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THE ERUPTION IN ASKJA, 1961
A PRELIMINARY REPORT

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ABSTRACT. Askja is a large caldera (45 km^2) within the Pleistocene Dyngjufjöll massif in Northern Iceland. An explosive eruption within this caldera in 1875 produced about 2 km^3 of rhyolitic tephra and led to the formation of a new caldera now occupied by Lake Öskjuvatn (11 km^2). During the 1920's four small effusive eruptions within Askja produced basalt lava.

The 1961 eruption was preceded by the formation of big solfataras on a N-S line along the eastern caldera wall. The eruption started in the same area two weeks later, on October 26, when an E-W-running fissure, 0.7 km long, opened up. The eruption was of the Hawaiian type, and lava fountains rose to a height of 500 m. Within the first 10 hours or so the lava flow reached a length of 7.5 km and an area of nearly 6 km^2. When the eruption ended five weeks later the area was 11 km^2. Until November 5 the lava solidified mainly as *apalhraun* (aa) lava, but from then on it was more fluid and solidified as *helluhraun* (pahoehoe) lava.

The two lava types differ with regard to their mineralogy. The lava produced before November 5 is characterized by relatively few phenocrysts of plagioclase and pyroxene in a groundmass of black glass that is opaque due to precipitation of ore. Olivine is not found. The fluid lava of the second phase contains more phenocrysts. Olivine is present and the glass brown and translucent. Three new analyses of Askja lavas are presented.

THE COURSE OF EVENTS (BY S. THORARINSSON)

Dyngjufjöll and Askja.—Askja is situated in the big lava waste Ódádahraun, in Northern Iceland. Literally Askja means a box. In reality it is a large caldera, about 45 km^2, in the volcanic massif Dyngjufjöll. This massif was built up during the latter half of the Pleistocene, mainly by basic rocks: palagonite tuffs and breccias and basalt lavas. The caldera floor is entirely covered by postglacial lava flows. Its height above sealevel is 1120 to 1150 m. The caldera walls rise to nearly 400 m above its floor and to 800 m above the surrounding plain. Figure 1 shows the outlines of the Dyngjufjöll massif compared with the outlines of other well known volcanic edifices in Iceland. The outlines of Dyngjufjöll suggest that the massif is probably the ruin of a huge stratovolcano, of about the same size as the largest active volcano in Iceland, Öræfajökull.

Eruptions before 1961.—We have no reliable information on any eruptions in Askja before 1874, but solfataras were known to exist there, as vapor was occasionally seen rising from the massif. It is possible or even probable that outpouring of lava did now and then in historical time take place both within the caldera and on the outer flanks of the Dyngjufjöll massif, but the 1874-1875 activity was in all probability preceded by more than two centuries of quiescence. It is certain that no big explosive eruption had occurred there for hundreds of years when in 1874 volcanic activity began in the southeast corner of the Askja caldera. The solfatara activity started to increase in Febru-

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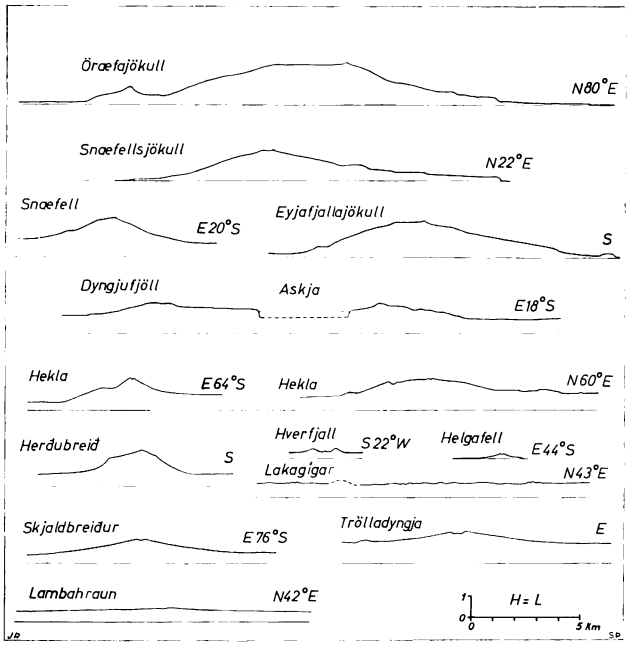


Fig. 1. The outlines of Dyngjufjöll and some other Icelandic volcanoes constructed from topographical maps. The horizontal lines mark the sea level.

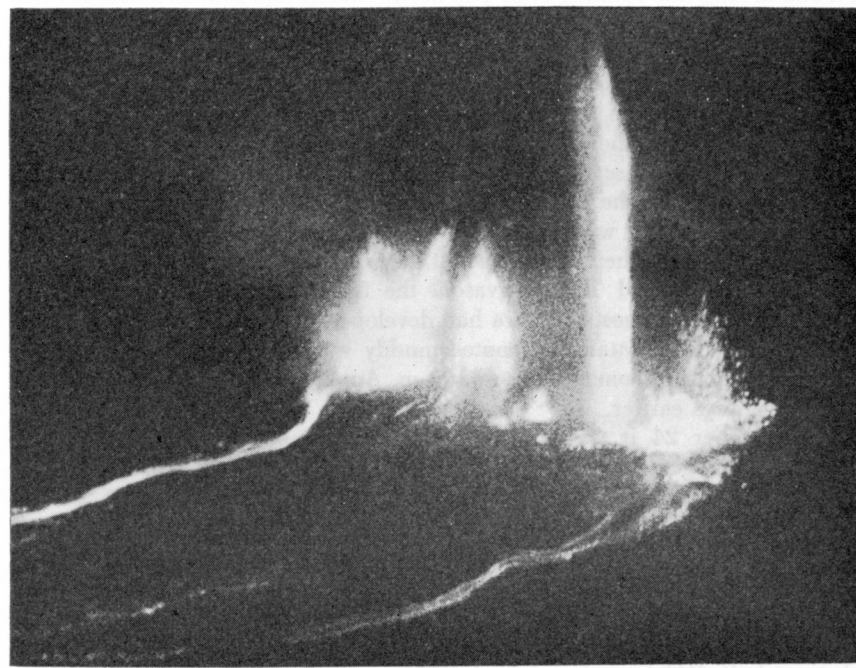
ary of that year. In late December a series of rather strong earthquakes occurred. They culminated on January 2, 1875, and on the following day "a column of fire" was observed from the Mývatn area. Yet the volcanic activity was on a small scale and limited mainly to violent solfatara activity until March 28-29, 1875, when an explosive eruption formed the crater Víti[1] in the caldera, 3 km north of the main solfataras (pl. 1-A). In less than 12 hours this crater, little more than 100 m wide, produced about 2 km^3 (calculated as freshly fallen) of rhyolitic tephra (SiO_2 69%). Some tephra reached eastern Scandinavia (Stockholm). In eastern Iceland whole settlements were temporarily abandoned and some of the farms permanently.

The Víti eruption was followed by the formation of a large subsidence within the main Askja caldera and now occupied by the lake, Öskjuvatn. Its area is now 11 km^2. The formation of this new caldera had already begun on a very small scale by February 16, 1875 (when Askja was visited by some Icelandic farmers), but it was mainly formed after the big rhyolitic explosive eruption. On July 14, 1875, when visited by a Scottish traveler, Watts, it had an area of 3 or 4 km^2 and a maximum depth of about 120 m. When mapped by a Danish expedition in July the following year, it had an area of 7 km^2 and a maximum depth of 230 m, and a small lake had begun to form on its bottom. The level of that lake gradually rose until 1907 when the caldera had nearly

[1] The word lighthouse appears to the left of the Víti crater on the American base map because the American Army Map Service mixed two similar Icelandic words—Víti, which means Hell and is a common name on craters, and Viti, which means lighthouse.

PLATE 1

A. View towards SW over the Víti crater, Öskjuvatn and the lava floor of the Askja caldera. In background the shield volcano Trölladyngja. Photo: J. Jónsson.



B. Aerial view from NW of the lava fountains at 2 A.M. on October 28. The height of the highest fountain is about 300 m. Photo: I. Magnússon.

reached its present size. The volume of the caldera is at least 1.5 km^3, that is, three times the volume of the tephra erupted in 1875 when calculated as solid rhyolitic rock.

In 1921-1923 Askja was active again, producing four small lava flows, Bátshraun (*hraun* = lava) in March, 1921, Mývetningahraun (2.2 km^2) in November, 1922, and two small flows in the southeast corner of the Askja caldera in 1923. Contrary to the 1875 eruption, the chemical composition of these flows is basaltic (cf. Sigvaldason below). The small volcanic island in lake Öskjuvatn appeared in 1926 and sometime during the period 1924-1930 a rather big basalt lava flow (16 km^2, volume about 0.1 km^3) was poured out from a 6-km-long fissure on the southern flank of the Dyngjufjöll massif (fig. 2).

The 1961 eruption.—On October 6 and 9, 1961, the seismographs in Iceland registered earthquake shocks, the foci of which were within the Dyngjufjöll massif. On October 10 it was noticed from an airplane on a reconnaissance flight over the Ódádahraun area that three solfataras were in action in an area where no such activity had been observed before. These solfataras were situated on the inner slope of the eastern caldera wall of Askja—a little above the caldera floor—and just south of Öskjuop, a pass, 1 km wide, through the eastern caldera wall.

On October 12 S. Thorarinsson and a cinematographer inspected and photographed this new solfatara area from the air (pl. 2-A), and Thorarinsson arrived on the spot the following day. The solfataras were found to be situated on a 350-m-long line running N-S. The northernmost and southernmost of those solfataras observed on October 10 were still very active, each discharging approximately 30 liters/sec of boiling mud suspension. The middle solfatara was already extinct but a small opening had formed about 70 m north of the southernmost one. Narrow (5 to 15 cm) fissures running N-S were observed in the solfatara area, and on the caldera plain west of the solfataras and between them and Víti there was a series of new fissures running approximately W10°N-E10°S. The width of the widest ones did not exceed 30 cm and most of them were less than half that wide.

On October 19, when the new solfatara area was visited by two geologists, G. E. Sigvaldason and T. Tryggvason, the above-mentioned opening 70 m north of the southernmost solfatara had developed to be by far the biggest and most active of the solfatars. It spouted muddy water occasionally 100 m high and threw head-size stones as far as 100 m. Apparently it had been still more active some days earlier.

On October 24 it was observed from a reconnaissance plane that the solfataras no longer emitted water but only vapor. On October 26 the seismographs in Reykjavík registered earthquake shocks in Askja at 10 56 25 and 11 00 34 IMT.[2] Passengers on a plane flying from Reykjavík to Akureyri noticed about 14 30 IMT that cumuli of bright clouds protruded intermittently (intervals 2 to 4 minutes) through the rather low strata of clouds that covered the Ódádahraun area. The pilot of an American jet plane which flew over that

[2] Tryggvason, E. Preliminary Seismological Bulletin. October, 1961. Vedurstofa Islands (mimeographed). IMT is one hour behind GMT.

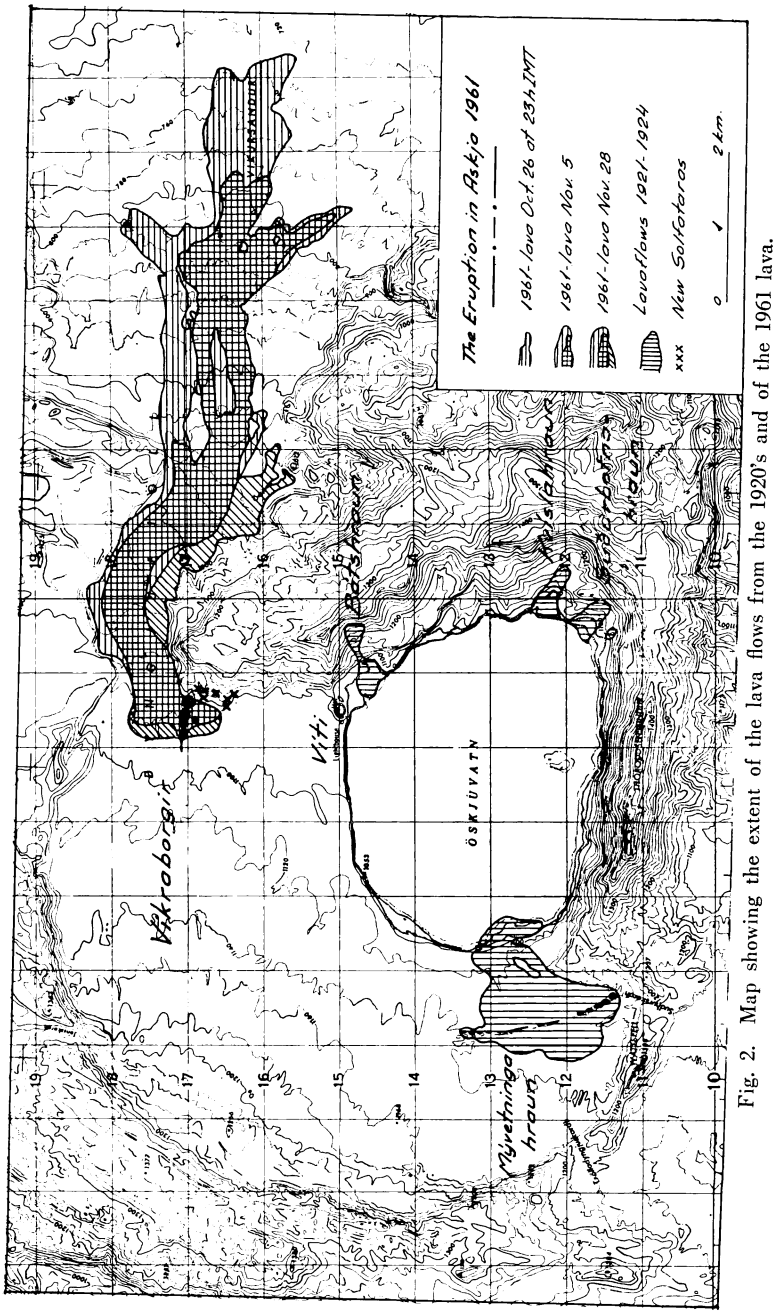


Fig. 2. Map showing the extent of the lava flows from the 1920's and of the 1961 lava.

area about 18 IMT reported glowing lava river belching forth and a cumulus rising about 30,000 feet. Between 22 40 and 23 40 IMT Thorarinsson and five other passengers were over Askja in a reconnaissance plane. The Dyngjufjöll area was then covered with clouds except where the upstream of heat from the lava river dispersed that cover. The approximate extension of the lava flow at 23 IMT is shown on figure 2. The area is 5.8 km[3] and the maximum distance of lava tongues from the craters 7.5 km. The glowing river that belched forth through Öskjuop was a spectacle beyond description. The eruption column rose to 6000 m and its upper parts were lit by full moon and flaming northern lights. A strong wind blew from the north and carried the column southwards. Now and then four fountains of brightly glowing lava were visible through the clouds; the easternmost was highest and its height was estimated at 500 m. On the whole the heights of these columns seemed to be rather constant.

Supposing that pouring out of lava on a large scale did not start until after 15 IMT, as at that time the rising of vapor columns was still intermittent and their height much lower than later, and assuming further that the average thickness of the lava at 23 IMT was 4 m, the average discharge of lava between 15 and 23 IMT was about 800 m[3]/sec. As the decided impression was that, when reconnoitered from the plane, the lava flow had already passed its climax and was diminishing, it seems probable that the maximum discharge of lava considerably exceeded 1000 m[3]/sec.

Shortly after midnight on October 27-28, three geologists, Th. Einarsson, G. E. Sigvaldason, and S. Thorarinsson reached Askja in jeeps together with two cinematographers and a few other visitors. On following days other geologists as well as a number of tourists visited the area. Although snowstorms sometimes made observations difficult or impossible, it may be said that until November the volcano was under nearly continuous observation by geologists or tourists. After November 7 the observation was sporadic, and after the middle of the month ceased, except from the air, because of heavy snowfalls. The following is an extract of a preliminary compilation of rather varying observation material.

As stated above, the lava flow had reached 7.5 km in length before midnight on October 26-27. Twenty-four hours later it had advanced about 1 km toward the east, and a front, 4 to 6 m high, then advanced 1 m per minute. During this evening and early night the lava fountains reached a maximum height of about 300 m (pl. 1-B). Viewed at close quarters from the rim of the caldera wall due east of the erupting fissure, they were strikingly like those so frequently photographed during the Kilauea Iki eruption and other Hawaiian eruptions. The total length of the eruption fissure as roughly measured the following morning was 700 m, and its direction the same as that of the above-mentioned fissures on the caldera floor, about W10°N-E10°S. The westernmost part of the fissure was already inactive when visited on the morning of October 28, and the small strip of lava it had poured out on both sides already so solidified on the surface that it was possible to walk on it. Toward the west the fissure ended in two separate miniature vents out of which a small amount of lava had been extruded. These lava mounds had pushed upward the layer

[3] All figures regarding the new eruption should be regarded as preliminary.

PLATE 2

A. The southernmost of the solfataras formed before the eruption.
Photo: S. Thorarinsson, Oct. 13, 1961.

B. The lava flow viewed towards the east on November 12, 1961.
Photo: S. Thorarinsson.

of firn and snow that had covered the area before the eruption, without melting it, so that flakes of this firn now rested directly on the new lava. From the eastern part of the fissure, about 350 m in length, four lava fountains rose, now considerably lower than during the night before. The velocity of the westernmost of the two lava rivers that flowed northwards from the fissure was, roughly measured, about 3 m/sec where leaving the craters. The new crater row has been given the name "Vikraborgir".

The plain between the craters and lake Öskjuvatn was covered by a layer of brownish black and porous tephra obviously formed by lava fountains. The grain size was rather uniform, 1 to 2 cm in diameter. At a distance of 2 km from the fissure the thickness of the tephra layer was only 15 cm. Thus the tephra production was small during the initial phase of the eruption and after that it was smaller still but sufficient, however, to build up crater walls which had reached about 40 m height when the eruption ended. Threads considerably coarser than normal Pele's hair were rather frequent east of the fissure. On the lake were great flakes of floating tephra and on the lukewarm pool in the Víti crater the tephra was still floating 6 weeks later.

The solfataras that had been active before the eruption were now quite extinct, long icicles already hanging from the rocky walls of the biggest one, but two new big solfataras had been formed just west of the extinct ones.

The surface of the new lava was, as far as could be seen, mainly that of aa lava (Icel. *apalhraun*) and broken-up pahoehoe with small patches of undisturbed ropy pahoehoe (Icel. *helluhraun*) surface in between.

During the following days the activity in the craters and the production of lava diminished gradually, although not regularly. On October 28 and 29 lava fountains occasionally reached a height of about 200 m, but the activity gradually changed to a Strombolian type, intermittent outthrowing of lava lumps though with an occasional recurrence of gushing fountains.

Between midnight on October 26-27 and November 5, the area of the lava flow increased about 4 km^2 and reached the length of 9.5 km (fig. 2), but during the same period new lava was superimposed on great parts of the former flow, so that on the whole the volume of lava was probably somewhat more than doubled. The average discharge of this period was of the order of 50 m^3/sec.

On November 4 the discharge of lava reached a minimum but in the afternoon the following day there began a temporary increase in the discharge, and at the same time the activity changed character. Until then the lava had flowed out through openings in the crater walls and formed open lava rivers, but now a more thin-flowing lava flooded the area immediately northeast of the craters, so that this area, which was very rough and rifted on October 4, was quite covered by a ropy pahoehoe lava when visited on November 6. From then on the lava left the craters "underground", in tunnels and tubes which reached the surface at various distances from the crater row, pouring out narrow runnels of thin-flowing lava that flowed at great speed and at times formed actual small lava lakes. Gradually this system of tubes and runnels extended to the remotest parts of the flow so that it became like a living limb with warm blood streaming through its veins. The discharge as a whole was on a small

scale. With the possible exception of November 5 and 6, it did not exceed 30 m^3/sec at any time after November 4, and usually it must have been much less than that.

It is not known with certainty when the eruption came to an end. When flown over on November 12 the activity of the fissure was seen to be mainly limited to one crater, which had by then built up an unbroken regular scoria wall. The glowing lumps thrown up from the small lava lake inside did not reach 100 m height. On November 28 the activity was similar, although on a considerably smaller scale. and lava was seen emerging from tubes up to 7 km distant from the craters (pl. 2-B). On that day lava emerged from underneath the margin of the first day's flow south and west of the craters and flowed northwards along the margin. It may be regarded as certain that the eruption lasted some days longer, probably not less than a week, but when on December 17 Askja was again flown over no signs of activity were observed, and even the inner sides of the crater walls were partly covered with snow.

The increase in the area of the lava flow between November 5 and 28 was about 1 km^2, and after that the increase in area was insignificant, if any. Thus the total area of the flow is about 11 km^2, and the total volume may preliminarily be estimated at 0.1 km^3. The eruption is thus on a small scale compared with the largest fissure eruptions in Iceland in historical times, yet bigger than many fissure eruptions that have occurred there, and about the size of a "normal" Mauna Loa eruption.

Although fissure eruptions are very frequent in Iceland, this is the first time (with the exception of the last Hekla eruption, which is a special type) that any fissure eruption in that country has been eye-witnessed by geologists. This new experience was therefore a very welcome supplement to the preserved written descriptions of earlier fissure eruptions in Iceland and it will be a clue to a better understanding of some of these descriptions. The 1961 eruption in Askja also adds a new chapter to the interesting and far from sufficiently studied volcanic history of the Dyngjufjöll massif and Askja.

PETROGRAPHY OF THE LAVAS (BY G. E. SIGVALDASON)

During the short eruption in the Askja caldera in October and November, 1961, changes in the physical character of the flowing lava were observed and minor variations in mineralogy could be detected.

As pointed out in a previous chapter on the course of events, the lava production can be divided into two phases by the physical behavior of the flowing lava and the rate of lava discharge.

A. Initial phase from October 26 to November 5, producing main bulk of erupted material, which solidified as *apalhraun* (aa lava). Toward the end of this period lava discharge was at a minimum.

B. Second phase from November 5 until activity ceased. Lava discharge on a moderate scale. The flowing lava was of much lower viscosity than in the previous phase and solidified as *helluhraun* (pahoehoe lava).

In the following preliminary description of mineralogy, these two lava types will be dealt with separately.

TABLE 1

Chemical analyses of Askja lavas

	1	2	3
SiO_2	50.87	50.31	50.33
TiO_2	2.95	2.98	2.94
Al_2O_3	12.92	13.10	12.23
Fe_2O_3	2.85	1.93	2.37
FeO	13.19	13.68	13.89
CaO	9.02	8.87	8.95
MgO	5.40	4.88	4.99
MnO	0.26	0.23	0.27
P_2O_5	—	0.27	0.28
Na_2O	2.46	2.86	2.81
K_2O	0.76	0.53	0.68
H_2O+	0.17	0.30	0.27
H_2O-	0.04	0.04	0.05
Total	100.89	99.98	100.06

1. Lava flow of 1921 (Analyst H. Jónsson).
2. Lava flow of October 26, 1961 (Analyst Sigvaldason).
3. Lava flow of November 16, 1961 (Analyst Sigvaldason).

Mineralogy.—The lava of October 26 to November 5 was characterized by relatively few phenocrysts of plagioclase and pyroxene in a groundmass of black ore-stained glass, and small microlithic plagioclase and pyroxene laths and magnetite.

The plagioclase microliths ranged in size from 0.02 mm x 0.09 mm to 0.005 mm x 0.03 mm. They formed single albite twins with fringed ends and no sharp crystal borders. Measurements of maximal extinction angles in oriented sections indicated a composition close to 60 percent An. Plagioclase phenocrysts were idiomorphic with sharp crystal borders. The An-content as measured by the same methods was close to 70 percent. Their size ranged from 0.1 mm x 0.7 mm to 0.2 mm x 1.0 mm.

Pyroxene microlites in the groundmass varied in size from 0.02 mm x 0.09 mm to 0.01 mm x 0.04 mm. whereas the phenocrysts measured 0.1 mm x 0.2 mm. Both phenocrysts and microliths were diopsidic augite (?), with the exception of a few grains of orthopyroxene (enstatite-bronzite) found in the lavas of the first phase.

Worth special mention is the black glass matrix, opaque due to precipitation of ore.

The highly fluid lava of the second phase contains more phenocrysts than the previous lavas. Orthopyroxene was not found in these lavas but plagioclase and clinopyroxenes are of similar composition as before. Few grains of idiomorphic olivine are present in contrast to the first lavas where no olivine was found. The groundmass is made of translucent brown glass and precipitation of ore dust has not taken place.

Chemical analyses.—New chemical analyses of the 1961 lavas are presented in table 1, along with an analysis of lava erupted in Askja in 1921. The lavas of the 1961 eruption as well as those of the activity period during 1921-

1929 are basalts containing occasional phenocrysts of olivine (second phase of 1961 eruption).

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