GEOLOGICAL PROSPECTING FOR POZZOLANIC MATERIALS IN ICELAND

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Iceland is made up mostly of basalt lavas. Significant amounts of other types of rock occur also; among them acid lavas with an estimated volume percentage of 8-10% of the total and detrital beds (sedimentary and pyroclastic) constituting another 6-10% of the total rock with much higher percentages in the Quaternary formation. The lavas are more or less crystalline throughout and are not very significant in this study. Our attention rather goes towards the detrital rocks where glassy varieties are abundant such as tuffs, ignimbrites and hyaloclastites. Both fresh rock and such that has been altered to various degrees as a result of burial or hydrothermal metamorphism is available for study. Of particular interest is the abundance of hyaloclastite (basaltic) and locally pitchstone (rhyolite or dacite) rock erupted under subglacial conditions in the course of repeated glaciations during the last 3 million years.

In SW-Iceland a 70 km broad band of rock formed during the last 3 million years is structurally symmetric.about the rift axis where volcanism is most recent. The State Cement Works of Akranes is located near the western margin of this zone of relatively recent activity from where derive most of the samples described in this study (Fig. 1)

Extensive geological mapping of SW-Iceland during the last few years led to the discovery of a number of rock units that seemed likely to possess pozzolanic properties. The prospecting reported here was carried out so as to include several varieties of rocks of different composition and different state of alteration. Certainly it cannot be regarded as exhaustive but it may indicate what type of rock we should look for more closely in future search. The premises that had to be fulfilled besides being likely to have pozzolanic properties were 1) good accessility, 2) nearness to Akranes or Reykjavík, 3) great quantities and 4) little or no overburden so as to enable open pit mining if some turned out to be useful.

Altogether 15 samples were collected from 14 different rock bodies. The location is shown in Fig. 1. The samples were taken randomly from the layer examined usually from well exposed walls where the structure and stratification could be clearly seen. The total weight of each sample was 40-50 kg. When layered or otherwise inhomogeneous, representative portions of the different layers were collected to compose the final sample. The sampled rock can be classified as follows according to the chemical composition and rock texture:

Group 1: pozzolans of basaltic composition including one sample of hyaloclastite sediment (no. 10),one sample of zeolitized pillow lava and tuff (no. 7) and 4 samples of hyaloclastite tuffs in different state of alteration (no. 1, 3, 13, 14).

Group 2: pozzolans of andesitic and dacitic composition including two samples of ignimbrite (no. 6, 9) and two samples of pitchstone (no. 12, 15).

Group 3: pozzolans of rhyolite composition including one sample of rhyolite from a lava flow (no. 11) 2 samples of ignimbrite (no. 4 and 5), one sample of pitchstone (no. 8) and one sample of altered pitchstone breccia (no. 2).

For location and outcrop description see appendix.

TABLE 1

Chemical analyses of pozzolanic materials from West-Iceland

Sýni nr.	1	2	3	4	5	6	7	8
SiO_2	41,26	66,53	47,99	63,63	73,73	55,90	43,20	72,4
Al_2O_3	10,91	11,37	11,56	13,97	12,58	13,60	13,18	11,9
TiO_2	2,35	0,18	2,81	0,57	0,27	1,38	1,48	0,2
Fe_2O_3	13,47	3,15	13,17	3,54	1,66	10,33	4,23	0,1
FeO	1,32	0,00	4,07	0,60	1,44	1,32	5,15	2,3
MnO	0,19	0,05	0,21	0,06	0,06	0,22	0,14	0,0
MgO	4,04	0,47	4,94	0,68	0,10	2,69	8,20	0,1
CaO	6,44	2,14	4,32	2,27	0,03	6,10	12,48	0
Na_2O	0,63	1,88	0,65	1,50	4,45	3,25	1,81	4,0
K_2O	0,40	2,27	0,87	1,47	3,49	1,14	0,20	2
H_2O	19,10	11,60	9,00	12,20	1,20	3,50	9,76	4,2
Σ	100,11	99,64	99,59	100,49	99,01	99,43	99,83	99

Sýni nr.	9	10	11	12	13	14	15	
SiO_2	62,30	47,06	76,13	60,93	41,67	45,58	67,25	
Al_2O_3	12,73	14,21	11,80	13,92	12,47	14,16	13,42	
TiO_2	0,41	2,98	0,26	0,86	1,92	1,61	0,58	
Fe_2O_3	0,36	9,17	1,04	3,07	8,26	4,04	2,37	
FeO	4,79	6,83	1,80	3,35	5,51	8,74	2,39	
MnO	0,08	0,20	0,02	0,15	0,19	0,18	0,11	
MgO	0,95	1,14	0,134	1,25	6,94	8,46	0,74	
CaO	2,70	8,11	0,39	3,96	9,29	9,86	2,68	
Na_2O	1,93	1,54	3,91	3,04	1,08	1,54	2,75	
K_2O	2,11	0,40	3,00	1,63	0,12	0,17	1,71	
H_2O	11,40	8,35	1,52	7,52	12,20	5,21	6,22	
Σ	99,76	99,99	100,00	99,68	99,65	99,55	100,22	

Table 1 shows the chemical analyses of the samples. The petrologic character is obvious with the basalts being low in silica but high in Ca, Mg and Fe contrary to the dacites and rhyolites which are high in silica and alkalies. The water content of the samples is generally high as a result of the hydrated glass, clay and zeolite which they contain. In the most altered samples (no. 2, 3, 9) potassium is higher than sodium and they appear slightly enriched in silica. Sample 10 is unexpectedly low in magnesia. The chemical analyses were made at the Science Institute, University of Iceland.

Representative samples of the rock were studied in thin section in order to get information on the mineralogy, mineral proportions and rock texture. The samples of intermediate and acid composition were not subjected to point counting because of their very fine grained texture which was only incompletely resolved by the microscope. Thin sections of sieve fractions have not been studied yet. Because of the rather homogeneous nature of most of the samples it is thought that the mineral proportions will not be significantly different between rock and sieve fractions. The clay minerals and zeolites have not been determined exactly using X-ray techniques.

The results of the microscopic examination of the Group 1 samples is shown in table 2.

Table 2

Constituents and mineral proportions of samples of basaltic composition.

Sample no.	1	3	7a	7b	10a	10b	10c	13	14	
tachylite	-	24,70	39,73	59,81	25,76		21,39	33,96	21,80	%
sideromelane	44,51	12,25	12,98	-	44,66		71,39	34,79	57,67	-
palagonite	39,02	54,94	23,45	-		96 %	3,54	13,33	8,51	-
clay	10,00			18,64	-					-
zeolites	5,69	2,56	11,24	10,03	-			2,50	3,10	-
calcite	-	1,00		2,40	13,17					-
Fe oxides	-	-			11,64	2 %	1,47	8,75	4,56	-
pl+px+ol	0,78	4,55	12,60	9,13	4,77	2 %	1,77	6,67	4,36	-

Thin section 7a is a hyaloclastite tuff whereas 7b is a pillow fragment. Samples 10a, 10b and 10c represent textural varieties which compose sample 10.

The rocks represented in table 2 are composed of tachylite (opaque basaltic glass) and/or sideromelane (translucent, isotropic, basaltic glass) that has undergone alteration to palagonite and montmorillonite type clay. Vesicles in the glass, if filled, contain either clay, calcite or zeolites. The glass shards are cemented by the alteration products (palagonite, clay, calcite or zeolites. One sample (no. 14) is almost fresh, one (no. 7) is particularly rich in zeolites, and one (no.3) is strongly altered to montmorillonite type clay. Samples no. 7 and 10 showed the best pozzolanic properties according to G. Gudmundsson's results (1).

The rocks of andesitic and dacitic composition consist essentially of glass. The ignimbrites (no. 6 and 9) contain fragments of basalt (xenoliths) amounting to some 10-20% of the total rock. The glass of no. 6 has a refractive index of 1.57-1.58 and shows only incipient alteration to opaline and zeolite. The glass of no. 9 has a slightly lower refractive index and shows a higher degree of alteration to opaline and clay. Both are unwelded and do not show devitrification products of feldspar and quarts common in the welded rhyolitic ignimbrite. The dacitic pitchstones (samples no. 12,15) consist almost entirely of glass which shows perlitic texture and has a refractive index of 1.51-1.52. In the glass occur microlites of plagioclase and pyroxene besides scattered fenocrysts of the same minerals. The pitchstone is partly altered to clay and opaline.

The Group 3 rocks which are rhyolitic in composition are all hypocrystalline rocks. The ignimbrite (samples 4, 5) consists of pumice fragments and shards. Devitrification to feldspar and quartz is extreme in the sample of welded ignimbrite. A small amount of rock fragments (basalt) is common to both samples. The pitchstone samples 2 and 8 are both largely devitrified due to alteration to clay and quartz besides abundant growth of spherulites of feldspar and quartz in sample no. 8. The rhyolite sample consists of a quartz feldspar intergrowth set in a groundmass of brownish spherulites probably feldspar and quartz also. Fenocrysts of feldspar and secondary quartz are common to all the rhyolites.

The results obtained on the pozzolanic properties of the rhyolitic rocks are generally poorer than those obtained for the andesites and dacites (1). This is possibly due to the higher crystallinity of the rhyolites of which the glass appears to be more liable to devitrification.

References.

(1) Gudmundsson, G., Investigations on Icelandic pozzolans, Reykjavík 1975.

(2) Gudmundsson, G., and Ásgeirsson, H., Some Investigations on Alkali-Aggregate Reaction, Cement and Concrete Research, 5, 211-220, 1975.

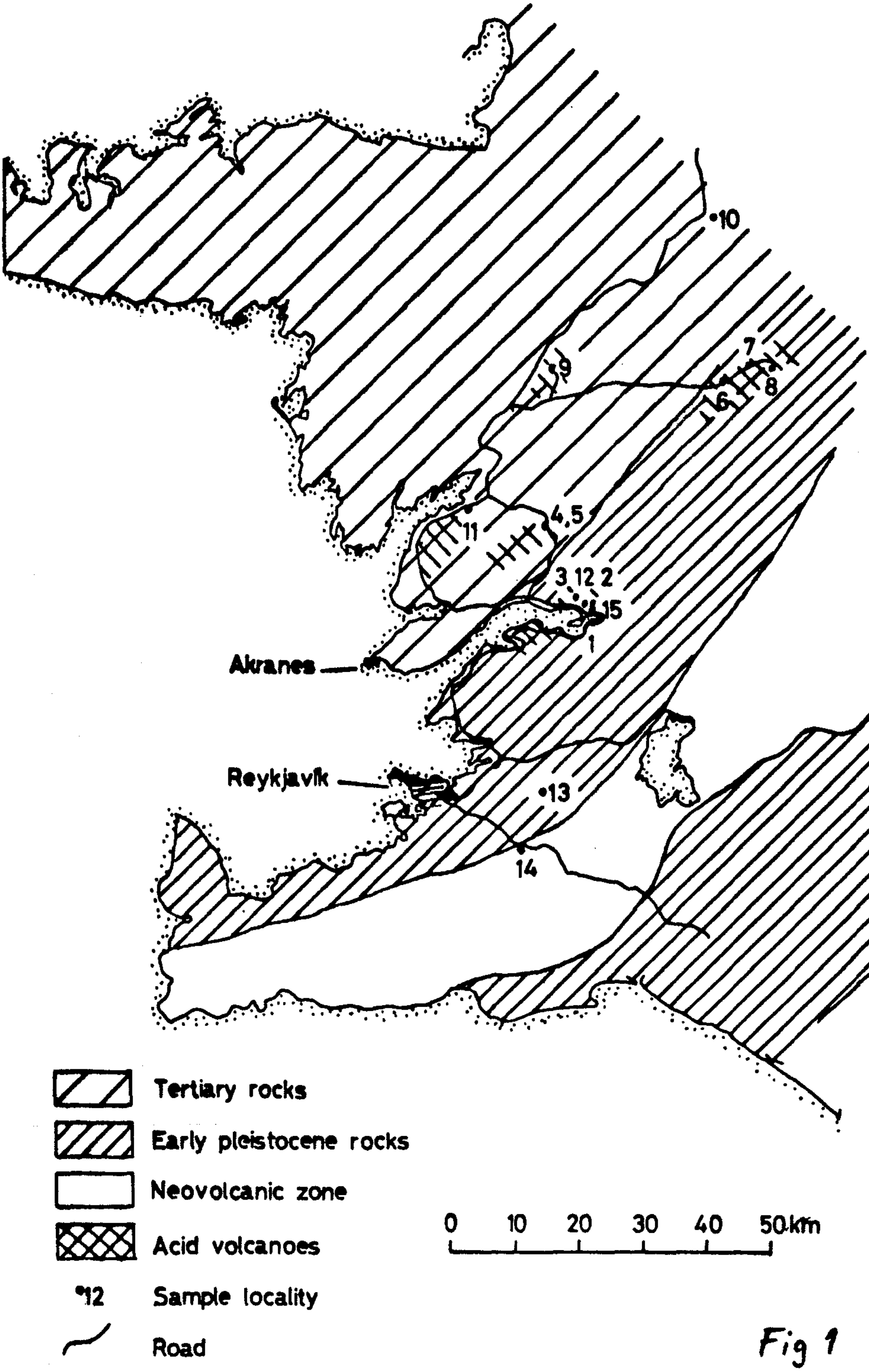
10
7
8
6
9
11
4,5
3 12 2
15
1
Akranes
Reykjavik
13
14
Tertiary rocks
Early pleistocene rocks
Neovolcanic zone
Acid volcanoes
12
Sample locality
Road
0
10
20
30
40
50 km

Fig 1

Appendix.

Location and outcrop description of samples reported in table 1:

(1) Múlafjall, Hvalfjördur. Road cut on northern side of the mountain. The hyaloclastite tuff forms a 10 m thick layer dark brown to black in colour. The base is conglomeritic but the upper part is a homogeneous finegrained tuff.

(2) North of Bláskeggsá Hvalfjördur. Small outcrop of yellowish chaotic pitchstone breccia. Intended for use as SiO_2 rich raw material for cement production.

(3) Lower slopes of Brekkukambur in Hvalfjördur behind camouflaged fuel tanks. Large mass of thoroughly altered hyaloclastite tuff and breccia of predominantly greenish colour, grading into redbrown where oxidized.

(4,5) Gully of Villingadalsá 1 km east of Stóra Drageyri and east of the road across Dragi. Base of layer (no. 4) consists of a loose tuff and agglomerate about 4 m thick overlain by a welded ignimbrite (no.5) 12 m thick at the sampling locality but thickening to more than 100 m towards north.

(6) Hellisgil near the farm Gilsbakki in Borgarfjördur. The ignimbrite layer is typically nonwelded and has a thickness of about 10-20 m in the general area around Hellisgil. At this locality the layer consists of a grayish pumiceous agglomerate. Reddish varieties prevail locally when the layer is followed along strike.

(7) Merkjagil between the farms Hallkelsstadir and Þorvaldsdalur in Hvítársída, Borgarfjördur. The pillow breccia and associated hyaloclastite tuff is exposed in a 10-20 m high wall just north of the road. The layer or pile extends over a large area on the slope to the north of the outcrop.

(8) Northern slope of the hill Tunga in Hvítársída, Borgarfjördur. From steep walls of pitchstone which form an exceptionally thick carapace on the top and margins of a rhyolite flow or dome which constitutes the top of the hill.

(9) Southern tip of the hill Hallarmúli above the farm Höll in Þverárhlíd, Borgarfjördur. 15 m thick layer of agglomeritic nonwelded ignimbrite of palegreen colour containing basaltic xenoliths. The layer is one of three exposed in Hallarmúli and separated by flows of basalt and andesite.

(10) Austurá tributary to the Heidarspardsá in Holtavörduheidi. Conspicuous sediment layer 40-50 m thick exposed in deep gullies cut into the slope east of Heidarspardsá. The sediment grades from conglomerate to finegrained siltstone. The fine matrix is mainly basaltic glass of hyaloclastite origin. Most pebbles are basalt.

(11) Skeljabrekka, Borgarfjördur. Rhyolite flow of great thickness and extent exposed near the mainroad 500 m west of the farm. The rock is light coloured with a distinct platy cleavage giving rise to extensive screes.

(12) Gully of Midsandsá Hvalfjördur. Pitchstone from lobes, pillows and breccia exposed in the walls of the gully.

(13) Seljadalur 15 km east of Reykjavík near old road across Mosfellsheidi. Extensive layer forming the eastern slope of the mountain Grímmannsfell. The rock at the sampling locality is a hyaloclastite tuff containing scattered lumps of lithic basalt.

(14) Arnarþúfur 14 km southeast of Reykjavík close to the near road to Bláfjöll. Ridge shaped hill of brown hyaloclastite tuff very poor in lithic fragments.

(15) Bláskeggsá, Hvalfjördur. Quarry exploited for SiO_2 rich raw material for cement production. The same material (designated rhyolite) was tested for pozzolanic properties in an earlier investigation (2). Lobes of pitchstone interlayered with greenish altered pitchstone breccia.