THE STATE ELECTRICITY AUTHORITY

THE LAYER SM_A

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THE LAYER SM_a IN SÁMSSTAÐAMÚLI

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Haukur Tómasson fil. cand., geologist S.E.A.

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1. Introduction

During the years 1960 to 1963 an extensive geological investigation has been carried out in the Búrfell area Southern Iceland, in connection with planning of hydroelectric power work there supervised by Harza Engineering Company, International.

As the geology is very complicated in the area, extensive drilling program was carried out, mainly in 1961 and 1962. In this report all information, field and petrographical, is collected about the layer SM_a, which will probably be the site of an underground powerhouse at Búrfell. The petrographical work is performed by Dr. Guðmundur E. Sigvaldason geologist at the University Research Institute and the petrographical descriptions and interpretations are usually taken direct from his reports to the State Electricity Authority.

2. The Geological setting

The geology of the Búrfell area has been described in several reports, most thoroughly in a report from Harza Engineering Company entitled "Búrfell Project" volume II, Appendix B.

The bedrock of the Búrfell area can be subdivided into the following series:

1) Hreppar series, which is of Pliocene to early Pleistocene age.
2) Móberg series, which is of late Pleistocene age.
3) Basalt flows and other volcanic products, of Postglacial age.

Temperature measurements were only made in holes in the Hreppar series as the other series are far too permeable to enable measurement of the temperature gradient.

The Hreppar series can be subdivided into various groups and formations through its relation to erosion unconformities. The oldest group is the Older Búrfell OB, which consists of clastic beds and flows of basaltic, andesitic and rhyolitic composition. A valley was eroded in the OB and was later filled with sand,talus and basalt beds. This valley filling is named the Sámsstaðamúli group (SM). This is because at present Sámsstaðamúli occupies the former site of the valley. The valley is called the SM unconformity. The two uppermost flows of the SM group have flowed over the whole of Búrfell.

The SM group in Búrfell and Skálarfell is covered by pillow lava and tuff breccia. These were formed by linear eruptions below a glacier and date from a glacial during the first half of the pleistocene. This formation is named the Búrfell pillow lava (BP).

Later a valley or canyon was eroded into the SM and OB groups and then filled by repeated basalt flows. This formation is named the Sámsstaðaklif Basalt (SB) as the typical outrop is around Sámsstaðaklif. The valley is called the SB unconformity.

The hole BH-8 is drilled in the OB group at the south end of Búrfell. The formation there consists of numerous basalt flows; this is the oldest part of Búrfell to outcrop.

The hole PT-2 is situated where the SB unconformity crosses the SM unconformity, in PT-2, therefore, the succession passes directly from the SB formation to the OB group.

The holes PT-14, PT-12, BH-14 and PT-21 are situated near a line from PT-2 perpendicular to the SM unconformity. PT-21 is situated well in the SM valley and goes through talus breccia and SM basalt beds. PT-14 is at the margin of the valley and this passes through talus breccia and reaches the OB group.

The hole T-6 is situated in the SM group. Its higher part goes through SM basalt beds, while the lower depths of the hole are in a thick layer of tuffaceous sandstone which fills the lowest part of the SM unconformity.

The basalt in Iceland as in many other places in the world shows that the earth has changed magnetic plarity several times and even that the magnetic polarity is cyclic with a cycle of approximately half a million years. The basalt in Búrfell shows the following magnetic polarity.

The OB in BH-8-normal magnetic polarity

The SM group and BP formation - reverse magnetic polarity

The SB formation - normal magnetic polarity

This shows that the Hreppar series in Búrfell and Sámsstaða-múli spans over three magnetic polarities.

On the assumption that the cycle of magnetic polarity is half a million years, the Hreppar series in this area should therefore cover one and a half million years. This indicates that the OB group is of very late Pliocene age, the SM and BP from the first half of the Pleistocene, and the SB of middle Pleistocene age.

3. The layer SM_a

According to the present authors interpreation SM_a outcrops on the west side of Sámsstaðamúli and is there up to or more than 20 m thick. At the south end of Sámsstaðamúli it spreads in dikes and apophyses which reaches high up in the mountain. The contact is dense and without vesicules both at top and bottom. At the top there is some breccia which seems to be due to an intrusion of small veins and apophyses of basalt into the fanglomerate.

In the drillholes in the power house area in Sámsstaðamúli a layer occurs with the same macroscopic appearance, i.e. dark dense basalt with small phenocrysts of felspar and dense contacts. Breccia is found both above and below, with all rock fragments of the same kind and macroscopically a direct continuation of the under- and overlying basalt. The matrix is in most cases sandstone but might in some cases be fanglomerate.

This breccia, which the author interprets as veins from the intrusive rock, can reach a considerable thickenss although scattered veins were not at first considered as belonging to the intrusive. The known maximum thickness of the intrusive rock in the power house area was 75 m. Many microscopic analyses were made of rock from SM_a and other rock in the Búrfell area. They were performed by the petrologist Guðmundur E. Sigvaldason of The University Research Institute. One sample was analysed from the outcrop of the intrusive rock and for correlation a sample from hole PT-5 was also taken. About PT-5 (depth 115 m) G.E. Sigvaldason states:

"Large phenocrysts of plagioclase in a groundmass of plagioclase laths and pyroxene grains. Interstices between crystals are filled with argillaceous minerals predominantly chlorite. This secondary product of original glass amounts to approximately 20 percent by volume of the rock.

The plagioclase phenocrysts have a rather mottled appearance. Crystal borders show embayments caused by beginning of alteration. Fractures and cracks in the crystals are frequently filled with some mica-like mineral (sericitisation) of high birefringence.

Furthermore some progressive zoning was observed.

Composition of plagioclase as estimated from γ index of refraction is 70% An; $n_\gamma \sim 1.575$.

Comparing this rock with the outcrop, many similarities exist, which make it strongly possible that both belong to the same body".

A sample was also analysed from the breccia above SM_a in hole PT-19 (depth 133,2 m) where a slide was taken across a contact of basalt and sandstone matrix. About this sample G E. Sigvaldason says:

Basalt:
Large phenocrysts of plagioclase and olivine in a glassy groundmass with microlites of plagioclase, pyroxene and olivine. The basalt is quite fresh and does not show any signs of alteration except for a few cracks close to the contact to the sandstone, which are filled with chlorite. Composition of plagioclase as estimated from γ - index of refraction is 70% An; $n_\gamma \sim 1.575$.

Sandstone:
The sandstone is extremely fine grained and contains fragments of various crystals, such as feldspar, pyroxene, magnetite etc. and a large amount of glass shards ranging in color from pale brown to opaque black. Some of the shards are chloritized, but alteration has apparently not taken place after formation of the sandstone. No definite cementing material was observed. The compactness of the stone should solely be attributed to the fineness of grain and load pressure.

Contact:
It is clear from the appearance of the hand specimen that the basalt has been intruded into the sandstone. Microscopic observation confirm this further: In a section across the contact a decreasing amount of microlites and increasing amount of glass is oberved going from the basalt towards the contact. At the very contact a change in color of the glass is observed from pale brown to dark brown indicating fusion and mixing of the sandstone material with the basalt.

Correlation between basalt of this sample and PT- 5 - 115 reveals fundamental differences with respect to mineralogy, since this sample contains large phenocrysts of olivine. It is therefore doubtful to attribute both samples to the same rock-body".

After this and further analysis of rock from SM_a an apparent discrepany was found between the field observations and the petrographic analysis. Referring to G. E. Sigvaldason

"From field observations the rock unit SM_a has been interpreted as a uniform intrusive body of varying thickness. Scattered samples of this unit were described in two previous reports from The University Research Institute. On the basis of petrographic analysis the samples from SM_a were divided into two groups:

1. Rocks containing large phenocrysts of plagioclase and olivine in a groundmass of plagioclase laths, pyroxene and opaque glass.
2. Rocks containing the above minerals except olivine.

Both rock types contained varying amounts of secondary alteration products, chiefly chlorite.

These findings were in contrast with the results of the field study since they gave rise to a possible interpretation of SM_a as three layer unit instead of a compact body. Systematic sampling for pertrographic study of sections through SM_a was therefore undertaken".

The sections were taken in holes PT-12 (4 samples) and PT-15 (3 samples) from the top of solid basalt to the bottom of the breccia below.

The result was, referring to G.E Sigvaldason:

"From the petrographic description it is obvious that both sections show similar variation with depth.

At the contacts rapid cooling has resulted in a higher content of glass in the groundmass and finer grain size. Secondary alteration of ferromagnesian minerals and glass is less pronounced at the contacts than in the middle of the section leaving olivine unaltered. Towards the middle ot the layer glass disappears from the groundmass and grain size increases due to slower cooling. At the same time secondary alteration of ferromagnesian minerals increases, and continuous chloritization of olivine can be followed from one sample to the next resulting in complete disappearance of olivine in the middle of the layer.

The alteration processes found in SM_a should be classified as autometamorphism, not related to the usual type of hydrothermal alteration. Solutions effecting this type of alteration originate within the cooling body and alteration takes place during or immediately after cooling. The more common type of hydrothermal alteration results from solutions, which originate outside the rock units and flow through the formation along permeable channels. In this case the most intense alteration takes place along these channels leaving the middle part of each unit less altered than the boarders.

With regard to the above interpretation it appears to be a safe conclusion to look upon SM_a as a single unit of probable instrusive character".

SM_a is completely impermeable and the reason for this is seen macroscopically; all joints are filled with a grenish blue flaky clay substance. An X-ray diffraction method was used by G.E. Sigvaldason to analyse this. The analysis showed that the clay was montmorillonite. Montmorillonite is a low temperature mineral and it is most easily interpreted here as a result of the final stage of the autometamorphism of an intrusive. Most of the clay which fills the joints and vesicules of the lava flows in Iceland has proved to be rock flour, as are the fines in moraines and the sediment load that the rivers carry today. The montmorillonite has sealed joints in all SM_a, tops and bottom not excluded, which rather supports an intrusive theory.

The main argument against the intrusive origin of SM_a is that "there appears no structural deformation to indicate the intrusion of such a large body" as stated in the Harza report. The present author admits that the structural deformation is surprisingly small for such a large intrusive body so close to the surface. However there is some structural deformation which can be traced if all beds with an intrusive character of the contacts and with the same mineral constituents are interpreted as belonging to the same rock body. The rock with this character is always in a similar position stratigraphically i.e. it is the lowest basalt bed of the SM basalt and is either lying in the tuffaceous sandstone or in the talus breccia. With respect to elevation, it can vary substantially; this is not at all surprising for an intrusive layer.
The lack of structural deformation might be explained as the result of pressure caused by a glacier load at the time the intrusion occurred. This pressure would be much greater than that due to the overlying rock alone.

During a glaciation after the SM group was formed a subglacial eruption occurred in the vicinity of Sámsstaðamúli. This produced the Búrfell Pillow lava (BP).

The author collected samples from BP for petrographic analysis. Four samples were analysed, taken over a cross section of over 150 m (i.e. from a little above the SM basalts to the top of Skálarfell). All the samples were similar to the olivine-bearing part of SM_a and could easily be part of the same rock body.

Extension of the SM unconformity to the north east indicates that it cuts the axis of Búrfell just at the end of the Búrfell Pillow lava. The Búrfell Pillow lava probably results from a linear eruption in an eruption fissure of the same alignment as the axis of Búrfell. A continuation of this eruption fissure should cut the SM valley.

The source of SM_a could be in the continuation of the BP fissure where it cuts the SM valley. The resistance to the magma was less in the young probably unconsolidated sediments of the SM group than to penetrate the SM basalts. The intrusion occurred in the tuffaceous sandstone and converted parts of it to intrusive breccia with the sandstone as matrix. The intrusion thins out towards the west and has also had a tendency to upward movement in the talus breccia near the unconformity. Ths SM basalt flows acted throughout as a roof for the intrusive.

The engineering significance of acceptance of SM_a as an intrusive, the same as is outcopping in the westside of Sámsstaðamúli, is that the SM_a in the power house area would be expected to be cube jointed as is the outcrop. The appearance of the SM_a cores also support such a suggestion, as they show close jointing in all the holes and all the way through in each hole. As SM_a was penetrated in 8 holes it is not reasonable to assume that all the holes hit the margin of a column in columnar jointed basalt.

The authors conclusion is that the weight of evidence for the intrusive origin of SM_a is sufficient to allow one to consider this theory as proved. SM_a is thus considered as being of intrusive origin and most probably resulting from a subglacial eruption from the same eruption fissure as formed the Búrfell Pillow lava.

Notes:
Basalt beds in the SM group are seperated with unbroken lines.
Boundaries between groups are indicated with dasheed lines.

LEGEND:

- Overburden
- Finiglacial (FG) Sand and Gravel unconsolidated
- Glacial till (GT) Moraine (boulder clay)
- Sámsstaðaklif basalt (BS) Basalt and volcanic breccia
- Búrfell pillow lava (BP)

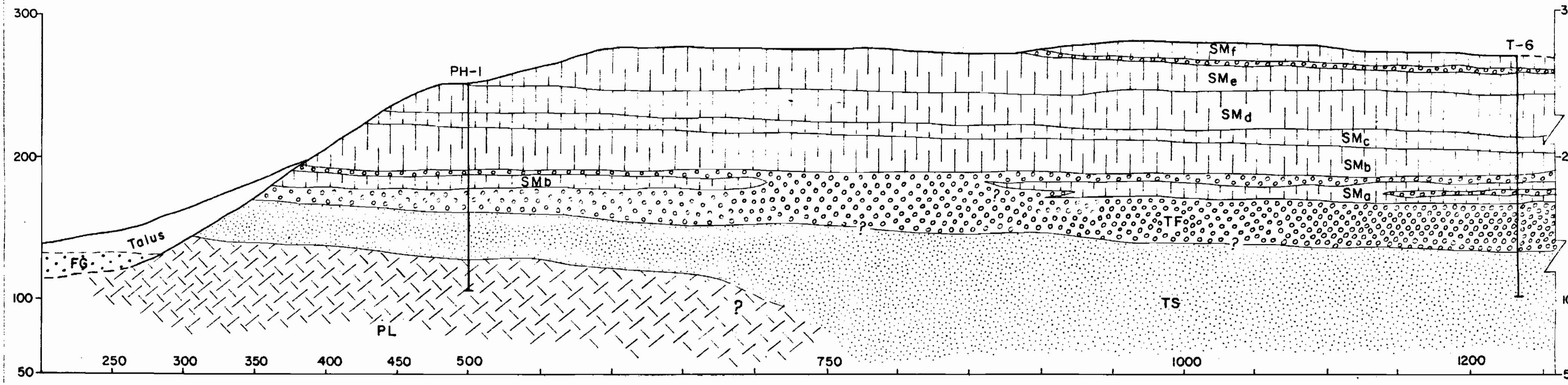
SÁMSSTAÐAMÚLI GROUP (SM)

- Basalt flows (SM) interfingerin with
- Talus fanglomerate (TF) and
- Tuffacious Sandstone (TS) with tongues of
- Pillow lava (PL)
- Older Búrfell (OB) Basalt, andesite and rhyolite flows with clastic interbeds.
- Boreholes
- Fault or major fracture some are with numbers F-1 to F-5

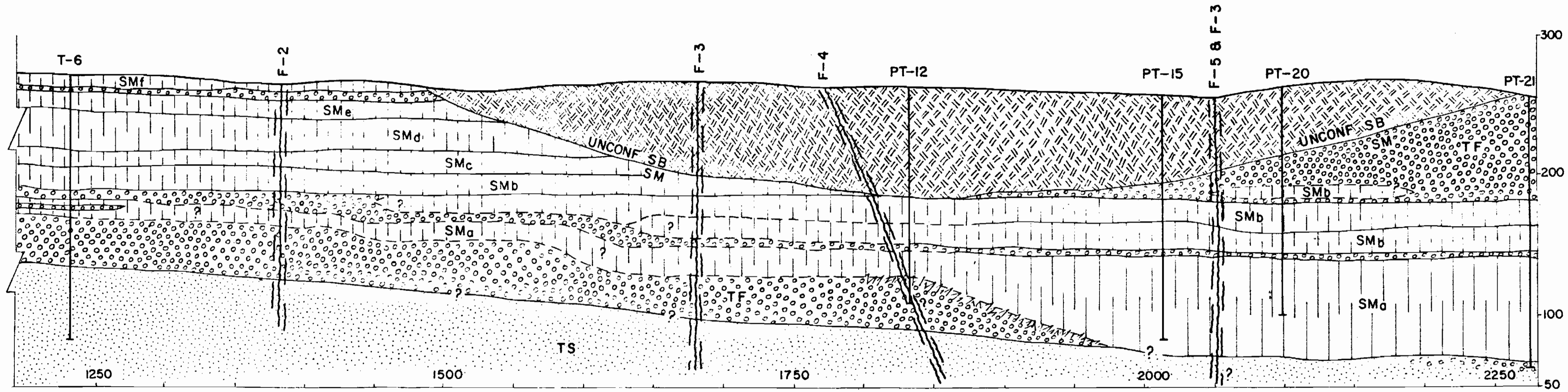
Scale 0 100 200 300 Meters

RAFORKUMÁLASTJÓRI		
SÁMSSTAÐAMÚLI		20.Sig/TA.
Geologic Map.		TNR. 451
		B - 277
	FNR. 6435	

Fig. 2.



A–A

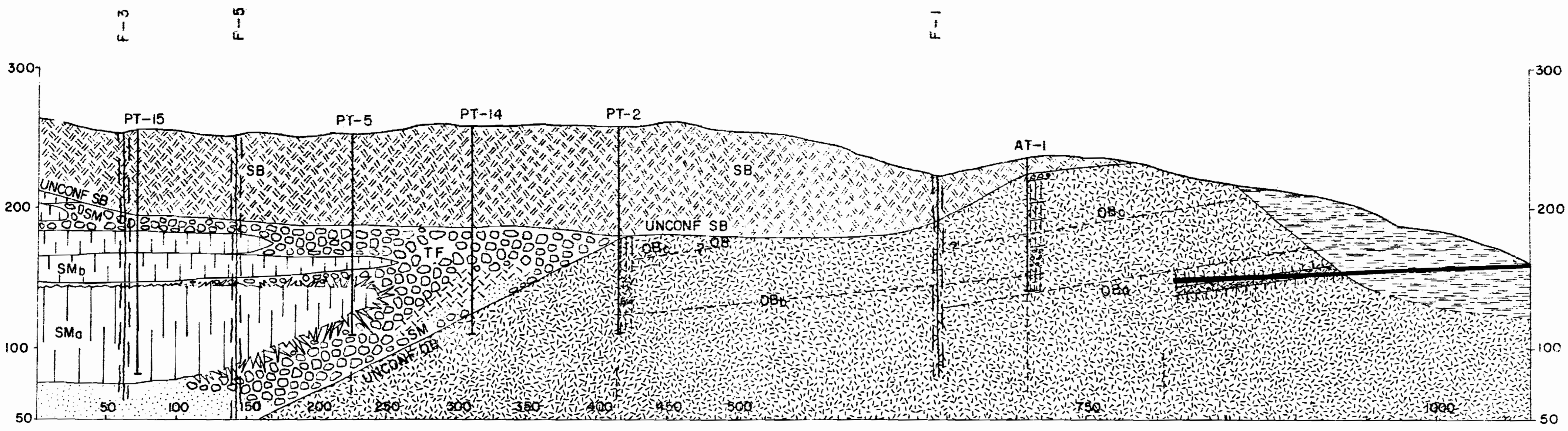


A–A cont.

Note:
Legend is on sheet 2 of 2

RAFORKUMÁLASTJÓRI	
SÁMSSTAÐAMÚLI	249.63 HT/Gyða
	Tnr. 453
	B-277
Geologic section Sheet 1 of 2	Fnr. 6437

Fig. 3



B-B

LEGEND

- Glacial Till formation moraine GT
- Sámsstaðaklif Basalt formation SB
- Sámsstaðamúli formation, basalt SMa-g
- —"—"—"—"— talusbreccia and fanglomerate TF
- —"—"—"—"— tuffacioas sandstone TS
- —"—"—"—"— breccia and sandstone inside TF
- Sámsstaðamúli formation, intrusive breccia, schematic
- Older Búrfell formation, (OB) drillholes and exploration tunnel are shown and dashed lines showing conections of strata
- Fault or major fracture
- Centerline drillholes

RAFORKUMÁLASTJÓRI

SÁMSSTAÐAMÚLI

Geologic section
Sheet 2of 2

1.10.'63 HT/Gyð
Tnr. 452
B-277
Fnr. 6436

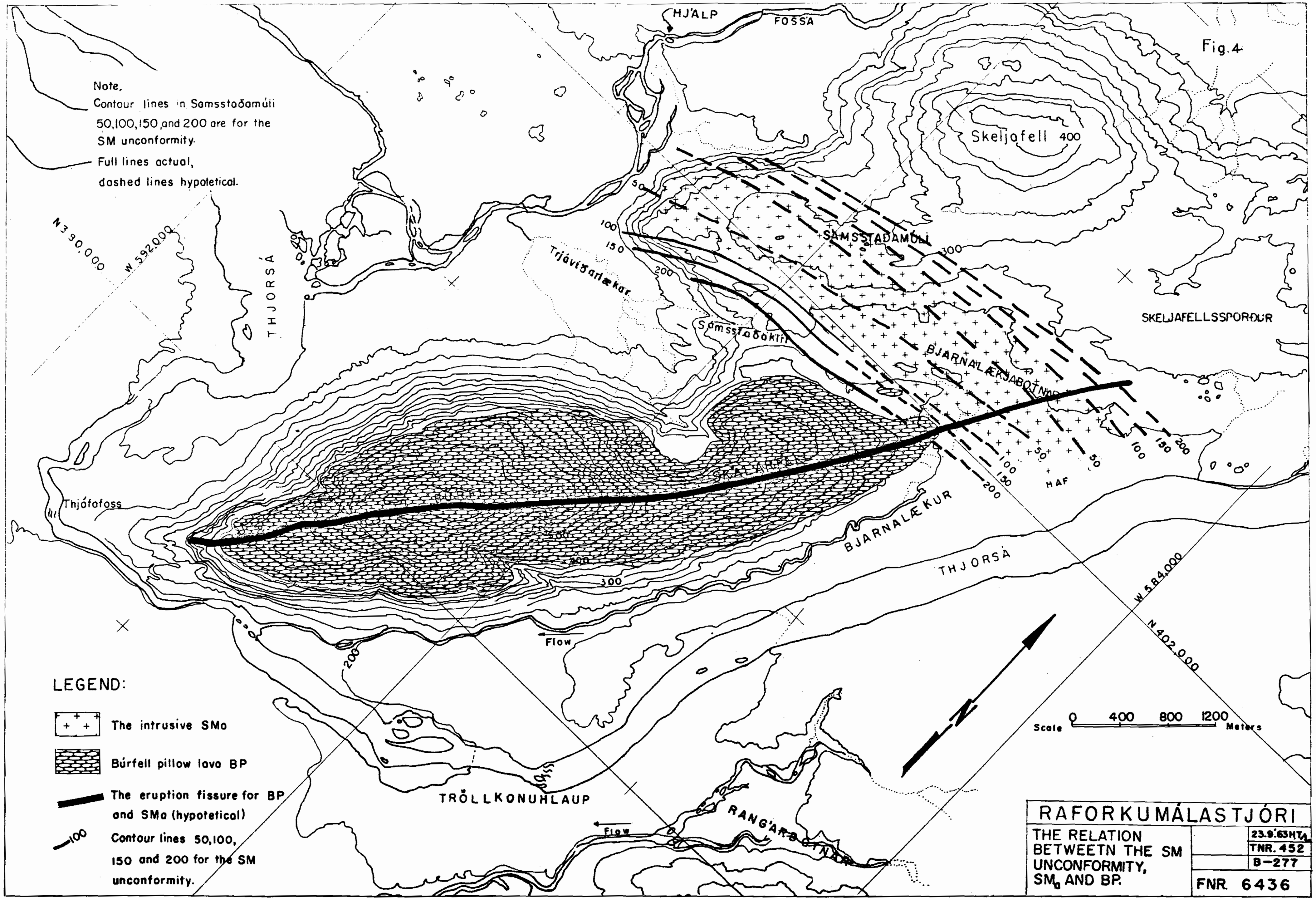


Fig. 4
Note,
Contour lines in Samsstaðamúli 50,100,150 and 200 are for the SM unconformity.
Full lines actual, dashed lines hypotetical.
HJÁLP
FOSSÁ
Skeljafell 400
SAMSSTAÐAMÚLI
SKELJAFELLSSPORÐUR
Trjáviðarlækur
Samsstaðaklif
BJARNALÆKJABOTNAR
BJARNALÆKUR
HAF
THJORSÁ
Thjófafoss
TRÖLLKONUHLAUP
RANGÁRBOTNAR
Flow
N 390,000
W 592,000
W 584,000
N 402,000
Scale 0 400 800 1200 Meters
LEGEND:
The intrusive SMa
Búrfell pillow lava BP
The eruption fissure for BP and SMa (hypotetical)
Contour lines 50,100, 150 and 200 for the SM unconformity.
RAFORKUMÁLASTJÓRI
THE RELATION BETWEETN THE SM UNCONFORMITY, SMa AND BP.
23.9.'63HTA
TNR. 452
B-277
FNR. 6436