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Volcanism, environmental forcing and the archaeological record.

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INTRODUCTION

In the summer of 1783 AD toxic gases from the Icelandic Laki fissure eruption were transported in through the atmosphere to Western Europe. This paper describes the dramatic environmental forcing and social responses, which followed. As an environmental catastrophe this event has few equals, yet there is little memory of it in folk lore, little evidence in the palaeoenvironmental record and no suggestion, outside Iceland, that people abandoned territory or were forced into conflict with their neighbours in competition for scarce resources. However, all the above are inferred as the consequences of far smaller eruptions of which we know far less and for events which may have a similar environmental consequences such as a bolide impact. This paper also presents the latest developments in ongoing research into the diverse environmental impacts of the Laki Fissure gases in Europe during the summer of 1783. , presents further detailed analysis of the environmental impact of the 1783 Dry

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Fog in Europe (Camuffo & Enzi, 1995; Grattan & Charman, 1994, Grattan & Brayshay, 1995; Grattan *et al.*, 1998). In particular it presents material recovered from documents from the Netherlands, France and Germany.

THE LAKI FISSURE ERUPTION: VOLATILE EMISSION AND GAS DISPERSAL

The Laki fissure eruption began on June 8 1783 and continued until early February 1784 (Thórarinnsson, 1969). During this period approximately 9.9×10^{13} grammes of acid were emitted of which 9.19×10^{13} grammes were sulphuric acid (Thordarson and Self, 1993), with hydrochloric and hydrofluoric acids included in the remainder (Péttersson *et al.*, 1984). Thordarson and Self (1993) suggested that 60% of the total volume was discharged over the first 48 days in five eruptive episodes, the first three of which occurred between June 8 - 14th. Estimates of the discharge of SO_2 based on this work indicate a daily acid discharge of 1.38×10^{12} grammes during June and July.

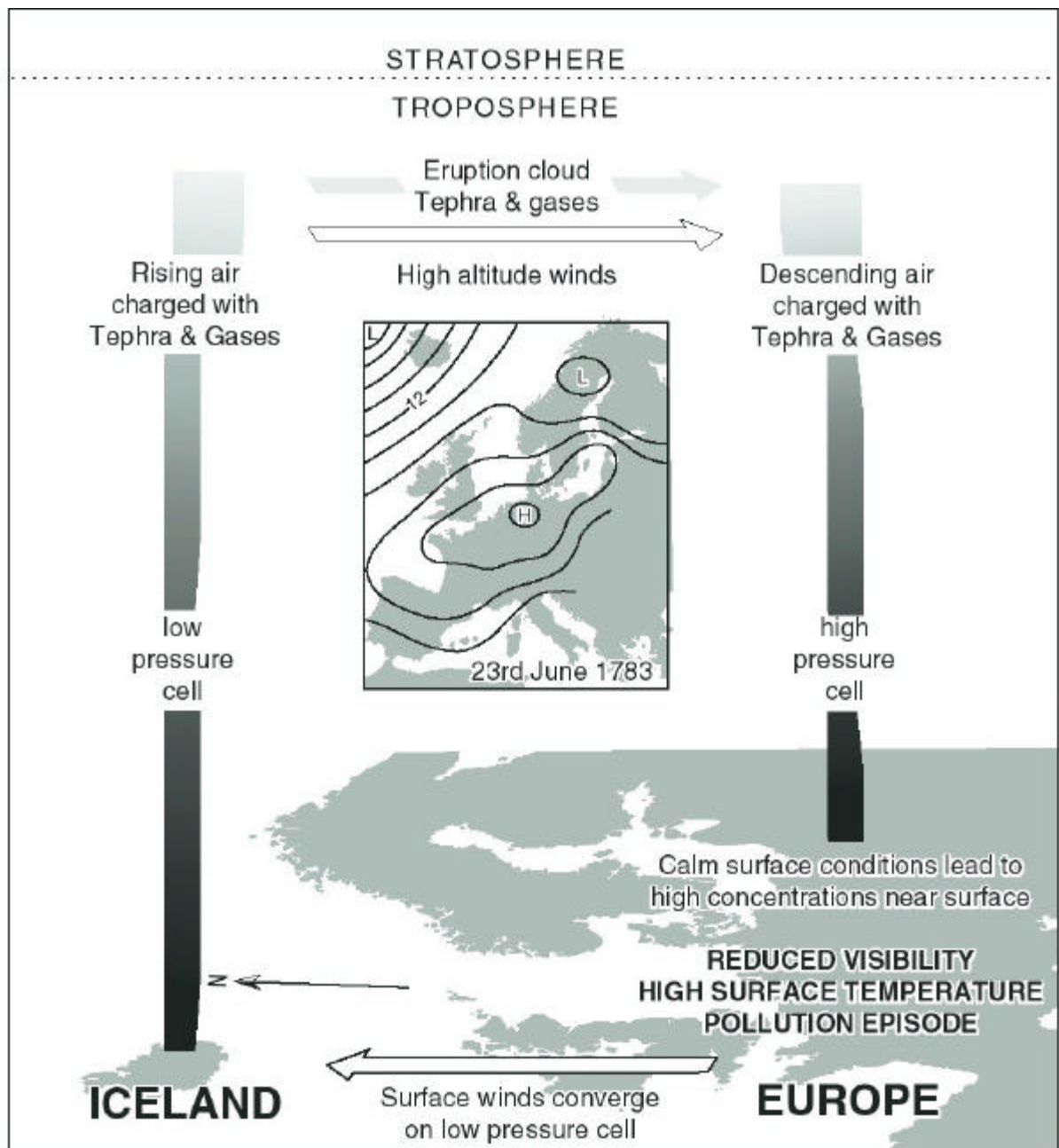


Figure 1. Transport and dispersal of volatile volcanic gases.

Fissure eruptions rarely possess sufficient energy to penetrate the stratosphere (Tripoli and Thompson, 1988) and Thordarson and Self (1993) concluded that although the Laki eruption frequently possessed sufficient energy to reach altitudes of 5km above sea level, the majority of emitted material was confined to the troposphere. The dispersal of material ejected to these altitudes depends on the speed and direction of high level rather than surface winds. While low level winds travel towards a low pressure centre, high altitude winds converge on high pressure areas. Anticyclonic weather dominated Europe's weather between June 21 and July 20 while a low-pressure area existed in the vicinity of Iceland (Kington, 1988). Volcanic material may therefore have been transported to Europe by high altitude convergent winds.

DESCRIPTIONS OF THE EXTENT OF THE SULPHUROUS FOG.

An important development is that for the first time eye witness accounts of the presence of the sulphurous fog in southern France and central Germany have been discovered. Previously these had only been reported third hand through traveler's tales and were open to question. Father Cotte recorded the presence of a sulphurous fog:

"Ces Brouillards, en certain Pays, comme en Provence et ailleurs avoient une odeur fétide, sulfureuse, et picotoient les yeux".

"These Fogs, in other countries, as in Provence and elsewhere bring a sulphurous stinking odour, which stings the eyes".(Cotte, 1783).

The fogs were also observed by many observers in the Department D'Eure et Loir and the Departement du Loiret (Rabartin & Rocher, 1993).

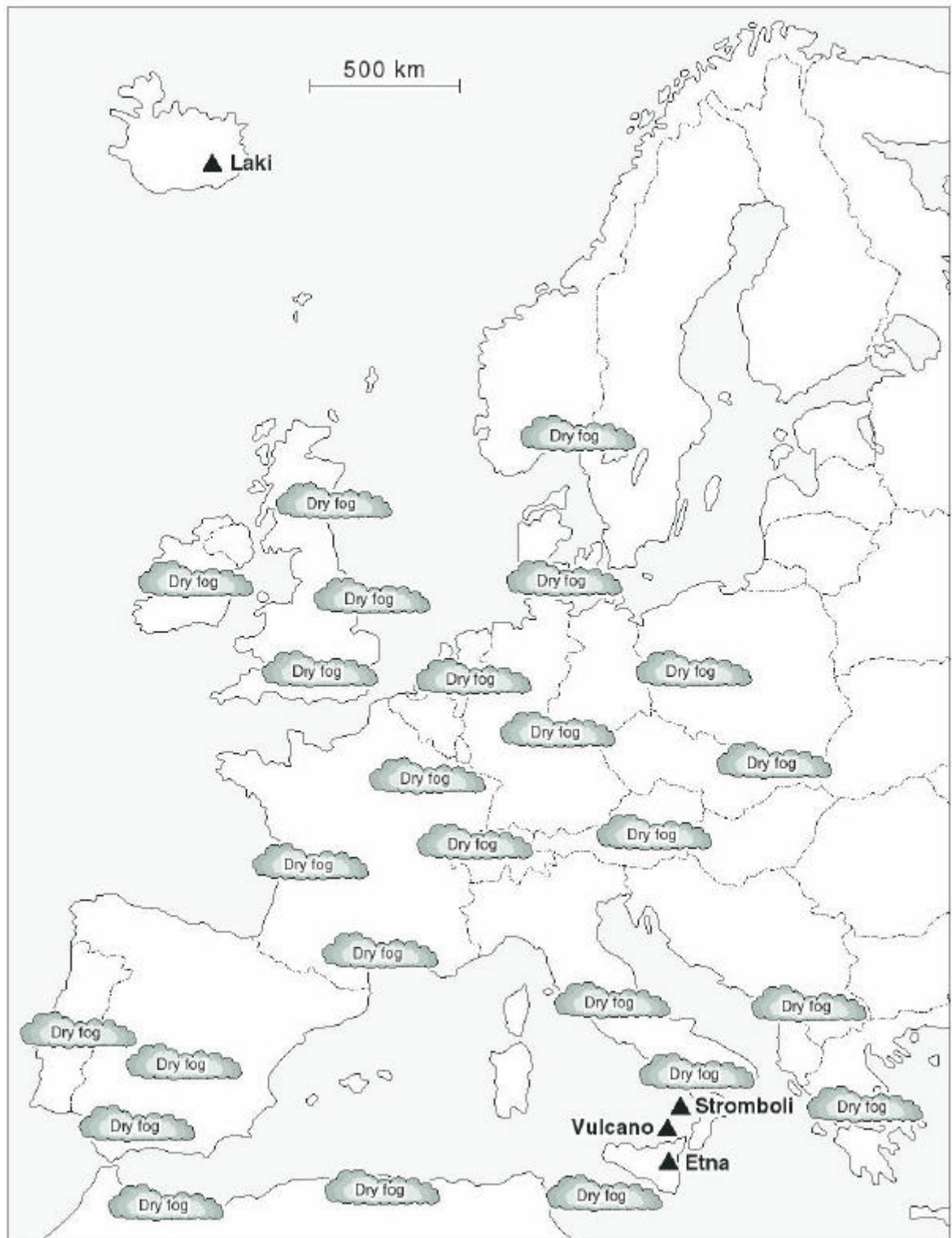


Figure 2. The extent of the Dry Fog in 1783.

A regional German Newspaper also drew attention to the strange phenomenon:

" Brief aus Mannheim, July 1st. Seit Juni 17. ein Nebel hat fortbestanden den tag und nacht und kann zweifellos gelten als ein außerordentliches phänomen. Die ältesten leute können nicht ähnliches, nichts überhaupt erfahren zu haben sich erinnern. Dieser nebel kommt vom Nordosten, und ist in den Bergen so allgemein, wie er auf den ebenen ist. Er ist auch sehr trocken, der durch das hygrometer nachgewiesen wird ..., welches die Sonne eine rote Farbe wie glühendes eisen hat und während des tages er, mit einer stifling hitze"

"Letter from Mannheim, July 1st. Since June 17th a fog has persisted day and night and can certainly be considered an extraordinary phenomenon. The eldest people cannot remember having ever experienced anything similar. This fog comes from the north-east, and is as common in the mountains as it is on the plains. It is also very dry, which is proved by the hygrometer. ... the sun has a red colour like glowing iron, and during the day it is very pale, with a stifling heat". (Meiningen Wöchentliche Nachrichten, July 12th).

Similar reports may be found in other German newspapers of the same date, in particular the "*Frankfurter Staatstistretto*" reported the fog and associated panic and alarm in its editions of the 12th and 17th July.

SOCIAL UNREST AND PANIC

The presence of the fog caused much panic and alarm in Britain, and British newspapers of the time reported similar responses amongst the peoples of the continent (Grattan & Brayshay, 1995). The descriptions presented below suggest that the sense of panic was greater in France and Germany than it was in Britain.

"La Peuple veut encore que le Curé ou le vicaire de la paroisse se tienne alors à la porte de l'église, revêtu du surplis et de l'étoile, avec de l'eau-bénite, pour faire L'exorcisme, comme si les nuages orageux étoient des diables ... Cette simplicité, ou plutot cette supertitiion, qui n'est pas pardonnable a des Peuples d'un Diocèse".

"The People wished the Priest or the vicar of the parish to hold an exorcism at the gate of the church. In full regalia, with holy-water, as if the stormy clouds were devils. ... Such simplicity, or rather such superstition, is not forgivable in a Christian people".(Anon, 1784).

Le Peuple, toujours étonné par la nouveauté des phénomènes don't il ignore les causes, en imagine ordinairement d'absurdes qui ajoutent a son effoi"

The People, astonished by these phenomena and unaware of the causes, believe every absurdity which they hear or imagine"(Anon, 1784).

"Nous avons été témoins de ces inquiétudes pendant la durée des brouillards qui ont régné cet été. Une terreur panique s'étoit emparée des esprits: on cherchoit la cause des ces brouillards"

" We have experienced disquiet during the fogs, which lasted all summer. Panic and fear seized one's spirits: we feared as to the cause as of the these fogs" (Cotte, 1783).

Fear of god, and belief that Armageddon was imminent is apparent in the tone of much of the correspondence of the period. These worries were not helped by the impact of the dry fog upon human health.

IMPACTS UPON PEOPLE

As more documents come to light it is clear that the impact of the fog upon human health could be profound (See also Grattan *et al.*, 1998).

Il fatiguoit les yeux; et a Sallon, les personnes qui ont la poitrine délicate, en étoient désagréablement affectées. Les habitants du Champsuar m'ont dit, que plusieurs personnes chez eux avioent eu de maux de tête et qu'en général ils avoient perdu une partie de leur appetit."

" It tires the eyes; and in Sallon, those people who have a weak chest, have endured some disagreeable symptoms. The inhabitants of Champsuar told me, that many people in the town have had headaches and that in general they have lost part of their appetite" (Anon, 1784).

"Ces gens avec les coffres faibles ont éprouvé une sensation semblable à cela éprouvée une fois exposées brûlant au soufre"

"Those people with weak chests experienced a similar sensation to that experienced when exposed to burning sulphur" (Swinden, 1786)⁴³

"Au commencement du mois de mars 1784, la paroisse de Champersu a été affligée d'une maladie pestillentielle; les malades se sentoient pris à la gorge. On prétend que les brouillards des mois de may, juin, juillet et août 1783, qui offusquoient le soliel qui paraissoit rouge comme du sang, pronostiquoient ce fléau".

"To the beginning of March 1784 and through the previous summer the parish of Champersu has been afflicted by an pestilence which afflicted the throat. One believes that the dry fogs of May, June, July and August (1783), that turned the sun

as red as blood delivered this curse” M. Dreux, Curé of Umpeau , Departement D'Eure et Loire (Rabartin & Rocher, 1993)

“ the fog ... is the cause of the tingling felt in the hands. eyes, lips and throat”
(Harreax, 1858)

Loss of appetite, difficulty breathing, engorgement of the throat, tingling of the hands and eyes are all symptoms of significant air pollution in excess of current guidelines for human health.

IMPACTS UPON PLANTS AND ANIMALS

New documents confirm earlier suggestions of the profound impact of the sulphurous fog upon vegetation.

"Quoique ce brouillard sût naturellement sec par la qualité, il devint cependant humide avec le vent d'est qui régna le 26, le 27, et le 28 Juin. Pendant ces trois jours, il deposa dans la nuit sur les végétaux un eau épaisse et gluante, d'un goût désagréable et un peu fetide. Cette Liquer laissa des traces de la plus grande cuasticite, les fleurs don't la vignes les oliviers étoient chargées surent brûlées, et tombèrent en très grande partie. Les Plantes légumineuses, comme les pois, les courges, les melons etc. surent très-mal traitées. Les Feuilles des arbres, et notamment celles des peupliers exposes a vent d'est, furent fletries. ... Ce brouillard ... etoit de la couleur de la fumée; il en avoit même l'odeur âcre et piquante"

Though this fog was naturally dry, it became wet during the east wind which blew from the 26 - 28 of June. During this time, at night, it deposited a sticky fluid on the vegetation. This had an unpleasant taste and a smelt a little fetide. This liquor was caustic and burned the flowers of the vine and the fruit of the olive, which fell to the ground. The leguminous plants, like peas, marrows, melons etc were very badly damaged. The leaves of trees, most notably those of the poplar were damaged. ... This fog... which was the colour of smoke had a bitter acrid odour" (Marcorelle, 1784).

List of Plants Affected by the Fog. Summarised from Brugmans 1787.

Plants that suffered the most Plants that suffered considerably Plants that suffered slightly Plants that were barely harmed.

Acorus calamus	Avena sativa	Acer	Aloe
Asphodelus luteus	Clematis erecta	Antirrhinum linaria	Brassica
Cal. officianalis	Fagus Castanea	Artemisia	Digitalis purpurea
Corylus avellana	Fagus sylvatica	Cannabis sativa	Hedera arborea
Hypericum spp.	Geranium	Chenopodium	Juniperus
Pinus silvestris	Graminae spp.	Erica	Lavendula Spica
Pinus cedrus	Helianthus annuus	Lupulus	Lemna gibba
Pinus abies	Mimosa sensitiva	Myrica gale	Lotus corniculatus
Populus alba	Papaver	Plantago lanceolata	Potentilla
Salix spp.	Primula veris	Ranunculus	Quercus robur
Vicia faba	Rumex	Tilia Europaea	Saxifraga
Populus nigra	Sagittaria	Triticum aestivum	Urtica urens



Figure 3: The extent of damage to vegetation in 1783.

DISCUSSION.

It can be seen above that the impact of the social and environmental impact of Laki fissure eruption upon Western Europe was profound. The event exhibits all an archaeologist could wish for or infer in an episode of major environmental forcing; damage and destruction of crops, human illness, social unrest that approached panic and fear of God. Most archaeologists or prehistorians would be content to use this event as a model to account for significant changes to vegetation or settlement pattern, which may have been inferred from the available records. The various tephra falls in Scotland and inferred settlement and pollen responses are a case in point. Yet the events of 1783 left no lasting trace. There is no folk memory of summer of 1783, there was no famine, indeed severe as it was there is as yet no trace of the dry fog in the environmental record at all.

The lessons to be drawn from the events of 1783 are twofold. First that the impacts of volcanic eruptions upon peoples far distant from the eruption may be severe. Second that it is dangerous to use the coincidence of a remote environmental forcing mechanism to explain dramatic changes in vegetation and settlement.

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