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BRIEF COMMUNICATION

On the mystery cloud of AD 536, a crisis in dispute and epidemic ergotism: a linking hypothesis

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In AD 536, some kind of natural catastrophe(s) darkened the sun by what has been called a mystery cloud or a dust veil. The darkening of the sun lasted for over a year and initiated dramatic changes of the climate in the Northern Hemisphere, resulting in a series of cold 'years without summer'. This climatic disaster has been linked to the so-called Migration Period crisis in Scandinavia, a time of population decline and reforestation of agricultural land. The extent of these changes and the relative importance of possible factors involved are matters in dispute; failed harvests and famine, plague, war and social changes have been discussed so far. The present comment puts forward the hypothesis that epidemic ergotism due to widespread contamination of food and fodder by poisonous ergot (*Claviceps purpurea*) also may have been a contributing factor. The main reason being the extreme weather conditions, which became exceptionally favourable for growth and spread of this highly toxic fungus in crops and pastures for several years in a row after the AD 536 event. It is pointed out how the ecological and toxicological characteristics of ergot are consistent with an irregularly distributed depopulation, a need of several generations for recovery, an extensive reforestation of agricultural land and migration of settlements from lowlands to higher grounds. It is also argued for the possibility that the wording in two verses of the Old Norse poem *Völuspá* actually was inspired by long-time memories of illness due to ergotism.

Keywords: Migration Period; Scandinavia; AD 536; *Claviceps purpurea*; ergot; ergotism; archaeobotany; osteoarchaeology; *Völuspá*

Introduction

In AD 536, some kind of natural catastrophe(s) initiated a decade of exceptionally cold climate in the Northern Hemisphere, as will be discussed more in detail below. This event, at the end of the Migration Period, has been linked to a demographic decline in Scandinavia. Failed harvests and famine, the Justinian plague, war and social changes have been put forward as possible elements in the much debated picture of what some call the Migration Period crisis. Not only the nature but also the extent of this demographic decline is a matter of debate, and there are scholars being sceptical as regards the use of 'crisis' as a proper designation for the changes taken into consideration (Näsman 2009, p. 107, 2012). Uncertainty about what may have happened is reflected by a conclusion in the proceedings from a joint Scandinavian conference on this topic: 'From the debate […] it is obvious that we have not yet reached any consensus as regards the understanding of the archaeological source material – neither its representativity nor its interpretation' (Näsman 1988, p. 228, our translation). There are still questions to be answered (Näsman 2012). Due to what is known about the Scandinavian climate and agriculture at the time in question, we want to draw attention to a hitherto overlooked factor worth including as a hypothesis in the ongoing debate – epidemic outbreaks of ergotism, i.e. food poisoning by ergot. Why and how ergot may have played a role even more serious than plague in a possible demographic crisis at the end of the Migration Period will be discussed in detail after a brief background on the ecological and toxicological characteristics of this highly poisonous organism.

Ergot

Ergot is a plant disease caused by the parasitic fungus *Claviceps purpurea*, which infects the developing grains of cereals and grasses. Rye is especially vulnerable, but the disease also affects barley and wheat and some 300 other plant species. The infected kernel is replaced by a seed-like sclerotium – the ergot (Figure 1) – containing fungal mycelium surrounded by a dark rind (Johnson 2013, Anon 1). The ergot is a 'chemical factory' producing more than 200 compounds, which include many different alkaloids with various powerful physiological properties (Lee 2009). The mix of components in this 'drug cocktail' and the ensuing toxic effects on humans and animals are influenced by a number of factors including the type of host plant, the soil and topography where the host plant grows and the climate during ergot formation (Matossian 1989, p. 13).

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Figure 1. Ear of rye with two toxic black ergots (Greenish 1920, p. 219).

One of the most important facts pertaining to the following discussion about a Scandinavian demographic crisis in the sixth century is the climate requirements for optimal growth of this fungus. It thrives when a freezing winter is followed by an overcast wet spring and cool summer (Matossian 1989, pp. 13f, Anon 1).

Ergot poisoning

It is beyond the scope of this brief communication to describe in detail the bewildering array of symptoms caused by ergot poisoning, ergotism. Suffice it to say that they include – among many other things – hallucinations, convulsions, miscarriage, reduced fertility and gangrene causing digits or hands or feet and even entire limbs to blacken, mummify and fall-off (Schumann 2005, Lee 2009). Written accounts of ergot poisoning are on record back to the 900s AD, and epidemics of the disease were common during the Middle Ages when gangrenous ergotism was known as the frightening 'Saint Anthony's fire' (van Dongen and de Groot 1995). It shall be underlined that ergot poisoning often was a lethal disease. During 10 epidemics of ergotism documented in the 1800s, the mean mortality rate among those who were taken ill was over 40%. The danger from ergot is compounded through its alkaloids being both potent and hardy. Disease occurs when the harvest of grain and the food prepared from it is contaminated by a certain share of ergots; as little as 2% in the grain used for bread can cause community-wide ergotism. Ergot alkaloids are also very stable and can retain their toxicity in the harvest for more than a year. In addition, their toxicity is not neutralized by baking at low heat or boiling for up to 3 hours (Matossian 1989, pp. 7, 12, 14).

Another point of importance to the following discussion is that children and teenagers are especially susceptible to food contaminated by ergot, since they – compared to adults – consume more food and thereby more toxins per unit of body weight. Furthermore, ergot toxins can pass into mother's milk, as well as the milk of domestic animals feeding on contaminated grass (Matossian 1989, pp. 9, 12).

Prehistoric ergot in southern Scandinavia

Occurrence of ergot in Scandinavia during the Migration Period has been demonstrated by archaeobotanical analyses of carbonized material from burnt houses in Sorte Muld on Bornholm and in Vallhagar on Gotland (Helbæk 1957, p. 272). Earlier presence of ergot is known from Jutland through the gut contents of the world famous bog body Grauballe Man, who had his throat cut some time 400–200 cal BC (Harild *et al.* 2007, pp. 175f, Heinemeier and Asingh 2007, p. 201). An even older find of ergot is on record from Vårgårda in south-western Sweden. The carbonized material in question – associated with a presumed harvest offering – has been dated to *c*. 630–550 BC by ^{14}C-analysis (uncalibrated, Regnell 2006, p. 50). Thus, at least 2500 years have passed since ergot first occurred in Scandinavia – where it still is present (although not much heard of due to control and counter-measures).

Since rye (*Secale cereale*) is especially vulnerable among the many host plants affected by ergot, the cultivation of this cereal in the 6th century AD is of particular interest regarding the hypothesis presented in this paper. In Denmark cultivation of rye appears to have been a fundamental component of the agriculture, at least locally, from the Roman Iron Age onwards (Grabowski 2011). A telling example is the gut contents of the Huldremose Woman, one of the famous bog bodies from Jutland; rye was a main ingredient in her last meal before she died around AD 100 (Asingh 2007, p. 296). Furthermore, the composition of carbonized straw in the remains of fillings from iron-smelting furnaces constitutes evidence of well-tended rye fields on Jutland at the end of the Roman Iron Age (Henriksen 2003). At that time, cultivation of rye was also established in Halland and Scania in southern Sweden, as well as the islands of Bornholm, Öland and Gotland in the Baltic Sea (Helbæk 1957, p. 264, Grabowski 2011). In southern Norway, the cultivation of rye has been traced back to the 5th century AD in Vestfold and Rogaland. It is not for nothing that the etymology of the county Rogaland

– and its inhabitants called *ryger* – can be traced back to words used for rye (Alm and Elvevåg 2012). To summarize: both ergot and one of its preferred hosts, rye, were part of the landscape being cultivated in southern Scandinavia in AD 536.

The climate change in AD 536 – perfect for ergot

In March of AD 536 people saw 'a most dread portent'; the sun darkened, became bluish and lost its brightness. It reminded of a solar eclipse, but the dimming of the sun lasted for over a year and was followed by unseasonable chill and failed harvests – all according to surviving records from several contemporary writers in the Mediterranean region and the Middle East (Stothers 1984, Arjava 2005, Gräslund and Price 2012). The cause(s) of this so-called 'mystery cloud' or 'dust veil' of AD 536 remains unclear. Volcanic eruption, meteorite impact or exploding comet, singular or plural – possibly in combination – are alternatives put forward (Stothers 1984, Rigby *et al.* 2004, Abbott *et al.* 2008, Gräslund and Price 2012). In order to put the magnitude of what happened into perspective, it can be mentioned that estimates of the atmospheric dust load caused by the AD 536 event(s) indicate that this was about twice as large as the one caused by the explosion of Tambora in 1815 (Stothers 1984), which is considered to be the last millennium's greatest volcanic eruption on Earth and the cause of a 3-year period with drastic global changes of the climate, resulting in worldwide failure of crops and famine (Wood 2014, pp. 2, 9–10). Although it remains unclear what exactly happened in AD 536, it is unquestionable that some kind of natural catastrophe(s) had dramatic effects on the climate in the Northern Hemisphere. Physical evidence is provided by dendrochronology (for references, see Gräslund and Price 2012). It is of particular interest that tree rings show a period of very slow growth for Scandinavian pines, beginning in AD 536 and continuing for the next 10 years. Since the growth of pine is determined by July temperatures (Arjava 2005), this finding indicates a series of exceptionally cold summers in Scandinavia at the end of the Migration Period. Furthermore, the event(s) under discussion also led to a period of colder winters and increased humidity (Gräslund and Price 2012). In other words: the extreme climate change beginning in AD 536, with a darkened sky, colder winters, wet springs and cold summers, constituted optimal conditions for growth of ergot.

In addition, it is quite possible that the cultivation of rye was accelerated in Scandinavia by the climatic catastrophe of AD 536. Rye, being the most frost-resistant of the cereals, could still be harvested when the crops of barley and wheat failed due to unfavourable weather conditions (Tvauri 2012, p. 104). The ability to grow on poor soils is another factor making rye highly competitive vis-à-vis other cereals (Behre 1992).

Long-term demographic effects of epidemic ergotism

Thus, we have so far established that the preconditions for food poisoning by ergot – the fungus itself, vulnerable foodstuffs and ideal weather – all coexisted in Scandinavia in the mid-sixth century. In the following, we will outline the hypothesis presented in this paper by discussing *how* widespread, epidemic ergotism may have contributed to the so-called Migration Period crisis, when the population of Scandinavia was reduced, perhaps by as much as half, and large areas of agricultural land returned to forest (Gräslund and Price 2012). We will elucidate this from several points of view: acute mortality, reduced birth rate, affected livestock and religious reactions.

As to acute mortality, we have already mentioned the experience from epidemics of ergotism recorded in the 1800s, when the death toll among those being affected averaged around 40% and could be as high as 70% in some places. For comparison, it can be mentioned that these figures are quite similar to the case mortality from bubonic plague before the era of antibiotics (Walløe 2008). There is, however, one important difference between ergotism and plague: those who survive poisoning by ergot do not develop any immunity to the disease – unlike survivors of plague. On the contrary, those who once have been affected by ergotism are, for unknown reasons, more sensitive to the poison at repeated exposures (Matossian 1989, p. 12). This constitutes a significant risk factor to keep in mind in a long-term perspective since ergot can be expected to have shown exceptionally abundant growth for several years after AD 536 due to the continuation of harsh weather and a probably increasing share of rye in the crops, as outlined earlier.

Regarding depopulation, reduced birth rate is an important effect of ergotism with several long-term aspects worth taking into consideration – not the least in perspective of the estimation that it took up to seven generations before the cultural landscape had recovered from what is called the Migration Period crisis (Gräslund and Price 2012). First, as mentioned earlier, women in childbearing age and younger girls – the next generation – belonged to those at highest risk to die from ergotism. Second, abortion can be induced by ergot alkaloids. In a Russian report from an outbreak of ergotism in 1896, it was concluded that 'if a pregnant woman got ergotism when she was in her first trimester, she aborted; if in her sixth or seventh month of pregnancy, the child died after birth'. It can be added that initially surviving infants born by mothers with ergotism also run a high risk of being affected and eventually die, since ergot toxins pass over in the mother's milk (Matossian 1989, pp. 9, 23). Alternatively, the babies soon died from starvation, if the ergot eaten by their mothers contained a certain alkaloid inhibiting milk production (Lee 2009). Finally, on top of all the other negative effects, ergot toxins also suppress fertility – the very ability to become pregnant (Matossian 1989, p. 9, Schumann 2005). Thus, if there were repeated epidemics of ergotism during the years without summer after AD 536, they can be expected to have had marked demographic effects for several generations.

As regards the livestock, there is a fundamental difference between epidemics of plague and epidemics of ergotism. Whereas plague spares livestock (Anon 3 2009, p. 5), ergotism affects cattle, pigs, horses, sheep and any other domestic animal (including poultry) feeding on grass or grain contaminated by ergot. The disease has also been documented in wild animals, e.g. moose and roe deer (McMullen and Stoltenow 1998, Uhlig *et al.* 2007). The effects are the same as in humans, including convulsions and gangrene. Even small amounts of ergot fed to cows may result in loss of milk and abortion (McMullen and Stoltenow 1998). Thus, infestations by ergot affect not only the utility of cultivated land for crops but also the utility of meadows and pastures to feed the livestock. Thus, if there were repeated epidemics of ergotism following the change of climate in AD 536, they may apparently have contributed to a widespread return of agricultural land to forest during the so-called Migration Period crisis.

In view of what is told in historical records from Scandinavia, we think that the possibility of religious beliefs connected to ergotism also deserves a comment – despite the duly noted lack of source material from the sixth century itself. Although it is questionable to generalize between societies separated in time by more than a millennium, it does not seem entirely unreasonable to assume that people in the mid-sixth century were affected by ideas about supernatural dangers like people in the 1600s – a century ravaged by witch hunts. A noteworthy aspect of this dark chapter in history is that some of these persecutions most likely were caused by ergot poisoning believed to be witchcraft, a felony punished by death. General economic crises then aggravated these responses (e.g. Behringer 1999, Pfister 2007). Extensive and detailed contemporary trial documentation from Norway provides strong support of the ergot hypothesis (Alm 2003). It is not unthinkable that people in the sixth century may have drawn the same conclusion – i.e. that the frightful symptoms of ergot poisoning were caused by black magic – resulting in the search for scapegoats and death sentences on top of the casualties from ergotism. Judging from the irrational reactions among people during the Black Death in the mid-fourteenth century, the death toll among such designated scapegoats may have been considerable. At that time, Jews were collectively accused of poisoning the water used by Christians and thereby causing the plague. The result was horrible pogroms with many casualties, especially in Germany (Harrison 2000, pp. 237ff). Another atrocity – practised in Sweden and Denmark – was ritual sacrifices of children, who were buried alive to avert the plague (Harrison 2000, p. 234). It cannot be excluded that reactions similar to those caused by the plague in the fourteenth century also were triggered by possible epidemics of ergotism 800 years earlier. What we definitely do know from contemporary written sources is that Mediterranean people interpreted the long darkening of the sun in AD 536 as a most dreadful omen of disaster (Arjava 2005). Scandinavians looking at the same darkened sun may have reacted in much the same way, as has been discussed on the basis of numerous gold deposits thought to be offerings to higher powers in order to have a dying sun restored (Axboe 1999, 2007, pp. 117ff, 156ff, Bondesson and Bondeson 2012). Another example of strong religious impact in this context is the conception that memories from the cold period of years without summer, following the darkening of the sun in AD 536, eventually were incorporated with Norse mythology as the terrible *Fimbulvinter*, which will foretell the end of the world in *Ragnarök* (Axboe 2007, pp. 121, 157, Gräslund and Price 2012). Interestingly enough, one of the earliest known written accounts concerning Norse mythology – the poem *Völuspá* in the Icelandic *Codex Regius* from the thirteenth century (KL 1976) – does not end with *Ragnarök*, but instead with a short comment on the subsequent rising of a new world. In one of the latter verses, there is a passage of particular interest regarding the hypothesis presented in this paper: *Muno ósánir akrar vaxa, bǫls mun allz batna* (Brøgger 1994, p. 114). Translations of this wording basically say that unused arable land will prosper and evil things will cease – e.g. 'On unsown acres the ears will grow, all ill grow better' (Hollander 1990, p. 12). One possible interpretation of this passage is that fields being prosperous in the new world had been unusable in the old one because of illness and therefore had been unsown, i.e. they had been lying in fallow. In line with this interpretation, one may speculate if the poet was influenced by long-time memories of devastating illness caused by something coming from the fields – like ergot. In fact, the passage about a '…wolf age ere the world crumbles…' in a previous verse of *Völuspá* (Hollander 1990, p. 8) dealing with the prelude of *Ragnarök* may well refer to ergot instead of the animal. Based on Germanic mythology, it has been suggested that the wolf was a symbolic embodiment of ergotism in ancient times, being reflected in the folklore by a name for ergot meaning wolf-tooth, and a demon living in the grain fields called the rye-wolf (Bové 1970, p. 5, Gerstein 1974, p. 148).

Ergotism, demographic irregularities and local migration

Archaeological data indicate that the depopulation of Scandinavia and the Baltic countries discussed here had a quite irregular distribution. Some settlements seem to have been more or less deserted, whereas others appear to have remained fairly unaffected (for discussion on source material and references, see e.g. Näsman and Lund 1988, Gräslund and Price 2012, Löwenborg 2012, Tvauri 2014). There is not yet any generally accepted explanation of such an irregularity (Näsman 2012). Epidemic ergotism is hereby introduced as a potential factor in the probably multifaceted background. As already mentioned, the toxicity and effects of ergot may show considerable differences from one time to another and from one place to another due to a number of factors in the environment (Matossian 1989, p. 13). Since rye is especially vulnerable to infestation by ergot, the share of rye in the crops obviously is an important factor from a quantitative point of view; the greater share of rye, the greater risk of ergot intoxication. Geological differences also have influence from one area to another. Soils with low content of certain trace elements, e.g. copper and boron, favour the growth of ergot (Johnson 2013, Anon 2 2008). Furthermore, the soil also influences the synthesis and the mix of various ergot alkaloids, and thereby the effects and the toxicity of the fungus. In addition, not only the weather in general but also local differences in the microclimate regarding both temperature and humidity is important to the growth and the toxicity of ergot (Matossian 1989, p. 13). In summary, it is conceivable that epidemic ergotism might have contributed to a significant Scandinavian depopulation on the whole, but the effects can be expected to have varied considerably from one place to another.

Environmental preferences of ergot also provide a clue to the origin of another observation regarding population geography. Following the AD 536 event(s), it appears that settlements in eastern central Sweden situated near wetlands and watercourses were abandoned and moved to higher and drier grounds nearby. It has been suggested that these relocations were triggered by rising ground water and overflowing rivers causing damage to wooden buildings due to spread of mould facilitated by increased humidity (Gräslund and Price 2012). We think that ergot adversely affecting people and livestock can be added as a possible contributing factor since marshy land with constant dampness favour the growth of ergot as well as mould (Matossian 1989, p. 14). In other words, to move to drier grounds was to move where most survivors lived in times of ergotism.

Concluding remarks

Based on what has been put forward, we suggest that epidemic ergotism should be added to the list of factors discussed concerning the background of demographic changes in Scandinavia linked to the so-called mystery cloud of AD 536 and its effects on contemporaneous climate. Contemporary records and dendrochronology indicate that the weather conditions following the AD 536 event became exceptionally favourable for the growth and spread of ergot in cereals and grass for as long as a decade. Through archaeological finds, it is also known for certain that this highly toxic fungus was an integral part of the mycological flora long before the sixth century in Scandinavia. Regarding the mortality among people taken ill, ergot poisoning equals untreated bubonic plague. For an agricultural society, however, epidemic ergotism can be expected to have an outcome even worse than plague, since ergot poisoning – contrary to plague – affects livestock in addition to the people. This factor, in conjunction with the complex and long-term toxicological effects of ergot, helps to explain certain currently unresolved aspects of the so-called Migration Period crisis in Scandinavia.

As regards future archaeological research dealing with this ‘crisis’ in dispute, it is of interest that physical evidence substantiating our hypothesis – that epidemic ergotism may have been a contributing factor – can be looked for in two ways. One involves archaeobotanical analyses aimed at elucidating the presence and relative proportion of ergot in finds of grain from the time in question. Considering the scarcity of data on prehistoric ergot published so far, however, one may question if the information being obtainable by macrofossil analysis ever will permit any conclusion as to the possible occurrence of epidemic ergotism in Scandinavia at the end of the Migration Period. On the other hand, the hypothesis discussed here may inspire future research focused on this particular issue, not only in the form of new excavations but also using already collected archive material. The same reasoning applies to the second line of investigation in this context, namely osteoarchaeological analyses. Although not entirely specific as to aetiology, skeletal lesions caused by gangrenous ergotism are sufficiently different from a number of other bone-affecting systemic diseases (Lefort and Bennike 2007) to be of potential value in the search for support of our hypothesis.

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