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Iron Age migration on the island of Öland: Apportionment of strontium by means of Bayesian mixing analysis

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ABSTRACT

Migration is a complex subject to approach in archeology and the new materials and methods available, such as isotope analysis and DNA, make it possible, and necessary, to ask new questions. The objective of this paper is to highlight the possibilities with using a new approach to migration on a population level by applying Bayesian mixing analysis of strontium isotopes. The selected case, the island of Öland in the Baltic, was based on 109 human samples dated to the Early (500 BC–AD 400, n = 71) and Late (AD 400–1050, n = 38) periods. The results from both periods demonstrate that the distribution of Strontium (Sr) is multimodal with several peaks not associated with the local variation. Our results show a large immigration to Öland from other geological areas, with 32% of the population in the Early period and 47% in the Late period being nonlocal. In order to unravel these distributions, we use a Bayesian mixing analysis. The Bayesian mixing analysis provides us with a mean to disentangle the distribution of Sr that is not uninformed. The gravity model, however simplistic, is relevant for explaining the strontium variation in the population in Öland both in the Early and Late period. Our results indicate a significant internal migration in Scandinavia that is increasing in the Late Iron Age at the same time as the Viking expansions (the more well studied external migration), which is usually the only migration discussed. We argue that the method proposed and tested on the case of Öland adds new perspectives for approaching migration patterns in general on a population level, a perspective that is hitherto lacking in archaeology.

1. Introduction

Migration is an area of study in archaeology that is focused upon defining deviance instead of contextualizing migration on a population level. Despite new methodologies allowing us, even compelling us, to pose entirely new questions to our sources, the process in studying migration and the questions asked remain largely the same. Here, we use the methodologies of isotope analysis in combination with Bayesian mixing models to explore one of the most well established theoretical models of migration—the gravity model. We use this method on a complete sample (i.e. not deviants) taken from the Swedish island of Öland in the Baltic Sea throughout the Iron Age (500 BC–AD 1050). By this approach we move migration studies in archaeology forward, not only by combining these methods, inherently calling for a "complete" (not deviant-focused) approach, but also by proposing and addressing new questions based in these methods rather than directed at them.

The Baltic and its larger islands, such as our selected case study Öland, entered a highly dynamic and communicative phase with the advent of the Iron Age in Scandinavia and the advances made in maritime communication (c.f. Randsborg, 1991; Callmer, 1992). Regardless of the archaeological sources in focus, the changes apparent between the Earlier (500 BC– AD 400) and Later Iron Age (AD 400–1050) are closely intertwined with communication outside of the local community. Despite recent significant methodological advances, studies of migration during the later period are still entrenched in the publicly engaging notion of "Viking expansions". The literature dealing with Viking legacy outside of Scandinavia is truly plentiful (despite a sometimes very limited material) and the interest has increased with the use of isotopic analysis in particular (c.f. Loe et al., 2014; Harding et al., 2015). Studies on migration, specifically those on isotopic analysis for provenance, are very often focused on burials which can be considered deviant in artefacts (imported artefacts) or style. Attention to these samples fails to get a full cross section of the

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entire population (c.f. discussion in Eckardt et al., 2014). In this study, measures were taken to avoid biased sampling by taking samples from diverse contexts, including as many burials as possible that were clearly dated. This allowed us to connect to a specific archaeological cultural context within a given time and place. Our approach will enable us to study migration processes, not deviant individuals. We probe questions concerning, for example, the nature of immigration involving Öland during the Iron Age. Is the proportion of locals the same over time? Are the migratory patterns the same if we compare the Early Iron Age with the Late Iron Age? Here, we examine the local situation within the southern Scandinavian Peninsula asking how our results would fit a much broader perspective involving the expansions we see emanating out from the Scandinavian Peninsula, a perspective that has been lacking.

Strontium (Sr) isotopic analyses offer a solid indication of geological origin that indicates at least some very clear cases of migrations of individuals during their lifetime. Many more complex aspects and facets of migration as a process could, however, remain elusive (for example seasonal, temporary, or returning migration). The distribution of Sr in a given region (for example, Öland) may be understood as a mixture of local and non-local isotope signatures. A reasonable assumption in the absence of migration is that the distribution of Sr in a population would be Gaussian with a mean and dispersion mimicking the local signature. Affected by migration in a region with a heterogeneous distribution of Sr, this distribution is likely to develop a multimodal shape reflecting the geographical heterogeneity of the sample, with the height of the different modes reflecting the proportion of individuals emigrating from that specific region (source).

Bayesian mixing models supply a framework for incorporating prior information into the analyses of a mixture of sources (Phillips and Gregg, 2001, 2003; Moore and Semmens, 2008; Parnell et al., 2010). According to Bayesian theory, statistical inference is based on the posterior distribution, a distribution that is given by the data and existing knowledge (i.e. the prior) (Hilborn and Mangel, 1997). We could work with an uninformative or flat prior meaning that all sources are equally likely to contribute to the distribution of Sr in the target population from Öland. But we could also adopt informative priors based on some prior knowledge of human migratory patterns, such as implied by the gravity model (Hodder and Orton, 1976:187). In this context, we employ a method that will incorporate the gravity model as a prior. Based on this model, we posit that non-local individuals are more likely to have originated from regions that are closer to Öland rather than further away, and define the priors in a Bayesian Mixing Model accordingly.

Migration implies the physical movement of humans from one area (origin) to another (destination), with the aim of settling temporarily or permanently at the destination. Once presented as a major force with a substantial explanatory power within cultural historical archaeology, its importance was actively diminished in the New Archaeology paradigm. However, following advances in natural sciences, human migration of the past is resurfacing as an active field of research within the field (Burmeister, 2000; Hakenbeck, 2008; Clark and Cabana, 2011; Cameron, 2013; van Dommelen, 2014). The aim of this paper is to advance the study of human migration in archaeology by asking new questions which have only been possible to pose through combining methods and theoretical approaches: Sr isotopes, the gravity model and Bayesian mixing. Using this approach we focus on migration processes rather than deviant individuals and provide a new perspective on the globally enticing phenomenon of “Viking expansions” using our case study of Öland. We also offer a new direction for migration studies in archaeology which is based not only on employing, but on *exploring* the full potential of methods like isotopic analysis by posing new research questions based on the method, rather than subjecting it to old questions. This is made possible with integration of isotopic analysis with archaeology on the theoretical level.

2. Material and methods

The material used in this study is the unburnt skeletal remains of 109 individuals excavated on Öland (Appendix A, Fig. 1). The individuals were selected primarily on the basis of available permanent teeth (premolars) for Sr isotopic analysis. Other selection criteria were aimed towards gaining as representative a material as possible regarding (in descending order of importance): date, region of the island, archaeological context (burial or other), age (from seven years and up), and sex. However, the available material could not fulfill all criteria equally. This is not only a product of preservation and excavation bias but is also reflective of the varied burial practices and differing contexts containing human remains during the Iron Age on Öland. Although more than one individual was frequently identified in the graves (primarily in the stone cists), only those remains that could be clearly identified and sorted with confidence into separate individuals were selected for further study. If more than one individual from a grave was suitable for analysis by the criteria stated above, they were included in the sample. The sample has been osteologically analyzed by one of the authors (HW).

In this article the data are presented as pooled into two periods: the Early Iron Age (500 BC–AD 400) and the Late Iron Age (AD 400–1050). In the case of burials, the distinction between the two periods is relevant in that there appears to be a significant shift in burial practices, from a mix of inhumation and cremation to a seemingly almost exclusive practice of cremation during the transition from the Early to the Late Iron Age (Beskow-Sjöberg and Arnell, 1987; Beskow-Sjöberg and Hagberg, 1991; Hagberg and Beskow-Sjöberg, 1996; Fallgren and Rash, 2001). In the Iron Age on Öland, as in Scandinavia in general, burial practices shifted back and forth from cremation to inhumation and both practices were used in parallel for much of the period. The uncremated individuals selected in this sample have an obvious bias as the parallel cremation practice removes a significant proportion of the entire population from analytical access. However, the uncremated population can be seen as representing a social identity (or possibly many social identities, shifting between the different periods) and its division by Sr is of interest in that respect also.

All but four of the sampled teeth are premolars and only enamel was sampled. The list of samples, various other information, and isotope results are provided in Appendix A. Premolars were selected for this study for functional, practical and representational reasons. The premolar is a common tooth; there are eight premolars in the dentition. The availability of the premolars is unsurpassed by any other tooth in the sense that an individual only needs to have one of the eight premolars preserved (in contrast to one of four first molars) in order to be sampled. Premolars are developed almost simultaneously and are therefore comparable to one another with regard to enamel composition. Another important feature is that the premolars are often usually not as worn as most other teeth (especially in comparison with first molars) in that enamel remains intact, even in very old individuals who can thus be included in the sample. In addition, premolars generally form after weaning so that the mother's diet has little effect upon the formation of the tooth (in contrast to first molars). Since sampling is always a destructive process another advantage to using premolars (rather than molars) is that they are less useful in terms of morphological or metric analysis and the scientific value lost by sampling a tooth is therefore lower. The animal samples were also taken from tooth enamel but the type of tooth differed depending