RECONNAISSANCE
PROSPECTION FOR BASE-METAL MINERALIZATION
IN
SOUTHEASTERN ICELAND

REYKJAVÍK
1970
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"This report has not been cleared with the Bureau of Technical Assistance of the United Nations, which does not, therefore, necessarily share the views expressed"

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1) GENERAL

As a part of the United Nations Technical Assistance to the Icelandic Government, a programme of reconnaissance prospection for base metal mineralization in southeastern Iceland has been set up in 1969. The programme for 1970 has been formulated in the cooperation with both Icelandic National Research Council and National Energy Authority (Orkustofnun).

To carry out this programme, together with the counterpart staff, I had been working in Iceland from 13 May 1970 until 30 October 1970. I would like to emphasize the great support, in every respect, given by the National Research Council and the National Energy Authority, to my mission and execution of the programme.

1.1. - The Aim of the Prospection

The small outcrops of base metal mineralization (copper, zinc, lead) have been known for many years in the Össura valley, Lón area in southeastern Iceland.

During the summer of 1969, some indications of other base metal mineralizations were revealed by a preliminary geological survey, complemented by regional geochemical prospecting in the vicinity of Össura valley. Although detected geochemical anomalies were not high, the general metallogenic environment in southeastern Iceland is such that it did not rule out the possibility that base metal deposits could exist there. Therefore the continuation of search for base metal mineralization, initiated in 1969, were extended 1970.
The programme of prospection for base metal mineralization during the summer 1970 involved the following phases:

a) A regional reconnaissance, looking for base metal deposits in the areas of Lón and Hornafjordur. The prospection was directed predominantly towards the intrusions of "acid" magmatic rocks (granophyres) in order to eventually locate significant concentrations of ore or mineralization which deserved more detailed exploration.

b) A more detailed prospection around the Reydara granophyre intrusion to enable a conclusive evaluation of the geochemical anomalies of copper and molybdenum, which were revealed during the geological survey carried out in 1969.

Shortly said, the prime objective in undertaking prospection has been to detect, if any, significant outcrops of base metal deposits, or manifestations of ore mineralization on which further exploration and development could be considered as economically justified, as well as to present a general evaluation of southeastern Iceland as a metallogenic unit with respect to base metal ore.

I would like to point out that this programme had not been fully completed but only partly, due to (a) short field season caused by climatic conditions in Iceland, (b) delay in delivery of the needed equipment, and (c) the large area of southeastern Iceland, which covers almost 2,000 sq km of mountainous terrain. But even so, the amount of obtained information on metallogenic features seems to be sufficient to enable some conclusive estimation, at the level of preliminary prospection, of outlook of base metal mineralization in southeastern Iceland.
1.2. - **Field and Laboratory Work**

The search for base metal mineralization in southeastern Iceland lasted from 18 June till 12 September 1970. Due to many rainy days, especially in August and September 1970, we had no more than 62 effective days for field prospection. During this period of time, we covered by the reconnaissance prospection an area of approximately 1,000 sq km (Fig. 1). The prospected area is very rugged, deeply dissected mountainous terrain, partly not easily accessible and in part almost unaccessible or covered by ice sheets.

A field chemical laboratory had been established at Höfn to perform chemical analyses of the collected geochemical samples. Due to delay in delivery of the necessary equipment, we had significant difficulties, but nevertheless, the following analyses were completed:

- 1,535 analyses of copper and zinc
- 176 analyses of molybdenum
- 72 analyses of lead
- 14 analyses of water

Apart from ten isotopic analyses, which were done in the laboratories in USA, and examination of ore minerals at the Faculty of Mining and Geology in Belgrade, no laboratory investigations of rocks were carried out in Reykjavik due to lack of facilities. Since all conclusions pertaining characteristics of rocks, mentioned in this report, are entirely based on the field observations, they should be considered only as preliminary.

1.3. - **Counterpart Staff**

The prospection in southeastern Iceland has been organized in cooperation with the National Energy Authority
Fig. 1.- The location of prospected area
(Orkustofnun). The following staff were assigned to the Project:

Dr Stefan Arnórsson, geochemist, was the liaison officer. Besides from his responsibility of the financial side of the Project, Dr Arnorsson had set up and supervised the field chemical laboratory, as well as performed chemical analyses of water. His assistance to the Project has been very valuable and is appreciated.

Mr Halldor Kjartansson, geologist, has been my field assistant. He also worked efficiently on prospecting for base metal mineralization in southeastern Iceland during the summer 1969. He received the UN Fellowship to study economic geology in Austria for the next two academic years (1970/72).

Six students from the University in Reykjavik - Pall Imsland, Haukur Johannesson, Gestur Gislason, Einar Gunnlaugsson, Guðmundur Ólafsson and John Fenger - collected the geochemical samples and performed chemical analyses (Gestur Gislason and Einar Gunnlaugsson). All students were very diligent. I would like particularly to point at Mr Pall Imsland as a promising student of geology.
2) BASE METAL MINERALIZATION IN LÖN - HORNAFJÖRDUR AREA IN SOUTHEASTERN ICELAND

Although Iceland is relatively large country, the known mineral resources are more than scant. Because of its location on a mid-ocean ridge, Iceland has so far been considered as an unpromising area with respect to ore deposits, particularly base metals (copper, lead-zinc, etc.), because of unfavourable metallogenic environment (vicinity of the mantle, probable lack of sialic crust or continental type, predominantly basic eruptions, very shallow intrusions of "acid" rocks, unfavourable structure to trap eventuel ore-bearing solutions, etc).

The geological setting of southeastern Iceland is, however, characterized by some specific and more interesting metallogenic features than other parts of Iceland, but similar to some extent to the Snæfellsnes area in western Iceland. Although basalt formations are predominant, several Tertiary intrusions of granitic magma derived from the upper mantle (granophyre-granite) are known in southeastern Iceland. Some small occurrences of hydrothermal base metal mineralization were formed in cogenetic association with the intrusions of "acid" magma in the Lön area.

The hydrothermal copper mineralization (chalcopyrite, accompanied with sphalerite and galena), found by the Össura river has been so far the only known outcrop of base metal mineralization in southeastern Iceland. During the summer of 1969, the outcrop was prospected in more detail than previously since its prospect was not particularly promising, further exploration was not undertaken.
(see the report - S. Jankovic, 1969). Although this occurrence does not seem economically important, at least at the stage of our present knowledge, yet it is a significant indication of the possibility that hydrothermal base metal concentrations could be formed under the metallogenic conditions of southeastern Iceland.

Starting from the known mineralization at the Össura river during the summer of 1970 the prospection was extended towards areas where intrusions of granophyre were exposed. As available period of time was limited (practically to two and half months), it was not possible to investigate all areas containing intrusions of "acid" magma in eastern and southeastern Iceland, but only in Lón and Hornafjordur, which were selected as most interesting from metallogenic viewpoint.

2.1. A Brief Review of the Geological Setting in Southeastern Iceland

Our prospection in southeastern Iceland has not been aimed to involve the investigation of geological setting in detail, but only to the extent which is closely related to the genesis of base metal mineralization (processes of deposition, and controlling factors of spatial localization). As stated above, both lack of laboratory facilities and short available period of time did not make possible a petrological study of the area, which was really needed, to be undertaken. Thus conclusions pertinent to the regional geology of this part of the country have to be considered at the time being only as preliminary.

The areas of Lón and Hornafjordur had not been systematically investigated as a whole, especially from a
petrological point of view, except the Austurhorn area (D.H.Blake, 1964) and some major intrusions of gabbro and granophyre (H.K.Cargill, L.Hawkes and J.A.Ledeboer, 1928). G.P.L. Walker of Imperial College and his collaborators carried out several years ago pioneering geological-volcanological studies, mostly in eastern Iceland, contributing a great deal to the general knowledge of mechanism of volcanic formations, extrusions of basalt lavas as well as the intimate association of "acid" and basic magma. Although these studies were related to the area where so far no base-metal mineralization has been known, the results are nevertheless of a general validity. The main papers published on this subject are listed under "References".

So far geological maps of southeastern Iceland are not available at scale 1:50,000, or even 1:100,000, except for the Austurhorn area (D.H.Blake, 1964). To link somehow our prospection with the geological setting of Lón and Hornafjordur areas, we prepared a provisional geological map (at scale 1:50,000) which is attached to this report. The main purpose of the present geological mapping was only to show the approximate distribution of the main types of rocks, but no claim either to completeness or to full accuracy, particularly to the petrological nature of some rocks.

2.1.1.- The geological environment of southeastern Iceland

is characterized by the widespread sequence of Tertiary basalt lava flows, interrupted several times by (a) central volcanic activity with large scale eruptions, (b) major intrusions - both basic and "acid" magma, (c) numerous minor intrusions, mostly dykes. The layers of
lacustrine sediments interbedded sporadically within basalts are observed also.

A) **Flood basalts** are composed mainly of olivine-basalts, porphyric basalts and tholeiitic basalts.

The basalt lavas predominant in eastern and southeastern Iceland have a great thickness\(^1\) and a rather uniform dip, generally leaning in a westerly direction and falling not steeper than 10° (steeper dipping occurs only around some of younger major intrusions, particularly intrusions of "acid" magma, as well as around volcanic centres).

B) **Eruptions, mostly from strato volcanoes of central type** are very widespread in southeastern Iceland. There are several central volcanoes in the prospected area: Lón, Kvosatindur and Vidibrekka at Kollumuli. The central volcanoes of Lón and Vidibrekka cover area over 10 sq km each.

The eruption from these central volcanoes led to the formation of large volume of basic, intermediate, and particularly, "acid" rocks, as well as composite rhyolite-basalt lavas.

**Rhyolites** occur as tuffs, agglomerates and pyroclastic rocks, and they are often flow-banded. Within composite lava flows (rhyolite-basalt), usually supplied by dyke-feeder, rhyolite overlies basalt. The rhyolite portion has sometimes a chilled pitchstone border, which can be seen, at intervals, within the rhyolite as well.

\(^1\) According to G.P.L.Walker (1964) "the total thickness, measured at sea level, is at least 10 km, but it is unlikely that more than a small fraction of this thickness occurred in any one vertical section".
Rhyolite lava flows, as well as basalt, were erupted in several phases, so that certain groups of lava-flows can be used as a stratigraphic marker horizon.

Andesitic rocks are also present in the prospected area. From the preliminary field observations it can be inferred only that andesitic lavas are far more voluminous in the Lón-Hornafjordur area than has been assumed so far. The intensive hydrothermal alteration during the volcanic stage (propylitization) caused often difficulties in distinguishing between basaltic and andesitic lava types.

The various facies of rhyolite were not separated, nor the distribution of andesite outlined on the geological map, as the detailed geological mapping has been beyond the scope of our programme.

The rhyolite lava flows are usually hydrothermally altered, especially in the core of central volcanoes. Within propylitic alteration, basalt lavas become usually green; chlorite, calcium carbonate, epidote, quartz, and zeolites are developed. The hydrothermal alteration of rhyolite is often characterized by the removal of iron from petrogenic minerals and formation of pyrite under the conditions of high sulphur concentrations-pyritic propylitization (the zones with abundant pyrite impregnations could be traced for several hundreds of meters at the head of the Njörflagil valley, east and northeast of Hafradalstindur).

C) **Major intrusions** of both basic and "acid" magma have been known for years in southeastern Iceland. Some of these intrusions have been described in detail by L.Hawkes (1928) and D.H.Blake (the Austurhorn area, 1964). During the present prospection, several other outcrops of
"acid" intrusions were found (Hnappadalstindur at Kollumuli, Utstungudalur at Lón, Hafragil) as well as certain indications of hidden granitic intrusion (the head of Laxardalur valley).

The intrusions are mostly like stock or small lacoliths. According to the composition, two main types of major intrusions can be distinguished:

a) **Gabbro intrusions** are known in several localities. Gabbro is generally coarse-grained, but pegmatitic facies are often widespread (the N.A.T.O. Base, Vesturhorn, etc).

Gabbro is almost always intimately - genetically and spatially - associated with "acid" intrusions - either close to granophyre massifs, or granophyre veined gabbro.

Apart from pyrite as secondary mineral (particularly high concentrations of pyrite can be seen in gabbro at the N.A.T.O. Base), gabbro occasionally contains also some very small individual grains of chalcopyrite, irregularly scattered.

**Intrusive facies of basalt** occur sporadically only, and they are represented by the columnar jointed rocks, which are mostly built up of tholeiitic basalts.

b) **Intrusions of granitic magma.** - From metallogenic viewpoint, the most interesting intrusions are intrusions of granitic magma ("acid" magma). The geological map at scale 1:50,000, which is enclosed with this report, shows the size and distribution of the intrusions of "acid" magmatic rocks in the prospected area. Although these "acid" rocks are usually termed as "granophyres", they include granites as well. Rhyolite intrusion have also been found oc-
casionally in the prospected area.

The granophyres are usually composed of quartz, and alkali feldspar with the addition of plagioclase; dark minerals comprise magnetite, augite, fayalite and/or hornblende. Minor constituents which are most common include apatite, allanite, epidote and zircon, sometimes also biotite, calcite, fluorite, and chlorite, sphene (L. Hawkes, 1928; D.H. Blake, 1964).

Although the composition of "acid" intrusions in the prospected area vary little, they are characterized by great structural differences, ranging from the porphyritic to typical granitic, with all gradations.

Briefly said, the main characteristics of the granophyre intrusions in the prospected area are as follows:

(a) Form and size: The intrusions of granophyre are usually stocks, with estimated volumes varying from a few up to 25 cubic kilometres (order of magnitude). The granophyre veining some gabbro massifs (like in Háragil in Lón) have volumes which do not usually exceed a few thousands of cubic metres.

(b) Structural control of emplacement: The country rocks of intrusive massifs are usually slightly affected by the intrusions. The intrusive brecciated zones, developed along the contact granophyre/basalt lava, could be seen sporadically only (like at the head of Kapadalur valley - the Slaufrudalur intrusion).

1) The rocks whose composition could correspond to "granodiorite" and/or "quartz-diorite" are also known, though very subordinate in bulk.
The up-doming of country rocks is usually restricted to the nearest vicinity of the granophyre contacts. The possibility that the restricted deformation of country rocks were caused, at least partly, by the prevalence of the intrusions within loose lava layers, should be left open.

Although the disturbance of the country rocks are not particularly prominent, nevertheless a general impression can be ascertained on some regional regularity in localisation of granophyre intrusions. It seems that "acid" magma ascended southeastward, while northeast-southwest direction is general strike of the intrusions.

(c) Level of intrusions: The granophyre intrusions took mostly place within subvolcanic level; some of these high level intrusions took place during certain phases of volcanic activity and were accompanied, at intervals, by pitchstone.

Although some of the high level intrusions almost reached the surface, still the general depth of intrusions can be estimated between 500 and 2,500 metres. Distinguishing high level intrusive rocks from extrusive is difficult locally, and transition from intrusive into extrusive facies are sporadically observed (Gjádalur).

The rate of erosion varies greatly. Some of the intrusive masses, like Ketillaugarfjall and Slaufrudalur intrusions, are deeply eroded (about 1,000-1,500 metres), while other intrusions are slightly exposed (Hnappadals-tindur at Kollumuli), or even hidden as was assumed for the granitic intrusion at the head of the Laxa valley.

(d) Marginal features of granophyre intrusions: Although abundant screes are often developed below the
granophyre outcrops, it is possible to observe in detail the relationship between granophyres and country rocks. Some of the most interesting features of the contact zone are as follows:

The contact between granophyres and country rocks (basalt lavas) is always sharp. Relying on the conclusions drawn by L. Hawkes and D.H. Blake, since the needed petrological studies were not carried out, no chilling of granophyre against basalts has been observed. But basalts are usually thermally metamorphosed along their contact with granophyres (hornfelsed rocks).

In the contact zone of some intrusives (Reydara, Austurhörn, Vesturhorn, etc) very thin but extensive veins of granophyres (0.5 up to 5 cm) penetrate irregularly the adjacent basalt lavas. Some of these thin veins can be traced in the country rocks up to 100-150 metres from the contact.

The roofs of the intrusions are often characterized by numerous dykes-apophyses of granophyre piercing overlying basalts (the intrusions at Reydara, Slaufrudalur, Vesturhorn, etc).

Very thin aplitic veins can be also sporadically observed.

Within metamorphosed aureoles, developed around intrusions of granophyres, extensively distributed epidote can be seen among other secondary minerals (particularly around the Reydara intrusion).

(e) Inner state of intruding magmas: There are some controversy regarding the state of intruding granitic magmas, whether they have been mobile, with abundant gaseous
phase, or whether they were very viscous crystal mush when they reached place of intrusion.

The very thin veins of "acid" magma, penetrating adjacent basalt, development of drusy cavities in granophyres could be considered as the indications that "acid" magmas, or at least a part of them, have to be fluid and very mobile at the time of their emplacement.

On the other hand, the lack of chilling of granophyres against country rocks, and the absence of evidence of contact metasomatic processes, which are usually caused by interstitial liquid from magma, suggest a more crystalline state of these intruding magmas.

No definite conclusion, at the time being, can be reached on the inner state of "acid" magma (or magmas), though this could be closely related to the formation of hydrothermal ore-bearing solutions.

(f) Association with basic rocks: The intimate - genetical and spatial - association of "acid" and basic magmatic rocks is one of the most striking petrological features of southeastern Iceland, and Iceland as a whole. This problem has been discussed for many years, but still the problem is basically open. Hawkes (1928), Gibson et al. (1963), Carmichael (1964), Blake (1965), Walker et al. (1964,1966) have studied the relationship between "acid" and basic magmas in eastern and southeastern Iceland.

The granophyres at the prospected area are almost always side by side with the gabbro, except the Reydara and Slaufrudalur intrusions where a granophyre-gabbro complex was not found. It seems also that the granophyre intrusion at Hnappadalstindur, revealed by the river Jökulsá, is composed of "acid" rock only.
The granophyre-gabbro complex was formed within a multistage process, with almost simultaneous emplacement of separate, but still liquid "acid" and basic magmas. With regard to gabbro, granophyre is usually younger, but metamorphic effects have not been observed, though veining of gabbro by granophyre is occasionally observed. Exceptionally, thin veins (up to 1 cm) of quartz and calcite, accompanied by some grains of galena and chalcopyrite were sporadically found in gabbro, near its contact with granophyre.

A particular feature of the association between "acid" and basic igneous rocks is presented by a mixed intrusive vein complex (or, net-veined complex). According to Blake (1964), the mixed-vein complex comprises a variety of basic magmatic rocks which are enclosed in, and veined by granophyre. Some of these basic inclusions within the complex have pillow-like forms. The genesis of these rocks have been studied in detail by Blake (1964).

D) Minor intrusions: The minor intrusions, mostly dykes, are very numerous in the prospected area, particularly in the core of central volcanoes (dyke swarms).

The composition of minor intrusions vary from basic to "acid" including composed dykes as well. It seems that minor intrusions cannot be, generally speaking, related to base metal mineralization.

E) Sediments: The lacustral sediments have been observed in several localities in the prospected area. The beds of sediment are interbedded with Tertiary basalt lavas. The thickness of beds varies usually from a few metres up to 20 metres. Some of these beds could be traced along the strike over 15 km.
2.1.2.- Age of igneous rocks.

The magmatic activity in the prospected area commenced in Late Tertiary times. According to data of K-Ar and lead isotope analyses, the stratigraphically oldest exposed lavas in southeastern and eastern Iceland are Miocene in age (about 10 M years). The age of the Slaufrudalur intrusion has been determined as about 9 M years, while the complex granophyre-gabbro at Austurhorn about 7 M years (Gales et al., 1966, Welke, 1968).

2.1.3.- The origin of "acid" igneous rocks.

The origin of the Icelandic "acid" igneous rocks has been debated for many years. Although Iceland lies on the Mid-Atlantic Ridge, the igneous complexes differ from other oceanic islands by some specific petrological features. The close association of "acid" and basic igneous rocks - in space and most probably in genesis - are of special interest. The "acid" rocks have large volume and extensive distribution, particularly in southeastern Iceland (about 10-12 per cent of the total volcanic pile, locally in the prospected area much more).

The equivocal interpretations of many, often controversial petrological features of "acid" magma and its relationship to basic magma, led to the postulation of various hypothesis on the origin of "acid" magma:

a) The "acid" magma was derived from the same source regions as the basalt magma, most probably from the upper mantle.

Regarding the mechanism for the origin of "acid" magmas, various processes could account for their genesis:
The "acid" rocks are a product of fractional crystallization from basic tholeiitic magma (Hawkes, Carmichael, Blake et al.).

The "acid" magma was derived directly from the mantle, without an intervening basalt liquid phase (Sigurdsson, 1967).

The model for the genesis of calc-alkaline igneous rock suite, proposed by Green and Ringwood (1966) for oceanic environment, suggests the generation of "acid" magma from a modified eclogitic upper mantle, within two-stage melting process.

b) The "acid" rocks originated from partial remelting of an ancient sial crust beneath Iceland.

The existence of a kind of sialic crust beneath Iceland could be more surmised than proved from the indications like:

- The volume of "acid" rocks seems too big to be explained only as a product of fractional crystallization from a basalt magma. Usually such processes yield 2-5 per cent of "acid" magma, even though the theoretical maximum reaches 7-12 per cent (Carmichael, 1964).

- The granitic xenoliths found in basalt at several localities in Iceland (Sigurdsson, 1967).

Even if a more convincing evidence for the existence of a sialic crust beneath southeastern Iceland is lacking, the formation of a rather thin, irregularly developed sialic crust\(^1\) should not be entirely excluded. It is a fact that thin lacustral sediment layers are interbedded within deep horizons of the Tertiary basalt sequence,

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1) But not the same type as continental crust
and it is not entirely unlikely that a remelting of such sediments can affect, to some extent, composition of intruding magmas, at least locally.

It is not intended to discuss in detail the possible origin of "acid" magma, though its genesis, the mechanism of emplacement, and evolution are of great metallogenic importance, providing the granitic magma is the source of base-metal mineralization in the prospected area. Only some data will be discussed, which could contribute to the knowledge of the origin of "acid" magma:

From strontium isotope analyses (Table 1), which show uniform $\text{Sr}^{87}/\text{Sr}^{86}$ ratios close to 0.702-0.703,

<table>
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<th>Rock</th>
<th>Locality</th>
<th>$\text{Nb, ppm}^x$</th>
<th>$\text{Sr, ppm}^x$</th>
<th>$\text{Sr}^{87}/\text{Sr}^{86}$</th>
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<td>Vesturhorn</td>
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<td>Slaufrudalur</td>
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<td>-&quot;-&quot;</td>
<td>100</td>
<td>50</td>
<td>0.7024</td>
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</table>

$x$ - determined by X-ray fluorescence
n.d. - not detectable

Table 1

Strontium Isotope Analyses from southeastern Iceland (Moorbath, Walker, 1965)
it could be concluded that the "acid" rocks, in all likelyhood were derived from the same sources as the basic rocks. A similar conclusion might be reached from the lead isotope measurements of some rocks from eastern and southeastern Iceland (Table 2). According to Welke et al. (1968),

<table>
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<th>Locality</th>
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<th>Pb$^{207}/$Pb$^{204}$</th>
<th>Pb$^{208}/$Pb$^{204}$</th>
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</tbody>
</table>

the data of lead isotope analyses are inconsistent with derivation of igneous rocks in Iceland, both basic and "acid" from a remelting of, or contamination with, ancient sialic material of the type of continental crust.

Summing up the foregoing discussion, the conclusion is reached that it seems more likely that "acid" igneous rocks in Iceland were formed as a product of frac-
tional crystallization of basalt magmas. The sequence in order of differentiation being basalt magma \(\rightarrow\) granodiorite magma \(\rightarrow\) granitic magma, or, within intrusive facies, (peridotite) gabbro \(\rightarrow\) gabbro \(\rightarrow\) diorite \(\rightarrow\) granodiorite \(\rightarrow\) granophyre/granite \(\rightarrow\) ± hydrothermal ore-bearing solutions.

The separation of "acid" magma from basaltic magma might have taken place at a rather shallow depth, near the oceanic crust; it seems very improbable that such processes could be developed in an environment where the pressure is very high (below a depth of 30-40 km - Yoder and Tilley, 1962\(^1\)).

2.2. Genesis of Base-Metal Mineralization.

The genesis of base metal mineralization was the starting point of our prospection in southeastern Iceland. Understanding of the processes which led or could have led to ore deposition as well as recognizing controlling factors of its spatial distribution is the basis to outline the prospecting programme.

It should be pointed out that the metallogenic features of oceanic islands, where a sialic crust of continental type is lacking, are so far rather uncertain. The mineral potentialities of base-metal mineralization in such metallogenic environments, where basalt is the dominant rock type and "acid" intrusions, if present at all, have very limited volumes, are considered, in general, as

---

1) It is likely that the most reasonable source of basalt can be expected at a depth of 50 to 60 km below the surface (Hawaii, etc).
not economically promising. The mineralization, if any, is mainly of a very small scope. Such general conclusions are based chiefly on the scarcity of so far known mineralization due to small quantity of water in primary basalt which can generate hydrothermal fluids only after it has assimilated more siliceous material containing more water. Whether this, so far generally accepted opinion, could be valid for the tecto-geological environment like in Iceland, is still uncertain.

Although some of the Pacific islands, where a huge copper deposit has been recently discovered, might be akin to Iceland from petrological point of view (composition of igneous rocks, their scope, origin from the upper mantle, etc), still they are related to different tecto-geological regional environment: they belong to the Pacific island arc structure.

What can be expected regarding base-metal mineralization from a magmatic complex of basic and "acid" rocks, or "acid" intrusions only, derived from the upper mantle and differentiated in an environment lacking sialic crust? Could economically significant deposits of base metal be generated from the granitic intrusions deriving from the upper mantle? According to investigations in south-eastern Iceland it seems justified at least, that such possibilities might not be entirely excluded, providing that favourable ore-trapping structures are developed.

As a possible model for mechanism of formation of hydrothermal base metal mineralization, a simple "end-member" process can be postulated:

1) The copper deposit at Bougainville, Solomon Islands, formed along the contact of Tertiary basalt lava and diorite (the impregnation type) contains over 600 mln. tons of ore with 0.45 per cent of copper and some gold.
Ore metal-bearing gaseous-liquid solutions were separated from the intrusion of granitic magma at a late stage of its crystallization. The ore deposits, if any, were formed by evolution of such hydrothermal solutions during their upward movement in directions controlled predominantly by pressure differentials, chiefly along zones built up of explosion breccias\(^1\), fractured zones, etc. Ore minerals were deposited from hydrothermal liquid solutions. Due to sharp drop in pressure, it is likely that deposition from ore-bearing solutions took place at relatively short intervals along their path of migration.

Within such processes, mineralized explosion breccias, dissemination at and/or near the contact granophyre/country rock, as well as brecciated vein-type hydrothermal deposits would be expected in the metallogenic environment of southeastern Iceland. Explosion breccias as a structural control of mineralization might be of particular interest as such structures were formed beneath the surface where there were no open fracture leading to the surface and rising gaseous-liquid solutions could be trapped below impervious rocks.

If the assumed model of ore formation was correct, the localization of ore mineralization in the prospected area should have been related to the contact zone of "acid" intrusion/country rock, as well as above the cupolas of intrusion, along fractures in the roof of intrusion.

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1) The term "explosion-breccias" has been used to describe breccias formed as a product of an explosion beneath the surface of the earth in which there was little movement of the blocks away from their original positions (\textit{Wright and Bowes}, 1968).
trusion and/or dyke-apophyses of "acid" rock piercing overlying country rock.

The mineralization has to be accompanied by hydrothermal alteration of the country rock.

The extrusive volcanic facies of "acid" rocks and land-based areas, where soluble or volatile material that reaches the surface, is easily dissipated, cannot be, in general, considered as favourable environment for base-metal mineralization. Even if such material was trapped, at least in part, the question remains whether volcanic emanations would have been adequate, in volume or content, to form economical base-metal deposits.

Some of the insignificant base metal occurrences, revealed in the prospected area, were deposited from hydrothermal brines, probably of meteoritic origin, and deficient in sulphur. Although the content of some base metal, particularly zinc can be rather high (up to 1 percent of zinc), the lack of sulfides in these mineral paragenesis is characteristic. Localization of these slight base-metal concentration usually takes place in rhyolite, along the very thin fissures (up to few millimetres).

For a quantitative estimation of the mineral potentialities in southeastern Iceland, the size of an "acid" intrusive body and the erosion level could be of interest:

a) Assuming that magmatic water, derived from a crystallizing "acid" intrusion, is the main constituent of ore-bearing hydrothermal solutions, it is evident that "acid" intrusions in southeastern Iceland are of rather small volume to release huge/sufficient amounts of water
necessary for formation of very large ore deposits. At present, one cannot, even theoretically, predict any figure pertinent to the scope of a possible base-metal mineralization, deposited from such solutions, except to mention that small deposits and/or disseminated mineralizations are more probable than large and compact ore bodies.

b) The erosion level lies rather deep, may be deeper than in any other part of the country. The granophyre intrusions are not too deeply dissected to be uninteresting in regard to the formation of hydrothermal ore-bearing solutions and its later preservation from erosion.

More detailed metallogenic explanations of the possibilities of base-metal mineralization in southeastern Iceland (mechanism of separation and concentration of base-metal, metasomatism/leaching from country rock, or "acid" intrusion by hydrothermal solution, etc) are beyond the scope of this report.
3) PROSPECTING CRITERIA AND USED PROSPECTING METHODS

The prospecting criteria should be established in accordance with the processes of ore deposition and regularity of its distribution in space. Therefore, bearing in mind the above mentioned characteristics of base-metal mineralization in southeastern Iceland, the prospecting carried out relied upon the following main criteria:

(1) Promising base-metal mineralization might be expected in cogenetical association with "acid" intrusions.

(2) Explosion-breccias, or dyke-apophyses of "acid" intrusives, as well as fractured zones, along and/or near the contact "acid" intrusion/country rock should be considered as main controlling factors of spatial localization of mineralization.

These eventual ore-bearing structures should not have reached the surface, or not been entirely open to the surface at the time of mineralization.

(3) Hydrothermal altered country rock.¹

Of course, these initial prospecting criteria might be, if needed, changed during future prospections in southeastern Iceland in consistency with new observations.

¹) Hydrothermal alteration caused/ore-bearing solutions should be distinct from regional hydrothermal propylitization, related to authometamorphic process within the volcanic stage.
The prospection in the area of Lón-Hornafjordur during the summer of 1970, comprised:

(1) A general geological survey, including the inspection of outcrops of igneous rocks, attempting to reveal certain indications which might be genetically related to base-metal mineralization and/or ore deposition. Particular attention was focused on contact zones around granophyre and rhyolite intrusions.

The chief aim of this surveying was to ascertain whether any outcrop of ore, or base-metal mineralization could be discovered. Excluding some parts of prospected terrain covered by large scree, the area of Lón and Hornafjordur is very well exposed. Therefore this direct examination of geological formations is a very useful way in searching for outcrops of base-metal mineralization in southeastern Iceland.

(2) The general geological survey has been supplemented by regional, reconnaissance geochemical prospection.

The application of geochemical prospection is rather handicapped in Iceland by the unfavourable climatic conditions (frost, etc) and their effects on dispersion pattern of base-metals.

Oxidation rate of sulfides in southeastern Iceland is extremely low. The sulfides (pyrite, chalcopyrite, sphalerite and galena) can be seen almost entirely fresh at outcrops. Therefore, secondary dispersion halos are very restricted, usually don't exceed scope of primary dispersion halos. Unusually low rate of base-metal entering into water does not make hydromorphic pattern to be
effectively used for the prospection in southeastern Iceland.

Mechanical dispersion halos are very widespread in the prospected area. Due to chemical stability of sulfide minerals under existing climatic conditions, as well as relatively short transport of ore minerals, it has been expected that mechanical dispersion halos might be helpful as prospecting guide in locating ore mineralization, outcrops or indications of ore mineralization.

To interpret correctly obtained values of geochemical samples, it has been needed to establish the background content of copper and zinc in various types of rocks in the prospected area.

The content of copper and zinc\(^1\) in the rocks varies in rather wide ranges. Table 3 shows the background and mean values of copper and zinc in "acid" and basic rocks in the prospected area. The frequency distribution of these metals is given in Figs. 2, 3, and 4. As it can be inferred from these data, a rather inhomogeneity of copper and zinc exists in their distribution in "acid" and basic rocks. Leaching and redistribution of these metals at magmatic stage, including propylitic alteration, led to impoverishment by copper and zinc in some parts of "acid" and basic rocks (particularly in rhyolite and granophyre which occasionally contain no more than 5-15 ppm of copper and zinc).

The threshold values are determined as 200 ppm of copper, and 300 ppm of zinc.

\(^1\) The geochemical prospection has been based on the distribution of copper and zinc, supplemented occasionally by determination of molybdenum and lead.
Table 3

The Background and Mean Values of Copper and Zinc in "Acid" and Basic Rocks in southeastern Iceland (ppm)

<table>
<thead>
<tr>
<th>Metal</th>
<th>Range/Mean</th>
<th>All samples</th>
<th>&quot;Acid&quot;</th>
<th>Basic rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 - 100(1)</td>
<td>100 - 160</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 - 200</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>Narrow Range</td>
<td>10 - 50</td>
<td>20 - 40</td>
<td>5 - 200</td>
</tr>
<tr>
<td></td>
<td>Wide Range</td>
<td>5 - 150</td>
<td>5 - 200</td>
<td>55 (1)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>48</td>
<td>32</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Threshold</td>
<td>200</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Zinc</td>
<td>Narrow Range</td>
<td>20 - 180</td>
<td>10 - 40(1)</td>
<td>70 - 150</td>
</tr>
<tr>
<td></td>
<td>Wide Range</td>
<td>5 - 230</td>
<td>5 - 60(1)</td>
<td>10 - 200</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>115</td>
<td>24 (1)</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>Threshold</td>
<td>300</td>
<td>250</td>
<td>220</td>
</tr>
<tr>
<td>Number of samples</td>
<td>1,525</td>
<td>625</td>
<td>184</td>
<td></td>
</tr>
</tbody>
</table>

(1) Highly altered rock; (2) Fairly fresh rock;

The rock samples were analysed in the field laboratory at Hlöfn.

According to the rate of concentration of base-metal, the revealed geochemical anomalies were classified
FIG. 2 FREQUENCY DISTRIBUTION OF COPPER AND ZINC IN GEOCHEMICAL SAMPLES IN LÓN AREA, SE ICELAND
1525 samples of Copper
1525 samples of Zinc
FIG. 3  FREQUENCY DISTRIBUTION OF COPPER AND ZINC IN "ACID" MAGMATIC ROCKS (GRANOPHYRE AND RHYOLITE) IN LÓN AREA, SE ICELAND (Samples: 625)
FIG. 4 FREQUENCY DISTRIBUTION OF COPPER AND ZINC IN BASIC MAGMATIC ROCKS (BASALT, GABBRO); 184 samples
into two groups: insignificant and significant (Table 4). Of course, the content of base metal is not always decisive factor a geochemical anomaly to be considered as "significant" or "insignificant". Other factors might also be important (scope of anomalous zone, its shape, geological setting etc).

<table>
<thead>
<tr>
<th>Metal</th>
<th>Geochemical anomalies (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Significant</td>
</tr>
<tr>
<td>Copper</td>
<td>over 500</td>
</tr>
<tr>
<td>Zinc</td>
<td>over 1,000</td>
</tr>
<tr>
<td>Lead</td>
<td>over 200</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>over 200</td>
</tr>
</tbody>
</table>
4) THE RESULTS OF PROSPECTION

The results of the general geological survey and geochemical prospection carried out during the summer 1970 in the area Lón - Hörnafjordur in southeastern Iceland are briefly as follows:

a) No deposits or occurrences of base-metal ore mineralization, which might be proposed to be explored in detail (drilling, mining exploratory workings, etc) were discovered.

Apart from the known outcrop of copper mineralization at Össura river, several other small occurrences of base-metal mineralization have been found.

b) Geochemical anomalies of copper, zinc, and/or molybdenum grouped into several areas were revealed by systematical sampling.

The location of collected geochemical samples, their types (primary rock, soil, stream sediment, rock debris, water) as well as the content of copper, zinc, lead, and molybdenum are shown in the geochemical map which is attached to this report.

The soil samples and stream sediment samples, including heavy fraction, if any, did not reveal any increasing content of base metal above their background values. So even slight geochemical anomalies were not observed within these types of samples. While this could have been expected for soil samples due to extremely low rate of migration of base metal by cold agneous solutions, the lack of ore minerals within stream sediments and heavy fraction is rather significant indication of very restricted
secondary, mechanical dispersion halos.

Rock fragments taken from colluviums, scree and along streams and rivers, as well as the samples of primary rocks, contain occasionally concentrations of copper and zinc above their background values:

**Copper:** The content of 200-500 ppm Cu in geochemical anomalies is most common. Such geochemical anomalies might be considered as insignificant if they are of very limited distribution (individual anomalies) and composed of material lacking chalcopyrite or other ore minerals. Even presence of individual, very seldom observed grains of chalcopyrite, occurring occasionally in the samples of gabbro, cannot be appraised as a valuable manifestation of ore mineralization.

The geochemical samples containing more than 500 ppm, particularly over 0.1 per cent of copper, with visible grains of chalcopyrite, occur within favourable metallogenic environment (explosive breccias, “acid”intrusions, etc) belong to significant geochemical anomalies, indicating a potential ore mineralization.

**Zinc:** The content of zinc in geochemical samples, ranging from 300 to 1,000 ppm, has been treated as slightly interesting; a more intensive attention has been paid to such anomalous samples when they were not single but abundant within certain area, lying in favourable metallogenic setting.

The samples containing over 0.1 per cent of zinc are worth of more detailed examination, especially when ore minerals or, at least, sphalerite were discernable.

Almost all revealed geochemical anomalies are
associated with "acid" intrusives and/or "acid" basic intrusive complexes and their contact zone with country rock.

The majority of insignificant geochemical anomalies of copper and zinc, as well as molybdenum, especially those with granophyre and rhyolite intrusions, are more related to the products of leaching and redistribution of base metal at late stage of crystallization or at volcanic stage, than to the constituents of ore paragenesis, deposited from ore-bearing hydrothermal solutions, which were formed and separated from parent "acid" magma. Many of the geochemical anomalies, containing over 0.1 per cent of copper and 0.5-1.0 per cent of zinc, were caused by base metal ore minerals.

The limited hydrogeochemical sampling carried out seems not to be efficient means of prospection in southeastern Iceland. The contents of copper, zinc and molybdenum in the collected samples, mostly seepages and springs, are listed in Table 5; the location of these samples is given at the geochemical map, enclosed with this report.

The content of copper, zinc and molybdenum in all these hydrogeochemical samples is not anomalous, except, to some extent, sample No. 5, which has been taken near of the outcrop of ore mineralization.

Excluding individual insignificant geochemical anomalies irregularly scattered over the prospected area, all other geochemical anomalies may be grouped into several areas, which are more interesting. By this way, the initial target of regional prospecting, covering over 1,000 sq. km, were narrowed down to approximately 50 sq. km to be prospected in detail.
Table 5

Analyses of Water Samples (ppb)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cu</th>
<th>Zn</th>
<th>Mo</th>
<th>pH</th>
<th>T, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 0016</td>
<td>&lt; 0.2</td>
<td>1.2</td>
<td>0.8</td>
<td>7.11</td>
<td></td>
</tr>
<tr>
<td>W 1050</td>
<td>&lt; 0.2</td>
<td>4.4</td>
<td>0.8</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>W 1051</td>
<td>&lt; 0.2</td>
<td>0.8</td>
<td>0.4</td>
<td>6.58</td>
<td></td>
</tr>
<tr>
<td>W 1052</td>
<td>&lt; 0.2</td>
<td>2.8</td>
<td>0.8</td>
<td>6.77</td>
<td></td>
</tr>
<tr>
<td>W 1053</td>
<td>&lt; 0.2</td>
<td>2.8</td>
<td>0.4</td>
<td>6.48</td>
<td></td>
</tr>
<tr>
<td>W 1071</td>
<td>&lt; 0.2</td>
<td>2.4</td>
<td>0.6</td>
<td>7.22</td>
<td></td>
</tr>
<tr>
<td>W 1074</td>
<td>&lt; 0.2</td>
<td>2.0</td>
<td>0.4</td>
<td>7.49</td>
<td></td>
</tr>
<tr>
<td>W 1078</td>
<td>&lt; 0.2</td>
<td>2.0</td>
<td>1.0</td>
<td>7.60</td>
<td></td>
</tr>
<tr>
<td>W 1081</td>
<td>&lt; 0.2</td>
<td>1.6</td>
<td>0.8</td>
<td>7.53</td>
<td></td>
</tr>
<tr>
<td>W 1082</td>
<td>&lt; 0.2</td>
<td>1.6</td>
<td>0.4</td>
<td>7.22</td>
<td></td>
</tr>
<tr>
<td>W 1083</td>
<td>&lt; 0.2</td>
<td>2.4</td>
<td>1.6</td>
<td>7.42</td>
<td></td>
</tr>
<tr>
<td>W 2041</td>
<td>&lt; 0.2</td>
<td>0.8</td>
<td>0.4</td>
<td>7.38</td>
<td></td>
</tr>
<tr>
<td>W 2043</td>
<td>&lt; 0.2</td>
<td>3.2</td>
<td>0.8</td>
<td>7.31</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3.9</td>
<td></td>
<td>1.8</td>
<td>7.38</td>
<td>5</td>
</tr>
<tr>
<td>19</td>
<td>1.1</td>
<td></td>
<td>1.6</td>
<td>7.52</td>
<td>9</td>
</tr>
<tr>
<td>20</td>
<td>&lt; 1.0</td>
<td></td>
<td>1.0</td>
<td>7.36</td>
<td>10</td>
</tr>
</tbody>
</table>

Analyst: Dr Stefan Arnorsson, Reykjavik.

Among the areas where some indications of ore mineralization were found, the following should be mentioned:

4.1. - Reydara.

So far the most interesting area with regard to base-metal mineralization in the Lón-Hornafjordur area
FIG. 5 THE VERTICAL SECTION THROUGH THE REYDARA GRANOPHYRE INTRUSION (SCHEMATICALLY ONLY, NO SCALE)

seems to be the Reydará granophyre intrusion and its vicinity. The known copper mineralization at Ósara river has been described in my last year’s report (Jenovics, 1969).

The Reydará granophyre intrusion, though very close to the road, has not yet been petrologically investigated or, at least, the publications on its petrological features are not available.

The intrusion is deeply dissected by the Reydará valley, vertically almost 700 metres, but still no floor of intrusion is visible. The remaining portions of the roof are still preserved at the top of the mountain. Several dykes-apophyses of granophyre are piercing overlying basalt lava (Fig. 5). The intrusion is partly well exhibited, but in part hidden below thick screes.
The granophyre is occasionally intensely altered, particularly on the south slope of the mountain (argillization prevails, at intervals silicification as well). Especially intense leaching of the granophyre, probably related to hydrothermal metasomatism at a late stage of the magmatic crystallization, can be observed near the roof (the inner contact of intrusive, as well as along dyke apophyses). These parts of the intrusion, as well as adjacent basalts contain often in places increased concentrations of base-metals (Fig. 5).

A provisional geological map, scale 1:10,000, shows approximately the distribution of the geochemical samples as well as the location of the outcrops of base-metal ore mineralization (Fig. 6).

Summing up the results of the preliminary prospection at the Reydara intrusion, it should be pointed out that:

a) No large and economically significant outcrops of base-metal deposits were found, but

b) Several indications of sparsely disseminated ore mineralization (molybdenum, and copper - zinc/lead) were observed within the intrusion and/or its country rock, which is hydrothermally altered basalt.

Molybdenum: The preliminary geological inspection of the Reydara intrusion, which was undertaken last year revealed some increased concentrations of molybdenum in the granophyre. Therefore this year more close attention was paid to these occurrences.

At the south slope of the mountain, within a rather small, highly silicified zone in the granophyre in-
FIG. 6.
trusion several selected hand-specimens of rock debris contained molybdenum ranging usually from 30 to 150 ppm, occasionally up to 250 ppm. Only two samples contained more than 500 ppm of molybdenum. Molybdenite has not been identified, but molybdenum ocher was discerned in the specimens containing over 500 ppm of molybdenum.

The anomalous content of molybdenum has also been sporadically observed near of the peak of Reydarar-tindur as well as at its northwestern slope. Although systematic sampling of this granophyre intrusion and its contact zone was not undertaken, it seems rather evident that the increased concentrations of molybdenum at the granophyre outcrop are very irregularly distributed and characterized by small scopes.

The contents of copper, zinc, and lead in the geochemical samples which are anomalous with respect to molybdenum concentrations, are almost always within the range of background values, usually far below their mean concentrations in granophyre. The increased concentrations of molybdenum are related, most probably, to processes of hydrothermal silicification, but generally not accompanied by sulphide ore mineralization. It seems as almost certain that local concentrations of molybdenum were formed on account of leaching of granophyre by hydrothermal solutions and redistribution of molybdenum, chemically closely associated with silica. This mobilization of molybdenum within the process of hydrothermal metasomatism of granophyre could have taken place at late stage of crystallization of "acid" magma.

Although the content of molybdenum in the geochemical samples which were collected during the summer of
1970, is far below the concentration of molybdenum in economically significant ore (approximately 2,000 ppm of Mo), still the definite conclusion can not be reached whether higher concentrations of this metal, revealed by our prospection, might be found elsewhere in the Reydara granophyre intrusion. The outlook is not particularly promising, but some possibilities are not entirely ruled out.

**Copper:** Some sparse occurrences of chalcopyrite mineralization have been found both in situ and in screens near the south contact of the granophyre with the basalt, especially along the dyke-apophyses of the granophyre (see the geochemical map of Reydara - Fig. 5 and Fig. 6).

The copper content in geochemical samples, irregularly distributed and with visible chalcopyrite varies from 0.05 to 0.3 per cent. Only two samples had 0.6 per cent of copper. More often the copper content of slightly anomalous geochemical samples are ranging from 200 to 350 ppm. Chalcopyrite in such geochemical samples was not observed.

Although systematical sampling has not been carried out, it seems that the mean content of copper at the surface of the Reydara granophyre as a whole and/or its contact zone is too low to be economically significant. However, it is still open whether smaller but richer ore mineralization might be found within the Reydara intrusion.

**Zinc and lead:** Although increased concentrations of zinc and lead (350-900 ppm, more frequent 350-400 ppm of zinc, and exceptionally up to 200 ppm of lead) were revealed in many geochemical samples, it is probable that these geochemical anomalies within the Reydara intrusion
are of local importance only.

**Hrossatindur:** At the western slope of the mountain Hrossatindur, at the Óssura valley, there are a few outcrops of zinc ore mineralization (sphalerite), associated with some lead (galena) and copper (chalcopyrite). Pyrite is very sparsely developed. Quartz and calcite are the main guange minerals.

The outcrops are mostly covered by scree, so that their evaluation presented in this report has to be considered only as preliminary.

The ore mineralization is very probably related to breccia-pipes of rhyolite, intruded into basalt lava. The hydrothermal mineralization is of low temperature, and its type seems similar to the copper mineralization at the Óssura river. It is very probable that both these ore mineralizations are genetically connected with the same process within which a certain zonation took place: sphalerite/galena association at Hrossatindur was formed in higher levels, while chalcopyrite, accompanied with slight mineralization of sphalerite/galena were deposited in deeper horizons. Vertical distance between these two occurrences is about 350 metres.

The width of outcrop below the peak of Hrossatindur might be tentatively estimated as up to 10 metres. The extension of the outcrop, which is covered by the scree, is uncertain. The content of zinc in the samples which were taken partly from the outcrops and partly from the scree varies between 1.0 and 13.0 per cent. An average content of zinc most probably does not exceed a few percent. The content of lead is usually between 0.1 and 0.3 per cent.
Although these occurrences do not look as very promising, nevertheless their more detailed investigation is justified.

4.2. - Fossadalur.

At the bottom of the stream at Fossadalur (the valley of Fossa) a few rhyolite dykes containing slight mineralization of zinc were found during the prospection. The rhyolite dyke which is close to the waterfall will only be described.

The rhyolite dyke intruded into basalt lava. Its width varies from 3 to 6 metres. Along the strike, the dyke can be traced over 100 metres (it is partly covered by scree). Within the dyke numerous, very thin fissures (usually 2-5 mm) have been developed, parallel with the general strike of dyke (Fig. 7). These fissures are filled by so far undetermined minerals, often black in colour. None of ore sulphide minerals have been identified. The wall rock is highly affected by hydrothermal solutions (argillic type of alteration).

The samples taken random from the outcrop of the rhyolite dyke had always increased content of zinc, ranging from 0.2 to 1.0 per cent. The copper and lead contents within the same samples were never anomalous but similar to their background values.

A tentative conclusion pertinent to the genesis can be drawn that the zinc mineralization was associated with leaching of rhyolite (but after its crystallization) by hydrothermal solutions, which mobilized zinc from rhyolite and from which zinc was deposited along very thin
FIG. 7  THE MINERALIZED RHYOLITE DYKE AT FOSSADALUR
(Schematic ally only)
fissures in the rhyolite (lateral secretion process). The lack of sulphide indicates absence of sulphur in this process.

Although the content of zinc at the rhyolite outcrop is too low to be economically significant, this occurrence is worth studying in detail. If primary sulphide ore minerals were later oxidized, the existence of richer zinc concentrations in deeper portions of the rhyolite dyke might not be entirely ruled out.

4.3.- Gjadalur.

Several geochemical anomalies of zinc have been revealed in the slaufrudalur granophyre intrusion, exposed by one of the right tributaries of the river Gja (the location is given at the geochemical map of the Lón-Hornafjordur area, scale 1:50,000).

The increased content of zinc has been gained from a fractured zone in the granophyre, near its contact with basalt lava (Fig. 8). This zone might be traced for over 100 metres along its strike, with a thickness of approximately 6-8 metres. The anomalous geochemical samples were taken from fissures and small pockets, formed within this zone, and filled up by soft material, composed mostly of hydrothermally altered granophyre (chloritized granophyre?).

The content of zinc in this altered material is rather uniform, ranging from 600 to 2,000 ppm, but the samples with 1,000-1,200 ppm of zinc prevail. Ore minerals including sphalerite were not seen. The zinc content in
adjacent granophyre (wall-rock of fissures) has the background value. The content of copper in the same geological samples showing anomalous zinc content does not exceed 200 ppm.

These geochemical anomalies of zinc are neither economically significant nor could they be considered as important indication of any larger ore mineralization. Most probably these increased concentrations of zinc were connected with local hydrothermal alteration of the granophyre.
4.4. - Vesturnhorn.

Within the contact zone of the Vesturhorn granophyre intrusion several geochemical anomalies have been gained.

Although the granophyre intrusion and its contact with the country rock (basalt lava and/or gabbro and mixed vein complex) is deeply exposed by erosion at Kastar valley (Kastardalur) and along the coast, still direct inspection of the granophyre or systematical geochemical sampling of its outcrop (primary rocks) have not been everywhere possible, due to thick screes, particularly at Kastardalur.

Among the geochemical samples, which were taken at intervals from 200 to 500 metres, several had over 0.1 per cent of copper, and one geochemical sample as much as 0.83 per cent of copper. The ore minerals, particularly chalcopyrite, were deposited mostly within single, very thin vein (up to 0.5 cm) irregularly scattered either in the granophyre or adjacent basalt and/or gabbro. Besides the insignificant thickness, the noted mineralized veins exhibit unfortunately slight extension as well.

So far as is known, it seems that the observed occurrences of base-metal mineralization, genetically related to the Vesturhorn granophyre intrusion, are more of mineralogical than economical interest. The obtained results can not apparently encourage any further detailed exploration of this area.
CONCLUSIONS

Summing up the results of the reconnaissance prospection for base metal mineralization, which has been carried out during the summer of 1970 in the area Lón - Hornafjordur in southeastern Iceland, the following main concluding remarks are presented below:

1) The prime objective of the prospection has been to detect, if any, significant outcrop of base metal deposit, or indications of ore mineralization which further exploration might be considered as economically sound.

2) The prospected area, which covers approximately 1,000 sq km, is built up of Tertiary basalt lavas accompanied by unusually large volume of "acid" extrusives (rhyolite). Relatively big stocks and dykes of "acid" igneous rocks (granophyre/granite, and rhyolite) and/or complex intrusions of "acid" and basic igneous rocks (granophyre/granite - gabbro) have been intruded into the extrusives.

Although the "acid" magma has been very mobile, as a result of relatively enrichment of volatiles at the late stage of its crystallization, the general geological environment of southeastern Iceland as a whole does not seem to be particularly favourable with respect to the formation of large hydrothermal base metal deposits. An impression has been gained that lack of suitable structure to trap ore-bearing solutions, if they were separated from "acid" magma at late stage of its crystallization, is main-
ly responsible for the scarcity of big base metal concentrations.

3) There are several outcrops of slight base metal mineralization (copper, zinc, lead and/or molybdenum) in the prospected area. Some of them, like the copper mineralization at Össura river, have been known for some time, while others were revealed during this prospection.

The base metal hydrothermal mineralization is genetically associated with intrusions of "acid" rocks (granophyre/granite, and rhyolite) which are most probably derived from the upper mantle. The mineralization occurs usually within granophyre and/or its contact zone with the country rock (basalt lavas), or it is related to rhyolitic explosion-breccias pipes.

4) The prospection did not reveal any outcrops of base metal deposits for which detailed exploration (including drilling, exploratory mine workings, etc) can be considered as justified.

5) Although the prospection did not find any large outcrops of base metal deposits, yet several smaller areas with some indications of base metal mineralization have been revealed. By this way the initial prospection target of 1,000 sq km has been narrowed down to approximately 50 sq km where some occurrences of base metal mineralization were located.

According to the present knowledge, it seems that the area of the Reydara granophyre intrusion is most interesting regarding base metal mineralization within the prospected area. Apart from the copper mineralization at
Össura river, and zinc outcrop at Hrossatindur, there are several other localities with slight and patchy distribution of copper and molybdenum. Due to very limited area of mineralization and low concentrations of base metals, these occurrences are only manifestations of ore mineralization but not economically significant outcrops of base metal deposits. However, I would like to point out that lack of large outcrops of base metal deposits around the Reyðara granophyre intrusion cannot be conclusive evidence to rule out entirely the possibility of the existence of richer and/or bigger concentrations of base metal genetically related to the "acid" intrusion. The probability is, however, small (but we have to take it into consideration).

Other occurrences of very slight base metal mineralization (Fossadalur, Vesturhorn, Hnappadalstindur) might be worth studying in detail, but at the time being they do not seem economically significant to incite exploratory workings (drilling, etc).

6) Although the prospection covered only a part of the area with "acid" intrusions, a tentative estimation, grounded on extrapolation and inference from geological knowledge gained on the mineral occurrences in the Lón-Hornafjördur area, might be reached that the type and concentration of base metal mineralization on other parts of eastern and southeastern Iceland are expected to be similar (like within prospected area).
RECOMMENDATIONS

Since the prospection carried out during the summer of 1970 did not discover any outcrops of base metal mineralization, which might justify detailed exploration, further looking for ore minerals in southeastern Iceland, if any, can be undertaken at the level of preliminary prospection only.

Bearing in mind that the outlook for economically significant base metal deposits is not particularly promising, although all possibilities are not entirely excluded, additional investigations could involve the following:

1) In order to complete prospection and ascertain conclusive evidence pertaining to the scope of known copper and zinc mineralization around the granophyre intrusion of Reydara, especially at Óssura valley, the geophysical surveying, particularly the method of induced polarization (IP) is recommended.

2) If the Icelandic Government is interested to set up a long-term programme for systematical mineral survey of the country, the following recommendations are proposed for southeastern and eastern Iceland:

a) Detailed geochemical prospection around "acid" intrusions (granophyre/granite, and rhyolite) in the area of Lón-Hornafjordur, complemented by geological mapping.
b) Regional geochemical prospection within the areas with "acid" intrusions, apart from the area which has been prospected during 1970 (see Fig. 1).

These investigations can be carried out by the Icelandic geologists (1-2 geologists and 2-3 students), and might be completed during two or three field seasons.

c) Regional airborne geophysical survey in the areas with "acid" intrusions.

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