PART I

The Alftafjordur Volcano

CHAPTER 1

Introduction

The greater part of the Austurhorn area is composed of the products of a Tertiary volcanic centre, here called the Alftafjordur volcano. This volcano is one of a number of volcanic centres known to occur in the Tertiary area of eastern Iceland (fig. 1), of which three have so far been described - Breiddalur (Walker, 1963), Thingmuli (Carmichael, 1962) and Reydarfjordur (Gibson, 1963, and Walker, 1959b) Flood basalts continued to be erupted from fissures during the activity of the volcanic centres and the two contrasting forms of vulcanicity more or less kept pace with each other. During the period of their activity, most of the volcanic centres were at times capped by volvanic cones which stood up above the surrounding flood basalts, but at other times the volcanic cones may have been completely overlapped and buried by flood basalts (Gibson, 1963, suggests that the Reydarfjordur volcanic centre may never have formed a topographical volcano). Many of the volcanic centres were undoubtably active at the same time, the periods of their activity overlapping, and it will be shown that the Alftafjordur volcano is more or less contemporaneous with the Breiddalur volcano, though the former probably ceased its activity first. The Breiddalur volcano itself was still active when the Thingmuli centre began its activity (Walker 1963). Thingmuli remained active long after the Breiddalur volcano became extinct.

The total extent and thickness of the Alftafjordur volcano is not known, as much of the volcano is hidden beneath Alftafjordur and the open sea, and only the upper south-western margins of the volcano are seen in the Austurhorn area. As well as in the Austurhorn area, however, the products of this volcanic centre are also known to occur north of Alftafjordur, near Djupivogur, and the centre must have been at least comparable in size with that of Breiddalur. Flood basalts and other lavas that are the lateral equivalent of the upper part of the Alftafjordur volcano, and similar lavas stratigraphically above the volcano, are exposed in western and south-western parts of the area mapped.

The Alftafjordur volcano resembles the other volcanic centres, in being made up of basic, intermediate and acid lavas and pyroclastic rocks; acid and intermediate rocks are practically confined in such centres, and the basic lavas of the volcano are characteristically much thinner than flood basalt lavas of similar composition.

As well as extrusive rocks, most of the many minor intrusions within the Austurhorn area, except those related to the much later Austurhorn gabbro-granophyre intrusion, are associated with the activity of the Alftafjordur volcano, as also is the hydrothermal alteration - propylitisation - which affects much of the area.

CHAPTER 2

Field Identification of Rock Types

Lavas

In the Tertiary areas of eastern Iceland it has become the standard practice to recognise five separate lave types - olivine-basalts, tholeiites, andesites, rhyolites and porphyritic basalts - which can be easily distinguished in the field (Walker 1959b, 1963, Carmichael 1962, Gibson 1963). The field characteristics of these lavas have been fully described in the references cited. The first four types form a continuous series from basic to acid and all transitional types, such as olivine-tholeiites and tholeiitic-andesites occur, though these cannot be reliably distinguished in the field. The porphyritic basalts on the other hand do not form part of this series, as they include all basalts with more than 5% feldspar phenocrysts, independent of whether the matrix is of tholeiite or olivine-basalt.

Between many of the lava flows there are thin red dust beds, usually about 20 cm. thick. These dust beds are made up chiefly of basalt glass and they appear to represent layers of volcanic ash (Hawkes, 1916) deposited during dust storms; such dust storms are very common in the interior of Iceland today.

The distinctions between the non-porphyritic lava types tend to become obscured when the lavas are affected by hydrothermal alteration associated with major volcanic centres. Where the alteration is most intense all the lavas become soft and greenish, and it is often almost impossible to distinguish between acid and basic rocks in the field. The red dust beds are particularly sensitive to this alteration, and become purple or green. The distinctions between lava types are also partly obscured close to major intrusions.

The relative proportions of the lava types differ in flood basalt areas from those in areas of central volcanic activity (table 2).

Olivine-basalts and porphyritic basalts are more abundant amongst flood basalts, tholeiites are equally common in either environment, while andesites and rhyolites are practically confined to the major volcanic centres.

The thickness of the individual lavas is related to some extent to the slope on which they were laid down and flood basalt tholeiites, laid down on a more or less horizontal surface, are generally thicker than tholeiites laid down on the sloping flanks of a volcano (table 1). However a distinction between flood basalt tholeittes and flank tholeiites can only be made with certainly where

Table 1. Average thicknesses of tholeiitic lavas (in metres)

	Average thickness
A. FLANK BASALTS	
Alftafjordur volcano	3.5m
Thingmuli volcano* (Carmichael, 1962)	6.0m
Breiddalur volcano (Walker, 1963)	4.0m
B. FLOOD BASALTS	
Breiddalur area (Walker, 1963) ...	14.0m
Reydarfjordur area# (Walker, 1959 b)	10.0m

*probably includes some flood basalts

#probably includes some flank basalts

there is also a difference in dip between the two types.

An estimate of the relative abundance of the lava types (and pyroclastic rocks) in the Austurhorn area which are the products of the Alftafjordur volcaniccentre are given in table 2, with similar estimates for two other areas in eastern Iceland for comparison. The estimate in the Austurhorn area is based on areal coverage and can only be regarded as approximate.

Table 2. Relative abundance of rock types

Rock type	Alftafjordur volcano	Thingmuli* (Carmichael, 1962)	Reydarfjordur# (Walker, 1959b)
Olivine-basalt	2%	7%	23%
Tholeiitic basalt	28%	50%	48%
Andesite	10%	18%	3%
Rhyolite	18%	21%	8%
Porphyritic basalt	1%	1%	12%
Pyroclastic rocks	21%	4%	6%

*mainly products from a central volcano

#mainly products from fissure eruptions (flood basalts).

Pyroclastic Rocks

The Tertiary pyroclastic rocks of eastern Iceland include tuffs, agglomerates, breccias, welded tuffs and welded agglomerates, and "emulsion" rocks (Walker, 1963 p. 47), and all gradations appear to occur between true pyroclastics and true lavas. The great majority of the pyroclastic rocks are associated with the activity of the Tertiary major volcanic centres.

Tuffs: These comprise all pyroclastic rocks made up predominantly of fragments less than 32mm in size (Wentworth and Williams, 1932) and they include both water-lain and sub-aerial varieties. The water-lain tuffs are acidic and typically pale green and are composed almost entirely of re-deposited acid pumice fragments. They are often poorly sorted though well bedded, with fine- and coarse-grained bands of varying thicknesses. Occasionally plant impressions are found on bedding planes within the bedded tuffs. In many cases these tuffs appear to be crater sediments. Sub-aerial tuffs are less well-bedded and more poorly sorted than water-lain tuffs and often contain isolated boulders and pebbles. Again these tuffs are usually acidic, though some contain appreciable amounts of basaltic material.

Agglomerates: All pyroclastic rocks made up mainly of fragments greater than 32mm in diameter and which are generally sub-angular or rounded are here called agglomerates, following Wentworth and Williams (1932). Agglomerates are typically unsorted and unbedded deposits, though a very crude bedding may be discernible. The included rock fragments range up to 10m or more in diameter, and in the Austurhorn area consist of rhyolite and basalt (including andesite), the latter tending to be the more rounded. No fragments of granophyre, granite or gabbro have been found here, in contrast with the volcanic centres of Thingmuli (Carmichael 1962) and Breiddalur (Walker 1963), where such rock fragments are common. Undoubted lava bombs have been found at a few localities. The matrix of the agglomerate is invariably acidic, and is usually a pumiceous tuff. Many of the agglomerates occur in volcanic vents or pipes (vent agglomerates) and all are probably very close to the source of their eruption.

Welded tuffs and agglomerates: Although a number of welded tuffs (ignimbrites) have been found in eastern Iceland (Walker, 1962) only one doubtful example is known in the Austurhorn area. This welded tuff, which occurs near Starmyri, contains sub-angular rock fragments, less than 32mm in diameter, in a very hard and fine-grained acid tuffaceous matrix. Poorly defined patches of welded agglomerate have been found among the pyroclastic rocks of Maelifell, at the southern margin of the core region of the Alftafjordur volcano. These patches contain sub-angular rock fragments and squashed acid pumice fragments enclosed within a bluish-grey rhyolitic matrix.

Tuffolavas: This term is used by Shirinian (1963) and other Soviet workers for xenolithic lava-like masses which appear intermediate in character between welded tuffs and normal lavas. Tuffolavas are characterised by an abundance of inclusions of pyroclastic origin enclosed within a rhyolitic or pitchstone matrix. A number of tuffolavas occur on Maelifell.

Volcanic Conglomerates

Occasionally within the volcanic pile there are some very restricted deposits which can be termed "volcanic conglomerates" (Wentworth and Williams, 1932). These are coarse, unbedded and unsorted water-lain beds containing rounded boulders up to more than 3m. in diameter. The boulders are usually of basalt and occur in a pebbly or gritty basaltic matrix. These deposits do not appear to be true pyroclastic racks, and they are probably river bed sediments.

In the Austurhorn area almost all the pyroclastic rocks are associated with the activity of the Alftafjordur volcano. Pyroclastic rocks are much more important here than at the other volcanic centres so far described (table 2), and this would appear to indicate that the activity of the Alftafjordur was particularly explosive in character.

CHAPTER 3

The Core of the Volcano

The core of the Alftafjordur volcano occupies the north-east of the area mapped and is characterised by an abundance of acid rocks, including lavas, pyroclastic rocks and small intrusions. Only part of the core is at present exposed, the remainder being hidden under Alftafjordur in the north and the open sea in the east.

That this area represents the true core of the volcano is shown by the following evidence:-

1. The lavas and bedded pyroclastics on the flanks of the volcano dip radially outwards from the core, (when corrections are made for the regional dip (fig 2)).

2. Acid rocks probably make up more than half of the total volume of the core. Pyroclastic rocks are particularly abundant, and it is suggested that the area was the site of repeated explosive eruptions.

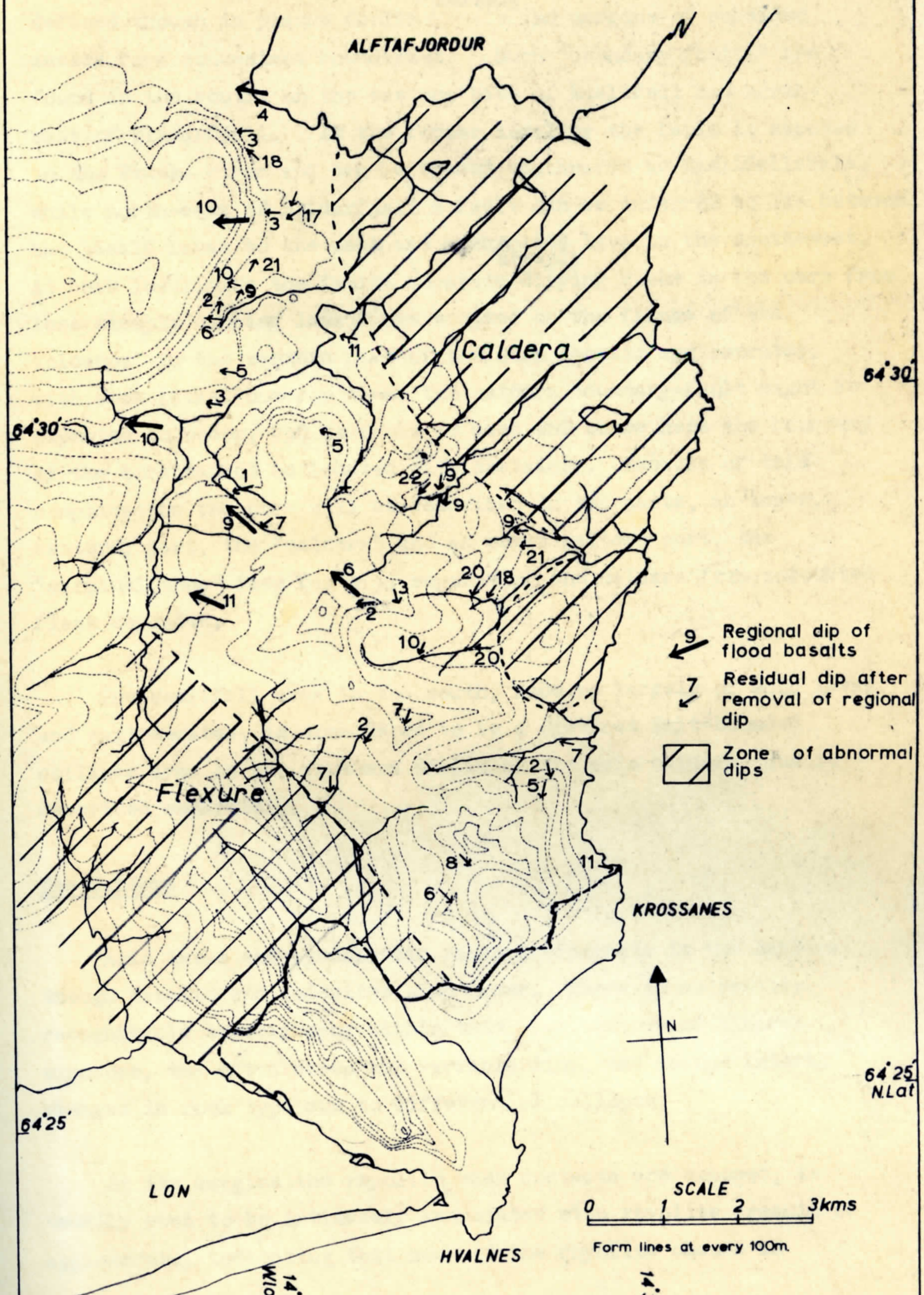
3. The core coincides with an area of intense hydrothermal alteration.

4. The lavas and bedded tuffs within the core often have steep and abnormal dips, which can be explained by collapse or cauldron subsidence.

5. Many minor intrusions occur in the area.

Low, drift-covered hills and mounds are typical of the core area, and exposures are generally found only in stream beds and in gullies. Because of the poor exposures it is often impossible to distinguish extrusive from intrusive rocks.

Fig.2 Map showing probable original depositional dips of the rocks



In general the limits of the core can only be arbitarily defined though in places faults marking the margins of subsided masses form convenient boundaries. Such "boundary faults" are found in the south, on the eastern side of Maelifell and north-east of Hlidarfjall. At the former locality the fault is exposed in the Fauska river and can be traced southwards to Maelifellshals, while north-east of Hlidarfjall a fault can be inferred to lie between the basalt lavas to the east and a rhyolite lava to the south-west. At both localities the faults separate steeply dipping rocks in the core from less steeply dipping lava flows erupted on the flanks of the volcano. In the western part of the core chaotic agglomerates, with some lavas. outcrop where the caldera boundary-fault might be expected to occur, but no fault is seen and hence here the boundary of the core cannot be located with certainty. Because of this complication the core will be described in two parts, an inner, eastern, part, the "caldera" and an outer western part, the "marginal zone" (see fig 3), separating the caldera from undoubted flank deposits.

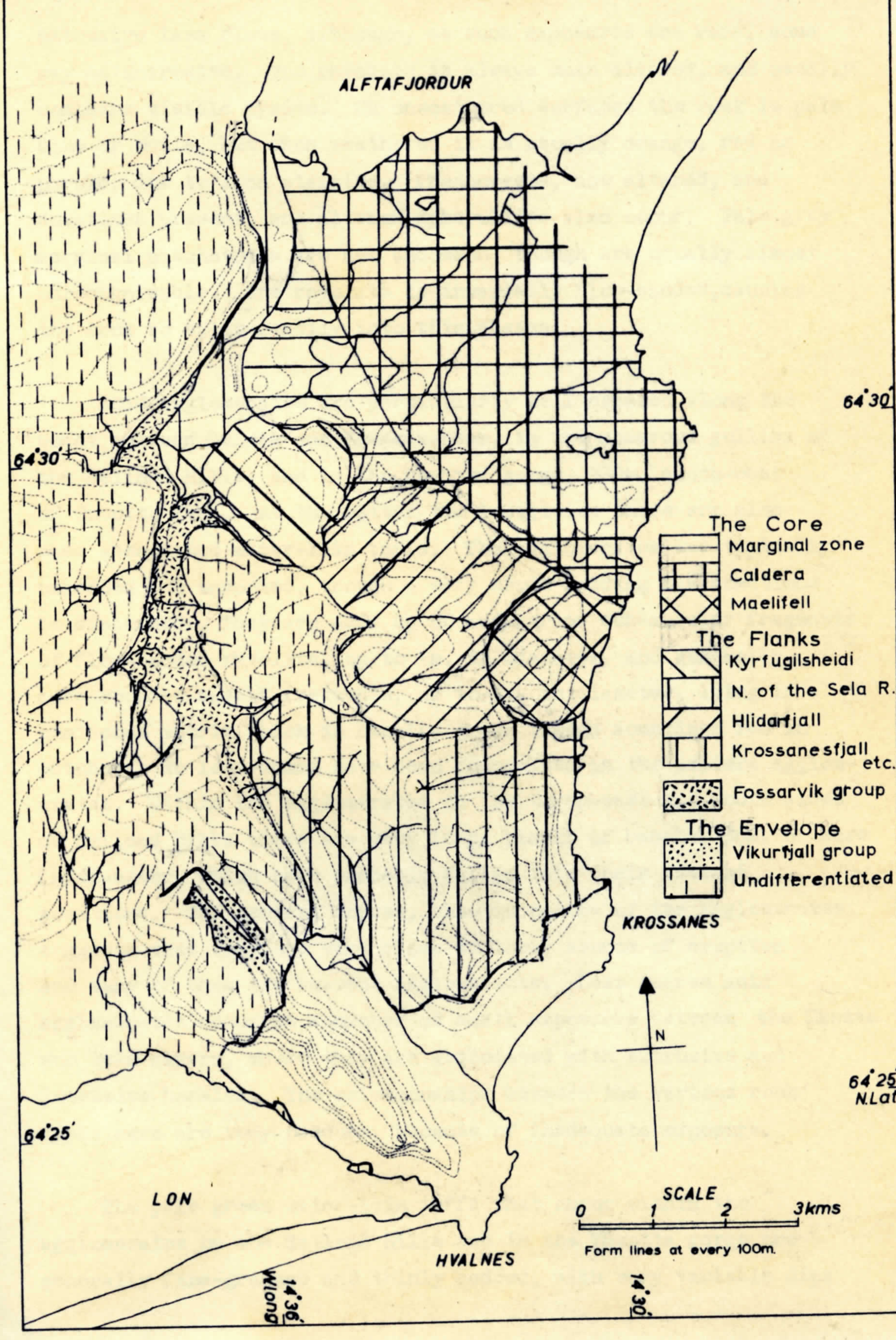
The Maelifell area in the south, made up largely of acid lavas and agglomerates, is considered to be a distinct fault-bounded collapse area on the southern margin of the main caldera, and is described separately.

The Caldera

Acid lavas and pyroclastic rocks predominate in the caldera, though basalts and andesites also occur. There is no readily recognisable stratigraphy within this area because of limited exposure, the often steep and variable dips, and abrupt lateral changes in rock type due to differential collapse.

At its margins the rhyolite, when contacts are exposed, is usually seen to be intimately associated with rhyolite breccia or agglomerate, indicating that much of the rhyolite occurs as

Fig. 3 Sub-divisons of the Alftafjordur Volcano



extrusive lava flows, although, as such exposures are rare, some may be intrusive. The rhyolite is always much altered, and usually contains visible pyrite. On unweathered surfaces the rock is pale blue or white, but when weathered it is usually orange, red or purple, due to iron staining. Phenocrysts, now altered, are sometimes present, and altered spherulites also occur. Pale grey marginal pitchstones are not uncommon, though are usually almost unrecognisable. The rhyolite is invariably flow-banded, causing the rock to split readily into thin plates.

Acid agglomerates are particularly well exposed along the coast between Selvik and Fauskasandur, in the numerous gullies of the Sellond Hills, and in the Thvotta gorge, 900m. south-west of Thvotta farm. At the latter two localities there are also some associated water-lain tuffs. The agglomerates are typically unbedded and unsorted, though a very crude bedding can sometimes be discerned. They are made up of angular or sub-angular fragments of flow-banded rhyolite, up to 1m. in diameter, and generally more rounded basalt fragments, up to 3m. in diameter, lying in a pumiceous matrix which is usually green though sometimes red in patches. No lava-bombs have been recognised in the caldera agglomerates. Within the agglomerates on the north-west and south sides of Sellond Hills there are very large blocks of basalt, 30m. or more in diameter, which have probably fallen into their present positions. The general coarse, chaotic nature of the agglomerates suggests that they are very close to their source of eruption and many of them may be vent agglomerates. Less coarse acid agglomerates occur at a number of small exposures between the Skotta and Sela rivers, where they are associated with extrusive and intrusive basalts. The relationships between the various rock types here are very obscure, because of inadequate exposure.

The pale green water-lain tuffs that occur within the agglomerates on the Sellond Hills and in the Thvotta gorge are generally fine-grained and thinly bedded, with very variable dips at the different localities. They must have initially been laid down nearly horizontally, possibly in small crater lakes, and their present variable dips is attributed to subsequent irregular collapse within the caldera.

Basic and intermediate lavas, with some interbedded tuffs, all cut by many 'minor' intrusions , occur at most of the coastal exposures within the caldera, as well as at a number of inland localities. The andesites are invariably less altered than the basalts, being generally quite hard and flinty while the basalts are usually soft and greenish.

Normally these lavas have shallow dips, but north-east of Hlidarfjall there is a tilted block of lavas dipping at over 50° to the north-north-east (fig 4a). This block, which consists of at least twelve separate basalt flows with an interbedded acid agglomerate near the base, appears to be completely surrounded by acid agglomerate. A possible continuation of this block occurs in the Thvotta river to the north-west, where there is a much smaller vertical mass of basalt. These steeply dipping masses are just inside, and strike roughly parallel to, the caldera margin, and appear to be marginal blocks of lavas that slipped into the caldera during a period of cauldron subsidence.

Though the basalts within the caldera usually contain only rare phenocrysts, there are some porphyritic lavas, notably at the basalt outcrop 1 Km. south-west of Thvotta farm. This outcrop is surrounded by acid pyroclastics, but only in the north-east, where the lavas are banked up against and interbedded with agglomerates, are the marginal relationships of the basalts seen. A possible site of a fissure eruption within the basalt outcrop occurs in the Thvotta gorge, where a porphyritic basalt flow possesses a well developed radial columnar-jointing (fig. 4a). The lava here lies in a small hollow (or vent) bounded by rubbly and agglomeratic porphyritic basalt which may be part of a small cinder core of the type typically associated with fissure eruptions. However, no

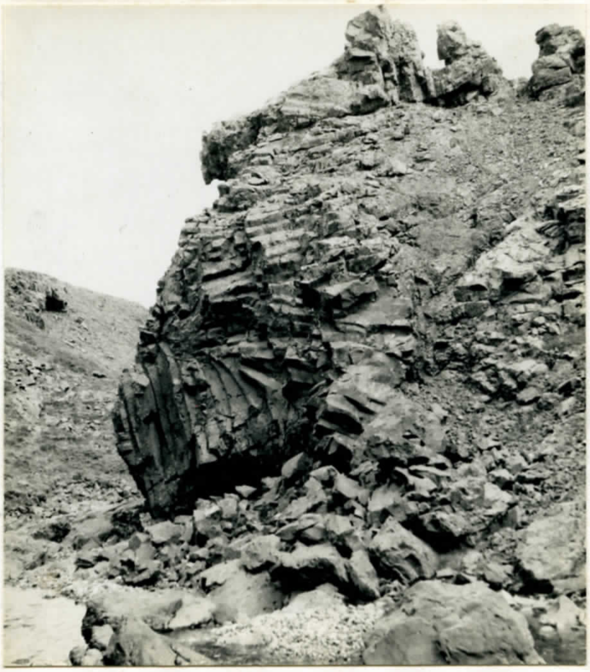


Fig. 4a. Radial columnar jointing in a porphyritic basalt lava flow. Thvotta River 1200m. south-west of Thvotta Farm.

Fig. 4b. Steeply dipping lavas just inside the southern margin of the main Alftafjordur caldera. The strike of the lavas is parallel to the caldera margin.

dyke-feeder for the lava is exposed.

The Marginal Zone

The outer limit of this zone is taken at the first appearance of bedded lavas and pyroclastics which definitely form part of the flank succession of the volcano (the flank deposits dip gently outwards from the core), while the inner margin is taken, quite arbitrarily, where it is reasonably certain that the rocks concerned lie within the confines of the caldera. The best exposures are found in Kyrfugil, on the northern side of Vidartungur and along the banks of the Sela river. In these exposures acid agglomerates predominate, though basic and acid lavas are also present. Details of some of the exposures are given below.

In Kyrfugil the lowest rocks seen are basaltic lavas which outcrop at the northern end of the gully. These lavas are overlain by a green, thinly-bedded, water-lain carbonaceous tuff, about 2m. thick, which is succeeded by coarse agglomerates. The agglomerates, which are unsorted and generally unbedded (fig.5a & b) contain sub-angular fragments of rhyolite, up to 1m. in diameter, and less numerous, more rounded boulders of porphyritic basalt, up to 3m. in diameter, in a green pumiceous matrix. A carbonised fossil tree was found in the agglomerate just above the water-lain tuff. From a distance the agglomerate is seen to possess a very crude stratification, with coarser layers, some 10m. thick, dipping to the north-west. A crude bedding can also be seen in the extreme north of Kyrfugil, where many flattened rhyolite bombs, up to 50cm. long, occur and give the agglomerate a layered appearance. The coarseness of the agglomerate and the present of rhyolite bombs indicate a nearby source of eruption, and the deposit may occupy a volcanic vent (the crude bedding probably indicates different stages of a single eruption). Described examples of bedded vent agglomerates include those of the Midland Valley of

Fig. 5a. Coarse chaotic agglomerate in Kyrfugil.

Fig 5b. Agglomerate in Kyrfugil showing crude statification, looking north.

Scotland (Geikie, 1897); Ben Hiant, Ardnamurchan (Richey and Thomas 1930) and the Faeroes (Geikie, 1897). Further south in Kyrfugil a rhyolite lava is exposed below the agglomerates, and some 30m, above the top of the rhyolite come the lowest exposed lavas, interbedded with agglomerates and tuffs, which form the flanks of the volcano outside the caldera area.

Agglomerates similar to those of Kyrfugil occur north of Svarthamrar and on the northern side of Vidartungur. At the latter locality rhyolite bombs are again present, and a rhyolite lava is exposed within the agglomerate, which passes upwards into basic lavas, with interbedded tuffs and agglomerates, on the flanks of the Alftafjordur volcano.

Further agglomerates occur on the banks of the Sela river and between Starmyri in the north and Vatnashlid in the south, where they are associated with basalt lavas. Here it is often impossible to tell whether a particular basalt mass is extrusive or intrusive. Near the Sela river, however, undoubted basalt lavas occur, some of which possess a crude columnar jointing. Often the lavas are blocky, and pass outwards into a basaltic agglomerate which itself passes outwards into acid agglomerates. These blocky lavas are tholeiitic, with about 1% of feldspar phenocrysts. Rhyolite masses also occur, one acid lava outcropping 1,500m. south of Starmyri; another, possibly extrusive, rhyolite occurs just north of the farm, while an "intrusive" rhyolite dome, with a columnar-jointed marginal pitchstone, occurs on the south shore of Alftafjordur. Also a single westerly-dipping welded tuff has been found, 1Km. south of Starmyri.