Journal of Archaeological Science: Reports 14 (2017) 575–579

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Nitrogen isotope evidence for manuring of early Neolithic Funnel Beaker Culture cereals from Stensborg, Sweden

Kurt J. Gron[a,*], Darren R. Gröcke[b], Mikael Larsson[c], Lasse Sørensen[d], Lars Larsson[c], Peter Rowley-Conwy[a], Mike J. Church[a]

[a] Department of Archaeology, Durham University, South Road, Durham DH1 3LE, UK
[b] Department of Earth Sciences, Durham University, South Road, Durham DH1 3LE, UK
[c] Department of Archaeology and Ancient History, Lund University, Helgonavägen 3, 223 62 Lund, Sweden
[d] The National Museum of Denmark, Frederiksholms Kanal 12, 1220 Copenhagen K, Denmark

ARTICLE INFO

Keywords:
Carbon and nitrogen isotopes
Funnel Beaker Culture
Neolithic
Cereal agriculture
Scandinavia
Manuring

ABSTRACT

Little is known about arable agriculture in the Early Neolithic (4000–3300 cal BC, Funnel Beaker Culture) of Southern Scandinavia. Archaeobotanical material is rare and few archaeological sites have yielded more than a small number of charred cereal grains. In this short communication, we present single-entity carbon and nitrogen isotope analyses of charred cereals from Stensborg, an early Funnel Beaker Culture site near Stockholm, Sweden. This cereal assemblage is important as it is large, well-preserved and consists of multiple crop species. Our isotopic results indicate that many of the Stensborg cereal crops had been manured and that there is intra- and inter-species variation in manuring. We interpret these data as evidence of an integrated regime of stock-keeping and small-scale agriculture in the early Funnel Beaker Culture near its northernmost limit.

1. Introduction

Farming practice in the first 700 years of the Funnel Beaker Culture (Early Neolithic, 4000–3300 cal BC, TRB) of the Scandinavian Neolithic is not well understood. Recent research has addressed movement, feeding environments, and birth season manipulation in domestic cattle in this period (Gron et al., 2015, 2016; Gron and Rowley-Conwy, 2017) but the evidence for arable agriculture is limited. Cultivation is suggested by the presence of several species of cereal, including emmer wheat (*Triticum dicoccum* (Schrank) Schübl), einkorn wheat (*Triticum monococcum* L.), naked barley (*Hordeum* sp. var. nudum) and bread wheat (*Triticum aestivum* L.) (Robinson, 2003; Hallgren, 2008; Kirleis et al., 2012), and by the presence of plough-marks below earthen long barrows (Beck, 2013). Therefore, while a century of research has fed a persistent debate regarding the underlying drivers of the origins of agriculture in the region (see Madsen et al., 1900; Fischer and Kristiansen, 2002; Andersson et al., 2016; Price, 2016), our basic understanding of the actual agricultural practices being employed is still limited. For example, whether animal manure was applied to crops prior to the Bronze Age is still debated (Bakels, 1997; Gustafsson, 1998; Grabowski, 2011).

In this short communication, we present carbon and nitrogen isotope analysis of three species of domestic cereals (emmer wheat, naked barley and bread wheat) from the Early Neolithic (hereafter EN) Funnel Beaker Culture (Swedish *Trattbägarkultur*, hereafter TRB) site at Stensborg, near Stockholm, Sweden. This assemblage represents one of the largest collections of carbonized cereals from Scandinavia during this early period. The site is located in one of the most northerly areas of the TRB North Group (Fig. 1; Hallgren, 2008; Müller, 2011; Sørensen, 2015) and the assemblage presents an opportunity for understanding early Neolithic northern European cultivation near its geographic, cultural and economic limits.

2. Methodological context, materials and methods

2.1. Stable isotope research in archaeobotany

Carbon and nitrogen isotopic analysis of charred plant remains is a relatively new application in archaeological science and a series of studies have shown its research potential for identifying the application of manure to increase productivity in cereals, recognized through higher $\delta^{15}N$ values (Bol et al., 2005; Bogaard et al., 2007, 2013; Fraser et al., 2011, 2013; Kanstrup et al., 2011, 2014; Kanstrup, 2012; Fiorentino et al., 2012; Nitsch et al., 2015). At present, the only available data of this type from the EN in southern Scandinavia consists of the bulk analysis of five naked barley grains from Frydenlund, Funen,

* Corresponding author.
E-mail address: k.j.gron@durham.ac.uk (K.J. Gron).

http://dx.doi.org/10.1016/j.jasrep.2017.06.042
Received 5 April 2017; Received in revised form 22 June 2017; Accepted 25 June 2017
2352-409X/

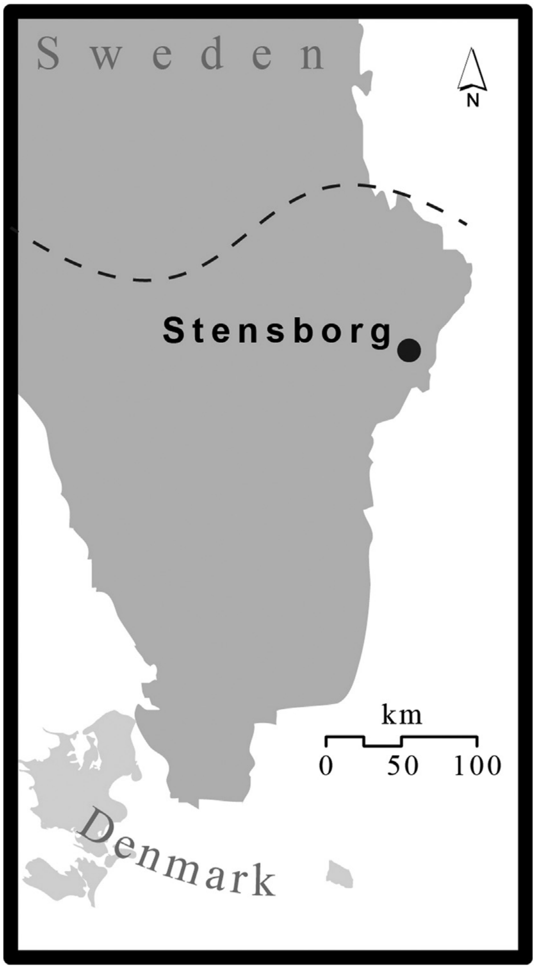

Fig. 1. The location of Stensborg in central Sweden. The dotted line indicates the approximate northernmost limit of the TRB North Group (after Hallgren, 2008; Müller, 2011).

Denmark (Kanstrup et al., 2014). This data was reported but not interpreted on the basis of divergence from the main dataset.

Cereal grains must be charred at or above 220 °C to carbonize effectively (Styring et al., 2013; Charles et al., 2015) and this may produce an offset in the isotope values from the carbonized grains compared to the fresh grains. However, there is some debate as to the extent of the effect of charring on δ^{13}C and δ^{15}N, mostly dependent on the thermal conditions and the duration of firing (Kanstrup, 2012; Bogaard et al., 2013; Fraser et al., 2013; Styring et al., 2013). δ^{13}C values are minimally or not affected (Fiorentino et al., 2012; Fraser et al., 2013). In contrast, δ^{15}N may be affected to a greater extent by charring, raising values above those on uncharred grains. Fraser et al. (2013) suggest that charring raises δ^{15}N values by 1‰, and this correction was applied by the pan-European study of Bogaard et al. (2013). Recent research has shown that the actual offset may be smaller and it is suggested by Nitsch et al. (2015) that a value of 0.31‰ be subtracted from data obtained on charred cereals to obtain a likely value for the material prior to charring.

Bogaard et al. (2013) identified manuring intensity based on ranges of cereal δ^{15}N values from long-term agricultural experiments and applied three levels of manuring (none or low < 3.0‰ δ^{15}N; medium 3.0–6.0‰ δ^{15}N; high > 6.0‰ δ^{15}N) to bulk samples of Neolithic cereal remains from across Europe. Nitrogen cycling between soil and plants is a complicated system that varies over time and space and manuring is not the only mechanism for raising nitrogen levels in soil. However, it is very difficult to directly measure the nitrogen levels (and δ^{15}N) in European soils of the mid-Holocene, as very few contemporary palaeosols exist in the archaeological record and those that do exist are likely to have experienced post-depositional chemical alteration. This makes direct comparison and quantification problematic. For example, there are no contemporary mid-Holocene palaeosols analyzed in the region around Stensborg and we do not know the baseline nitrogen values in the soils of the woodland clearings that were the likely focus for early cereal agriculture in the region. However, a recent isotopic analysis of wild woodland herbivores in the Mesolithic and Neolithic of southern Scandinavia (Gron and Rowley-Conwy, 2017), which also reviewed the existing literature, demonstrated that the highest δ^{15}N values in the bone collagen of these herbivores was 6.1‰ (Craig et al., 2006), with average values much lower at ca. 4.5‰. It is therefore reasonable to assume that the forest plants consumed by the herbivores were a trophic level (very conservatively estimated at 3‰) lower than these values (Bocherens and Drucker, 2003), placing all but the absolute highest soils within the 'none to low' range of manuring intensity identified by Bogaard et al. (2013), and more than likely lower. Therefore, we have chosen to apply the δ^{15}N manuring ranges outlined by Bogaard et al. (2013) to our data, mindful of the interpretive caveats that do exist.

2.2. *The study site of Stensborg*

Stensborg is located ca. 25 km south-west of the centre of what is today Stockholm, just south of the community of Tumba in Stockholm County (Fig. 1). In the Neolithic, the site was located adjacent to a deep bay, and enclosed on the other three sides by several streams and a ridgeline. Archaeological material was first identified by an unusual number of surface finds of broken and/or burned lithics, and subsurface excavations uncovered a series of pits containing objects, some originating from hundreds of kilometers away (Larsson and Broström, 2011, 2014).

Most notable of the subsurface finds were a series of pits in clay, several of which contained thousands of carbonized grains but little crop-processing debris and no weed seeds, indicating careful cleaning prior to burning (Larsson and Broström, 2011, 2014). These three pits, referred to as Pit 1, Pit 2, and Pit 3, contained single pit fills and over a thousand cereal remains each, including emmer wheat, naked barley and bread wheat (quantification in Larsson and Broström, 2011: 196). Very little charcoal was found with the archaeobotanical remains and so the archaeobotanical assemblage has been interpreted as being: 1) either deliberately charred grain placed through structured deposition (Richards and Thomas, 1984); or 2) the accidently charred remains of the cleaned cereal product becoming incorporated into the pit fills (Hillman, 1984).

Single-entity cereal grains from each pit were AMS radiocarbon-dated (Larsson and Broström, 2011) to produce the following dates: Pit 1: 4760 ± 50 bp (LuS-9570), Pit 2: 4710 ± 75 bp (LuS-9571), Pit 3: 4800 ± 50 bp (LuS-9184). Calibrated ranges at 95% confidence (2σ) were obtained using the IntCal13 atmospheric dataset (Reimer et al., 2013) and the OxCal v4.3 calibration program (Bronk Ramsey, 1995, 2001), producing an overlapping date range of 3693–3360 cal BC from the three pits. This spans the transition between the Early Neolithic I (ENI) and the Early Neolithic II (ENII) periods of the Scandinavian early Neolithic (Larsson and Broström, 2011, 2014).

2.3. *Sampling and analysis of cereals for isotopic research at Stensborg*

We undertook a single-grain analytical approach for the following two reasons. Firstly, we wanted to observe the variance between the grains analyzed for each species from each pit. Secondly, we wanted to examine if there were any systematic isotopic offset between grains of differing preservation. In all, 80 carbonized cereal grains were selected for analysis (Supplementary Table 1). Different species were sampled in order to determine any difference in crop husbandry. We chose 10 grains of the best preservation (see below) from each pit, allowing our