The Skagafjörður Volcanic Zone – An ephemeral Rift Zone

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Abstract
In the Skagafjörður district, North Iceland, an unconformity with a sedimentary layer divides the strata pile into Neogene and Pleistocene volcanic successions. Neogene volcanism faded out 4-5 Ma when the area drifted out of the volcanic zone near the diverging boundaries of the North American and Eurasian crustal plates, after which erosion took over for about a million years. Volcanism started again at the beginning of the Pleistocene. Lava flows covered the eroded Neogene landscape and an unconformity was formed. It is proposed that the Pleistocene volcanic rocks above the unconformity all belong to a short-lived axial rift zone, the Skagafjörður zone. Eruptive sites belonging to this zone can be found dispersed in the area between the Hofsjökull central volcano and the mouth of Skagafjörður. The oldest volcanic formations of the Pleistocene rock series are from about 1.7 Ma, when rifting in the area started. The activity culminated in the early Pleistocene but declined in the late Pleistocene, and in the Holocene the activity seems to have been restricted entirely to the Hofsjökull central volcano. A prominent fault and fissure system belongs to the Skagafjörður zone. The tectonics indicate extension. It is suggested that a decline in the activity of the Iceland Mantle Plume, 2-3 million years ago, caused a rift jump away from the hot spot below Vatnajökull and formation of a temporary rift zone, the Skagafjörður zone, which for a while bridged the shortest way between the Reykjanes-Langjökull zone and Kolbeinsey ridge.

Keywords: Volcanic zone, spreading ridge, ridge jump, Iceland hot spot, mantle plume.

1. Introduction

The study area covers in a broad sense the Skagafjörður district, North Iceland (Fig. 1). The southern part of the area is a mountainous terrain with peaks reaching over 1,000 m, culminating in the glacier of Hofsjökull, an active central volcano with an ice-filled caldera and a summit reaching over 1,800 m a.s.l (Björnsson 1988). In the northern part lies the large Skagafjörður fjord, with its small islands, between the major peninsulas Skagi and Tröllaskagi. The North Iceland Volcanic Zone is 100 km to the east and the centre of the Iceland Hot Spot is somewhat farther to the southeast below the Vatnajökull glacier (Sæmundsson 1979).

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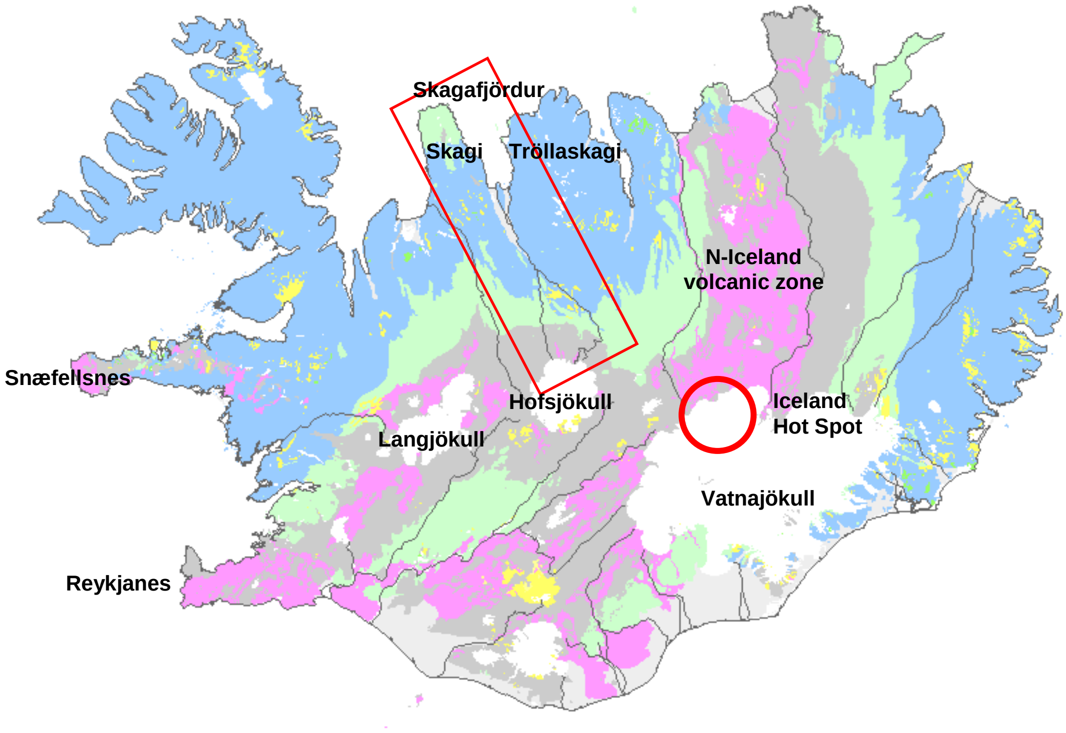

Fig. 1. Geological map of Iceland. The research area is indicated by a red frame. Blue = Neogene regions. Green = Plio-Pleistocene areas (3.3-0.8 Ma). Grey = Late Pleistocene. Violet = Holocene lavas. Yellow = rhyolite. (Modified from Jóhannesson and Sæmundsson 1998).

The recent volcanism of the Skagafjörður zone was recognised by Pjetursson (1905). By investigating the state of erosion and alteration he established a Pleistocene age for the basaltic lavas and plugs in the district. Líndal (1964) investigated the Skagafjörður valleys in 1938 and 1939 and discovered the Skagafjörður unconformity. He described the different dip of the strata above and below it and the thick coarse sedimentary layer at the unconformity.

Einarsson (1958, 1959, 1962) carried out intensive observations on the geology and geomorphology of the Skagafjörður district, and measured sections through the Plio-Pleistocene sediments. He also performed pioneering work in paleomagnetism and used it for dating the rock series (Einarsson 1959, 1962). Everts (1972) and Everts et al. (1975) published a geological map with a detailed description of the northern part of the Skagi Peninsula, including chemical rock analyses and K/Ar dates. Sæmundsson (1974) discussed the tectonics of Skagafjörður and their relation to the Tjörnes Fracture Zone. Sigurðsson et al. (1978) and Schilling et al. (1978) investigated the petrology and structure and geochemical variations in the area between Skagi and the Langjökull glacier.

Various publications on the geology of the Skagafjörður Valleys appeared between 1978 and 2000. Kaldal and Víkingsson (1978) and Harðarson and Guðmundsson (1986) described the stratigraphy, Karlsdóttir et al. (1991) discussed and mapped the geothermal activity, Jóhannesson (1991) published a general geological description, Hjartarson et al. (1998) published a bedrock map with a geological description of the area and Arnórsson and Sveinbjörnsdóttir (2000) described the hydrogeology.

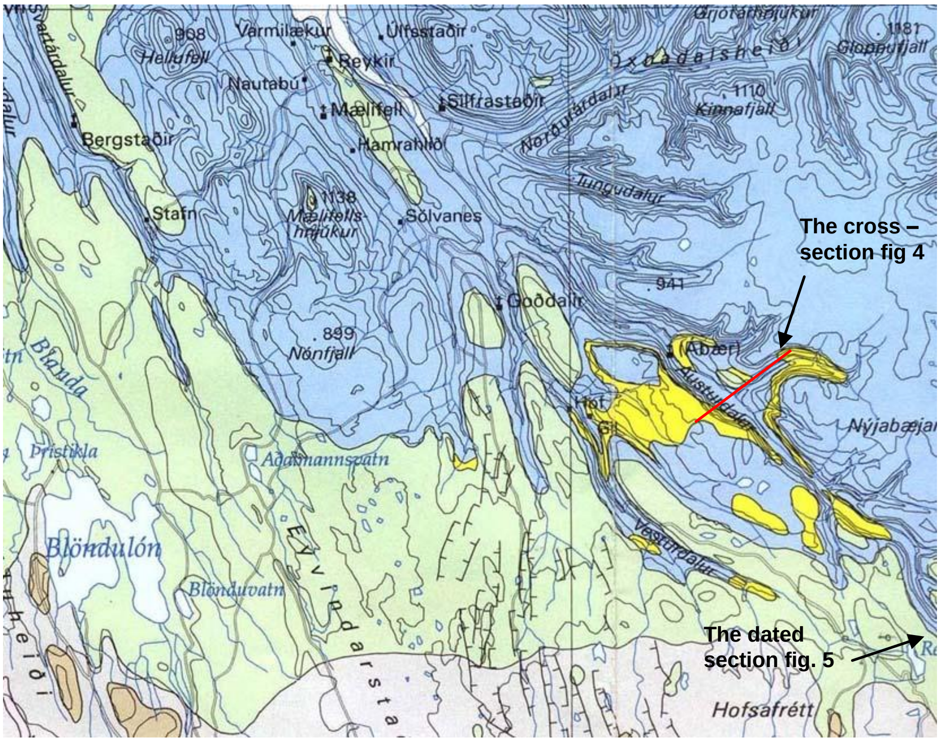

Fig. 2 Main features of the geology of the Skagafjörður valleys. Blue = Neogene succession. Green = Plio-Pleistocene. Grey = Late Pleistocene. Yellow = rhyolites of the Tinná Central Volcano. (From Jóhannesson and Sæmundsson 1998).

2. Rift jumps

The main features of the overall geology and tectonics of Iceland are explained as a complex interaction between the North Atlantic Mid-Ocean Ridge and the Iceland Mantle Plume. Although the North Atlantic region is spreading symmetrically away from the mid-ocean ridge, the ridge itself is drifting slowly to the NW with respect to the plume. About 55 Ma the ridge and the plume started to interact (Vink 1984, Lawver and Müller 1997, Bernstein et. al 1998, Jones 2003). The result was intense volcanism and increased heat flow into the crust. Later on Iceland was formed as a result of this interaction.

Table 1
Rift zones and rift jumps

Rift zone	*Time of formation Ma*	*Ref.*
Northwest Iceland rift zone	24	Hardarson et al. (1997)
Snæfellsnes-Húnaflói rift zone	15	Hardarson et al. (1997)
Reykjanes-North Iceland rift zone	6-7	Sæmundsson (1979)
Eastern rift zone	2-3	Sæmundsson (1979)
Skagafjörður rift zone	1.7	The present paper

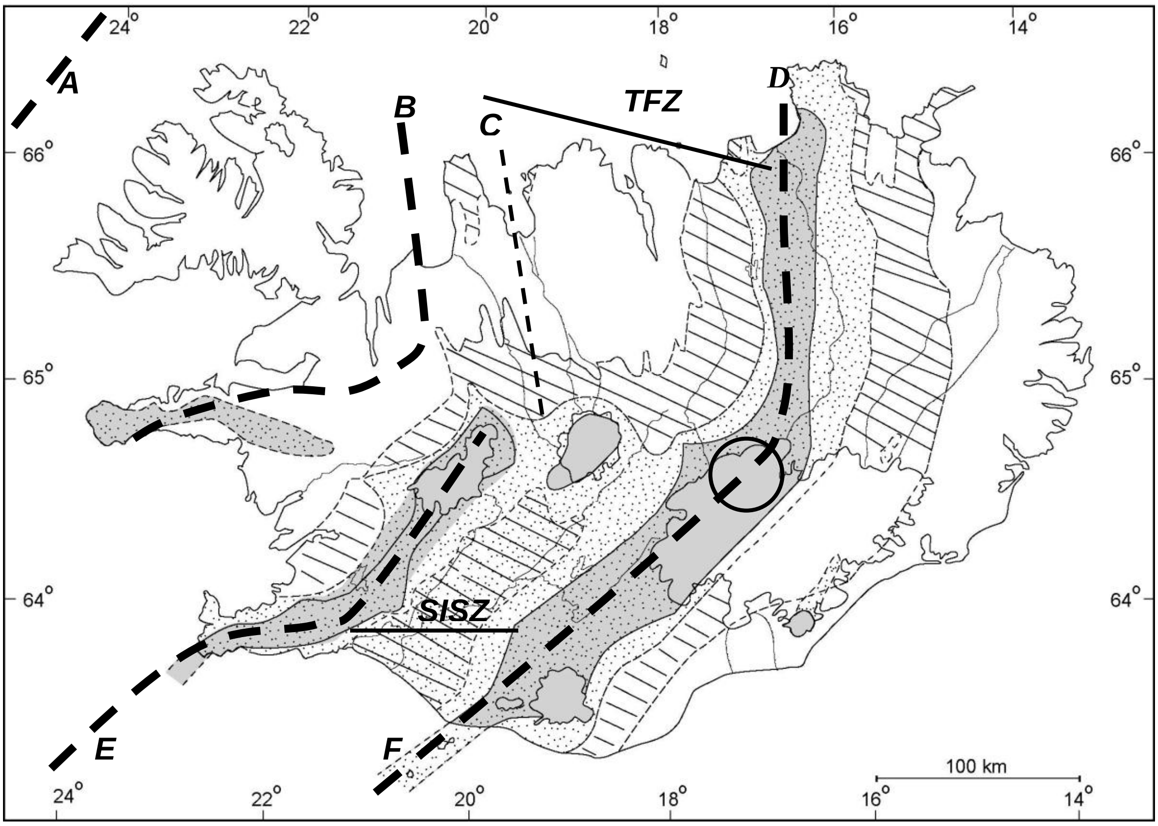

Fig. 3. The neovolcanic zones and rift systems in Iceland. ***A*** *= Northwest rift axis;* ***B*** *= Snæfellsnes-Húnaflói rift axis;* ***C*** *= Skagafjörður rift axis;* ***D*** *= North Iceland rift axes;* ***E*** *= Reykjanes-Langjökull rift axis;* ***F*** *= The propagating Eastern rift axis.* ***SISZ*** *= South Iceland seismic zone;* ***TFZ*** *= Tjörnes fracture zone. The circle represents the location of the Iceland plume.*

As the ridge migrated over the plume the latter is thought to have shifted the spreading axis repeatedly through rift jumping. Several jumps have been proposed in the geological history of Iceland (Table 1). The Northwest rift zone is thought to have formed about 24 Ma west of the Northwest Peninsula (Fig. 3) (Hardarson et al. 1997). It was active for 8-10 million years but then rift jump occurred and a new zone was established in the Snæfellsnes-Húnaflói region. There it was active for another 8-10 million years but c. 6-7 Ma it jumped again to form the North Iceland zone (Sæmundsson 1974,1979, Jóhannesson 1980, Kristjánsson and Jónsson 1998). In Southwest and South Iceland the picture is a little more complicated as there exist two parallel rift zones. The rift zones and rift jumps are listed in Table 1.

These jumps seem to be related to a tension between the mantle plume and the ridge. The rift axis crossing Iceland does not bridge the gap between the Reykjanes and Kolbeinsey ridges (Fig. 3). Instead it has been displaced eastwards and is connected to the main ridges by transform faults (Sæmundsson 1979, Hardarson et al. 1997). The plume tends to trap a segment of the ridge above itself by transform displacements. The force required for this is released in the earthquakes on the transform faults in South Iceland and off the north coast of the country.

3. The stratigraphic successions

The bedrock and strata pile of the Skagafjörður district can be divided into three main successions (Fig. 1):
1. Neogene volcanic succession
2. Sedimentary group of the unconformity
3. Pleistocene volcanic succession
The major Skagafjörður unconformity divides successions 1 and 2.

3.1. The Neogene succession

The Neogene volcanic succession below the unconformity originates in axial rift zones at the boundary between the North American and Eurasian crustal plates, the lower part (> 7 Ma) in the Snæfellsnes-Húnaflói rift zone but the upper part (< 7 Ma) in the North Iceland rift zone (Article 5 in this thesis). The Neogene succession is composed predominantly of basaltic lavas with thin fine-grained interbeds but there also exists a voluminous silicic centre, the Tinná Central Volcano (Article 2 in this thesis). Although this was not a stratovolcano, it rose above the environment and formed a mountainous area of rhyolite domes and other eruptive centres several hundred metres high. Paleomagnetic observations and Ar/Ar-dates indicate that the volcano was active 5-6 million years ago. A detailed description of the Neogene stratigraphy is given in the Appendix. Volcanism died out as the area drifted out of the volcanic zone.

3.2. The Skagafjörður unconformity

The unconformity between the Neogene succession and its sedimentary group is marked by an erosion surface that outlines the ancient valley system of the district. The unconformity is marked by a change in the strike and dip of the adjacent successions. Lava flows below it dip 5 - 15° S whereas flows above it dip 2-8° S, towards the Hofsjökull massif (Appendix, 6.1). This southward dip fluctuates east-west by as much as15-20°, but the main orientation is to the south.

The sedimentary layers inside the successions below and above the unconformity differ, reflecting dissimilar climatic and environmental conditions. Below the unconformity, the stratigraphy is indicated by thin tuffaceous red-brown silt layers of aeolian origin and fine-grained, fluvial and lacustrine layers with regular bedding. The sediments seem to have been formed in a temperate climate. Above the unconformity, the sediments are much coarser and more irregular in structure and bedding. Till layers and glaciofluvial sediments have been identified (Appendix, 4). The eruptives also change, both petrologically and structurally. Composite olivine basalt layers forming shield volcanoes and hyaloclastite formations, both very rare below the unconformity, become dominant in the upper pile.

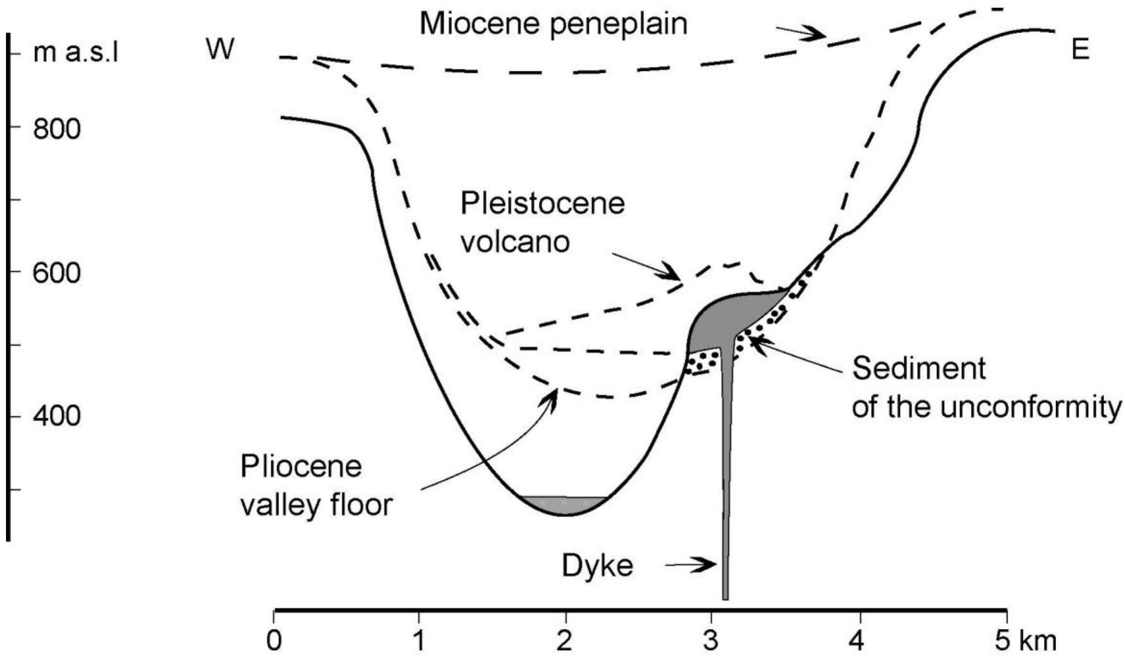

Fig. 4. Cross-section through the Austurdalur valley. Traces of the Pleistocene volcano can be seen in its eastern slopes along with the feeder dyke resting on the remains of old sediments. The dashed lines indicate some stages in the development of the valley; the Miocene peneplain (~5 Ma), the Pliocene valley and its sedimentary layer (~2 Ma). The Pleistocene volcano (~1.5 Ma) is also outlined. Today the valley is 600 m deep, in Pliocene it was 400-500 m deep.

The unconformity indicates that the area drifted away from the active volcanic zone. Accumulation of new extrusives halted and erosion took over, weathering the surface and carving out new landscape. The surface of the unconformity reflects the late Neogene - early Quaternary topography and the initial form of the Skagafjörður valley system. The valleys were mature and already several hundred metres deep, carved out of the primordial volcanic plateau (Fig. 4, see also Article 3 in this thesis). The forerunners of Austurdalur and Vesturdalur valleys were eroded on each side of the Tinná volcano. The principal valley of Skagafjörður district was eroded below the recent sea level but was narrower than it is today.

3.3. The sedimentary group

After the erosion of the valley system it started to fill up again for some unknown reason. Thick sedimentary layers were accumulated forming the sedimentary group of the unconformity that can be traced for long distances. It is thickest in the valleys, reaching tens or even hundreds of meters, but thinner in the highlands and completely absent in some places. In the central part of the Skagafjörður Valley it forms a 50-200 m thick uncapped layer. There the Pleistocene volcanic succession, if it ever existed at all, has been entirely eroded away. The sediments divide the Neogene and Quaternary successions on the Skagi Peninsula, as they do in the Skagafjörður valleys (Everts 1975). The southernmost locality is at the rivulet Geldingsá, where the sediments form a 55 m thick clastic layer (Fig. 5).

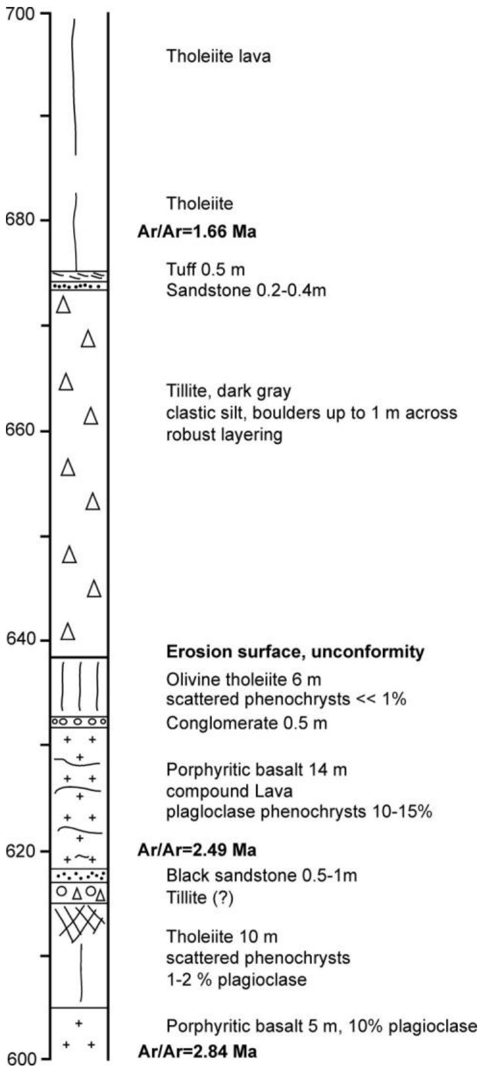

Fig 5. A section across the unconformity at Austurdalur valley near Geldingsá, north of Hofsjökull. Here the unconformity spans 0.8 million years. The location of the section is shown in Fig. 2.

The internal structure of the sediments, and their thickness, vary from place to place. The layering is sometimes irregular but more often roughly horizontal. In many localities the grain size has an upward grading i.e. with a fine-grained lower part and a coarser upper part. It is most obvious in the slopes of Vesturdalur and its tributaries. The grain size distribution is unusual, with rounded boulders up to 1 m in diameter or more situated in a sandy and silty ground mass. Most of the sediment seems to be of fluvial and glaciofluvial origin, reflecting a glacial and periglacial environment and rivers with a high transport ability.

3.4. The Pleistocene succession

Volcanic activity started again in the Skagafjörður area in the early Pleistocene after a quiescence that had lasted for millions of years (Article 5 in this thesis). New lavas covered the land and filled up depressions and valleys forming the Pleistocene volcanic succession. This is divided into three series based on stratigraphical position and paleomagnetism. These consist of early Pleistocene formations with reverse paleomagnetic polarity (the topmost lavas in Fig 5), mid-Pleistocene formations, also with reverse polarity but starting with a normal paleomagnetic subchron (Yaramillo) and late Pleistocene formations spanning the Brunhes paleomagnetic chron (Appendix, 5; see also the Bedrock map).

The oldest known formations of the Pleistocene succession are individual lavas of olivine and porphyritic basalts covering the sediments of the unconformity. They are they have been studied most thoroughly in the Vesturdalur valley both to the west and to the east of Goðdalir. These lavas seem to have flowed along the early Pleistocene valleys of the district, covering fluvial deposits. The Austurdalur Pleistocene Volcano is thought to belong to this formation. It was made of porphyric basalt lava erupted on a short fissure in the Austurdalur valley. Erosion has cut a prominent section through the lava, its feeder dyke and the sediments below (Fig. 4). Later on widespread tholeiites were accumulated in the southwest part of the field. They were followed by an early Pleistocene composite olivine basalt formation. All the lava flows have reverse paleomagnetic polarity (R).

The mid-Pleistocene formation begins with a short normal paleomagnetic subchron. It has been identified in a few places, comprising1-3 layers in each locality. They form a discontinuous horizon inside the succession which is mostly made of porphyritic and olivine tholeiite lavas. Glaciogenic layers have not been found inside the formation. It has been suggested that the subchron represents the Yaramillo geomagnetic event, which is about 1 million years old (Hjartarson et al. 1997). Above this horizon, hyaloclastite formations become more common than before. Several hyaloclastite mountains have been mapped in the southern part of the area. They are thought to have been formed subglacially. There are also widespread composite olivine tholeiites and tholeiite lavas. Volcanic products of the northern part of the zone consist predominantly of interglacial lavas.

The most recent volcanic formations are thought to be from the late Pleistocene, less than 0.8 million years old and with normal polarity of the Brunhes magnetic chron (Appendix, 5.3). At this time the volcanism was declining and retreating to the southern part of the area. There is a continuous cover of recent formations, shield volcanoes and lava fields from the interglacials and pillow lavas and hyaloclastite ridges from the glacial periods. These are scattered over the northern part of the district. The best-known member of this formation is the island of Drangey (Jóhannesson 1991), a famous historical site depicted on the coat of arms of the Skagafjörður district (its location is shown in Fig. 5). Active volcanism during the Holocene was entirely restricted to the Hofsjökull central volcano (Jóhannesson and Sæmundsson 1998a).

4. Volcanic sites and the size of the Skagafjörður Zone

The length of the Skagafjörður zone, from Hofsjökull to the northern tip of the Skagi Peninsula, is 150 km. Its width is 50-60 km (Fig. 6). The area on land is therefore 8,250 km^2 but it is a reason to believe that the Skagagrunn bank north off Skagi is a continuation of the Pleistocene basalt area (Everts 1975). The thickness of the Pleistocene eruptives varies greatly from place to place, from about 100 m on the Skagi Peninsula in the north to 200-300 m in the central highlands north of Hofsjökull. All the Pleistocene lavas in the main Skagafjörður Valley have been eroded away, if indeed they ever existed there. The geological evidence indicates a low productivity of volcanic material.

Table 2 lists known Pleistocene volcanoes and volcanic vents in the Skagafjörður zone. The central part of the area, from the Norðurárdalur valley to Sauðárkrókur, is without any known eruptive centres (Fig. 6).

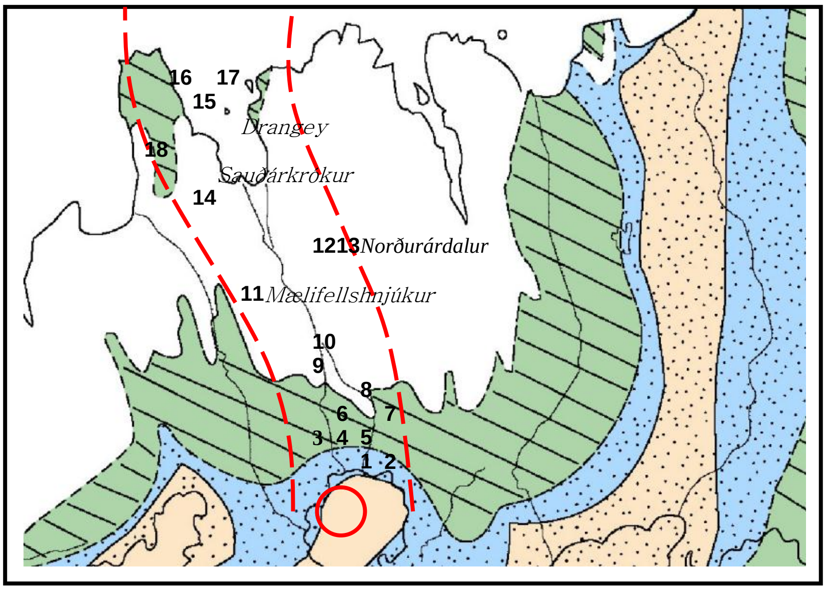

Fig 6. The Skagafjörður Volcanic Zone. Numbers = volcanic vents (see Table 2). Circle = the Hofsjökull caldera. Brown = Holocene volcanic zones. Blue = Late pleistocene. Green = Plio-Pleistocene (0.8-3.3 Ma) White = Neogene (>3.3 Ma).

Table 2
Pleistocene volcanoes and volcanic vents in the Skagafjörður Volcanic Zone

No.	*Name or place*	*Type*	*Polarity*	*Estim. age Ma*
1	Orravatn basalt	Crater row?	N	0.5
2	Orravatn	Shield volcano	N	0.5
3	Austurkvísl	Shield volcano	N	0.5
4	Sáta	Shield volcano	N	0.5
5	Hraunþúfa	Shield volcano	R	1
6	Bleikáluháls	Hyaloclastite mountain	R	1
7	Geldingsá	Dyke	R	1-2
8	Austurdur Pleist. volcano	Interglacial lava and dyke	R	1-2
9	Goðdalafjall	Dyke	R	1-2
10	Hlíðarfjall	Dyke	R	1-2
11	Mælifellshnjúkur	Hyaloclastite mountain	R	1-2
12	Kotagil, Norðurárdalur	Lava remains		
13	Heiðarsporður, Norðurárd.	Hyaloclastite remains		
14	Gönguskörð at Tindastóll	Subglacial pillow lava	N	< 0.8
15	Drangey	Submarine hyaloclastite ridge	N	< 0.8
16	Ketubjarg	Interglac. hyaloclastite + dyke	R	1-2
17	Þórðarhöfði	Interglacial lava and dyke	N	< 0.8
18	Selfjall	Craters	R	1-2

5. Tectonics

Faults and fissures of the Skagafjörður valleys can be divided into three main systems; the Neogene system the active Pleistocene - Holocene system and the Hofsjökull fissure swarm. The main trend of them all of them is N-S, with normal faulting (Karlsdóttir et al. 1991). The fourth system lies north of the mouth of Skagafjörður, the active transverse tectonics of Northern Iceland (the Tjörnes Fracture Zone), trending WNW (Garcia et al. 2002).

5.1. Neogene faulting

Neogene faulting is rather difficult to distinguish in the landscape. Erosion has wiped out the scarps of the faults and the fissures are filled with secondary minerals. This faulting is restricted to the Neogene regions and in some places it is covered by younger formations. Most of the faults are small (0-20 m throw) but faults with up to 120 m throw have been mapped. An important part of the tectonics is the caldera fault of the Tinná Central Volcano (Article 2 in this thesis, see also the Appendix, 6 and the Bedrock map). Neogene tectonics were active in the Late Miocene - Pliocene while the Neogene succession was accumulating but became extinct when the area had drifted out of the volcanic zone.

5.2. Pleistocene-Holocene tectonics

Pleistocene-Holocene tectonics are easily recognized in the area as they often left scarps and clear-cut lineaments in the landscape. They also cut through the whole pile, the Neogene and Quaternary successions and in some places the loose overburden is also disturbed. A prominent bundle of faults has been mapped near the 75 km long eastern border of the Skagafjörður district (Jóhannesson and Sæmundsson 1998b). In the eastern slopes of Vesturdalur valleys lies a system of faults that cuts the Pleistocene pile. It is composed of four normal faults trending NW - NNW. The throw is towards the east, 50 –100 m altogether. Lava has flowed into one of the fault indicating that its has the same age as the lava pile and the other faults are most likely of similar age. This faulting is believed to be related to rift tectonics.

Weak and scattered seismic unrest indicates active tectonics throughout the area between Hofsjökull and the Skagafjörður mouth. Larger earthquakes occur occasionally. The largest recorded one was 5.0 on theRichter scale. It occurred on the sea floor, 7 km northwest off Drangey, on 11 July 1964 (Icelandic Meteorological Office, homepage).

5.3. The Hofsjökull fissure swarm

The Hofsjökull fissure swarm cuts through the highlands north of the Hofsjökull glacier forming long, prominent scarps and grabens. It seems to be connected to the huge ice-filled caldera of the volcano. The age of the caldera is not known. Surface disruption, weak seismicity and volcanism under the glacier indicate permanent activity. The length of the fissure swarm is somewhat unclear as it grades into the Pleistocene fault system. The main trend is N-NNW (Karlsdottir et al. 1991, Vilmundardóttir et al.1997).

The active Pleistocene-Holocene tectonics and the Hofsjökull fissure swarm are in fact manifestations of the same phenomenon, i.e. an axial rift zone in the Skagafjörður district. Although it is fading out it is not quite extinct, but the spreading is presumably slowly approaching zero.

6. Geothermal fields

The Skagafjörður district is known for its geothermal fields (Karlsdóttir et al. 1991). The activity is far higher than in the adjacent districts in terms of both heat and utilisation. Five municipal heating services operate in the district, togetherwith many small private heating centres for house and greenhouse heating. All the geothermal fields are in the Neogene bedrock but are connected to the young tectonics that broke up the strata pile, forming geothermal aquifer systems. No explanation has been given for this high discharge of geothermal heat in the Skagafjörður district but here it is assumed to be connected to the short lived Pleistocene axial rift zone of Skagafjörður.

7. Petrology

Sigurðsson et al. 1978 made an extensive petrological and chemical study of basalts in a 220 km long profile from the Langjökull area to the tip of the Skagi Peninsula. They found an abrupt change at 65º 10', about 20 km north of the glacier, that separates the areas petrologically. Basalts in the Langjökull area are relatively primitive MgO and Al_2O_3-rich olivine tholeiites. Basalts of the Skagafjörður zone, on the other hand, are relatively evolved iron-titanium-rich tholeiites. Rocks most comparable to the Skagi tholeiites are found among the transitional alkali basalts in the southern parts of the Eastern Volcanic Zone (Sigurdsson et al. 1978). Jakobsson (1979) found a similar abrupt change in the propagating Eastern Volcanic Zone where the petrology of the eruptives changes from tholeiitic to transitional alkali basalts.

8. The age of the Skagafjörður Zone

When the pioneer geologist Helgi Pjetursson (1905) discovered the young formations in Skagafjörður district at the beginning of the 20th century he proposed that they were of Pleistocene age. Later observations have not changed this estimate. It was improved by the geological investigation and paleomagnetic work of Einarsson (1959) and was further strengthened by K/Ar dates (Everts et al. 1972, Everts 1975). Everts's samples were collected on the Skagi Peninsula and from a recent formation on the east coast of Skagafjörður. The dates give the time interval 0.5 - 2.6 Ma but the margins of error are large in some cases.

In the present study seven samples were collected in the Skagafjörður Valleys for Ar/Ar dating. Four of them were taken from basaltic lavas directly above the unconformity and two from basaltic lavas directly below it. The last one was collected from the Skati rhyolite dome, a little further down in the Neogene pile. The distribution of the samples should reveal the supposed widening of the age gap of the unconformity from south to north, from the highlands near Hofsjökull and northwards to the lower Vesturdalur valley (Table 3) (Article 5 in this thesis).

The dates from above the unconformity indicate that the activity of the Skagafjörður Volcanic Zone started near the beginning of the Pleistocene, 1.6-1.7 Ma. According to the date no. 17177 in Austurdalur, near the confluence with Geldingsá, volcanism began at 1.66 Ma. A little later the first Pleistocene lava flows reached the lower part of Vesturdalur 40 km farther north, which is where dates nos. 17160 and 17169 are from. The lavas are 1.48 Ma old and lie directly on the sediments. The

dated samples have reverse polarity and fit with the mid Matuyama geomagnetic field prevailing 1.07-1.77 Ma (Cande and Kent 1995).
The date from Austari Jökulsá near Geldingsá (no. 17175) below the unconformity gave 2.49 Ma or upper Pliocene age. It has normal polarity and has the best fit with the Reunion II (polarity subchron C2r.2r-1).

Dates nos. 17175 and 17177 are from the same section and give the maximum time gap of the unconformity at its southernmost exposure. There it spans 0.8 million years. Towards the north it widens mostly due to the erosion of the Neogene succession and is about 4 Ma in lower Vesturdalur.

Table 3.
Ar/Ar dates from the Skagafjörður valleys*

Locality (m a.s.l.)	*Relation to the unconformity*	*Pol-arity*	*No.*	*Ar/Ar-age Ma* ± 1σ
Djúpagil innra, 386 m, Vesturdalur	Above	R	17160	1.482 ± 0.060
Hlídarfjall, 335 m, Vesturdalur	Above	R	17169	1.468 ± 0.017
Goðdalakista, the topmost lava, 585 m.	Above	R	17172	1.256 ± 0.016
Austurdalur, near Geldingsá, 600 m.	Below	N	17173	2.841 ± 0.043
Austari Jökulsá, 620 m, near Geldingsá	Below	N	17175	2.486 ± 0.068
Austari Jökulsá, 660 m, near Geldingsá	Above	R	17177	1.659 ± 0.024
Skati Dome, Tinnárdalur, 650 m	Below	R	17181	5.212 ± 0.016

* The dates are described in Article 5 in this thesis

9. Discussions

The recent volcanism in the Skagafjörður Valleys and on the Skagi Peninsula has long been a matter of discussion and its relation to the axial rift zone of North Iceland has been unclear. For a while it was supposed to be a forerunner of the present-day North Iceland rift zone (Sæmundsson 1967, 1974, Everts 1975) but later it has been regarded as an instance of intraplate volcanism (Sæmundsson 1979).

Sigurðsson et al. (1978) investigated the petrology and structure in the area between Skagi and the Langjökull glacier and found that the recent volcanism was rift-related. They suggested that 2.5 Ma rifting in the Reykjanes-Langjökull zone propagated northward through a 15 km thick crust, giving rise to an ephemeral Skagi zone. They also proposed that this rifting was related to a period of increased spreading in Northern Iceland 0.5-2.5 Ma or, alternatively, that the Skagi zone might have arisen owing to temporary cessation of rifting in the North Iceland zone and consequent rift jumping to the west. This latter assumption seems in good accordance with the geological evidence in the Skagafjörður district described in this paper.

The classification of Hofsjökull inside the volcanic belts of Iceland where it towers above the surrounding area in between the Reykjanes-Langjökull Volcanic Zone and the North Iceland zone, has been problematic. It has sometimes been claimed that it functions as a connection between the main volcanic areas, the Reykjanes-Langjökull zone, the North Iceland zone and the Eastern zone (i.e. Einarsson 1991). In many recent papers it is interpreted as an independent spreading zone, the Mid-Iceland zone (e.g. Hardarson et al., 1997). This opinion might be adapted to the idea of the Skagafjörður rift zone. Accordingly, the activity in Hofsjökull and its fissure swarm should be interpreted as the remains of activity in a deceasing rift zone.

The Skagafjörður Volcanic Zone was formed around 1.7 Ma. Then a rift jump seems to have occurred from the North Iceland Rift with a 100 km displacement towards the west. This jump was in the opposite direction to previously recorded rift jumps in Iceland, away from the hot spot. No hiatus is known inside the Pleistocene succession of the North Iceland rift zone, so the Skagafjörður zone only partly took over the spreading activity. This is the explanation of its rather low productivity of volcanics. For one million years or so, two parallel rift axes were active simultaneously in North Iceland.

A reason for this event and a rift jump towards west, away from the plume, might be advanced. Sigurdsson et al. (1978) suggested that rifting in Skagi was related to either a period of increased spreading in North Iceland 0.5-2.5 Ma or to a temporary cessation of rifting in the North Iceland zone and consequent rift jumping to the west. Here the later assumption will be adopted and connected to ideas about a pulsating plume.

The plume has caused several rift jumps as the ridge drifts across it, as mentioned earlier. At certain times the activity of the plume culminates, but at other times it declines. V-shaped ridges oblique to the Reykjanes ridge are thought to reflect these pulses, and they are thought to indicate peaks in the plume’s activity 15 and 6 Ma (Voigt 1971, Voigt and Avery 1974, Jones 2003). This would suggest that the energy brought to the crust differs from one time to another.

As shown by Abelson and Agnon (2001) the Iceland Plume seems to have been in a phase of low activity about 1.5 million years ago. Here it will be suggested that at that time it lacked the energy to control the North Iceland rift zone and keep it in place and thus it failed to maintain the transform faults and associated earthquake activity. A new rift zone without any transform faults started to form, bridging the shortest way between the Reykjanes and Kolbeinsey ridges. This became the Skagafjörður zone. Volcanism started in Skagafjörður and its valleys. Later on the power of the mantle plume increased again. It gained energy to keep control over the rift zone. Volcanic activity increased in the North Iceland Volcanic Zone but died out in the Skagafjörður area. The zone there was left incomplete. This discussion leads to the prediction that the Skagafjörður ridge jump was an overture for the next major rift jump in the country, which will be towards west, indicating a parting of the Mid-Atlantic ridge and the Iceland Hot Spot.

10. Conclusions

The geological setting, recent volcanic formations, tectonics and geothermal activity on a rather narrow and well-defined belt between Hofsjökull and Skagi, together with submarine formations in the Skagafjörður fjord and north of Skagi, leads to the conclusion that this is a short-lived and immature rift zone. For a while it bridged the shortest way between the Reykjanes-Langjökull ridge and the Kolbeinsey ridge. Spreading, together with spreading volcanism, started in the area around 1.7 Ma. The zone seems to have propagated from both ends, towards north from the Hofsjökull area and towards south from the submarine Kolbeinsey ridge. The central part of the area, between the propagating belts, perhaps never became volcanically active; at any rate, no eruptive centres are known there. The zone was uncompleted in the sense that the activity was short-lived: it did not form a tectonic syncline or a flexure or central volcanoes, with the exception of Hofsjökull, the only active volcano of a spreading zone with diminishing activity.

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