74	6.9	20
No. of measured layers/tests	35 m	35	35	21
Total thickness	114.4 m			

6.3 SEDIMENTARY ROCK

The sedimentary rocks expected at the powerhouse site and on the tunnel routes are described in detail in chapter 4, (see also the borehole logs in Appendix 2). At the tunnel elevations these rocks are mostly conglomerates, silty sandstone and clay rich siltstone of various colours. Some geotechnical properties of the sedimentary rocks are summarized below in Table 6.

TABLE 6. Some geotechnical properties of the sedimentary rocks.

	Thickness (m)	RQD (%)	Q (Rock mass quality)	Uniaxial strength (MPa)
Min	0.1 m	0	0.1	15
Max	10.3 m	100	8	120
Typical	0.2*/2-6 m**	60-90	<1-3	30-60
Weighted average	2.1	61	2.6	54
No. of measured layers/tests	32	32	32	6
Total thickness	67.8 m			

*Typical "red interbeds" in the lava pile

** Other sedimentary layers

6.4 FAULT BRECCIA

Crushed basalt (and scoria) cemented with silt and clay has been found in some boreholes, interpreted as a fault breccia. This rock is badly to moderately cemented. The width of the fault breccia unit is normally estimated less than 1.5 m but the crushed rock zone adjacent to the fault can be a few meters wide. The RQD's and the Q-values of the breccia are low to very low.

Three samples of assumed fault breccia from borehole FV-38 at the surge shaft site (FA-suite) were point load tested, soon after drilling. The average Point load strength index, I_{s50} was 1.1 MPa (min 0.4, max 2) and the apparent uniaxial compressive strength was 25 MPa (min 8, max 44).

6.5 BASALTIC DYKES

A few basaltic dykes can be seen in surface outcrops in the powerhouse/tailrace tunnel area or heading towards it. These dykes are almost vertical (perpendicular to the lavas) and made of hard, massive and highly jointed basalt. Most of them are 3-5 m thick. Thus one may encounter quite a few dykes during the tunnelling. The dykes are usually quite good tunnelling rock, but some water leakage into the tunnel is likely to accompany them.

Two samples of the dyke near the bottom of borehole FV-6 were point load tested, giving apparent uniaxial strength of 152 and 273 MPa.

7. GROUNDWATER AND SEEPAGE

The groundwater seepage in the area mostly occurs along faults, fractures, dykes and possibly also some contacts between layers.

Sudden drops in piezometric surfaces that took place during the drilling of boreholes FV-1 and 2, indicate separate aquifers (see Fig. 9). These aquifers are divided horizontally by almost impermeable sedimentary horizons in the basalt sequence and probably to some extent vertically by sealed faults. Permeable faults will act as vertical conductors between aquifers.

The drops in the water table in boreholes FV-1 and 6 during drilling, might possibly be explained by hydraulic jacking i.e. opening of joints/faults due to the pressure of the water column inside the borehole which amounted to over 30 bar during the last water table drop in FV-1.

In 1981, elaborate permeability tests were performed in borehole FV-1 [4]. Figure 10 shows the calculation of Transmissivity (T) for various intervals of this hole. The highest average value measured in the test was 2.3×10^{-5} m^2/s. Possible leakage into the tunnels is discussed in Ref [4]. Water bearing faults would greatly increase the leakage into the tunnel, at least temporarily. Temperature at powerhouse elevation is approximately 20°C, as measured in borehole FV-1 in 1981.

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[6] Orkustofnun 1972: *Skýrsla um jarðfræði við Jökulsá á Fljótdal sumarið 1970.* (Report on geological investigation at the river Jökulsá in Fljótsdalur, by Elsa G. Vilmundardóttir).

[7] Stapi Geological Services, 1990: *Sandgerði; Geological report for the deepening of the harbour entrance at Sandgerði.* Prepared for The Icelandic Harbour Authority.

[8] Haimson, B.C.1981: *Hydrofracturing Stress Measurements. Hole FV-1, Teigsbjarg.* Report prepared for Orkustofnun, Reykjavík, Iceland.

[9] Norwegian Geotechnical Institute 1974: *Analysis of Rock Mass Quality and Support Practice in Tunnelling and a Guide for Estimating Support Requirements.* By N. Barton, R. Lien and J. Lunde.

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FIGURE 1

YFIRLIT YFIR BERGGRUNN ÍSLANDS
GENERAL GEOLOGY OF ICELAND

SKÝRINGAR / LEGEND

○ ÚTKULNAÐAR MEGINELDSTÖÐVAR FRÁ TERTÍER OG ÁRKVARTER (0,7 - 15 m. á.)
EXTINCT CENTRAL VOLCANOES, TERTIARY AND PLIO-PLEISTOCENE (0.7 - 15 m. y.)

● VIRKAR EÐA DORMANDI MEGINELDSTÖÐVAR (YNGRI EN 0,7 m. á.)
ACTIVE OR DORMANT CENTRAL VOLCANOES (≤ 0.7 m. y.)

/ SPRUNGUREINAR
FISSURE SWARMS

↘ ALMENNUR JARÐLAGAHALLI
GENERAL DIP OF LAVAS

HAUKUR JÓHANNESSON 1989 (LÍTILSH. BREYTT)
(SLIGHTLY MODIFIED)

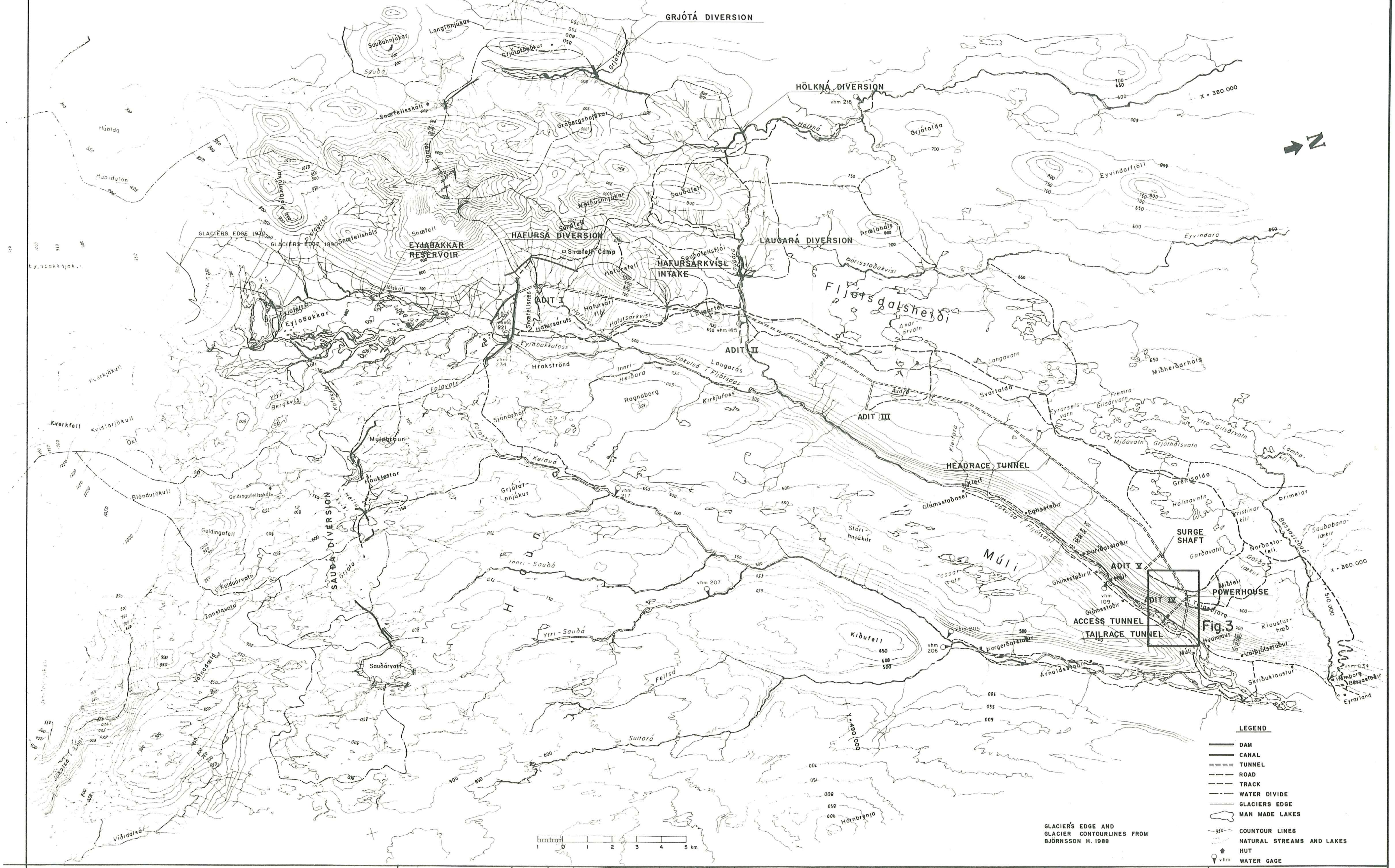
▧ TERTÍER BERGGRUNNUR (ELDRI EN 3,1 m. á.)
TERTIARY BEDROCK (> 3.1 m. y.)

▨ ÁRKVARTER BERGLÖG (0,7 - 3,1 m. á.)
PLIO-PLEISTOCENE BEDROCK 0.7 - 3.1 m. y.)

░ SÍÐKVARTER BERGGRUNNUR (YNGRI EN 0,7 m. á.)
UPPER PLEIST. AND POSTGLAC. BEDROCK ≤ 0.7 m. y.)

□ SETFYLLUR FRÁ NÚTÍMA
OUTWASH PLAINS

FIGURE 2



No	Reference Drawings	No	Transmittal Letter No	Date	Revision	By	Chkd	Appd	No	Transmittal Letter No	Date	Revision	By	Chkd	Appd

VST Ltd VERKFRÆÐISTOFA SIGURÐAR THORODDSEN Reykjavik Iceland
EWI Engineers-Consultants Electrowatt Engineering Services Ltd Zurich Switzerland
ALMENNA VERKFRÆÐISTOFAN Reykjavik Iceland
Rafhönnun Reykjavik Iceland

LANDSVIRKJUN
The National Power Company, Iceland

FLJÓTSDALUR GENERAL

PROJECT PLAN

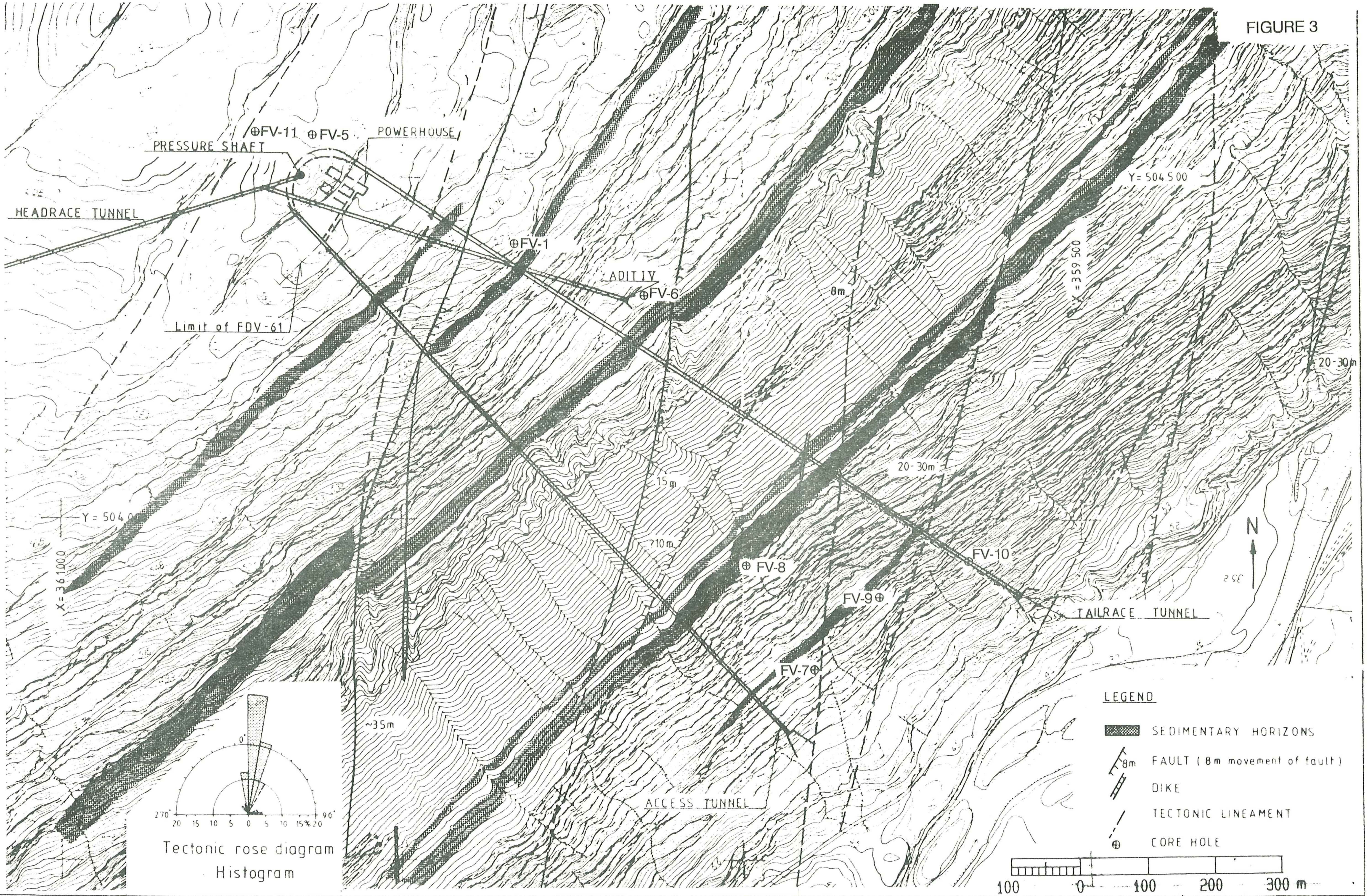
Dsgn | Chkd | Dwn HS. | Chkd ASL | Subm JS | Reviewed Civil Mech Elec

Approved VST AV EWI RH

Date OCTOBER 1990

Dwg no FDV00-02

FIGURE 3



VST VERKFRÆÐISTOFA SIGURÐAR THORODDSEN ALMENNA VERKFRÆÐISTOFAN	EWI Rafhönnun	LANDSVIRKJUN The National Power Company Iceland FLJÓTSDALUR ACCESS TUNNEL	MAIN GEOLOGICAL FEATURES	
Dsgn JTG	Chkd SP	Dwn SHJ	Chkd	Approved VST L.P.
Date OCTOBER 1990	Dwg No 90 324 61-07			

No. Reference Drawings | No. Transmittal Letter No. Date Revision By Chkd Appd | No. Transmittal Letter No. Date Revision By Chkd Appd

FIGURE 4

FLJÓTSDALUR HYDROELECTRIC PROJECT

POWER HOUSE - TAILRACE TUNNEL

Geological Section

Boreholes FV-7, 8 and 9 are projected into the section along the strike direction, N 10° E. See location of boreholes and section on figure 3.

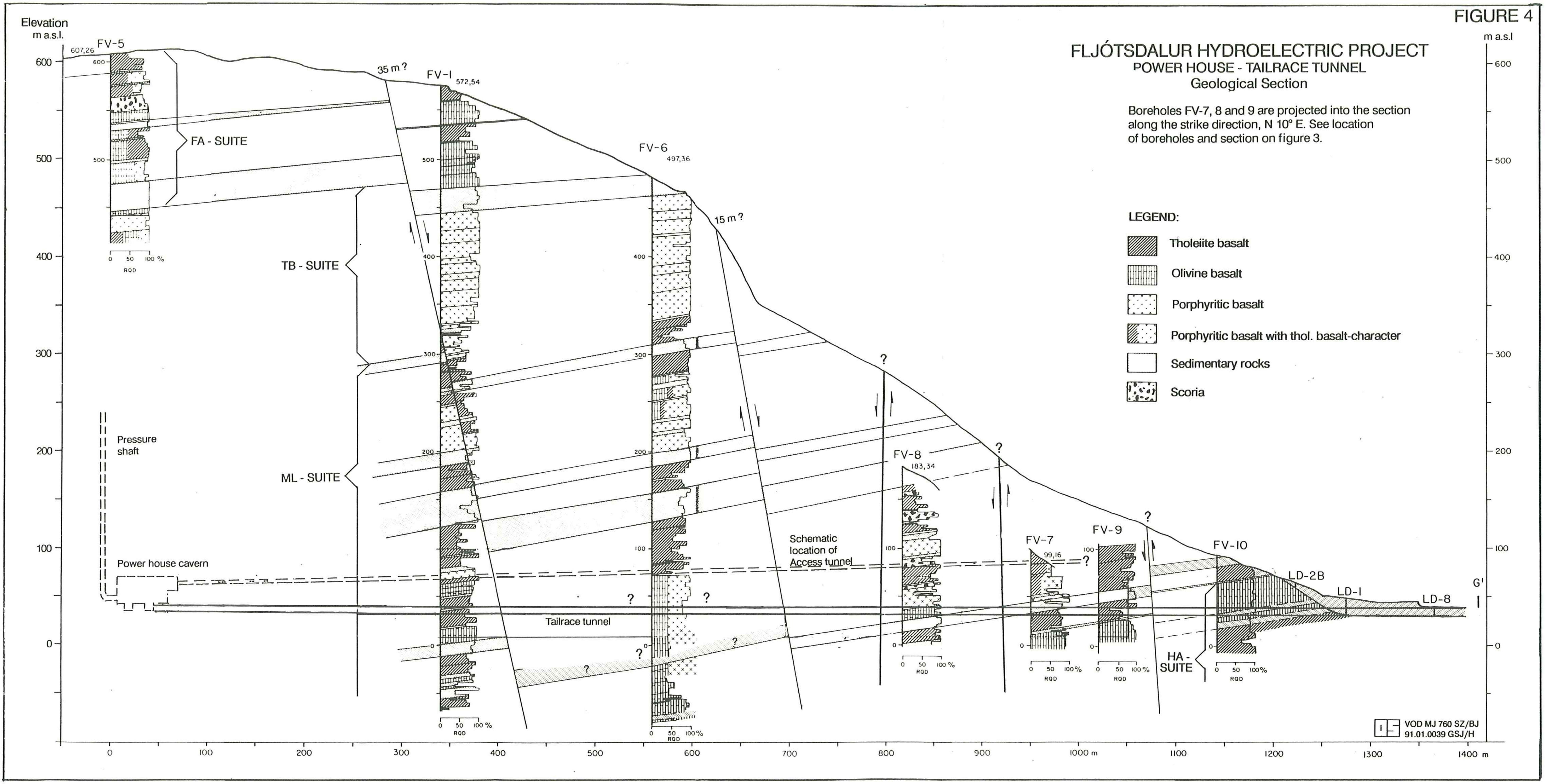
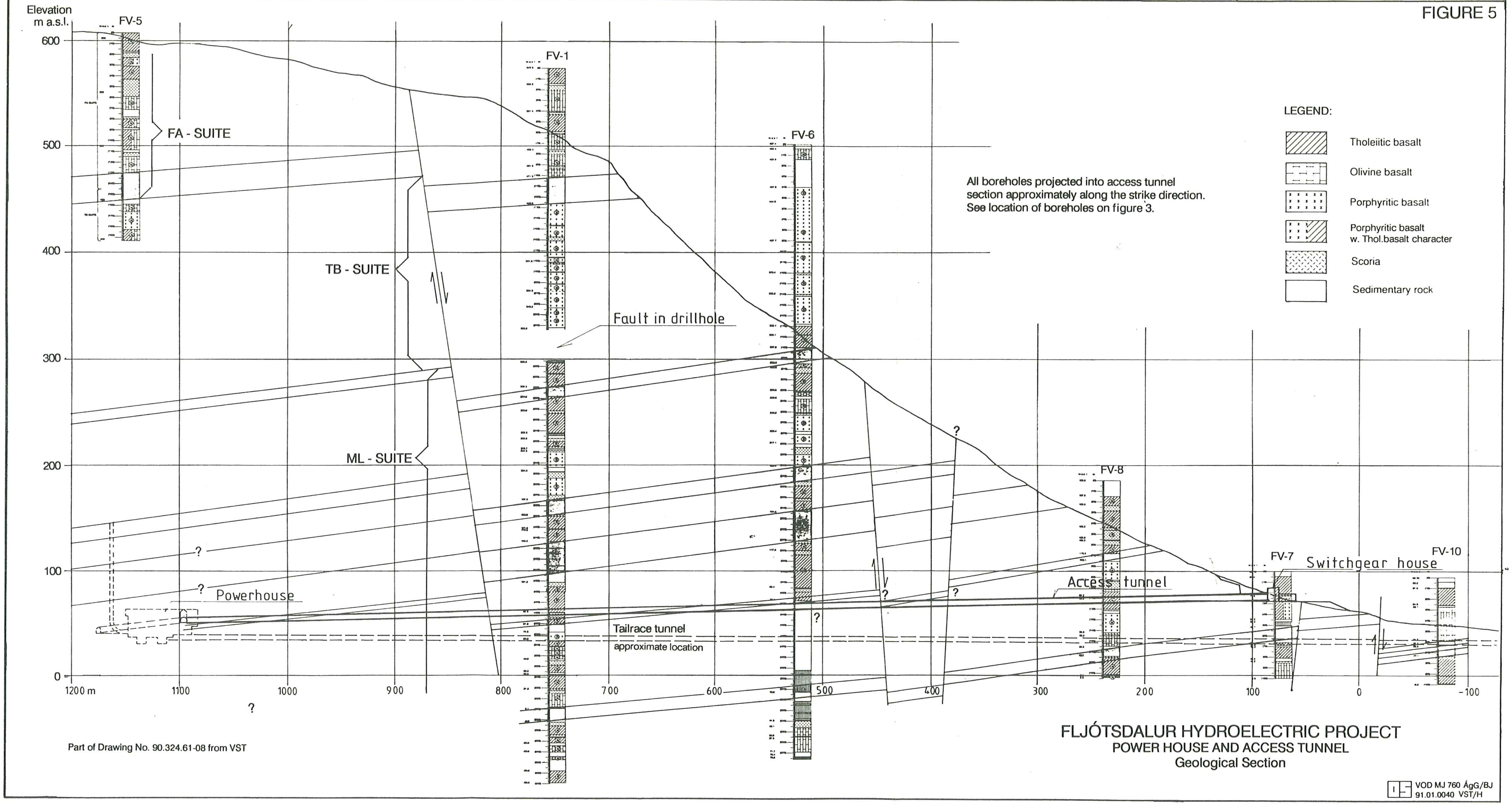


FIGURE 5



All boreholes projected into access tunnel section approximately along the strike direction. See location of boreholes on figure 3.

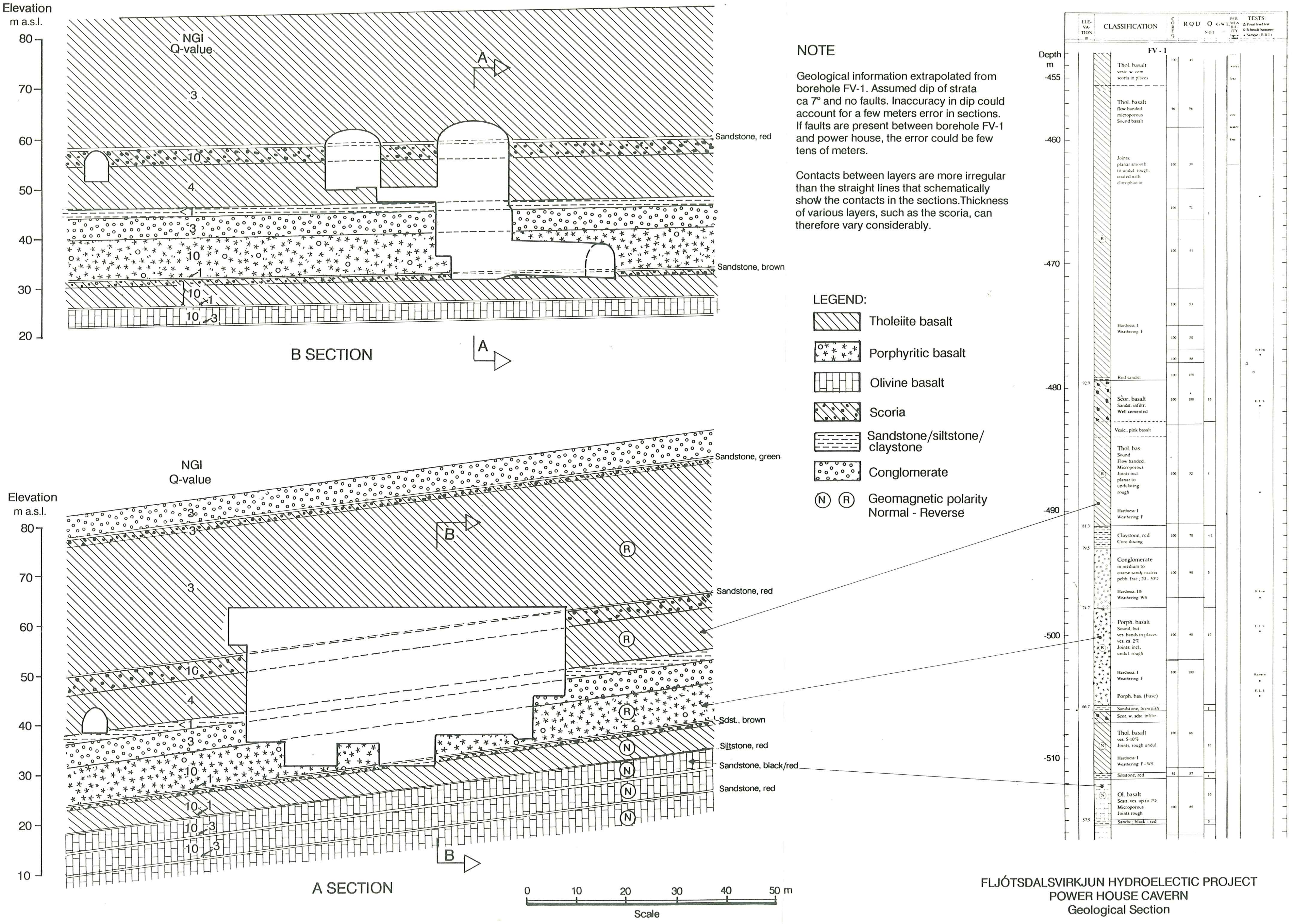
Part of Drawing No. 90.324.61-08 from VST

FLJÓTSDALUR HYDROELECTRIC PROJECT
POWER HOUSE AND ACCESS TUNNEL
Geological Section

VOD MJ 760 ÁgG/BJ
91.01.0040 VST/H

VOD MJ 760 BJ
91.01.0033 AÅ

FIGURE 6



NOTE

Geological information extrapolated from borehole FV-1. Assumed dip of strata ca 7° and no faults. Inaccuracy in dip could account for a few meters error in sections. If faults are present between borehole FV-1 and power house, the error could be few tens of meters.

Contacts between layers are more irregular than the straight lines that schematically show the contacts in the sections. Thickness of various layers, such as the scoria, can therefore vary considerably.

LEGEND:

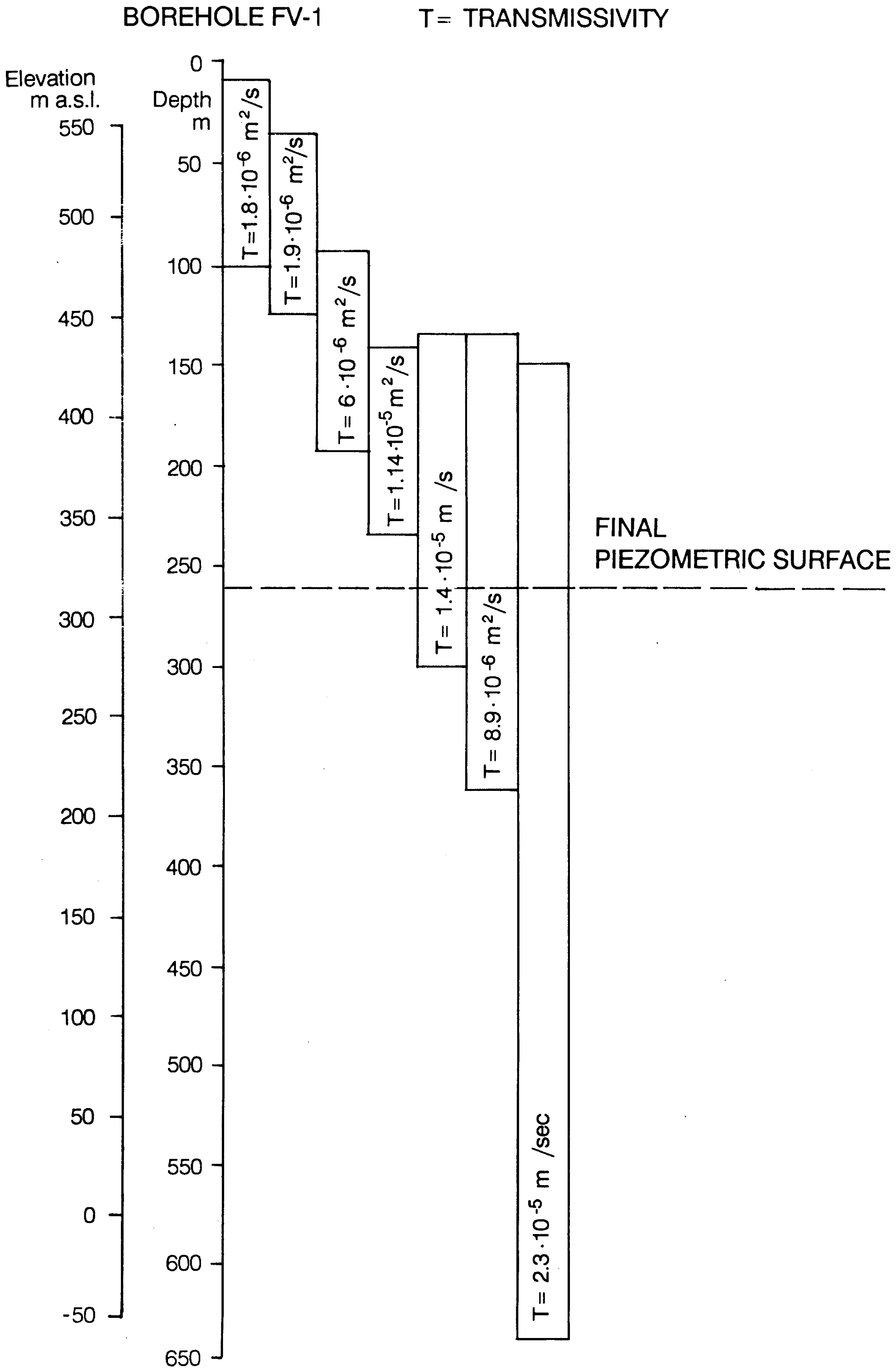
- ▨ Tholeiite basalt
- ▨ Porphyritic basalt
- ▦ Olivine basalt
- ▨ Scoria
- ▤ Sandstone/siltstone/claystone
- ▨ Conglomerate
- Ⓝ Ⓡ Geomagnetic polarity Normal - Reverse

FLJÓTSDALSVIRKJUN HYDROELECTIC PROJECT
POWER HOUSE CAVERN
Geological Section

VOD MJ 760 SZ
91.01.0034 H

FIGURE 10

TRANSMISSIVITY MEASUREMENTS IN BOREHOLE FV 1



APPENDIX 1

Laboratory tests on rock samples 1980 - 1984, from the Powerhouse and Tailrace/Access tunnels area.

Tests by:

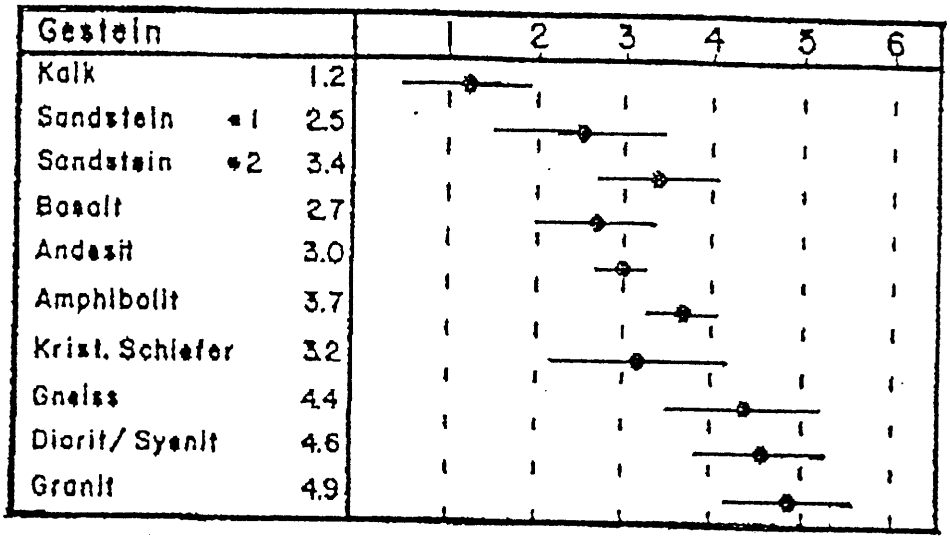
- Atlas Copco - Jarva, Switzerland.
- University of Wisconsin, U S A.
- Robbins Co., Seattle, U S A.
- Queens University, Ontario, Canada.

Tests by Atlas Copco - Jarva, Switzerland, 1981.

Courtesy of GEOTEST, Zollikofen, Switzerland

No. of hole	depth m	Uniaxial Compressive Strength MPa	Rock type	Point Load Index; I_{s50} MPa	Cerchar Abrasivity Index * (0.1 mm)
FV - 1	530.0	234	Thol. basalt	8.2	1.8
FV - 1	540.9	152	Thol. basalt	8.9	1.8
FV - 8	130.0	210	Ol./thol. basalt	13.1	2.5
FV - 8	153.0	258	Olivine basalt	11.2	1.9

* The table below shows long term experience from the Geotest Laboratory, Zollikofen, Switzerland (Courtesy of dr. E. Büchi)



See also: Suana, M. and Peters, Tj., 1982: *The Cerchar Abrasivity Index and its Relation to Rock Minerology and Petrography.* Rock Mecanics 15, 1 - 8 Springer-Verlag.

Labratory Hydrofracturing Tests
by Professor B. C. Haimson,
University of Wisconsin, Madison, U S A; 1981.

Borehole FV - 1 Depth; m	Lab. Hydrofracturing Tensile Strength: $T_{(lab)}$ MPa	Breakdown Pressure: $P_{c\ (lab)}$ MPa	Rock type
505 505	11.3 9.3	9.5 7.8	Porph. basalt

See Ref. [8]. This layer is expected near the floor of the Powerhouse Cavern.
(see figure 6)

Tests by the
ROBBINS Co.
Seattle, Washington, U S A; 1980.

Hole no.	Depth m	Uniaxial Compressive Strength; P S I	M O H S Hardness Range	Density g/cm^3	Rock type
FV - 1*	477.4	24830 21725 20690 22760	2 - 6	2.97	Tholeiite basalt
-	-	**22500**	-	-	
FV - 8	157.6	2465 3700	2 - 6	2.45	Conglo-merate
-	-	**3080**	-		
FV - 8	174.4	27900 21700 17050 18600	2 - 6	2.95	Tholeiite basalt
-	-	**21325**	-	-	
FV - 8	179.0	17050 13950	2 - 6	2.99	Tholeiite basalt
-	-	**15500**	-	-	-

* This layer is expected to form the roof of the Powerhouse Cavern; see fig. 6.
Mean values are printed bold

Tests done for Orkustofnun (National Energy Authority) by Ms. E. L. Sveinsdóttir (M.Sc. Thesis) Queens University, Ontario, Canada.

See ref. [10] and notation 2 pages back.

PORPHYRITIC BASALT

Bore hole	Bore hole depth (m)	ρ* (g/cm^3)	ρ (g/cm^3)	L/D	σ_c (MPa)	E (GPa)	μ	Φ (degr.)	Triax	Uniax
FV-1	499.7	2.64		2.3	98.46	18.447	----	46	X	
	499.9	2.70		2.2	77.23	26.642	0.134	47		X
	500.1	2.75		2.5	103.57	16.215	----	44	X	
	500.3	2.76	2.87	2.4	159.13	38.411	0.137	40		X
	500.4	2.78		2.3	133.45	21.180	----	47	X	
	500.6	2.78		2.4	134.32	30.216	0.127	54		X
	505.0	2.84		2.4	156.14	31.030	----	54	X	
	505.2	2.77		2.5	143.93	26.736	----	41	X	

This layer is expected near the floor of the Powerhouse Cavern; see fig. 6.

SCORIA **

Bore hole	Bore hole depth (m)	ρ* (g/cm^3)	L/D	σ_c (MPa)	E (GPa)	μ	Φ	ρ (g/cm^3)	Triax	Uniax
FV-1	481.5	2.07	2.4	12.90	1.581	---	7		X	
**	481.6	2.09	2.3	17.96	3.310	0.144	28	2.79		X
	481.7	2.08	2.4	18.40	3.235	---	0		X	
	482.1	2.14	2.5	23.56	3.750	0.134	46			X
	482.25	2.12	2.5	14.40	2.096	---	8		X	
	482.5	2.10	2.5	22.99	3.528	---	0		X	
	482.7	1.94	2.5	14.31	2.620	---	0		X	
	482.85	2.09	2.3	25.33	4.418	0.148	50			X
FV-9	63.9	2.09	2.3	10.59	3.253	0.179	37			X
	64.0	2.26	2.3	11.70	3.977	---	10		X	
	64.1	2.18	2.3	7.32	3.440	---	14		X	
	65.0	2.25	2.5	23.36	7.050	---	6		X	
	65.1	2.40	2.4	27.03	6.300	---	18		X	
	65.5	2.29	2.4	10.24	3.505	---	22		X	
	65.6	2.29	2.2	15.15	4.425	0.233	20			X
	65.9	2.33	2.4	27.94	5.157	---	30		X	
	66.0	2.35	2.4	21.34	6.793	0.153	46			X

** This layer is expected near top of the walls of the Powerhouse Cavern; see fig. 6.

OLIVINE BASALT

Bore hole	Depth (m)	ρ* (g/cm³)	L/D	σ_c (MPa)	E (GPa)	μ	Φ degr.	Triax	Uniax	ρ (g/cm³)
FV-8	132.8	2.87	2.5	164.27	30.340	0.109	24		X	
	135.6	2.91	2.5	209.60	24.254	-----	38	X		
**	135.8	2.88	2.4	143.62	19.115	-----	44	X		
	135.9	2.88	2.5	209.00	26.459	-----	47	X		
	136.1	2.92	2.6	141.02	18.740	-----	54	X		3.02
	136.2	2.91	2.4	203.51	35.322	0.089	34	X		
	136.3	2.90	2.4	243.53*	22.056	-----	54*		X	
FV-9	95.4	2.84	2.4	115.49	39.879	0.151	52		X	2.95
	95.7	2.81	2.4	177.36	31.547	-----	44	X		
	96.2	2.83	2.4	126.17	29.104	-----	46	X		
	97.1	2.84	2.4	178.89	32.786	-----	44	X		
	97.4	2.84	2.4	200.99	33.248	-----	42	X		
	98.2	2.86	2.4	151.28	35.638	-----	44	X		
	98.4	2.87	2.4	170.73	45.920	0.161	45		X	
FV-10	40.1	2.84	2.4	128.85	26.043	-----	34	X		
	42.2	2.88	2.4	111.15	30.584	-----	30	X		2.97
	42.4	2.88	2.1	148.13	36.035	0.137	49		X	
	44.5	2.89	2.4	176.46*	32.181	-----	54*	X		
	44.7	2.89	2.3	173.46	48.524	0.158	52		X	
	48.7	2.89	2.4	162.90	30.527	-----	32	X		
	48.9	2.81	2.4	120.92	38.600	0.138	48		X	
	51.8	2.90	2.5	235.44	38.037	-----	52	X		
	54.0	2.93	2.5	221.67	37.238	-----	54	X		

* indicates joint failure

** Ol./thol. basalt (see core log).

THOLEIITE BASALT

Bore hole	Borehole Depth (m)	ρ* (g/cm³)	L/D	σ_c (MPa)	E (GPa)	μ	Φ degrees	Triax	Uniax
FV-8	172.1	2.85	2.4	165.82	22.056	-----	52	X	
	172.2	2.86	2.4	179.40	26.380	0.118	38		X
	173.6	2.92	2.5	441.19	39.140	-----	50	X	
	173.8	2.82	2.7	273.56*	37.470	-----	72*	X	
	174.0	2.91	2.3	389.04	35.416	-----	50	X	
	174.15	2.94	2.3	395.97	49.492	0.092	51		X
	176.0	2.87	2.3	209.36	28.664	-----	40	X	

* indicates joint failure

NOTATION

E	Young's modulus
μ	Poisson's ratio
ρ^*	Dry bulk density
ρ	Absolute density
ϕ	Friction angle
σ_c	Compressive strength
$\sigma_{c\ uniax}$	Compressive strength calculated from uniaxial tests
$\sigma_{c\ triax}$	Compressive strength calculated from triaxial tests

APPENDIX 2

Core logs, technical data and field tests from the Powerhouse and Tailrace/Access tunnels area.

Legend for core logs and abbreviations

List of **core samples**
for investigation at Building Research Institute.

Borehole FV - 1;
report on Technical data, report on Point Load and Schmidt hammer tests and detailed core log (168 to -66 m a.s.l).

Borehole FV - 6;
report on Technical data, report on Point Load and Schmidt hammer tests and detailed core log (113 to -77 m a.s.l).

Borehole FV - 7;
report on Technical data, report on Point Load and Schmidt hammer tests and detailed core log (99 to 0 m a.s.l).

Borehole FV - 8;
report on Technical data, report on Point Load and Schmidt hammer tests and detailed core log (183 to 0 m a.s.l).

Borehole FV - 9;
report on Technical data, report on Point Load and Schmidt hammer tests and detailed core log (106 to 6 m a.s.l).

Borehole FV - 10;
report on Technical data, report on Point Load and Schmidt hammer tests and detailed core log (91 to -9 m a.s.l).

LEGEND
for the core logs
including abbreviation used

Thol. basalt - thol. bas. - **tholeiite basalt -**
Usually hard rock, sometimes brittle and most often flow-banded.

Olivine bas. - ol. bas. - ol. basalt - **olivine basalt -**
Coarser texture and not as hard as thol. basalt, olivine crystals present but not necessarily detectable in hand specimen..

Porph. bas. - porph. basalt - **porphyritic basalt -**
Basalt containing phenocrysts (plagioclase) approx. >5%; can have either ol. bas. or thol. bas. character. Usually very sound or dense rock.

Thol./ol. bas. - Ol./thol. bas. - **olivine and/or tholeiite basalt-** *Basalts having the characterics of both mentioned types.*

Porph./thol. bas. or Porph./ol. bas. - **porphyritic olivine or tholeiite basalt -**
Porphyritic basalt having characteristics of olivine or tholeiite basalts.

Congl. - **conglomerate -**
Usually of fluvial or glaciofluvial origin; pebbles usually small and angular. Most often well cemented.

Sdst. - sandst. - **sandstone -**
Can be of fluvial or lacustrine origin, sometimes stratified. Red sdst.; tephra-rich in a few cases but usually very thin and sometimes clay-rich.

Scor. bas. - **scoriaceous basalt -**
Usually scorioaceous top or base of lava flow, usually well cemented and sometimes fairly sound rock.

Scoria *Usually poorly cemented, fragmented glassy basalt and basalt blocks.*

Undul. - **undulating** - (joints) - *Frequently inclined columar joints.*

Incl. - **inclined** - (joints) - *Frequently columar joints.*

Horiz. - **horizontal** - *Usually describing joints or flow structures.*

Vert. - **vertical** - (joints) *Frequently vertical columar joints.*

Ves. - **vesicles** -. Vesic. - **vesicular -**

Scatt. - **scattered** - (vesicles, phenocrysts, ect.)

Microp. - **micropores - microporous -** *Usually found in sound rock.*

Chloroph. - **chlorophaeite -** *Clay related mineral, dark in colour, frequently coating joints and vesicles*

Chab. - **chabasite -** *Zeolite, coating to filling joints and vesicles*

Char. - **character -** (*ol. bas. char.*)

Cem. - **cemented -**

Infilt. - **infilterated** -. *Scor. w. sdst. infiltr.; usually fairly well cemented scoriacous top of lava.*

Tuffac. - **tuffaceous** - *Sediment containing tuff, usually acid.*

Fragm. - **fragmented** - **fragmental** - **fragment** - broken rock.

ø - diam. - **diameter** - (*of pebbles or vesicles*)

w. - with - (*containing or showing*)

Phen. - **phenocrysts** - *large crystals of variable amount in basalt lavas*

Hardness - (ISRM Working Party 1975)
most frequently used: **I** (*UCS: >200 Mpa*), **IIIa** (*UCS: 200 - 70 Mpa*) *and* **IIb** (*UCS: 70 - 25 Mpa*)

Weathering - (ISRM Working Party 1975)
most frequently used: F = fresh, WS = slightly weathered, WM = moderate weathering

UCS - Uniaxial Compressive Strength

PLT - **Point Load Test - Results given in MPa (megapascals)**

CORE % - core recovery - per cent

R Q D - Rock Quality Designation -
10/30/50/100 : per cent of unjointed core pieces longer than 10, 30, 50 & 100 centimeters respectively (10 cm if not otherwise indicated).

- **Q** - Rock mass quality classification system
Norwegian system (Barton et al. 1974), modified Icelandic version used for basaltic rocks.

LU - Lugeon unit - Permeability value obtained by water pressure test.
1 LU = 1 liter of water penetrating through the walls of 1 m of hole per minute, under the pressure of 10 bar

B. R. I. - Building Reasearch Institute (Reykjavík) *Samples tested 1990*

N. G. I. - Norwegian Geotechnical Institute

S I N T E F - Foundation for Scientific and Industrial Reasearch at the Norwegian Institute of Technology - *Tests carried out in Trondheim (Norway) 1990*

A. Copco - Atlas Copco - *Samples tested by "Geotest" (Suisse) 1981 and 1990*

E. L. S. - *Samples tested 1984 at Queens University, Canada by Edda Lilja Sveinsdóttir*

Haimson - *Samples tested at University of Wisconsin (U.S.A.) in connection with the Hydraulic Fracturing Measurements 1981*

Robbins - *Samples tested by Robbins Inc., Seattle (U.S.A.) 1980 - 81*

N E A - Orkustofnun - *the Icelandic National Energy Authority* -

B J - Birgir Jónsson, Orkustofnun

Á H - Árni Hjartarson, Orkustofnun

Þ H H - Þórólfur H. Hafstað, Orkustofnun

Ó B S - Ómar Bjarki Smárason, Stapi Geological Services

Fljótsdalur Hydro Project
Core samples

Core samples from holes drilled before 1990; sent to Building Reasearch Institute for further invesigation, following relogging of the core near the end of the year 1990.

Core-hole: no.	Depth of selected sample top; m	botm; m	Rock type	Strati-graphic suite
FV - 1	105.2	107.3	sandstone	TB
FV - 1	193.5	196.3	porph. bas.	TB
FV - 1	271.0	272.5	sdst./congl.	ML
FV - 1	380.0	381.7	tillite	ML
FV - 1	410.0	411.2	thol. bas.	ML
FV - 1	443.8	445.5	sandstone	ML
FV - 1	464.6	466.0	thol. bas.	ML
FV - 1	488.5	489.8	thol. bas.	ML
FV - 1	491.0	491.2	red siltst.	ML
FV - 1	495.4	496.8	conglomerate	ML
FV - 5	95.5	97.0	ol./thol. bas.	FA
FV - 6	562.5	563.9	dyke	-
FV - 7	59.1	60.5	sandstone	ML
FV - 8	66.3	67.7	thol. bas.	ML
FV - 8	135.5	137.0	ol. basalt	ML
FV - 9	92.4	93.9	ol. basalt	HF
FV - 10	20.0	21.5	thol. bas.	ML
FV - 10	33.9	35.3	ol. basalt	HF
FS - 30	111.2	112.6	ol. basalt	HA

NATIONAL ENERGY AUTHORITY
Hydropower Division
1990-11-25

Report
ÞHH-90-08i
þhh

Fljótsdalur Hydro Project
FV - 1

The hole is situated on the eastern side of the "Teigsbjarg" hill. It was drilled to investigate the geology at the site of the proposed **powerhouse.**
Coordinates: x=360336; y=504404; h=572.5 m a.s.l.

Time drilled: July 2nd to August 9th 1980.

Contractor: Jarðboranir h/f (Iceland Drilling Co. Ltd.)
Rig type used: Craelius D 1000.
Diamond bit: Step crown, occ. pilot type, NQ wireline core barrel and rods.
Drillers: Sigurður Sveinsson, Hreinn Sigurgeirsson and their crews.

Diameter of hole: 75.7 mm, yielding 47.6 mm core (NQ-size).
Depth of hole: 639.0 m, mainly through basalt lavas of the "FA", "TB" and "ML" suites, reaching down to the "HF" one.

Casing: diameter; 4", length; ca. 1 m.

Grouting: None (total cement used; 100 kg).

Ground water: Water table was close to surface until the hole reached the depth of 60.5m, where the water table fell down to 29m. Second lowering of the water table; to 80.5m took place when the hole reached the depth of 124m. Third lowering; to 145m, occured when the depth of 172m was reached. Then the water table was stable until the hole reached the depth of 455m; then it fell down to 265m below surface and had not changed when the final depth was reached.

Water pressure tests: Seven intensive recovery tests made by N. E. A. Transmissivity appears to lie betveen 10 m /s and 10 m /s.

Hydraulic Fracturinging Test including oriented stress measurements down to 500 m depth; performed by Professor B. C. Haimson, University of Wisconsin, Madison U. S. A. in June 1981.

NATIONAL ENERGY AUTHORITY
Hydropower Division
1990-12-31

Report
ÞHH/BJ-90-11a-a
eva

Fljótsdalur Hydro Project
Borehole FV - 1

This report deals with the results obtained from Point Load tests and Schmidt hammer tests on the relogged core, in November and December 1990. It must be pointed out, that the values obtained might be influenced by the age of the core.

Point Load Tests

Typical samples for point load test were 40 - 50 cm long, allowing for 7 - 10 tests, out of which the highest and lowest values were discarded and the average calculated for the remaining values. Additional samples, tested in December 1990, are printed bold.

Depth of tested sample top; m	Depth of tested sample botm; m	Rock type	Strati-graphic suite	Point load strength index; Is_{50} MPa*	"Apparent" uniax. compr. strength; σ_c MPa**
7.0	8.0	thol.basalt	FA	9.2	202
19.5	20.0	scor.ol.basalt		0.7	15
44.1	44.7	ol.basalt ves.		9.4	206
75.0	75.5	scor.ol.basalt		3.7	82
87.0	87.5	ol.basalt		10.3	226
104.0	**104.4**	**sandstone**		**2.7**	**58**
124.8	125.3	siltstone	TB	1.1	24
151.4	152	porph.basalt		9.1	199
190.0	190.4	porph.basalt ves.		3.8	83
220.0	220.5	porph.basalt		8.2	180
252.8	253.4	thol.bas.	ML	11.1	244
273.4	**273.8**	**sdst./congl.**		**2.3**	**52**
301.5	302	thol.bas.		9.9	218
340.0	340.6	porph.bas.		8.8	193
382.3	**382.7**	**tillite**		**1.3**	**28**
417.9	418.4	sandstone		0.67	15
442.9	**443.4**	**sandstone**		**1.2**	**27**
462.8	**464.3**	**thol.bas.**		**8.7**	**192**
478.1	478.7	thol.basalt		10.7	236
494.0	**494.4**	**conglomerate**		**0.4**	**9.3**
538.2	538.8	scor.thol.bas.		1.4	32
566.0	566.6	ol.basalt		9.9	217
628.8	629.5	thol.basalt ves.	HF	4.9	108

* Calculated: Gauge reading : 1.5 (ELE-chart) : 0.98 (correction for NQ-core size) = Is_{50}

** Calculated: $Is_{50} \times 22 = \sigma_c$

Schmidt Hammer test

The samples were typically about 20-25 cm long and 16-22 readings were made in each test. Ten of the lowest values were discarded, in accordance with the ISRM procedure, and the average calculated for the remaing values. The equipment used was type L and the impact energy was 0.74 Nm.

Depth of tested sample top; m	botm; m	Rock type	Strati-graphic suite	Schmidt Rebound Hardness
7.6	7.9	thol.basalt	FA	31
10.4	10.6	thol.basalt		40
19.4	19.7	scor.ol.basalt		25
43.7	44.0	ol.basalt		33
73.1	73.4	ol.basalt		23
85.7	86.0	ol.basalt		38
122.0	122.5	siltstone	TB	27
152.5	153	porph.basalt		42
192.3	192.8	porph.basalt		41
221.1	221.3	porph.basalt		40
254.8	255.2	thol.basalt	ML	44
300.7	301.1	thol.basalt		43
340.6	341.1	porph.bas		43
417.4	417.9	sandstone		28
478.8	479.2	thol.basalt		43
537.8	538.2	scor.basalt		22
565.6	566.0	ol.basalt		41
629.3	629.5	thol.basalt	HF	25

VOD MJ 760 ÞHH
90.12.0732/27 T

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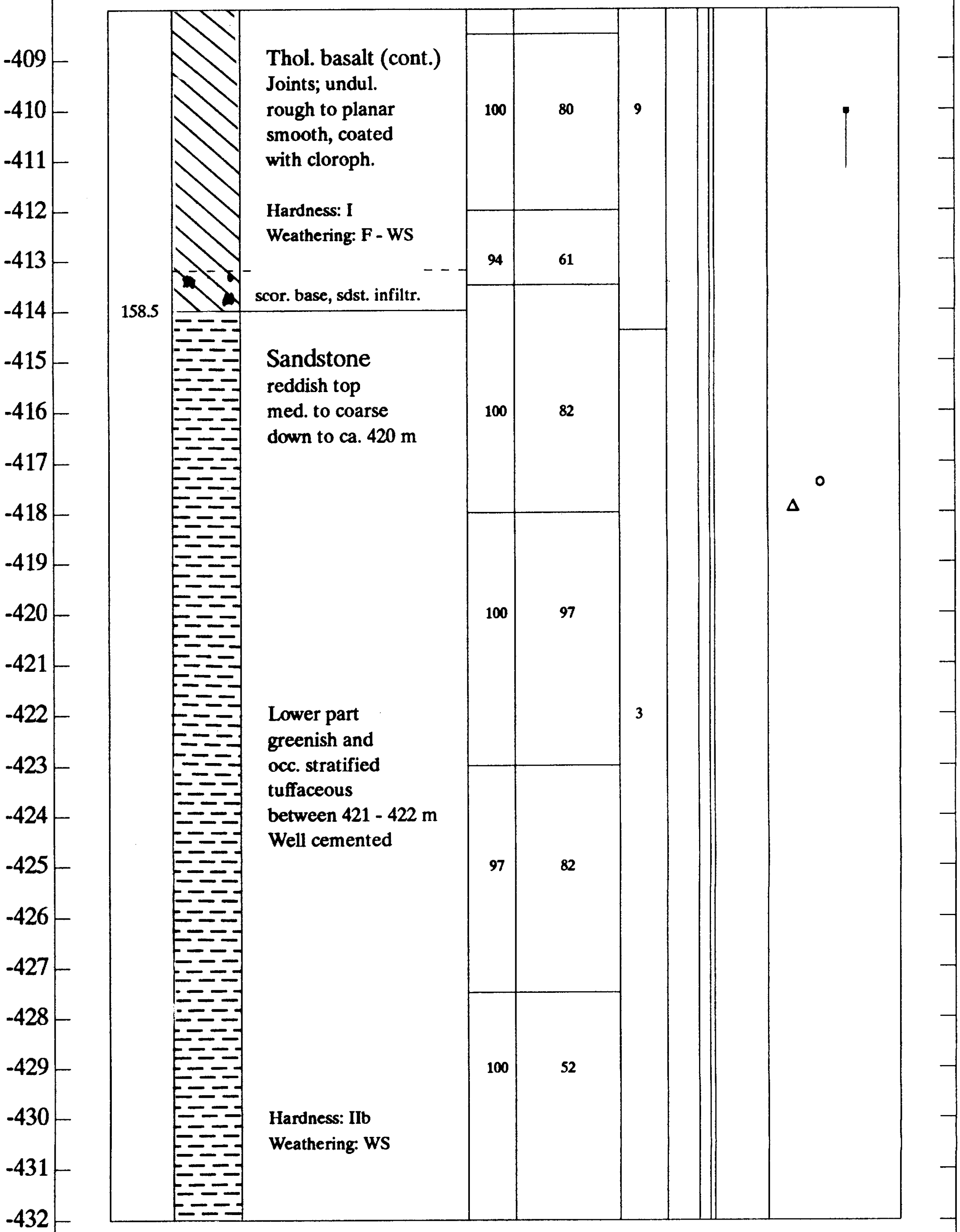

	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: △ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)
-409		**Thol. basalt (cont.)**						
-410		Joints; undul. rough to planar smooth, coated with cloroph.	100	80	9			▪
-411								
-412		Hardness: I Weathering: F - WS						
-413			94	61				
-414	158.5	scor. base, sdst. infiltr.						
-415		**Sandstone** reddish top med. to coarse down to ca. 420 m						
-416			100	82				
-417								○
-418								△
-419								
-420			100	97				
-421								
-422		Lower part greenish and occ. stratified tuffaceous between 421 - 422 m Well cemented			3			
-423								
-424								
-425			97	82				
-426								
-427								
-428								
-429			100	52				
-430		Hardness: IIb Weathering: WS						
-431								
-432								

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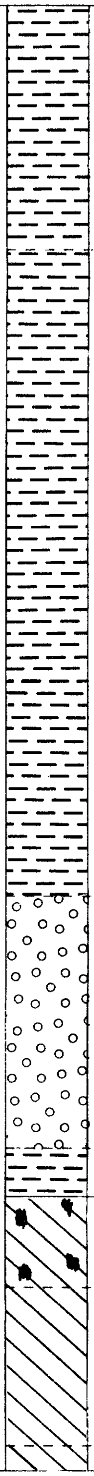

ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test, O Schmidt hammer, ■ Sample (B.R.I.)
	Sandst. (cont.) broken by vertical undulating joint	100	71				
136.5	Sandstone fine grained w. occ. pebb., usually small Boulder, vesic. at 439 m ø 50 cm	100	90				
		100	96	3			Robins ■
	Hardness: IIb Weathering: WS	97	40				
	Conglomerate pebb. up to 5 cm pebb. frac. 30 - 40%	100	92				Robins ■
	Sandstone fine, greenish						
121.0	Scor. basalt w. sdst. infiltr.	100	49			circ. water loss	
	Thol. basalt vesic. w. cem. scoria in places						

-433
-434
-435
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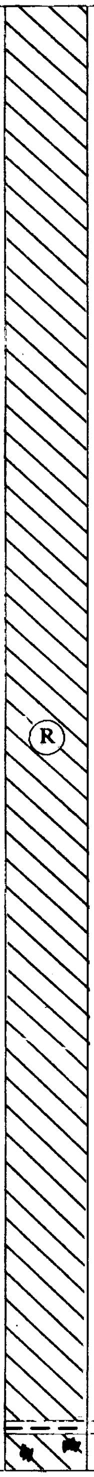
FV - 1 sheet 20 of 27



ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test, o Schmidt hammer, ■ Sample (B.R.I.)
-457	**Thol. basalt** flow banded	96	56				
-458	microporous.					circ.	
-459	Sound basalt					water	
-460						loss	
-461							
-462	Joints; planar smooth	100	39				
-463	to undul. rough, coated with						
-464	clorophaeite						
-465		100	71				■
-466				3			
-467							
-468							
-469		100	44				
-470							
-471							
-472							
-473		100	53				
-474							
-475	Hardness: I Weathering: F						
-476		100	50				
-477							Robins
-478		100	88				■ Δ
-479	Red sandst.	100	100				o
-480	92.9						

VOD MJ 760 ÞHH
90.12.0732/27 T

ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test, O Schmidt hammer, ■ Sample (B.R.I.)

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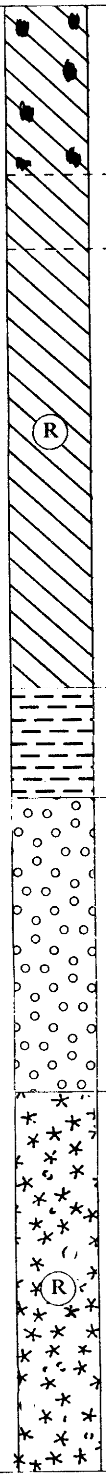

Depth	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	TESTS
-481 to -483		**Scor. basalt** Sandst. infiltr. Well cemented	100	100	10	E. L. S. ■
-483 to -484		Vesic., pink basalt	100	52	4	
-484 to -491		**Thol. bas.** Sound Flow banded. Microporous Joints incl. planar to undulating rough Hardness: I Weathering: F				■
-491 to -493	81.3	**Claystone, red** Core discing	100	70	<1	
-493 to -498	79.5	**Conglomerate** in medium to coarse sandy matrix pebb. frac.; 20 - 30% Hardness: IIb Weathering: WS	100	90	3	Robins ■
-498 to -504	74.7	**Porph. basalt** Sound, but ves. bands in places ves. ca. 2% Joints; incl., undul. rough Hardness: I Weathering: F	100 100	90 100	10	E. L. S. ■ Haimson ■

-481 -482 -483 -484 -485 -486 -487 -488 -489 -490 -491 -492 -493 -494 -495 -496 -497 -498 -499 -500 -501 -502 -503 -504

VOD MJ 760 ÞHH
90.12.0732/27 T

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	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: △ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)
-505		Porph. bas. (base)						E. L. S ▪
-506	66.7	Sandstone, brownish			1			
-507		Scor. w. sdst. infiltr.						
-508 -509 -510		Thol. basalt ves. 5-10% Joints, rough undul. Hardness: I Weathering: F - WS	100	88	10			
-511		Siltstone, red	92	57	1			
-512 -513 -514		Ol. basalt Scatt. ves. up to 7% Microporous Joints rough	100	85	10			
-515	57.5	Sandst.; black - red			3			
-516 -517 -518 -519		Ol. basalt Microporous w. scatt. ves. Joints; rough, incl.	97	82	10			
-520		Sandst., red			3			
-521 -522		Ol. basalt Ves. at top, microporous incl., rough joints			10			
-523 -524	49.5	Sandstone brownish w. occ. scor. fragm.	98	77	2			
-525 -526 -527 -528		Thol. basalt Fragmented w. sdst. infiltr. Fragm. ca. 90%	100	73	4			

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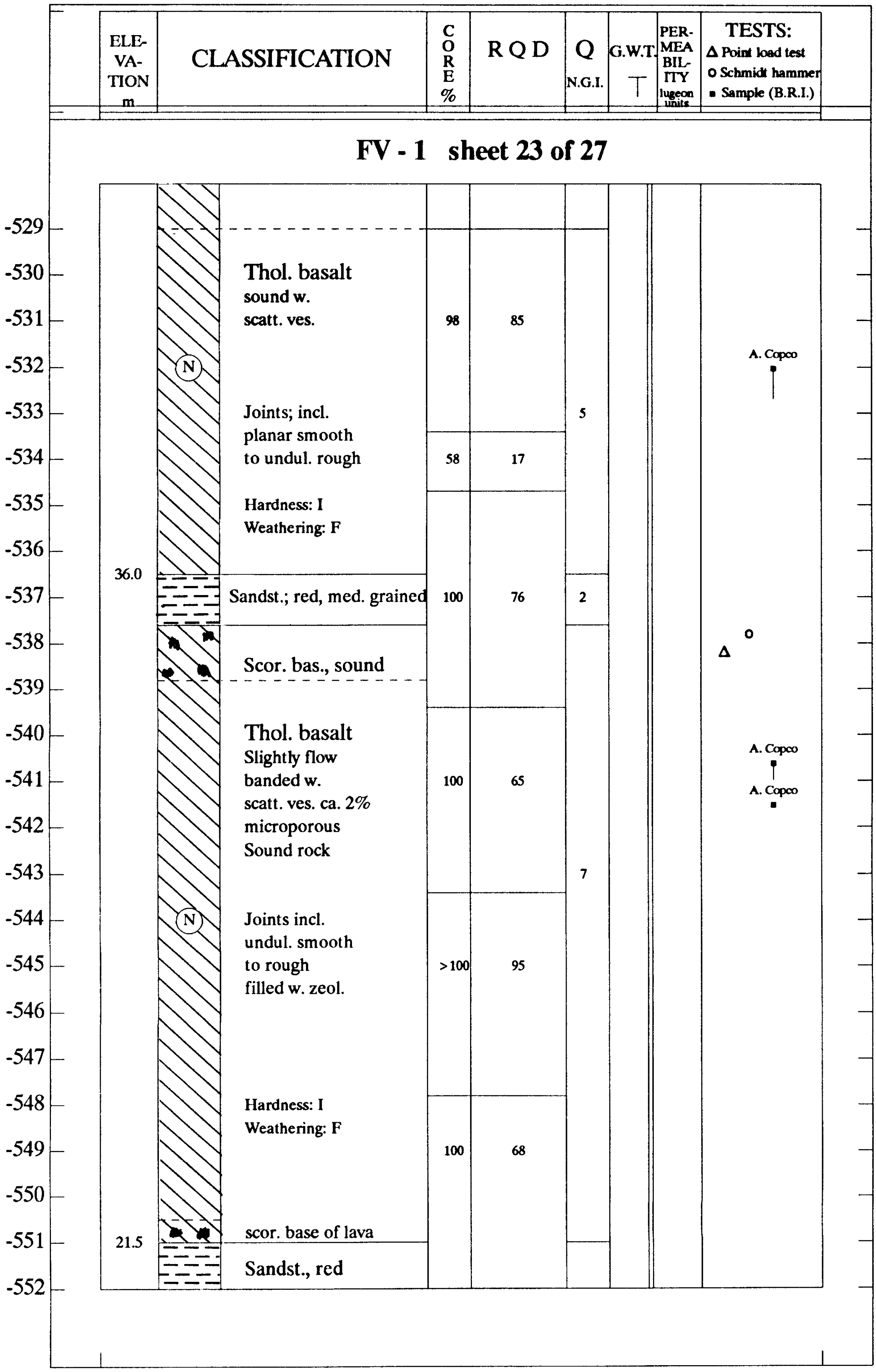

ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)

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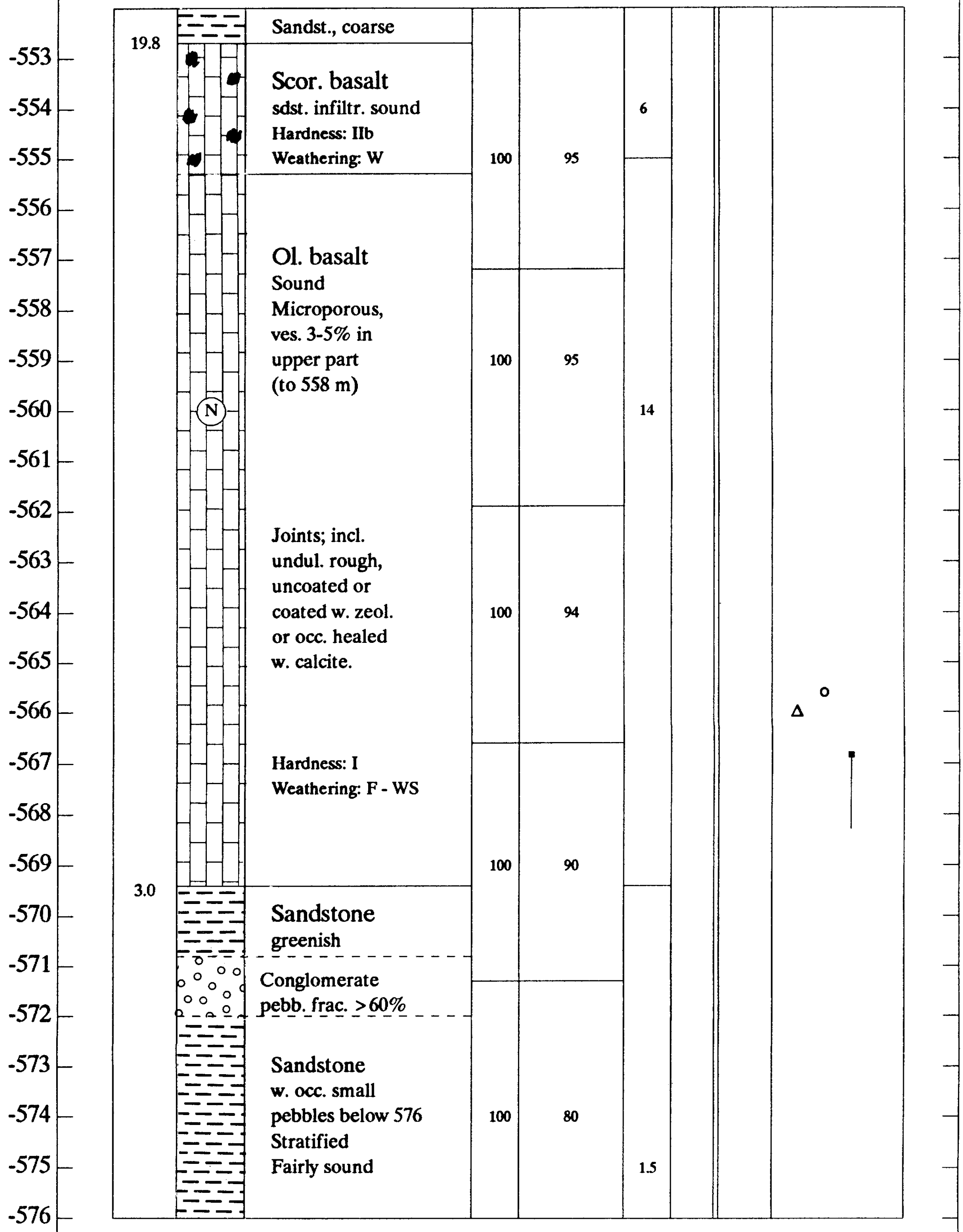

Sandst., coarse

Scor. basalt
sdst. infiltr. sound
Hardness: IIb
Weathering: W

Ol. basalt
Sound
Microporous,
ves. 3-5% in
upper part
(to 558 m)

Joints; incl.
undul. rough,
uncoated or
coated w. zeol.
or occ. healed
w. calcite.

Hardness: I
Weathering: F - WS

Sandstone
greenish

Conglomerate
pebb. frac. >60%

Sandstone
w. occ. small
pebbles below 576
Stratified
Fairly sound

VOD MJ 760 ÞHH
90.12.0732/27 T

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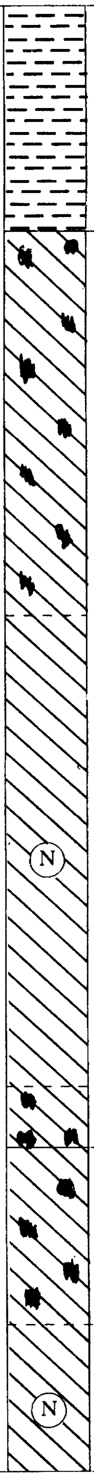

	ELE-VA-TION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PER-MEA BIL-ITY lugeon units	TESTS: Δ Point load test O Schmidt hammer ▪ Sample (B.R.I.)
-577		Sandstone (cont.)						
-578		w. scatt. small pebbles; 1 - 3%	100	84	1.5			
-579								
-580	-7.2							
-581		Scor. bas.						
-582		sdst. infiltr. near top						
-583		fairly sound ves. 2 - 3%	100	67	2			
-584		broken by vertical joint						
-585		Hardness: IIa Weathering: WF - WS						
-586								
-587		Thol. basalt	100	74				
-588		Flow banded Dense						
-589		Ves. in places up to 10%						
-590		Joints; planar rough to smooth	100	93	7			
-591		Slightly coated w. clorophaeite						
-592		Hardness: I						
-593		Weathering: F						
-594								
-595	-22.2	Scor. base; ves. 10-15%	100	81	3			
-596		Scor. basalt						
-597		Hardness: IIa - IIb Weathering: WF						
-598			100	70	4			
-599		Thol. basalt Flow banded						
-600		Ves. 3 - 5%						

VOD MJ 760 ÞHH
90.12.0732/27 T

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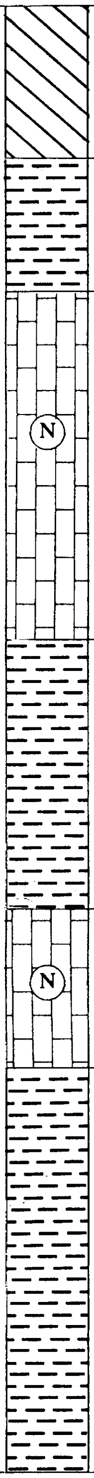

	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: △ Point load test ○ Schmidt hammer ■ Sample (B.R.I.)
		Thol. basalt (cont.)	95	77				
-601		Joints; planar smooth						
-602	-29.8	to undul. rough Hardness: I Weathering: F						
-603		**Red sandstone**	95	91				
-604		poorly cem. lower part Hardness: IIb			0.2			
-605	32.2	Weathering: WS						
-606		**Ol. basalt** Ves. w. dense middle	95	81				
-607		Ves. up to 20% Joints; undul. rough			9			
-608								
-609		Hardness: IIa Weathering: WS	90	84				
-610	-37.9							
-611		**Acid tuff**	90	44				
-612		Joints; planar smooth			0.2			
-613			100	37				
-614		Hardness: IIb						
-615	-42.3	Weathering: WS **Ol. basalt**	100	88				
-616		ves. 5 - 10%	95	100	4			
-617	-44.9	Hardness: IIa Weathering: WS						
-618			95	38				
-619		**Sandstone**						
-620		Greenish, rather coarse,			1			
-621		no stratif.	80	38				
-622								
-623								
-624								

VOD MJ 760 ÞHH
90.12.0732/27 T

ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)

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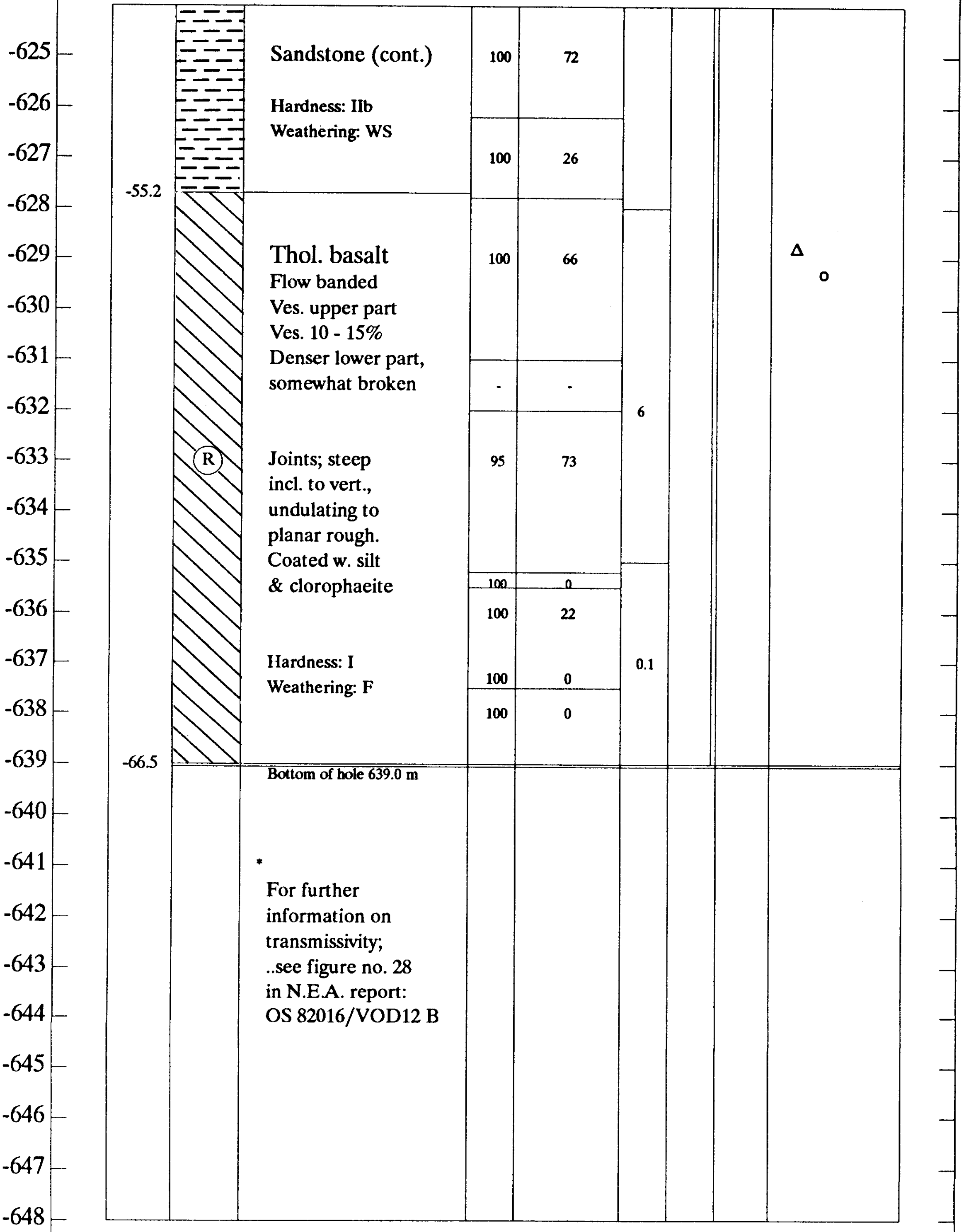

ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	TESTS
	Sandstone (cont.) Hardness: IIb Weathering: WS	100	72		
		100	26		
-55.2	Thol. basalt Flow banded Ves. upper part Ves. 10 - 15% Denser lower part, somewhat broken	100	66	6	Δ ○
		-	-		
	Joints; steep incl. to vert., undulating to planar rough. Coated w. silt & clorophaeite	95	73		
		100	0	0.1	
		100	22		
	Hardness: I Weathering: F	100	0		
		100	0		
-66.5	Bottom of hole 639.0 m				

*
For further information on transmissivity;
..see figure no. 28
in N.E.A. report:
OS 82016/VOD12 B

Fljótsdalur Hydro Project
FV - 6

The hole is situated at "Teigsbjarg". It was drilled to investigate the geology at the site of the proposed **powerhouse.**
Coordinates: x=360145; y=504325; h=497.4 m a.s.l.

Time drilled: Down to 492.5 m in the summer 1980, and completed 7th to 14th August 1981. Part of the drill string stuck in hole; it is therefore clogged at 247 m.

Contractor: Jarðboranir h/f (Iceland Drilling Co. Ltd.)
Rig type used: Craelius D 1000.
Diamond bit: Step crown and "pilot", NQ wireline core barrel and rods.
Drillers: Sigurður Sveinsson, Karl Valdimarsson, Ólafur Guðnason.

Diameter of hole: 75.7 mm, yielding 47.6 mm core (NQ-size).
Depth of hole: 576 m, starting in the "FA" suite, through the "TB" suite and the "ML" suite, where it penetratess disturbed strata along a dyke.

Casing: diameter; i.d. ø ca. 3" (NX), length; 3 m.

Grouting: None. Rather much cement used because of intensive trials to change the direction of drilling.

Ground water: At ground level until the hole reached the depht of 180 m. At 160 m until 372 m depth of hole; then at 220 m. Max. accessable depth is 247 m because of lost drill string.

Water pressure tests indicated relatively low water take.

NATIONAL ENERGY AUTHORITY
Hydropower Division
1990-12-31

Report
ÞHH/BJ-90-11d
eva

Fljótsdalur Hydro Project
Borehole FV - 6

This report deals with the results obtained from Point Load tests and Schmidt hammer tests on the relogged core, in December 1990. It must be pointed out, that the values obtained might be influenced by the age of the core.

Point Load Tests

Typical samples for point load test were 40 - 50 cm long, allowing for 7 - 10 tests, out of which the highest and lowest values were discarded and the average calculated for the remaining values.

Depth of tested sample top; m	botm; m	Rock type	Strati-graphic suite	Point load strength index; Is_{50} MPa*	"Apparent" uniax. compr. strength; σ_c MPa**
398.5	398.9	thol. bas	ML	12.8	282
484.4	484.8	dyke (ol. bas.)	-	12.4	273
507.4	508.2	dyke	-	6.9	152
561.2	561.7	ol. bas.	-	9.6	212

* Calculated: Gauge reading : 1.5 (ELE-chart) : 0.98 (correction for NQ-core size) = Is_{50}

** Calculated: Is_{50} x 22 = σ_c

Schmidt Hammer test

The samples were typically about 20-25 cm long and 16-22 readings were made in each test. Ten of the lowest values were discarded, in accordance with the ISRM procedure, and the average calculated for the remaing values. The equipment used was type L and the impact energy was 0.74 Nm.

Depth of tested sample top; m	botm; m	Rock type	Strati-graphic suite	Schmidt Rebound Hardness
401.0	401.4	thol. bas.	ML	44
421.1	421.3	thol. bas.		47
484.8	485.0	dyke	-	39
509.0	509.2	dyke	-	31
561.7	562.0	ol. bas.	-	45

VOD MJ 760 ÞHH
91.01.0026 T

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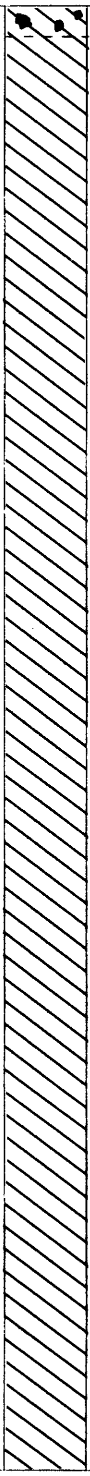

	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
	112.9	Scor. basalt						
-385								
-386		Thol. basalt Very dense w. flow banding. Ves.; < <1%, micropores & small scatt. ves.						
-387								
-388			100	55				
-389								
-390		Joints; steeply incl. to vert., planar to undul. rough, coated w. chlorophaeite, celadonite and zeolites	100	53				
-391								
-392								
-393								
-394			100	91				
-395								
-396					4			
-397								
-398			100	72				Δ
-399								
-400								
-401			100	50				o
-402		Hardness: I Weathering: F						
-403								
-404			100	67				
-405								
-406								
-407			100	80				
-408								

VOD MJ 760 ÞHH
91.01.0026 T

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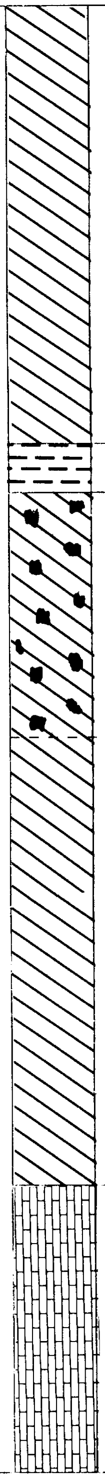
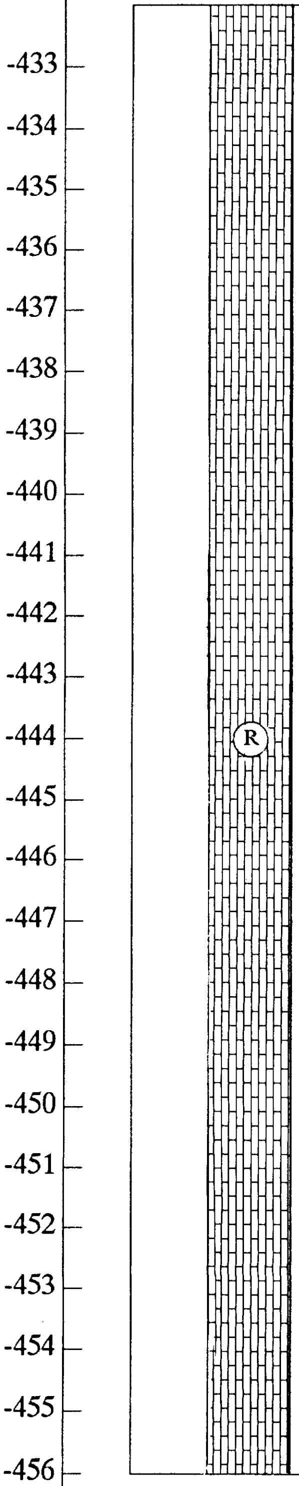


	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
-409		Thol. basalt (cont.) Dense	100	100				
-410								
-411			100	40				
-412		Hardness: I Weathering: F			4			
-413			100	80				
-414			100	96				
-415		Red sandstone			2			
-416	81.4	Scor. basalt						
-417		Sound w. sandst. infiltr. (10%).						
-418			100	81	7			
-419		Hardness: IIa Weathering: WS						
-420								
-421		Thol. basalt						o
-422		Dense with flow banding. Ves.; <1%, elong. up to ø 2 cm	100	35	2			
-423			100	54				
-424		Joints; planar smooth	100	20				
-425		to undulating rough coated with zeolites						
-426		and chlorophaeite	100	0				
-427	70.1	Hardness: I Weathering: F						
-428			100	97				
-429		Dyke Ol. basalt						
-430		Hardness: I Weathering: F - WS						
-431			100	100				
-432								

ELE-VA-TION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T. ⊤	PER-MEA BIL-ITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)

FV - 6 sheet 3 of 8



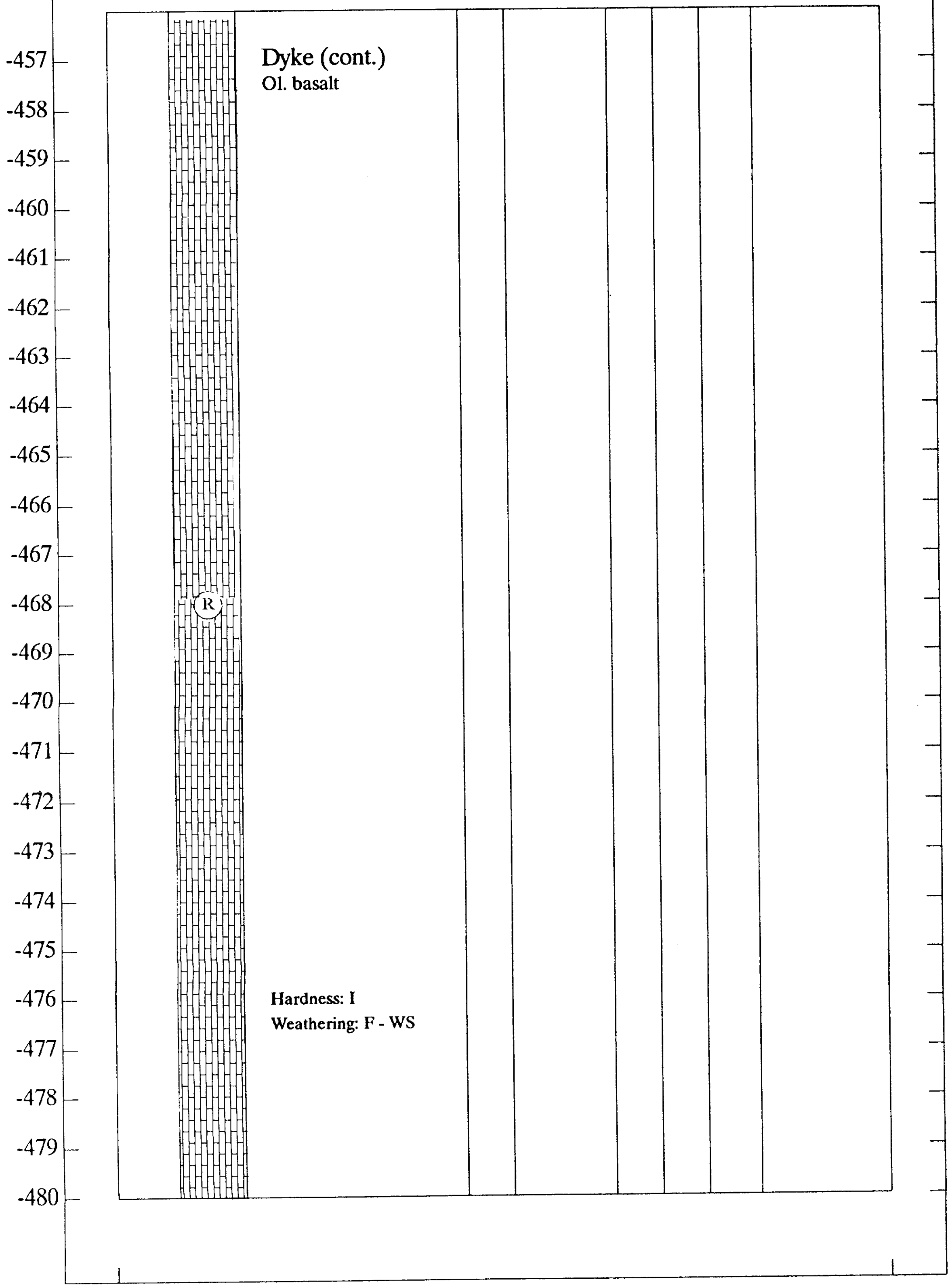
Dyke (cont.)
Ol. basalt,
slightly porph.
Small vesicles,
(ø 1 - 5 mm)
evenly scattered.
Ves.; ca. 5%
microporous and
denser in places

Hardness: I
Weathering: F - WS

VOD MJ 760 ÞHH
91.01.0026 T

ELE-VA-TION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T. ⊤	PER-MEA-BIL-ITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)

FV - 6 sheet 4 of 8



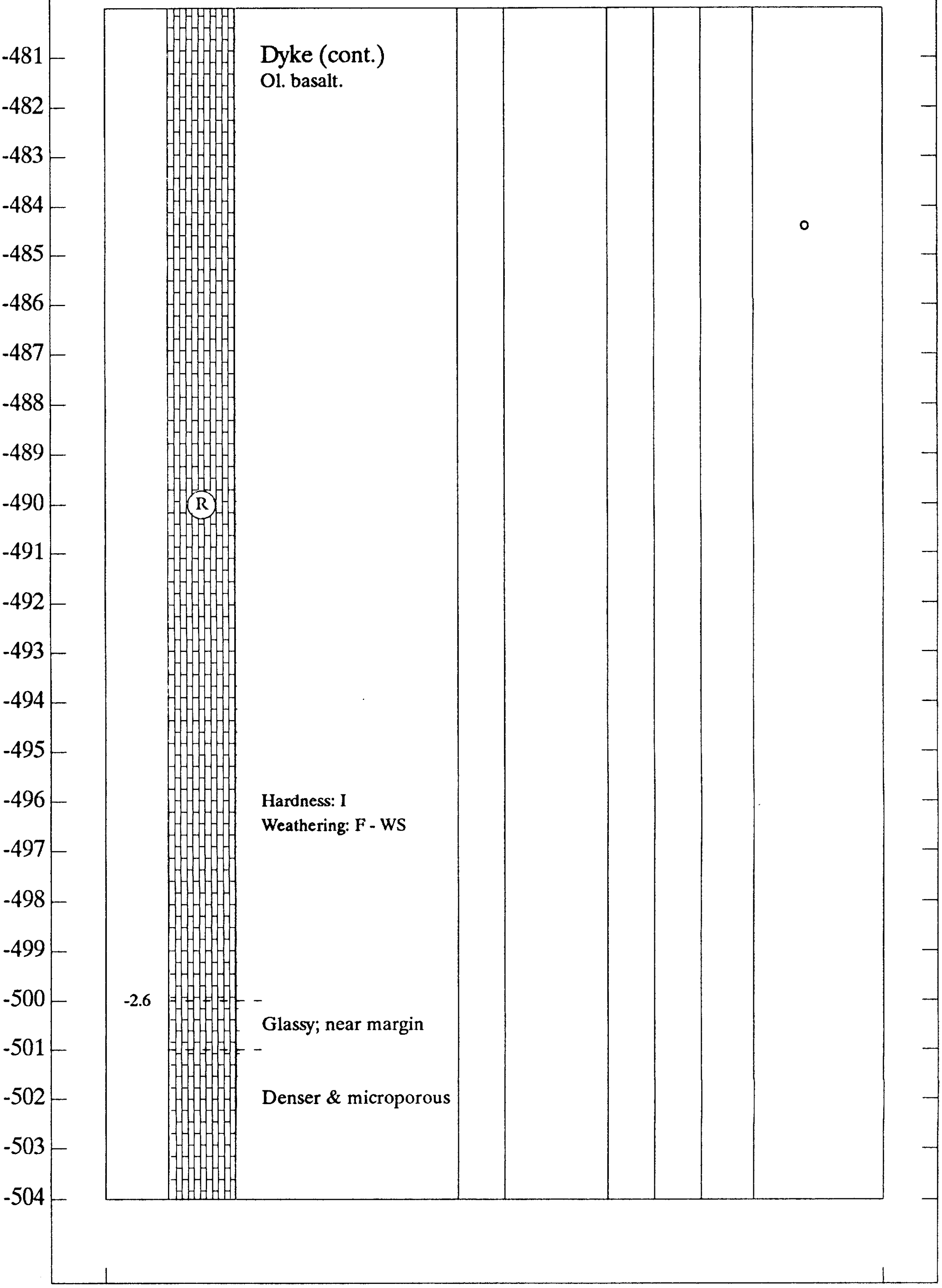
Dyke (cont.)
Ol. basalt

Hardness: I
Weathering: F - WS

VOD MJ 760 ÞHH
91.01.0026 T

ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)

FV - 6 sheet 5 of 8



Dyke (cont.)
Ol. basalt.

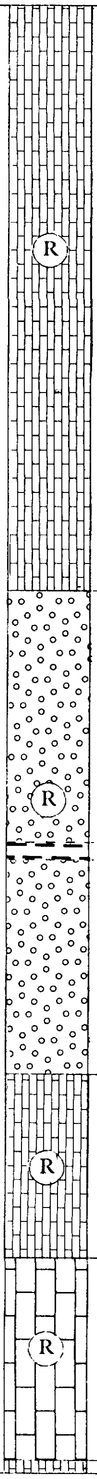
Hardness: I
Weathering: F - WS

Glassy; near margin

Denser & microporous

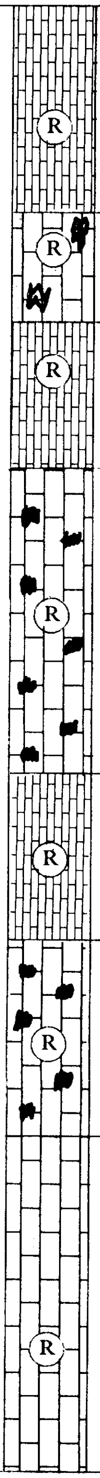
VOD MJ 760 ÞHH
91.01.0026 T

FV - 6 sheet 6 of 8



	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: ∆ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
-505		Dyke (cont.) Ol. basalt						
-506								
-507								
-508		Hardness: I Weathering: F - WS						∆
-509								o
-510								
-511		Joints healed with zeolites from 511 m, glassy margin.						
-512								
-513								
-514	-16.2							
-515		Congl./sandst. Stratified Poorly cem. to 516 m						
-516								
-517					0,5			
-518		Red/green silt						
-519								
-520		Hardness: IIa Weathering: WS - WM						
-521								
-522								
-523		Dyke dense with small vesicles						
-524								
-525	-27.1							
-526		Ol. basalt						
-527								
-528								

FV - 6 sheet 7 of 8



-529
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ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: △ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)
	Dyke (cont.)						
-35.8	Ol. basalt Brecciated			6			
	Dyke with vertical flow structure			3			
	Scor. basalt Joints; undulating rough, with slippy clay Hardness: IIa Weathering: F						
	Dyke			8			
-49.1	Scor. basalt well cemented w. large ves. Hardness: IIa: Weathering: F - WS						
	Ol. basalt Sound rock Small vesicles in upper part, dense, micropor. in lower part Joints; undul. rough			13			

FV - 6 sheet 8 of 8

	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: △ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)
-553		Ol. basalt (cont.)			13			
-554	-56.6	Dyke Ⓡ						
-555								
-556		Ol. basalt (cont.) dense, sound lower part						
-557								
-558								
-559								
-560		Ⓝ			13			
-561								△
-562								○
-563								▪
-564		Hardness: I Weathering: F - WS						
-565								
-566								
-567								
-568		Scor. base, sound						
-569	-71.7	Sandst./tuff, Reddish top						
-570								
-571		Greenish						
-572					1			
-573		Pinkish-brown tuff						
-574		Hardness: IIb Weathering: WF - WM						
-575	-77.6	Bottom of hole; 575 m						
-576								

NATIONAL ENERGY AUTHORITY
Hydropower Division
1991-01-04

Report
ÞHH-90-081
þhh

Fljótsdalur Hydro Project
FV - 7

The hole is situated at the foot of the "Teigsbjarg" hill. It was drilled to investigate the geology near the site of the proposed **access tunnel.**
Coordinates: x=359877; y=503781; h=99.2 m a.s.l.

Time drilled: September 20th to 24th 1980.

Contractor: Jarðboranir h/f (Iceland Drilling Co. Ltd.)
Rig type used: Sullivan.
Diamond bit: Step crown, BQ wireline core barrel and rods.
Drillers: Árni Guðmundsson, Gísli Jónsson and Ásgeir Ásgeirsson.

Diameter of hole: 60.0 mm, yielding 36.5 mm core (BQ-size).
Depth of hole: 99.7 m, mainly through "ML" suite, reaching down to the "HF" one.

Casing: diameter; ca. 3" i.d. (NX), length; 4.6 m.

Grouting: None.

Ground water: Almost at ground level.

Water pressure test indicates low water take.

NATIONAL ENERGY AUTHORITY
Hydropower Division
1990-12-31

Report
ÞHH/BJ-90-11e
þhh

Fljótsdalur Hydro Project
Borehole FV - 7

This report deals with the results obtained from Point Load tests on the relogged core, in December 1990. It must be pointed out, that the values obtained might be influenced by the age of the core. No Scmidt hammer tests where made as the core is BQ-size.

Point Load Tests

Typical samples for point load test were 40 - 50 cm long, allowing for 7 - 10 tests, out of which the highest and lowest values were discarded and the average calculated for the remaining values.

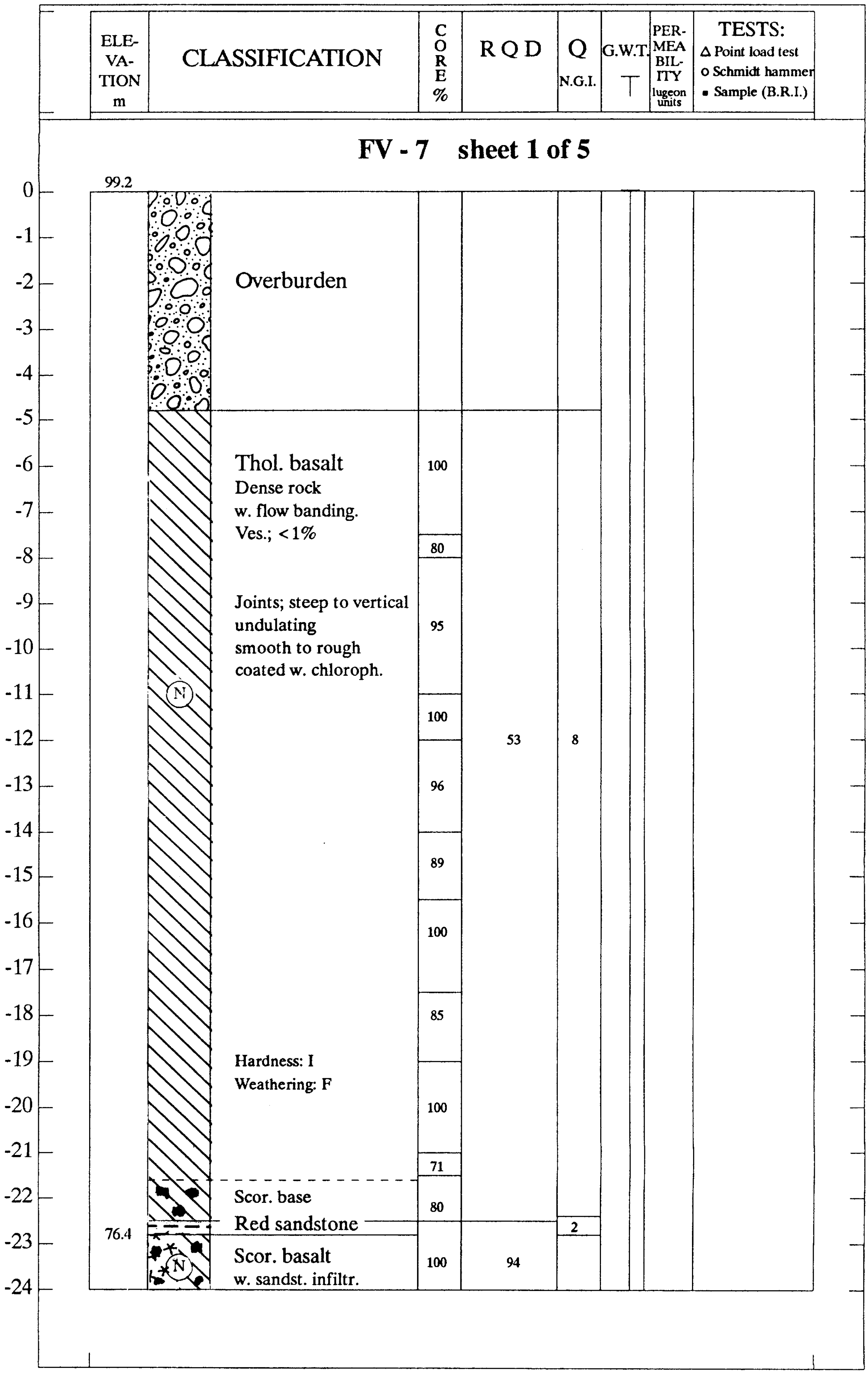
Depth of tested sample top; m	Depth of tested sample botm; m	Rock type	Strati-graphic suite	Point load strength index; I_{s50} MPa*	"Apparent" uniax. compr. strength; σ_c MPa**
38.35	39.0	porph. bas.	ML	9.7	212
45.0	45.5	sandstone		2.4	52
57.7	58.2	sandstone		2.2	47

* Calculated: Gauge reading : 1.5 (ELE-chart) x correction for BQ-core size = I_{s50}

** Calculated: I_{s50} x 22 = σ_c

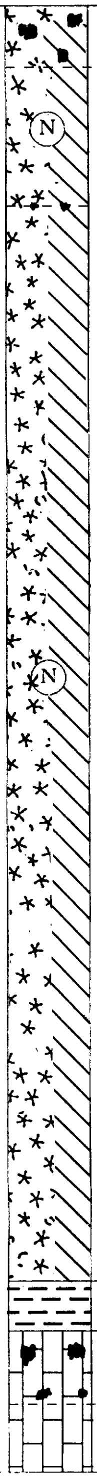
VOD MJ 760 ÞHH
91.01.0027 T

FV - 7 sheet 1 of 5



VOD MJ 760 ÞHH
91.01.0027 T

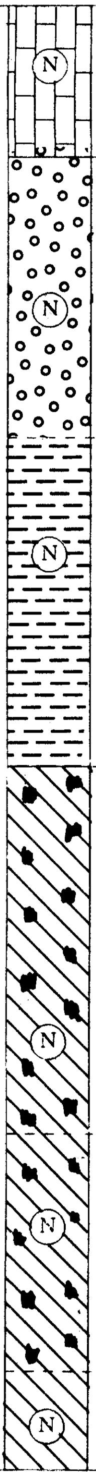
FV - 7 sheet 2 of 5



	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
		Ves.; ca 10%	100	23				
-25								
-26		Porph./thol. bas. Sound rock	100	94				
-27		<- flow unit boundary scor. basalt 27.1 - 27.6 m						
-28								
-29								
-30		Ves.; 1 - 2% Scatt. elong. up to ø 1 - 2 cm						
-31								
-32								
-33								
-34			98	80	10			
-35		Joints; steeply incl. Planar to undul. rough, slightly coated with chlorophaeite						
-36								
-37								
-38							0.1	Δ
-39								
-40								
-41			89	38				
-42								
-43		Hardness: I Weathering: F	95	71				
-44								
-45	54.3	Red sandstone			2			Δ
-46	53.5	Scor. basalt w. sandst. infiltr.	100	100	6			
-47		Olivine basalt						
-48								

VOD MJ 760 ÞHH
91.01.0027 T

FV - 7 sheet 3 of 5



ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
	sound rock ves. ca. 3% Hardness: IIa Weathering: WS	100	100	(10)			
48.7	Congl./sandst. Fine graind congl. pebble fraction; 50%	100 100	99 35	(6)			
	Dark sandstone with pebbels (10%) Hardness: IIb Weathering: F - WS	100	80	(10)		0.1	Δ ▪
38.7	Scor. basalt with sandst. infilt.; 30% Ves.; 10%, filled with zeolites Hardness: IIa - IIb Weathering: F - WS	100	69	(6)			
	Scor. basalt Pinkish in places Sound rock Hardness: IIa Weathering: F - WS	100	75	(8)			
	Thol. basalt Dense rock	100	94				

-49
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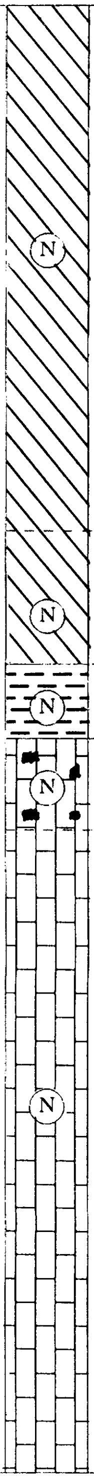
FV - 7 sheet 4 of 5



	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
-73 -74 -75 -76 -77 -78 -79 -80		Thol. basalt (cont.) Ves.; ca 1% elongated, 1-2 cm Joints; steeply incl. to vert. planar to undul. rough, coated, filled and healed with zeolites Hardness: I Weathering: F Healed fractures below 79 m	100	79	(8)		0.1	
-81 -82		Scor. basalt Rather broken Hardness: IIa	100	52	(4)			
-83	16.4	Red sandstone Hardn.: IIb, Weathering: WS	100	92	(2)			
-84 -85	15.2	Scor. basalt w. sdst. infiltr.; 10%	100	90	(12)			
-86 -87 -88		Ol. basalt Sound rock; ves. ca. 1 - 2% filled with zeol.	97	93				
-89 -90 -91 -92 -93		Joints; undul. rough coated or healed w. zeol. and coated with chlorophaeite	100	93				
-94 -95 -96			93	94				

FV - 7 sheet 5 of 5

ELEVATION m		CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: △ Point load test ○ Schmidt hammer ■ Sample (B.R.I.)
	Ⓝ	Ol. basalt (cont.) Hardness: I Weathering: WS	100	100			0.1	
-0.6		Bottom of hole; 99.7 m						

-97
-98
-99
-100
-101
-102
-103
-104
-105
-106
-107
-108
-109
-110
-111
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-113
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-115
-116
-117
-118
-119
-120

NATIONAL ENERGY AUTHORITY
Hydropower Division
1991-01-04

Report
ÞHH-90-08m
þhh

Fljótsdalur Hydro Project
FV - 8

The hole is situated at the "Teigsbjarg" hillside. It was drilled to investigate the geology near the sites of the proposed **access and tailrace tunnels.**
Coordinates: x=359980; y=503931; h=183.3 m a.s.l.

Time drilled: September 29th to October 24th 1980.

Contractor: Jarðboranir h/f (Iceland Drilling Co. Ltd.)
Rig type used: Sullivan.
Diamond bit: Step crown and "pilot", BQ wireline core barrel and rods.
Drillers: Árni Guðmundsson and Ásgeir Ásgeirsson.

Diameter of hole: 60.0 mm, yielding 36.5 mm core (BQ-size).
Depth of hole: 183.7m, through the lower half of the "ML" suite.

No casing.

Grouting: None.

Ground water: Approximately 4 m below ground level.

Water pressure test indicates low water take.

NATIONAL ENERGY AUTHORITY
Hydropower Division
1990-12-31

Report
ÞHH/BJ-90-11f
þhh

Fljótsdalur Hydro Project
Borehole FV - 8

This report deals with the results obtained from Point Load tests on the relogged core, in December 1990. It must be pointed out, that the values obtained might be influenced by the age of the core. No Scmidt hammer test where made as the core is BQ-size.

Point Load Tests

Typical samples for point load test were 40 - 50 cm long, allowing for 7 - 10 tests, out of which the highest and lowest values were discarded and the average calculated for the remaining values.

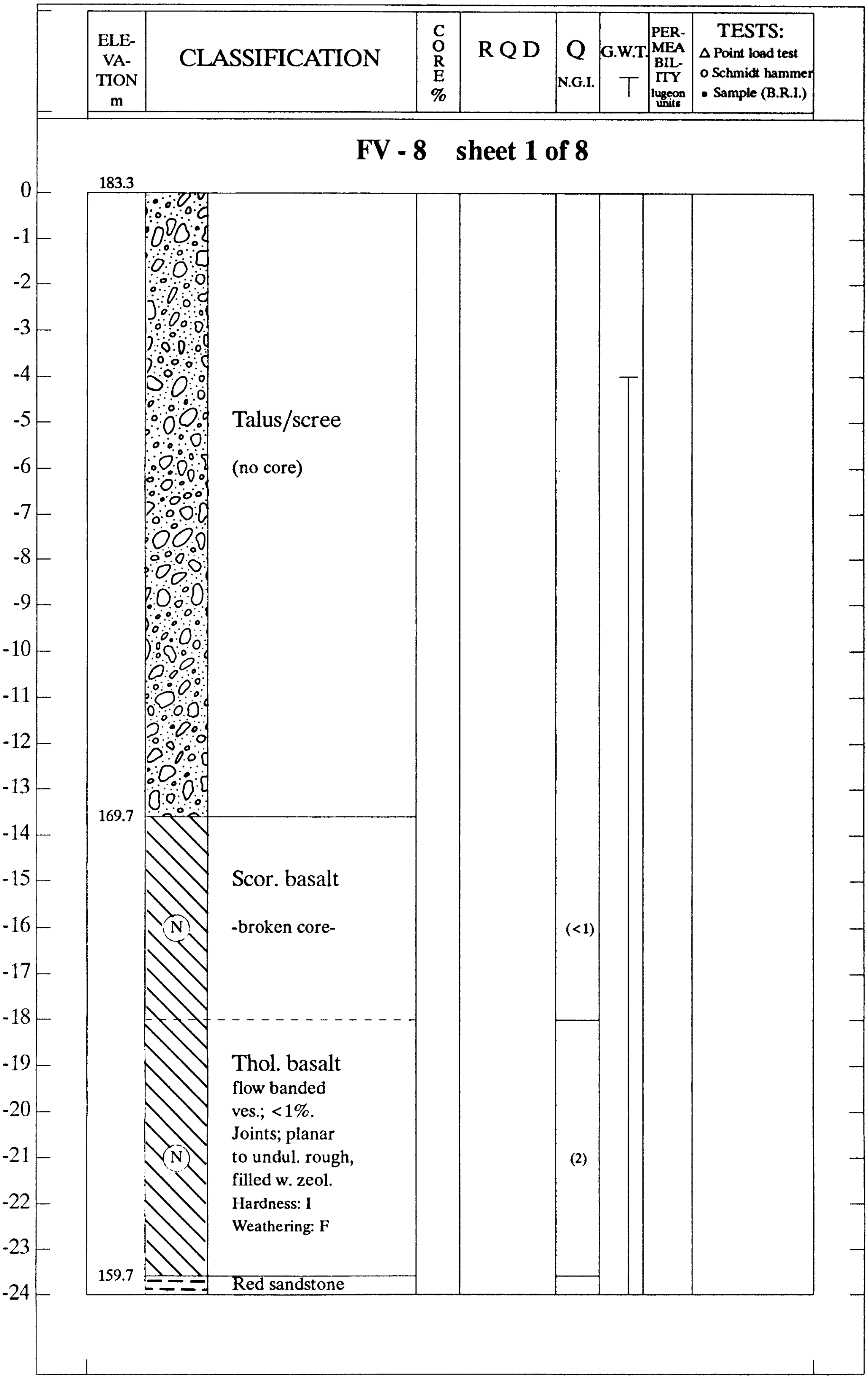
Depth of tested sample top; m	Depth of tested sample botm; m	Rock type	Strati-graphic suite	Point load strength index; I_{s50} MPa*	"Apparent" uniax. compr. strength; σ_c MPa**
47.3	47.8	scor. bas.	ML	0.8	17
67.8	68.3	thol. bas.		13.0	284
87.6	88.0	porph. bas.		7.5	166
137.2	137.4	ol. basalt		11.3	250
160.1	160.4	sdst. (sound)		5.5	120
160.4	160.8	sdst. (stratif)		3.0	67
176.0	176.9	thol. bas.		12.0	261

* Calculated: Gauge reading : 1.5 (ELE-chart) x correction for BQ-core size = I_{s50}

** Calculated: $I_{s50} \times 22 = \sigma_c$

VOD MJ 760 ÞHH
91.01.0028 T

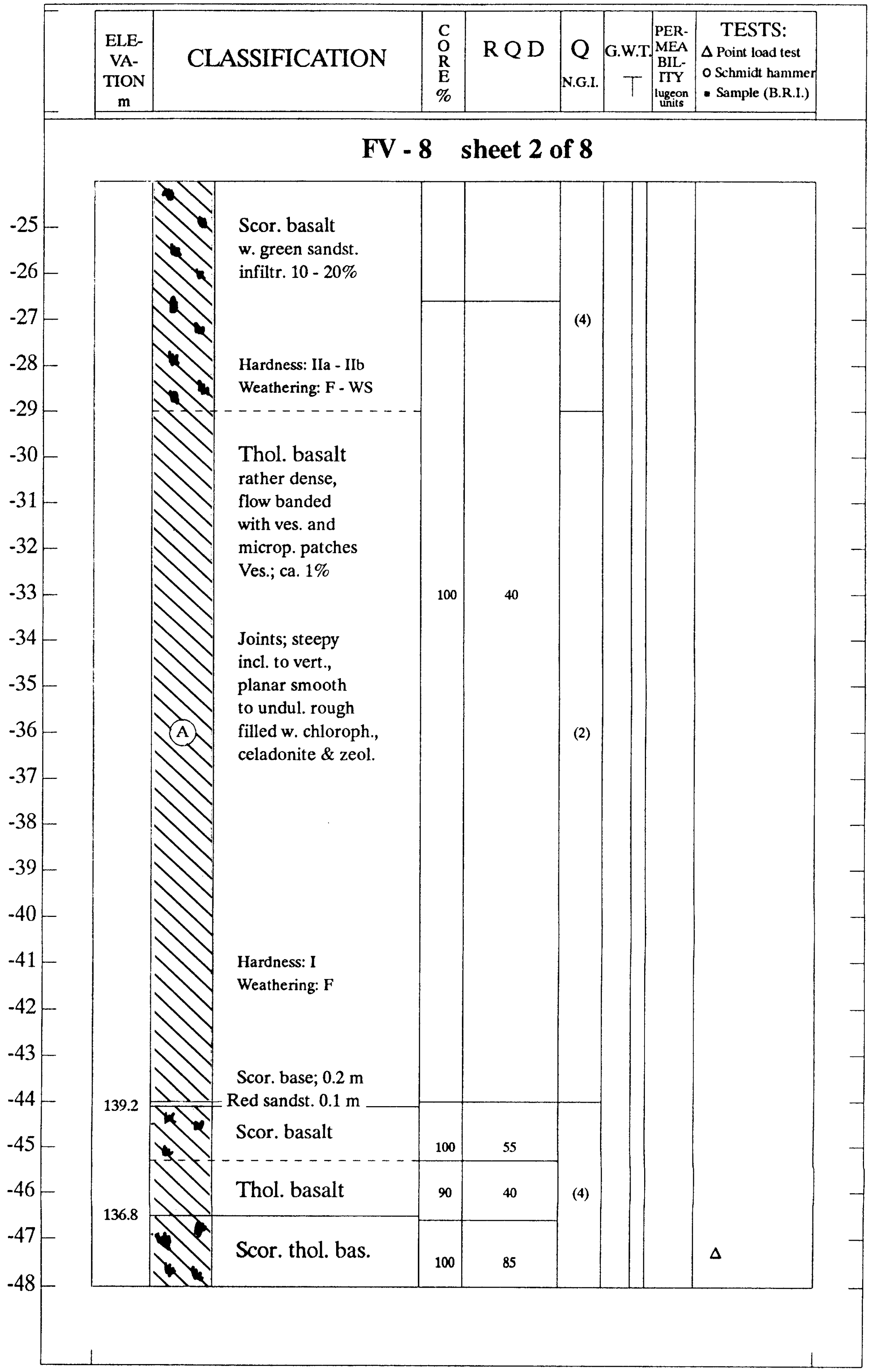
FV - 8 sheet 1 of 8



ELE-VA-TION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PER-MEA BIL-ITY lugeon units	TESTS: △ Point load test ○ Schmidt hammer • Sample (B.R.I.)
183.3	Talus/scree (no core)						
169.7	Scor. basalt -broken core-			(<1)			
	Thol. basalt flow banded ves.; <1%. Joints; planar to undul. rough, filled w. zeol. Hardness: I Weathering: F			(2)			
159.7	Red sandstone						

VOD MJ 760 ÞHH
91.01.0028 T

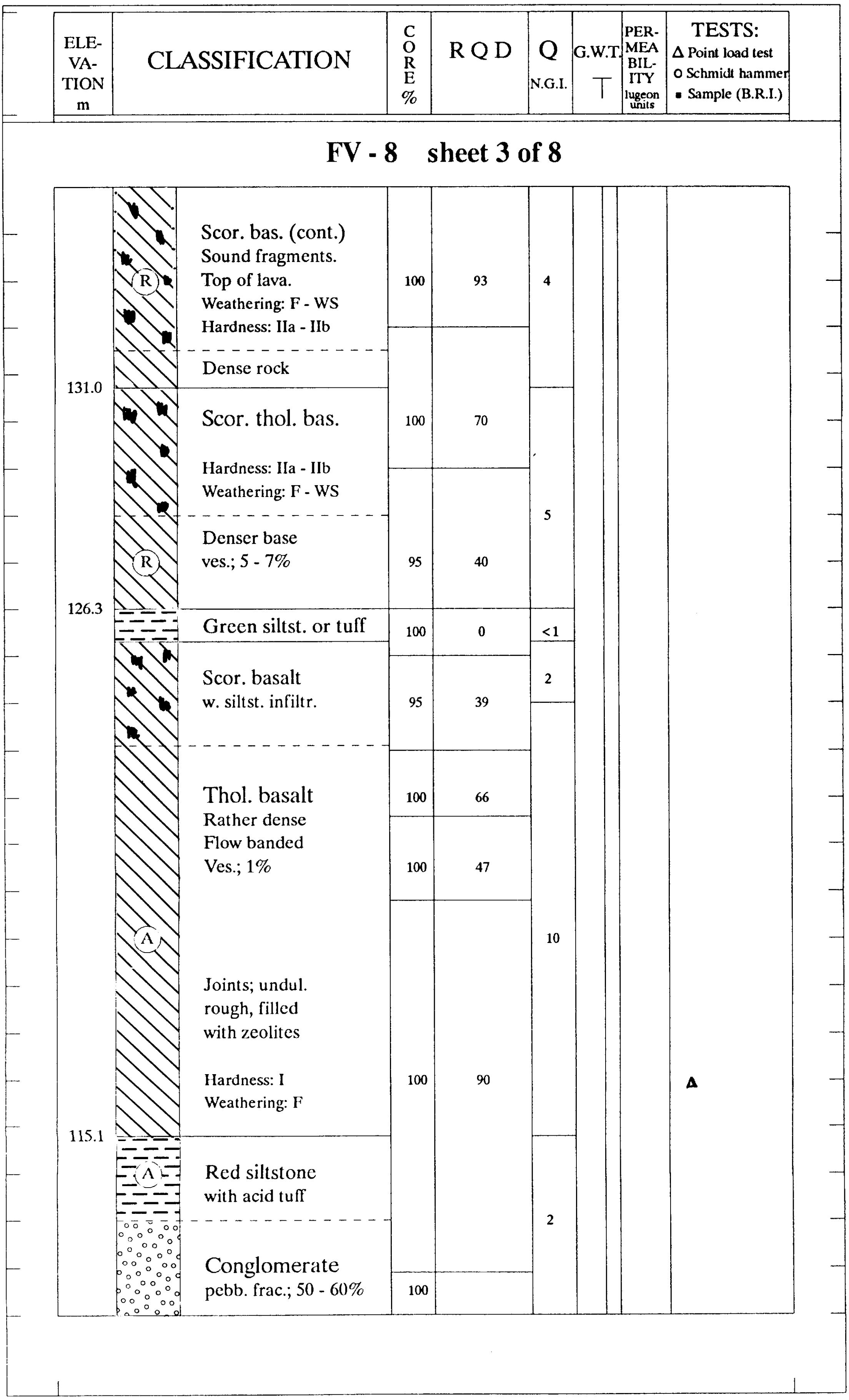
FV - 8 sheet 2 of 8



	ELEVATION m	CLASSIFICATION		CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test O Schmidt hammer ▪ Sample (B.R.I.)
-25			Scor. basalt						
-26			w. green sandst. infiltr. 10 - 20%						
-27						(4)			
-28			Hardness: IIa - IIb						
-29			Weathering: F - WS						
-30			Thol. basalt						
-31			rather dense, flow banded						
-32			with ves. and microp. patches						
-33			Ves.; ca. 1%	100	40				
-34			Joints; steepy						
-35			incl. to vert., planar smooth						
-36		A	to undul. rough filled w. chloroph.,			(2)			
-37			celadonite & zeol.						
-38									
-39									
-40									
-41			Hardness: I Weathering: F						
-42									
-43			Scor. base; 0.2 m						
-44	139.2		Red sandst. 0.1 m						
-45			Scor. basalt	100	55				
-46			Thol. basalt	90	40	(4)			
-47	136.8		Scor. thol. bas.	100	85				Δ
-48									

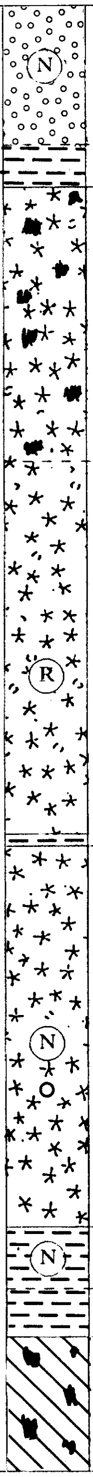
VOD MJ 760 ÞHH
91.01.0028 T

FV - 8 sheet 3 of 8



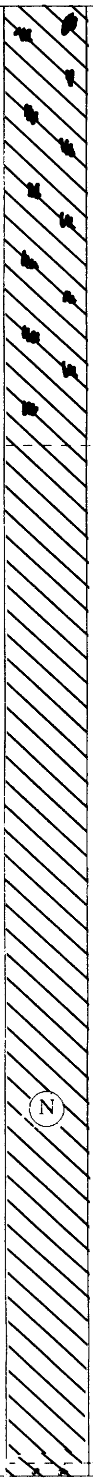
VOD MJ 760 ÞHH
91.01.0028 T

FV - 8 sheet 4 of 8



	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test O Schmidt hammer ▪ Sample (B.R.I.)
-73 -74		Pebb. diam. ø 2 - 4 cm occ. boulders; ø 15 cm Hardness: IIa - IIb Weathering: WS	100	70	2			
-75	108.3	Sandstone						
-76 -77 -78 -79		Scor. basalt Sound rock Top of lava ves.; 3 - 5% Hardness: IIa Weathering: WS						
-80 -81 -82 -83 -84 -85		Porph. basalt Plag. phen.; 10% Sound rock; ves.; 2 - 3% Joints; undul. rough filled with zeolites Hardness: I Weathering: F - WS	100	100	16			
	97.8	Red sandstone			2			
-86 -87 -88 -89 -90 -91		Porph. basalt Sound rock Plag. phen.; 10% Ves.; 5% filled with zeolites Joints; undul. rough Hardness: I - IIa Weathering: WS			16			Δ
-92	91.3	Red sandstone	100	78				
-93		Yellowish tuff			2			
-94 -95 -96		Scor. basalt fragmented to 97 m	100	25	5			

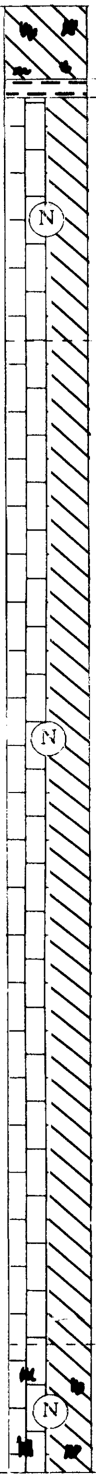
FV - 8 sheet 5 of 8



	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
-97		Scor. basalt (cont.)						
-98		Sound rock below 97 m	100	85				
-99								
-100					5			
-101		Hardness: IIa Weathering: F - WS						
-102								
-103	80.1							
-104			100	93				
-105		Thol. basalt Rather dense, scatt. ves.; 1% up to ø 1 cm						
-106								
-107								
-108								
-109		Joints; steeply inclined, planar to undul. rough, coated w. chloroph.						
-110					10			
-111			100	70				
-112								
-113								
-114								
-115								
-116								
-117		Hardness: I Weathering: F	100	90				
-118								
-119								
-120								

VOD MJ 760 ÞHH
91.01.0028 T

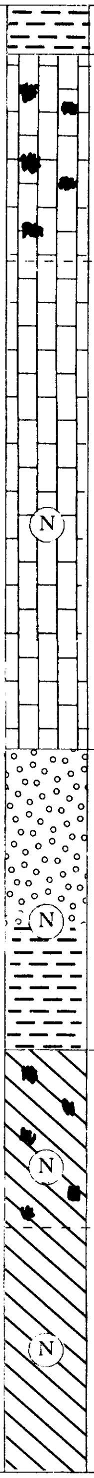
FV - 8 sheet 6 of 8



ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test, o Schmidt hammer, ■ Sample (B.R.I.)
	Scor. base; 1.5 m			10			
-121 61.2	Red sandstone						
-122							
-123	Scor. basalt broken in places			5			
-124	ves. ca. 5%.	100	80				
-125							
-126							
-127	Ol./thol. basalt Sound rock.						
-128	Slightly porph. 1 - 2% Ves. scatt. ca. 2%	100	30				
-129	elongated up to 2 cm						
-130		100	80				
-131		100	34				
-132							
-133	Joints; steeply incl. undulating rough,						
-134	coated w. chloroph. and some filled			11			
-135	with zeolites Clay filled joints						■
-136	at 131.9 m (10 cm) & 132.3 m (2 cm)						
-137							Δ
-138		100	90				
-139							
-140	Hardness: I Weathering: F						
-141							
-142							
-143	Scor. base; 2 m						
-144							

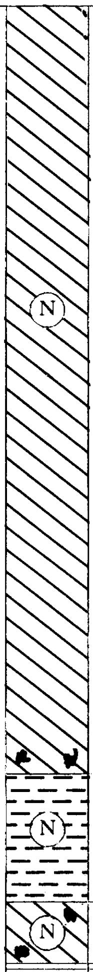
FV - 8 sheet 7 of 8

-145 -146 -147 -148 -149 -150 -151 -152 -153 -154 -155 -156 -157 -158 -159 -160 -161 -162 -163 -164 -165 -166 -167 -168



ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T. ⊤	PERMEABILITY lugeon units	TESTS: Δ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)
38.5	Red sandstone			5			
	Scor. basalt w. sdst. infiltr. Sound rock. Hardness: IIa Weathering: WS	100	90	15			
27.1	Ol. basalt Slightly porph. (<1%) Sound rock, w. small ves. & micropores. Ves.; <1% Joints; steeply incl. to vert.; undul. rough. Coated w. zeolites & chlorophaeite or or filled to healed with zeolites Hardness: IIa Weathering: WS						
22.2	Congl./sandst. Stratified. Coarser above 157.8 m w. pebb. ø 1 - 4 cm. Stratif. sandst. in lower part. Hardness: IIa - IIb Weathering: WS			8			Δ Δ
	Scor. basalt with sandstone infiltr. (10-20%) Hardness: IIa Weathering: WS			11			
	Thol. basalt Dense rock, ves. <1% micropor. flow banding occurs.			14			

FV - 8 sheet 8 of 8



	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test O Schmidt hammer ▪ Sample (B.R.I.)
-169		Thol. basalt (cont.)						
-170		Joints; inclined, planar to undul.						
-171		rough, coated or filled with zeol.						
-172								
-173								
-174			100	95	14			
-175								
-176								Δ
-177								
-178		Hardness: I Weathering: F						
-179								
-180		Scor. base of lava						
-181	2.7	Red sandstone	100	75				
-182		Rather broken. Some stratification			(<1)			
-183		Scor. basalt w. sdst. infiltr.						
-184	-0.4	Bottom of hole; 183.7 m						
-185								
-186								
-187								
-188								
-189								
-190								
-191								
-192								

Fljótsdalur Hydro Project
FV - 9

The hole is situated at the foot of the "Teigsbjarg" hill. It was drilled to investigate the geology near the site of the proposed **tailrace tunnel.**
Coordinates: x=359785.9 y=503941.3; h=106.2 m a.s.l.

Time drilled: July 7th to July 12th 1981.

Contractor: Jarðboranir h/f (Iceland Drilling Co. Ltd.)
Rig type used: Craelius D 1000.
Diamond bit: Step crown, NQ wireline core barrel and rods.
Drillers: Sigurður Sveinsson, Karl Valdimarsson, Ólafur Guðnason.

Diameter of hole: 75.7 mm, yielding 47.6 mm core (NQ-size).
Depth of hole: 100 m, through lower part of the "ML" suite, reaching down to the "HF" one.

Casing: diameter; i.d. ca. 3" (NX), length; 4.5 m.

Grouting: None.

Ground water: 10.5 m below ground level

Water pressure tests indicate low water take; 2 LU from 63 m to bottom.

NATIONAL ENERGY AUTHORITY
Hydropower Division
1990-12-31

Report
ÞHH/BJ-90-11g
þhh

Fljótsdalur Hydro Project
Borehole FV - 9

This report deals with the results obtained from Point Load tests and Schmidt hammer tests on the relogged core, in November 1990. It must be pointed out, that the values obtained might be influenced by the age of the core.

Point Load Tests

Typical samples for point load test were 40 - 50 cm long, allowing for 7 - 10 tests, out of which the highest and lowest values were discarded and the average calculated for the remaining values.

Depth of tested sample top; m	botm; m	Rock type	Strati-graphic suite	Point load strength index; I_{s50} MPa*	"Apparent" uniax. compr. strength; σ_c MPa**
25.4	25.8	scoria	ML	0.6	13
91.5	92.0	ol. basalt	HF	7	153

* Calculated: Gauge reading : 1.5 (ELE-chart) : 0.98 (correction for NQ-core size) = I_{s50}

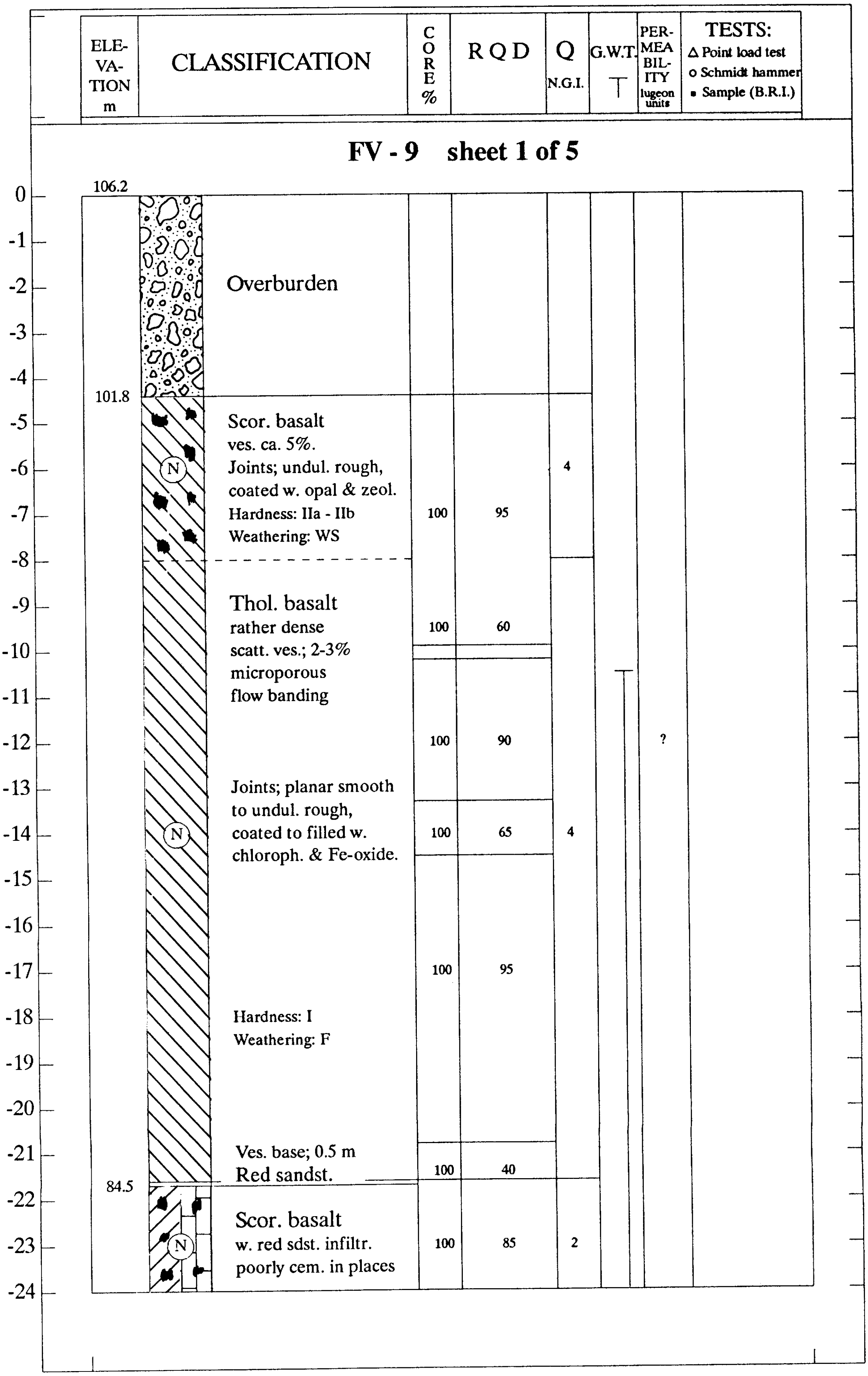
** Calculated: $I_{s50} \times 22 = \sigma_c$

Schmidt Hammer test

The samples were typically about 20-25 cm long and 16-22 readings were made in each test. Ten of the lowest values were discarded, in accordance with the ISRM procedure, and the average calculated for the remaing values. The equipment used was type L and the impact energy was 0.74 Nm.

Depth of tested sample top; m	botm; m	Rock type	Strati-graphic suite	Schmidt Rebound Hardness
25.4	25.9	scoria	ML	10
92.0	92.3	ol. basalt	HF	42

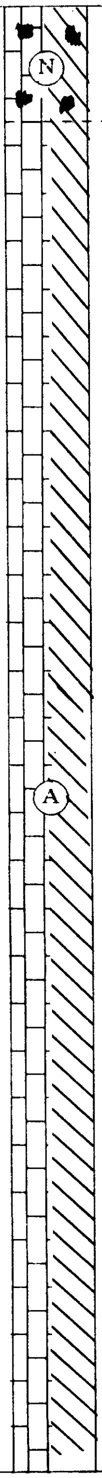
FV - 9 sheet 1 of 5



ELE-VA-TION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T. ⊤	PER-MEA BIL-ITY lugeon units	TESTS: △ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)
106.2	Overburden						
101.8	Scor. basalt ves. ca. 5%. Joints; undul. rough, coated w. opal & zeol. Hardness: IIa - IIb Weathering: WS	100	95	4			
	Thol. basalt rather dense scatt. ves.; 2-3% microporous flow banding	100	60	4	⊤		
		100	90			?	
	Joints; planar smooth to undul. rough, coated to filled w. chloroph. & Fe-oxide.	100	65				
	Hardness: I Weathering: F	100	95				
	Ves. base; 0.5 m Red sandst.	100	40				
84.5	Scor. basalt w. red sdst. infiltr. poorly cem. in places	100	85	2			

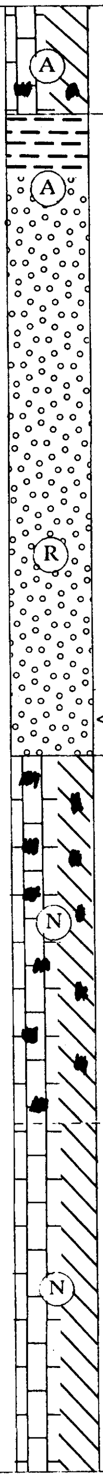
VOD MJ 760 ÞHH
91.01.0029 T

FV - 9 sheet 2 of 5



	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
-25		ves. 5 - 10% and up to ø 5 - 6 cm Hardn.: IIa-b, Weathering: WS	100	85	2			o Δ
-26 -27 -28 -29	80.3	Ol./thol. basalt rather dense scatt. ves. ca. 2% elongated ca. 1 cm Incl. micropor. flow banding occurs	100	50				
-30 -31 -32 -33		Joints steeply incl. to vert. planar to undul. rough coated or filled w. clay, zeol. & Fe-ox.	100	95				
-34 -35 -36 -37			100	90	6		?	
-38			55	30				
-39 -40 -41 -42 -43 -44		Core fractured along vertical joints.	100	70				
-45 -46 -47 -48		Hardness: I Weathering: F	100	100				

FV - 9 sheet 3 of 5

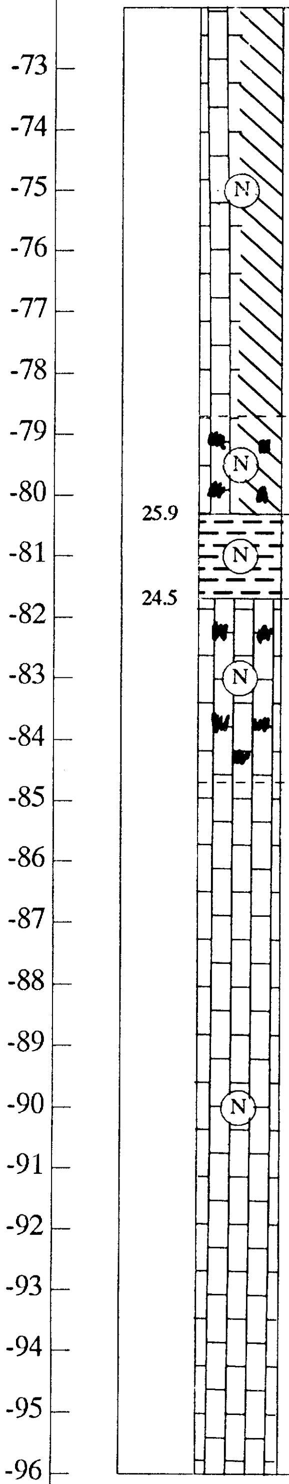


	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
-49		Ol./thol bas. (cont.) Scor. base; 0.5 m	100	70	6			
-50	56.4	Sandst./congl.						
-51		Red sandstone down to 50.7 m	100	95				
-52		Conglomerate in sandy matrix;						
-53		stratified pebb. frac.; 40-50%						
-54		ø mostly < 5 cm			4			
-55			100	100				
-56							?	
-57		Hardness: IIa - IIb Weathering: WS						
-58								
-59								
-60	45.9	<- acid tuff Green sdst.; 0.5 m	100	75				
-61		Scor. basalt w. sdst. infiltr.						
-62		(10 - 20%)						
-63					6			
-64		Hardness: IIa - IIb Weathering: WS						
-65			100	100				
-66								
-67		Ol./thol. basalt					2 LU	
-68		rather broken ves. scatt. 1-2%	100	30				
-69		micropores occur.						
-70			100	60	8			
-71		Fractures/fault: 71.5 m - 78.5 m						
-72								

VOD MJ 760 ÞHH
91.01.0029 T

ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)

FV - 9 sheet 4 of 5



ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS
	Ol./thol. bas. (cont.) Joints undul. rough filled & healed w. zeolites Hardness: IIa Weathering: F - WS Fault breccia?	100 100	65 55	8			
25.9	Scor. base						
24.5	Red/grey sandst	100	85	<1			
	Scor. basalt w. sdst. infiltr. ves. ca. 10% Hardness: IIa Weathering: WS					2 LU	
	Ol. basalt dark grey, ves. 5 - 7% to 88.5 m. Large ves. (5-10%) scatt. in lower part filled to half filled w. zeol. (mes., stilb.) Joints; steeply incl. to vert. filled to healed w. zeol. & silt. Undulating, rough Hardness: IIa Weathering: WS	100 100	90 100	12			Δ ○ ▪

FV - 9 sheet 5 of 5

	ELE-VA-TION m		CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T. ⊤	PER-MEA BIL-ITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)
-97			Ol. basalt (cont.)						
-98		Ⓝ		100	100	12		2 LU	
-99									
-100	6.2								
-101			Bottom of hole; 100 m						
-102									
-103									
-104									
-105									
-106									
-107									
-108									
-109									
-110									
-111									
-112									
-113									
-114									
-115									
-116									
-117									
-118									
-119									
-120									

NATIONAL ENERGY AUTHORITY
Hydropower Division
1991-01-04

Report
ÞHH-90-08o
þhh

Fljótsdalur Hydro Project
FV - 10

The hole is situated at the foot of the "Teigsbjarg" hill. It was drilled to investigate the geology near the site of the proposed **tailrace tunnel portal.**
Coordinates: x=359662.5 y=503941.3; h=90.8 m a.s.l.

Time drilled: July 12th to July 17th 1981.

Contractor: Jarðboranir h/f (Iceland Drilling Co. Ltd.)
Rig type used: Craelius D 1000.
Diamond bit: Step crown, NQ wireline core barrel and rods.
Drillers: Sigurður Sveinsson, Karl Valdimarsson, Ólafur Guðnason.

Diameter of hole: 75.7 mm, yielding 47.6 mm core (NQ-size).
Depth of hole: 100 m, starting in the "ML" suite, but mainly in the "HF" one.

Casing: diameter; i.d. ca. 3" (NX), length; 4.6 m.

Grouting: None.

Ground water approx. at 10 m. Variations (3.3 - 8.8 m) observed while drilling.

Water pressure tests: Two tests performed by N.E.A. indicating little water take. Between 84 m and 100 m; 3 LU.

NATIONAL ENERGY AUTHORITY
Hydropower Division
1990-12-31

Report
ÞHH/BJ-90-11h
þhh

Fljótsdalur Hydro Project
Borehole FV - 10

This report deals with the results obtained from Point Load tests on the relogged core, in December 1990. It must be pointed out, that the values obtained might be influenced by the age of the core.

Point Load Tests

Typical samples for point load test were 40 - 50 cm long, allowing for 7 - 10 tests, out of which the highest and lowest values were discarded and the average calculated for the remaining values.

Depth of tested sample		Rock type	Strati-graphic suite	Point load strength index; Is_{50} MPa*	"Apparent" uniax. compr. strength; σ_c MPa**
top; m	botm; m				
19.6	20.0	thol. bas.	ML	12.0	264
35.6	36.0	ol. basalt	HF	8.5	188
85.1	85.6	thol. bas.		10.2	225

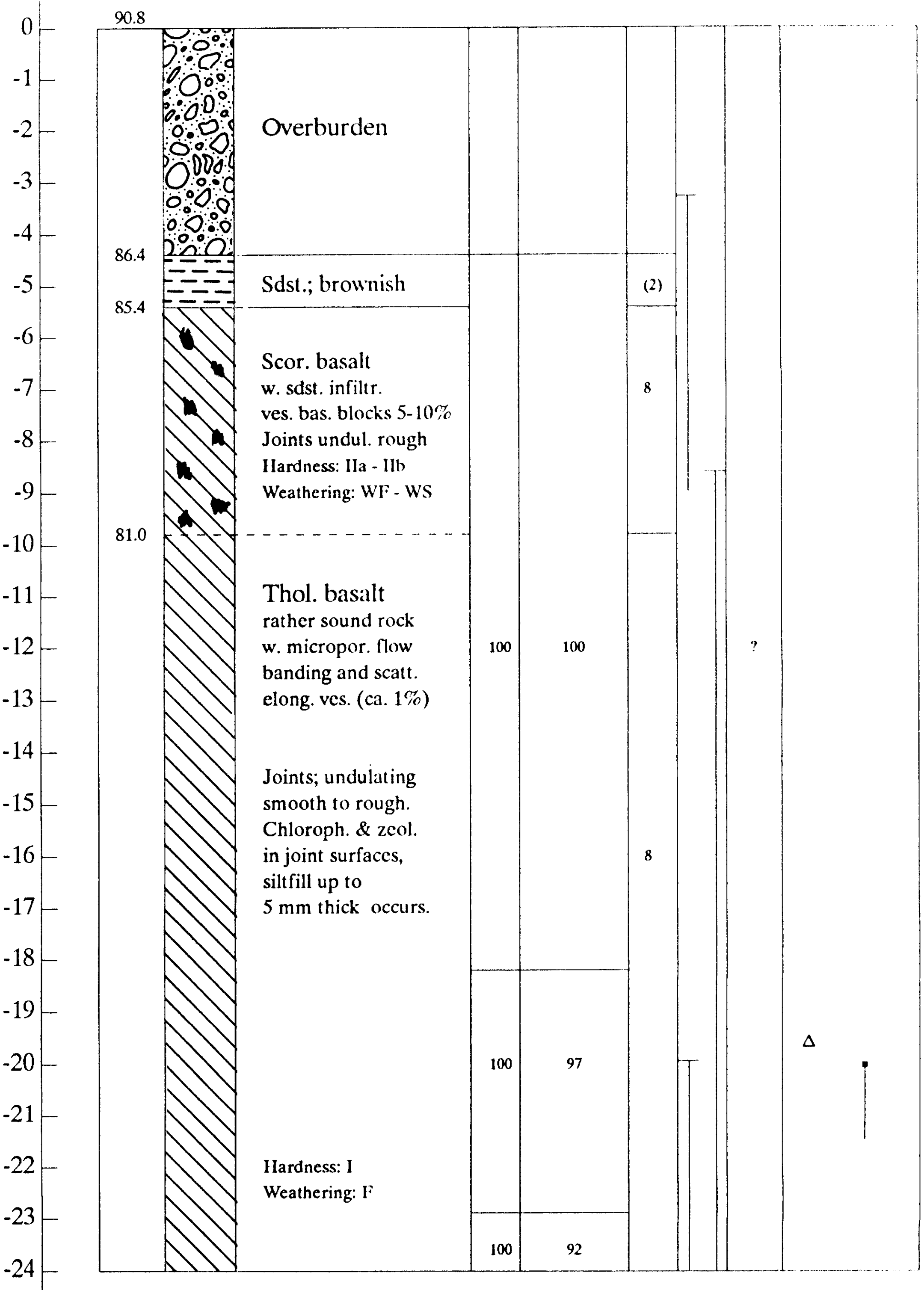
* Calculated: Gauge reading : 1.5 (ELE-chart) : 0.98 (correction for NQ-core size) = Is_{50}

** Calculated: Is_{50} x 22 = σ_c

VOD MJ 760 ÞHH
91.01.0030 T

ELE-VA-TION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test o Schmidt hammer ▪ Sample (B.R.I.)

FV - 10 sheet 1 of 5



Overburden

Sdst.; brownish

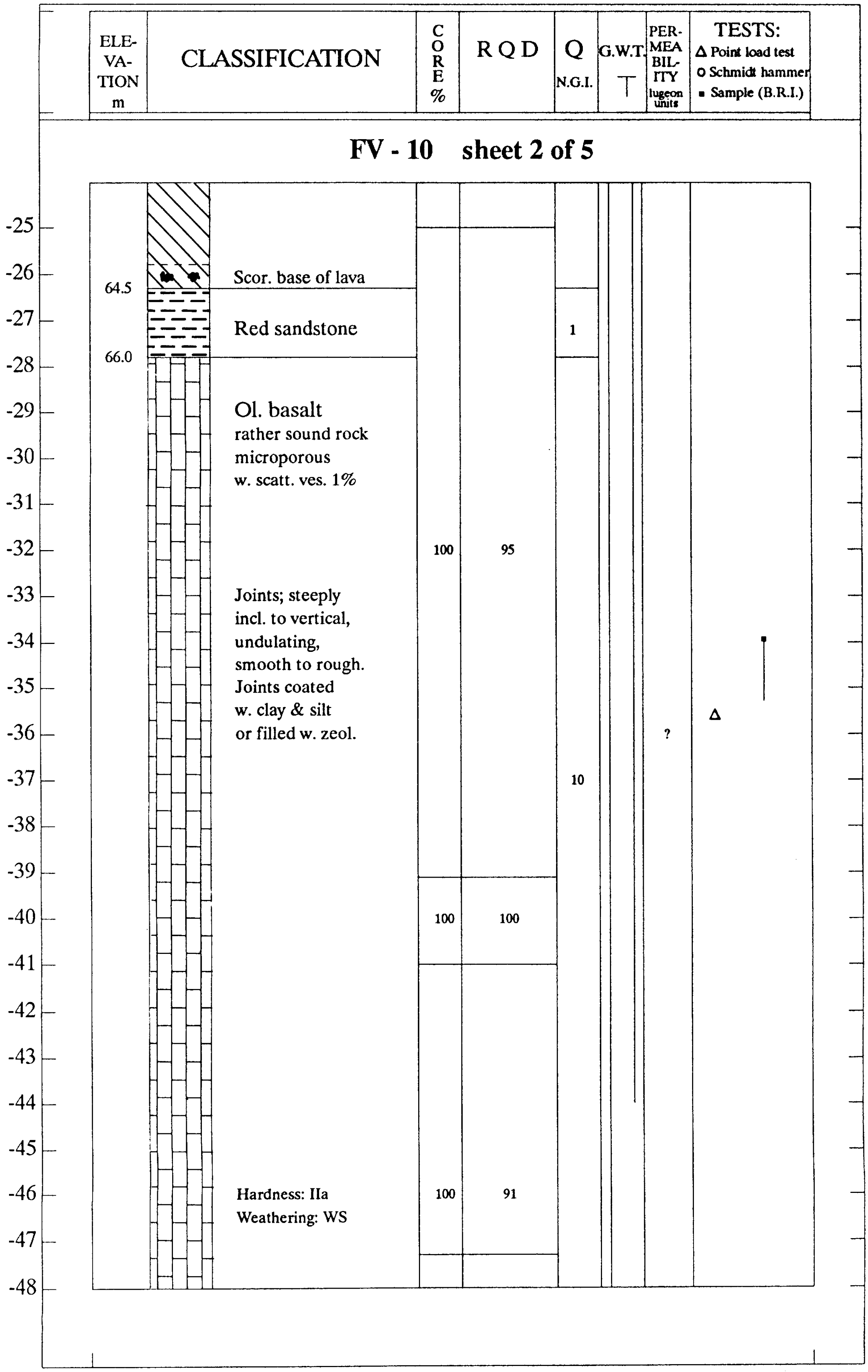
Scor. basalt
w. sdst. infiltr.
ves. bas. blocks 5-10%
Joints undul. rough
Hardness: IIa - IIb
Weathering: WF - WS

Thol. basalt
rather sound rock
w. micropor. flow
banding and scatt.
elong. ves. (ca. 1%)

Joints; undulating
smooth to rough.
Chloroph. & zeol.
in joint surfaces,
siltfill up to
5 mm thick occurs.

Hardness: I
Weathering: F

FV - 10 sheet 2 of 5



Scor. base of lava

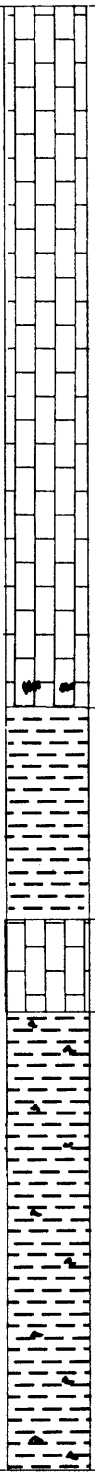
Red sandstone

Ol. basalt
rather sound rock
microporous
w. scatt. ves. 1%

Joints; steeply
incl. to vertical,
undulating,
smooth to rough.
Joints coated
w. clay & silt
or filled w. zeol.

Hardness: IIa
Weathering: WS

FV - 10 sheet 3 of 5



	ELEVATION m	CLASSIFICATION	CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: Δ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)
-49		Ol. basalt (cont.)						
-50			100	90				
-51								
-52								
-53					10			
-54								
-55			100	100				
-56								
-57								
-58			100	94				
-59		Scor. base of lava						
	31.2							
-60							?	
		Red silt - sdst.	100	100				
-61		& acid tuff with cobbles			<1			
-62		at 62.5 m	100	78				
-63	27.8	Ol. basalt						
-64		ves.; 10 - 15%	30	?	4			
	29.3							
-65								
-66		Basaltic tuff & sandstone						
-67			100	84				
-68		Joints undul. rough some healed w. zeol.			2			
-69								
-70		Hardness: IIb Weathering: WS						
-71								
-72								

VOD MJ 760 ÞHH
91.01.0030 T

FV - 10 sheet 4 of 5

	ELE-VA-TION m	CLASSIFICATION	CORE %	R Q D	Q N.G.I.	G.W.T.	PER-MEA BIL-ITY lugeon units	TESTS: Δ Point load test O Schmidt hammer ▪ Sample (B.R.I.)
-73		Tuff & sdst. (cont.)	100	100	3			
-74 -75 -76 -77 -78	17.1	Thol. basalt ves. upper part (5-15%) to 79 m. Dense lower part w. scatt. small ves. (1%) and prominent micropor. flow banding	100	83				
-79			100	88				
-80 -81 -82			100	100				
-83 -84 -85		Joints planar smooth to undul. rough, steeply incl. to vertical. Chloroph. coatings, opal & zeolite fillings in joints.	100	82			3 LU	Δ
-86			100	92				
-87 -88			100	64				
-89 -90 -91 -92			100	87				
-93 -94 -95 -96		Hardness: I Weathering: F	100	100				

VOD MJ 760 ÞHH
91.01.0030 T

	ELE-VA-TION m	CLASSIFICATION		CORE %	RQD	Q N.G.I.	G.W.T.	PERMEABILITY lugeon units	TESTS: △ Point load test ○ Schmidt hammer ▪ Sample (B.R.I.)

FV - 10 sheet 5 of 5

-97		▨	Thol. bas. (cont.)						
-98		▨		100	100			3 LU	
-99		▨	Scor. base; 0.8 m	53	100				
-100	-9.2		Bottom of hole; 100 m						
-101									
-102									
-103									
-104									
-105									
-106									
-107									
-108									
-109									
-110									
-111									
-112									
-113									
-114									
-115									
-116									
-117									
-118									
-119									
-120									