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Sill Intrusion and Associated Compressive Regimes: Examples from Basaltic Sills of the Faroe Islands and their Ambient Basaltic Host-rocks

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Abstract: Sills of predominantly mafic compositions are ubiquitous in many onshore and offshore extension-related sedimentary basins worldwide and do in some instances also appear in extension-related volcanic settings like those of North Atlantic islands such as NW Britain, Iceland and the Faroe Islands. Both of these settings are typically composed of sub-horizontal layered strata, in which individual layers may possess some variations with respect to mechanical properties/strengths. Previous models on sill intrusion have commonly invoked sill development, where intruding melts advance sub-horizontally through relatively weak layers and cut upwards through stronger ones at relatively steep angles (ramp-flat geometries), while other models point to gradual and continuous sill climbing largely irrespective of mechanical properties in layered host-rocks. Various researchers have previously attributed intrusion of inclined and/or saucer-shaped sills to regional far-field shortening/compression within actual intrusion areas, while others point to sill emplacement in more neutral environments, when it comes to prevailing pressure conditions. The model presented in this contribution indicates that emplacement of saucer-shaped sills in the lava successions of the Faroe Islands not only caused uplifts of their respective overburdens following ultimate inflation, but did in some instances also impose sub-horizontal compression/shortening of surrounding host rocks, so as to trigger faulting and displacement within some of these. In turn, compression/stresses, built up in surrounding host-rocks in response to sill inflation, likely triggered post-magmatic faulting within outer parts of the actual solidified sills themselves.

Keywords: Faroe Islands, basaltic rocks, sill intrusion, thrust faults, overburden uplift

INTRODUCTION

Sills of basaltic compositions occur in widespread areas around the Globe, preferably in settings exposed to previous extensional events such as sedimentary basins onshore and offshore as well as in some onshore igneous environments, which are related to previous extensional/rifting events too (1). Onshore examples of such intrusions in sedimentary basins include sills from southern parts of Africa (2,3), while offshore equivalents can be found in widespread areas off NW European and W African margins for instance (4,5,6). When it comes to basaltic sills cropping out in various igneous settings such as volcanic lava piles, such intrusions have been reported previously for NW Britain, Iceland and the Faroe Islands (7,8,9,10,11). In general, sills may display a wide array of geometries and may occur in a wide array of mutual configurations, from individual intrusions to widespread and intricate sill complexes (5,6,7,12).

It is universally accepted amongst researchers in geology that orientations of principal stress axes in areas experiencing sub-lateral extension (σ_3 is sub-horizontal), be it in the upper mantle and/or in the uppermost crust, will result in melt transport to the

Earth's surface via sub-vertical dykes. When it comes to magma propagation, an absence of sub-lateral extension in the uppermost crust would mean that options other than sub-vertical magma transport may become relevant too. Ascending magmas generally transform from feeder dykes to sill intrusions in settings/altitudes, where the least principal stress axis (σ_3) rotates from a sub-horizontal to a sub-vertical orientation, while the other two principal stress axes (σ_2 and σ_1) display sub-horizontal orientations (13). Most current models on intrusion of saucer-shaped sills in such settings favour a propagation mechanism, where the sills grow and climb in response to interaction between advancing melts and overlaying free surfaces, where melts in layered host-rocks of various mechanical properties supposedly propagate sub-horizontally along mechanically weak layers and cut/climb across stronger ones at relatively steep angles at intervals (14,15). Other models suggest intrusion of saucer-shaped sills during periods of regional sub-horizontal compressive stress/shortening within the uppermost crust (13,15,16).

With respect to the Early Paleogene saucer-shaped sills, intruded into the upper parts of the lava successions of the Faroe Islands, two opposing models have been proposed in previous studies. One model proposes sill emplacement in response to regional sub-horizontal shortening/compression (15,16), while the other invoke local sill intrusion into host-rocks that display an absence or a near-absence of sub-horizontal compression/extension (7,8,11).

In this contribution, physical characteristics at selected margins of the Streymoy Sill, Faroe Islands, and adjacent host-rocks are examined/measured in order to determine, whether any measurable interactions occurred between and/or within these during and subsequent to sill emplacement and solidification. Based upon findings on these matters, attempts are made to determine whether any unidirectional regional compression/shortening triggered sill intrusion in the actual area, or if interaction between initial magmatic pressure and a more neutral local host-rock environment (pressure-wise) governed ultimate intrusive mechanics/styles of the actual sills. In addition, assessments are made with respect to potential pressure effects on host-rocks from sill intrusion/inflation and vice versa, with focus on potential effects on young solidified Faroese sills from pressure, stored in ambient host-rocks, in the course of and in response to their intrusion and subsequent inflation.

GEOLOGICAL FRAMEWORK

Situated in the north Atlantic at the NW European margin, the Faroe Islands forms a central part of the North Atlantic Igneous Province (NAIP), which also includes areas in W Greenland, E Greenland, NW British Isles, Rockall Plateau and the Vøring/Møre Margins, offshore W Norway ((17). The exposed parts of the Faroe Islands are in their entirety made up of various volcanic, intrusive and sedimentary basaltic rock suites, mostly arranged in sub-horizontal layers. Initially, these basaltic successions measured an estimated maximum 6.6 km in thickness and covered an area of several tens of thousands of square kilometres, all resting on a ~30 km thick stretched basement, being the remnants of a sunken ancient micro-continent (18,19).

In brief, the original Faroese basaltic successions can be sub-divided into seven main formations (20), which can be termed from below: The Lopra Formation (~1075 m); the Beinisvørð Formation (~3250 m); the Prestfjall Formation (~9 m); the Hvannhagi Formation

(40 – 50 m); the Malinstindur Formation (1250 – 1350 m); the Sneis Formation (≤ 30 m) and the Enni Formation (~900 m) (Fig. 1).

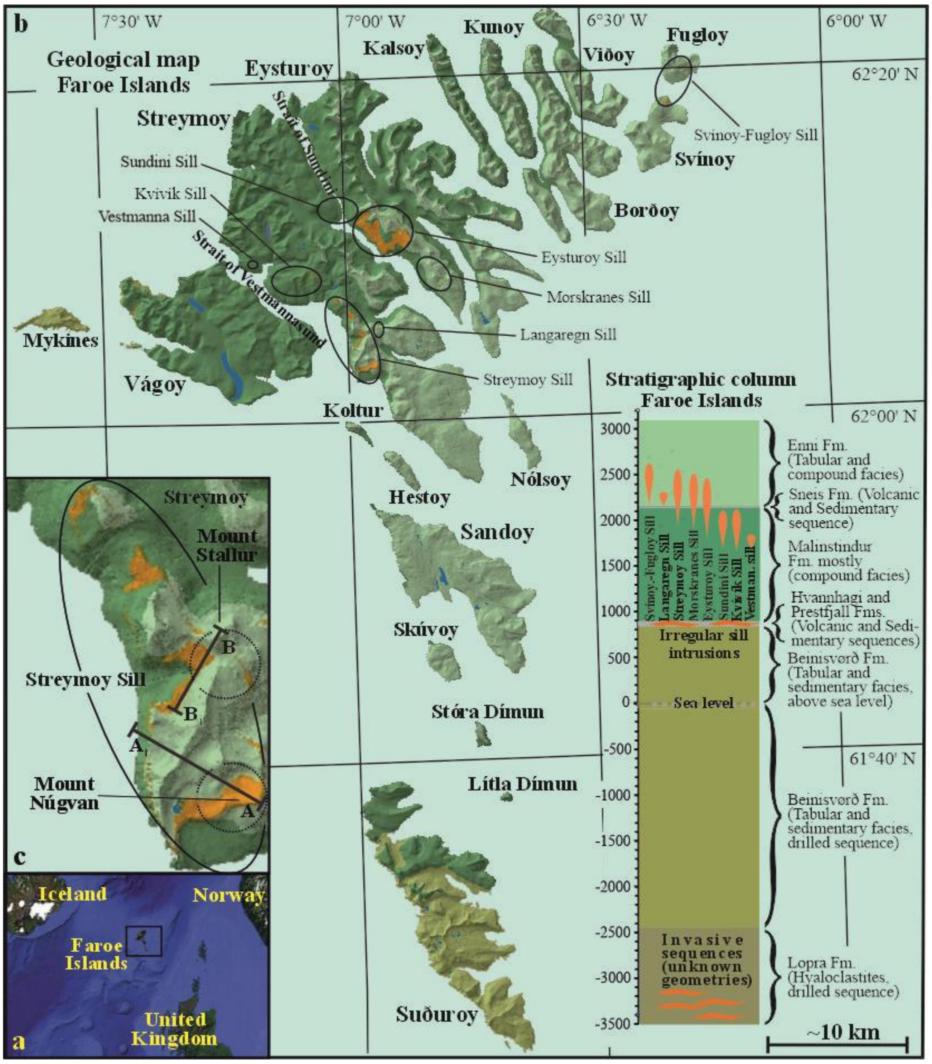


Figure 1: Map-view(s) of the North Atlantic area including the Faroe Islands (Modified from: Hansen, 2024). a. Geographical location of the Faroe Islands in a North Atlantic perspective. b. Geographical characteristics and geological composition of the Faroe Islands (Geological formations from: Passey and Jolley, 2009). c. The black dotted circles indicate geographical locations within the Streymoy Sill, SE segment, focused upon in this contribution. Bars denoted A – A1 and B – B1 refer to profiles presented in Fig. 10 and Fig. 11 respectively.

Measured ages for these formations range from ~61 Ma to ~55.8 Ma (21). All parts of the Faroese lava successions host sub-vertical dyke systems of various lengths and thicknesses, while the uppermost Malinstindur, Sneis and Enni formations are also intruded by a number of sill intrusions of various sizes (7,8,11,22,23). These latter range in ages from ~55.5 Ma for the largest to ~50.5 Ma for the smallest sills (24). All Faroese sill intrusions were fed through moderately inclined feeders that transformed to sub-vertical orientation a few tens of meters below sill-feeder contacts (7,8,11,23) (Fig. 2a, b). The sills of the Faroe

Islands represent a variety of development stages, from uniform thick and fully developed intrusions to wedge-shaped intrusions with relatively thick upper/outer margins and much thinner (a few tens of centimeters thick) lower/outer margins at opposite ends (Fig. 2c).

DEFORMATION IN FAROESE SILLS AND AMBIENT HOST-ROCKS

Low-angle faults are commonly observed in exposed parts of Faroese sills and are occasionally encountered in adjacent host-rocks to these sills too.

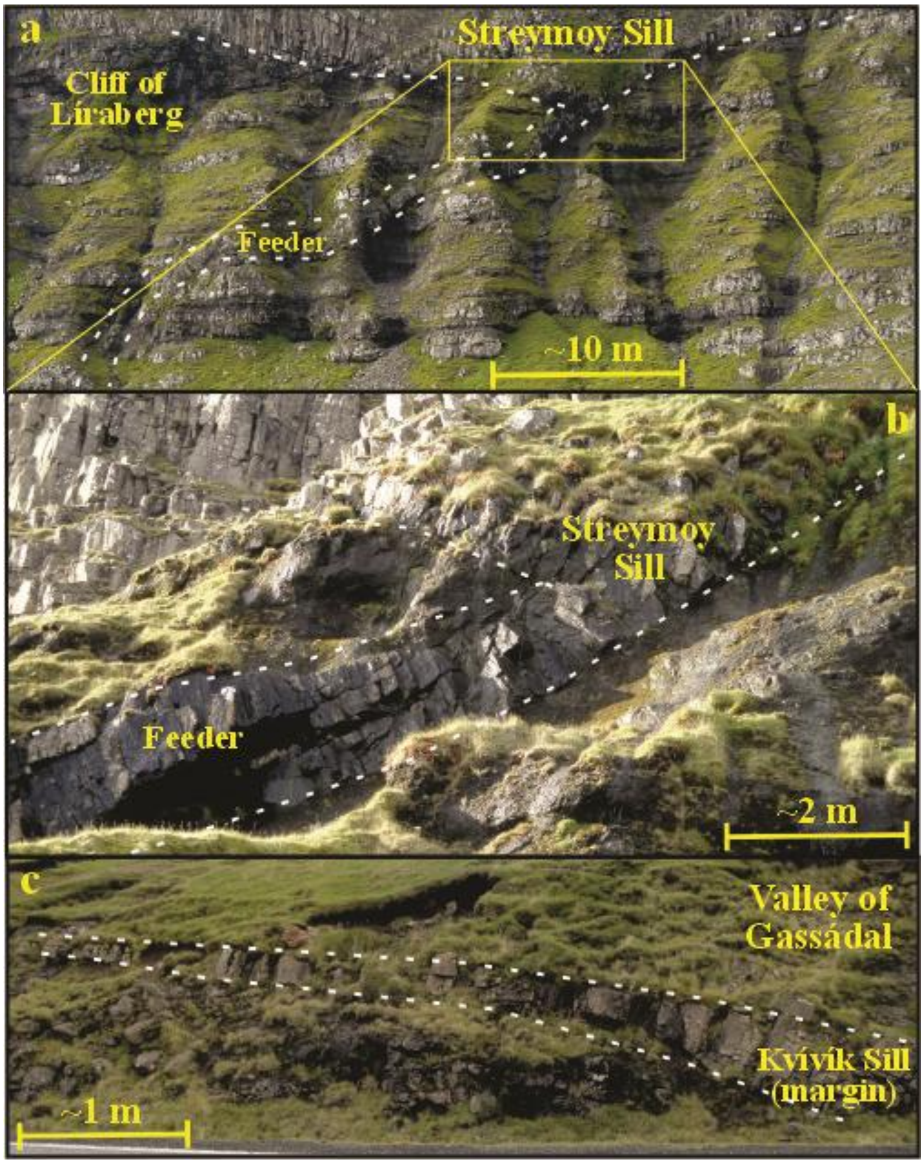


Figure 2: Examples of feeders and margins of Faroese sills. a. Inclined feeder to the Streymoy Sill transforms to sub-vertical orientation ~15 m below feeder-sill contact. b. Closer view of the feeder-sill contact in the same area. c. Thin inclined margin of the Kvívík Sill, where the parts to the right measure ~50 cm and the parts to the left measure ~25 cm in thicknesses. Sill and feeder outlines are indicated with white dashed lines.

When it comes to sill-hosted faults in e.g. the Faroese Streymoy Sill, these commonly occur as low-angle irregular sort of en-echelon faults in inclined sill sections and as oppositely directed (conjugated) low-angle faults in sub-horizontal sill sections (Fig. 3a-d). It is pertinent to note that strikes in faults observed within Faroese sills are not necessarily oriented orthogonal to (two-dimensional) cliff faces, in where they occur. Faults occurring in basaltic host-rocks adjacent to Faroese sills can occasionally be observed in sub-vertical cliff faces in relatively close proximity of actual sill margins. These faults do not uncommonly occur as sets of conjugated low-angle faults (Fig. 3e).

Some parts of the host-rocks surrounding the Streymoy Sill in the Mount Stallur area appear to have been displaced relative to one another at some point. Relevant examples include a host-rock suite containing a thick relatively light-coloured lava horizon, cropping out in local NW facing cliffs. A part of the actual horizon appears atop the Mount Stallur itself, while other parts crop out at lower altitudes farther to the NE away from the local sill margin, where another noticeable discontinuity, involving the actual horizon, appear in the local landscape (Fig. 4a-c). Discontinuities involving the same lava horizon can be observed on the opposite side of Mount Stallur too, where they appear as three distinct relatively low cliffs cropping out at different altitudes in an otherwise gently sloping landscape (Fig. 4d-f). Field measurements/observations demonstrate that the moderately inclined upper NE margin of the Streymoy Sill in this same Mount Stallur area transforms into a thick (~20 m) NW ⟷ SE and WNW ⟷ ESE directed sub-vertical dyke/chimney that extends several hundred meters farther towards the SE. The actual thick dyke displays a change in orientation of around 25° just to the NE of Mount Stallur) (Fig. 4f).

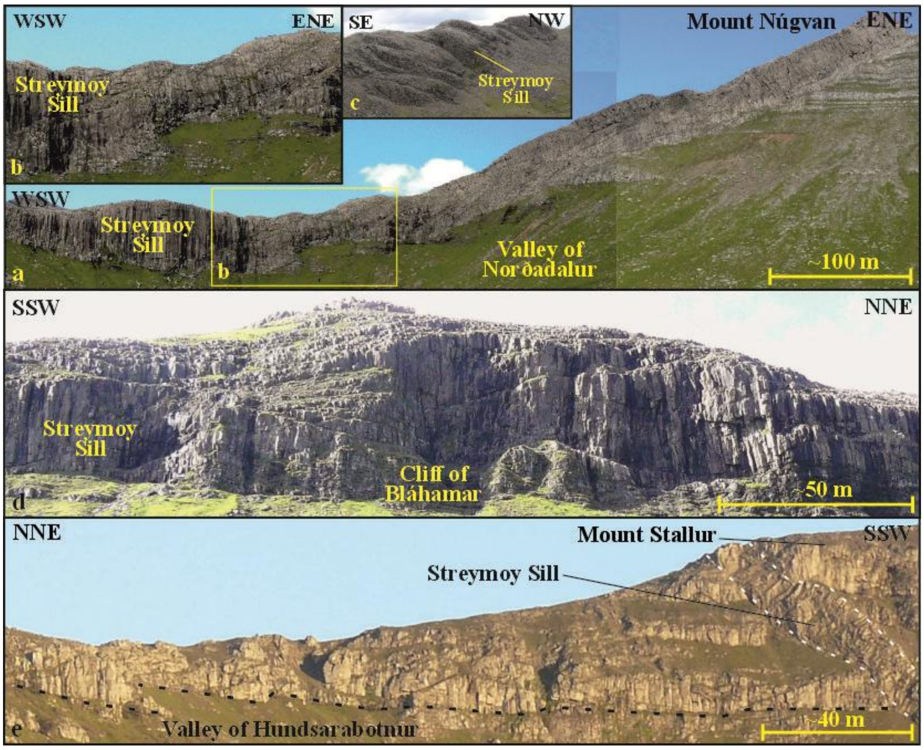


Figure 3: Low-angle faults in basaltic rocks of the Faroe Islands. a. Low-angle faults in sub-horizontal and inclined SE margin of the Streymoy Sill. b. Closer view of section of the same sill. c. Low-angle faults for the same sill as seen from the opposite/back side of the same locality/area. d. Low-angle faults in the Streymoy Sill at the Cliff of

Bláhamar. e. Low-angle faults in thick light-coloured host-rock marker horizon to the NNE of contact with the NNE margin of the Streymoy Sill. Sill outlines are indicated with white dashed lines and bottom contact of marker horizon is indicated with black dashed lines.

DISCUSSION

Relatively recent studies, focused on the saucer-shaped geometries typical for Faroese sills, came to the conclusion that these likely formed initially by propagation of thin magma fronts, which generally climbed gently in a mole-like fashion through layered ambient host-rocks irrespective of mechanical differences between host-rock layers and without noticeable interaction with the Earth's free surface (7,8,11). The reasoning behind this theory rests on the fact that the least developed Faroese sills (Kvívík, Sundini and Morskranes sills) display wedge-shaped geometries, where their thinnest margins measure only a few tens of centimeters in thicknesses while still displaying gently climbing geometries (Fig. 2c). Similarly, the obvious geometrical changes in recorded feeder dykes to Faroese sills from sub-vertical to moderately inclined orientations just beneath feeder-sill junctions (E.g. Fig. 2a , b) cannot be attributed to any interaction with the Earth's free surface. Other much thinner feeders to Faroese sills (20 – 50 cm thick) display similar geometrical characteristics. Hence, climbing in response to large-scale sill inflation coupled with interaction with the Earths free surface, as commonly envisaged as a main requirement for sill climbing in the uppermost crust, is 'not' an option in these cases.

Instead, a mechanism, where depth dependent variations of Young's Modulus triggered uneven small-scale (semi)elastic displacement on either side of initial thin advancing magma fronts, can adequately account for gradual sill climbing in the uppermost crust of the Earth (8). It is likely that initial thin magma fronts of developing Faroese sills advanced in a radial fashion as lobes or fingers from geographically restricted sources/feeders, as proposed for other settings too (12), whilst climbing at the same time (11). As the thicker fully developed Faroese sills display geometries identical to their less developed counterparts and occur in similar host-rocks, it is overwhelmingly likely that they too developed in manners similar to those of the wedge-shaped intrusions.

Relatively soft/thin inter-basaltic layers of tuff and/or sedimentary materials in host-rocks on either side of thin developing Faroese sills could have accommodated parts of associated host- rock dilation prior to main inflation phases, but it is quite likely that emplacement and ultimate inflation of these voluminous magmatic bodies within the Faroese lava successions ultimately caused a noticeable build-up of compressive stresses and/or some mechanical failure within these. Similar generation and storage of compressive stresses within competent host-rock layers within basaltic lava successions on either side of intrusive sheets have been reported previously too for thin sub-vertical dyke intrusions in Iceland (25). Moreover, various modelling imitating physical conditions similar to those of the uppermost crust, strongly suggest that e.g. igneous intrusive bodies of various sizes have the potential to cause build-up of stresses in various host-rock suites of the uppermost crust, which can be preserved within these for geological time scales of hundreds of thousands to millions of years (26,27).

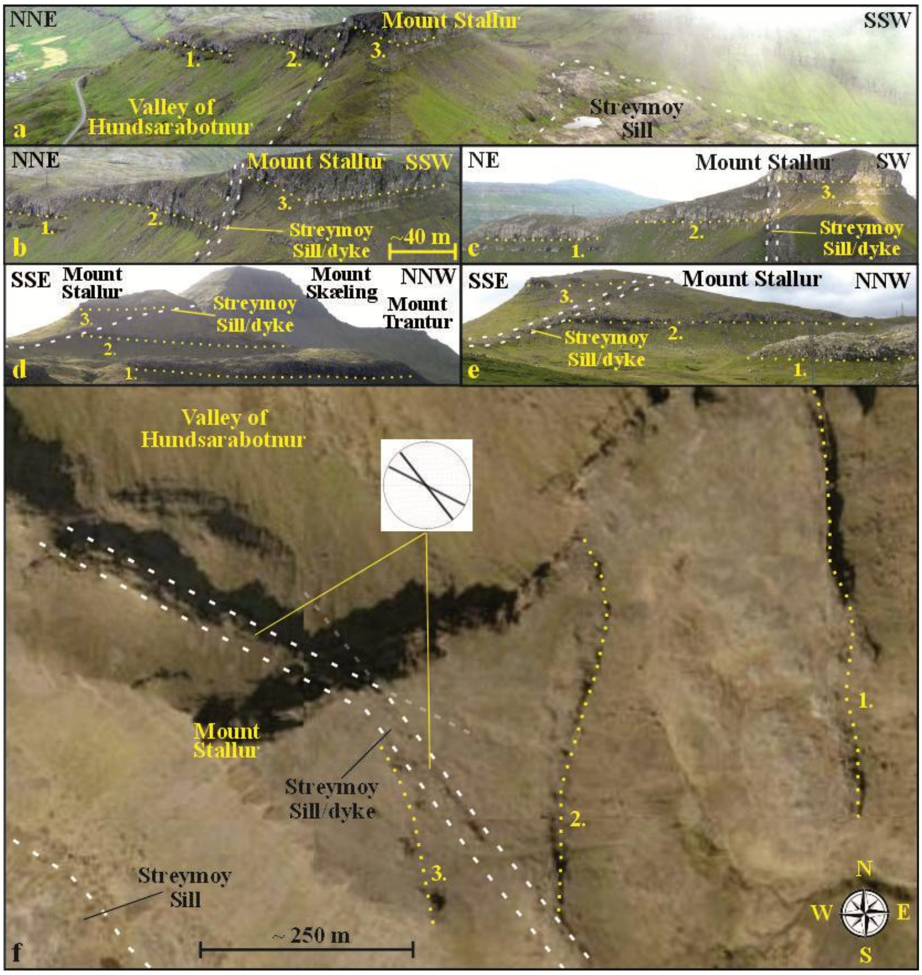
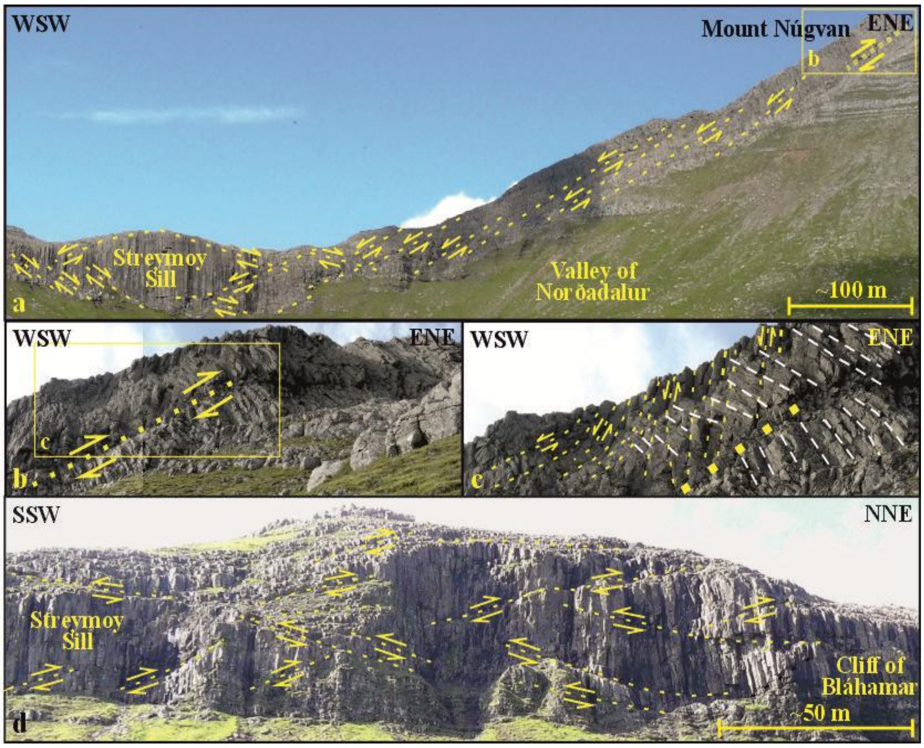


Figure 4: Views from different angles, distances and altitudes of the area around Mount Stallur. a. b. and c. A discontinuous host-rock marker horizon defined by yellow dotted lines, occurs at three different altitudes (Labelled 1., 2. and 3.) in a NW facing cliff on either side of the NE margin of the Streymoy Sill, SE segment. d. and e. Views of the same discontinuous marker horizon (same yellow markings) on the gently sloping opposite side of Mount Stallur. f. Map view perspective (Aerial image from Kortal Fo, Umhvørvisstovan, Faroe Islands) illustrating the nature of a discontinuous host-rock marker horizon in the Mount Stallur area. A thick dyke (~20 m with a kink on it) emanating from the NE rim of the Streymoy Sill is clearly visible in most of the images. Sill and dyke outlines are marked with white dashed lines.

The physical characteristics displayed by Faroese sills and their ambient host rocks, as presented in the previous section, point to two main issues that require relatively detailed assessments, namely the origin/reason of/for the development of low-angle faults within actual sills and in adjacent host-rocks, as well as origin/reason of/for displacement of thick basaltic horizons within some host-rock suites.

When it comes to the low-angle faults, which are commonly exposed within the Streymoy Sill, these display characteristics typical for sheet-like rock suites, which have experienced compression/shortening sub-parallel to their sub-horizontal bases and to dip orientations within their more inclined outer sections (Fig. 5a; Fig. 5d).

A closer inspection of the inclined SE extreme of the Streymoy Sill, SE segment, in the area around Mount Núgvan reveals a somewhat more complex structural development within this geographically restricted part of the actual intrusion. Here, the lower half near the tip of the actual sill has been displaced slightly down-slope relative to the upper half, with these being separated by a relatively thick (~50 cm) 'dextral' shear zone, oriented sub-parallel to the dip of the actual inclined sill section, which can be traced for a distance of around 100 meters (Fig. 5a-c). The formation of such characteristics would be in accordance with a mechanism in which the sill tip at this locality experienced compressive reactive stresses stored in ambient host- rocks shortly subsequent to inflation and solidification of the actual sill, with sub-horizontal stress components in host-rocks being of sufficient magnitude so as to generate the observed shear movement.



<u>Figure 5</u>: Faults and joints in exposed margins of the Streymoy Sill. a. Relative shear movements (one-sided yellow arrows) in a few selected main low-angle faults cropping out in the Mount Núgvan area. b. A thick fault (thick yellow dotted line) bisects the uppermost ~100 m of the sill margin at Mount Núgvan, where the upper part appears to have moved towards the ENE relative to the lower part (dextral). c. Initial columnar jointing (white dashed lines) atop the thick fault at the same locality has been rotated anticlockwise and exposed to sub-vertical faulting close to the mountain top (yellow dashed lines), which then experienced clockwise rotation farther down slope. d. Relative shear movements (one-sided yellow arrows) in low-angle faults cropping out in the Cliff of Bláhamar area.

Further scrutiny of this particular geographical locality reveals that the initial columnar jointing atop the actual thick shear zone did at some point experience a slight anticlockwise rotation as opposed to similar jointing below it. In turn, these same rotated columnar joints were dissected by relatively closely spaced sub-vertical (‘sinistral’) fractures/faults near the tip of the sill on Mount Núgvan, which were themselves gradually rotated clockwise farther down-slope in a westerly direction, until they became more or less aligned with the more conspicuous larger faults, which characterize the Streymoy Sill in this area (Fig. 5b, c). The structural characteristics atop the actual shear zone would be in accordance with a mechanism, in which gravity from the sill overburden caused normal faulting to develop at the very top of the actual inclined sill section, but where sub-lateral reactive stress stored within ambient host-rocks in response to sill intrusion/inflation increasingly contributed to the faulting farther down the relatively steep mountain slope so as to ultimately produce thrust/reverse faulting down-slope towards less inclined sill sections.

The thick ‘dextral’ shear zone within the Streymoy Sill near the top of Mount Stallur likely came into being shortly after crystallization of a still warm intrusion, while subsequent ‘sinistral’ faulting atop the same shear zone and farther down-slope likely occurred in a noticeably cooler and more contracted/shrunk intrusion. It is worth noticing that actual dip orientations in various outer inclined parts of e.g the SE segment of the Streymoy Sill vary systematically from SSW oriented dips in the NE parts all the way through SW, W, WNW, NW, NNW, N, NNE, NE to ENE oriented dips in the SW parts of the actual sill segment (Fig. 6).

Measurements of principal stress axes (σ_1, σ_2 and σ_3), based on orientations of conjugate low-angle thrust faults within the actual sill segment, point to a relatively close and systematic association between local dip orientations and orientations of local principal stress axes (Fig. 6). The results of these measurements render it quite unlikely that any unidirectional regional stress regime caused all the observed thrust faults. Rather, it appears that the ultimate inflation of the actual sill induced and stored compressive stresses within ambient host-rocks, which became more or less aligned with general dip directions, prevailing for the various sill sections. In turn, the stresses stored in the actual host-rocks most likely reacted upon the actual sill, once its initial magmas had crystallized (and shrunk somewhat), thus generating the observed thrust faults.

It is noteworthy that unevenly oriented sets of conjugate thrust faults of various sizes/extent occasionally occur in relatively close association with one another in basal sill sections in the extreme SE parts of the actual intrusion, i.e. variously oriented stress fields did occasionally overlap in basal sill sections within this geographically restricted area. Such characteristics would be in accordance with various local stress orientations in adjacent inclined outer sill sections converging at lower levels closer to basal sill sections.

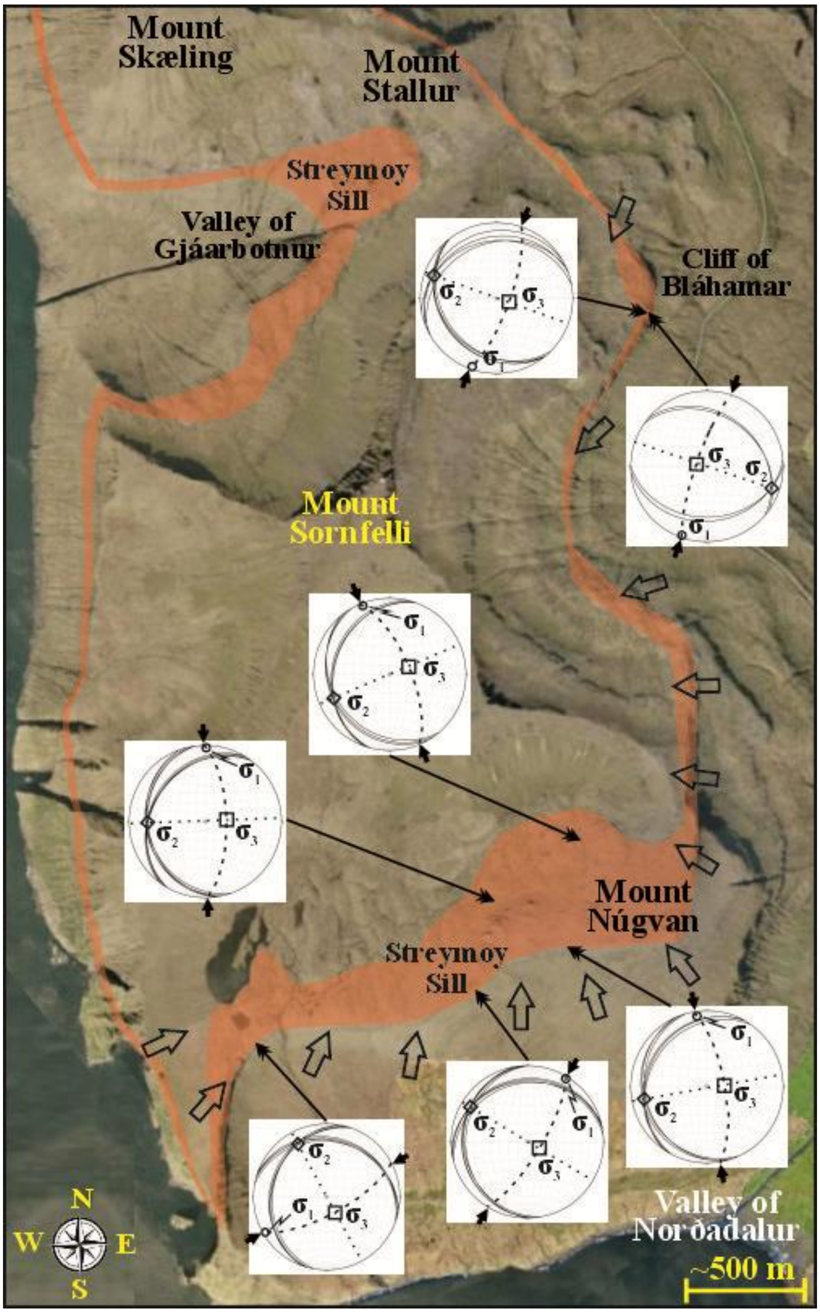


Figure 6: Map view of exposed parts/outlines of the Streymoy Sill, SE segment (Aerial image from Kortal Fo, Umhvørvisstovan, Faroe Islands). Open black arrows indicate systematic variations in dip orientations for the various sill sections. Small inset figures represent stereo-plots based on conjugate low-angle fault sets from locations shown in Fig. 5. Relative principal stress axes are denoted σ_1 (largest), σ_2 (middle) and σ_3 (smallest). Tiny black arrows associated with the stereo-plots indicate orientations of largest principal stress axis σ_1, while longer thin black arrows point to geographical locations of measurements.

Assessments regarding characteristics, displayed by a conspicuous host-rock marker horizon adjacent to the NE border of the Streymoy Sill, SE segment, exposed in the Mount Stallur area, show without much doubt that a part of this horizon (Labelled 3. in Fig. 4) was sub-vertically uplifted by ~35 to ~40 meters relative to the average elevation of its counterparts (Labelled 1. and 2. In the same figure), in association with ultimate emplacement and inflation of the inclined sill section in this area. Physical processes/mechanisms, required to explain the noticeable sub-vertical discontinuity between actual marker horizon 1. and 2., in addition to a few less pronounced discontinuities exposed at the bottom contact of horizon 2., may appear somewhat nebulous at a first glance, as no known intrusive bodies, which could have caused such discontinuities/uplifts, reside underneath this particular area. However, orientations of the low-angle faults, being hosted by the actual host-rock horizon, in addition to characteristics displayed by a conspicuous shear-zone between horizon parts 1. and 2. seem to suggest a compression-related origin. In these instances, the measured principal stress axis σ_1, displayed by conjugate faults in the actual area, is oriented in a roughly NE-SW direction (Fig. 7a), i.e. roughly orthogonal to the NE margin of the Streymoy Sill just to the SE Mount Stallur (Fig. 4f). Also, mineral lineation (slickenfibers) within a shear-fault cropping out in the shear-zone between horizon parts 1. and 2. are oriented in roughly NE-ENE and SW-WSW directions, where the upper part of the actual fault was displaced in a roughly northeasterly direction relative to the lower part (Fig. 7b-e).

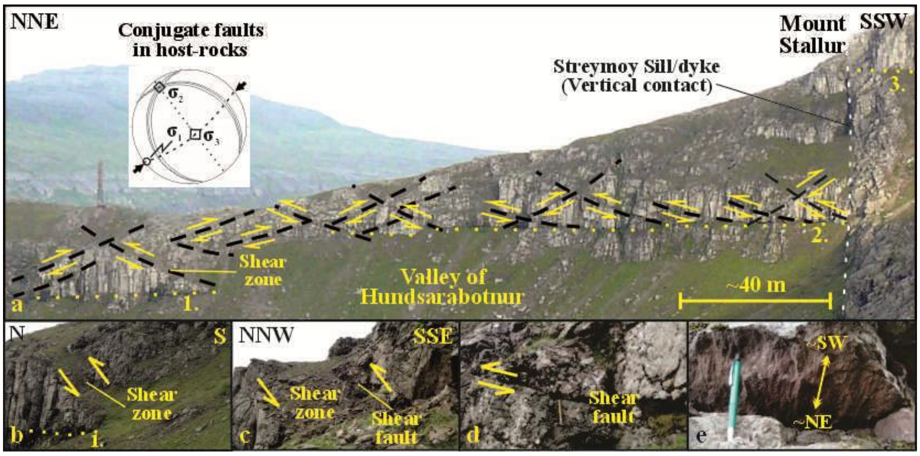


Figure 7: Displacement/deformation of a thick basaltic host-rock marker horizon (Labelled 1., 2. and 3.) adjacent to a sub-vertical dyke/sill margin in the Mount Stallur area. a. General σ_1 orientation in inset stereo-plot, representative of local conjugate thrust faults (black dashed lines), suggests that these developed in response to sub-horizontal roughly NE-SW directed compression. b. and c. Closer view of a shear zone indicated in a. d. Closer view of a shear fault indicated in c. e. Roughly NE-SW directed mineral lineation ('slickenfibers') in the upper part of a shear fault shown in d. One-sided yellow arrows in all part-figures indicate relative shear movements. Dotted yellow lines in a. and b. indicate base of displaced marker horizon. Double yellow arrow in e. indicates direction(s) of mineral lineation. The margin of a thick dyke emanating from the NE contact of the Streymoy Sill, as shown in a., is outlined by a white dashed line.

During inflation from a near-zero thickness to ~20 m, the approximate thickness, which can be observed/measured in the actual dyke/chimney today, these initial melts must have displaced surrounding host-rocks with a roughly similar distance in a sub-horizontal direction.

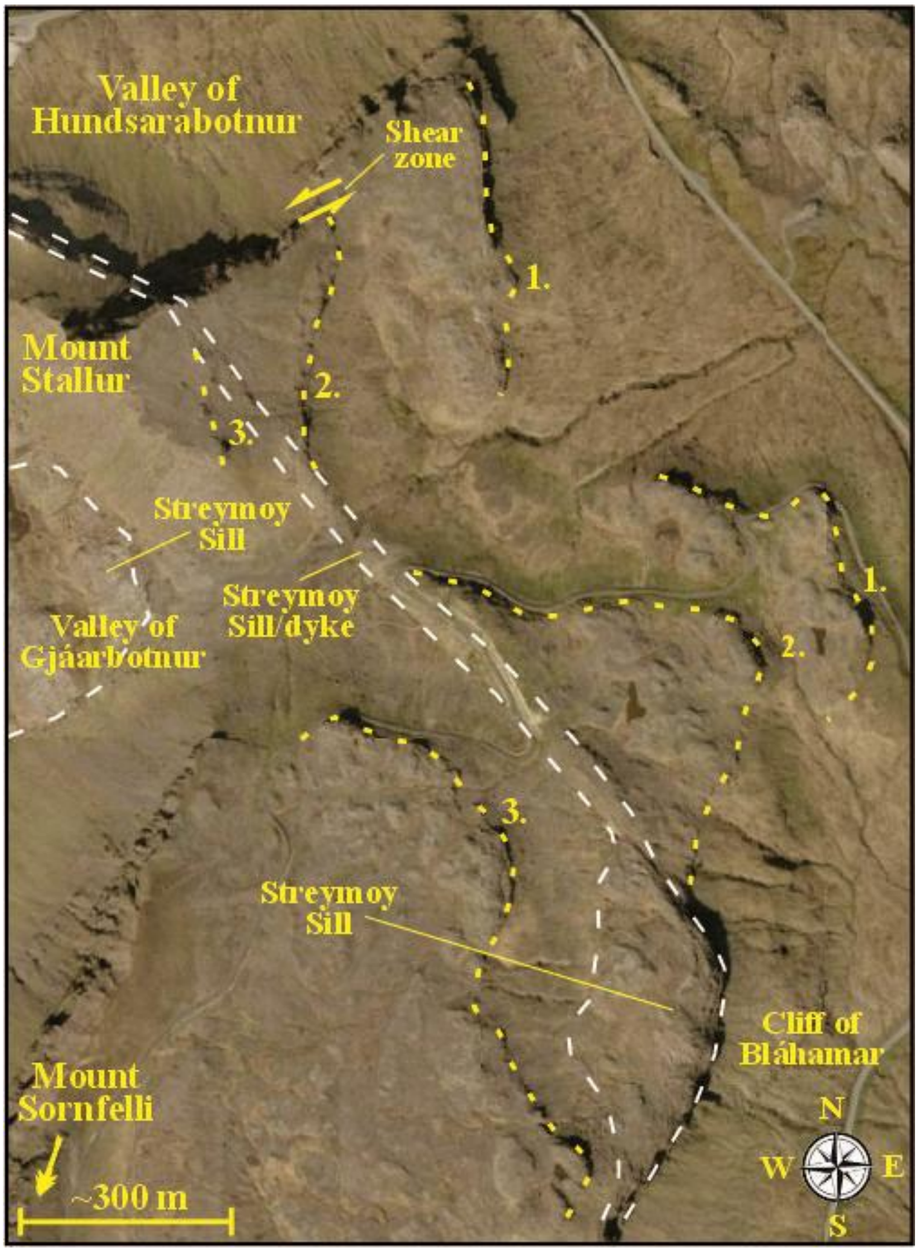


Figure 8: Map view of the area around the NE margin of the Streymoy Sill (Aerial image from Kortal Fo, Umhvørvisstovan, Faroe Islands). The extent of the area affected by host-rock displacement, as demonstrated for the area around Mount Stallur, can be extrapolated southwards for the length of the actual thick sub-vertical dyke, i.e. for around a kilometer towards the area around the Cliff of Bláhamar. Markings are as in Fig. 4c.

Accordingly, the faults and discontinuities observed in and between marker horizons 1. and 2. in the cliff face just to the NE of Mount Stallur and the sub-vertical NE margin/dyke of the SE segment of the Streymoy Sill, most likely developed in response to the inflation of the actual sub-vertical dyke/chimney. The notion that the displacement between marker horizon 1. and 2. and deformation/displacement(s) within horizon 2. likely developed in response to inflation of the actual sub-vertical dyke/chimney, emanating from the NE margin of the Streymoy Sill, and not in response to contemporaneous regional unidirectional stress actions, is strengthened by the measured variations in principal stress axes for other parts of the same sill and by variations in orientation of the actual thick dyke itself by around 25° (Fig. 4f; Fig. 6). This latter variation may in part stem from pre-existing fractures or weak zones within ambient host-rocks in the Mount Stallur area though.

It is not straightforward to accurately assess the depth to which the thick sub-vertical NW-SE trending dyke/chimney, emanating from the NE rim of the Streymoy Sill in the Mount Stallur area and towards areas farther to the SE, extends, but field evidences suggest that its base probably reach a stratigraphic depth approximately down to the base of the local marker horizon labelled 1. (Fig. 4). Still, it is pertinent to note that the displacement of host-rocks in response to inflation of the actual thick dyke in this area solely occurred at crustal levels higher than the inclined upper margin of the main sill body itself. Hence, the faulting observed in the Streymoy Sill in e.g. the Bláhamar area occurred at a later stage and in response to pressure stored in host-rocks residing at lower stratigrapical levels than those, which include horizons 1. and 2.

Discontinuities similar to those displayed by the thick marker horizon, cropping out in the Mount Stallur area, are also clearly visible/detectable in the mountain range farther towards the SSE and S (Fig. 8; Fig. 9). Hence, the intrusion and subsequent inflation of the Streymoy Sill, SE segment, and the thick dyke emanating from its NE rim, had a profound effect on the local landscape from the area around Mount Stallur to the area just north of the Cliff of Bláhamar.

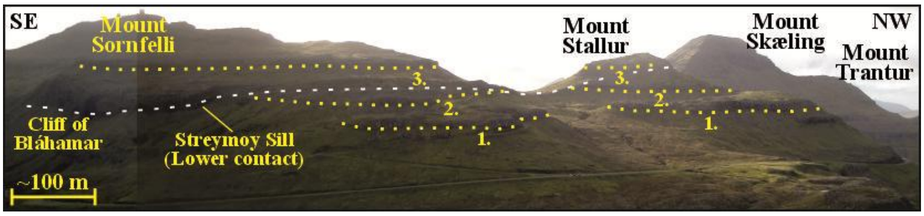


Figure 9: Same as in Fig. 8, but in panorama view towards the SW.

It might be envisaged that sub-horizontal and/or sub-vertical displacements of basaltic lava horizons, as can be observed locally within basaltic successions elsewhere in the Faroese archipelago, could in some cases reflect actions of unknown intrusive bodies in actual areas, like it was the case with some host-rocks adjacent to the Streymoy Sill.

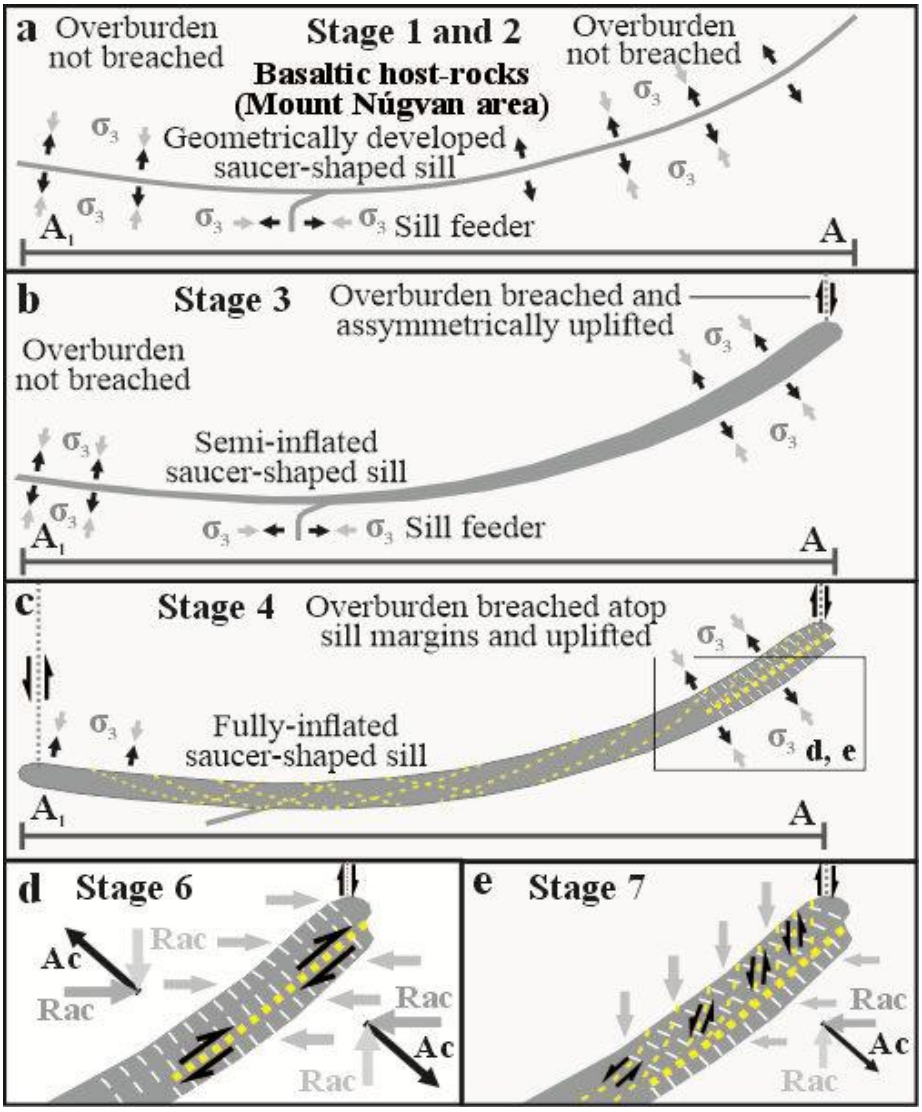
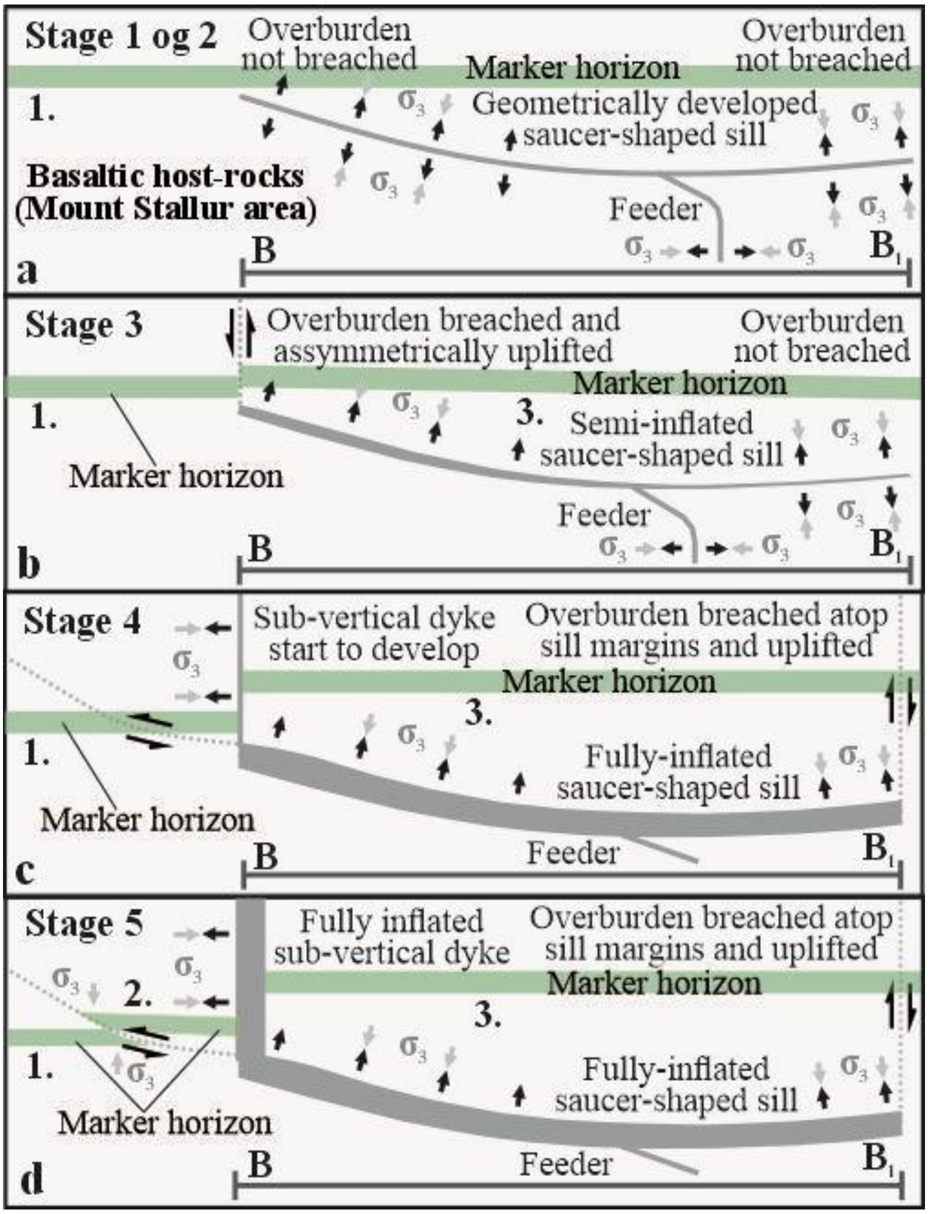


Figure 10: Simplified profiles of inclined SE margin of the Streymoy Sill, SE segment, (Longest axis) in the Mount Núgvan area (Profile A – A1 in Fig. 1C). a-e. Magmatic/structural evolution outlined in 'Summary and concluding remarks' in the main text. Small black arrows indicate magmatic pressure on ambient host-rocks while small grey arrows indicate reactive stresses (σ_3) within these. White dashed lines indicate initial columnar jointing, while yellow dotted and dashed lines indicate subsequent faulting within the actual sill. Black one-sided arrows indicate relative shear movements. Larger arrows labelled Ac in d. and e. indicate general active/magmatic stresses from the intrusion on ambient host-rocks, while associated gray arrows labelled Rac indicate sub-vertical and sub-horizontal components of general reactive stresses within ambient host-rocks.

SUMMARY AND CONCLUDING REMARKS

Based on the observations/measurements presented above together with associated assessments and interpretations focusing upon characteristics displayed by two distinct areas of the SE segment of the Streymoy Sill and selected host-rocks, the conclusions reached in this contribution can be briefly summarized in a timeline perspective as following:

1. Initial basaltic melts, which gave rise to Faroese sills in general, likely ascended through most parts of the uppermost crust via sub-vertical feeders, which ultimately deflected to become moderately inclined for several meters or a few tens of meters immediately below their transformations to sill intrusions, in response to rotations of local principal stress axes (σ_1, σ_2 and σ_3). The basic saucer-shaped geometry, displayed by all Faroese sills, likely developed in response to initial radial propagation of magma fronts in mole-like manners as thin lobes or fingers, where depth-dependent variations of Young's Modulus within ambient host-rocks resulted in gentle continuous climbing of advancing melts, where overlaying free surfaces were not noticeably affected prior to the main inflation phases (Stage 1 and 2; Fig. 10a; Fig. 11a).
2. Subsequent partial sill inflation, initiated at outer inclined sections of the Streymoy Sill, resulted in the breaching and asymmetric uplift/tilt of overburdens, including parts of host-rock marker horizon labelled 3. in the Mount Stallur area (Stage 3; Fig. 10bB; Fig. 11b).
3. The magmatic pressure that drove the overall development of the Streymoy Sill from onset to a fully inflated intrusion likely resulted in generation and storage of reactive stresses within these in the course of action, in addition to breaching and uplifting entire sill overburden(s) atop sill margins including host-rock marker horizon 3. in the mount Stallur area (Stage 4; Fig. 10c; Fig. 11c).
4. Subsequent to ultimate inflation of lateral and inclined sill sections, compressive forces related to ultimate inflation of a dyke/chimney emanating from the NE margin of the Streymoy Sill, SE segment, caused host-rock marker horizon 2. to be up-thrusted on top of initial marker horizon 1. in the Mount Stallur area (Stage 5; Fig. 11d).
5. Following ultimate inflation and solidification of the Streymoy Sill, SE segment, sub-horizontal re-active forces, stored in surrounding host-rocks during earlier sill inflation events, likely affected the top of the still warm inclined sill rim in the Mount Núgvan area so as to cause a ~100 m long dextral shear zone, sub-parallel to local sill dip and strike orientations, to develop (Stage 6; Fig. 10d). At a later point, a combination of gravity and sub-horizontal re-active forces, stored within ambient host-rocks in the Mount Núgvan area, likely resulted in moderate anticlockwise rotation of initial columnar jointing above the local dextral shear zone in a cooler and more contracted intrusion and in the generation of relatively closely spaced sub-vertical faults across initial columnar jointing. These sub-vertical faults gradually transformed to low-angle faults down-slope (Stage 7; Fig. 10e).



<u>Figure 11</u>: **Simplified profiles of inclined NE margin of the Streymoy Sill, SE segment, (Shortest axis) in the Mount Stallur area (Profile B – B1 in Fig. 1c). a-d. Magmatic/structural evolution outlined in 'Summary and concluding remarks' in the main text. Small black arrows indicate magmatic pressure on ambient host-rocks while small grey arrows indicate reactive stresses (σ_3) within these. Black one-sided arrows indicate relative shear movements.**

Author Contributions

The author (Dr. Jógvan Hansen) solely produced all parts/aspects of this contribution.

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