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Understanding long-term charcoal dynamics in the environment: Evidence from high-latitude archaeological deposits.

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Charcoal is produced when biomass is exposed to high temperatures and low oxygen availability (pyrolysis). This process raises biomass carbon content and lowers oxygen/hydrogen content as chemically stable aromatic rings are formed. These then coalesce towards an endpoint of ordered polyaromatic microcrystalline domains, conferring a high degree of chemical stability (Eckmeier et al., 2007). Charcoal carbon therefore appears highly resistant to alteration or degradation in the environment, raising the prospect of its use via addition to soils (as biochar) as a valuable means of carbon sequestration, but also makes it an invaluable source of archaeological and palaeoenvironmental proxy data, used to reconstruct
records of fire history, human societal and climatic change. Key to both of these is the concept of charcoal as one of the most environmentally recalcitrant forms of carbon; this is supported by evidence for the persistence of virtually unaltered charcoal in soils and sediments over periods of many millennia. Yet despite its environmental resistance, mass balance studies of charcoal in both tropical and boreal soils have indicated that it is possible for progressive alteration, and even loss, of charcoal is possible in some settings. The prospect of alteration and degradation of some charcoal over centennial or even decadal timescales has crucial implications for efforts both to optimize the sequestration of carbon as biochar over extended timeframes, and for the use of charcoal as an accurate record of archaeological and environmental data, including for radiocarbon dating. Essentially, we need a better understanding of the mechanisms by which charcoal is altered in the environment, the timescales over which this alteration occurs, and the factors that control the speed and direction of such alteration.

Here, we present the results of a study contrasting physical and chemical characteristics of both modern analogue charcoal produced in controlled conditions, and a suite of charcoal samples from high latitude archaeological sites, with a focus on Iceland. Settlement of the previously pristine ecosystem of Iceland in c.AD 870 resulted in a series of large, localized archaeological charcoal deposits comprising both domestic hearths and purposeful charcoal production pits. Samples from these deposits have been exposed to environmental conditions for up to c.1000 years and represent a variety of thermal regimes, where material from charcoal pits is formed at 300-500°C, and material from hearths is likely to have resulted from a wider temperature range, with upper limits >500°C. Modern analogues were formed from both replica hearths and pits, and in controlled laboratory conditions. By comparing the characteristics of these samples, and placing the archaeological samples within a well-established palaeoenvironmental framework, this work aims to provide a quantitative insight into how production and deposition conditions can dictate the stability of charcoal in the environment over extended timescales.