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Geology of the country rock hosting Slaufrudalur: Can caldera structures explain magma genesis and emplacement of Iceland's largest granite pluton

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1. Abstract

Magma intrusion and the generation of silicic magmas are fundamental processes controlling volcanic behavior and continental crust formation. Exposed plutons provide key constraints on these processes, yet the geological context of silicic plutonic systems in oceanic rift environments remains poorly resolved. Southeast Iceland hosts large Neogene plutonic complexes within anomalously thick (>40 km) oceanic crust, making it a prime natural laboratory for investigating silicic magma generation in a basalt-dominated, plume-influenced setting. Here, we present new detailed geological mapping, photogrammetric analysis, and three-dimensional reconstruction of the Slaufrudalur pluton, Iceland's largest exposed granitic intrusion, and its surrounding rocks. Our results reveal a complex volcano-tectonic system comprising four previously unrecognized silicic volcanic centers preserved as caldera-bounded pyroclastic successions, conduit facies, and shallow intrusions. The spatial association between these volcanic centers and the pluton indicates a close genetic and mechanical relationship, consistent with either pluton emplacement exploiting pre-existing volcanic architecture or, alternatively and more favorably, volcanism being guided by pluton-related deformation and fracture networks.

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The geological framework developed in this study demonstrates that silicic magmatism in the Slaufrudalur area was more extensive and diverse than previously recognized and provides a foundation for future investigations into the evolution of silicic volcanic and intrusive systems in southeast Iceland.

2. Second-language abstract (Icelandic)

Kvikuinnskot og myndun kísilríks bergs eru grundvallarferli sem stýra hegðun eldstöðva og myndun meginlandsskorpu. Opnur í djúpberg veita lykilupplýsingar um þessi ferli, en jarðfræðilegt samhengi kísilríkra djúpbergsmyndana á úthafshryggjum er enn óljóst.

Suðausturland hýsir umfangsmikil Neógen djúpbergskerfi í óvenju þykkri (>40 km) úthafsskorpu og er því kjörinn náttúrulegur rannsóknarvettvangur til að kanna myndun kísilríkrar kviku í basaltríku umhverfi mótuðu af möttulstrók.

Hér kynnum við nýja nákvæma jarðfræðikortlagningu, myndmælingar og þrívíddarendurgerð á Slaufrudalsinnskotinu, stærsta opna granítinnskoti Íslands, ásamt grannbergi þess. Niðurstöðurnar leiða í ljós flókið eldfjalla- og sprungukerfi sem samanstendur af fjórum áður óþekktum eldstöðvakerfum með kísilríku bergi, sem er varðveitt í gjóskulögum innan öskjurima, gosrásarmyndunum og grunnum innskotum.

Rýmissamband eldstöðvanna og innskotsins bendir til náinna tengsla, bæði hvað varðar uppruna og höggun. Annað hvort hefur innskotið nýtt sér fyrirliggjandi eldfjallaarkitektúr við innskot sitt eða að eldvirkni hafi stjórnast af aflfræðilegum áhrifum innskotsins og tilheyrandi brotakerfum.

Jarðfræðilegur rammi sem settur er fram í þessari rannsókn sýnir að súrt bergkvikuvirkni á Slaufrudalssvæðinu var umfangsmeiri og fjölbreyttari en áður var talið og leggur grunn að frekari rannsóknum á þróun súrra eldstöðva- og innskotskerfa á Suðausturlandi.

3. Introduction

Magma intrusion, crustal storage, and recycling, together with the generation of silicic magma, are fundamental geological processes that influence volcanic behavior and hazards and played a key role in the formation of the earliest continental crust. Exposed plutons provide essential constraints on these processes by recording the solidified remnants of magmatic systems. Plutons in Iceland are of particular interest because they preserve a wide range of igneous processes and because Iceland may represent a modern analogue for continental crust formation on the early Earth (e.g. Carmichael 1967; Martin et al. 2008; Reimink et al. 2014; Carley et al. 2014; Law et al. 2024).

The deeply eroded Southeast part of Iceland exposes large plutonic complexes (Fig. 1), the solidified remnants of km^3-sized bodies of mafic and silicic magma that fed eruptions in Neogene volcanoes (Furman et al. 1992a, b). Notably, this area also exhibits a crustal thickness of >40 km (Kumar et al. 2007), making Southeast Iceland a prime target for investigating the construction of quasi-continental crust.

Studying the plutons of Southeast Iceland can therefore not only reveal how they assembled in the Earth's upper crust, but also provides keys for solving a number of fundamental questions:

1. How are large volumes (several km^3) of silicic magma produced in a basalt-dominated setting devoid of subduction?

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2. What controls the location, style, and speed of assembly of large magma bodies in the upper crust prior to eruptions?

While most of the plutons of Southeast Iceland have been studied in terms of their composition and emplacement (Blake 1966; Roobol 1974; Mattson et al. 1986; Åberg et al. 1987; Furman et al. 1992b, a; Thorarinsson and Tegner 2009; Burchardt et al. 2010, 2012; Weidendorfer et al. 2014; Padilla et al. 2016; Rhodes et al. 2021), their broader geological context remains poorly constrained. Early geological mapping and radiometric dating provided an incomplete and highly generalized view of the region, leaving large areas effectively unmapped (Fig. 1). More recent petrological, structural, and geochronological studies have improved understanding of individual plutons (e.g. Padilla 2016; Rhodes et al. 2021) but have also highlighted the possible importance of crustal recycling in silicic magma generation (Carmody 1991; Carley et al. 2020). However, the spatial, structural, and temporal relationships between plutons and their host rocks have yet to be examined in detail, limiting our ability to assess the efficiency and controls of these processes.

The Slaufrudalur pluton is Iceland's largest exposed granitic intrusion (Burchardt et al. 2010, 2012), but its overall volcanic and structural context is poorly constrained. Although its internal architecture (Beswick 1965; Quintela et al. 2025a), geochemistry (Carmody 1991; Padilla 2015; Carley et al. 2020), and emplacement mechanisms (Cargill et al. 1928; Beswick 1965; Burchardt et al. 2010, 2012; Quintela et al. 2025b), have been investigated, the surrounding host-rock stratigraphy and structural framework have not been mapped in sufficient detail to assess the volcano-tectonic environment into which the pluton intruded.

Understanding this context is essential for two reasons. First, the generation, storage, and emplacement of silicic magma in Iceland remain subjects of active debate (Sigmarsson et al. 1991; Jónasson et al. 1992; Jónasson 2007; Martin and Sigmarsson 2007, 2010; Bindeman et al. 2012; Charreteur et al. 2013; Banik et al. 2018; Rhodes et al. 2021). Second, Southeast Iceland differs markedly from the better-studied mid-Eastern Iceland region (e.g. Walker 1964; Watkins and Walker 1977; Óskarsson and Riishuus 2020), in-part lacking extensive rift-parallel dyke swarms, exposing multiple hypabyssal plutonic bodies, and displaying a more varied structural geology, suggesting a tectono-magmatic evolution that deviates from classical models.

A key limitation in understanding this region is the lack of detailed geological mapping (see, e.g.: Blake 1970; Torfason 1979, 1985). Without knowledge of the host-rock stratigraphy, volcanic centers, and structural features, it is not possible to assess whether pre-existing structures influenced silicic magma emplacement or whether the pluton itself generated its own fault and dyke system (Quintela et al. 2025b). Addressing this gap is critical for reconstructing the tectono-magmatic history of Southeast Iceland and for evaluating how silicic magmas accumulate in a plume-influenced oceanic crust environment.

3.1. This study and relationship to ongoing research

Recent fieldwork and structural analyses have revised interpretations of the Slaufrudalur pluton. Studies by Quintela et al. (2025a, b) indicate that pluton emplacement was accommodated by dextral strike-slip faulting within

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a subterranean pull-apart structure, implying formation in an off-rift or inter-rift setting rather than within a simple extensional rift zone.

In this study, we present new geological mapping, photogrammetric analysis, and a 3D reconstruction of the Slaufrudalur pluton and its host rocks. We identify several previously unrecognized silicic volcanic centers preserved as caldera-bounded pyroclastic sequences, conduit facies, and shallow silicic intrusions, and document their spatial relationships to the pluton. These observations reveal a far more complex volcanic and structural architecture than previously recognized.

Our study aims to:

- Map and characterize silicic volcanic and volcaniclastic formations surrounding the Slaufrudalur pluton.
- Reconstruct the geometry of the pluton using field observations and photogrammetry.
- Evaluate whether older silicic centers or structural weaknesses influenced pluton emplacement.
- Reassess the geodynamic setting of Southeast Iceland in light of these new constraints.

Together, these results provide the first integrated volcanic, structural, and intrusive framework for Iceland's largest silicic pluton and contribute to ongoing debates about crustal evolution and silicic magma generation in oceanic environments.

4. Geological background and previous work

4.1. Iceland today

Tectonic and magmatic activity in Iceland is the product of the interaction between the Mid-Atlantic ridge and the Iceland mantle plume (Vink 1984; Sigmundsson 2006). Throughout the Holocene, volcanic activity has occurred within axial volcanic zones that represent on-land mid-ocean ridge plate boundaries, and off-rift (or flank) zones where no plate spreading occurs (Fig. 1; Sæmundsson 1974, 1979; Thordarson and Larsen 2007; Einarsson 2008). Several volcanic zones are currently active, including the Northern, Eastern, Western, and Reykjanes Volcanic Zones; active off-rift volcanic belts include the Öræfajökull-Snæfell Flank Zone (ÖVB), the Snæfellsnes Volcanic Zone, and the propagating tip of the Eastern Volcanic Zone (sometimes referred to as the South Iceland Volcanic Zone (Einarsson 2008)). These zones are connected by transform plate boundaries, such as the South Iceland Seismic zone (SISZ), linking the Eastern and Western Volcanic Zones, and the Tjörnes Fracture Zone, linking the Northern Volcanic Zones with the offshore Kolbeinsey Ridge (Fig. 1; Sæmundsson 1979; Jóhannesson and Sæmundsson 1998; Einarsson 2008).

Within the neovolcanic zones, magmatic and tectonic activity occurs within en-echelon arranged volcanic systems, each typically consisting of a fissure swarm (comprising normal faults and eruptive fissures) and, in many cases, a central volcano (Thordarson and Larsen 2007; Einarsson 2008; Jakobsson et al. 2008). Age dating of volcanic systems reveals they are active for between 1–2 My (Flude et al. 2008; Banik et al. 2018, 2021, 2023, 2026; Carley et al. 2020; Askew et al. 2020; Rooyakkers et al. 2021; Árnadóttir et al. 2023), though recent dating of a Neogene system suggests slightly longer timescales of up to 2.4 My (Carley et al. 2017; Askew et al. 2020). Plate spreading is primarily accommodated through normal faulting, dyke intrusions, some of which feed basaltic fissure eruptions. In contrast, central volcanoes give rise to both basaltic and silicic effusive and explosive eruptions, some

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accompanied by caldera collapse (Walker 1963; Hartley and Thordarson 2012; Askew 2020). At depth, these central volcanoes are fed by complex plumbing systems, providing sites where evolved magma can form and accumulate (Furman et al. 1992b; Jónasson 2007).

Evolved rocks (intermediate–silicic) account for around 10–15% of the rock outcrop of Iceland (Walker 1966; Sæmundsson 1979), with intermediate rocks only making up a small amount of this value. Mafic rocks account for 80–85% of the rock outcrop, whilst the remaining ~5% is various volcaniclastic or sedimentary rocks. Volcanic silicic rocks account for ~ 90% of silicic rock outcrops in Iceland, the remaining ~10% being intrusive rhyolites and granitoids (estimated from 1:250,000 geological map of Iceland, Icelandic Institute of Natural Science).

4.2. Eastern Iceland: mapping history and volcanic architecture

The East coast of Iceland preserves an exceptional geological archive (Fig. 1). Regional tilting toward the active volcanic zones, combined with deep glacial erosion, has exposed 10–12 km of volcanic succession dating to ~14 Ma (Walker 1974; Torfason 1979; E. Mussett et al. 1980). Although drilling and geophysical studies provide useful constraints (Flóvenz and Gunnarsson 1991; Staples et al. 1997), geological mapping and radiometric dating remain the primary tools for reconstructing Iceland's Neogene magmatic and tectonic evolution.

The area between Seyðisfjörður and Álftafjörður (Fig. 1), here termed mid-Eastern Iceland, forms the basis of many current geodynamic models (Bodvarsson and Walker 1964; Helgason 1984, 1985; Martin et al. 2011; Óskarsson and Riishuus 2013; Óskarsson 2015). Foundational mapping by G.P.L. Walker and colleagues in the 1950s–60s established the regional flood-basalt stratigraphy and the architecture of extinct central volcanoes (Walker 1960, 1963; Gibson 1963; Bodvarsson and Walker 1964). Mapping revealed that surface fissure swarms are underlain by dyke swarms and graben structures (Walker 1974), and that central volcanoes consist of a core of inclined sheets, emanating from upper crustal magma bodies (Walker 1963; Fridleifsson 1983; Burchardt et al. 2011). Major (km^3 sized) fossil magma bodies are only found to crop out as plutons in southeastern Iceland (Torfason 1979; Furman et al. 1992b), where emplacement depths are <5 km.

Rocks adjacent to plutons and dyke swarms show contact metamorphism (e.g. Fridleifsson 1983, 1984), while the surrounding lava pile records regional burial metamorphism (Walker 1960). Vesicle-filling zeolite assemblages allowed Walker (1960) to infer fossil geothermal isotherms and estimate erosion levels, which range from ~2000 m in southern mid-East Iceland to ca. 1100 m in the North of Eastern Iceland (Walker 1960, 1974; Neuhoff 1999; Gústafsson 1992).

The westward tilt of the lava pile means that units generally become older eastward and that rocks of similar age follow N–S-trending isolines (Walker 1974). More recent mapping, paleomagnetism, and geochronology refine this pattern, showing a broader younging from northeast to southwest (Kitagawa et al. 2008; Martin et al. 2011; Óskarsson and Riishuus 2013; Burchardt et al. 2022a).

This general structure of en-echelon arranged extinct volcanic systems getting younger towards the plate boundary has been explained with static crustal accretion and burial at the plate boundary and preservation of peripheral volcanic systems that successively drift outwards (Bodvarsson and Walker 1964; Pálmason 1981). Irregularities in lava-pile dip and age patterns, however, indicate that the volcanic zone has shifted through time via "rift jumps"

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driven by plate–plume interactions (Jóhannesson 1980). The transition between successive volcanic zones is characterized by overlapping activity (Gibson and Piper 1972), as currently seen with the active Western and the Eastern Volcanic Zones (e.g. Sigmundsson 2006). Helgason (1984) further proposed that rift jumps may be smaller, more frequent, and multidirectional, helping explain the distribution of extinct volcanic systems in Eastern Iceland.

4.3. Southeast Iceland: a more complex volcanic province

Southeast Iceland, here defined as the Neogene geological successions between Álftafjörður in the Northeast and Skaftafell in the Southwest (Fig. 1), presents a more complex and less-regular volcano-tectonic architecture than mid-Eastern Iceland. Moreover, the density of extinct volcanic systems is notably higher than in mid-Eastern Iceland, and numerous shallow-crustal plutons, emplaced in the upper <5 km of crust, are exposed (Cargill et al. 1928; Walker 1960; Annels 1967; Walker 1974; Torfason 1979, 1985; Carmody 1991; Klausen 2006). Some of these plutons appear to occur in isolation, hosted within the basaltic lava pile (e.g. Slaufrudalur and Reyðarártindur), while others are exposed within seemingly older central volcanic rocks (e.g. Austurhorn and Ketillaugarfjall).

While no studies exist on regional metamorphism, Walker's (1960) estimates for mid-Eastern Iceland indicate an increase in the erosional depths southward. This deeper erosional level of Southeast Iceland may partly explain why plutons are exposed, any further understanding of the differences between mid-Eastern and Southeast Iceland are hindered by incomplete geological mapping and missing modern geochronological data. Aside from the seminal work by Torfason (1979), previous studies of volcanic and magmatic activity in Southeast Iceland focused on individual volcanic systems or plutons, often in isolation without the surrounding geological context of the host rock setting.

The Geitafell volcanic system (Fig. 1) with its well-exposed gabbro plutons, sheet swarms, and fossil geothermal system has perhaps been best studied (Annels 1967; Newman 1967; Fridleifsson 1983; Burchardt and Gudmundsson 2009; Liotta et al. 2020), and it is seen as a fossil analog to volcanoes like Krafla (Liotta et al. 2020). Other central volcanoes in Southeast Iceland have been studied for particular features, such as their inclined sheets (Þverártindur; Klausen (2006)) and regional dyke swarms (Álftafjörður; Paquet et al. (2007); Urbani et al. (2015); Birnudalstindur; Klausen). However, many of them remain unmapped and poorly understood.

A similar disparity exists in research on the plutons. Many of them remain either entirely unstudied or have only recently been mapped and studied for the first time (e.g. Reyðarártindur, Fig. 1; Twomey et al. (2021); Rhodes et al. (2021, 2024)). In contrast, a few major plutons have received comparatively high attention. Austurhorn (also called Eystrahorn), a large plutonic complex that comprises gabbroic and granitic parts has been studied for its petrology, geochemistry, and internal structure (Cargill et al. 1928; Beswick 1965; Mattson et al. 1986; Åberg et al. 1987; Furman et al. 1992a, b; Thorarinsson and Tegner 2009; Weidendorfer et al. 2014; Padilla et al. 2016). Vesturhorn (also called Vestrahorn), a composite gabbroic-granitic complex has been studied to a lesser extent (Roobol 1974; Mattson et al. 1986). The Slaufrudalur pluton (Fig. 1), Iceland's largest granitic intrusion, has been studied thoroughly for its petrography, geochemistry, and structure (Beswick 1965; Burchardt et al. 2010, 2012; Cargill et al. 1928; Carmody 1991; Torfason 1979; Quintela et al. 2025a, b; Furman et al. 1992a; Padilla 2015).

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Adding to this disparity, the major plutons have been dated (Gale et al. (1966) (K-Ar); Moorbath et al. (1968)(K-Ar); Åberg et al. (1987) (Rb-Sr)), and recently re-dated (Martin et al. (2011); Padilla et al. (2016); (zircon U-Pb)) and re-analyzed for their geochemistry (Carley et al. 2020; Law et al. 2024). The recent renewed interest in the plutons reflects partly the ongoing debate about how to produce cubic kilometers of silicic magma in a mid-ocean ridge setting. In a larger context, the granitic plutons of Southeast Iceland are still studied to provide clues as to how continental crust formed in a subduction-free early Earth (Reimink et al. 2014), though with modern conclusions that Iceland cannot be used as an analog for early earth (Carley et al. 2020; Law et al. 2024).

4.4. Previous work on the Slaufrudalur pluton

Slaufrudalur (Fig. 1; note, valley location also spelled Slufrudalur (e.g. Fig. 2) according to "Örnefnaskrá Náttúrufræðistofnun") was first described in detail by Cargill et al. (1928), who interpreted its steep, subvertical wall contacts and concordant roof as evidence for emplacement via cauldron subsidence. During pluton emplacement by cauldron subsidence, magma is transferred upwards as a series of repeated magmatic intrusions from an underlying reservoir into a newly forming, shallower magma body . Most of the studies following Cargill et al. (1928) either adopted this emplacement model (Beswick, 1965) or added additional observations in favor based on mapping of the internal structure (Carmody, 1991; Quintela et al. 2025a) and structural mapping and three-dimensional reconstruction of the Slaufrudalur pluton (Burchardt et al. 2010, 2012). Notably, four alternative emplacement mechanisms have been put forward: (1) Torfason (1979) recognized that lava layers at either end of the Slaufrudalur valley dip in opposite directions, which he interpreted as evidence of doming caused by pluton emplacement (see Section 6.2 for new data on lava dips). (2) Gudmundsson (2011), based on the horizontal layering in the pluton, favored pluton emplacement by stacking of sills. (3) Burchardt et al. (2012) supported the cauldron subsidence model but ascribed the stepped pluton-roof contact and intensive fracturing of the overlying rocks to magmatic stoping. Most recently, (4) Quintela et al. (2025) studied the structural geology of the pluton-wall and -roof contacts, as well as host-rock deformation and proposed that the pluton was emplaced in a transtensional, subterranean pull-apart structure. More specifically, this interpretation was based on the nature of the contacts, which are made up of an array of oblique slip Riedel shear fractures. For a detailed discussion of the proposed emplacement mechanisms, the reader is referred to Quintela et al. (2025b).Beswick (1965) provided a detailed textural and petrographic characterization of the Slaufrudalur rocks that range from granodioritic to granitic textures. Based on geochemistry and petrology, Carmody (1991) proposed that the Slaufrudalur magmas might have originated from partial melting of hydrated basalt crust, consistent with crustal recycling processes. Carley et al. (2020) also indicate a hydrated crustal input into silicic magma at Slaufrudalur, based on zircons with $\delta^{18}O$ as low as ~4 ‰, though this is not a focused study on the Slaufrudalur pluton.

At least 2000 m (valley floor) to 1000 m (mountain top) of material is estimated to have been removed from the area exposing the Slaufrudalur pluton (Carmody 1991) based on zeolite mineralization estimates in mid-Eastern Iceland (see above), though this estimate has not been validated for Southeast Iceland or tested by modern methods. According to the known geology of the area, the isolated existence of the Slaufrudalur pluton within the basaltic lava pile is somewhat of a conundrum, as some typical evidence of large-scale mafic magmatism, such as gabbroic

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intrusions, dyke swarms, or basaltic remnants of a central volcano, should be apparent. Even lateral magma transport from the close-by gabbroic-granitic Vesturhorn complex, speculated by Burchardt et al. (2012), can be refuted based on more recent U-Pb zircon dating. According to Padilla (2015), Vesturhorn is more than 2 Ma younger (4.02±0.03 Ma) than Slaufrudalur (6.38±0.05 Ma).

In summary, a key limitation of many previous studies is their narrow focus: most examine plutons in isolation, sometimes even only single mineral phases within the pluton, as mentioned previously, without fully considering the surrounding stratigraphy or structural context. In this study, we aim to address that gap by situating the Slaufrudalur pluton within its broader geological setting, with particular focus on its relationship to its host rock and nearby silicic caldera structures.

5. Methods and materials

5.1. Fieldwork and geological mapping

Geological field campaigns were conducted over several summers. During these campaigns, detailed field observations were made across the study area, focusing on lithology, stratigraphic relationships, bedding orientation, faulting, and the geometry of magmatic sheet intrusions.

Field mapping was supported by oblique aerial photography acquired in August 2021 using a Nikon D850 camera. Additional high-resolution imagery of outcrops was captured using uncrewed aerial vehicles (UAVs or drones), a DJI Phantom 4 Pro and a DJI Mavic 3 Pro, across several key localities.

5.1.1 Criteria for identifying central volcanoes and caldera structures

We defined *central volcanoes* and *caldera structures* in the field based on a combination of lithological, structural, and stratigraphic observations. Key criteria include:

- The presence of silicic volcanic rocks (e.g., ignimbrites, rhyolite lavas, tuffs).
- Shallow (hypabyssal/sub-volcanic) silicic conduit or vent features.
- Sharp, fault-bounded contacts between silicic units and surrounding plateau basalt stratigraphy, lacking transitional interfingering.
- Structural depressions or bowl-shaped geometries based on field and virtual outcrop observations.
- Spatial confinement of volcaniclastic units (based on the above points).

These criteria allowed us to distinguish caldera-related sequences from the basaltic stratigraphy and to map multiple discrete volcanic centers across the study area which were previously unknown.

5.2. Geospatial data and GIS mapping

Digital mapping was conducted using QGIS software. The geological map and all geospatial data were compiled into a GeoPackage (GPKG) format and prepared for publication. A 2×2 m resolution digital elevation model (ísIandsDEM) from the Natural Science Institute of Iceland was used as the base terrain layer (https://dem.gis.is/mapview/?application=DEM). Additional spatial context was provided by high-resolution aerial imagery from Bing and ESRI basemaps.

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5.3. Photogrammetry and structural mapping

UAV imagery was processed into dense point clouds and textured 3D surface models using Agisoft Metashape, virtual outcrop model georeferencing was improved and checked with ground control points from the 2x2 m íslandsDEM. Outputs were exported in both KMZ and OBJ formats, projected in WGS84 / UTM Zone 28N, with associated textures in JPEG format. These virtual outcrops were imported into GeoVis3D (version 2.00), where structural features such as bedding planes, faults, and magmatic intrusions were mapped using the best-fit-plane method, requiring a minimum of three points per planar feature. The resulting structural measurements, including spatial coordinates and orientation data, were exported as CSV files for further analysis.

5.4. Sampling and petrographic analysis

Selected rock samples were collected during field campaigns for thin section preparation (by Precision Petrographics Ltd.) and petrographical analysis. Standard optical microscopy was used to examine mineral assemblages, textures, and alteration features and secondary minerals associated with both hydrothermal and contact metamorphism alteration.

5.5. 3D Reconstruction of the Slaufrudalur Pluton

To investigate the geometry and emplacement history of the Slaufrudalur pluton, a 3D model was constructed using a combination of field-based observations and photogrammetry-derived outcrops. OBJ files were imported into MOVE software (PE Limited (Petex)), where the contact between the pluton and surrounding host rocks was traced using the Line tool on both the virtual outcrops and the base DEM. Outlines of surrounding formations were taken from the geological map and incorporated into the model.

The model was constrained by:

- 25 vertical sections parallel to the long axis of the pluton (strike 025°), spaced at 200 m intervals.
- 50 vertical sections perpendicular to the pluton's long axis (strike 115°), also spaced at 200 m intervals.
- 5 horizontal slices from sea level up to 500 m elevation, covering the full areal extent of the pluton.

This structural framework enabled a volumetric and geometric reconstruction of the pluton, including interpretation of its roof and wall contacts in relation to surrounding volcanic units.

6. Results

6.1. General geology

The mapped area (Fig. 2) is dominated by subaerial 'plateau' basalt flows. Typical volcaniclastic 'interbeds' or 'redbeds' as seen in the mid-East formations, are not seen in the map area. Instead, the boundaries are usually weathered and eroded away by surface weathering and erosion. That is except where interbedded units (i.e. non-lava) form thicker sequences of sediments such as notable breccias, sandstones, and conglomerates (e.g. Fig. 2).

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The lavas are typically coherent flows; their internal architecture was not a focus of this study. They form a lava pile, which is considered the typical formation in the Neogene sequences of Iceland.

Our geological map (Fig. 2) shows that over 85% of the area outside of the pluton is composed of basaltic lava flows. Most are aphyric to mildly phyric (<5%), with normal magnetic polarity (though reversals are observed but do not offer good stratigraphic relation currently) based on field fluxgate magnetometer data.

Porphyritic basalts (field definition of >10% macrocrysts of feldspar), observed throughout the map area, serve as stratigraphic markers. However, due to the irregular dips and limited exposures, these horizons are often difficult to correlate between valleys (Suppl. Map 1). Several porphyritic lavas in Endalausidalur likely correlate with outcrops seen in Lambatungnadalur to the north, and Kapaldalur to the south (Fig. 2). Porphyritic lavas in Gjádalur which appear to correlate with lavas found to the north on Hvammsheiði may be related to more southerly porphyritic markers but due to the pluton's presence and irregular dips (Fig. 2 and 3) correlation cannot be confirmed.

However, in several areas, this "normal" lava pile architecture is disrupted by the presence of previously unmapped silicic units, volcaniclastic material 10's–100's meters thick and several hundred meters across, and an abrupt transition from plateau basalts to silicic pyroclastic material. These zones, which deviate from the expected stratigraphy and lithological continuity of basaltic sequences, form the basis for identifying central volcanoes and caldera structures. Silicic volcanic rocks, largely concentrated in four zones, cover approximately 2.85 km^2 (<3%) of the mapped area. Despite their limited areal extent, they record episodes of silicic magmatism and are interpreted to mark the remnants of former central volcanoes. The areas are:

- Þorgeirsstaðadalur – 0.2 km^2
- Kapaldalur – 0.3 km^2
- Kvosir – 2.1 km^2
- Hvammsheiði – 0.1 km^2

Intrusions account for just under 10% of the mapped area. The Slaufrudalur pluton alone covers approximately 8% (or 9.74 km^2), with smaller felsitic intrusions at Hvammsheiði (~0.6%) and in Laxárdalur (~0.38%). Notably, basaltic dykes are rare across the area. While central volcanoes associated with rift zones in Iceland are commonly associated with dyke swarms, such structures are largely absent between Höfn and Álftafjörður. Instead, mafic sheets, silicic sheets, and plutonic bodies dominate, similar to the geology observed in the currently active ÖVB and SIVZ.

Table 1. Observations of regional units, excluding units ascribed to mapped silicic formations.

	Unit Type	Observations
Regional units/units outside individual formations	Plateau basalt lavas	Dominant lithology (>85% of map area), generally aphyric to mildly phyric (<10% macrocrysts; predominantly plagioclase), normal polarity, chlorite-epidote-quartz alteration, local porphyritic (>10 % macrocrysts) marker flows.
	Basaltic dykes	Vertical to subvertical, mainly NE striking, mostly tholeiitic and aphyric; rare olivine-phyric and porphyritic varieties.
	Basaltic inclined sheets	Decimeter- to meter-thick sheets, locally forming swarms..

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	Silicic dykes	Predominantly NE-striking, quartz/feldspar-bearing, hemicrystalline. Easily observed in aerial imagery.
	Silicic sills and inclined sheets	Similar to dykes in mineralogy and textures. Some larger sheets in e.g. Laxárdalur.
	Pitchstone sheets	Rare glassy silicic intrusions identified in Laxárdalur and upper Kapaldalur.

6.1.1 Alteration

Alteration in the map area is generally of chlorite-epidote-quartz facies. Secondary mineralization of chlorite, epidote, and quartz is pervasive throughout the lava pile, occurring within each unit, though is concentrated on the contacts between lava layers, where vesicularity was originally highest and where volcaniclastic interbeds provided high permeability pathways. Alteration minerals occur within vesicles, and along grain boundaries, in many cases primary mafic minerals may be seen in the groundmass and phenocrysts of some samples to alter to chlorite. Some lavas may be highly altered; their groundmass is difficult to discern in thin section, being replaced by clays and chlorite. Epidote is less common than chlorite but is still pervasive throughout the stratigraphy, it occurs in similar manners to chlorite though most often in vesicles and former voids within the rocks. Secondary quartz, where present, occurs within vesicles or veins. Silicic sheets often appear less altered than the lava pile they intrude.

6.2. Structure of the lava pile

Field and photogrammetric measurements of the orientation of layering in the basaltic lavas of our study area show a larger variability compared to what is observed in mid-Eastern Iceland (e.g. Óskarsson and Riishuus 2013, 2020). Quintela et al. (2025b) used lava orientations to identify deformation (subsidence or doming) caused by the emplacement of the Slaufrudalur pluton. They concluded that there is some local deformation of the lavas overlying the pluton, which corresponds to small-scale irregular tilting of the roof rocks. At distances of >200 m from the pluton, the lava pile appears unaffected by the pluton, and lava orientations can be assumed to reflect the regional geological structure.

However, the regional pattern (that is over the southeast Iceland area) that emerges also differs from what is observed in mid-Eastern Iceland (Óskarsson et al. 2017; Óskarsson and Riishuus 2020) in that there is no general westward dip. Instead, our study area shows local variability with NW-ward dips of 9° (mean) in the west, SSW-ward dips of 6° in the south, NW-ward dips of 6° in the east, and SW-ward dips of 13° in the northeast (Fig. 2 – displays field measurements, not averages; Suppl. Fig. 1 – displays dips from field and virtual outcrops measurements, and averages; Quintela et al. (2025b)). Locally, lava orientations fluctuate strongly, and no clear pattern emerges (Fig. 2).

Faults of any type are rare in the study area and restricted to the immediate vicinity of the Slaufrudalur pluton. Quintela et al. (2025b) provide a detailed study of the fracturing and faulting associated with the emplacement of the Slaufrudalur pluton.

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6.3. Caldera structures and silicic formations

We identify three distinct new volcanic centers, Þorgeirsstaðadalur, Kapaldalur, and Kvosir, described below (see Fig. 2). These centers display discordant lateral boundaries with the surrounding basaltic lava pile and include effusive and pyroclastic eruptive silicic units as well as silicic intrusions. A fourth area, Hvammsheiði, is described, as it displays hypabyssal to cryptic-lava felsitic units emplaced in a silicic ignimbrite and sediments – an indicator of an evolved magmatic source or central volcano.

6.3.1 Þorgeirsstaðadalur Formation

Description

Most of Þorgeirsstaðadalur bedrock consists of aphyric basaltic lava flows, except for two distinct porphyritic basalt flows forming whale-back erosional features and waterfalls low in the sequence, as well as one porphyritic flow at the closure of the valley (Fig. 2). Approximately 2.3 km up the valley from the valley opening, the sequence is truncated by a steep fault that strikes WSW (ca. 230°) that mark the abrupt transition from the lava pile into the formation. Fig. 3A displays the rocks in relation to each other. The first unit, shown in Fig. 3 A and B as 001 (unit number to aid description), to be described is a gray ignimbrite. It is poorly sorted, containing angular lithic clasts of mafic rock, and occasional feldspar phenocrysts, in a fine-grained gray ash matrix that is locally vesicular. Throughout the unit are variably sized, irregularly shaped white pyroclasts (Fig. 3C and 3C inset), which are generally altered and replaced by secondary mineralization, usually quartz. In the field some apparent vesicularity is noted in the white pyroclasts indicating a likely silicic pumice origin. A sharp vertical contact was mapped bounding unit 002.

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Table 2. Þorgeirsstaðadalur Formation units and observations.

Formation / Area	Unit	Lithology / Type	Textures & Structures	Mineralogy / Components	Alteration & Metamorphism	Interpretation
Þorgeirsstaðadalur Formation	Þ001	Ignimbrite	Poorly sorted, angular lithics, irregular white pyroclasts (fiamme/pumice), sharp fault-bounded geometry	Mafic lithics, feldspar phenocrysts, silicic pumice fragments	White pyroclasts commonly replaced by quartz	Pyroclastic flow deposit
	Þ002b	Granitoid intrusion	Coarse-grained intrusive body, irregular contact with ignimbrite	Quartz + feldspar-rich granitoid	Syn-magmatic deformation near fault zone	Granitoid intrusion exploiting active fault system
	Þ002	Welded/sintered volcaniclastic ignimbrite	Matrix-supported, clast-rich, 'fluidal' white enclaves	Feldspar phenocrysts (up to ~15%), basalt and gabbro lithics, granophyric granitoid enclaves	Alteration of groundmass and other minerals. Diffuse boundaries around granitic enclaves.	Lithic-rich welded/sintered ignimbrite representing conduit or vent facies
	Þ003	Agglomerate / welded pyroclastic rock	Chaotic clastic texture, welded matrix, fiamme aligned with flow foliation	Felsite clasts, silicic fiamme	Variable alteration	Conduit facies ignimbrite/breccia
	Þ003b	Massive felsite / rhyolite	Massive, cliff-forming unit, cross-cut by mafic sheets	Silicic composition	-	Welded ash-tuff unit
	Upper tuff sequence	Layered tuffs and ignimbrites	Alternating ash tuff, lapilli tuff, ignimbrite, reworked horizons	Devitrified ash tuff, pumice clasts and fragments, lithics mafic/silicic	Green pervasive chlorite	Pyroclastic and volcaniclastic succession
	Upper red tuffaceous unit	Mafic volcaniclastic layer	Red-purple colour, reworked vesicular clasts	Mafic volcanic detritus	Weathered	Sedimentary-volcaniclastic deposition

Intruding into the ignimbrite – unit Þ001 – is a coarse feldspar-quartz granitoid, indicated as 002b (Fig. 3), it displays a sharp contact with basalts due to the fault shown in Fig. 3D (marked as “silicic intrusive”) but displays a more undulating and irregular contact with this ignimbrite as shown in Fig. 3C. This granitoid intrusion is not physically linked to the Slaufrudalur pluton granite, though the small exposure and lack of contextual field data for this intrusion precluded further study.

Unit Þ002 (Fig 3A, B and 4A) in this formation is a gray-green volcaniclastic rock, containing white patches. The unit contains a high percentage of clasts but is highly altered, potentially consisting of devitrified or altered cryptocrystalline fine ash, and is matrix supported. The matrix contains up to 15% feldspar phenocrysts and variable angular to sub-angular lithics of fine-grained and coarse-grained mafic rock (basalt and gabbro); the mafic lithics show sharp—even at thin section scale—boundary contacts with the matrix (Fig. 4B; Suppl. Fig. 2A). White,

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irregularly shaped and rounded "enclaves" of quartz-feldspar granite (granophyric texture; Suppl. Fig. 2B) occur in patches in the outcrop, but much of the outcrop is inaccessible, so no mapping assessment of the patchy extents was viable. The granitic "enclaves" display altered and diffuse boundaries with the host matrix, i.e., no distinct boundary is visible. Rather, the grain boundaries in the granite are infiltrated by finer grained material and alteration is greatest at the boundaries. A series of subvertical faults (140°–160°) cut through the riverbed exposures, deforming both the host basalt and the ignimbrite of unit 001 (Fig. 3D).

To the west, a canyon exposes a chaotic, clastic agglomerate (Fig. 3A, B, and Fig. 4C – unit Þ003) in contact with the white-patch gray-green clastic unit Þ002. The contact was only inferred as accessibility hampers observations. The agglomerate is variable in texture throughout; some patches contain centimeter to decimeter scale clasts of red-white felsite and are clast supported within a black welded glassy matrix (e.g. Suppl. Fig 2C). Other parts are more matrix supported, displaying a welded matrix with white silicic fiamme clasts aligned with flow foliation (Fig. 4C). A massive, white felsite occurs above this and is inferred to be related to unit Þ003, as the units' display no distinct contact, appearing to grade from the more clastic Þ003 to the more massive Þ003b (Fig. 3A, Fig. 4D). Þ003b is a very fine grained to glassy (non-visible grains) unit of white ash-tuff. The canyon units are bound by an irregularly shaped, but steeply-dipping unconformity at the western exit of the canyon, above which shallow-dipping basaltic lava pile is exposed.

Within this lava pile, is a ~5 m thick layered, pumice-rich tuff with alternating sub-units of ignimbrite, lapilli tuff, ash tuff, and lesser, 10's cm's thick reworked subunits (Fig. 4E; Suppl. Fig. 2D). The unit is concordant between basaltic lavas exposed in the valley floor. Up the valley, the stratigraphy is composed of aphyric lavas, porphyritic lavas, and volcaniclastic interbeds, including a red tuffaceous layer with reworked vesicular clasts (Fig. 4F; Suppl. Fig. 2E). These units are crosscut by the granite pluton in the upper two canyons emanating from the valley.

Interpretation

The Þorgeirsstaðadalur Formation records the remnants of a small silicic sub-volcanic area characterized by a complex association of conduit facies, pyroclastic deposits, and effusive units. Several units are interpreted as vent- or conduit-related ignimbrites based on their lithic-rich character, dense matrices, and structural relationships with fault zones bounding the valley. The close relationship between the silicic units Þ001–Þ003b suggests a shared origin, possibly a single explosive event manifesting as different lithologies within a shared conduit.

Unit Þ002 is interpreted as a welded or sintered ignimbrite, as indicated by its clast-rich nature, angular lithics, and dense matrix. The presence of granite enclaves suggests entrainment of plutonic material from depth during magma ascent, whereas the uniform distribution of angular mafic lithics implies intense mechanical fragmentation of wall rock during emplacement. The spatial association of this unit with the valley-bounding fracture indicates that magma ascent was localized along this structure.

While the majority of deformation associated with the faults observed is brittle, the deformation of the granitoid intrusion—unit Þ002b—which bounds unit Þ001 and the basaltic country rock, as shown in Fig. 3C and 3D, indicates syn-magmatic faulting associated with this granitoid. The granitoid intrusion may closely follow the other units in emplacement, possibly representing a late-stage squeeze-up of magma from which the other melts were derived (Haywood et al. 2026).

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Higher in the stratigraphy along the main valley floor, the interlayered sequence of silicic tuffs and basaltic lavas reflects local silicic volcanism coupled with continuous basaltic volcanism.

Taken together, the preserved units do not represent a single, simple caldera architecture. Instead, the formation records silicic volcanism at multiple crustal levels, involving conduit-dominated explosive activity, lava emplacement, and shallow basin infill. Cross-cutting relationships indicate that the conduit facies are younger than the valley-filling ignimbrites and tuffs.

6.3.2 Kapaldalur Formation

Table 3. Kapaldalur Formation units and observations

Formation/ Area	Unit	Lithology	Textures & Structures	Mineralogy / Components	Alteration & Metamorphism	Interpretation
Kapaldalur Formation	K001	Ignimbrite / conduit unit	Vertical flow foliation, abundant elongated fiamme, welded texture	Quartz and feldspar phenocrysts, lithic fragments	Strong clay alteration, fracturing, secondary mineralization (pyrite/epidote), devitrification	Shallow conduit or vent ignimbrite
	K002 – Felsite	Felsite (altered rhyolite)	Fissile, weathered, poorly exposed	Silicic composition	Pervasive alteration oxides, pyrite, and weathering	Likely related to ignimbrite, subvolcanic rhyolite
	K003 – Volcaniclastic diamictite	Volcaniclastic sediment	Thick, poorly sorted deposit	Granite, granophyre, rhyolite, basalt, gabbro/dolerite clasts	-	Debris-flow / lahar-like volcaniclastic basin infill
	K004 – Monomictic basalt breccia	Autobreccia	Clast-supported, little matrix, single basalt type	Basalt with sub-ophitic plagioclase-clinopyroxene texture	Minor alteration	Autobrecciated lava flow or proximal lava-collapse deposit
	Overlying basalt lavas	Plateau basalts	Limited exposures on ridges	Basalt	Weathered and covered by scree	Post-formation units

Description

Kapaldalur is a hanging valley southeast of the Slaufrudalur pluton (Fig. 2). At its southern end, three rivers expose a series of volcaniclastic deposits near the pluton contact. These units, collectively termed the Kapaldalur Formation, are shown in Fig. 5 and 6 and Table 3. The formation is exposed over >1 km^2, but since the valley end is covered by glacial moraines and scree slopes, contact relationships are largely obscured.

On the western side of the valley, up a small tributary river, is a distinct felsic sequence – originally mapped as granite pluton. Part of this section is unit K002, a white to orange colored felsite (Fig. 6A; Table 3), whilst another part of this unit is a distinct subunit K001 (Table 3) with vertical flow foliation and stretched pumice clasts (fiamme) displaying a roughly vertical alignment in outcrop (Fig. 6B, C, and D). It displays a devitrified and often altered glass matrix, quartz and feldspar phenocrysts (typically embayed and/or fragmented e.g. Suppl. Fig. 3), and consists of ~10% vesicles filled in with secondary minerals. Pumice clasts vary in size from <1 cm to ca. 40 cm and generally display a vertically elongate but otherwise irregular shape (Fig. 6D). The rock displays a high degree of alteration, indicated by its intense white to blueish green color and characterized by pervasive fracturing, grain mottling, clay

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alteration, and secondary mineralization. In hand samples, we distinguish four types of lithics, including different basalts (most common), fine-grained felsite (common), banded rhyolite (rare), and microgranite (very rare). Parts of the unit also appear coarser grained in thin section, which are likely lithic clasts (Suppl. Fig. 3). The ignimbrite is not laterally extensive and forms a small outcrop in the valley below Mosfell. The surrounding felsite is likely related to the ignimbrite, but it is highly fissile, altered, and scree covered. This unit contacts the granite pluton to the north and it is bounded to the west and south by the sequence of autobrecciated basalt (Fig. 2 and 5).

The easternmost unit is unit K003, a ~140 m thick volcaniclastic sedimentary (diamictic) unit (Fig. 2; Table 3), containing clasts of granite exhibiting granophyric feldspar-quartz intergrowths, gabbro (/dolerite), basalt, and rhyolite (Fig. 6E and F). Mafic clasts are typically more rounded than those less mafic types, though thin section analysis shows a single granophyric texture grain with a sub-rounded boundary (see Suppl. Fig. 3).

A basaltic autobreccia (K004; Table 3; Fig. 6G) is traceable throughout several tributaries and with a minimum thickness of 60–80 m exposed over several hundred meters. The basalt breccia is composed entirely of a single basalt type with a coarse sub-ophitic groundmass of plagioclase and clinopyroxene crops out throughout the small tributaries of the main river (Fig. 2 and 6G). The basalt is clast supported, with no matrix visible save some small basalt fragments. It is structurally bounded to the south by K003, volcaniclastic unit (Fig. 5), though no contact is visible, so no age relationship can be gained. It is not possible to link this autobreccia to a flow in the surrounding lavas.

A planar, subvertical unconformity divides the breccia K004 and diamictite K003 from the pluton and the lava pile to the south. This structural discontinuity may be an unconformity or fault though interpretation is based on aerial imagery as outcrop conditions do not allow close inspection (Fig. 5).

Above the Kapaldalur Formation are basaltic lavas, outcrops of which are confined to some ridges and gullies as shown in Fig. 5. Small outcrops of porphyritic lavas crop out toward Mosfell (Fig. 2). The amount of scree and till overlying the rocks in the head of the valley makes tracing flows and judging stratigraphic relationships difficult (e.g. Fig. 5).

Interpretation

The Kapaldalur Formation records part of the infill of a small, fracture-bounded silicic volcanic basin, potentially representing part of a caldera or structurally controlled collapse depression with an exposed radius of ~1 km. The preserved units were emplaced within a pre-existing surface depression rather than an erosional valley, as there is no evidence for significant glacial or fluvial incision capable of producing the observed geometry and lithologies. The dominant volcaniclastic unit represents a major depositional phase characterized by poor sorting, limited internal stratification, and mixed clast populations. Angular silicic lithics indicate primary pyroclastic input, whereas rounded polymictic clasts, including granitic fragments, reflect reworking and mass-flow processes. The overall deposit shows many characteristics of secondary volcanic mass-flow deposits (e.g. debris flows or lahars), although syn-eruptive pyroclastic contribution cannot be excluded. The presence of granitic lithics indicates erosion or excavation of intrusive material during eruption or deposition, though their source, local or distal, cannot be constrained.

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The Kapaldalur ignimbrite is interpreted as a welded vent- or conduit-related pyroclastic unit based on its fiamme-bearing texture, vertical flow foliation, aligned clasts, and confined outcrop geometry. These features indicate emplacement at shallow, upper hypabyssal crustal levels (≤500 m), likely feeding eruptive activity at the surface. Silicic lithic clasts within the ignimbrite may have been derived from the adjacent Slaufrudalur pluton or from a deeper silicic mush zone. Although the ignimbrite closely bounds the pluton, pervasive alteration and poor exposure prevent direct assessment of contact relationships.

6.3.3 Kvosir Formation

Table 4. Kvosir Formation units and observations.

Formation / Area	Unit	Lithology / Type	Textures & Structures	Mineralogy / Components	Alteration & Metamorphism	Interpretation
Kvosir Formation	Lithic-bearing ignimbrites	Ignimbrite	Lithic-rich, pumice-rich, poorly exposed in scree slopes	Silicic and mafic lithics, pumice	Altered green (diffuse chlorite) glassy matrix	Repeated silicic eruptions - caldera-fill pyroclastic deposits
	Epiclastic breccias	Sedimentary breccia	Non-pyroclastic breccias interbedded with ignimbrites	Variable lithologies including silicic clasts	-	Reworked volcaniclastic deposits; sedimentation between eruptive phases
	Kv001 – Northern rhyolite lava	Rhyolite lava	Massive, flow foliated, irregular and brecciated contact with ignimbrites	Hemihyalinic, glass, quartz, feldspar	-	Effusive silicic volcanism
	Kv002 – Orange-pink ignimbrite	Welded ignimbrite	Foam-like texture, welded pumice-rich fabric	Pumice, sparse (5%) mafic lithics	Devitrification and alteration	Pyroclastic flow deposit
	Kv003 – Southern rhyolite lava	Rhyolite lava	Vesicular, strong flow foliation	Hemihyalinic, glass, quartz, feldspar	Altered glass matrix	Silicic lava erupted within caldera basin
	Kv004 – Reworked volcaniclastic unit	Volcaniclastic sediment	Thin unit between lavas and ignimbrites	Subrounded clasts, mafic to silicic fragments. Matrix of sand-silt sized grains with pervasive interstitial alteration.	Pervasive throughout matrix, clays, oxides.	Sedimentation between eruptive phases
	Southern ignimbrites	Welded to unwelded ignimbrites	Black glassy welded units/sub-units and white unwelded	-	Chlorite and epidote alteration	Repeated explosive silicic eruptions
	Overlying basalt lavas	Plateau basalts	Disconformity between lavas and silicic units, basalt lavas, aphyric to <5% plag-phyric.	Basalt	Weathered, zeolite to chlorite alteration throughout groundmass	Post-caldera lava cover

Description

Kvosir (Fig. 2), a secluded and picturesque valley at the head of Gjádalur, is notable for its brightly colored landscape that is distinct from the dark basalts surrounding it (Fig. 7). From above the Kvosir waterfall (Fig 2; Kvosafoss) the valley floor exposes basalts and sediments, including a sedimentary unit varying from clastic

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sandstone to laminated, cross-bedded siltstone with trace fossils (Fig. 8A). Thin section analysis of the sediment reveals epidote alteration, suggesting low to moderate hornfels metamorphism (Suppl. Fig. 4A and B).

In the valley, the plateau basalts are sharply cut by a subvertical unconformity, which delineates the abrupt transition into the volcaniclastic rocks of the Kvosir Formation outcropping to the west of this feature (Fig. 7). The volcaniclastic outcrops are fissile, forming slopes dominated by scree and obscuring most contact relationships. The Kvosir Formation continues into Afdalur to the north (Fig. 2 and 7), which displays a similar landscape morphology to the southern Kvosir valley.

The scree ridge of Seti, set between Afdalur and Kvosir, (Fig. 2 and 7) is dominated by pyroclastic rocks sharply bounding the mafic rocks and sediments of the surrounding strata. Scree samples taken in traverses along the base reveal variable lithic-rich ignimbrites (e.g. Fig. 8B) intercalated with infrequent epiclastic breccias (i.e., no visible pyroclasts). The pyroclastic rocks contain pumices and variable degrees of both silicic and mafic lithics hosted in an altered green glassy matrix (e.g. Fig. 8B); individual units or sub-unit relationships cannot be mapped. A poorly sorted sedimentary breccia outcrop in Afdalur displays a variety of sub-angular clasts from 1-2 cm to ~20cm in size. Clast lithologies are also variable from mafic to silicic igneous rocks, including clasts of coarse-grained (visible groundmass crystals 2mm≤5mm), feldspar-quartz silicic rock.

The north-easternmost exposures in Afdalur (Fig. 7C), those that bound plateau basalts, are lithic rich ignimbrites and breccias. An ~80 m thick monomictic breccia of basalt overlies those breccias close to the unconformity in this area. Poor exposures limit outcrops to the west until the head of the valley, where a rhyolite lava (unit Kv001) is exposed in the riverbed, and is overlain by an orange-pink-white ignimbrite (unit Kv002; Fig. 7 and 9D). The ignimbrite is foam-like in appearance in some exposures, where vesicular pumice clasts dominate the deposit and are welded/sintered to the glass matrix (Suppl. Fig. 4C). Sparse (<5%) angular mafic lithics occur throughout the unit. This ignimbrite can be roughly traced on aerial images to the south, in Kvosir, where it also crops out high in the scree slope. Overlying basaltic lavas and a prominent dark-red rhyolite lava that forms the peak and ridge at the head of Afdalur and northern Kvosir.

In the more southerly part of Kvosir are a rhyolite lava (unit Kv003; Fig. 8E) and a series of silicic ignimbrites. A small, 2 x 2 m outcrop (scree pieces suggest a continuation to the slope northwards) of reworked volcaniclastic unit (Kv004) is exposed between rhyolite lava and the ignimbrites to the south (Fig. 8F). The rhyolite lava—Kv003—in this locality is moderately vesicular and displays strong flow foliation (Fig. 8E). Petrography reveals an altered, glassy to microcrystalline groundmass (Suppl. Fig. 4D). The southernmost ignimbrites are variably welded to unwelded and exhibit secondary alteration characterized by chlorite and epidote (Fig. 8F). An accessible outcrop displays a black, glassy rock, with a strong flow foliation and moderately plagioclase phyric texture.

To the south and southwest, the Kvosir Formation is unconformably overlain by are weathered basaltic lavas (Fig. 7).

Interpretation

The Kvosir Formation records an unconformity-bounded depression, which we interpret as a caldera infill. Chaotic pyroclastic deposits, rhyolite lavas, and sedimentary units indicate repeated silicic eruptive activity within a confined basin. The presence of stacked units of pyroclastic material and lack of interfingering with surrounding

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basaltic lavas support this interpretation, while the absence of correlatable distal deposits indicates a deep exposure level.

Rocks within the caldera are pervasively altered, dominated by epidote- and chlorite-bearing assemblages consistent with hydrothermal alteration. Higher-grade contact metamorphism east of the caldera indicates the presence of the Slaufrudalur pluton beneath the adjacent valley floor, though may also be a result of alteration related to post-caldera collapse magma degassing of geothermal circulation from the magma storage zone underlying the caldera.

6.3.4 Hvammsheiði Volcanic Centre Formation

Table 5. Hvammsheiði Formation units and observations.

Formation / Area	Unit	Lithology / Type	Textures & Structures	Mineralogy / Components	Alteration & Metamorphism	Interpretation
Hvammsheiði Volcanic Centre	Ignimbrite	Silicic lithic-rich ignimbrite	Fine ash matrix with abundant juvenile silicic clasts, pumice-rich	Altered silicic pumice, ash	Secondary chlorite-filled fiamme, matrix alteration	Pyroclastic flow deposit
	Slaufling intrusion	Felsitic sill/laccolith	Concordant geometry, fissile	Microlitic groundmass, rare quartz phenocrysts	Devitrified glass, alteration of interstitial material	Very shallow hypabyssal intrusion (intrudes ignimbrite)
	Plateau basalts above Slaufling	Basalt lava sequence	Associated porphyritic marker horizons	Basalt	-	Resumption of plateau basalt volcanism
	Sandstone unit	Sedimentary unit	Bedded, locally cross-bedded	Sand-sized clastic material	Minor alteration	Fluvial environment
	Conglomerate	Coarse sedimentary unit	Erosive basal contact, rounded clasts	Polymictic rounded clasts	-	High-energy fluvial environment
	Upper volcaniclastic unit	Polymictic volcaniclastic rock	Clast-rich, poorly exposed	Possible juvenile silicic clasts	Altered and weathered	Either epiclastic deposit remobilising various volcanic clasts, or reworked pyroclastic deposit
	Slaufey intrusion	Felsitic sill/laccolith	Flow foliation, vesicle-like voids, hemi-crystalline texture	Very fine quartz, silicic groundmass	Strong clay alteration, vesicle infilling	Sub-volcanic intrusion or crypto-dome/crypto-flow

Description

North of Gjádalur, the mountain of Hvammsheiði displays a sequence of plateau basalts interbedded with clastic sediments and a pyroclastic formation beside two felsitic intrusions (named as Slaufling (0.35 km^2) and Slaufey (0.21 km^2) for this study (Fig. 2 and 10A)). The nearby Birnudalur (Fig. 2) displays outcrops of silicic rocks, composite sheets, and prominent faults, though the type of formation these silicic rocks are part of remains uncertain due to limited access and steep terrain.

The Hvammsheiði volcaniclastic units crop out in gullies near the two intrusions. The lowermost is a silicic ignimbrite along the southern and southeastern flanks of the Slaufling intrusion (Fig. 2, 10A, and 10B). Where best

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exposed, it appears as a dark blue outcrop with white speckles, composed of a fine ash matrix and angular silicic juvenile clasts (Fig. 9C). Morphologically irregular white altered clasts may represent altered pumice; vesicular pumices and fiamme are filled in with secondary chlorite (Suppl. Fig. 5A). Though limited in exposure, it is traceable as a scree to the northeast and is at least 20 m thick in its most complete section.

Slaufling is an asymmetric felsitic sill with concordant bottom and top contacts that dip gently, parallel to the host basalt lavas. The unit is gray-white with no visible groundmass, fissile and most of the exposure consisting of loose scree (Fig. 9A and B). The discordant wall contacts are obscured by scree except at the southeastern wall where Slaufling intrudes the Hvammsheiði ignimbrite (Fig. 9B). The intrusion is exposed from ~140 to 260 m above sea level (a.s.l.), giving it a minimum thickness of ~120 m. The groundmass contains two microlite populations from 25–75 µm and 1–5 µm, together with pervasive altered interstitial material likely representing devitrified glass (Suppl. Fig. 5C). The rock also contains sparse quartz phenocrysts (<1%).

Above Slaufling, plateau basalt lava pile stratigraphy resumes, outcrops of porphyritic basalt are found above the Slaufling intrusion that stratigraphically correlate with similar units found to the southwest and at Kvosafoss (Fig. 2). Outcrops are limited to hummocks of the cores of basaltic lava flows that are missing base and top contacts, as well as interbeds between lavas. Around 100 m above Slaufling's top contact, a sedimentary unit crops out (Fig. 9D). This consists of a reddish sandstone (Suppl. Fig. 5B) overlain by an erosive, clast-supported conglomerate with well-rounded lithics.

A phyric (~10% plagioclase macrocrysts) basalt overlies this sediment, which is overlain by a poorly exposed volcaniclastic unit interbedded with additional phyric (~10% macrocrysts) basalts. This unit is polymictic (Fig. 9E); some clasts may be juvenile, though exposures are too limited for firm conclusions. This section of sequence is crosscut by the Slaufey intrusion (Fig. 9A).

Slaufey, located higher on the ridge (Fig. 9A), is also an inflated felsitic sill with concordant top and bottom contacts towards the surrounding basalt lavas. Slaufey rocks, in outcrop, appear more weathered and fissile compared to those of Slaufling, with scree covering most exposures (Fig. 9A). Along a dry streambed on its southeastern margin, Slaufey is in contact with phyric (5–10% plagioclase macrocrysts) basalt lavas and (though no direct contact is seen) volcaniclastic rocks. The Slaufey rock is a pale reddish color with visible flow foliation and vesicle-like voids. Fresh surfaces are gray-white. In thin section (Suppl. Fig. 5D), foliation is expressed through grain size variation and pervasive clay alteration. The groundmass is hemicrystalline, consisting of very fine-grained quartz (<10 µm) and pervasive secondary clays. Rounded voids, suggestive of vesicles, are infilled with red-black opaque to mildly translucent minerals; some fibrous, radial alteration minerals may be replacing glass.

Interpretation

The Hvammsheiði Volcanic Centre preserves volcaniclastic units, ignimbrites, fluvial sediments, and reworked silicic deposits interbedded with basaltic lavas, together with shallow silicic intrusions (Fig. 9). These assemblages are uncommon within the regional lava pile (hence their inclusion here) and most indicate proximity to a silicic volcanic center that is either eroded or not exposed. Stratigraphic relationships and correlations with porphyritic basalt units at Kvosafoss indicate that the Hvammsheiði Formation represents part of the oldest exposed stratigraphic units in the study area.

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The two felsitic intrusions, Slaufling and Slaufey, show contrasting textures and alteration states, indicating emplacement from separate magma batches. Both intrusions were emplaced at very shallow, hypabyssal levels along stratigraphic weaknesses such as ignimbrites and volcaniclastic units, facilitating sill-like to laccolithic geometries. Textural features in Slaufey, including vesicles and hemi-crystalline texture, are consistent with near-surface emplacement and possible crypto-flow or dome-like behavior.

Although petrographically distinct from the Slaufrudalur granite, both Slaufling and Slaufey align along a NNE–SSW trend coincident with the long axis of the Slaufrudalur pluton (Fig. 2 and 10A).

6.4. New observations on the Slaufrudalur pluton

Based on photogrammetry and new field observations, we re-mapped the outline and shape of the Slaufrudalur pluton (Fig. 10). While we principally agree with previous mapping by Burchardt et al. (2010, 2012), we made some changes to how the pluton contact with the surrounding rocks is mapped in five areas:

(1) Slaufrudalur (valley). Based on the pluton contact (with basalts) orientation and the extent of contact metamorphism and fracturing typical for the pluton roof (Quintela et al. 2025b), the western contact in the valley is reinterpreted as a roof contact (not a wall contact) (Fig. 10A; Suppl. Fig. 6).

(2) Kapaldalur. Our field investigations revealed that the rocks in the valley are pyroclastic lithologies and conduit units of the Kapaldalur Formation (Fig. 6), not altered basalt. Observations also revealed that the contact between the pluton and the Kapaldalur Formation is offset from the canyon floor towards the flank of Mosfell (Fig. 2, 5, 11B).

(3) Skeggil. Previously, the granite exposed at the junction between Skeggil and Gjádalur (Gjádalur granite) was interpreted as an isolated intrusion (Burchardt et al. 2010, 2012; Cargill et al. 1928; Carmody 1991). However, observations of the contact relationships of the Gjádalur granite and the fault structure (here called Skeggil fault) bounding the main part of the Slaufrudalur pluton towards the North by Quintela (2025b) and ourselves (Fig. 2 and 11C), indicate that the Gjádalur granite is an extension of the main part of the pluton. It is exposed here at a lower stratigraphic level due to the Skeggil fault structure creating a step down in the pluton roof at this location. Burchardt et al. (2010, 2012) previously described the Skeggil fault as bounding the main pluton body as a straight, subvertical fault contact. Notably, the rocks surrounding the pluton do not appear displaced along the fault or the dyke-like feature(s). The dyke-like feature(s) in prolongation to the Skeggil fault extends to the Kvosir caldera margin (Suppl. Fig. 8), but a crosscutting relationship cannot be determined.

(4) Upper Gjádalur: We observed a sub-horizontal contact between the pluton and the overlying basaltic lava at Kvosafoss (Suppl. Fig. 8). A sedimentary unit (Fig. 8A; described in 6.3.3 Kvosir Formation), observed between Kvosafoss and Kvosir Formation, exhibits mild contact metamorphic characteristics (hardened unit, alteration minerals), and lavas in the same section exhibit fracturing and veining indicative of roof contact fracturing. The contact at Kvosafoss is reinterpreted as a roof contact (instead of a wall contact).

(5) A 20 m wide granite dyke is observed at Skeggtindar (Fig. 2 and Suppl. Fig. 6). The dyke crops out coincidental with, and along strike from, an E–W striking fracture which extends to another roof step above Þorgeirsstaðadalur (visible in Fig. 3A). No deformation is observed within the pluton at this fracture, marking it as a syn-magmatic structure.

Based on points (1) and (4), we redrew the Western wall contact from its exposures in Endalausidalur towards the North to continue below the contact-metamorphosed and fractured roof basalts in Slaufrudalur (valley) and in Gjádalur. We chose to extend the pluton to the Kvosir caldera margin based on western wall strike observations and point 4.

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Based on the photogrammetry and our re-mapping, we produced a new reconstruction of the shape of the Slaufrudalur pluton (Fig. 10D-F). This reconstruction shows that the pluton is about 7 km in N–S direction with a Western contact mostly striking N–S and an Eastern contact striking NNE–SSW. The pluton short axis is about 2 to 2.5 km long, widening N-wards. The pluton walls are sub-vertical, while the roof is mostly sub-horizontal to very gently NW-dipping at elevations of 500 to 600 m a.s.l.. A structural high occurs in the area of the Skeggtindar ridge with elevations of 800 to 865 m a.s.l.. From there, the roof dips towards the NNW, where its last exposure is located at 250 m a.s.l. at Kvosafoss. In the Northeast, a portion of the pluton (former Gjádalur granite) bound by the Skeggil fault occurs with the roof located at elevations below 300 m a.s.l. Hence, the offset of the pluton roof along the Skeggil fault step ranges from ca. 350 m in the Southeast to ca. 100 m at Kvosafoss. Towards the North, the reconstructed pluton roof continues below the level of exposure. Since the above-described dyke-like feature continues in prolongation of the Skeggil fault (e.g. Suppl. Fig. 8), we chose to model the Skeggil fault as the wall contact towards the North.

Regarding the base of the pluton, field observations do not indicate that the current level of exposure (down to ca. 45 m a.s.l. in Endalausidalur) is close to the bottom of the pluton, and there is no data (drilling or geophysical) on its subsurface extension. We therefore chose to model the pluton down to a depth of 50 m below sea level and acknowledge that with further data this value is likely to change. This results in a total pre-erosional pluton volume of 8.7 km^3, which agrees with estimates by Burchardt et al. (2010, 2012).

6.5. Magmatic sheet intrusions

The study area hosts several different types of magmatic sheet intrusions of mafic, silicic and mixed compositions (Fig. 11 and 12). The area notably lacks basaltic sheet intrusions, or dyke swarms, comparable in density to other areas in mid-Eastern Iceland (Walker 1974; cf. Óskarsson and Riishuus 2020).

Instead, in the study area we distinguish two main types of basaltic intrusion:

(1) Basaltic dykes – These are vertical to subvertical, typically decimeter- to meter-scale intrusions. While dykes occur throughout the study area, they are more prevalent in the west (Laxárdalur and Loklausidalur) and in the north (Hvammsheiði) (Fig. 11A and B). Most are aphyric tholeiitic dykes with NE strikes (Fig. 11C). Only a few exceptions were observed: one porphyritic dyke and one olivine basalt dyke ("brown dolerite", similar to those described at Geitafell and by Annels (1967)), both located in Loklausidalur, as well as two olivine basalt dykes (a ~20 cm wide dyke and another larger dyke) in Þorgeirsstaðadalur. No basaltic dykes were observed within the Slaufrudalur pluton.

(2) Basaltic inclined sheets – These occur in swarms or clusters. One partial swarm appears in Loklausidalur and Laxárdalur, where decimeter-scale sheets dip to the north and southeast. Additional inclined sheets are found in the eastern Mosfell ridge, Kapaldalur, and Endalausidalur. None of these sheets were found to crosscut the Slaufrudalur pluton, although local mingling between basaltic magma and the granite has been documented on the northeastern flank of Mosfell (Quintela et al. 2025a).
The densest swarm of inclined basaltic sheets occurs in the northern part of the Slaufrudalur and adjacent host rocks, especially in Þorgeirsstaðadalur and along the Skeggtindar ridge (Fig. 11B). Here, tholeiitic sheets up to 2 m thick intrude the pluton, its basaltic wall and roof rocks, and the Þorgeirsstaðadalur Formation. Their orientations suggest a center of convergence located beneath the northern part of the pluton, approximately in the Skeggil area (Fig. 11C).

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In contrast to the relatively scarce basaltic intrusions, silicic sheet intrusions are more commonly seen across the entire study area (Fig. 12A; Suppl. Fig. 9). Sheets are variably oriented throughout the area, with some distinctions possible between sheets peripheral to the pluton and those outwith the near-pluton area (Fig. 12B and below). Silicic sheets are generally holocrystalline though the very fine groundmass is rarely distinguishable in the field, they may or may not contain phenocrysts of quartz and/or feldspathoids; hemicrystalline (rhyolitic) textures are not uncommon, indicating rapid cooling, though crosscutting (intrusive) relationships are generally evident. The best exposures occur in streambeds, where the silicic sheets show sharp, flow-banded margins with cm-scale undulations (differing microlite-glass content (Suppl. Fig. 9)) when in contact with the basaltic lava pile sequences (Fig. 12C). Sheet interiors are massive and often gray to white on a fresh surface, light gray to orange on weathered surfaces. Some sheets display evidence of mixing with more mafic magma (Suppl. Fig. 9), e.g., in the northernmost canyon diverting from the upper end of Kapaldalur and in Brunnárdalur, where composite intrusions are found near a large fault that runs E-W through the lower valley. Generally, the silicic sheets weather easily and often form inclined or vertical incisions or trails of pink to white scree in the flanks of the lava pile ridges below the outcrop itself (Fig. 12D). In total, we observed two pitchstone sheets, one in Laxárdalur and one in upper Kapaldalur (Suppl. Fig. 9), crosscutting the basaltic lava pile.

We distinguish two types of silicic sheet intrusions, based on their relationship with the Slaufrudalur pluton:

(1) Pluton-derived silicic sheet intrusions emanating from the pluton into the overlying roof basalts and following fractures caused by pluton emplacement (Fig. 12E). These are described in detail by Quintela et al. (2025b).

(2) Peripheral silicic sheets in the rocks surrounding the pluton (Fig. 12B). Various silicic sheet intrusion geometries occur, ranging from subvertical dykes to transgressive sills/inclined sheets, both ranging in thickness from decimeters to several tens of meters. The orientations of these silicic sheets lets us distinguish two sub-types:

a) *Silicic dykes*, predominantly NE-striking, and
b) *Sills and inclined sheets* dipping in various directions from 0° to 80° dip (e.g. Fig. 12D).

While some silicic sheets occur within the Slaufrudalur pluton, they are hard to find due to poor exposure and lack of color contrast with the host granite. As such we lack observations of crosscutting relationships between the silicic sheets in the host rocks with the pluton. In contrast, we observed silicic sheets that crosscut all host rocks outside of the pluton itself, including the entire lava pile exposed in our study area from sea-level to over 1000 m a.s.l. and through all silicic volcaniclastic formations described above.

7. Discussion

In this study we unravel the geological context of Iceland's largest granitic pluton Slaufrudalur. We establish foundational knowledge on the host-rock stratigraphy, geological structures, and relationships with newly discovered volcanic centers to ultimately assess whether pre-existing volcanic deposits and structures influenced silicic magma genesis and emplacement of the Slaufrudalur pluton. Furthermore, the study contributes to

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reconstructing the tectono-magmatic history of Southeast Iceland. Below, we discuss, first the silicic volcanic centers, then their relationship with the pluton, and finally implications for the geodynamic setting of the area.

7.1. Silicic volcanic centers at Slaufrudalur: architecture and implications

In total, this study discovered four previously unmapped silicic volcanic formations near the Slaufrudalur pluton: The Þorgeirsstaðadalur Formation preserves remnants of a small silicic center, including welded ignimbrites and conduit facies rhyolites that exploited fault-controlled pathways and indicate shallow (<5 km) magma ascent and localized explosive activity. The Kapaldalur Formation represents a depression laterally bound by an unconformity and filled by volcaniclastic deposits and a welded (conduit) ignimbrite, most likely suggesting caldera-style collapse. Kvosir, the largest exposed silicic formation, represents part of a fault-bound collapse caldera with an infill of pyroclastic and lava units and pervasive hydrothermal alteration. Hvammsheiði records volcaniclastic sequences partly concordant with the lava pile, as well as shallow silicic sills (Slaufling and Slaufey; Fig. 2). Hence, each formation or volcanic center shows evidence of explosive or effusive silicic activity mostly discordant to the lava pile, in some cases displaying evidence for caldera collapse.

Placing the silicic formations into the stratigraphy of the study area is therefore challenging. For instance, the Kvosir Formation likely represents the subsided interior of a collapse caldera, and quantifying the amount of subsidence would require finding equivalent extra-caldera units. However, all silicic formations are overlain by basaltic lavas and cut by silicic sheets and in the case of the Þorgeirsstaðadalur Formation even basaltic sheets, thus providing some relative age constraints. Furthermore, the general younging of the lava pile towards the west, at least in the northern part of the study area, implies that the Hvammsheiði Formation is older than the Kvosir Formation as a mapped porphyritic marker horizon can be found between Kvosafoss and Hvammsheiði. Unfortunately, the local variations in the lava pile orientation and the presence of the pluton prevents us from placing the other formations in the relative stratigraphy. Here, further detailed mapping of marker horizons such as the porphyritic lavas, dating of the silicic formations, and establishing the magnetostratigraphy of the lava pile will be necessary in the future.

Existing geochronological data mostly focuses on the plutons (Reyðarártindur to 7.30 ± 0.06 Ma; Slaufrudalur 6.38 ± 0.05 Ma, Vestrahorn 4.02 ± 0.03 Ma, Padilla, (2015); Padilla et al. (2016); 4.3 ± 0.2 Ma and 3.9 ± 0.1 Ma, Martin et al. (2011), Austurhorn 6.5–5.3 Ma (Martin et al. 2011; Padilla 2015). However, none of the newly identified silicic formations described in this study have yet been dated, preventing direct assessment of whether they pre-date, post-date, or were coeval with emplacement of the Slaufrudalur pluton. In fact, very little geochronological data exists from the host-rocks of the plutons and intrusions in the southeast of Iceland, One of the very few dates in the area is from a silicic intrusion and silicic breccia in Össurá, just north of Reyðarártindur pluton dated to 2.7 ± 0.1 Ma and 2.6 ± 0.1 Ma respectively (Kremer and Bird 2018). So constraints are only possible from age dating in mid-Eastern Iceland (e.g., Askew et al. 2020). Future geochronological work is therefore essential for establishing the temporal framework of silicic volcanism and magmatism in the area.

The four silicic formations identified in this study differ somewhat from the extinct central volcanoes in mid-Eastern Iceland (Walker 1958, 1963; Gibson 1963; Carmichael 1967; Blake 1970; Gústafsson 1992; Charreteur et

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al. 2013; Askew et al. 2020; Hughes et al. 2026). The exposed areas (Kvosir < 3 km^2 exposed; Kapald., Þorgeirss., Hvamms. <1 km^2) are smaller than those of silicic volcanoes with calderas in the mid-East Fjords (e.g. Breiðdalur volcano exposed over >150 km^2 and the caldera exposed over ~30 km^2; Walker (1963), Askew (2020)), although this difference may at least partly be explained by outcrop conditions. The most remarkable difference with the mid-Eastern central volcanoes is the proximity, with ~3–6 km between the four centers in the mapping area, compared to >30 km between coeval and successive central volcanoes, such as Reyðarfjördur, Breiðdalur, Þingmúli, and Álftafjörður (Fig. 1). Only the Borgarfjörður eystri – Loðmundarfjörður area in the northern East Fjords features a similar density of silicic centers with distances between roughly coeval silicic calderas and eruptive vents of ~ 3–13 km between Dyrfjöll, Njarðvík, Breiðuvík, and Herfell (Fig. 1; Carley et al. (2017); Burchardt et al. (2022b)). The Borgarfjörður eystri area also displays a long period of magmatism and volcanism (Carley et al. 2017), similar to current age data on southeast Iceland (Martin et al. 2011; Padilla 2015; Kremer and Bird 2018). Further age constraints on the silicic formations of our study area will shed more light on the actual density/proximity of silicic volcanism in time.

7.2. Geometry and emplacement of the Slaufrudalur pluton

Remapping and new reconstruction on the Slaufrudalur pluton (Section 6.4 above) have yielded new interpretations of its geometry. Compared to previous reconstructions by Burchardt et al. (2010) and (2012), this study has extended the Slaufrudalur pluton to the NW and established the Gjádalur granite in the NE as part of the main pluton. In the S this study's new pluton reconstruction is somewhat smaller than previous models due to remapping Kapaldalur.

While the aim of this study is not to investigate the mode of emplacement of the Slaufrudalur pluton, we will briefly discuss the previously suggested models in terms of their implications for the setting and structural control of magma emplacement. The most commonly suggested mechanism of emplacement of the pluton is cauldron subsidence (Cargill et al. 1928; Beswick 1965; Burchardt et al. 2010, 2012), a type of subterranean caldera collapse (Clough et al. 1909). This mechanism is consistent with the steep, discordant wall contacts of the pluton and a lack of uplift or subsidence of the surrounding rocks. The latter observation is corroborated by detailed quantitative mapping of the surrounding strata, using photogrammetry (see simplified map in Fig. 2) by Quintela et al. (2025b). Their results confirm Torfason's (1979) observation of lava dips in the Slaufrudalur valley, but demonstrate that the irregular pattern of lava dips in the area is not systematically linked to the pluton. Instead, pluton-related deformation is restricted to the rocks directly overlying the pluton and expressed as locally higher dips in various directions due to small-scale faulting in the pluton roof. Quintela et al. (2025) also mapped these faults in the pluton roof along with the pluton wall contacts and wall-to-roof transitions. They suggest measurements and observations are best explained by the pluton walls representing NNE-striking strike-slip faults and the wall-to-roof transition, as well as the roof faults being controlled by associated Riedel shear fractures. The strike-slip nature of the pluton wall faults implies that magma was emplaced within a subterranean pull-apart structure (Quintela et al. 2025b). Oblique kinematic indicators along the wall faults indicate a degree of pluton floor subsidence that made space for magma emplacement (Quintela et al. 2025b).

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In the context of the Quintela et al. (2025b) model, the Skeggil fault and the dyke-fracture-roof step in the Skeggtindar can be explained as syn-magmatic extensional step-over structures between the strike-slip faults that form the pluton walls (Fig. 2 and Suppl. Fig. 7). Quintela et al. (2025b) also discuss that the observed deformation patterns are inconsistent with sill stacking (cf. Gudmundsson et al. 2011).

While for this study, a final verdict on the mode of emplacement is not necessary, the cauldron subsidence vs. strike-slip models have implications for the geodynamic setting of the Slaufrudalur pluton. These are discussed in Section 7.5.

7.3. Relationship between the Slaufrudalur pluton and the silicic centers

A central question to this study is whether the silicic centers pre-date the pluton, post-date it, or are partly coeval (Fig. 13). This question has implications for the structural controls of pluton emplacement – dictating whether it intruded into relatively uniform or structurally preconditioned crust (Fig. 13). Without focused geochronological data, all scenarios remain possible, but our geological and structural observations permit several robust inferences:

- At Hvammsheiði, the Slaufling and Slaufey sills occur in prolongation of the Slaufrudalur pluton at distances of approximately 900 m and 2,000 m. Nevertheless, we did not observe any structures between the intrusions. Also, the textures in the Slaufling and Slaufey sills are indicative of shallow (hundreds of m depth) emplacement, while the Slaufrudalur pluton exhibits textures indicating deeper emplacement, despite being exposed at similar elevations.
- In Kapaldalur, the contact between the pluton and the Kapaldalur Formation appears to follow the unconformity that delineates the wall fault of the Kapaldalur caldera (Fig. 2 and 5). The pluton is in direct contact with the felsites and mafic breccias of the Kapaldalur Formation, as well as close to (ca. 170 m distance from) the pumice-bearing ignimbrite. Overall, the pluton is exposed at the same elevations and above the Kapaldalur Formation. Hence, the pluton appears to cut/intrude into the Kapaldalur Formation, but outcrop conditions are not favorable for unambiguously establishing a relative age relationship.
- At the same time, felsic plutonic lithics in some of the rocks of the Kapaldalur Formation indicate reworking of underlying granitoid plutonic material, but it is to date unclear if this material is from the Slaufrudalur pluton or other unexposed intrusions underlying the area.
- In Þorgeirsstaðadalur, the pluton is exposed at stratigraphic elevations above the Þorgeirsstaðadalur Formation. The silicic rocks of the Þorgeirsstaðadalur Formation are exposed at distances of approximately 250 m from the pluton wall faults. In the northernmost exposure of the pluton wall fault in one of the tributaries of Þorgeirsstaðadalur, the pluton wall cuts through the basaltic lavas overlying the Þorgeirsstaðadalur Formation. However, a large part of the Þorgeirsstaðadalur Formation is exposed as conduit silicic pyroclastic units or in close relationship with faults, so the actual depth of formation of these rocks and their age relative to the pluton cannot be established based on field evidence. In upper Gjádalur, the contact metamorphism and fracturing typical for the pluton roof rocks extend all the way to the margin of the Kvosir caldera, which led us to reconstruct an extension of the pluton towards Kvosir (Fig. 13). We cannot rule out that the pluton extends even further beneath the Kvosir Formation. Plutonic silicic lithics in the silicic rocks of northern Kvosir, ca. 2 km from the nearest pluton outcrop, suggest the presence of granites in the subsurface. However, geochemical analysis will need to establish whether these granites are related to the Slaufrudalur pluton.
- The Skeggil fault and the dyke-like feature that occurs in its prolongation towards Kvosir connect the silicic centers of Kvosir and Þorgeirsstaðadalur (Fig. 2 and 13; Suppl. Fig. 7 and 8). In Þorgeirsstaðadalur, some rocks of the Þorgeirsstaðadalur Formation show clear signs of syn-magmatic

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faulting along fault structures that occur in the riverbed in prolongation of the Skeggil Fault. Hence, the Skeggil fault may have affected the emplacement of some of the Þorgeirsstaðadalur Formation. Alternatively, the Skeggil Fault may have been influenced by a pre-existing fault.

- The silicic sheets that crosscut all volcanic formations in the study area play a key role in unravelling the relationship between the geological history of silicic magmatism. Since our mapping could not establish the relationship between the pluton and the peripheral sheets, future geochemical and geochronological analyses of the sheets need to solve this question. In any case, they testify to excessive and widespread silicic magmatic activity beyond the lifetime of the silicic volcanic centers.

In summary, these findings paint a picture of complex and prolonged silicic magmatism in the area, including multiple phases of intrusive and volcanic activity. While the pluton and the silicic centers share structures, a definitive answer as to the relationship between the pluton and the silicic centers requires detailed dating of key formations.

7.4. Structure and stratigraphy of the lava pile surrounding the Slaufrudalur pluton

The stratigraphy of the mapped area is dominated by Miocene subaerial basaltic lava flows, locally interbedded with volcaniclastic sediments and interrupted by pyroclastic units. While this stratigraphy broadly resembles the west-dipping, regular "cake-layer" lava pile architecture typical of mid-Eastern Iceland (Walker 1964, 1974; Óskarsson and Riishuus 2020), our mapping reveals substantial deviations:

- The structure of the lava pile in the mapping area differs from that observed in mid-Eastern Iceland, displaying substantial local variability with no coherent regional tilt that cannot be explained by deformation due to pluton emplacement alone (Suppl. Fig. 3; Quintela et al. 2025b). This indicates that the study area does not conform to the simple model of burial, tilting, and southwestward imbrication of successive volcanic systems typical of the mid-East Fjords. There, deviations from the regional westward dip only occur associated with the central volcanoes (Óskarsson and Riishuus 2020) and locally around magmatic intrusions (e.g. Mattsson et al. 2018). Only the Borgarfjörður eystri – Loðmundarfjörður area in the northern East Fjords displays similarly irregular lava orientations, which Burchardt et al. (2022a) relate to a paleo-location away from the main rift zone or a different configuration of rift zones. Overall, the pattern of lava orientations in our study area therefore requires alternative explanation, and may be due to, for example, central volcano edifice loading, deformation related to magmatic intrusion emplacement, or small-scale tectonic movements. Further investigation into the stratigraphy and potential tilting of the lavas is necessary.
- Several concordant sedimentary units are found throughout the area, varying from poorly sorted breccias, mass flow deposits, sandstones and siltstones, to conglomerates (e.g., Fig. 8 and 11). This indicates a significant fluvial environment throughout the area (and over the timescale of the stratigraphy), implying a wetter and more dynamic paleoenvironment than that inferred for the mid-Eastern successions which are dominated by aeolian sediments and tuffs (Bodvarsson and Walker 1964; Óskarsson and Riishuus 2013).
- The rocks in the mapped area display pervasive greenschist metamorphism characterized by the occurrence of secondary chlorite, epidote, and quartz and a notable absence of zeolites that are typical for the rocks of mid-Eastern Iceland (Walker 1974). Hence, the study area experienced higher temperatures (and potentially higher pressures) than the mid-East Fjords. This might be a result of the presence of plutonic bodies and their low-grade contact metamorphism and hydrothermal systems increasing the geotherm in this area. Alternatively, the area may have experienced deeper burial, with temperatures and pressures up to chlorite-epidote stability, than previously envisioned (e.g. Fridleifsson (1983), Annels (1967), and Newman (1967) suggestions of <1km emplacement depths).

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- Mapping has noted a scarcity of rift-parallel mafic dyke swarms compared to mid-Eastern Iceland, where dyke swarms delineate the extent of the fissure swarms from extinct volcanic systems and record regional extension (Walker 1960, 1975; Óskarsson and Riishuus 2020). This study area contains isolated dykes with a NE strike, small clusters of basaltic inclined sheets, and widespread silicic sheets that do not define a classical rift-parallel dyke swarm. Whilst we cannot rule out partial erasure of the swarm by erosion, it seems unlikely that there would be no record of a swarm in the rocks around the map area. Thus, these differences suggest that the study area was not part of an axial rift segment during the Neogene. The basaltic inclined sheet swarms testify to localized mafic magmatism fed by shallow magma reservoirs below the current level of exposure (cf. Burchardt et al. 2011; Galland et al. 2014). The inclined sheet swarm in the northeast of the study area postdates the Slaufrudalur pluton and may provide an age constraint on the youngest observed mafic magmatism in the area.

7.5. Implications for the Geodynamic Setting and Silicic Magma Genesis

The structural and volcanic complexity of the Slaufrudalur region challenges the classical model in which extinct volcanic systems form a simple en-echelon chain controlled by systematic rift-parallel extension with a clear age progression as a function of the distance to the active rift. Instead, the spatial distribution of volcanic centers resembles caldera clusters such as Borgarfjörður eystri (Burchardt et al. 2022b), as well as off-rift environments such as the southern tip of the EVZ (South Iceland Volcanic Zone - SIVZ e.g., Tindfjöll, Eyjafjallajökull) or areas where new volcanism builds upon older central volcano material at e.g. Öræfajökull. These are areas where silicic magmatism is concentrated, but well-established rifting and therefore dyke-fed fissure swarms are mostly absent. Similar interpretations have previously been proposed for southeastern Iceland more broadly (Torfason 1979; Fridleifsson 1983).

A placement of the Slaufrudalur area outside the Neogene rift zone is corroborated by the absence of regional dyke swarms and normal faults indicative of crustal extension, irregular lava pile orientations, and the presence of seemingly small and structurally isolated volcanic centers.

As noted previously, Quintela et al. (2025b) inferred that the Slaufrudalur pluton was emplaced between NNE-striking strike-slip faults. In Iceland, present-day strike slip faulting roughly parallel to the rift axis occurs between overlapping volcanic systems with differential amounts of rifting, for example in the NVZ (e.g. Green et al. 2014; Ágústsdóttir et al. 2019). Strike-slip faulting is also reported along propagating rift segments such as the EVZ and SIVZ (e.g. Siler and Karson 2009). While we have not found large-scale strike-slip faults beyond the Slaufrudalur pluton, we recognise the need for further mapping, as well as high resolution geochronology and geochemistry.

In terms of geochemistry, silicic magma genesis in the Slaufrudalur area could be placed in a regional framework of silicic magmatism in Iceland. There, silicic magma generation is generally attributed to a combination of prolonged fractional crystallization of basaltic magmas (Bowen 1928; Carmichael 1964; MacDonald et al. 1990; Furman et al. 1992a; Marsh 2006), partial melting of altered crust (Helz 1973; O'nions and Grönvold 1973; Sigurdsson and Sparks 1981; Oskarsson et al. 1985; Coogan et al. 2003; Jónasson 2007; Martin and Sigmarsson 2007; Gillis 2008; Zakharov et al. 2019; Troch et al. 2020), and assimilation within upper crustal magma reservoirs (Nicholson et al. 1991; Masotta et al. 2018). Geochemical and isotopic studies from eastern and southeastern Iceland have demonstrated that evolved magmas cannot always be explained by simple fractional crystallization alone and many require contributions from altered crustal material (Martin and Sigmarsson 2010; Martin et al.

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2011; Charreteur et al. 2013; Padilla et al. 2016; Carley et al. 2017; Banik et al. 2026). The geological relationships documented in the Slaufrudalur area are consistent with prolonged crustal magmatic activity, including repeated emplacement of silicic sheet intrusions, development of multiple silicic volcanic centers, eruption of ignimbrites and rhyolite lavas, and emplacement of the Slaufrudalur pluton. Together, these features suggest that evolved magmas were generated and stored repeatedly within the upper crust during the late Miocene.

While the mapping presented here does not directly constrain petrogenetic processes, it provides a geological framework compatible with models involving long-lived (>100Ka) crustal magma reservoirs, repeated recharge, and progressive remelting of altered volcanic crust. Future geochemical, isotopic, and geochronological studies will be required to determine the relative importance of these processes in generating silicic magmas in the Slaufrudalur region.

8. Conclusions

Detailed mapping of the Slaufrudalur region in Southeast Iceland reveals multiple, previously unrecognized silicic volcanic centers: Þorgeirsstaðadalur, Kapaldalur, Kvosir, and Hvammsheiði. These are associated with some or all of the following: discordant contacts with the surrounding basaltic lava pile, basin or depression features, pyroclastic units, shallow (subvolcanic) conduits, and in some cases, close-to-surface silicic intrusions, all of which are consistent with the presence of subsided collapse caldera interiors.

New 3D reconstructions of the Slaufrudalur pluton show that it has a stepped roof geometry and is bounded by major faults, including the Skeggil fault, which align with the eastern margin of the Kvosir caldera and straddle the Kapaldalur and Þorgeirsstaðadalur formations. The pluton is now mapped with a slightly larger footprint, and a possible conduit dyke extruding from it at Skeggtindar.

In contrast to classical rift volcanic systems in Eastern Iceland (Walker 1960), this region lacks extensive mafic dyke swarms. Instead, the area displays widespread and juxtaposed silicic activity as sheets, volcanic centers, and the Slaufrudalur pluton. This structural and lithological complexity of the area challenges earlier interpretations of this part of Southeast Iceland as a monotonous basaltic lava pile hosting the pluton. Instead, the area displays a dynamic interplay of effusive, explosive, and intrusive silicic magmatism, concentrated in discrete, partially preserved, centers within the lava stratigraphy.

Collectively, these findings show that Southeast Iceland does not conform to the classical mid-Eastern Iceland setup of volcanic systems, but instead records a structurally partitioned, near-rift or off-rift environment during the Neogene. Silicic volcanism and granite emplacement occurred within this complex setting, likely displaying overlapping and complex relationships to be investigated further. In particular, we emphasize the necessity to investigate the following research questions:

1. **Geochronology**: What is the temporal relationship between the centers, the lava pile, and the pluton?
2. **Subsurface geometry of the pluton**: How far does the pluton extend below its visible exposures? Geophysical methods could shed light on this question.

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3. **Geochemical connections**: Are the country rocks genetically linked to the pluton? Were the silicic volcanic rocks (or deeper counterparts) the source material for the large amount of silicic magma in the pluton? Or did the pluton feed some of the silicic volcanic rocks?
4. **Regional geochemical framework**: Can regional geochemical sampling and analysis construct a more robust picture of the geodynamic setting?
5. Finally, our study indicates that there is still a need for detailed geological mapping to be undertaken as larger scale studies may not cover the ground in enough detail. What other hidden volcanoes are waiting to be found?

9. Author contributions

Robert Askew: conceptualization, funding acquisition, data collection, interpretation, manuscript & figures
Steffi Burchardt: conceptualization, funding acquisition, data collection, interpretation, manuscript & figures
Catherine Gallagher: data collection, interpretation, manuscript & figures
Sæmundur Ari Halldórsson: conceptualization, funding acquisition, project management
Olivier Bachmann: conceptualization, funding acquisition, interpretation
Razvan Gabriel-Popa: conceptualization, funding acquisition, interpretation
Kristján Jónsson: conceptualization, funding acquisition, interpretation
Renae Gupta: data collection, interpretation
Orlando Quintela: data collection, interpretation
Emma Rhodes: data collection, interpretation
Birgir Óskarsson: data collection, interpretation
Elisa Piispa: data collection, interpretation
Tobias Mattsson: data collection, interpretation

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11.Data availability

The geological map is available on Zenodo as a GPKG with associated metadata.

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13.Figure captions

Figure 1. Geological map of mid-Eastern and Southeastern Iceland including the location of extinct central volcanoes and the trend of regional dykes according to Walker (1975) and Burchardt et al. (2022a). Geological map by Jóhannesson and Sæmundsson (1998). Inset displays the main geodynamic features of Iceland: RR (Reykjanes Ridge) and KR (Kolbeinsey Ridge), the transform zones TFZ (Tjörnes Fracture Zone) and SISZ (South Iceland Seismic Zone), the rift zones RP (Reykjanes Peninsula), WVZ (West Volcanic Zone), HVZ (Hofsjökull Volcanic Zone), NVZ (North Volcanic Zone), and EVRZ (East Volcanic Rift Zone), as well as the flank zones SVZ (Snæfellsnes Volcanic Zone), SIFZ (South Iceland Flank Zone), and ÖSFZ (Öræfajökull-Snæfell Flank Zone).

Figure 2: Geological map of the mountains west of Papafjörður and north of Hornafjörður. Relevant place names are indicated. The formations described in the text are Kapaldalur, Þorgeirsstaðadalur, and Kvosir; Hvammsheiði is also described. Map projection: Lambert 1993. Coordinate grid projection: ISN93 / Lambert 1993 (EPSG:3057).

Figure 3: Þorgeirsstaðadalur overview and field outcrop images. A) Inset, locality map (see Fig. 2). UAV image westwards towards Skeggtindar, the granitic pluton is exposed near the summit and displays a clear step in the roof contact (see text). The Skeggil fault trace is not shown, it traces roughly through the pass seen on the right of the image. The silicic volcanics are highlighted in the image and the location of the fault is shown. Annotation numbers refer to subfig. B. B) Image direction shown in A, outcrop view of the Þorgeirsstaðadalur welded and sintered units (002 and 003), cross-cutting a pyroclastic unit (001). White dotted lines indicate the contacts of the dark gray welded and sintered unit 002. The unit 002b appears associated with 002, a contact between it and the pyroclastic unit 001 marked with black dotted line. 003 is a welded pyroclastic unit related to the rhyolite of 003b (*: Fig. 4A. **: Fig. 4D.). C) Pyroclastic unit 001 in outcrop, black arrows indicate some of the fiamme-like clasts, often altered by quartz mineralization. Red filled arrows to right of image denote boundary with coarse granitoid intrusion of 002b. D) The fault boundary, the fault is utilized by intrusions (subfig. B unit 002b). In the image, the white unit is felds-qtz-plag bearing granitoid, the host rock and outer fault unit is chlorite-epidote-quartz altered basalt. Pen is around 12 cm long, hammer ~29cm.

Figure 4: Þorgeirsstaðadalur units continued, outcrop and hand sample scale images. A) Vertical contact between 002, clastic, welded and sintered unit, and highly altered basalts. Image location shown in Fig. 3B (*). B) Welded unit 002 (Fig. 3B) hand sample in outcrop. Clast boundaries noted with black arrows, right clast coarse grained plagioclase clinopyroxene gabbro; left clast fine grained mafic. Clasts are sub-angular. Also visible are feldspar phenocrysts (white mineral on image). C) Fiamme and clasts, denoted by black arrows, within the agglomerate of 003 (Fig. 3B), portions of the unit are more brecciated, others appear as shown here, low-foliated and welded. Camera lens cap ~6 cm. D) The massive rhyolite body above the welded agglomerate of 003, basaltic sheets highlighted cross-cutting the unit. Image is taken on foot (location in Fig. 3B **), the cliff represents close to 100 m from base to top. E) Layered tuff and ignimbrite. Well structured, with some variability in the layers, see text. F) Purple colored mafic tuff beneath a basaltic lava flow.

Figure 5: Panorama of the head of Kapaldalur, location shown on inset. A) Stitched panorama, red arrows: sheet locations. B) Sketch of units' outcrops. Note the almost 180° view field. Pluton: Slaufradalur granitic pluton outcrop. Br.: Mafic monomictic (auto-) breccia. Ign.: Ignimbrite. Vcc: Volcaniclastic sequence. Light blue indicates basaltic lavas. The fracture described in the text is shown in B leading up to a small step/gully in the landscape.

Figure 6: Field images from Kapaldalur Formation's main units. A) Granite to ignimbrite (altered felsite) contact, look direction to north, the contact zone is highly altered with pervasive mineralization including pyritization. B) Outcrop exposure of the ignimbrite's fiamme bearing section, black arrows indicate some of the altered fiamme locations, they are roughly vertical in orientation and altered often by green chlorite or weathered away. C) Ignimbrite (and felsitic section) contacting with breccia, look direction South – image from roughly opposite. Person ~170cm. Ignimbrite section indicated in this image relates to subfig. B and C. D) Hand sample scale of the ignimbrite fiamme bearing section, here alteration is more ferrous though fiamme still weather out readily, white arrows indicate some of the fiamme/pumices. Pen ~14 cm. E) Volcaniclastic diamictite (indicated in Fig. 5 as Volcaniclastic sequence) outcrop example. White arrows indicate small block sized clasts (~10-15 cm). Book 20cm height. F) Hand sample scale image of part of the volcaniclastic unit. Lens cap 6 cm. G) Monomictic breccia from the autoclastic unit, large core-like section of the unit indicates lava-flow morphology. Person ~170 cm. Inset of G is thin section (XP) image of subophitic textures found in this basalt.

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Figure 7. The Kvosir formation, a caldera infill sequence bounded by sharp caldera fractures (or faults) A and B) – Kvosir formation, aerial image (crewed flight). Image direction westwards. No scale on image. Red arrows in A indicate the orange pink ignimbrite described in text and Fig. 9C. B) A simplified geological map overlay displaying the caldera infill (ignimbrites, breccias, other sediments), silicic lavas are shown separately. Plateau basalts not colored. K.R.: Kvosatindur rhyolite lava and possible conduit. Caldera fracture represents the roughly vertical contact between the caldera infill and the surrounding plateau basalts in that area. The "Upper boundary" denotes a boundary in the upper part of the valley between basalt lavas and the caldera infill, some local deformation in the upper boundary lavas is pointed out by white arrows. C) Drone image (see inset in A, view direction, North). Scale of near image is shown. The contact between the lavas and infill at the caldera fracture (location shown in A), A.B.: Autobreccia basalt, depression infilling basalt, inferred contact is displayed. S.I.: Silicic intrusion through E.B.: Epiclastic breccia. M.I. Mafic intrusion also through E.B.. The K.R. may extend above though this has not been mapped (marked with "unknown"). Inset map displays the location on simplified Fig. 2.

Figure 8. Kvosir units in outcrop, as described in the text. A) Sedimentary unit found in the Kvosir valley above Kvosafoss and outwith the caldera (Fig. 2). Laminated siltstone to sandstone. Hammer pick 12 cm. B) Block of lithic-bearing ignimbrite, brown (altered fiamme). Found within the Seti sequence. Camera lens 6cm. C) Ignimbrite (pale orange-pink sintered unit). Image displays white blocks sintered in glass and foam-like sections. Hikin pole visible section ~30 cm. D) A vesicular rhyolite lava in Kvosir. Shoe scale bottom right (~6 cm visible). E) A pyroclastic (ii) and reworked volcaniclastic (i) sequence within the caldera. Hammer shaft 30 cm. F) Outcrop (inaccessible) in Kvosir, welded (black) ignimbrite sandwiches a white unwelded breccia. Outcrop 10 m at highest point.

Figure 9: Hvammsheiði formation outcrops. A) Hvammsheiði aerial view (crewed aircraft) displaying the location in relation to the Slaufrudalur pluton. Slaufey and Slaufling are indicated alongside the delineation of volcaniclastic rocks abutting them (bracketed letters indicate subfig locations). Steeply dipping lavas are indicated on the ridge southwest of Hvammsheiði. B) Outcrop view of Slaufling-ignimbrite contact. The fissile and weathered nature of the rocks means direct contacts are generally not found. C) Speckled rock, outcrop of unwelded, pumice lapilli ignimbrite abutting Slaufling. Hammer shaft 30 cm. D) Epiclastic sediment, location indicated on A. Lowermost lithology is sandstone, bedded and poorly cross bedded from fine to coarse sandstone. Hammer shaft 40 cm. Dotted line indicates contact with the upper conglomerate, the contact appears to be erosive, sandstone beds are cut in some sections. The clasts are well rounded, and largest clasts are up to 10-15 cm. Overlying lava seen in upper part of subfigure. E) Volcaniclastic rock contacting with Slaufey, unknown origin, clastic with significant number of sub-angular silicic clasts. Location shown on simplified Fig. 2 inset map.

Figure 10. Mapping and reconstruction of the Slaufrudalur pluton. A) Virtual outcrop constructed from oblique aerial photographs showing the nearly complete cross section through the Slaufrudalur pluton exposed in the Skeggtindar ridge above Slaufrudalur (valley). The pink to beige granitic rocks of the pluton stand in stark contrast to the grey-brown basaltic lavas that host the pluton in this valley. The wall contact of the pluton is sub-vertical and discordant, while the roof contact is concordant with an apparent Westerly dip in this section. B) Oblique aerial photograph looking North across a large part of the Slaufrudalur pluton. In Kapaldalur, the pluton intrudes the Kapaldalur Caldera Formation, which is well exposed in the canyon in the bottom left of the image. Previously, Burchardt et al. (2010, 2012) mapped the pluton contact in the base of this canyon and the host rocks as altered basalt, in agreement with Cargill et al. (1928). C) Virtual outcrop constructed from UAV (drone) images looking from close to Kvosafoss along the Skeggil fault. Overall, the Skeggil fault is straight and sub-vertical. In outcrop, it can display intrusive or cataclastic features. D-F) Three-dimensional reconstruction of the shape of the Slaufrudalur pluton, color-coded by elevation. The location of the section in A) is indicated in D). Note the flat roof and steep walls of the pluton. In this new reconstruction, the Gjádalur granite is interpreted as connected to the main body of the Slaufrudalur pluton. The Skeggil fault forms a major step in the pluton roof between both parts.

Figure 11. Basaltic sheet intrusions in the study area. A) Distribution and orientations of basaltic sheet intrusions as measured in the field and using photogrammetry. Some symbols were moved to avoid overlap. 21 sheets removed from map for clarity, but without affecting the overall pattern. Refer to Fig. 2, area modified slightly, grid Lambert 1993. A) and C) modified from Quintela et al. (2025b). B) Panorama of UAV images (location indicated in A) of the slope of Skeggtindar in upper Þorgeirsstaðadalur. Here, the Slaufrudalur pluton and its roof rocks are cut by numerous basaltic inclined sheets (indicated by yellow arrows), most of them dipping N. Sheets are approx. 1 m thick. C) Stereographic projection of poles to basaltic sheet orientation planes in a lower hemisphere, equal area projection.

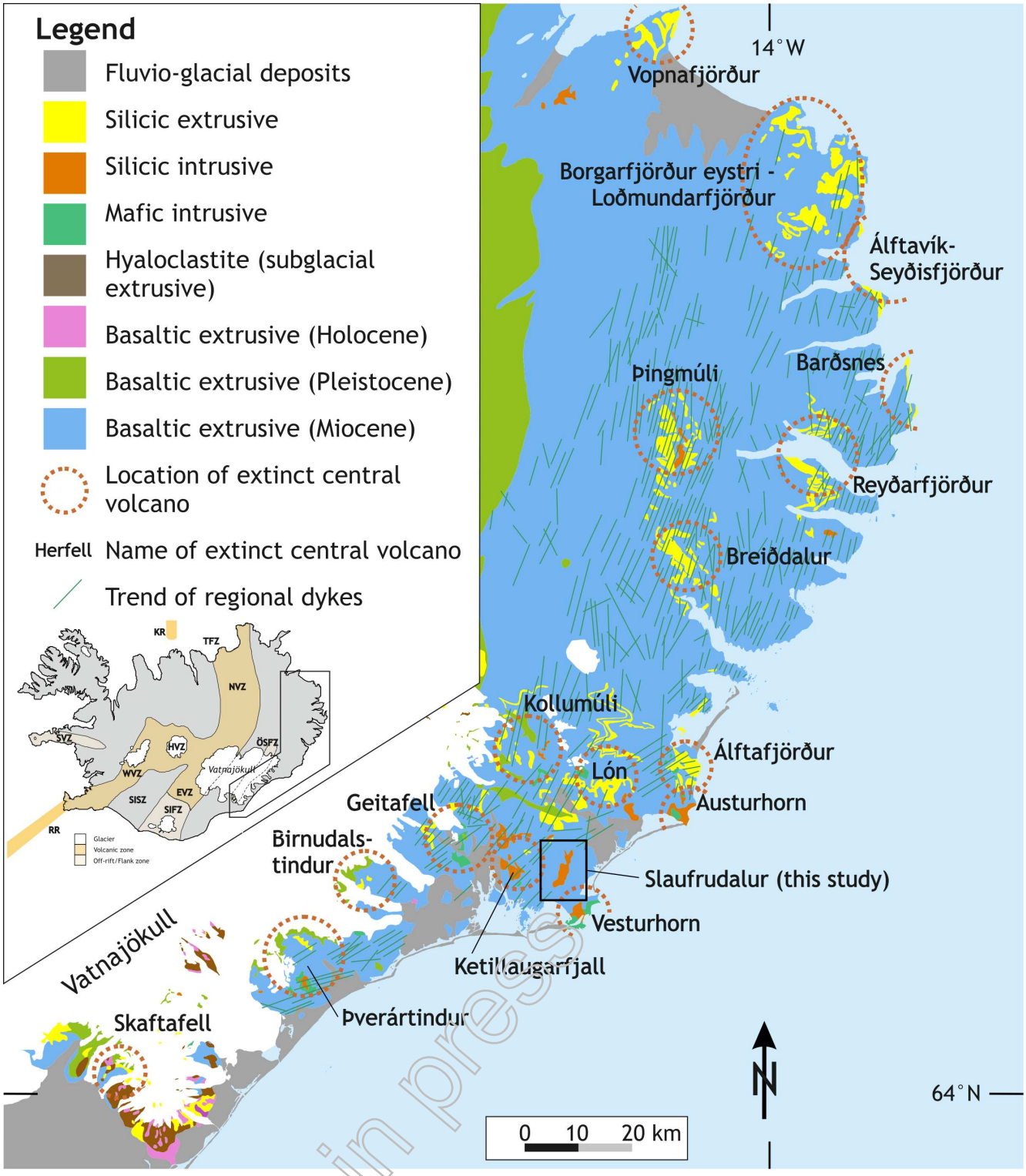
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Figure 12. Silicic sheet intrusions in the study area. A) Distribution and orientations of silicic sheet intrusions as measured in the field and using photogrammetry. Some symbols were moved to avoid overlap. 26 sheets removed from map for clarity, but without affecting the overall pattern. Refer to Fig. 2, area modified slightly, grid Lambert 1993. A) and B) modified from Quintela et al. (2025b). B) Stereographic projection of poles to silicic sheet orientation planes in a lower hemisphere, equal area projection. All silicic sheets left, silicic sheets peripheral to the Slaufrudalur pluton right. C) Field photograph of the margin of a silicic sheet exposed in the river in Endalausidalur. Location indicated in A). D) UAV image of silicic sheets (sills and inclined sheets) in the Skálir cliff above Road 1 N of Höfn. Sheets are meters to approx. 10 m thick. Location indicated in A). E) UAV photo of the slope of Skeggtindur in upper Þorgeirstaðadalur. Here, silicic sheets emanate from the Slaufrudalur pluton into its roof rocks following roof fractures. Sheets are approx. 1-2 m thick. Location indicated in A).

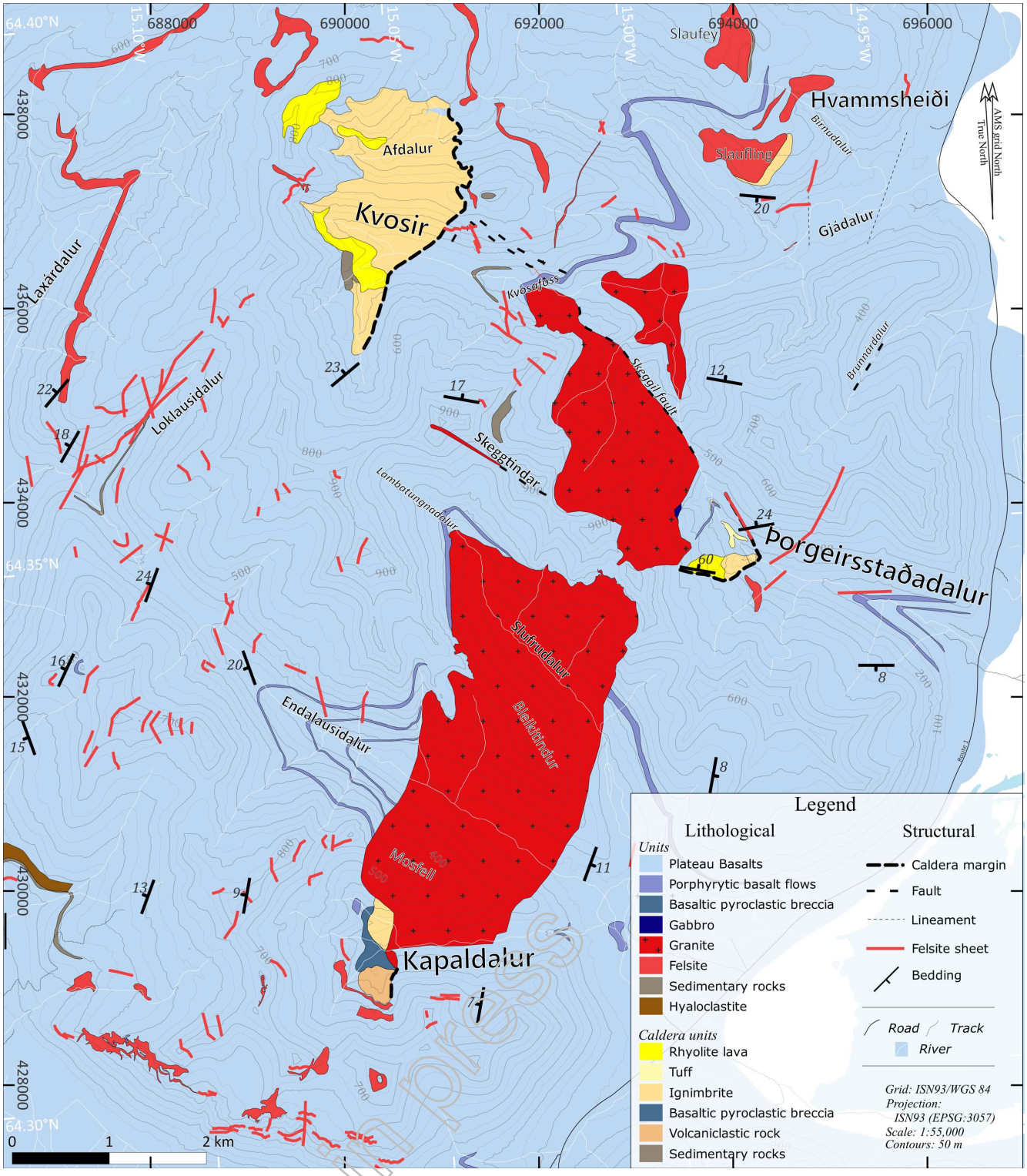
Figure 13: A proposed model of geological evolution of the area. Two models for pluton and volcanic center evolution. A – Preexisting volcanic centers form host rock to the pluton. i) Small silicic centers form. ii) Transtensional faulting preceding pluton emplacement linked by volcanic center structures. iii) Pluton emplacement and floor subsidence of beneath-pluton block. iv) Final stage of emplacement and current geometry. B – Pluton emplaces via transtensional faulting and floor subsidence; volcanic centers and conduit systems establish along plutonic structures. i) Transtensional faulting and pluton emplacement. ii) Pluton emplacement in sill-like fashion and floor subsidence. iii) Continuation of ii. iv) Conduits and caldera structures form along pluton margins and structures. Schematically drawn – not to scale and missing complexities. Kvosir is represented at the "back" of each figure, though its relative timing is unknown. C – Current day map view of the pluton and main silicic centers. Kv – Kvosir; Þg – Þorgeirsstaðadalur; Kd – Kapaldalur. Colors roughly equate to map symbology (Fig. 2), except the pluton (pink) which is adjusted for clarity.

FIGURES

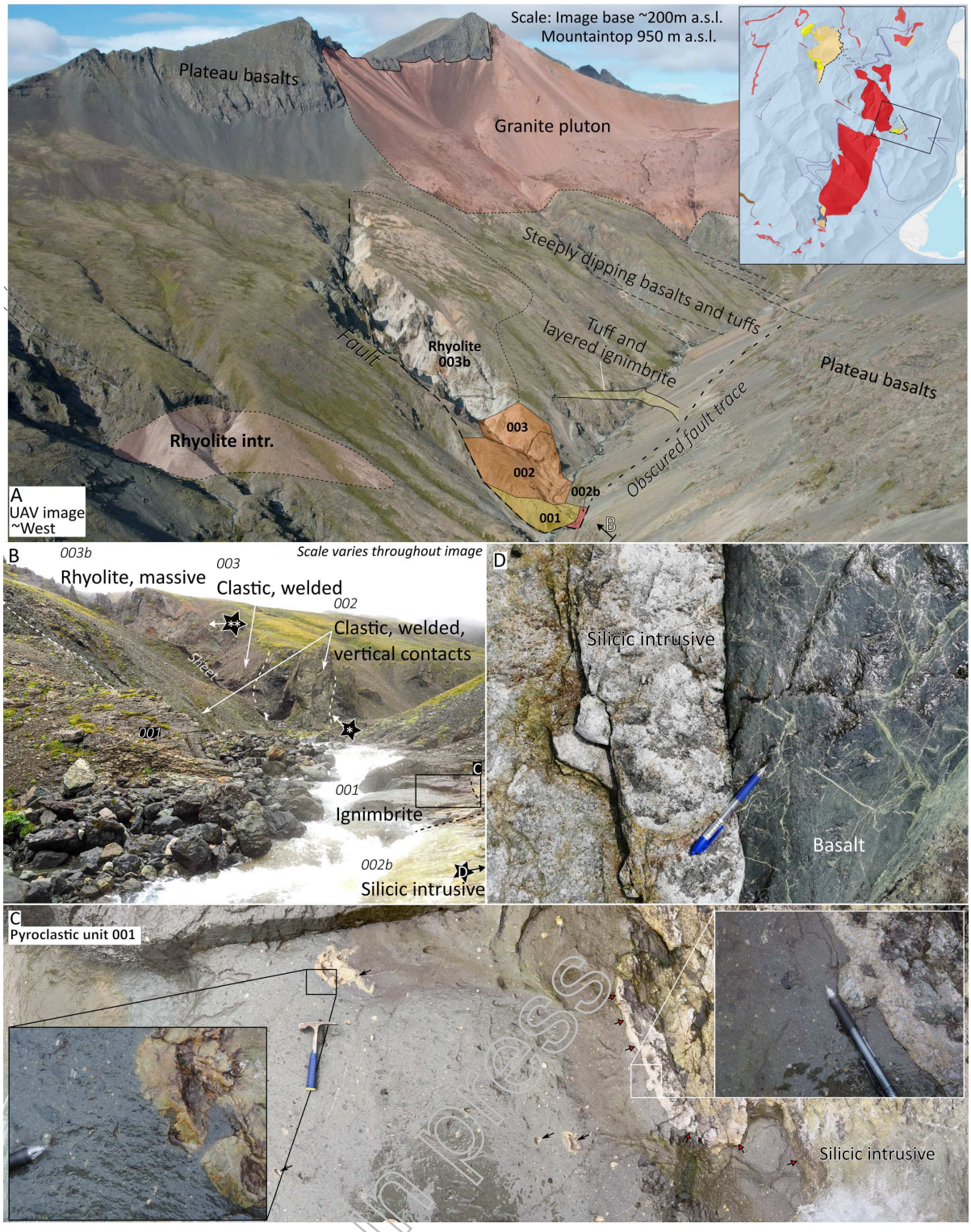
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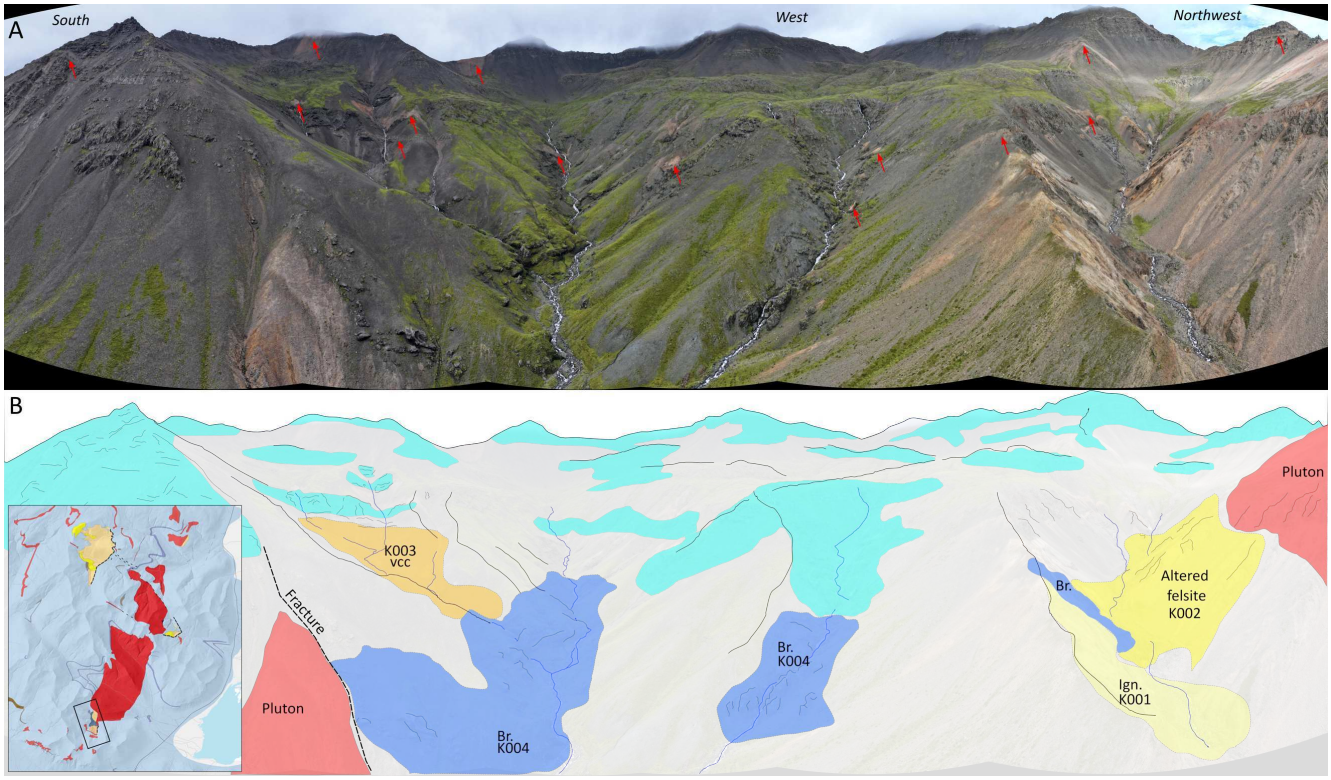


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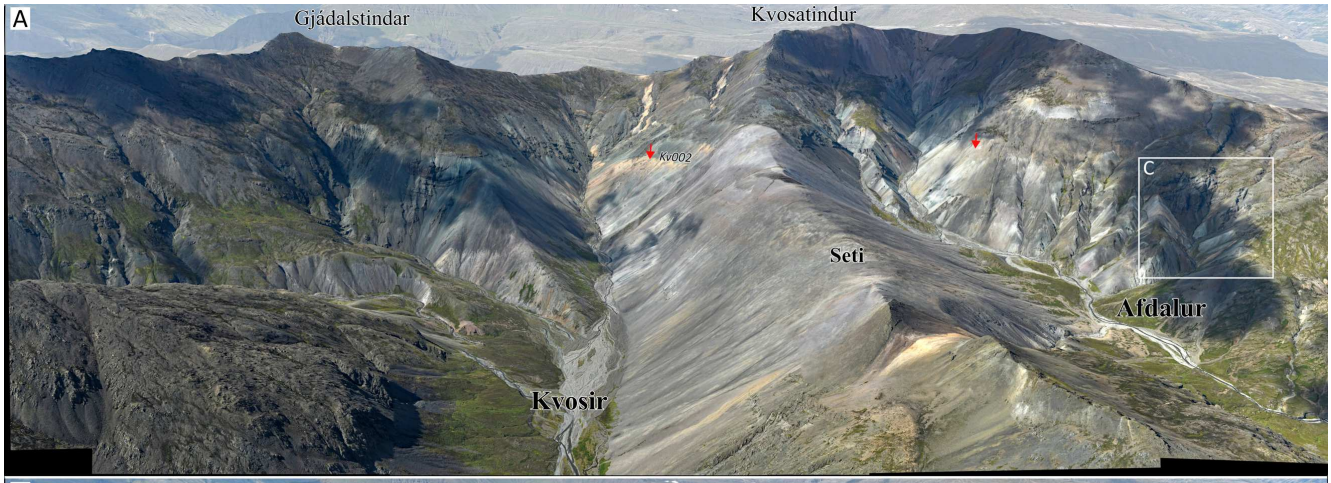
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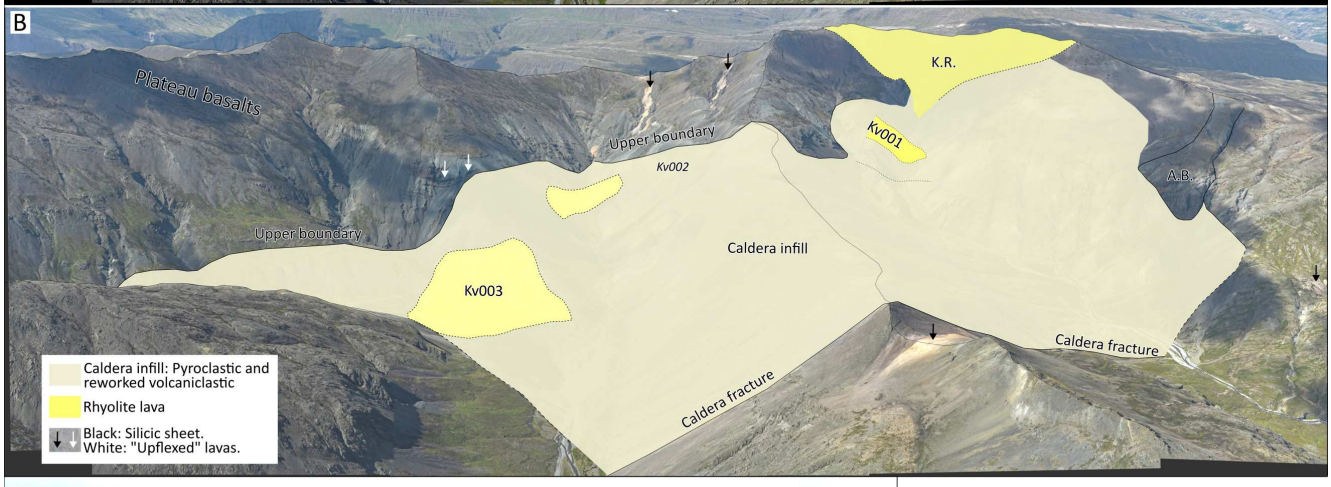


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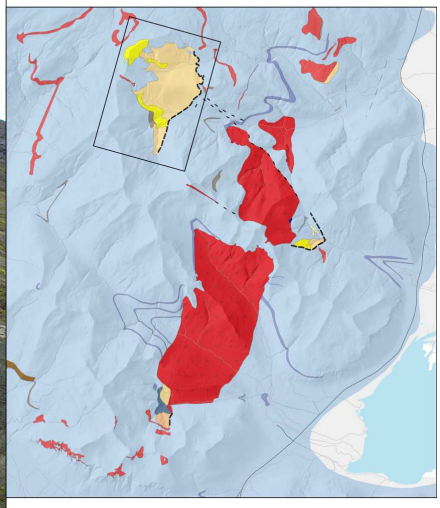


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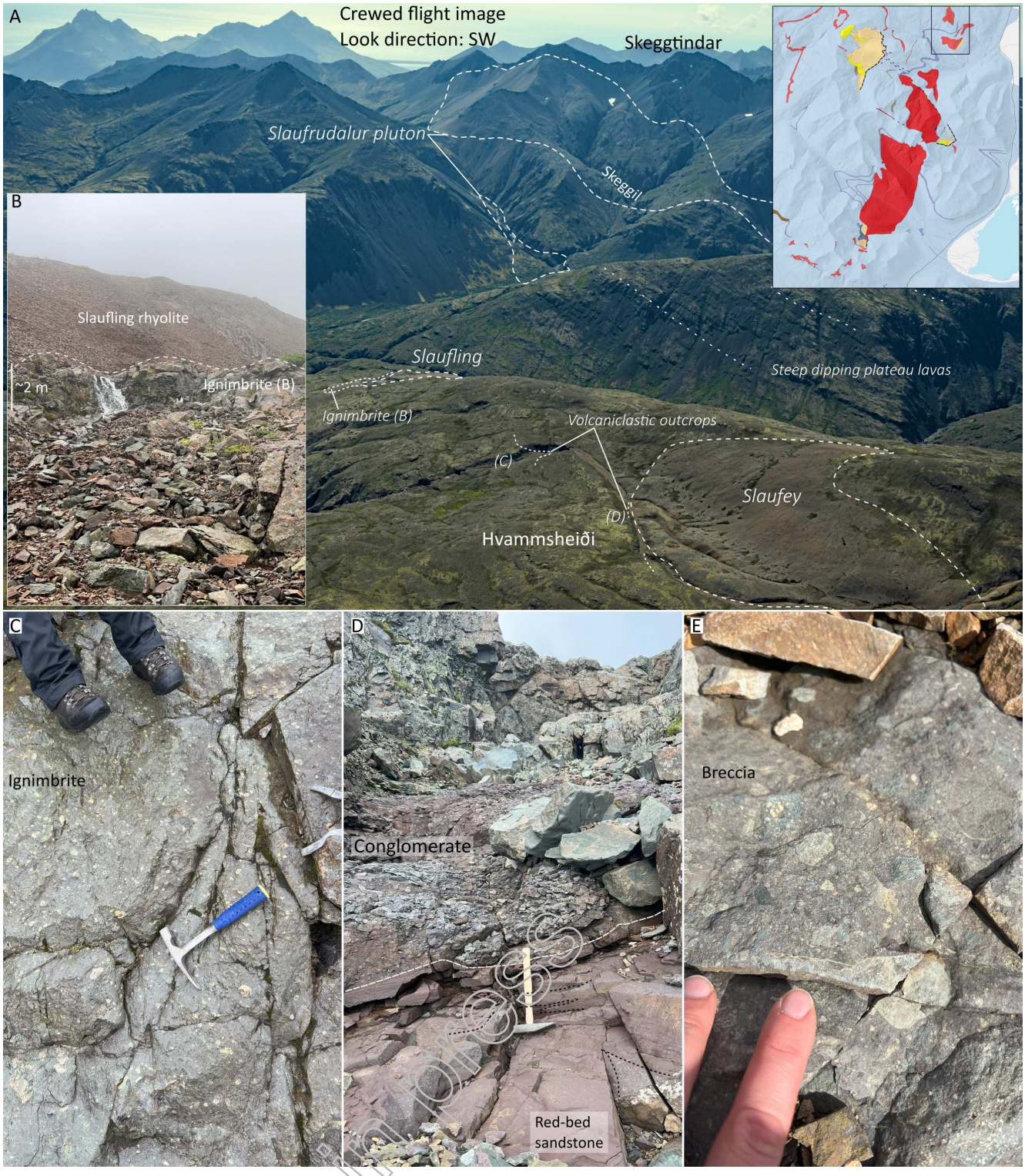




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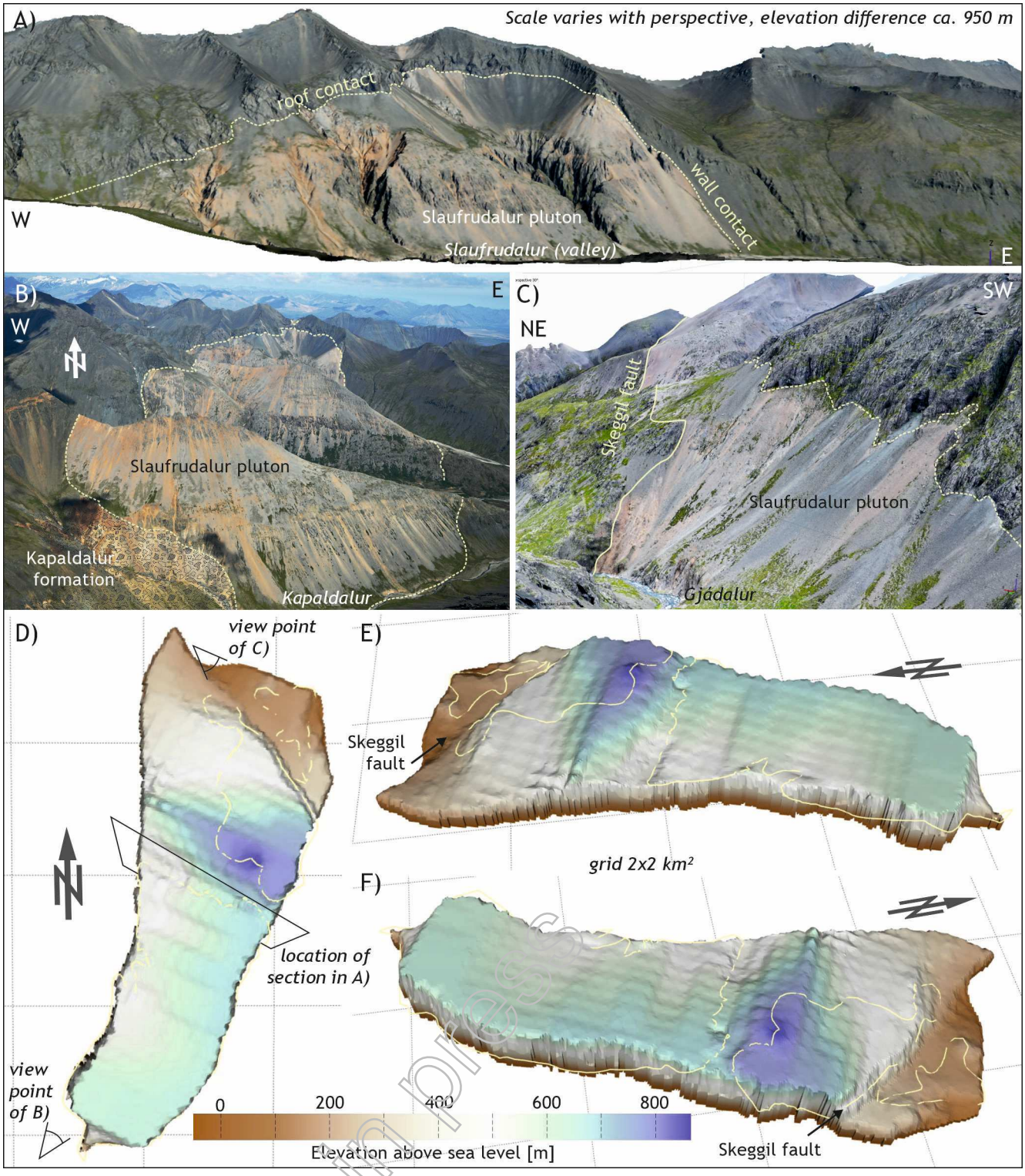


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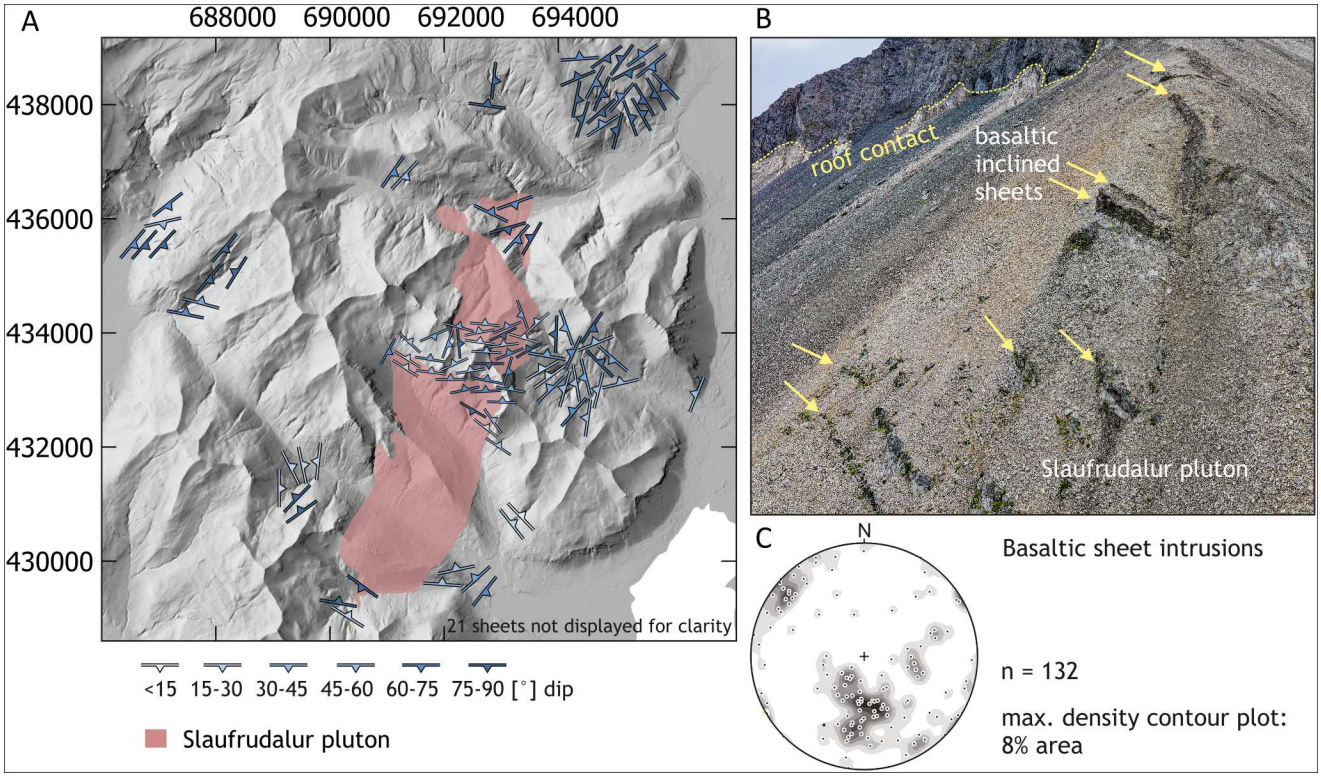


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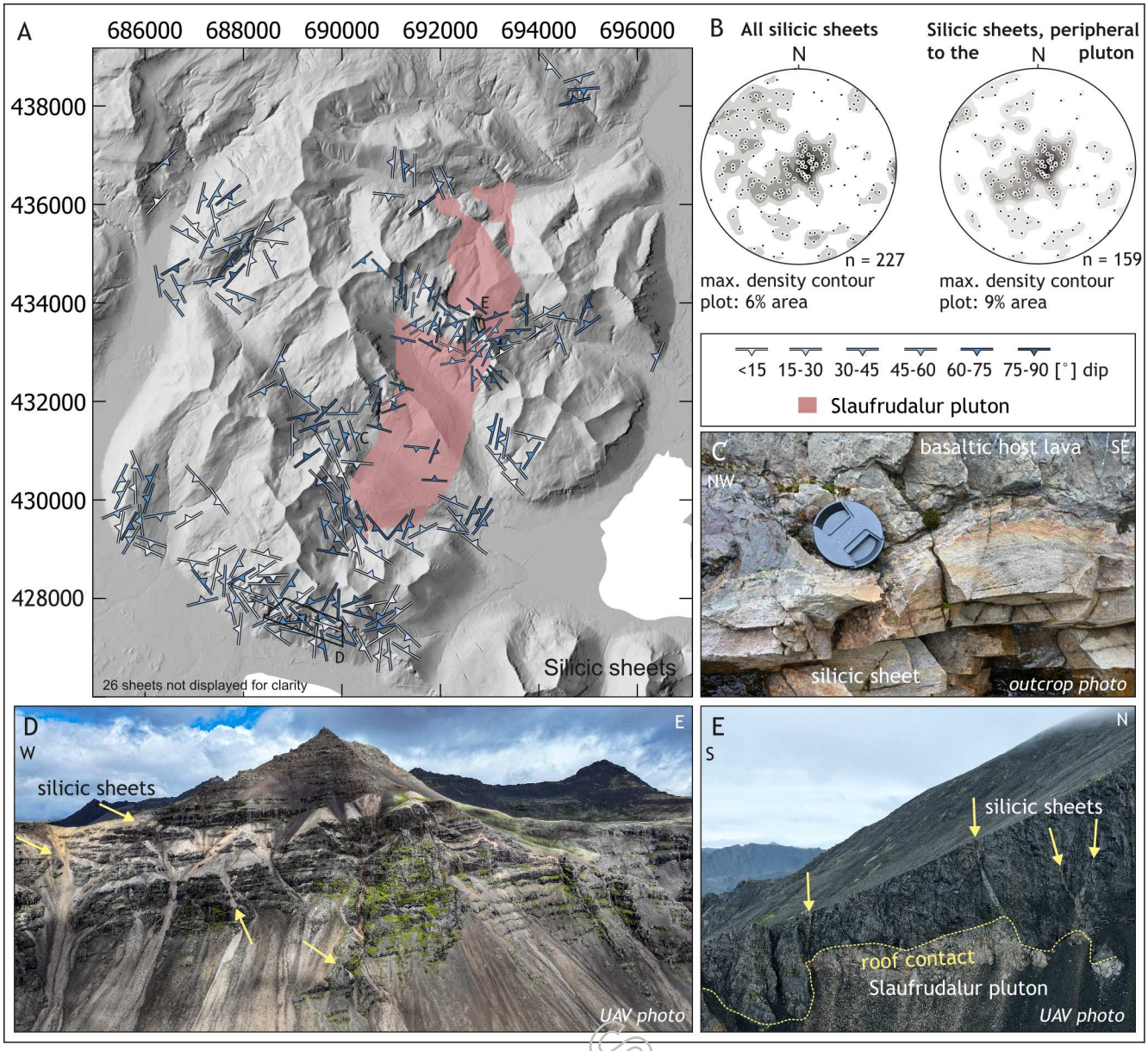
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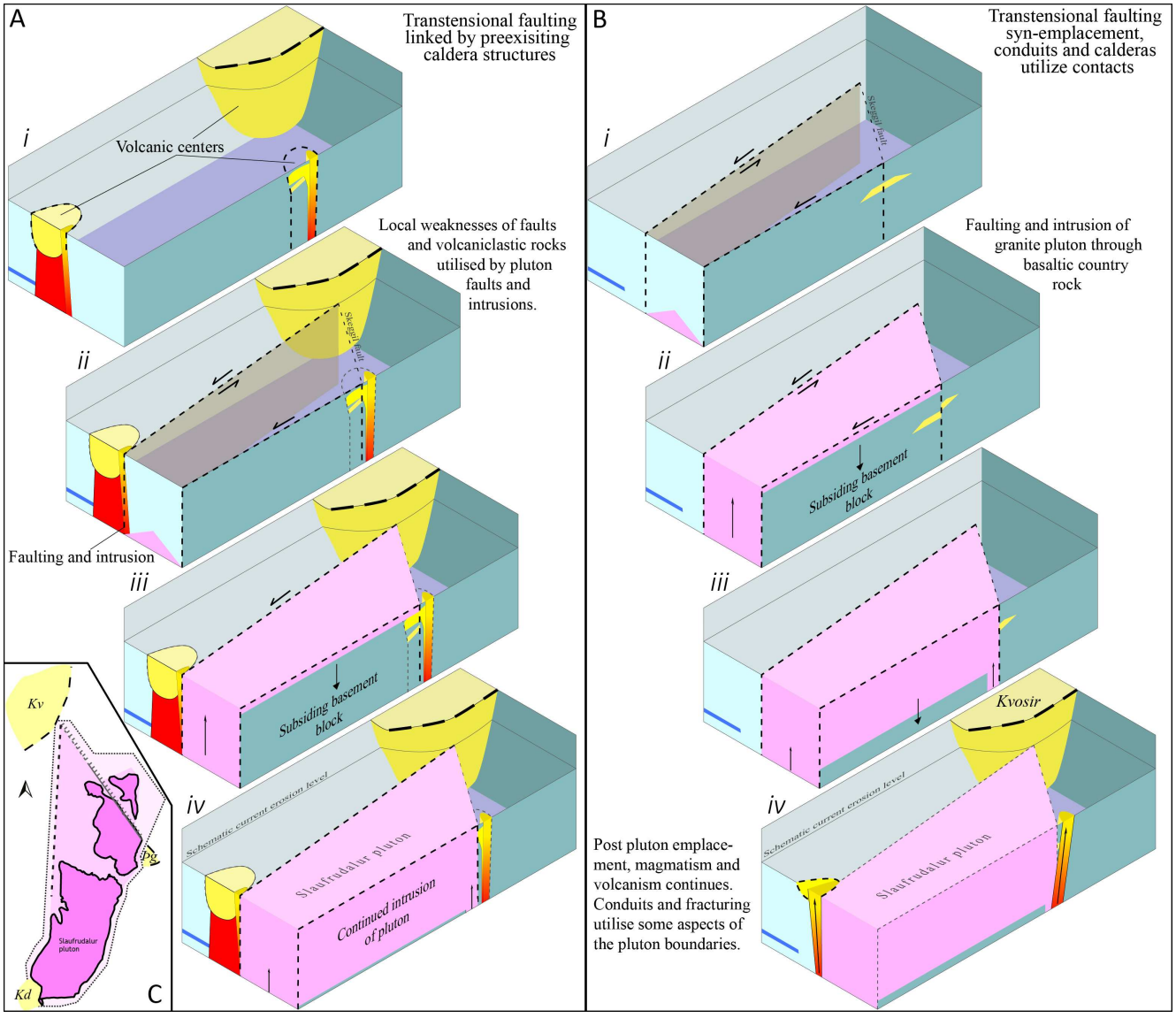
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