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The Fagradalsfjall and Sundhnúkur Fires of 2021–2024: A single magma reservoir under the Reykjanes Peninsula, Iceland?

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Abstract

The Reykjanes Peninsula (RP) hosts several volcanic lineaments that have been periodically active over the last 4000 years. Since 2021, following a ca. 800-year quiescence, eight eruptions have occurred on the RP, with more expected in the future. To better understand the origins of this renewed volcanism and help forecast future eruptions, we examine (i) if the ongoing volcanism is fed from a single or multiple magma storage zone(s) or from several smaller reservoirs and; (ii) where the zone(s) are located (i.e. mantle or lower or upper crustal depths). Using major and trace element geochemistry, oxygen isotopes, and seismic tomography we rule out a single, RP-scale, deep-seated magma storage zone. Instead we propose the presence of a ca. 10-km-wide region of crustal-level (9–12 km) magma accumulation beneath the Fagradalsfjall volcanic lineament that fed both the 2021–23 eruptions of the Fagradalsfjall Fires and the 2023–24 eruptions of the Sundhnúkur Fires.

KEYWORDS

Iceland, magma storage and ascent, recent volcanism, Reykjanes peninsula

1 | VOLCANISM ALONG THE REYKJANES PENINSULA (RP)

Basaltic eruptions are common in Iceland. On average, an eruption takes place every 3 to 5 years, varying considerably in terms of eruption types, styles, magnitude, and duration (e.g. Thordarson & Höskuldsson, 2008). At central volcanoes, basaltic eruptions are typically short-lived (days to weeks) and relatively small with a dense rock equivalent (DRE) volume < 0.3 km^3, while basaltic fissure eruptions can last for years (Thordarson et al., 2001; Thordarson & Self, 1996, 2003). The Reykjanes Peninsula (RP) hosts the Reykjanes Volcanic Belt (RVB), which features eight major volcanic lineaments that have been periodically active over the last 4000 years. They are, from east to west, (i) Bláfjöll, (ii) Brennisteinsfjöll, (iii) Krýsuvík, (iv) Trölladyngja, (v) Fagradalsfjall, (vi) Svartsengi, (vii) Eldvörp and (viii) Reykjanes (Figure 1a). Notably, volcanism along the RP is characterised by long repose intervals of some 800 years between major eruption periods (e.g. Sæmundsson et al., 2020; Figure 2). The 2021 eruption on the Fagradalsfjall Volcanic Lineament (FVL) marked renewed eruptive activity on the RVB after 781 years of dormancy (Bindeman et al., 2022) and eight individual eruptions have taken place over the last 3 years. Based on prior eruptive behaviour, this pattern is likely to continue for the coming centuries, posing considerable risk to the local population and important infrastructure on and adjacent to the RP (e.g. Keflavík airport, several geothermal power plants, popular tourist destinations, and population centres like Keflavík, Hveragerði, Þorlákshöfn, Grindavík, Vogar, Reykjanesbær, Suðurnesjabær and Greater Reykjavík). Below we summarise the 2021–2024 eruptions on the RP. A description of the older eruptive episodes on the RP is provided in the Appendix S1.

Significance statement

Volcanic products from the 18 December 2023 Sundhnúkur eruption on the Reykjanes Peninsula are broadly petrologically and geochemically similar to those erupted during the 2021–23 Fagradalsfjall Fires. Recent eruptions on the Reykjanes Peninsula therefore involve similar magma source(s), implying a connected magma plumbing system. Using seismic tomography and earthquake location data, we show that the lavas erupted since 2021 were supplied from a crustal magma accumulation zone located at about 9–12 km depth under the Fagradalsfjall volcanic lineament, from where they migrated along inclined pathways to supply the current eruption sites at Sundhnúkur. Our findings are important in light of the threat to human settlements and vital infrastructure from volcanic activity as there is a need for an improved understanding of the magma supply system that feeds the ongoing eruptive events.

1.1 | The three eruptions of the Fagradalsfjall Fires (2021–2023)

Following 3 weeks of seismic unrest and ground deformation (e.g. Sigmundsson et al., 2022; Zali et al., 2024), a volcanic eruption commenced on a 180-m-long linear vent segment along the FVL at Geldingadalir on 19 March 2021 and lasted until 18 September (183 days; Figure 1b). This was the first eruption on the RP in 781 years and was characterised by a series of linear vent systems that ejected lava, tephra, and volcanic gases (mainly CO_2, CO, SO_2). Between 5–13 April, a total of five new vent systems formed, lengthening the vent system to ~800 m. Over the next 2 weeks, these vent systems ceased to be active one by one until only one remained (e.g. Eibl et al., 2023). From May onwards vent activity became distinctly episodic, whereby each episode started with rapidly escalating lava fountaining and surface lava effusion, which then gradually declined until coming to a halt. The eruption featured profound changes in magma composition, interpreted to reflect magma delivery from at least two different mantle sources, with a progressively more enriched source dominating the magma composition in the later stages (Bindeman et al., 2022; Halldórsson et al., 2022). The abrupt shift in magma composition during the early stages of the 2021 eruption at Geldingadalir is consistent with the interpretation that a fresh batch of enriched magma was injected into a lower crustal magma storage zone at 10–12 km depth in the months to years prior to the start of the eruption (e.g. Flóvenz et al., 2022; Kahl et al., 2023). The second eruption of the Fagradalsfjall Fires was the Meradalir eruption (3 to 21 August 2022; 18 days; Figure 1b), which began with lava fountaining of low to moderate intensity (<30 m high) from a 350-m-long NNE oriented fissure. In addition to tephra, a spectrum of pāhoehoe and ʻaʻā lava types were emitted and built up a lava flow field over portions of the 2021 lavas (e.g. Krmíček et al., 2022; Thordarson et al., 2023). The third eruption of the Fagradalsfjall Fires was the Litli-Hrútur eruption (10 July to 5 August 2023; 26 days; Figure 1b), which was preceded by earthquake swarms located just NE of the 2022 Meradalir vent system and began with moderately intense (up to 50 m high) lava fountaining along a 1-km-long NE–SW trending *en echelon* vent system (Krmíček et al., 2023; Thordarson et al., 2023). By August 2023 the lavas of the Litli-Hrútur eruption had reached the Meradalir lava field and started to overrun some of the previous lavas, creating a single but compound lava flow field.

1.2 | The eruptions of the Sundhnúkur Fires (2023–2024 and ongoing)

Recent unrest on the Svartsengi Volcanic Lineament (SVL) featured one major plate boundary tectonic event on 10 November 2023 (Sigmundsson et al., 2024), followed by several short (hours to weeks) eruptions in December 2023 and January and February 2024, a longer one in March to May 2024, plus another one that started in late May 2024 (IMO, 2024; Figure 1b). Seismic unrest started around 20 October 2023 and intensified significantly on 26 October, while surface inflation indicated magma accumulation at 4–5 km depth beneath Svartsengi. The unrest escalated steadily over the following 2 weeks and culminated in a major earthquake swarm on 10 November 2023, resulting in a major tectonic event in the town of Grindavík forming a set of grabens within a 5-km-wide zone, with lateral and vertical movements in excess of 1 m. At Svartsengi the pre-event surface inflation was ~10.5 cm and the subsequent subsidence associated with the 10 November tectonic event was 36.5 cm (Sigmundsson et al., 2024), implying movement associated with this event far exceeds the change that can be implemented by removal of magma accumulated in the shallow storage zone beneath Svartsengi. This tectonic event resulted in complete evacuation of

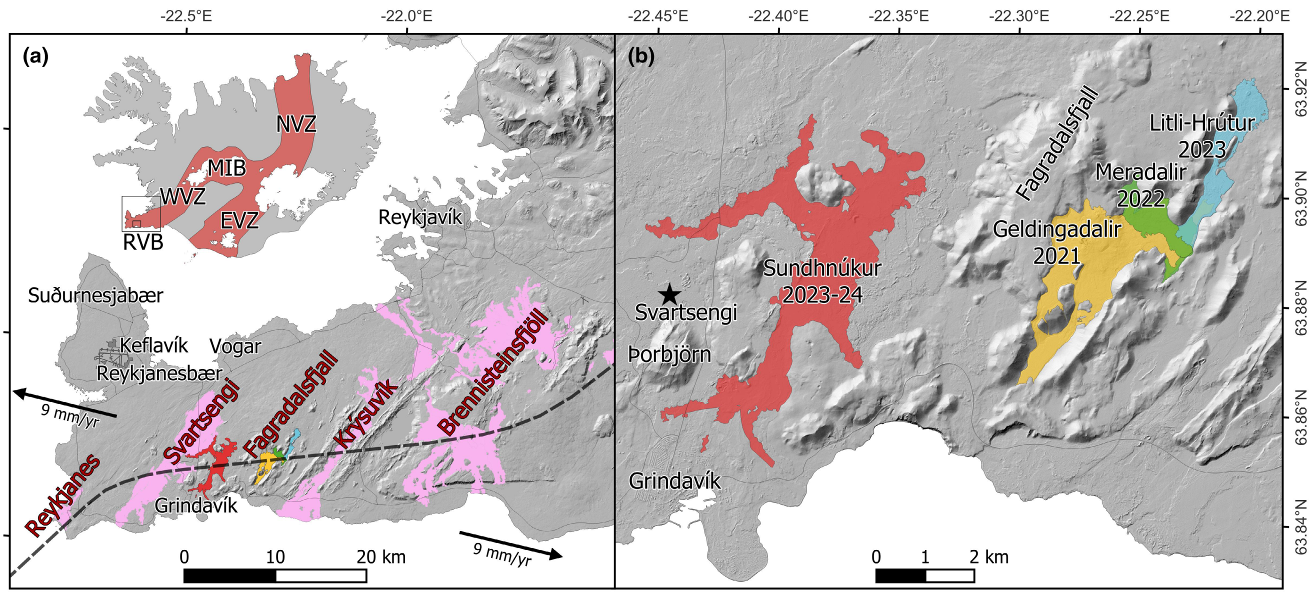

FIGURE 1 The Reykjanes Peninsula and recent eruption sites. (a) Map of Iceland showing the main rift zones (inset) and a close-up of the Reykjanes Peninsula (RP), with the major volcanic lineaments and recent lava fields highlighted. EVZ, Eastern Volcanic Zone; MIB, Mid-Iceland Belt; NVZ, Northern Volcanic Zone; RVB, Reykjanes Volcanic Belt; WVZ, Western Volcanic Zone. (b) Close-up of part of the RP showing the three successive lava flows of the Fagradalsfjall Fires that have now joined to create a single larger lava field (Geldingadalir, yellow; Meradalir, green; and Litli-Hrútur, blue) as well as the latest lava field at Sundhnúkur (red). Star shows the location of the Blue Lagoon.

the town. Surface inflation resumed at Svartsengi in the wake of the 10 November tectonic event and, when inflation was similar to pre-event levels (i.e., ~10–12 cm), rapid ~8 cm deflation of the area coupled with an intense earthquake swarm was followed by an eruption on 18 December 2023 (IMO, 2024). The eruption featured a 3.5 km-long vent system close to the ~2400-year BP Sundhnúkur vent system. It started with intense lava fountaining (300 m + high) and magma discharge of ~400 m^3/s. The intensity dropped off abruptly and within 6 h the magma discharge was <<50 m^3/s. The eruption ended on 21 December 2023 after having produced a lava field covering 3.4 km^2. After ~4 weeks of continued inflation (~13 cm at Svartsengi GPS station), a new eruption started on 14 January 2024, on a vent system on the southern segment of the SVL and ~ 1–2 km north of Grindavík. No deflation at Svartsengi followed this event. About 80% of the erupted lava was diverted away from the town by newly built protection barriers, although part of the erupting vent system cut through it, sending lava in the direction of Grindavík. Later that day a smaller fissure opened up ~100 metres north of Grindavík, inside of the lava barrier, sending lava into the outskirts of the town and destroying three homes. The eruption lasted until 16 January (~36 h) and the lava flow field covered 0.7 km^2. After 3.5 weeks of inflation (~13 cm), the third eruption occurred on 8 February, again along the SVL. The onset of the eruption was preceded by a seismic swarm on the SVL near Stóra-Skógsfell and was followed by ~9 cm deflation at Svartsengi. The new fissure rapidly reached a length of 3 km, extending north and south from the initial opening, producing lava that advanced both to the west and east of the vent system. The western branch crossed the Grindavík road and cut the hot waterline to Reykjanesbær, Suðurnesjabær and Vogar (Figure 1). However, the main lava streams remained outside of the barriers that safeguarded the Svartsengi power plant and the Blue Lagoon. The eruption lasted for <24 h and the flow field extended over ~4 km^2. After ~20 cm of inflation over 5 weeks, the fourth SVL eruption event began on 16 March. As before, it began with intense lava fountaining (200 m + high) and high magma discharge (~300 m^3/s) along with ~10 cm deflation at Svartsengi. The activity tapered off within a day with a drop in the magma discharge to <<50 m^3/s. The activity consolidated on the southern end of the initial vent system and ended in mid May. At the time of writing (May 2024), another eruption commenced in late May with a magma discharge of a few cubic metres per second and a lava flow field that now covers an area in excess of 6 km^3 (i.e., IMO, 2024).

2 | PURPOSE AND AIM OF STUDY

Ongoing eruptions allow for continuous monitoring of compositional variations and determination of changes in the magma storage and supply system(s) that feed an eruption. One of the crucial questions that has arisen since activity began on the SVL regards the subsurface connection beneath the FVL and SVL. It is important to determine if these eruptions are fed from one larger magma storage region in the crust or the mantle, or if they represent separate magma batches that ascended through independent conduit or plumbing systems. If the latter is the case, it implies individual volcanic activity at distinct centres along the peninsula in the coming months and years, whereas an extensive magmatic storage zone would allow for the

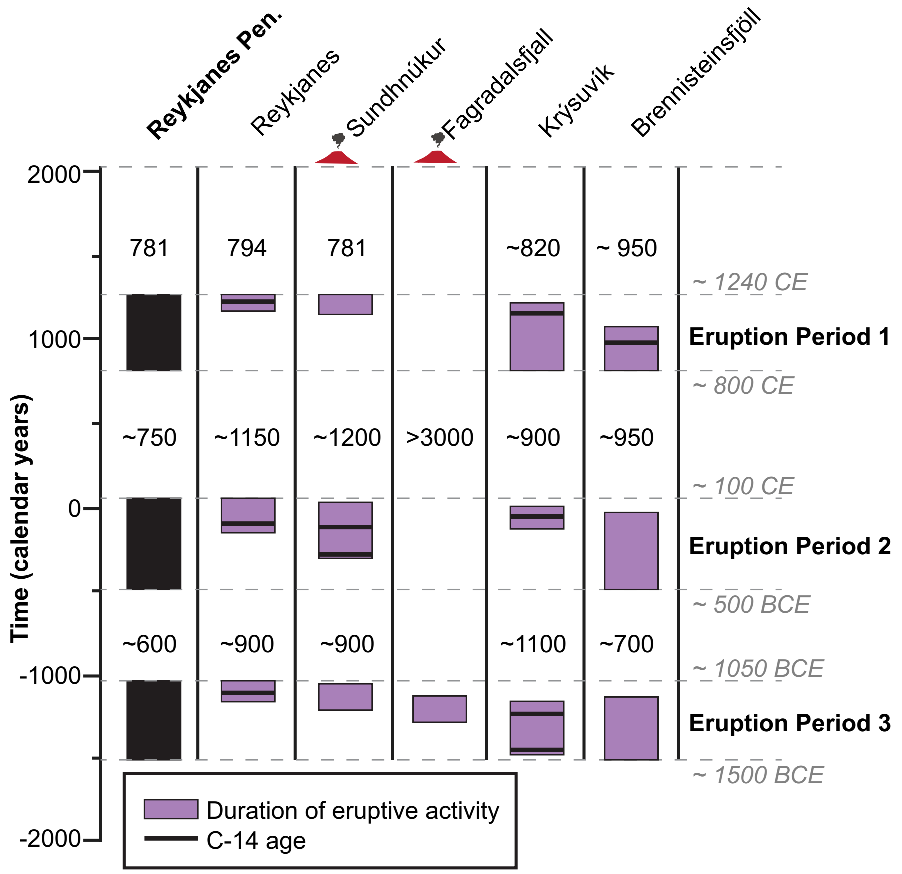

FIGURE 2 Eruption periods on the Reykjanes Peninsula (RP) over the last 4000 years. The time scale is in calendar years (CE, Common Era; BCE, Before Common Era). The purple bars indicate eruption activity within individual volcanic lineaments, while each eruption period on the RP as a whole is indicated by black bars. The length of each repose period is indicated by the figures between the bars. Carbon-14 age determinations are indicated by black horizontal lines inside the purple bars. Figure modified after the ISOR online geological map of Iceland (jardfraedikort.is) and Sæmundsson et al. (2020).

possibility of several eruptions occurring simultaneously along the peninsula (Figure 3). Here we compare new geochemical data from whole rocks and minerals from the 2022 Meradalir and 2023 Litli-Hrútur eruptions on the FVL and the December 2023 eruption on the SVL (see Appendix S1 for methods) with available data for the 2021 Geldingadalir eruption to establish if the two series of eruptions have similar or different compositions, which can help determine if they share a common evolutionary history. This comparison is complemented by seismic tomography derived from recent seismicity to identify the likely magma storage regions. These data are interpreted in conjunction to better understand how RVB eruptions may continue in the coming months to years.

Given the volcanic activity of the last 3 years, and the geological evidence for repeated and prolonged eruption periods on the RVB, increased eruption frequencies should be expected for the foreseeable future. Widespread volcanism on the RP could have considerable societal consequences, from repeated evacuation efforts (e.g. Grindavík, Blue Lagoon) to inundation and destruction of key infrastructure, such as roads, power plants, electrical, gas and sewage lines, water mains, and population centres. Since the RP hosts the majority of Iceland's population, a large number of people could be affected by the renewed volcanic activity. In addition, Grindavík harbour, a key port for the fishing grounds around the Reykjanes Ridge, could be closed or filled with lava, leading to severe economic losses. The geothermal power plants at Svartsengi, Reykjanes, Hellisheiði and Nesjavellir, important suppliers of hot water and electricity in Iceland, are at risk of being damaged or destroyed by RVB eruptions. This could lead to interruption of energy and heat supplies for communities across the RP and for the only international airport on the island, Keflavík. Moreover, several experimental installations, like the CARBFIX and SULFIX programs and connected laboratory installations that aim to study CO_2 and H_2S sequestration into porous basaltic rock substrate, could be damaged (Kristjánsdóttir & Kristjánsdóttir, 2021). Finally, the Blue Lagoon is one of Iceland's most important tourist attractions and, according to the Icelandic newspaper Morgunblaðið (Jan 2024), losses from closure have already amounted to over 4 billion Icelandic crowns (ISK).

3 | RESULTS

3.1 | Whole rock petrography and geochemical data

The December 2023 eruption products from Sundhnúkur show similar petrographic features to the lavas of the 2021–23 Fagradalsfjall Fires, displaying between 10 and 20 vol.% crystals of plagioclase > olivine > clinopyroxene > Fe-Ti oxides (cf. Krmíček et al., 2022, 2023). Notably, olivine occurs as both relatively large (~1 mm), rounded crystals and as microcrystals showing at times skeletal morphologies. With respect to variations in whole rock major element chemistry

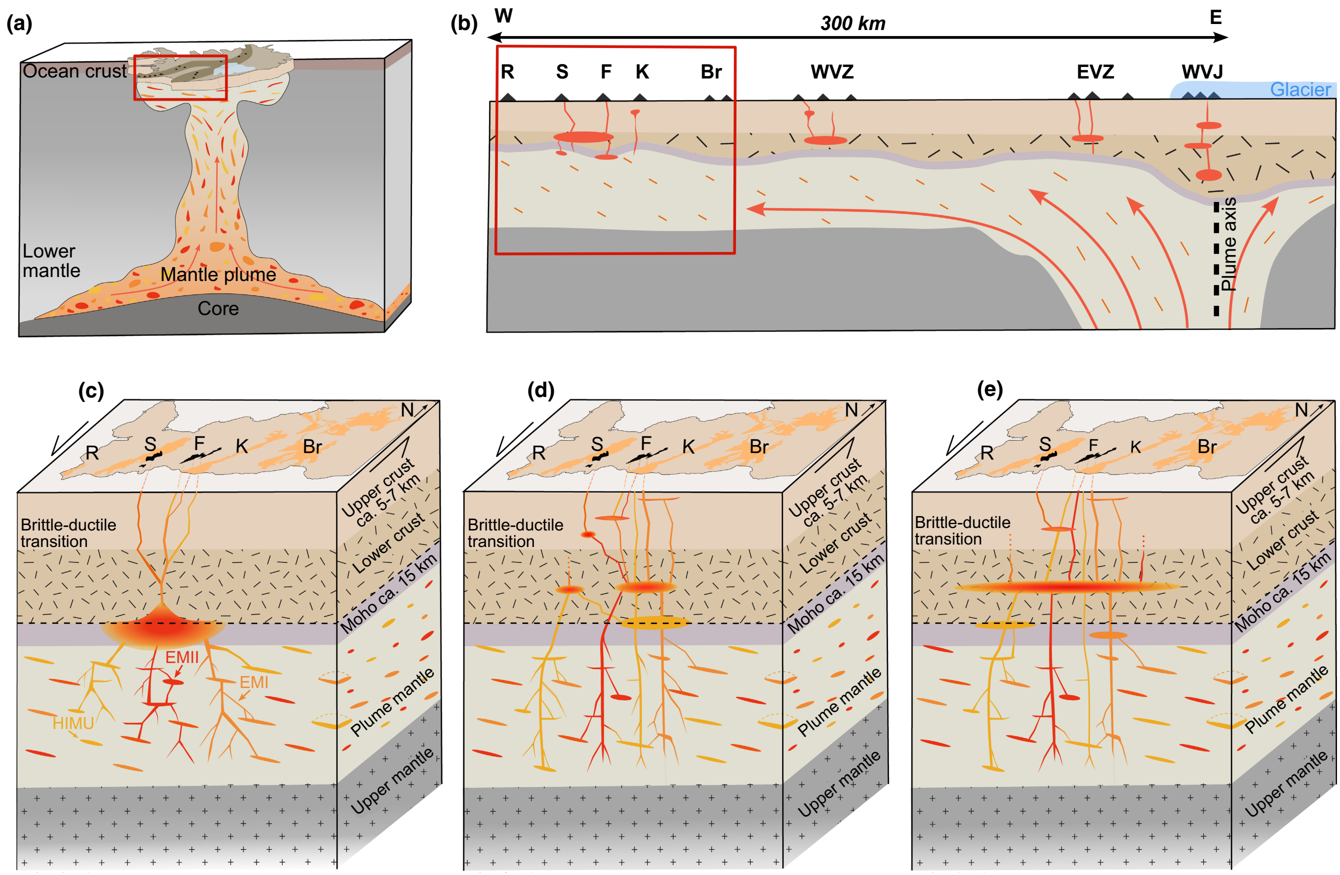

FIGURE 3 Concept sketch of Icelandic magmatism. (a) Iceland's volcanoes are fed by a deep-seated mantle plume that intersects the Mid Atlantic Ridge, leading to intensified volcanism along the main rift zones in central and SE Iceland. (b) The Reykjanes Peninsula is fed by the lateral extent of the upwelling Iceland plume and is undergoing intensified plate motion at present (Ducrocq et al., 2024). However, the detailed magma supply system and the exact origin of the erupting lavas is not yet understood. (c–e) Initial models considered the recent eruptions to be fed from a reservoir in the lowermost crust (e.g. c; Halldórsson et al., 2022), whereas subsequent work raises the possibility of crustal storage (e.g. d; Radu et al., 2023). A third possible scenario involves a relatively large crustal reservoir that could feed multiple systems at the surface simultaneously (e.g. e; Gee et al., 1998; Peate et al., 2009). Br, Brennisteinsfjöll; EVZ, Eastern Volcanic Zone; F, Fagradalsfjall; K, Krýsuvík; R, Reykjanes; S, Svartsengi; WVJ, West Vatnajökull; WVZ, Western Volcanic Zone.

over time (Figure 4; Figures S1 and S2), lavas erupted during the first 50 days of the 2021 Geldingadalir eruption differ from later lavas with respect to numerous geochemical parameters such as MgO wt.%, Cr ppm, K_2O/TiO_2, Nb/Zr, and La/Yb (Figure 4), which show an overall rapid increase during this initial eruption period. However, incompatible element ratios such as K_2O/TiO_2 and La/Yb display relatively flat trends for the first ca. 12 days of the 2021 eruption, before steeply rising until ca. day 50 (Figure 4c,e). The pattern(s) observed for the first 50 days of the Geldingadalir eruption stand in contrast to lavas from the latter parts of the 2021 Geldingadalir event through the 2022 Meradalir, 2023 Litli-Hrútur, and 2023 Sundhnúkur eruptions, which show a progressive decrease in e.g. MgO wt.% and Cr ppm (Figure 4a,b) and a tendency for ratios such as K_2O/TiO_2, Nb/Zr, and La/Yb to plateau over time (Figure 4c–e). Notably, the 2023 Sundhnúkur lavas have relatively low MgO contents and show a sharp increase with respect to some element oxides and trace element concentrations (e.g. Fe_2O_3, TiO_2, Na_2O, Ni; Figure S1). Despite these differences, the FVL and SVL lavas are broadly similar (Figure 4), implying a common ancestral derivation, as discussed below.

3.2 | Trace elements in olivine

Trace elements in Sundhnúkur olivine (Figure 5) form a continuation of the trends previously established for Fagradalsfjall Fires olivine by Krmíček et al. (2022, 2023) on plots of Ni versus Sc (Figure 5c) and Mn versus Zn (Figure 5d). The 2023 SVL olivine microphenocrysts possess the lowest Ni contents of all the 2021 to 2023 eruptions. Data for olivine phenocrysts and microphenocrysts overlap on a Ni versus Sc plot, but these groups are significantly different on a Mn versus Zn plot (Figure 5c,d). Although 2023 SVL olivine data overlap with olivine data from the FVL eruptions, the microphenocrysts are the most evolved of all groups, showing the highest Mn and Zn contents.

3.3 | Oxygen isotopes values of the Sundhnúkur lavas

Two glassy lava samples from the Sundhnúkur lavas of December 2023 yielded $\delta^{18}O$ values of 5.2‰ (repeat = 5.3‰; ±0.2 2σ) for

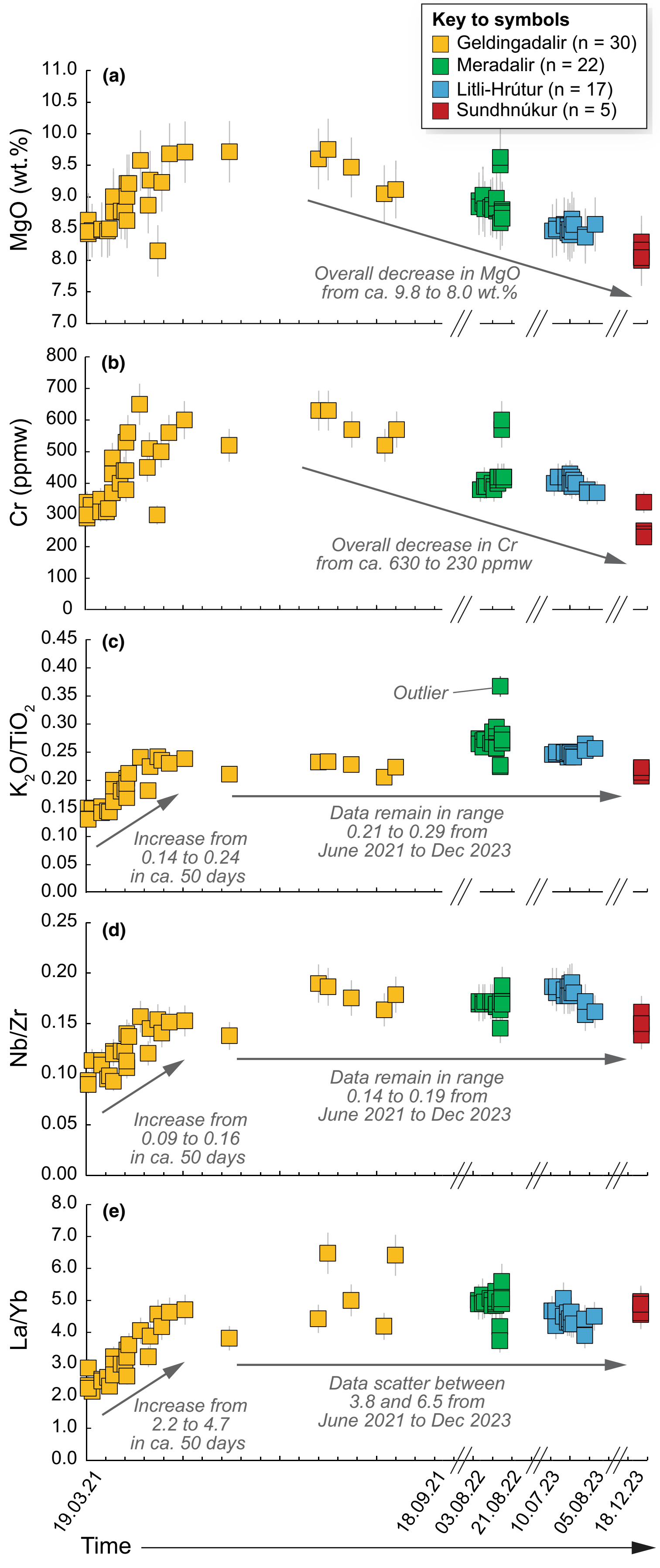

FIGURE 4 Geochemical time-series plots of Fagradalsfjall and Sundhnúkur lavas. (a) MgO wt.%, (b) Cr ppm, (c) K_2O/TiO_2, (d) Nb/Zr, and (e) La/Yb versus time for the main eruption pulses on the FVL and SVL from 2021 to 2023. Note that following an initial increase during the first 50 days of the Geldingadalir eruption, MgO and Cr show an overall decrease with time between June 2021 and December 2023. Ratios of K_2O/TiO_2, Nb/Zr, and La/Yb also increase during the first 50 days of the Geldingadalir eruption, but then tend to plateau until December 2023. The Sundhnúkur lavas appear to form a continuation of the Fagradalsfjall trends for these parameters (see text for details). All oxide data were normalised to 100% before plotting. Uncertainty on major and trace element data is estimated at better than 5% and 10%, respectively (shown as error bars). Where no error bars are visible, uncertainty is smaller than symbol size. Geldingadalir data are from Bindeman et al. (2022).

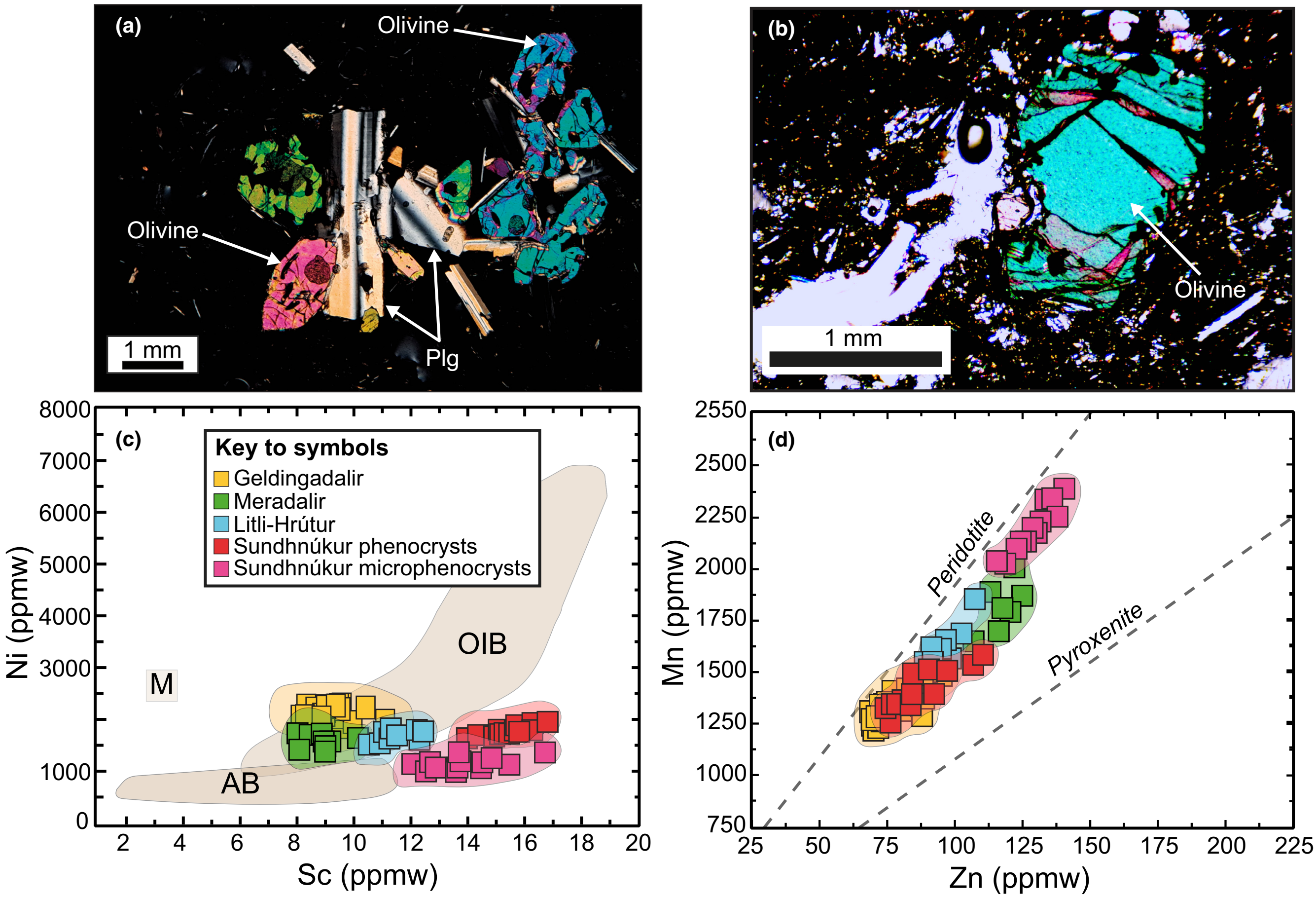

FIGURE 5 Trace elements in olivine. (a, b) Olivine textures in 2023 Sundhnúkur lavas. (c, d) Trace element plots of Ni versus Sc and Mn versus Zn for FVL and SVL olivine. Fields for olivine from oceanic island basalts (OIB), arc basalts (AB) and mantle (M) are plotted after Foley et al. (2013). Sundhnúkur samples fit into a trend of progressively changing data groups of the 2021 to 2023 Fagradalsfjall eruptions, implying a common evolutionary history. The data also imply that the dominant mantle source that gave rise to the parental magmas for these eruptions is peridotite. Data for Meradalir and Litli-Hrútur olivine are from Krmíček et al. (2022, 2023), respectively.

sample 301223-01 and 5.2‰ (repeat = 5.0‰; ±0.2 2σ) for sample 301223-05. The $\delta^{18}O$ values of the Sundhnúkur samples therefore fall within the range of previously published values for the 2021 Geldingadalir eruption, as reported by Bindeman et al. (2022), and plot mildly lower than Atlantic Mid Ocean Ridge Basalt (MORB).

3.4 | Seismic tomography and event relocations

Seismic events from August 2023 until the end of January 2024 were relocated using the tomographic model in Hobé (2022) derived with pre-eruption seismic data. The P- and S-wave velocity models were then updated in a joint inversion for velocities and hypocentral parameters with new data (see Appendix S1 for methods). Depth sections through the Vp/Vs ratio model and a cross section are shown in Figure 6. We note a high Vp/Vs ratio anomaly below ca. 9 km depth under the FVL that we interpret as an accumulation of melt in the lower crust, as discussed below. This anomaly is illuminated by seismicity down to 12 km depth and is the only magma reservoir in the analysed section. Moreover, there are no clusters of deep seismicity in any other part of the RP, although there are single deep events elsewhere.

In Figure 6, seismicity is colour coded for each month, where the white dots mark the seismicity from August and September 2023. These earthquakes occur primarily in the north-eastern end of the FVL (Figure 6a,c), signalling that magma likely entered this plumbing system after the July 2023 Litli-Hrútur eruption. In late October, the seismicity started shifting to the SVL. Seismicity between the two lineaments at about the 15 km mark on the cross section (Figure 6f) and at 4–6 km depth may be indicative of a magma pathway. Seismicity also occurred along a subparallel lineament further west (i.e., the Eldvörp volcanic lineament), best seen in Figure 6a,b. In the following months, there was relatively little seismicity in the FVL.

4 | DISCUSSION AND CONCLUSIONS

To address the question of whether the RP is underlain by (i) a purely mantle-fed magmatic system, (ii) a magma storage zone within the crust, or (iii) a deep-crustal magma storage zone that extends under

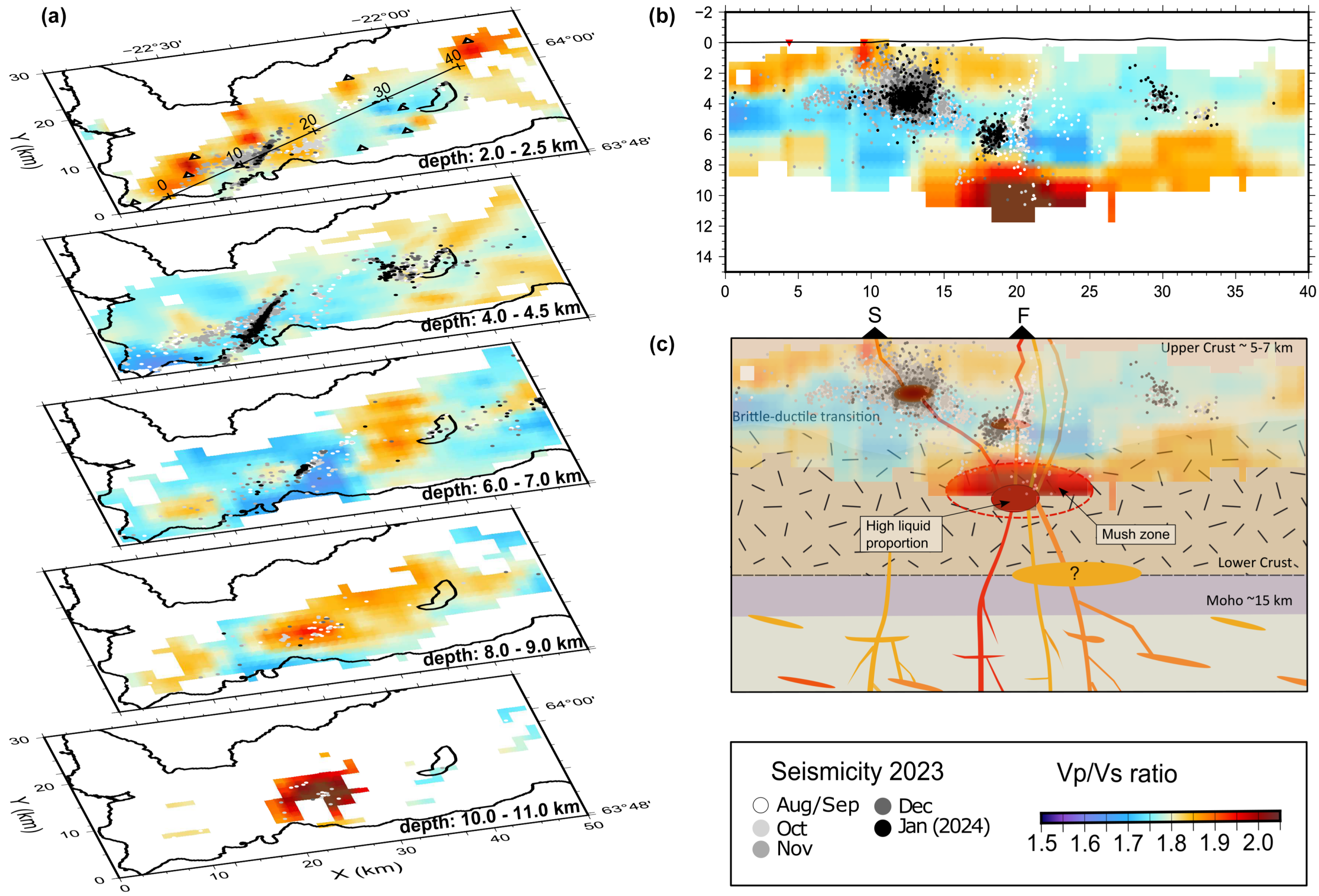

FIGURE 6 Seismic tomographic model and earthquake distribution. (a) Depth slices showing Vp/Vs ratio variations, indicating a higher liquid proportion beneath Fagradalsfjall at ≥9 km. (b) Cross section through the model (depth in km on the *x*-axis and distance in km on the *y*-axis) showing earthquakes from August 2023 to January 2024 emanating from this high liquid body. (c) Interpretation of seismicity showing two essential magma supply routes. One is along a vertical direction towards the Fagradalsfjall eruption site (F) and the other towards the Svartsengi Volcanic Lineament (S) further west showing a vertical and lateral transport component. We suggest that the main magma reservoir supplying the recent Fagradalsfjall and Svartsengi/Sundhnúkur eruptions resides in the lower crust under Fagradalsfjall, instead of in the mantle or under the entire peninsula.

the peninsula (Figure 3), we combine geochemical and seismic tomography data. Whole rock and mineral geochemical data show that the 2023 SVL eruption produced lava compositions that, for the most part, continue the trends established by the lavas of the late 2021 to 2023 Fagradalsfjall Fires (Figures 4 and 5). A first-order observation is therefore that all of the recent FVL and SVL magmas are derived from a similar magma source (excluding perhaps the early parts of the 2021 Geldingadalir eruption), or a similar combination of sources, which are different to the source(s) of previous magmas erupted on the RP (e.g. Bindeman et al., 2022; Halldórsson et al., 2022; Krmíček et al., 2022, 2023; Thordarson et al., 2023). Given the abundance of plagioclase in the recent eruption products and the frequent occurrence of crystal clots and aggregates (Figure 5a), crustal storage and fractionation are highly likely, as plagioclase is mainly stable at crustal depths and in the uppermost mantle under Iceland and the occurrence of hopper-shaped quench olivine is generally a sign for rapid ascent and shallow-level crystallisation (Donaldson, 1976). However, fractionation alone cannot explain all of the geochemical variations observed here, which suggests that additional processes contributed to the genesis and evolution of the recent FVL and SVL magmas, such as magma mixing and replenishment(s) by melts of variable degrees of evolution. Indeed, the decrease in MgO and Cr and relatively stable K_2O/TiO_2 and La/Yb ratios from the latter portion of the 2021 eruption to the 2022 and 2023 eruptions may be a signal for mixing via replenishment with more evolved and enriched melts formed by lower degrees of mantle melting. Some samples show evidence for incorporation of recycled components (i.e. crystal mush), creating outliers in the dataset, such as high Fe and Ti in the December 2023 Sundhnúkur samples, possibly due to accumulation of Fe-Ti oxides. Importantly, many geochemical ratios are similar for lavas from the FVL and SVL (Figure S2), implying a shared parental lineage for all seven of the recent eruptions on the Reykjanes peninsula. We also note that the $\delta^{18}O$ values of the latest eruption are similar to those of the 2021 Geldingadalir eruption, which is consistent with similar magma source(s) and insignificant assimilation of low-$\delta^{18}O$ crust (e.g. Condomines et al., 1983). The geochemical data presented here therefore support a common origin for the Fagradalsfjall and the Sundhnúkur magmas and suggest that the degree of mantle melting, magma mixing, fractionation, and cumulate recycling all play a role in the genesis of the recently erupted RP lava suites. With continued eruptions on the RP, we anticipate that future investigations will provide further insights into the roles of the various processes that control magma genesis along the RP.

Seismic tomography reveals a high-Vp/Vs anomaly at 9–12 km depth that may extend deeper, but its width is restricted in lateral dimension to ~10 km centred on the FVL. This was previously observed in data from May 2020 (Hobé, 2022) and the seismic data presented here confirm its presence and size. Notably, there is no indication of magma accumulation in the lower crust elsewhere in the RP. Reliably estimating the melt fraction based on the anomaly reported here is challenging, but a Hashin-Shtrikman-Walpole model according to Lyakhovsky et al. (2021) requires a melt fraction of up to 26% to raise the Vp/Vs ratio from the normal 1.8 to the observed 2.0. From the tomographic image in Figure 6, the dimension of the reservoir is approximately $10 \times 5 \times 4\,km^3$, implying a magma volume in the imaged part of the reservoir on the order of $50\,km^3$. The build-up of this reservoir was first noted with data from May 2020 (Hobé, 2022) but was not observed in the study by Tryggvason et al. (2002), which implies that the reservoir formed after 2002 but prior to 2020, probably via an initial intrusion, followed by a recharge in 2021 and possibly again in 2023. Crucially, the seismicity data provide information on when the magma transferred from the FVL to the SVL. In late October 2023, there was ample seismicity at about 2 km depth at the southern end of the FVL. This was followed by deep seismicity (9–11 km depth) in the southwestern end of the FVL and within the 9–12 km magma storage zone. The seismic swarm continued into November, culminating with several magnitude 5.0 events on the SVL on November 10. This increase in seismicity coincided with the onset of surface inflation centred on Svartsengi, signalling the onset of magma inflow into a storage reservoir at 4–5 km depth beneath Svartsengi (Sigmundsson et al., 2024). After this, there is a lack of seismicity connecting the SVL with the deeper magma storage, likely due to uninterrupted flow into this shallow magma storage region.

The combined geochemical and seismic evidence therefore suggest that the FVL and SVL magmas were derived from a common magma storage zone of modest size at ca. 9–12 km depth in the lower crust under Fagradalsfjall. This zone continues to deliver magma to both the FVL and SVL via inclined pathways in the crust (Figure 3d). A purely mantle-fed magmatic system or a peninsula-wide deep-seated magma storage zone is not indicated at present nor is the presence of two isolated plumbing systems feeding the FVL and SVL independently.

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CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interests.

DATA AVAILABILITY STATEMENT

The data underlying this study are available in the Tables S1 and S2 and as a Zenodo dataset at https://doi.org/10.5281/zenodo.10959981.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix S1

Tables S1 and S2

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