Holocene eruptions within the Katla volcanic system, south Iceland: Characteristics and environmental impact

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Abstract – *Holocene volcanism within the Katla volcanic system is characterized by: 1) explosive (hydromagmatic) basaltic eruptions along volcanic fissures within the Mýrdalsjökull caldera; 2) explosive silicic eruptions from vents associated with the caldera and 3) predominantly effusive basaltic eruptions involving both the central volcano and the fissure swarm. Typical Katla eruptions are accompanied by basaltic tephra fall, lightning and glacial floods (jökulhlaups) of meltwater, ice and volcanic debris. Twenty eruptions have occurred in the last 11 centuries. The volume of airborne tephra varies by three orders of magnitude, with an estimated volume of 1.5 km^3 of freshly fallen tephra from the largest historical Katla eruption. The length of documented eruptions varies from 2 weeks to over 5 months. The average repose period since 1500 AD is 47 years with maximum deviations of 33 and 34 years. All Katla eruptions during the last 400 years have begun in the spring-fall season. At least 12 silicic Katla eruptions are known from the period ca. 1700 BP and 6600 BP. The silicic magma was most likely erupted by hydromagmatic explosive eruptions. The tephra dispersal axes indicate vent locations within the caldera or along the caldera rim. The volume of airborne silicic tephra varies by orders of magnitude, the largest and most widespread is tephra layer UN with uncompacted tephra volume of 0.3 km^3. Intervals between the silicic eruptions have varied from ca. 100 to ca. 1000 14C yrs. Two major "fires" and 5-10 relatively minor, partly effusive eruptions have occurred during the Holocene. The 10th century Eldgjá and the 6800 BP Hólmsá fires are the largest known Holocene eruptions within the Katla system. A $\geq$75 km long, discontinuous and partly subglacial eruptive fissure was active during the Eldgjá eruption. The opening phase on most fissure segments was explosive, followed by an effusive phase on the subaerial segments. The eruption produced a voluminous basaltic tephra layer with a minute silicic component, two major lava fields and possibly a hyaloclastic flow deposit. Large jökulhlaups accompanied the eruption. The combined volume of erupted material may exceed 19 km^3 DRE. Eruptions on the Katla system have caused extensive environmental changes during the past 1100 years. The Eldgjá fires radically changed the landscape, hydrology and utilization potential of large areas in South Iceland. Since then, jökulhlaups accompanying eruptions within the caldera have escaped eastwards, raising the Mýrdalssandur plain and extending its coastline southwards.*

INTRODUCTION

The Katla volcanic system, South Iceland, as defined by Jakobsson (1979), is a Holocene feature superimposed on upper Pleistocene hyaloclastites and lava flows (Jóhannesson *et al.*, 1990). A central volcano partly covered by the ice cap of Mýrdalsjökull and an associated fissure swarm form the SW-NE trending 80 km long system (Figure 1). The hyaloclastite massif reaches an altitude of 1380 m a.s.l. under the ice cover. The massif encompasses an ice-filled caldera with an area of 110 km^2 and a depth of 700 m (Björnsson *et al.*, 1993; this volume). Three glaciers descend to the south, east and northwest from the ice cap onto the lowlands through deep gaps that they eroded in the caldera walls. Seismic activity has been mostly confined to two areas within and immediately to the west of the caldera (Einarsson, 1991).

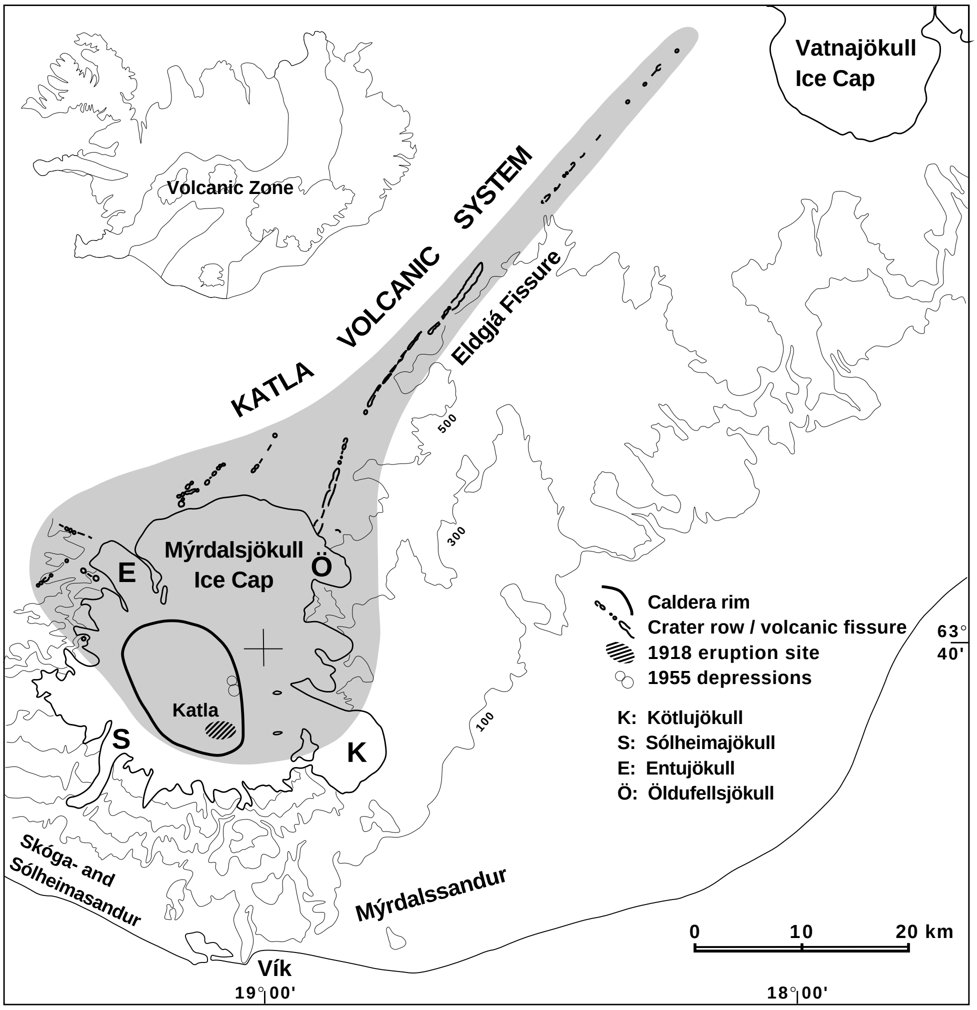


Figure 1. The Katla volcanic system in S-Iceland (shaded) as defined by Jakobsson (1979). Subglacial caldera below Mýrdalsjökull ice cap as defined by Björnsson *et al.* (1993 and this volume). Inset: Location map of Iceland and volcanic zone. – *Kötlueldstöðvakerfið (skyggður flötur) samkvæmt Sveini Jakobssyni (1979). Útlínur öskjunnar eru dregnar samkvæmt Helga Björnssyni o.fl. (1993 og grein í þessu hefti). Gígar og gígaraðir eru dregnar eftir loftmyndum frá Landmælingum Íslands.*

Transitional alkali basalts with a narrow compositional range dominate both the Holocene and Pleistocene volcanics (Jakobsson, 1979; Meyer *et al.*, 1985). A shallow, infrequently replenished magma chamber was postulated by the latter to explain the petrology of the products. The existence of a low velocity anomaly, interpreted as a shallow subcaldera magma chamber, has recently been demonstrated (Guðmundsson *et al.*, 1994). Two eruptions have occurred within the Katla system every century on average during the last 1100 years (Thorarinsson, 1975; Larsen 1993). Only the Grímsvötn and Veiðivötn volcanic systems have higher eruption frequency (Thorarinsson, 1974; Björnsson and Einarsson, 1990; Larsen *et al.*, 1998).

Holocene volcanism within the Katla volcanic system seems to fall into three categories (Larsen, 1994): 1) Explosive hydromagmatic basaltic eruptions on short volcanic fissures below the Mýrdalsjökull ice cap are the most common events of the Katla system. These usually occur within the caldera and during recent centuries have concentrated close to its eastern boundary. These eruptions are accompanied by tephra fall and jökulhlaups (glacial floods), that since the 12th century have apparently followed the path of Kötlujökull onto Mýrdalssandur. They appear to be the typical Katla eruptions as far back as the record from soil-sections goes. The number of Holocene basaltic eruptions is unknown but may exceed 170.
2) Explosive silicic eruptions from vents below the ice cap, apparently within the caldera. They are accompanied by tephra fall and probably by jökulhlaups as well. At least 12 eruptions are known from soil-sections in the surrounding area and several others are anticipated. These are the second most common eruptions in the Katla system.
3) Predominantly effusive basaltic eruptions within the fissure swarm and along the margin of the central volcano. Most of these eruptions probably had an explosive component as well in cases where the fissures reached below the ice cap. The longest fissures are up to 75 km long. Huge lava flows have accompanied some of these eruptions, which are the least common type of activity in the Katla system.

In some eruptions of the first and third category a very minor component of silicic glass has been detected in the basaltic tephra, and fragments of light coloured rock are among the scant lithics in some tephra layers. Comprising much less than 1% of the erupted material in all known cases, these occurrences are considered too small to justify an additional category of "mixed" silicic and basaltic eruptions.

Katla eruptions and/or jökulhlaups have been mentioned in documents since the 12th century and have been described in contemporary writings since the 16th century (Biskupa Sögur, 1858; Storm, 1888; Annálar 1400-1800, 1922-87; S.t.s. Ísl. IV, 1907-15; P. Sveinsson, 1919; G. Sveinsson, 1919; Jóhannsson, 1919). Several authors have described various aspects of the Holocene explosive and effusive basaltic eruptions and their products (Thoroddsen, 1894; Robson, 1957; Thorarinsson, 1955, 1959, 1975, 1980; Jónsson, 1978; Jakobsson, 1979; Larsen, 1979, 1993, 1996; Einarsson *et al.*, 1980; Miller, 1989; Zielinski *et al.*, 1995; Guðmundsdóttir, 1998; Thordarson, *et al.*, in press). The jökulhlaups have been described in contemporary writings and treated by more recent authors (Thorarinsson, 1957; Rist, 1967; Haraldsson, 1981; Jónsson, 1982; Sigurðsson, 1988; Maizels, 1993; Björnsson, 1993; Larsen, 1993; Karlsson, 1994; Larsen and Ásbjörnsson, 1995; Tómasson, 1996). The Holocene silicic eruptions have only recently been studied (Ólafsson *et al.*, 1984; Larsen, 1994; Larsen *et al.*, in press; Newton, 1999). Rhyolites exposed as nunataks around the caldera rim and as pyroclastic flows outside the ice cap are thought to be of Late-glacial age (Jóhannesson *et al.*, 1990; Lacasse *et al.*, 1995). Pre-Holocene eruptions have been treated by several authors (e.g. Lacasse *et al.*, 1995) but are beyond the scope of this paper.

In this paper, the characteristics of the three types of eruption will be summarized and their environmental impact briefly evaluated. The main emphasis will be on the historical period (i.e. the last 1100 years).

CHARACTERISTICS OF THE HOLOCENE VOLCANISM

Explosive basaltic Katla (K) eruptions

Typical Katla eruptions are explosive, hydromagmatic eruptions accompanied by often widespread tephra fall, lightning in the eruption cloud and enormous jökulhlaups consisting of meltwater, ice and volcanic debris. The only historically recorded volcanic products consist of airfall tephra and water-transported debris. During the opening stages the Katla eruptions are subglacial, but apparently melt their way through the overlying $\geq$400 m thick ice cover in a matter of hours, if precursory earthquakes felt in nearby areas can be taken as a mark of the beginning of the eruptions. The last Katla eruption to break through the ice and become subaerial occurred in 1918. It began on October 12 and lasted for about 3 weeks.

A sustained eruption column of vapour, gases and tephra usually develops during the first hours of subaerial activity at Katla. On the first day of the 1918 event the eruption cloud reached an elevation of 14 km above sea level as measured from Reykjavík, about 160 km west of the volcano (Eggertsson, 1919). At closer range it was seen as a fast rising cloud with a convoluted upwind margin, and the basal part was described as black, becoming whitish in the upper reaches (Sveinsson, 1919; Jóhannsson, 1919). Lightning flashed in and above the cloud at intervals of a few seconds and tephra fall commenced to the east of the volcano within an hour of the first cloud sighting. On the second day of eruption, tephra fall was reported from Reykjavík and from Höfn 200 km to the east of the volcano.

Tephra fall can occur at any time during Katla eruptions but the explosive activity is usually most intense, and tephra production greatest, during the first days (S.t.s. Ísl. IV, 1907-15; G. Sveinsson, 1919). The tephra is deposited both as lobate fans and as thin veils around the volcano, manifesting a distribution pattern which is significantly different from that of short-lived plinian eruptions of similar magnitude (Figure 2). The reported tephra fall area in the 1918 eruption exceeded 50.000 km^2 on land. Occasionally, tephra from the first days of Katla eruptions has reached the Faroe and Shetland Islands and during the 1625 eruption tephra fall reached the European mainland (Thorarinsson, 1981). The direction of the main tephra fall has been to the east, northeast or southeast in eight out of 17 eruptions for which the tephra distribution is known (Figure 3). The maximum thickness of airborne Katla tephra is not known as the thickest part is not preserved due to deposition on the glacier, but thicknesses in excess of 0.5 m have been reported (G. Sveinsson, 1919). The maximum measured thickness of compacted tephra at distances of 25 km from the source is $\geq$30 cm.

The volume of airborne Katla tephra varies between eruptions by at least three orders of magnitude. The most voluminous tephra layer is thought to be the K-1755 layer with an estimated volume of 1.5 km^3 of freshly fallen tephra (Thorarinsson, 1975). The smallest tephra layers mapped so far have volumes of less than 0.02 km^3. The volume of water-transported volcanic debris is unknown but two estimates indicate volumes of between 0.7 and 1.6 km^3 during the K-1918 eruption (Larsen and Ásbjörnsson, 1995; Tómasson, 1996).

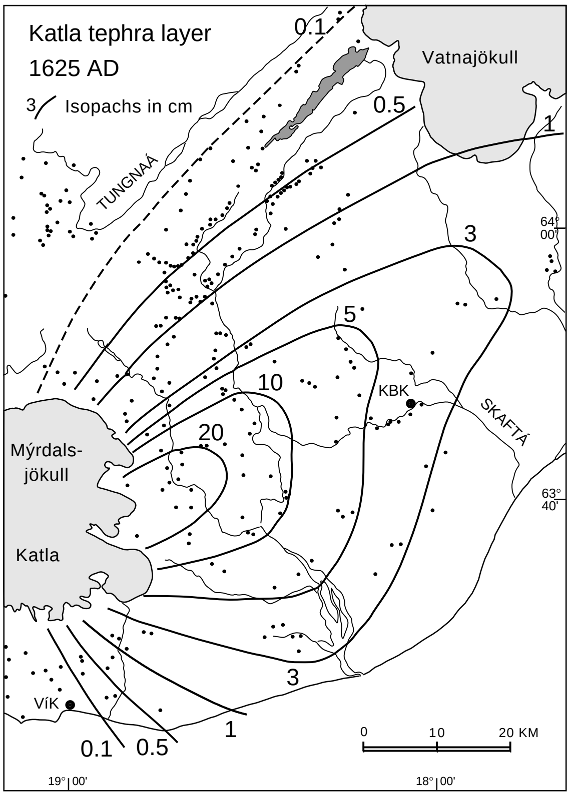
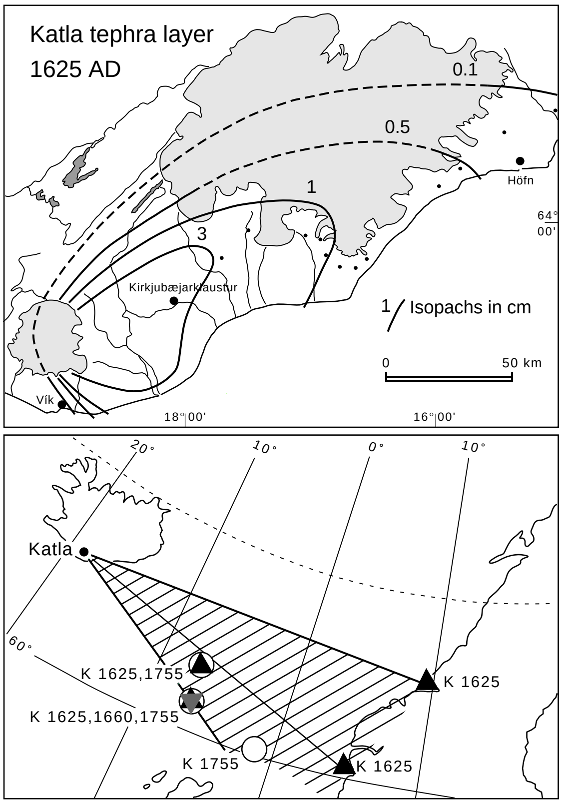


Figure 2a. Dispersal of the 1625 Katla tephra. isopachs of proximal and distal deposits on land. – *Dreifing gjósku í Kötlugosinu 1625. Jafnþykktarlínur gjóskunnar á landi.*

The duration of documented Katla eruptions since 1625 has varied from 2 weeks to over 5 months (Table 1) but some eruptions probably fall outside this range. The last three Katla eruptions to melt through the ice cover lasted 20-28 days. The average repose period since 1500 AD is 47 years with maximum deviations of 33 and 34 years. The shortest repose period known so far is 13 years, between the eruptions in 1612 and 1625, while the longest one is about 80 years.



Figures 2b and 2c. Dispersal of the 1625 Katla tephra. b) isopachs of proximal and distal deposits on land. c) occurrences outside Iceland (from Thorarinsson, 1980). – *Dreifing gjósku í Kötlugosinu 1625. b) jafnþykktarlínur gjóskunnar á landi. c) Staðir þar sem gjóskufalls varð vart utan Íslands (Samkvæmt Sigurði Þórarinssyni, 1980).*

The date of 14 Katla eruptions is known to the year (Table 1) and is approximately known for six others. The time of the year is known for nine eruptions, all of which began during the period May-November. Small jökulhlaups in June 1955 and July 1999 may have been caused by subglacial volcanism. Accordingly, all Katla eruptions during the last 400 years have begun during this time of the year. Although four centuries are a short time in the lifespan of a volcanic system, this implies that Katla eruptions are more likely to begin during the spring-fall season than in wintertime.

Table 1. Historical eruptions of the Katla system. Tephra layers, thought to represent these eruptions have been identified in soil sections around Mýrdalsjökull. With the exception of K-1823, K-1245 and the two 12th century layers all thepra samples have been chemically analysed in order to verify their origin. Three eruptions, previously labelled K-1311, K∼1000 and K-x, have been dropped from the list as the tephra layers representing them where found to belong to other eruptions within the Katla system. The latter two are part of the Eldgjá tephra. Dates: ◦ as summarized by Thorarinsson (1975), • Einarsson *et al.* (1980), ∗ Larsen (1984), ⋆ Haflidason *et al.* (1992), ⋄ Hammer (1980) and Zielenski *et al.* (1995). – *Gos á Kötlukerfi á sögulegum tíma. Gjóskulög, sem talin eru mynduð í þessum gosum, hafa fundist í jarðvegssniðum í nágrenni Mýrdalsjökuls. Öll nema K-1823, K-1245 og 12. aldar lögin hafa verið efnagreind til staðfestingar á uppruna þeirra. Þrjú gos, sem áður voru talin til Kötlu, K ca. 1000, K-x og K-1311, falla af skrá þar eð í ljós hefur komið að gjóskulögin eru úr öðrum gosum á Kötlukerfinu. Tvö þau fyrst nefndu eru hluti af gjóskulaginu úr Eldgjárgosinu.*

Eruption site	Eruption year/cent.	Date	Length days	Preceding years
Katla	(1955◦)	June 25		(37)
Katla	1918◦	Oct 12	24	58
Katla	1860◦	May 08	20	37
Katla	1823◦	June 26	28	68
Katla	1755◦	Oct 17	∼120	34
Katla	1721◦	May 11	>100	61
Katla	1660◦	Nov 03	>60	35
Katla	1625◦	Sept 02	13	13
Katla	1612◦	Oct 12		32
Katla	1580◦	Aug 11		∼80
Katla∼	1500∗			
Katla	15. cent			
Katla∼	1440∗			(24)
Katla	1416◦			(59)
Katla∼	∼1357•			(95)
Katla	1262◦			17
Katla	1245◦			(66)
Katla∼	1179◦			
Katla	12. cent			
Eldgjá	934/938⋄			
Katla∼	920⋆			(16)
Katla	9. cent			

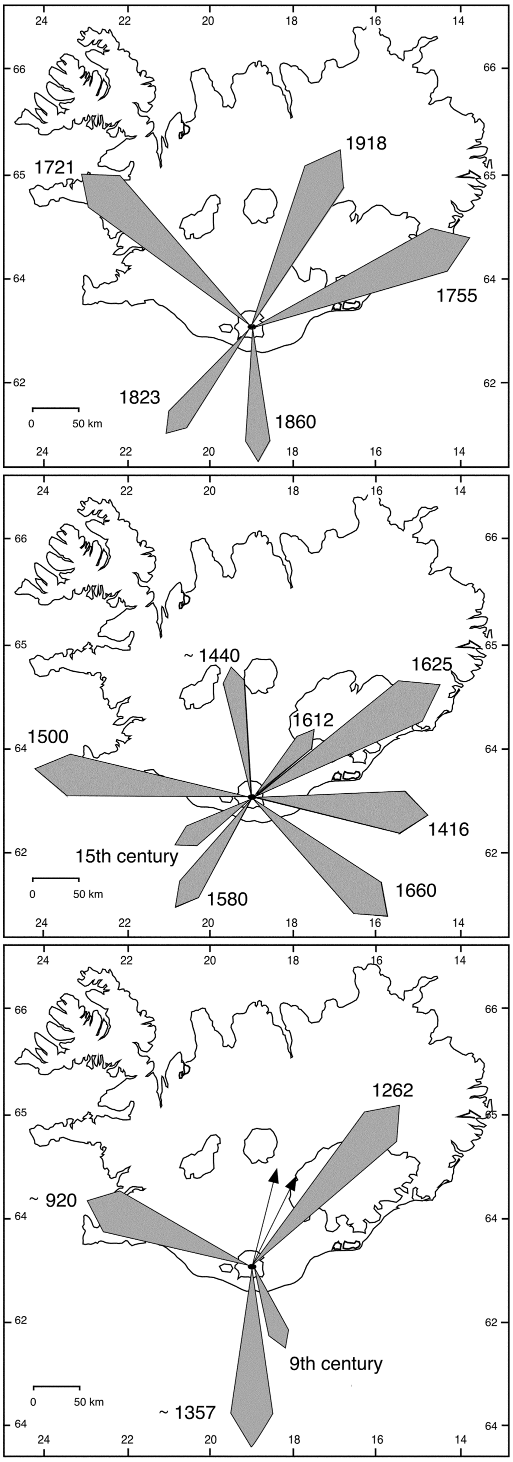


Figure 3. Main axes of thickness for some historical basaltic Katla tephra layers. Partly based on Thorarinsson (1975) and Larsen (1978). Thin arrows indicate minor tephra layers. The distribution is in fairly good agreement with prevailing wind patterns at the 500 mb level (Jónsson, 1990). – *Meginþykktarásar nokkurra gjóskulaga frá Kötlu. Að hluta til samkvæmt Sigurði Þórarinssyni (1975) og Guðrúnu Larsen (1978). Grannar örvar tákna litla gjóskugeira. Stefna gjóskugeira er í allgóðu samræmi við tíðni vindátta í 500 mb fletinum yfir Íslandi (Trausti Jónsson, 1990).*

An average eruption frequency of two eruptions per century during the last 11 centuries is implied by 20 documented eruptions and/or tephra layers (Table 1). The maximum observed frequency is three eruptions in the 15th and 17th centuries. A similar eruption frequency since ca. 7000 14C yrs BP is implied by the number of tephra layers in proximal soil sections. A prolonged period of repose after the 10th century Eldgjá event may have exceeded 200 years.

Katla tephra is coal-black to brownish black and consists mostly of highly fragmented, poorly to moderately vesiculated glass with grain sizes in the ash and lapilli range. Crystals are scarce. The lithic component, when present, consists of small light grey subrounded rock fragments. The glass composition (Table 2) of tephra from Katla is normally homogenous in a single layer (the notable exception, layer K-x, being part of the 10th century Eldgjá eruption). Layers from individual Katla eruptions are difficult to distinguish from each other on major element chemistry alone.

Most Katla tephra layers show distinct bedding due to intermittent deposition and shifting wind strength and wind directions during the eruption. A fine grained lower part and a coarser upper part characterize some of the layers (e.g. K ~1357, Einarsson *et al.*, 1980), implying that the first erupted tephra is more highly fragmented than that of later stages, probably as a result of abundant meltwater at the eruption site during the early stages of the eruptions. The opposite has also been observed (e.g. K 1755, Guðmundsdóttir, 1998), indicating less favourable water to magma mass ratio in the early stages, possibly as a

Table 2. Chemical composition of basaltic tephra from intracaldera eruptions of the Katla system. – *Efnasamsetning glers úr basísku Kötlugjóskulagi, K-1625.*

K tephra	n	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
K 1625	7	46,28	4,56	12,62	14,75	0,23	4,89	9,97	2,72	0,71	0,72	97,44
		0,46	*0,22*	*0,33*	*0,30*	*0,03*	*0,08*	*0,24*	*0,12*	*0,05*	*0,12*	*0,69*

result of rapid escape of meltwater from the eruption site or high initial mass eruption rates.

The vent area in several historical Katla eruptions is known either from sightings (1755, 1860, 1918) or from direct observation of the site (1823, 1918). In the latter case, the vent area was in the southeastern part of the caldera, near its margin. The location of ice cauldrons formed in 1955, as shown by Rist (1967), does not coincide with the location of the 1918 and 1823 eruption sites, which lie some 3 km farther south as described by G. Sveinsson (1919) and Austmann (S.t.s. Ísl. IV, 1907-15).

Katla eruptions apparently occur on short fissures, but their length and orientation is difficult to assess from the scant descriptions. If the 1955 incident was caused by an eruption, a NNW-SSE trending 1-1.5 km long fissure is implied by the cauldrons. Its orientation is sub-parallel to the caldera rim as defined by Björnsson *et al.* (1993 and this volume). The ice depression over the 1918 vent was 0.8-1 km wide from north to south but the E-W length could not be determined (G. Sveinsson, 1919). Another source estimated the length of the depression to about one Danish mile (7-8 km) whereof a 0.5-0.8 km long chasm near its NW termination was thought to be the vent area (P. Sveinsson, 1919). The depression may have been partly modified by meltwater channels, in which case the original fissure was shorter than implied by the depression.

All documented Katla jökulhlaups since the late 12th century have escaped from the caldera along the Kötlujökull pass onto Mýrdalssandur, with the exception of a minor "jökulhlaup" from below Sólheimajökull during the 1860 eruption (Hákonarson, 1860). Accounts of volcanogenic jökulhlaups onto Skóga- and Sólheimasandur in the 13th and 14th centuries are not supported by field data (Dugmore, 1987; Larsen and Dugmore, unpubl. data), as the last jökulhlaup to leave detectable deposits in sections around these sandur plains occurred in the early 10th century. Prehistorical jökulhlaups also escaped through the Entujökull pass (Sigurðsson, 1988). The historical jökulhlaups have emerged in several outbursts onto Mýrdalssandur, those of the first day usually being most voluminous. The first 15 km of their route lies below, within or on top of the Kötlujökull glacier, and they may emerge out from under its snout or break out well above the ice margin. The locations of the outlets determine the routes across Mýrdalssandur, some of which are shown in Figure 4.

Jökulhlaups accompanying Katla eruptions are a mixture of meltwater, ice and volcanic debris, mostly in the ash and lapilli range (Einarsson, 1975; Sveinsson, 1994). They have been defined as debris flows (Jónsson, 1982; Maizels, 1993), water floods (Karlsson, 1994; Tómasson, 1996) and as alternating between mud flows and water flows (Björnsson, 1993) on their 35-40 km route from the eruption site to the coast. The velocity of the leading edge of the 1918 jökulhlaup on Mýrdalssandur plain was close to 20 km/h or 6 m/s according to eyewitness accounts (Jóhannsson, 1919) while sediment structures indicate a velocity of up to 15 m/s in channels (Maizels, 1993). The maximum discharge for the 1918 jökulhlaup has been estimated at 100.000 to 300.000 m^3/s and the volume of meltwater has been estimated to be as much as 8 km^3 (Tómasson, 1996). Estimates of water-transported volcanic debris vary between 0.7 and 1.6 km^3 respectively (Larsen and Ásbjörnsson, 1995; Tómasson, 1996).

Lightning is common in the clouds of the Katla eruptions. Lightning frequency appears to correlate to the intensity of the eruption, but occurrences are also reported when activity is low. When frequency is highest, lightning occurs at intervals of a few seconds. Most appear to be intracloud discharges but strikes be-

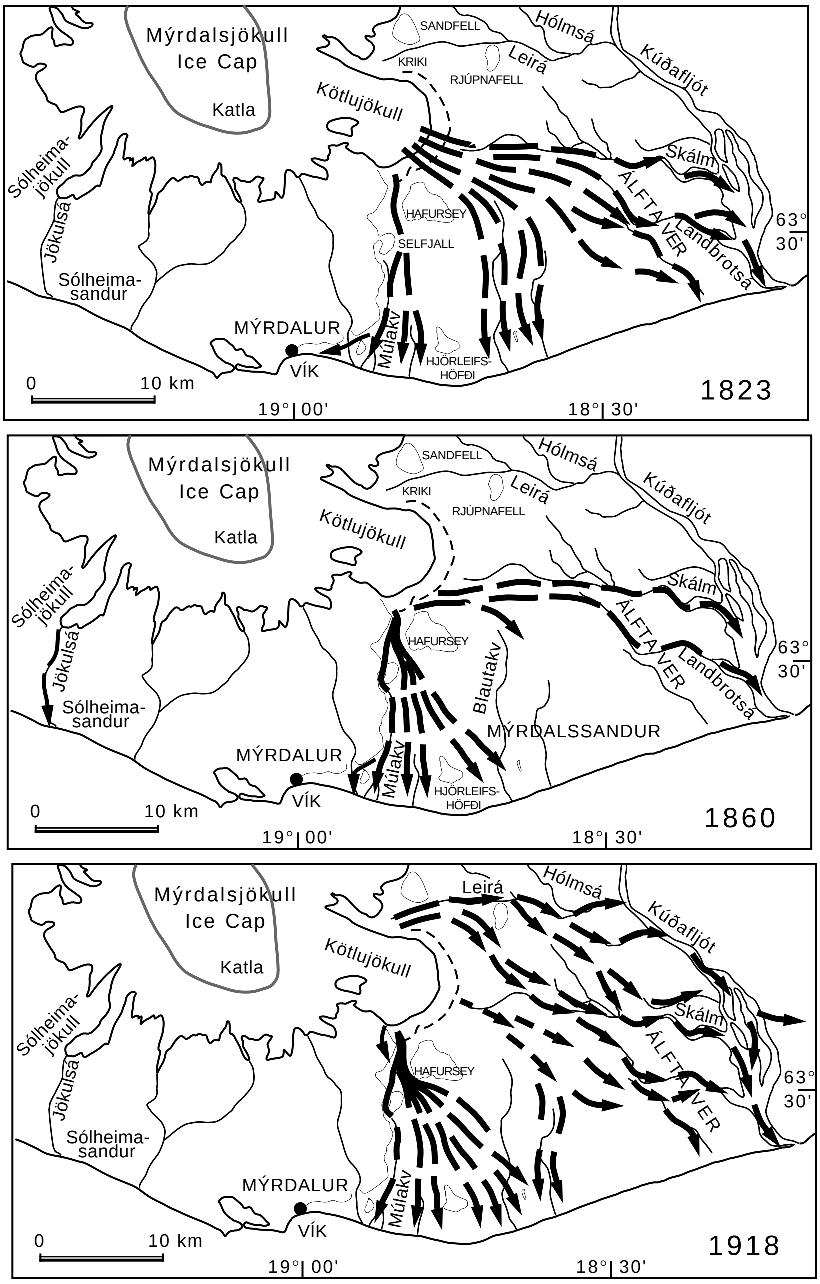


Figure 4. Routes of three Katla jökulhlaups across the Mýrdalssandur plain shown with black arrows (Larsen, 1993). In all instances since 1600 AD, a substantial part or the main body of the jökulhlaups have emerged at the southwest corner of Kötlujökull and flooded the western part of the sandur plain. In 1721, 1755 and 1918 parts of the jökulhlaup emerged at its northern margin at Kriki during the initial outburst. In 1823 the main part of the jökulhlaup emerged at the central portion of Kötlujökull and repeatedly flooded the eastern part of the sandur plain and the Álftaver district. The latter is usually affected only by the initial outburts of the jökulhlaups. In 1860 a minor flood also escaped onto Sólheimasandur. – *Helstu leiðir hlaupanna 1823, 1860 og 1918, sýndar með örvum. Í öllum tilfellum síðan um 1600 hefur verulegur hluti eða meginhluti hlaupanna komið fram við suðvesturhorn Kötlujökuls og farið um vestanverðan Mýrdalssand. Í Kötlugosunum 1721, 1755 og 1918 kom hluti hlaupanna fram í Krika. Í Kötlugosinu 1823 kom meginhlaupið fram úr miðjum Kötlujökli og hlaupvatn flæddi um austanverðan Mýrdalssand og niður í Álftaver allan gostímann, sem er óvenjulegt. Í gosinu 1860 kom einnig smáhlaup undan Sólheimajökli.*

tween cloud and ground also occur. People and livestock have occasionally been killed by lightning, even at distances of 30 km from the volcano (S.t.s. Ísl. IV, 1907-1915). In the 1918 eruption the telephone could not be used nor electricity maintained for extended periods of time (G. Sveinsson, 1919). Other electrical phenomena, such as St. Elmo's fire, are also reported. Lightning may be the most serious - and the most underestimated - hazard of future Katla eruptions.

Explosive silicic Katla (Sil-K) eruptions

Explosive silicic Katla eruptions have only recently been recognized as a distinct phase in the Holocene activity of the Katla volcanic system (Larsen, 1994; Larsen *et al.*, in press). Such eruptions were not observed or described during historical time. A few of the tephra layers produced in these eruptions were previously known as significant key layers in the regional tephrochronology of S-Iceland (Larsen, 1984) due to their distinct grain characteristics and easy identification and correlation in the field. Others have only recently been mapped.

Some 12 Holocene silicic tephra layers originating below the Mýrdalsjökull ice cap have been identified so far (Larsen *et al.*, in press). All were erupted between ca. 1700 yrs BP and ca. 6600 yrs BP (Table 3 and Figure 5). Older layers are found but their origin has not been verified. The location of the vent area below the ice cap can be inferred by plotting the axes of some of the silicic tephra layers (Figure 6). The axes of two bilobate tephra layers meet within the caldera, indicating a vent area near its centre. Vents at the caldera fracture cannot be excluded in other cases. Silicic domes are found at the caldera rim and some of them, e.g. at E-Kötlukollur, are thought to be of late-glacial age as they have chemical characteristics similar to pre-Holocene tephra from the Katla system (Lacasse *et al.*, 1995). Some of the Holocene silicic tephra layers may be part of dome-forming eruptions. The caldera is unlikely to have been icefree during prolonged periods of the Holocene and the silicic magma was most likely erupted under similar conditions as the basaltic magma, in the presence of ice/meltwater in hydromagmatic explosive eruptions.

Table 3. Radiocarbon dates and estimated age of silicic tephra layers from the Katla system. (From Larsen *et al.*, in press). – *Geislakolsaldur og áætlaður aldur súru gjóskulaganna frá Kötlu (samkvæmt Guðrúnu Larsen o.fl., í prentun).*

SILK tephra	Age B.P.	Lab. no
Layer YN	1676±12	GU-7091
Layer UN	2660±50	SSR-2805
Layer MN	2975±12	GU-7021
Layer LN	3139±40	GU-7019
Layer N4	c. 3600	
Layer N2	c. 4200	
Layer N1	c. 4900	
Layer A1	c. 5000	
Layer A7	c. 6200	
	6400±80	U-4604
Layer A8	c. 6400	
Layer A9	c. 6600	

Most of the silicic tephra layers are lobate, with two or three well defined main lobes, the largest layer being a noteable exception (Figure 7). Many of the layers are thin and consist of fine ash, while the largest tephra layers have grains in the lapilli range as well. Three layers contain distinct needle shaped grains and have accordingly been named the upper (UN), middle (MN) and lower (LN) needle layers.

The silicic Katla tephras have a distinct glass colour and grain characteristics. The tephra has an olive-green to greyish-green hue when seen in soil-sections. The coarser grain sizes consist of three distinct grain types: rods of fibrous glass, up to several cm long and a few cm in diameter, with elongated vesicles and very thin walls, breaking easily into small "needles"; equant or slightly elongated grains of highly vesiculated glass with irregular vesicles; and poorly vesiculated, black scoriaceous grains. The maximum observed length of rodlike grains is over 8 cm with a diameter of 1-2 cm at a distance of 30 km. Lithics have not been found so far. The needles are unique among the Holocene Icelandic tephras but have some resemblance to the platy fines of the 1362 tephra from the ice-covered Öræfajökull volcano.

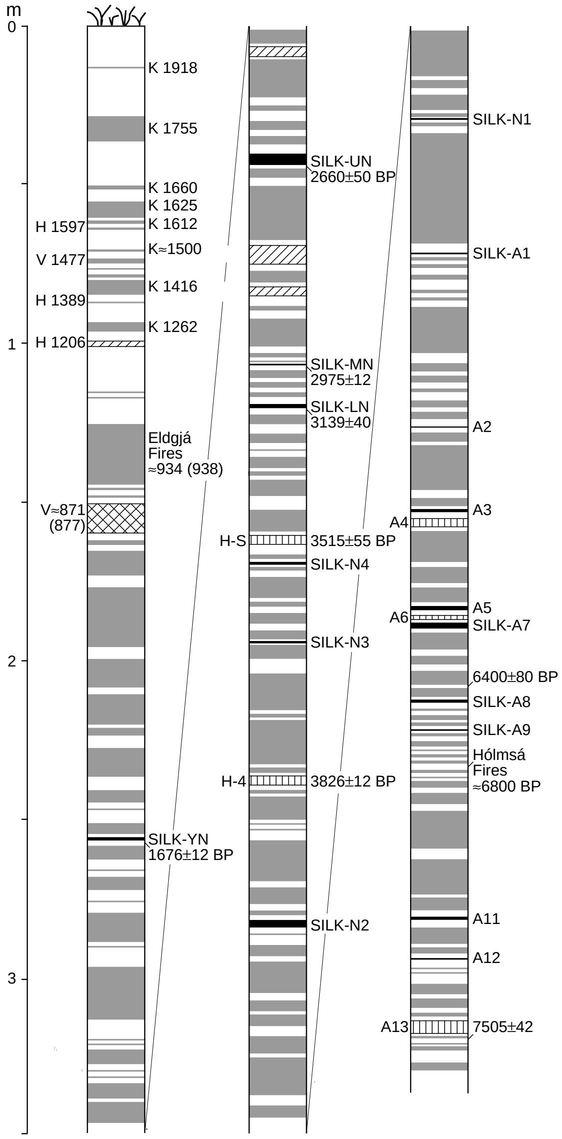


Figure 5. Composite soil section from areas east of Mýrdalsjökull ice cap, showing the regional tephra stratigraphy and where the products of the Eldgjá fires and Hólmsá fires fit in (from Larsen *et al.*, in press). Historical dates are A.D. while for prehistoric dates B.P. is preferred over B.C. (from Thorarinsson, 1975; Larsen, 1979, 1984; Hammer *et al.*, 1980; Dugmore, 1989; Dugmore *et al.*, 1995; Grönvold *et al.*, 1995; Zielinski *et al.*, 1995, 1998; Olsson, Larsen and Vilmundardóttir, unpubl. data). Dark layers (blackish, brownish) are shown as grey bands, the majority being basaltic Katla layers. The silicic Katla layers (greenish) are shown as black bands. Light- or two-coloured marker tephras from other volcanic systems are ruled. The Eldgjá tephra layer, the lava flows and several jökulhlaup-deposits fit into the regional tephra stratigraphy of S-Iceland at a specific stratigraphical level, here indicated by the tephra alone. K: Katla, H: Hekla, V: Veiðivötn systems. SILK: silicic Katla layers. The letters N and A refer to localities in the field. – *Samsett jarðvegssnið með gjóskulögum, sem sýnir gjóskulagaskipan austan Mýrdalsjökuls (samkvæmt Guðrúnu Larsen o.fl., í prentun). Aldur gjóskulaga á forsögulegum tíma er gefinn í geislakolsárum, í samræmi við töflu 3. Dökk gjóskulög (svört eða brúnleit í jarðvegi) eru höfð grá á teikningunni, flest þeirra eru basísk Kötlulög. Súru Kötlulögin (grænleit í jarðvegi) eru höfð svört. Ljósleit eða tvílit leiðarlög frá öðrum eldstöðvakerfum eru strikuð. Sýnt er hvar gosefni frá Eldgjárgosi (táknað með gjóskulaginu) og Hólmsáreldum (strik vísar á legu) eru í jarðvegsstaflanum. K: Kötlu-, H: Heklu-, V: Veiðivatnakerfi. Bókstafirnir N og A ásamt tölustaf vísa til sýnatökustaða.*

The volume of airborne silicic tephra varies between eruptions but does not exceed 0.5 km^3 in any layer mapped so far. The largest and most widespread is the tephra layer UN (Figure 7). The area within the 0.2 cm isopach on land is about 15.000 km^2, and compacted volume is 0.16 km^3, corresponding to 0.27 km^3 of uncompacted tephra. The second largest is layer LN with an uncompacted tephra volume of 0.2 km^3. The remaining layers are smaller still and the smallest ones are estimated to be less than 0.01 km^3 in volume. Maximum thickness values are not known for any of the layers as the proximal part of the tephras was deposited on ice. Maximum observed thickness amounts to 12 cm at a distance of 30 km from the centre of the caldera.

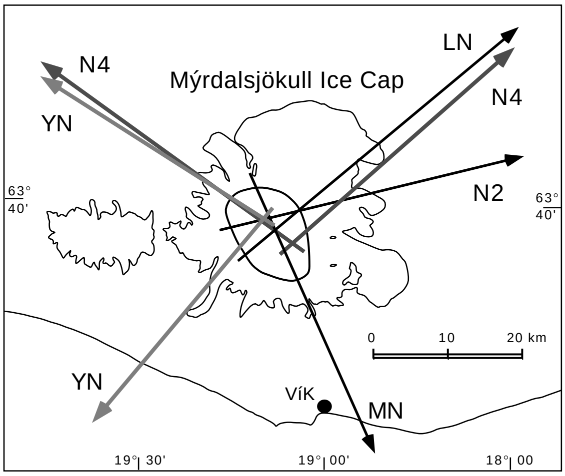


Figure 6. Axes of thickness for some silicic Katla tephra layers extended into the caldera, indicating potential source areas within the caldera. – *Þykktarásar nokkurra súrra Kötlulaga eru framlengdir þannig að þeir ná inn í öskjuna. Tvö gjóskulaganna eru tvíása og ásarnir skerast innan öskjunnar, sem bendir til upptaka inni í henni. Ásar hinna gjóskulaganna lenda þar á milli. Þegar um einn ás er að ræða er þó ekki hægt að útiloka að upptökin gætu verið í öskjubrotinu.*

Some of the silicic tephras have been dated by radiocarbon analyses of organic material immediately above or below the tephras. The youngest layer, YN, is dated at 1676±12 14C yrs and the second youngest and largest, UN, is dated at 2660±50 14C yrs (Table 3). The oldest layer verified to be silicic Katla tephra was erupted about 6600 14C yrs BP.

The 12 silicic eruptions identified so far are not evenly spaced during the period in question. The eruption frequency was highest between ca 6200 and 6600 14C yrs ago when three eruptions occurred, and between ca 2700 to 3600 14C yrs ago when four of the twelve eruptions took place. Thus, the interval between eruptions has varied from about 100 to about 1000 14C yrs.

The glass composition of the 12 tephra layers analysed so far is similar for all the tephras. The SiO_2 content lies in the range of 63-67% (Table 4 and Larsen *et al.*, in press) and the overall composition has remained remarkably stable over five millennia. Grains of basaltic and rhyolitic glass, possibly scavenged from the vent or conduit, occur in at least one of the layers. The composition of the silicic magma differs significantly from that of the Pre-Holocene silicic tephra deposits on the southern slopes of the volcano (Lacasse *et al.*, 1995).

The duration of the silicic eruptions is not known. The geometry of the tephra layers indicates that the tephra was erupted in separate bursts forming distinct well defined fans or lobes. Some of the lobes are narrow, indicating short-lived events (minutes or hours). Some of the tephra layers are bi- and trilobate, and changes in wind-direction between deposition of individual lobes indicate relatively long quiet periods (hours, days, weeks). This implies that many of the eruptions consisted of several relatively short-lived explosive events at intervals of unknown length. Intermittent activity may even have continued for a few years, similar to the 1821-23 activity at the neighbouring Eyjafjallajökull volcano. Another possibility is that the activity was continuous but only tephra from the largest events was deposited outside the ice cap. The volume of airborne silicic tephra indicates relatively small eruptions, of similar or smaller magnitude than the typical Katla eruptions. The distribution of the tephra suggests that the explosive activity was of low intensity, not capable of supporting high sustained eruption columns.

Jökulhlaups accompanying eruptions in the area defined by the axes of thickness within the caldera (Figure 6) could, under present conditions, escape through any of the three gaps occupied by the glaciers Entujökull, Kötlujökull and Sólheimajökull. Jökulhlaups accompanying eruptions at the caldera fracture could also escape along other routes, depending on the location of the vents. No water-transported material with the chemical characteristics of the Holocene silicic tephras has been found on the flood plains around Mýrdalsjökull, but glass chemistry has revealed that several of these eruptions contributed to ocean-rafted pumice, which has been found on coasts around the North Atlantic (Newton, 1999; Larsen *et al.*, in press). The wide distribution is more likely the result of the properties of the pumice, which allowed it to stay afloat for a long time, than an indication that the

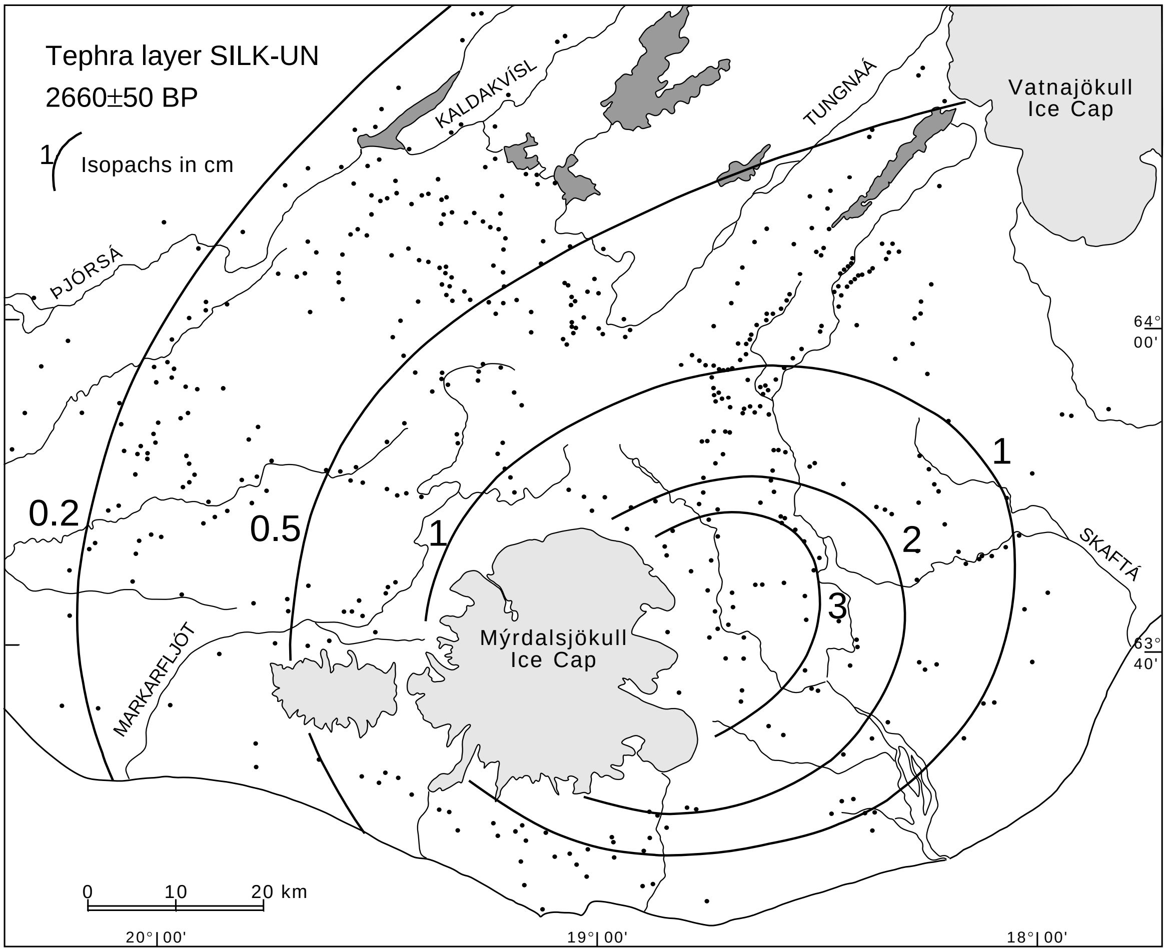


Figure 7. Dispersal of the largest silicic tephra layer, SILK-UN, on land. This tephra layer forms a single lobe with near circular isopachs while some of the other silicic layers are bi- or trilobate with narrow, well defined lobes. – *Útbreiðsla stærsta súra Kötlulagsins frá Nútíma, SILK-UN, á landi. Lögun jafnþykktarlína er nánast hringlaga og þykktarásinn ógreinilegur. Önnur súr Kötlulög eru gjarnan tví- eða þríása og gjóskugeirarnir eru mjóir með greinilegum þykktarás.*

Table 4. Chemical composition of silicic tephra from intracaldera eruptions of the Katla system (Larsen *et al.*, in press). – *Efnasamsetning glers úr stærsta súra Kötlugjóskulaginu, SILK-UN.*

SILK tephra	n	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
SILK-UN	10	64,16	1,33	13,95	5,94	0,20	1,36	3,40	4,37	2,59		97,30
		0,41	*0,06*	*0,24*	*0,31*	*0,03*	*0,08*	*0,13*	*0,20*	*0,11*		*0,54*

pumice volumes or the floods that transported them were particularly large.

Predominantly or partly effusive basaltic eruptions

Major events: The "Fires"

Effusive basaltic eruptions are the least common events on the Katla volcanic system. Between 5 and 10 relatively minor eruptions, that were at least partly effusive and produced small lava flows, and two major "fires" producing large lava flows, are known to have taken place during the Holocene. The former occurred on short fissures on the western and northern periphery of Mýrdalsjökull central volcano and are thought to be more than 4000 14C yrs old (Jóhannesson *et al.*, 1990). In the two "fires", fissures also opened up on the NE trending fissure swarm. They are the largest and most hazardous Holocene events of the Katla volcanic system. This chapter focusses mostly on the younger fires.

The older "fires" (Hólmsá fires) are about 6800 14C yrs old. The lava flows, now partly covered by the products of the younger fires, can be shown to fit into the regional tephra stratigraphy of S-Iceland at a specific stratigraphical level (Figure 5). The lavas followed depressions and river channels down the Álftaversafréttur area at least as far as Atlaey (Figure 8) and possibly all the way to the coast of that time. Their southward extension is hidden below an extensive cover of younger lava. The volume of lava is tentatively estimated to be ca. 5 km^3. The length of the eruptive fissure is not known, but a minimum length of 8-10 km outside the present ice margin near Öldufell is inferred by the paths taken by the lava.

The younger "fires" (Eldgjá eruption) took place in the early 10th century (Larsen, 1979), most likely around 934-938 AD (Hammer *et al.*, 1980; Zielinski *et al.*, 1995). The ca. 75 km long fissure extends from the Katla caldera beneath the Mýrdalsjökull ice cap in the southwest, through the mountainous terrain northeast of the ice cap to Eldgjá proper and continues intermittently to Stakafell mountain (Figure 8). It is the longest known eruptive fissure to be active in historical time (last 11 centuries). The eruption produced a widespread basaltic tephra layer, composed of several distinct units, and two major lava fields (Robson, 1957; Miller, 1989; Larsen, 1996; Thordarson *et al.*, in press). Possibly, a hyaloclastite flow accompanied the eruption. Jökulhlaups occurred along the subglacial part of the fissure.

The Eldgjá event is of particular importance because of its magnitude and because it is the cause of the most extensive environmental changes brought about by volcanic activity in Iceland during the last 11 centuries.

The Eldgjá fires of the 10th century: The fissure and the products

About one-fifth of the total length of the Eldgjá fissure lies below the present Mýrdalsjökull ice cap. The exact locations of the subglacial fissure segments are not known but isopachs of individual units of the Eldgjá tephra layer define at least two major segments. The southwesternmost of the two is located to the west of Kötlujökull, lying either within the present caldera or along its eastern margin/fracture. Another major segment lies to the west of Öldufellsjökull, possibly separated from the adjoining subaerial segment by a minor discontinuity or a dextral shift.

The 60 km long subaerial part of the fissure runs through hillocky landscape and becomes increasingly discontinuous to the northeast (Figures 1 and 8). Individual fissure segments occupy the low areas and are connected by shallow graben structures extending across topographical highs. Locally the fissure opened up in a pre-existing valley or a depression. This section of the eruption fissure is an 8 km long, 400 m wide and 150 m deep chasm after which the eruption is named, Eldgjá proper. The depression was occupied by a river at the time of eruption as evidenced by the scarps of a pre-eruption waterfall which was sealed off by the eruption products in the NW-wall of the chasm, close to the present waterfall.

By far the greatest part of the airborne Eldgjá tephra was erupted on the subglacial part of the Eldgjá fissure (Figure 9). Hydromagmatic explosive activity appears to have been dominant throughout the eruption there. Isopachs of the tephra layer as a whole indicate that the main source area of the airborne tephra was west of Öldufellsjökull. Isopachs of individual units show that the first tephra to become airborne emerged there and at S-Eldgjá.

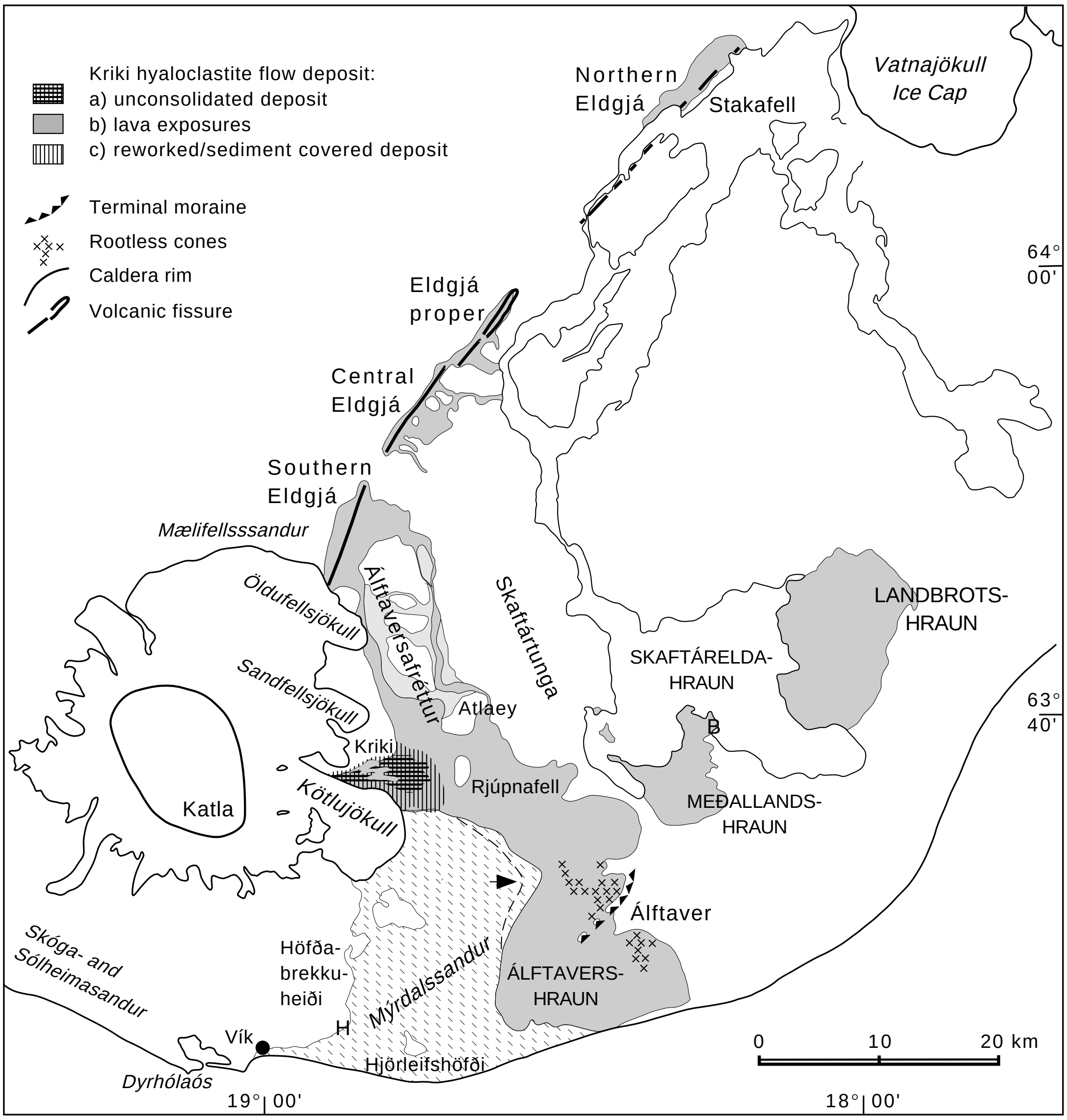


Figure 8. The Eldgjá lava flows (darker shading). Exposed parts of lava flows from the Hólmsá Fires are also shown (lighter shading). Lava flows from the Skaftár Fires are shown for comparison. The lava from Southern Eldgjá first flowed in two branches, along the Hólmsá river bed and a channel cut into jökulhlaup debris, then coalesced to form the lava field Álftavershraun. At the western margin of the lava, a solid line shows the outermost exposures of lava. A broken line shows the margin as inferred by magnetic measurements; an arrow indicates the location of the traverse. The late flow lobes are not shown. The lavas from other segments coalesced in the gorge of the river Skaftá and formed a single lava field with different local names, Landbrotshraun and Meðallandshraun, now partly covered by the Skaftár lava (outlines after Jóhannesson *et al.*, 1990). B and H show the location of the Botnar and Höfðabrekka farms. – *Sjá texta á bls. 15.*

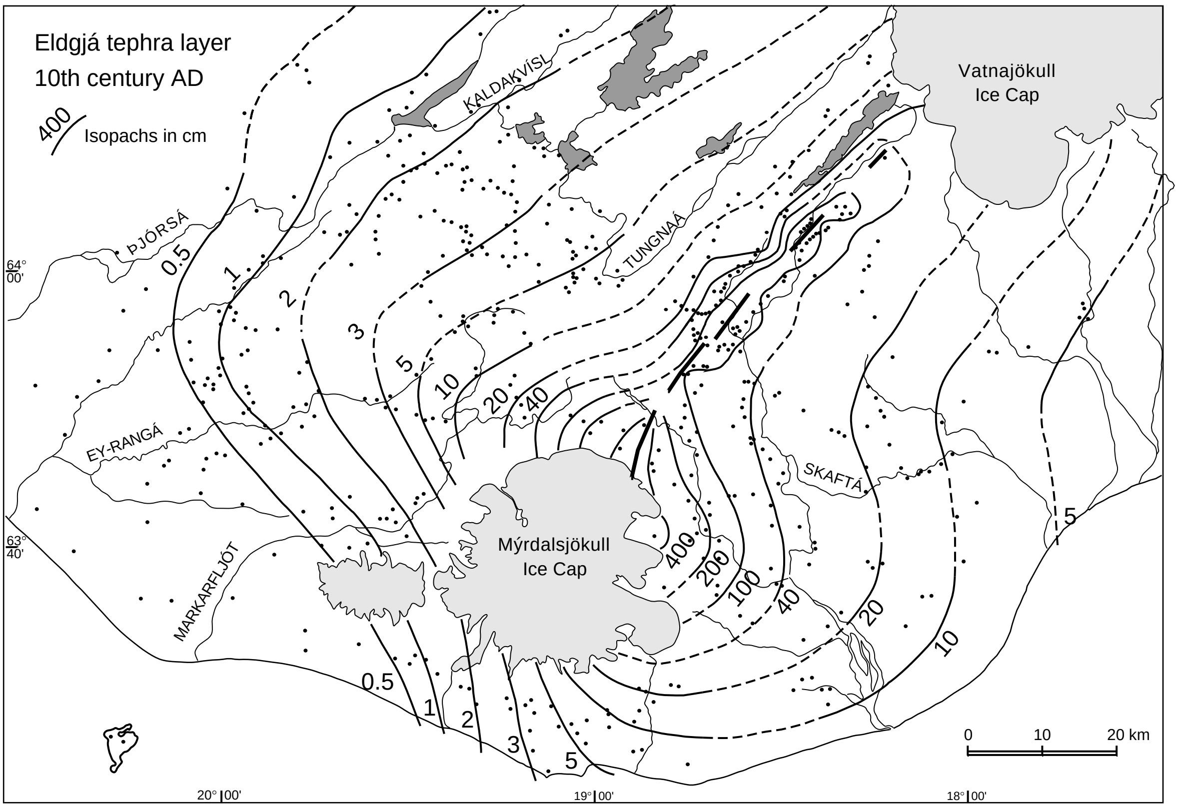


Figure 9. Isopach map of the Eldgjá tephra layer. Loci of high productivity are evident from the isochrones. The Eldgjá tephra layer was previously thought to be the product of three 10th century eruptions, the Katla-x, the Eldgjá and the Katla 1000 eruptions (from Larsen, 1996). – *Útbreiðsla Eldgjárgjósku á Suðurlandi. Jafnþykktarlínurnar sýna að gjóskuframleiðsla var mest vestan við Öldufellsjökul, þ.e. á þeim hluta sprungunnar sem liggur undir jökli í framhaldi af S-Eldgjá. Gjóska úr Eldgjárgosi var áður talin vera úr þrem gosum á 10. öld, og hlutar gjóskulagsins báru þá önnur nöfn, K ca. 1000 og K-x (Guðrún Larsen, 1996).*

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8. mynd – *Hraun úr Eldgjárgosi (dekkri skyggingin). Útlínur hrauna frá Skaftáreldum eru sýndar til samanburðar og einnig það sem sést af hraunum frá Hólmsáreldum (ljósari skyggingin). Hraun frá syðri hluta Eldgjárgossprungunnar runnu í tveim álmum niður fyrir Atlaey en sameinuðust í einn hraunfláka þar neðan við. Álftavershraun er hér notað um allan hraunflákann. Vesturjaðar hraunsins er hulin framburði jökulhlaupa, en heildregna línan sýnir hvar enn sést til hrauns á yfirborði. Brotna línan sýnir hvar hraunjaðarinn gæti legið samkvæmt segulmælingum, örin bendir á hvar mælilínan lá. Hraunbrúnir innan hraunflákans norðan við Álftaverið eru ekki sýndar. Gervigígar í Álftavershrauni eru táknaðir með krossum. Hraun frá öðrum hlutum Eldgjárgossprungunnar sameinuðust í farvegi Skaftár og mynduðu hraunfláka, sem nú er að hluta hulinn af Skaftáreldahrauni. Meðallandshraun er hér notað um vesturhlutann og Landbrotshraun um austurhlutann. Útlínur hraunanna eru dregnar samkvæmt Hauki Jóhannessyni o.fl. (1990). Gosefni sem mynda „hlaupkeilu"í Krika (blanda af gjósku, bólstrabrotum og hrauni) eru krossstrikuð nema þar sem sést í hraun, og lóðrétt strikuð þar sem yngri hlaup hafa flutt efni til. Jökulgarður norðan Álftavers er táknaður með þríhyrningum. B: Botnar í Meðallandi. H: Höfðabrekka í Mýrdal.*

emerged there and at S-Eldgjá. The third tephra unit was erupted on the Caldera segment. Activity then continued on the Öldufell segment, while airborne tephra emerged only intermittently on the Caldera segment. This tephra is highly fragmented and closely resembles typical Katla tephra.

On the subaerial segments of the Eldgjá fissure, explosive activity caused by high extrusion rates and vigorous degassing took place simultaneously with the effusion of lava (Miller, 1989), but was probably also enhanced by high ground water table and surface water during the initial phases. This activity was pronounced on the Central-Eldgjá and Eldgjá proper segments, and resulted proximally in extensively welded spatter deposits and distally in scoria deposits interfingering with hydromagmatic tephra from the subglacial part.

The Eldgjá tephra was mainly carried southeast but a smaller lobe extends northwest (Figure 9). At least 15 individual units from various parts of the fissure can be discerned. The tephra from the subglacial part of the fissure is distinctly bedded, with a maximum observed thickness of 4.5 m at ca. 5 km from the source and up to 2 m and 1 m at a distance of ca. 10 km and 20 km, respectively. Along the subaerial part, scoria and spatter form proximal deposits up to 15 m thick, thinning rapidly away from the fissure, occasionally forming sheets of spatter-fed lava that flowed up to 5 km from the source (Jakobsson, 1979; Miller, 1989). The land area covered by tephra is at least 20.000 km^2 but the area at sea has not been estimated. The volume (compacted) of the Eldgjá tephra on land is close to 2.7 km^3 within the 0.5 cm isopach, corresponding to 0.9 km^3 calculated as dense rock equivalent (Larsen, 1996). The total volume has not been calculated, due to large dispersal to the sea, but is estimated to exceed 4 km^3 or 1.3 km^3 DRE.

A hyaloclastite flow deposit is found along the northern margin of Kötlujökull glacier at Kriki, east of the Kötlujökull pass (Figure 8). It is extensively gullied by water, providing numerous exposures of its internal structures, and is partly overlain by a thin moraine. The main body consists of three subunits or facies but its base is nowhere exposed. The lowermost exposed subunit consists of irregularly jointed lava and pillow lava with a highly irregular surface. Vertical or subvertical protrusions of pillow basalt extend into the middle subunit, which is mainly made up of hyaloclastite breccia consisting of poorly consolidated scoriaceous ash to bomb size clasts, fragments of pillows or irregularly jointed lava and small isolated pillows. The protrusions of pillow basalt occur mostly in the lower half, occasionally extending into the upper part where thin horizontal lava sheets are also intercalated with the breccia. In one instance a couple of thin (20-50 cm) dykes emerge from a protrusion, extending up through the middle and the uppermost subunit, forming a small sheet. The uppermost unit consists of poorly consolidated layered hyaloclastite tuff with occasional cross-bedded or slumped layers. The Kriki hyaloclastite flow is very similar to the standard hyaloclastite unit defined and described by Bergh (1985) and Bergh and Sigvaldason (1991), with the exception that the lowermost facies, regularly jointed lava, has not been observed. Bergh (1985) interpreted the observed features to have formed when the flows were discharged from a subglacial into a subaqueous environment, a condition that cannot be met at Kriki. Walker and Blake (1966) envisaged such flow in a tunnel created by a preceeding jökulhlaup. The Kriki hyaloclastite flow deposits emerge out from under the present margin of Kötlujökull at 600 m a.s.l. and can be followed for 6-7 km until they disappear at ca 300 m a.s.l. below younger alluvials from glacial rivers and jökulhlaups. Contacts between the Álftaver lava and the Kriki deposits are nowhere exposed. Water transported debris, which directly overlies remnants of primary, bedded Eldgjá tephra at 160 m a.s.l. on the southwest slope of Rjúpnafell, is tentatively correlated to the Kriki deposits. The implication is that the debris flow was emplaced during the Eldgjá eruption. The volume of the Kriki deposits outside the glacier margin is about 0.5 km^3.

Voluminous lava flows, comparable in volume to those of the 1783 Skaftá fires, were erupted on the subaerial part of the Eldgjá fissure. The lavas were channelled along river gorges and valleys down to the lowland where they formed extensive lava fields in the districts of Álftaver, Meðalland and Landbrot (Figure 8). Productivity was highest on the $\geq$8 km long

S-Eldgjá segment where the 345 km^2 western lavas, including the Álftaver lava field, emanated while all the remaining subaerial segments contributed to the 435 km^2 eastern lavas, including the Meðalland and Landbrot lava field. The lava fields were previously thought to have a combined volume of 14-16 km^3 (Miller, 1989) but new field observations indicate that it may exceed 18 km^3 (Thordarson *et al.*, in press). The lava fields are pahoehoe lavas, dotted with, and in places dominated by, rootless vents (pseudocraters), indicating emplacement over wet ground or shallow lakes. The main lobe of the Álftaver lava extends more than 50 km from the source to the south coast, while several shorter lobes with distinct flow fronts occur closer to the source. Activity on the subaerial part apparently outlasted that on the subglacial part and may have continued intermittently for a prolonged period, as implied by the late flow lobes.

Jökulhlaups accompanied the Eldgjá eruption but their extent and timing are only partly known. A fan deposited by a major jökulhlaup emerging south of Öldufell (or from below Öldufellsjökull), conformably overlain by bedded Eldgjá tephra, was most likely emplaced during the early stages of the Eldgjá eruption. Other potential early flood deposits occur on Mælifellssandur and north of Álftaver. Debris fans that can be fitted into the eruption sequence were formed during the later stages of the eruption by floods apparently emerging near Öldufell and Sandfell. Such debris is found on the lower slopes of Atlaey where it fits into the tephra stratigraphy at the same level as the Eldgjá tephra. There it overlies or intercalates the airfall deposit and is also found sandwiched between lava lobes. Evidence of a jökulhlaup from below Sólheimajökull in the early 10th century is found on the vegetated slopes east of the outwash plain. This is the last verified occurrence of a jökulhlaup leaving a discernible deposit of volcanic debris in that area (Larsen and Dugmore, unpublished data). The deposit either belongs to the Eldgjá event or the previous Katla eruption (ca. 920).

The Eldgjá tephra and lavas have the chemical characteristics of the Katla volcanic system, being a transitional alkali basalt with high iron and titanium content (Table 5 and Jakobsson, 1979). A tephra unit erupted on the caldera segment during a late stage of the explosive phase contains minor amounts of silicic (SiO_2 ca 64%) glass interspersed in the basaltic tephra. This component resembles the silicic tephra layers described in the previous section. A characteristic feature of the basaltic tephra units erupted within the caldera is the abundance of small glomerocrysts, mostly plagioclase, in the glass. Contamination of FeTi basalt by acid melt would result in crystallization of plagioclase. Compositional variations along the Eldgjá fissure as described by Miller (1989) indicate contamination by tholeiite, which is most pronounced at the northern part of the fissure, confirming Jónasson's (1974) observations.

Course of events in the Eldgjá fires

The course of events during the Eldgjá eruption is not known in detail. The first material to appear was tephra erupted on the topographically low fissure segments west of Öldufellsjökull and at S-Eldgjá. Jökulhlaups from below Öldufellsjökull seem to have accompanied this activity, and emanation of lava from S-Eldgjá may have begun at the same time. Next to appear was a batch of tephra erupted on the caldera segment, seemingly in a single short burst, while activity on the first-mentioned segments appears to have been continous. Tephra units indicate that the remaining subaerial fissure segments became active in a stepwise fashion, first C-Eldgjá, followed by Eldgjá proper and finally by N-Eldgjá. Lava production probably began with the first appearance of tephra on each segment. The duration of this phase, the progressive stage, is not known. By analogy with the 1783-85 Skaftá fires it may have lasted weeks (Thordarson and Self, 1993). Ejection of airborne material from the caldera segment resumed after the opening of the C-Eldgjá segment. Activity at the caldera may have ceased or been reduced as other segments set in. Alternatively, activity on the caldera segment may have been continuous with the greatest part of the material emplaced as hyaloclastic flow(s) through the Kötlujökull gap down to Kriki, only a small part of the material becoming airborne until a later stage.

The duration of the Eldgjá event may have been years. The well defined fronts of some of the late lava lobes may be taken as an indication that the under-

Table 5. Chemical composition of basaltic tephra from the Eldgjá fires, Katla system. Bulk sample from the bedded tephra layer where it is 4 cm thick. Slight differences between gla and glb may indicate different source areas on the >75 km long fissure. The third type, glx, may be scavenged from bedrock. – *Efnasamsetning basísks glers úr Eldgjárgjósku. Heildarsýni af 4 cm þykku lagskiptu gjóskulagi. Mismun á efnasamsetningu gla og glb má líklega rekja til uppruna á mismunandi hlutum gossprungunnar. Glerkorn með lægra* TiO_2*, glx, gætu verið aðskotakorn úr berggrunni.*

Eldgjá tephra	n	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
E 934/938 gla	6	46,07	4,65	12,10	15,09	0,18	5,07	10,64	2,72	0,71		97,22
		0,36	*0,25*	*0,36*	*0,49*	*0,03*	*0,28*	*0,25*	*0,09*	*0,04*		*0,55*
E 934/938 glb	5	47,75	4,65	12,34	13,93	0,18	4,61	9,68	2,99	0,88		97,01
		0,35	*0,09*	*0,16*	*0,08*	*0,03*	*0,14*	*0,25*	*0,10*	*0,07*		*0,50*
E 934/938 glx	3	49,45	2,52	12,38	13,40	0,19	5,41	10,77	2,50	0,39		97,01
		0,29	*0,11*	*0,38*	*0,09*	*0,02*	*0,07*	*0,05*	*0,08*	*0,02*		*0,58*

lying lava had solidified before they were emplaced. The volcanic signal from Eldgjá in the Greenland ice cores extends over 3-6 years (Hammer, 1984; Zielinski *et al.*, 1995) and may be a realistic indicator of the length of the eruption. The effects, however, have lasted to this day.

ENVIRONMENTAL CHANGES IN THE PAST 11 CENTURIES

The most extensive environmental changes in inhabitated areas in Iceland, caused by volcanic activity during the last 1100 years, began by the Eldgjá eruption. These changes can be assessed by geological/tephrochronological studies and with the help of written sources, both the early chronicles that briefly describe the conditions and natural phenomena met by the Norse settlers, and later contemporary sources (Íslensk Fornrit I; S.t.s.Ísl. IV, 1907-15). Only the more "local" effects of the historical eruptions will be treated here, i.e. those of lava emplacement, tephra falls and jökulhlaups. The regional effects, in particular those of the Eldgjá event, are discussed elsewhere (e.g. Zielinski *et al.*, 1995; Thordarson *et al.*, in press). Prehistoric changes are not addressed here.

The pre-Eldgjá environment

A partial reconstruction of the pre-Eldgjá environment is possible on the basis of current geological and historical knowledge.

Álftaversafréttur north of Atlaey was extensively vegetated prior to the Eldgjá eruption. Thick soil had formed on the Hólmsáreldar lavas since their emplacement ca 6800 14C yrs ago (cf. Figure 5). On the surrounding hyaloclastite hills even thicker soil with up to 170 individual tephra layers had accumulated to more than 8 m thickness in places. This soil cover is still preserved on some of the hills, e.g. in Atlaey. The major river of the area, Hólmsá, flowed in places on the Hólmsá lava between banks of soil several metres thick, similar to its present course at Hrífuneshólmi, just before it joins Kúðafljót.

In front of of the gap occupied by Kötlujökull a low and wide alluvial cone is implied by the geometry of the encircling Eldgjá lava (Figure 8). Before the emplacement of the lava, meltwater and jökulhlaups probably had free passage in easterly directions, while a gently curving terminal moraine in the northern part of the Álftaver district (Figure 8) protected the vegetated region to the south.

In the Meðalland district the Eldgjá lava (Figure 8) is at least partly underlain by sandur deposits or alluvial flats, presumably by the rivers Tungufljót and Skaftá. The area may also have been overrun by pre-Eldgjá jökulhlaups from below Kötlujökull. Primary bedded Eldgjá tephra can be seen immediately below the lava, resting directly on top of the sandur, about 1 km east of the farm Botnar. In the Landbrot district the Eldgjá lava flowed across large wet areas, as evidenced by extensive fields of rootless cones. Thick, broken-up soil along its northern edge, in places thrust into heaps or small ridges, indicates that part of this area was vegetated when overrun by the lava.

The field observations are supplemented by descriptions of the conditions that met the first settlers in the late 9th-early10th century in the Book of Settlement, and these two independent sources support each other on certain points. One description places a large lake in the Álftaver district. Present geological conditions support the existence of a lake behind the moraine in the northern part of Álftaver (Figure 8), where rootless cones indicate that the lava flowed over a wet area or into a lake before banking against the moraine. Descriptions and definitions of the early settlements imply that large parts of the area now known as Mýrdalssandur were suitable for farming, i.e. extensively vegetated. This implies that rather stable or low energy conditions had prevailed in the area for an extended period.

The 9th century coastline can be crudely reconstructed from the descriptions in the Book of Settlement and from younger descriptions (S.t.s. Ísl. IV, 1907-15). The former refers to a fjord in the area to the west of cape Hjörleifshöfði, with the head towards the cape. It has recently been argued that the fjord was a lagoon behind a sandbarrier (Imsland and Larsen, 1993), analogous to the present inlets on the south and southeast coast (Figure 8). The younger sources describe conditions along the coastal cliffs between Vík and Höfðabrekka where no beach existed until after 1660 A.D.

Consequences of the Eldgjá fires

Immediate effects of a catastrophic event

The Eldgjá eruption changed the landscape, hydrology and utilization potential of large areas in S-Iceland. About 800 km^2 of land were covered by new lava that raised the topography, blocked waterways and permanently changed the run-off pattern of an area extending from the Mýrdalssandur in the west to Landbrot in the east. A considerable part of the 800 km^2 overrun by the lavas was vegetated. Over 20.000 km^2 were affected by the tephra fall on land. Some 2600 km^2 were covered by over 20 cm thick tephra and severely damaged. Of these, roughly 600 km^2 were buried below more than100 cm thick deposits and permanently laid waste.

The changes were most radical within 30 km east of the Mýrdalsjökull massif. Álftaversafréttur, Skaftártunga and Álftaver were affected by heavy tephra fall, lava flows, a hyaloclastite flow and jökulhlaups. The lava from S-Eldgjá followed river valleys and gorges to the low areas, forcing rivers in Álftaversafréttur out of their beds. At Álftaver the lava banked against and was deflected westwards by the moraine, filling in a lake/wet area in the process, then turning southwards to the coast of that time, possibly extending it seawards. The lava fronts on the sandur east of Kötlujökull blocked previous routes of meltwater and jökulhlaups to the east. Hyaloclastite flows at Kriki may have changed the topography below Kötlujökull and consequently the pre-eruption paths of meltwater. A tephra blanket more than 1 m thick suffocated the existing vegetation and filled in gullies and depressions. Extensive soil erosion followed, which may have resulted in complete denudation locally, e.g. in Álftaversafréttur. Where the thickness exceeded 0.5 m the tephra prevented recovery of the vegetation for centuries. After more than a millennium some of these areas still have only a thin, easily punctured soil and vegetation cover.

The extent and effects of jökulhlaups accompanying the Eldgjá event cannot be realistically estimated because the Eldgjá lavas and post-Eldgjá jökulhlaups in the Mýrdalssandur area have covered most of their tracks. The nickname Aurgoði (Lord of the mud) of a second generation Norse settler in that area implies that water-transported sediments (aur = mud) occurred within his estate. Broadly speaking, areas along the eastern and northern periphery of the Mýrdalsjökull ice cap may have been affected to a greater or lesser extent by the Eldgjá jökulhlaups.

Topographical changes below the Mýrdalsjökull ice cap can only be guessed at. Accumulations of volcanic debris within the caldera and elsewhere along the subglacial part of the erupting fissure are likely to have caused changes locally. Erosion by meltwater may have been substantial in some areas. Subsidence of the caldera floor as a consequence of such large eruption is also a definite possibility. Whatever the causes, drainage from the caldera was permanently altered as a consequence of the Eldgjá event; pre-Eldgjá jökulhlaups escaped through the Sólheimajökull and

Entujökull gaps (e.g. Larsen, 1978; Dugmore, 1987; Sigurðsson, 1988), as well as the Kötlujökull gap, while post-Eldgjá jökulhlaups have been confined to the Kötlujökull gap.

Lasting effects: The post-Eldgjá changes

When volcanic activity was resumed after the +200 year repose following the Eldgjá eruption, new conditions had developed on the sandur plain in front of Kötlujökull. The Álftaver lava was now a high area that formed a barrier obstructing meltwater flow to the east. Hyaloclastite flow(s) at Kriki had, possibly, raised the topography on the northern side of Kötlujökull by tens of metres and changed the topography below the glacier significantly. The combined effect was to direct jökulhlaups escaping through the Kötlujökull pass in a southerly direction, into the lower lying areas to the west of the lava fields.

Some recovery of the areas damaged by the Eldgjá eruption took place during the long repose. The areas along the edges of the Eldgjá lava fields are likely to have developed in the same way as Brunasandur in front of the 1783 Skaftáreldar lava, which became vegetated within decades and farmable within two centuries (Thoroddsen, 1911). In the following centuries, revegetated areas and farmlands within and along the borders of the present sandur plain were gradually destroyed (e.g. S.t.s. Ísl. IV, 1907-15).

Tephra fall affected the neighbouring areas, sometimes severely, but the effects were temporary. Permanent damage on the scale inflicted by the Eldgjá tephra has not reoccurred. Compared to the jökulhlaups, airfall tephra plays a minor role in the post-Eldgjá changes.

Changes caused by the post-Eldgjá jökulhlaups can be assessed from many sources. The first documented occurrence of a jökulhlaup after more than 200 years repose was Höfðárhlaup that flooded the western part of Mýrdalssandur shortly before 1179 AD, destroying several farms and two churches within the Höfðabrekka parish (Biskupa Sögur 1878). The comment in the Book of Settlement that a sandur plain, Höfðársandur, now lies where there was previously a fjord, suggests that significant changes had taken place when the comment was written in the late 12th or early 13th century (Íslensk Fornrit I). Farms within the Álftaver lava were flooded and abandoned in the late 15th century (Gestsson, 1987; Árnadóttir, 1987), indicating that by then jökulhlaups could flood the lava field. This implies that the surface of the sandur plain west of the lava field had been raised to a point where jökulhlaups were no longer deflected by the lava edge and that the sandur was progressing onto the lava field. Continuation of this developement is seen in all the documented jökulhlaups since 1625 (S.t.s.Ísl. IV, 1907-15). The shoreline at various times since the Norse settlement can be reconstructed with reference to the Book of Settlement and younger sources (e.g. S.t.s. Ísl. IV, topographic maps from 1904 onvards). An extension of up to 4 km from the pre-Eldgjá shore is implied by such reconstructions. The permanent addition to Mýrdalssandur along the 30 km of shore between Vík and Álftaver lava is at least 60 km^2.

Evidence of the changes is also preserved in the soil in areas within and adjacent to Mýrdalssandur. The soil that began to form on the Álftaver lava shortly after the eruption, is devoid of windblown sand size material until the early 15th century. This change becomes noticeable above the tephra layer from the 1416 Katla eruption and increases drastically above the 1625 Katla layer. The increasing influx of windblown material is best explained by sand blowing in from areas close to the Álftaver lava, i.e. a growing sandur plain.

Frequent renaming of the rivers on Mýrdalssandur implies that both their courses and character have repeatedly changed through time. Some have disappeared while others have appeared temporarily following major jökulhlaups. The most recent example is the disappearance of the Sandvatn river, a glacial river in the middle of Mýrdalssandur, following the 1918 jökulhlaup.

The picture emerging from the pieces of information is the following: When volcanic activity resumed after a long repose, jökulhlaups accompanying Katla eruptions repeatedly flooded the area between the Álftaver lava field and the hyaloclastite mountains of Höfðabrekkuheiði. Different parts were affected in different eruptions but the overall effect of repeated deposition of water-transported debris was to fill in lagoons, raise the sandur surface and enlarge the sandur plain at the expense of vegetated areas, shift river courses and extend the shoreline southwards.

DISCUSSION

The recurrence time of eruptions in each of the three categories of volcanic activity within the Katla system apparently differs by orders of magnitude. The intracaldera basaltic eruptions occur at intervals of decades while the silicic eruptions occurred at intervals of centuries and the "fires" involving both the central volcano and its fissure swarm occur at intervals of thousands of years. The past eleven centuries are atypical, firstly because of the major "fires" in the 10th century, and secondly because no silicic eruptions have been identified during this period.

The eruption frequency presented in this paper should be regarded as a minimum for the intracaldera basaltic eruptions and silicic eruptions. Only subglacial eruptions that broke through the ice cover and left a tephra layer are recorded. Small subglacial events such as the 1955 and 1999 events, some of which may have been small eruptions, went unnoticed until this century. The long repose after the Eldgjá eruption is defined by the absence of tephra layers in soils formed during the following centuries, and events that did not leave such evidence may have taken place during this interval. Infrequent rifting episodes resulting in major "fires" are, however, in accordance with the location of the system within a zone of propagating rift.

The absence of silicic eruptions after the Eldgjá eruption may imply that the magma system below the central volcano was disrupted or reorganized as a result of that event. The fairly homogenous glass composition of the 12 tephras erupted in the interval between the two "fires" indicates that stable conditions prevailed during that period. The fact that the composition of the Holocene silicics differs significantly from the pre-Holocene silicics may similarily indicate significant changes of subcaldera conditions at an earlier stage, either as a result of the 10300 14C yrs BP eruption (Lacasse *et al.*, 1995; Bard *et al.*, 1994) or of the Hólmsá fires some 6800 14C yrs ago.

The hyaloclastite flow deposits at Kriki may be the first Holocene deposits of this kind that have been identified in Iceland. The relationship to the other Eldgjá products is still not sufficiently clear and further field work is needed to establish an unambiguous correlation. The apparent low productivity of airborne tephra within the caldera is, however, readily explained if most of the magma erupted there escaped from the caldera as a hyaloclastite flow.

Changes in subglacial drainage routes of post-Eldgjá jökulhlaups towards the Kötlujökull gap can have several causes. Different ice thickness within the caldera as a result of different climate conditions cannot be disregarded, e.g. migration of the ice divide, which Dugmore and Sugden (1991) proposed to explain changes in maximum advances of Sólheimajökull during the Holocene. Other plausible causes for changed drainage routes are a shift in location of intra-caldera eruption sites or altered caldera topography. The latter would also affect the outlet glaciers and might explain some of the changes observed by Dugmore (1987) and others. Considering the magnitude of the Eldgjá event and the activity within the caldera, changes of caldera topography cannot be discounted as a contributing factor, while an eastward shift of post-Eldgjá eruption sites is the most straightforward explanation.

Old traditions regarding settlements in the Mýrdalssandur area become understandable in light of the changes caused by the Eldgjá eruption. Large parts of the area now known as Mýrdalssandur were, without doubt, favourable for farming before the Eldgjá eruption. In the two quiet centuries following the eruption, some of the areas laid waste by lava flows and jökulhlaups recovered, if only temporarily. In such a case the existence of farms along the now sand-covered western edge of the lava flow, as well as elsewhere along the edges and on islands within the lava, is readily explained. Tales of clusters (hverfi) of farms, both at the time of the Norse settlement and in the centuries following the Eldgjá eruption, in areas now laid waste, do not contradict what is currently known about the geological and geographical conditions. These tales may therefore contain some large grains of truth - or simply be true.

The greatest hazard in historical Katla eruptions has been that of the accompanying jökulhlaups, because of the short warning time for people and livestock exposed to the floods and because of the damage inflicted on the environment. This hazard is reduced with the current monitoring of the volcano. The most serious effects of future Katla eruptions could, however, be on power transmission in Southern Iceland as a result of tephra fall and lightning in the eruption cloud. The latter is potentially the greatest hazard to people and livestock in areas within 30-40 km of the eruption site. A modern community with power transmission lines, television aerials and electrical fences (rural areas) is more vulnerable to this menace than earlier communities in the vicinity of the volcano.

SUMMARY AND CONCLUSIONS

Intracaldera basaltic eruptions, the typical hydromagmatic Katla eruptions, occur at intervals of decades. The average frequency during the last 9 centuries is close to two eruptions per century, with the shortest and longest interval of 13 and 80 years, respectively.

Intracaldera silicic eruptions occurred at intervals of hundreds of years in the period 6600 - 1700 BP. The average frequency was close to two eruptions per millennium, and the shortest and longest interval were ca. 100 and ca. 1000 years, respectively.

Large, predominantly effusive fissure eruptions, involving both the central volcano and fissure swarm occur at intervals of thousands of years. Two such episodes are known in the Holocene. They represent major rifting episodes that may modify the volcanic system, including the subcaldera conditions.

Katla eruptions of known calendar dates all began in the spring-fall season. Future eruptions may follow that trend. The vent area in most historical Katla eruptions was apparently in the eastern part of the caldera. The best documented locations lie within the southeastern corner of the caldera.

Twelve silicic eruptions took place in the ca. 5000 year period between the Hólmsá and Eldgjá fires, during which time the composition of silicic magma remained fairly homogenous. The interval since the last silicic eruption ca. 1700 14C years ago is the longest on record. The reason as to why silicic activity has not recurred may be subcaldera changes brought about by the Eldgjá event. A substantial silicic eruption cannot, however, be excluded in the future.

Vent areas in the silicic eruptions have been associated with the caldera. Accompanying jökulhlaups may have escaped from the caldera through any of the three gaps, depending on pre-Eldgjá topography and the ice thickness in the caldera.

The 75 km long Eldgjá fissure is one of the longest known fissures active in a single Holocene eruption. The Eldgjá tephra is the third or fourth largest historical tephra layer in Iceland and the lava flows are the among largest in recorded history. A hyaloclastite flow that escaped from the caldera through the Kötlujökull gap appears to be part of its products.

Since activity on the Katla system was renewed in the 12th century, after an apparent repose of some 200 years, all associated jökulhlaups have escaped through the Kötlujökull pass onto Mýrdalssandur. Possible explanations are changes in ice thickness, subglacial topography of the caldera and/or the location of the eruption site.

The immediate environmental effects of the Eldgjá event included permanent or temporary destruction of large vegetated areas by tephra fall, lava flows and jökulhlaups. Between 3000 and 4000 km^2 were severely affected, whereof several hundred km^2 were permanently laid waste. The drainage pattern of at least a 2000 km^2 subaerial and subglacial area was permanently altered.

Long-term environmental changes brought about by the Eldgjá event are exemplified by the post-Eldgjá jökulhlaups and include 1) lateral extension and raising of the surface of the Mýrdalssandur plain; 2) extension of the sandur coast line to the south; 3) changes in the course of rivers and 4) continuing destruction of vegetated areas by jökulhlaups.

The immediate and long term changes following the Eldgjá event may be the most extensive environmental changes caused by volcanic activity in Iceland since settlement 11 centuries ago.

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ÁGRIP

Eldgos á Kötlukerfi á Nútíma; einkenni þeirra og áhrif á næsta umhverfi

Eldstöðvakerfið sem kennt er við Kötlu er um 80 km langt, breiðast suðvestast og mjókkar til norðausturs (1. mynd). Megineldstöð þess er fjallendið undir Mýrdalsjökli, með allstórri öskju og jarðhitasvæðum.

Gos á Kötlueldstöðvakerfinu á nútíma virðast hafa verið af þrennu tagi:

1) Basísk þeytigos á gossprungum sem opnast undir jökli, líklega oftast innan Mýrdalsjökulsöskjunnar. Þetta eru hin dæmigerðu Kötlugos og jafnframt algengustu gosin bæði á sögulegum og forsögulegum tíma.

2) Súr þeytigos á gosopum sem opnast undir jökli, að því er virðist innan öskjunnar. Vitað er með vissu um 12 slík gos og þau gætu verið fleiri. Þau eru næst algengustu gosin á Kötlukerfinu á forsögulegum tíma.

3) Basísk flæðigos á gossprungum innan megineldstöðvarinnar og á sprungureininni norðaustan Mýrdalsjökuls. Stærstu gosin á Kötlukerfinu eru af þessu tagi. Vera má að mörg þeirra séu í raun blönduð gos, þ.e. bæði þeyti- og flæðigos, vegna þess að hluti gossprungnanna opnast undir jökli. Milli basísku þeytigosanna líða áratugir, milli súru þeytigosanna líða aldir og milli elda á borð við Eldgjárgos og Hólmsárelda líða árþúsund.

Kötlugos á sögulegum tíma eru um 20 talsins og þar af 18 síðustu 1000 árin. Þá er miðað við gos sem brutust upp úr jöklinum og skildu eftir sig gjóskulag í jarðvegi í nágrenni Mýrdalsjökuls (2. og 3. mynd og tafla 1). Kötlugos eru öflug þeytigos og gosmökkurinn hefur náð meira en 14 km hæð á fyrsta degi. Kötlugosum fylgir gjóskufall, jökulhlaup og eldingar í gosmekki. Þau hafa staðið frá 2 vikum upp í meira en 5 mánuði. Gjóskufall er yfirleitt mest fyrstu gosdagana en getur orðið hvenær sem er allan gostímann. Magn gjósku sem komið hefur upp í Kötlugosum er mjög breytilegt. Stærsta gjóskulagið sem myndast hefur í Kötlugosi á sögulegum tíma er talið vera K 1755, og er áætlað magn loftborinnar gjósku um 1.5 km^3 (nýfallin gjóska). Magn gjósku í smæstu gjóskulögunum er tveimur stærðargráðum minna. Meðallengd goshléa síðan um 1500 er 47 ár og mestu frávik í hvora átt 33 og 34 ár. Síðan um 1500 hafa öll Kötlugos hafist á tímabilinu maí-nóvember. Jökulhlaupin eru blanda af vatni, krapa, ísstykkjum og gosefnum. Meginhlaupin í öllum Kötlugosum síðan á 12. öld hafa komið undan Kötlujökli, eftir því sem nú er best vitað (4. mynd). Hámarksrennsli er talið vera á bilinu 100.000 til 300.000 m^3/sek. Magn gosefnanna sem hlaupin bera fram er breytilegt, í Kötlugosinu 1918 er það talið vera milli 0.7 og 1.6 km^3. Jökulhlaupin hafa lengstum verið talin hættulegasti þáttur Kötlugosanna. Eldingar eru algengar í gosmekki Kötlugosa. Þeim getur slegið til jarðar í a.m.k. 30 km fjarlægð frá Kötlu og orðið þar fólki og fénaði að bana.

Að minnsta kosti 12 súr forsöguleg gjóskulög eru ættuð frá Mýrdalsjökli (5. mynd og tafla 3). Útbreiðsla og lögun gjóskugeiranna bendir til að súru

þeytigosin hafi í flestum tilfellum staðið fremur stutt. Þykktarásar gjóskulaganna benda til upptaka innan öskjunnar en ekki er hægt að útiloka að einhver þeirra eigi upptök við jaðra öskjunnar (6. mynd). Magn loftbornu gjóskunnar í þessum gosum er fremur lítið. Gjóskufallssvæði stærsta lagsins á landi er rúmir 15000 km^2 innan 0.2 cm jafnþykktarlínu (7. mynd) og rúmmál gjóskunnar eins og hún er í jarðvegi (þjöppuð) er um 0.16 km^3. Það samsvarar um 0.27 km^3 af nýfallinni gjósku. Yngsta gjóskulagið er um 1700 geislakolsára og það elsta sem þekkt er með vissu er um 6600 geislakols ára (tafla 3). Að minnsta kosti sum þessara gosa ollu jökulhlaupum sem báru vikur til sjávar, því rekja má uppruna sjórekins vikurs á ströndum handan Atlantshafs til þeirra.

Stór flæðigos eru sjaldgæfustu viðburðirnir á Kötlukerfinu. Vitað er um tvo slíka „elda“ á sprungureininni norðaustan Mýrdalsjökuls á nútíma. Þeir fyrri, sem ef til vill mætti nefna Hólmsárelda, urðu fyrir um 6800 geislakolsárum. Í þeim runnu hraun niður Álftaversafrétt frá gossprungum norðaustan Mýrdalsjökuls. Ekki er fullljóst hversu langt þau hraun ná til suðurs því þau eru hulin yngri hraunum að hluta og magn gosefna er því ekki þekkt. Hraunin eru minni að flatarmáli en Álftavershraun og vafalítið einnig að rúmmáli, sem gæti þó verið um 5 km^3. Á 10. öld varð stórgos á gossprungu sem nær frá Kötlusvæðinu til norðausturs um Eldgjá að Stakafelli, alls um 75 km leið (8. mynd). Í því gosi runnu hraun niður Álftaversafrétt og í sjó fram í Álftaveri, og niður í Landbrot og Meðalland. Rúmmál þeirra er a.m.k. 14 km^3 og nýlegt endurmat bendir til allt að 18 km^3. Stærsta gjóskulag sem myndast hefur á Kötlukerfinu á nútíma og varðveitt er í jarðvegi er úr þessu gosi (9. mynd). Mesta mælda þykkt er rúmir 5 m og innan 1 m jafnþykktarlínu eru um 600 km^2. Magn gjósku á landi innan 0.5 cm jafnþykktarlínu er um 2.7 km^3 og áætlað heildarmagn um 4 km^3 (þjöppuð) en það samsvarar um 4.5 og 6.7 km^3 af nýfallinni gjósku, og 0.9 og 1.3 km^3 af föstu bergi. Þetta er líklega fjórða stærsta gjóskulag sem fallið hefur hérlendis á sögulegum tíma. Hugsanlegt er að hluti gosefnanna hafi brotið sér leið frá öskjunni niður í svonefndan Krika, sem blanda af hrauni, gjósku og bræðsluvatni. Rúmmál gosefnakeilunnar þar er lauslega reiknað um 0.5 km^3. Heildarmagn gosefna í Eldgjárgosinu gæti því verið yfir 19 km^3 reiknað sem fast berg. Í Eldgjárgosinu flæddu jökulhlaup fram sunnan Öldufells yfir Álftaversafrétt, og fram úr Krika sunnan Sandfells en ekki er vitað hversu vítt þau fóru neðan Rjúpnafells. Hlaup fóru einnig til norðurs út á Mælifellssand.

Gos á Kötlukerfinu hafa valdið einhverjum mestu umhverfisbreytingum sem orðið hafa á láglendi Íslands á sögulegum tíma. Eldgjárgosið breytti landslagi, vatnafari og nýtingarmöguleikum á stórum landssvæðum á Suðurlandi. Eldgjárgjóskan olli varanlegu tjóni á gróðurlendi þar sem þykkt hennar var meiri en 1 metri á Álftaversafrétti, á Snæbýlisheiði og í nágrenni gossprungunnar. Eldgjárhraunin runnu að hluta yfir gróið land og þau breyttu einnig farvegum vatnsfalla. Eftir Eldgjárgos hafa öll meginhlaup í Kötlugosum farið um skarð Kötlujökuls niður á Mýrdalssand, en stórhlaup um skarð Sólheimajökuls hafa lagst af. Með Eldgjárgosinu hófst sú þróun sem leitt hefur til myndunar Mýrdalssands eins og við þekkjum hann í dag.

Fyrir gosið í Eldgjá er líklegt að stórir hlutar svæðisins, sem nú er sandur og hraun, hafi verið grónir og Álftaversafréttur ofan Rjúpnafells gæti hafa verið algróinn. Þykkur jarðvegur hafði myndast á hraununum frá Hólmsáreldum og sums staðar á þeim rann Hólmsá í farvegi með þykkum jarðvegsbökkum, líkt og nú eru við farveginn hjá Hrífuneshólma. Vatnagangur hefur verið minni þá en nú, bæði vegna minni jökuls og vegna þess að fyrir Eldgjárgos fóru jökulhlaup einnig um skörð Sólheimajökuls og Entujökuls. Jökulgarður norðan við Álftaver hefur hlíft því við vatnagangi (8. mynd) og gæti vel hafa haldið uppi stöðuvatni. Þyrping af gervigígum ofan við jökulgarðinn bendir til að þar hafi hraunið runnið út í vatn eða yfir bleytur. Jarðfræðilegar aðstæður styðja því lýsingu Landnámu á staðháttum og atburðum á fyrstu áratugum norræns landnáms. Ekki er vitað hvar eða hversu mikið tjón varð af völdum jökulhlaupanna því ummerkin eru horfin undir framburð yngri hlaupa. En leiða má að því líkur að viðurnefnið „aurgoði“ á syni landnámsmannsins Hrafns hafnarlykils sé örstutt lýsing á aðstæðum á óðali sem áður var kennt við skóg (Dynskóga).

Eldgjárgosinu fylgdi lengsta goshlé sem vitað er um á sögulegum tíma á Kötlukerfinu en ekkert Kötlugjóskulag er þekkt frá næstu 200 árum (tafla 1). Vafalítið hefur eitthvað af þeim svæðum, sem gosefni úr Eldgjárgosi spilltu, gróið upp á þeim tíma og orðið byggileg, á ný, t.d. með jöðrum hraunanna, líkt og gerðist á Brunasandi eftir að Skaftáreldahraun rann. Sagnir um byggðahverfi á Mýrdalssandi á fyrstu öldum eftir norrænt landnám, hvort heldur sem er fyrir eða eftir Eldgjárgos, eru ekki í neinni mótsögn við jarðfræðilegar aðstæður.

Þegar gos hófust á ný í Kötlu eftir rúmlega 200 ára goshlé voru aðstæður breyttar. Jökulhlaupin fóru nú öll um skarð Kötlujökuls út á Mýrdalssand. Þegar Álftavershraunið rann hækkaði það landið austantil á svæðinu. Vesturjaðar hraunsins hefur í fyrstu risið miklu hærra yfir sandinn en nú og lokað leiðum vatns til austurs. Meðan svo var hljóta hlaup að hafa lagst af meiri þunga á svæðið vestan hraunsins þar sem land var lægra. en jafnframt hækkað sandinn þar og fært ströndina fram. Hafi gosefnakeilan í Krika myndast í Eldgjárgosinu hefur land einnig hækkað norðan við núverandi Kötlujökul og beint bræðsluvatni og jökulhlaupum til suðurs um svæðið milli Höfðabrekkuheiðar og Álftavershrauns. Sandurinn er nú jafnhár hrauninu á köflum og hefur kaffært hraunjaðarinn á stórum svæðum.

Ekki er ljóst hvers vegna Kötluhlaup fara nú um skarð Kötlujökuls fremur en hinna skriðjöklanna tveggja, Sólheimajökuls og Entujökuls. Vel er líklegt að stórgos eins og Eldgjárgos hafi áhrif á allt eldstöðvakerfið og geti valdi breytingum á kvikugeymum og landslagi, t.d. í öskju megineldstöðvarinnar. Þar undir hafa fundist merki um grunnstætt kvikuhólf. Það er allrar athygli vert að ekkert súrt Kötlugos er þekkt frá síðustu 1700 árum, sem er lengsta goshléið í um 7000 ár. Einnig má benda á að öll súru Kötlugosin, sem þekkt eru með vissu, urðu milli tveggja elda, þ.e. Hólmsárelda og Eldgjárgoss, og efnasamsetning kvikunnar hélst furðu stöðug þann tíma en er frábrugðin efnasamsetningu súrrar kviku sem upp kom í gosi í lok ísaldar. Vera má að stóru viðburðirnir valdi breytingum á kvikukerfinu, sem helst síðan nokkuð stöðugt þess í milli. Upphleðsla gosefna eða sig á botni öskjunnar gætu skýrt breyttar hlaupleiðir, einnig breytt ísþykkt og ekki síst breytt lega gosstöðva.

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Grains of silicic Katla tephra. The largest grains (shown in both photographs) are about 4 cm long. See also text on page 9. – *Súr Kötlugjóska, sjá bls. 23. Stærstu kornin, sem eru stækkuð á neðri myndinni, eru um 4 cm löng. Glerið í þeim myndar trefjar sem brotna auðveldlega í smærri nálarlaga korn.* Ljósmyndir/*Photos.* Ævar Jóhannesson.