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# Borehole geology. An introduction for the U.N. training programme at N.E.A

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# BOREHOLE GEOLOGY

AN INTRODUCTION FOR THE U.N.
TRAINING PROGRAMME AT N.E.A.

by

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ABSTRACT

This manual represents a general orientation of the tasks of borhole geology. The NEA system of recording and filing drilling data is described. The tasks of geochemistry/mineralogy in subsurface exploration of geothermal areas are briefly described. Separate lab manuals will be provided in subjects within the field of geochemistry/mineralogy which have been included in the line named "Borehole geology" in the U.N. training programme.

## INTRODUCTION

The tasks of borehole geology is to collect and process drilling data and evaluate the results of drilling. A close cooperation with the drill crew and the geoscientists working on the prospecting and subsurface exploration is required. Some of the geochemical and mineralogical aspects of subsurface exploration have been included in the "Borehole geology" line of the U.N. training program.

Fig. 1 and table 1 summarize the tasks of borehole geology and the tasks of geochemistry and mineralogy in subsurface exploration.

The "Borehole geology" line comprises both the work at the drill site and the work at the geochemical lab. Except in rare cases, this work is covered by two persons; one at the drill site the other in the lab. Either function is a specialized kind of work and requires different skills.

The lab work requires a much better background in geochemistry and mineralogy/crystallography than necessary for a drill site geologist. Besides a good petrographic background a good knowledge of the drilling process is essential for the drill site geologist.
It is however desirable that the lab man has some insight into the drilling process and that the drill site geologist knows what is going on at the lab. This secures a better continuity of the project and a better cooperation between the people working on the same project.

The following text gives an outline of the main duties of the drill site geologist and a description of the routine of data collection at the geothermal drills in Iceland.

Only a superficial description of the lab work is given as the various steps are treated in more detail in the lab manuals.

## 1. DUTIES OF THE DRILL SITE GEOLOGIST

The drill site geologist collects, uses and files all data necessary to make a stratigraphic section. This includes diagrams or reports on penetration rate, load pressure of the drill, dimension of hole, drillpipes and casings, quantity of circulation water, location of aquifers and probably also temperature, diameter and inclination measurements performed during drilling.

The drill site geologist analyses drill cuttings simultaneously with the drilling and constructs stratigraphic section, loates the exact depth of casings and gives advice to the drillers in matters depending on geology and stratigraphy. After drilling the drill site geologist will normally perform the completion tests on the drillhole (pumping with compressed air, stimulation with injection packer, multiple step injection tests etc.). These tests are normally done by the prescription and supervision of the projects hydrologist.

The drill site geologist is supposed to process and present the drilling data in tables or diagrams for convenient use of the geoscientists working on the project.

### 1.1 Penetration rate.

The penetration rate is recorded continuously on the bigger drill-rigs whereas on the smaller rigs the drillers record the time for drilling each drillpipe. The average penetration rate is calculated from their reports. On fig. 2 is shown a part of a diagram of penetration rate from the "geolograph" on the bigger rigs. The drill site geologist (or his assistant) measures the diagram meter by meter with a scale also shown on the diagram. At intervals, corresponding to addition of a new drillpipe, the graph is discontinuous and one sometimes has to estimate the penetration rate. A graph of penetration rate against depth is then drawn alongside the stratigraphic section. The load pressure used during drilling is also marked in for comparison and interpretation of changes in penetration rate.

## 1.2 Correction of sample depth.

Samples of cuttings are collected by the drillers at every second meter of penetration. The sample boxes are marked with the time of collection and the depth according to the drillhole depth shown on the geolograph. The greater the depth the longer the travel time of cuttings up-hole. To estimate the travel time one must know the velocity of water flowing up the hole and the rate of sinking of the cuttings. The first factor can be calculated from the diameter of the hole and drillpipes and the quantity of water flowing. The second factor is difficult to calculate due to the irregular shape and varying grain size of the cuttings. The measured sinking rate of drill cuttings (basalt from the Reykir area) of different grain size was found to be in the order of 5-20 m/min. The average of 12 m/min is often used in estimating the travel time. In case of very coarse cuttings 20 m/min is used and 5 m/min for the extremely finegrained ones. Such estimates give the scale of the correction, but no exact location of stratigraphic contacts etc. For example if we know that the travel time of the cuttings is about 60 min and the penetration rate is 10 m/h we know that the real sample depth is about 10 m above the depth marked on the sample box.

For a more exact location of stratigraphic contacts one uses the changes in penetration rate and sometimes also the geophysical logs of the hole (mainly diameter and resistivity). The resistivity logs are especially useful when distinguishing between thin rock units of similar penetration rate.

## 1.3 Preparation of samples and analysis of cuttings.

The samples of cuttings are collected at 2 m interval in 100 ml boxes. At 100 m interval bigger samples are taken (in 1-3 l boxes). When drilling in new areas the larger samples are taken at randomly chosen depths. In well-known areas the sample depths are chosen from the stratigraphic sections of previous drillholes. The bigger samples are meant for chemical analysis and mineral separation, as the normal size samples are too small for that purpose.

A part of each sample of cuttings is transferred to a low and wide sample box suitable for direct inspection under the binocular microscope. The cuttings are washed free of "dust fraction" and mud. Then the sample is immersed in water and analysed under the binocular microscope. The purpose of water immersion is partly to shorten the time elapse from drill penetration and obtaining the results from the analysis and partly because all the structural details and color shades may be more clearly seen than in dry cuttings. It is especially easier for beginners to analyse samples immersed in water than dry.

After inspection the sample is dried. A small part of this sample is used to construct a section of the drillhole which is convenient when making quick checks and comparisons between different sections. Those sections are made by gluing samples on scaled carton strips. Each strip represents 200 m of drillhole section. The scale is 2.5 m = 1 cm. Thin sections are made from the inspection samples whereas samples intended for X-ray runs are picked from the bulk samples. In most cases the preliminary analysis of cuttings in the binocular microscope is sufficient to fulfil the geologists' function at the drill site. In special cases thin sections and even X-ray diffraction determination may be needed during drilling.

The inspection of thin sections is done shortly after drilling and the results used to make the final stratigraphic section.

### 1.4 Recording of aquifers during drilling.

Changes in water circulation are recorded during drilling. The quantity of water pumped down is normally controlled by counting the strokes of the water pumps. This is either done regularly by the drillers or by mounting of a registrating equipment. The upflow is checked regularly by measuring the water level in the drill pool (vessel ) or by a registration meter in the "flow line" (outflow). Loss or gain in water circulation occurs when the drillhole dissects an aquifer. The relative water pressure within the aquifer and the height of the water column (in the hole) decides if water is lost or gained.

When possible during drill stops and after drilling of the hole the temperature is recorded. During drilling and shortly after drilling the aquifers show up as cooling points. At this stage all the minor aquifers show up more clearly than later when the hole has fully heated up. The most reliable record of aquifers in the drillhole is achieved by logging continuously the temperature difference at one meter intervals (differential temperature logs). The yield of each aquifer can also be recorded by logging with a "flow meter".

The drill site geologist duty is to collect all this information and interpret them in cooperation with other members in his working group. The location and yield (loss or gain of circulation water or direct measurement) of each aquifer is marked on the stratigraphic section.

### 1.5 Completion tests.

No general rules can be laid down concerning completion tests made on drillholes as it depends on what kind of geothermal area one is drilling into. The purpose of the tests is to evaluate the yield of the drillhole, to estimate the draw down during production and to estimate the permeability of the field.

Some of the most common completion tests are pumping with compressed air, pumping of water down under pressure with or without the use of an inflatable packer and step draw-down tests. The effects of the tests on other drillholes in the area are recorded contemporaneously.

### 1.6 Processing of data and filing.

The stratigraphic section is checked by inspection of thin sections before the construction of the final version. The dimensions of the hole and casings are marked on the same drawing and also the load pressure of the drill, location and yield of aquifers, penetration rate and the geophysical loggings. Fig. 3 illustrates the NEA standard for representing sections of drillholes.

The drill site geologist makes a description of each stratigraphic unit and a summary of the proceeding of drilling.
He draws diagrams and tables of the proceedings of the completion tests. The report of the drilling of each hole includes normally those things and is also supplemented with the hydrologists interpretation of the completion tests and preliminary interpretation of geophysical loggings and sometimes the first results of geochemical investigations of rocks and fluid are included.

## 2. LAB WORK

The NEA has a geochemical lab for wet-chemistry, XRD, mineral separation and the making of thin sections and polished specimens for the micro probe. NEA has an agreement with the Nordic Volcanological Institute for the use of their microprobe and with the University for the use of XRF and an infra-red spectrofotometer. NEA owns equipment to prepare samples to run on the IR and XRD.

The first step in the study of alteration is a routine identification of the main alteration minerals.

The next stage is a mineralogical and petrochemical study combined with results from fluid chemistry and geophysical loggings.

The effort used and how far one goes in the geochemical investigation must be judged in the case of each project.
It is however desirable to use time and manpower during the initial phase of a large project.

Fig. 1.

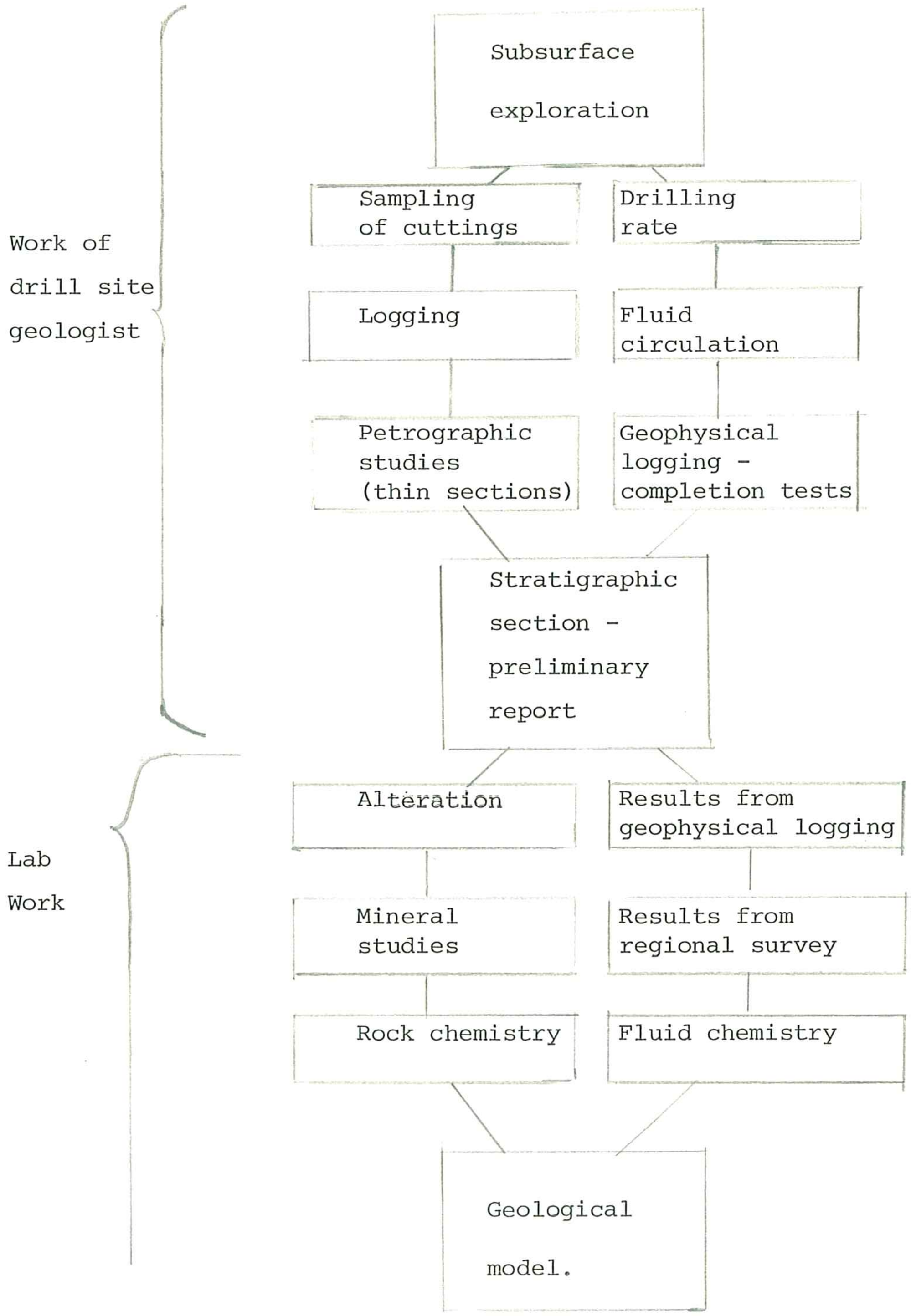
Work of
drill site
geologist
Subsurface
exploration
Sampling
of cuttings
Drilling
rate
Logging
Fluid
circulation
Petrographic
studies
(thin sections)
Geophysical
logging -
completion tests
Stratigraphic
section -
preliminary
report
Lab
Work
Alteration
Results from
geophysical logging
Mineral
studies
Results from
regional survey
Rock chemistry
Fluid chemistry
Geological
model.

TABLE 1

Tasks of petrography and geochemistry in geothermal subsurface exploration.

Surface exploration:

No direct participation until at a late stage when the decision of drilling an exploratory well has been taken. At this stage the petrologist will go through all available data from the surface exploration, visit the field etc.

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Exploratory drilling:

1. Advisatory work on the drill-site. Geological logging, recording of aquifers and collection of data concerning the drilling process.
2. Processing the drilling data - making stratigraphic sections, fix aquifer depths and temperature, evaluate results of well tests etc.
3. Mineralogical and geochemical study of cuttings/core.
4. Study of mineral/solute equilibria.
5. Participate in interpretation of geophysical well logging results.

6. Participate in solving scaling problems.

7. Make a geological model of the area and participate in development of a general model of the geothermal area.

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Production drilling and production

1. Improvement of results from 1-6.

2. Refining of the model of the geothermal area.

Recorder Chart 718TPW—8FS Metric
(8 Lines—Type "FS")

CHANGE CHARTS AT 8:00 A. M. AND 8:00 P. M.

**G-8** (12 HOUR) **Geolograph Oil Field Services Chart** ®

PRINTED IN U.S.A. A/GC

OPERATOR

NO.

LEASE

LOC

SEC. 75 T. R.

COUNTY

STATE KG-3

DATE ON 13/6

T. D. OFF

TIME ON 8:00 A. M. ☐ 8:00 P. M. ☐ T. D. ON

DR'LG TIME | DR'LG OPER.

(CIRCLE SCALE USED)

☐ Torque ☐ Atmosphere Pump
☐ R. P. M. ☐ R. P. M.
☐ P. Strokes ☐ P. Strokes

WEIGHT IN THOUSANDS OF KILOGRAMS

2,0

36 m

1,5

1,5

38

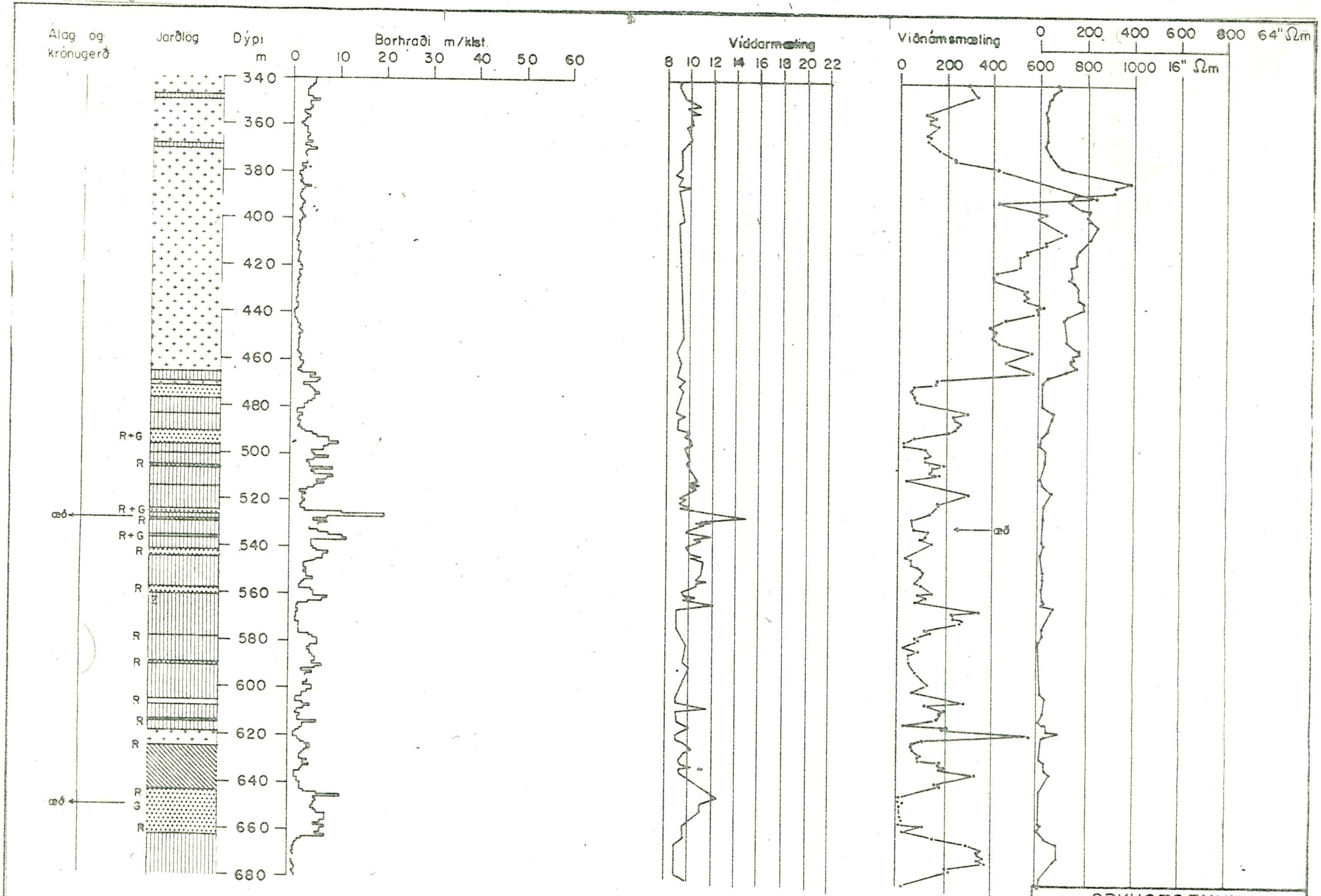
1,5

Malin fardur

40

1,0

Fig. 3.

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Víddar- og Viðnámsmælingar af GG-1

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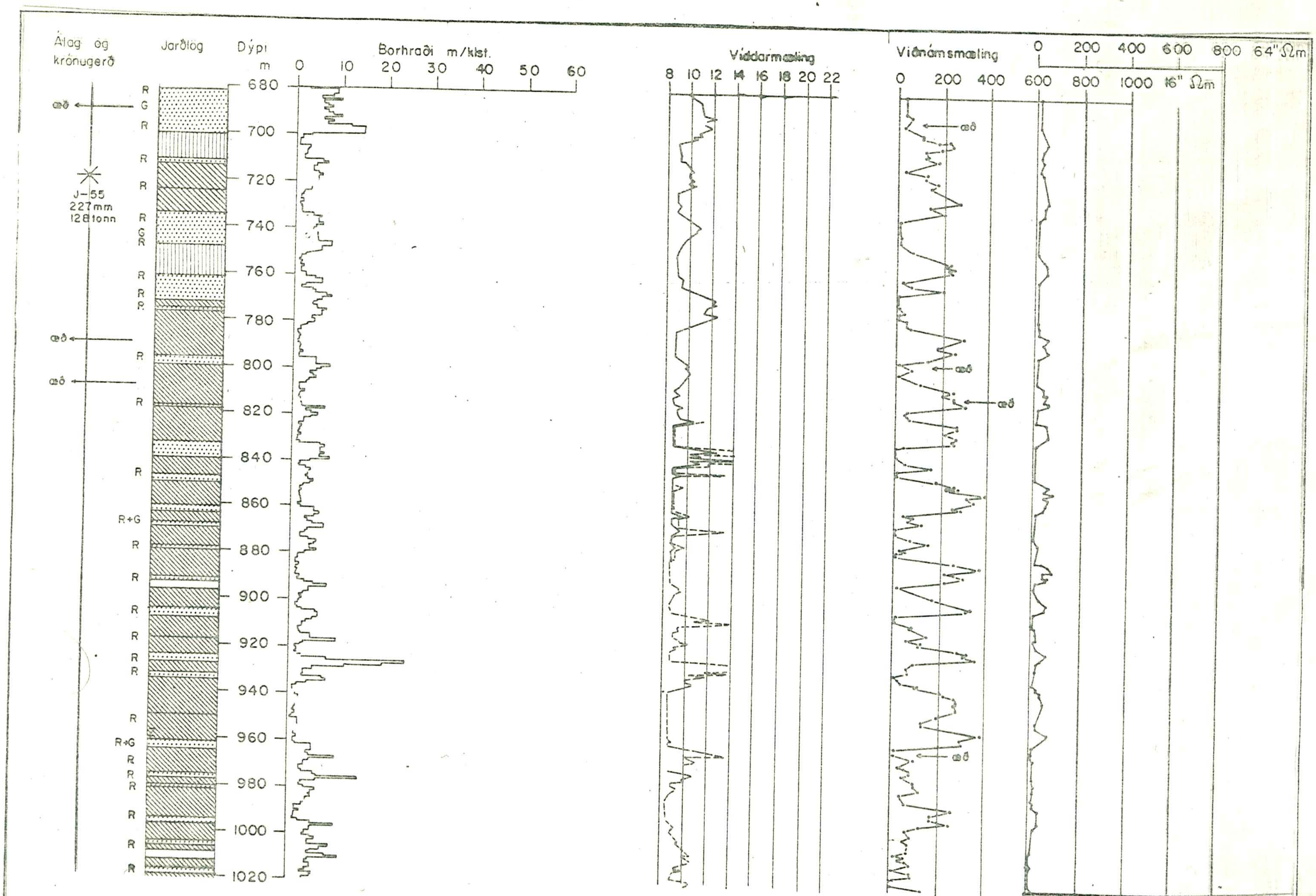
| Blað 2 af 4 | Viðnám Eviat | |

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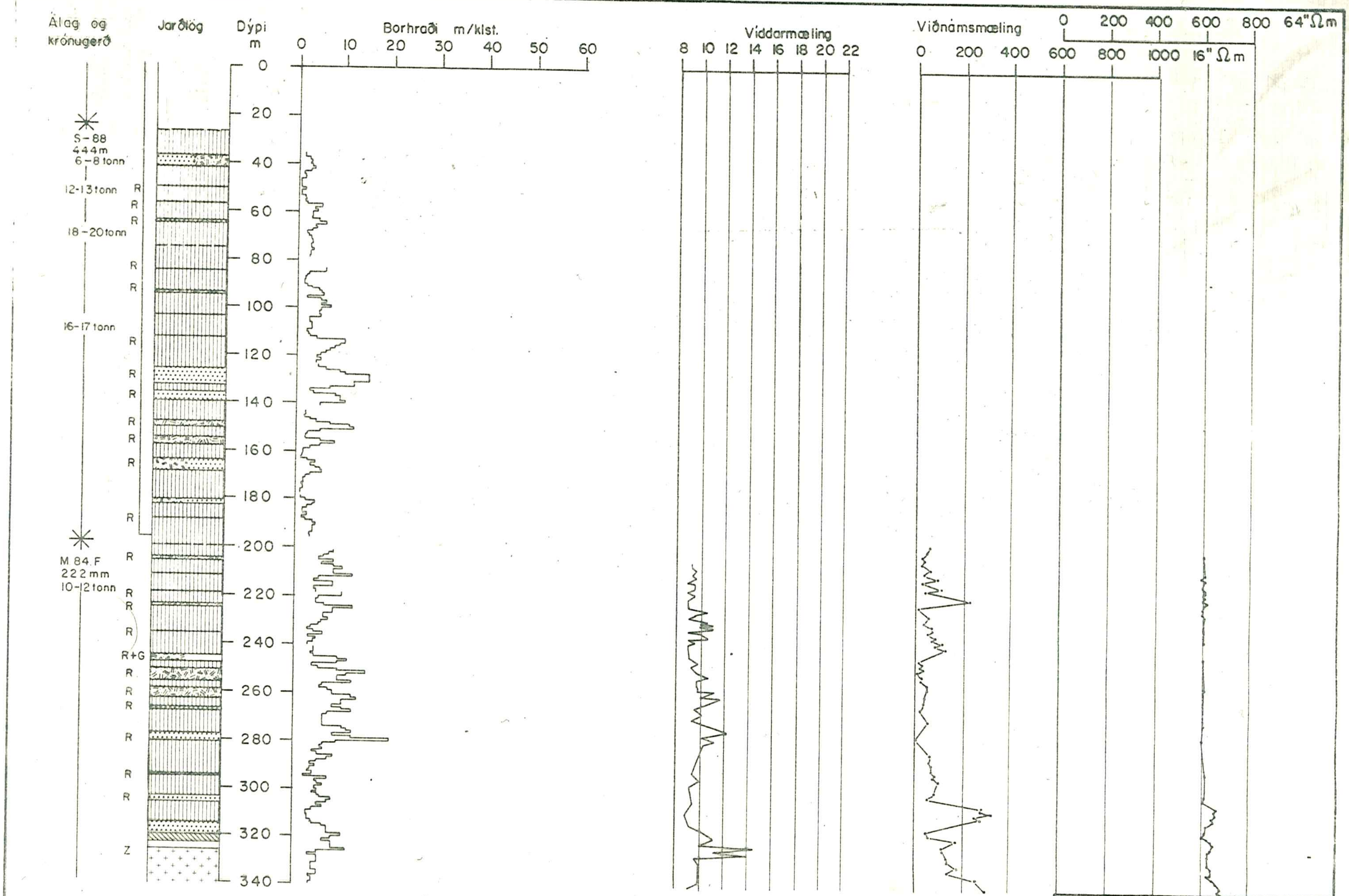


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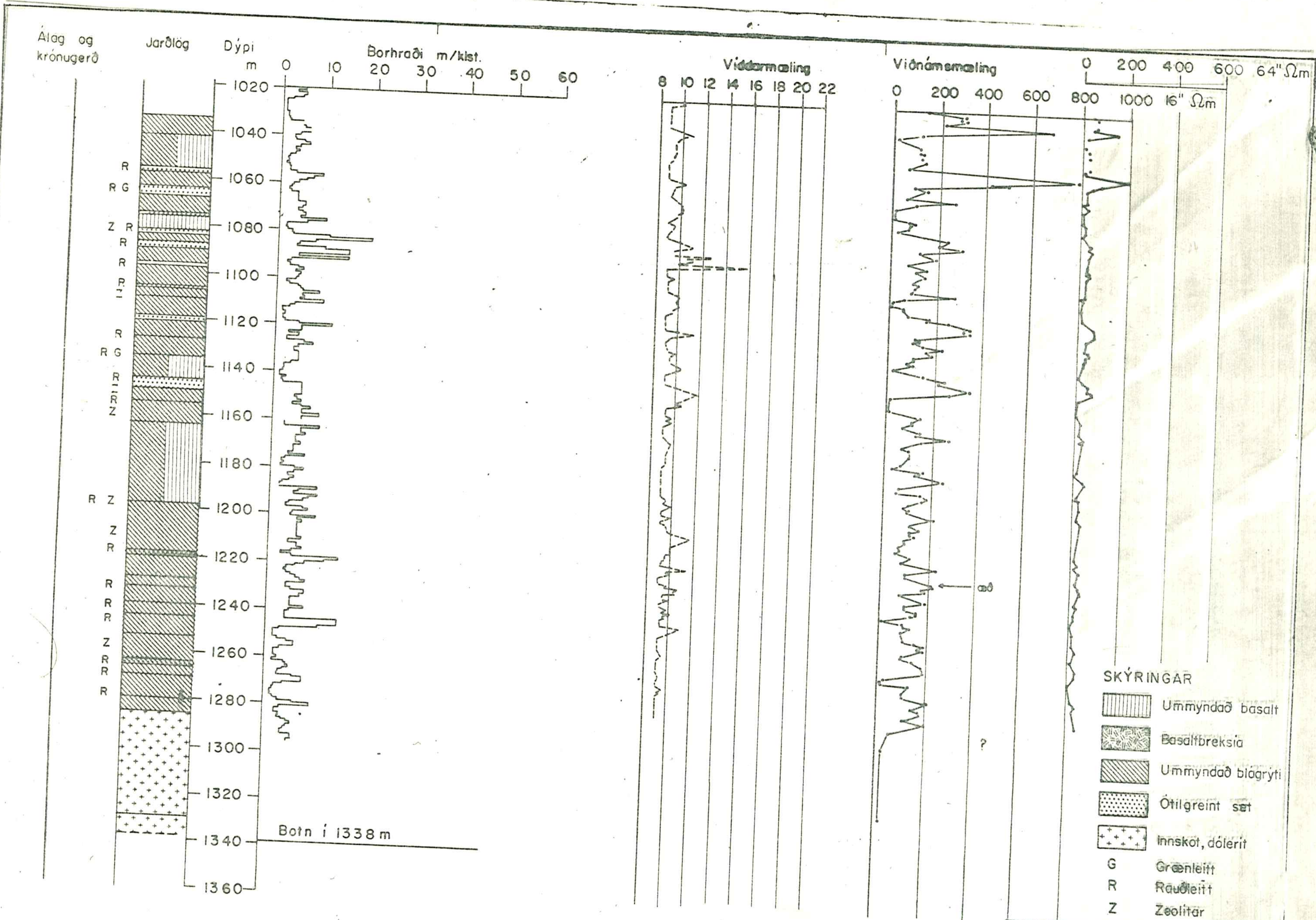


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