Original Study

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New Perspectives on the Late Neolithic of South-Western Sweden. An Interdisciplinary Investigation of the Gallery Grave Falköping Stad 5

Abstract: This article presents the results of an interdisciplinary study combining archaeology, osteology, and stable isotope analyses. The geological conditions and richness of megalithic graves in Falbygden is suitable for studies of Neolithic human remains. Nevertheless, the Late Neolithic period (2350–1700 BC) is poorly investigated. This paper explores new knowledge of the Late Neolithic megalithic population in Falbygden. In-depth osteological and archaeological studies focusing on a single gallery grave (Falköping stad 5) were conducted. Radiocarbon dating and carbon, nitrogen, and strontium isotope analyses of teeth from twenty-one individuals revealed the time of the grave’s use, as well as the subsistence and mobility practices of the buried individuals. The grave was already in use during the first part of the Late Neolithic and used into the second part of the period by individuals of different origin. Furthermore, the results indicated changing population dynamics in the Late Neolithic Falbygden, with increased human mobility, variability in subsistence strategies, and growing population density.

Keywords: subsistence, mobility, health, Scandinavian Late Neolithic, south-western Sweden, isotopes, osteology

1 Introduction

This paper discusses a Late Neolithic burial community, focusing on all identified individuals from a gallery grave in south-western Sweden. It uses an interdisciplinary approach that combines archaeology, osteology and isotope analysis on human remains from a single grave, which in turn allows in-depth studies of the variation in the megalithic population on a local and regional scale.

Osteological and isotope analyses are continuously developing and have become well established in archeological research (Eriksson, 2004; Eriksson & Lidén, 2013; Eriksson et al., 2008; Fernandes et al., 2015; Forander et al., 2008; Knipper et al., 2015; Montgomery & Evans 2006; Bergerbrant et al., 2013; Sjögren et al., 2016). Interdisciplinary studies combining archeology, osteology, and biochemical analyses are not as common, but are currently at rapid development (Carlie et al., 2014; Knipper et al., 2017; Pearson & Meskell, 2015; Scorrano et al., 2014; Wilhelmson, 2017a). These interdisciplinary studies are often based on large numbers of samples from extensive study areas. However, the sample size from each site is generally low, which could generate data biased by low variability within each site, thus providing overly generalized results.
Falbygden, in the inland of south-western Sweden, is an important area for research on Neolithic megalithic graves in Scandinavia (Ahlström, 2009; Scarre, 2010; Shanks & Tilley, 1982; Sjögren, 2003; Tilley, 1994). It has one of Northern Europe’s largest concentrations of passage graves and a substantial number of gallery graves. The numerous megalithic graves and various find concentrations indicate its status as an important area during the Middle and Late Neolithic (3350–2350/2350–1700 BC) (Bägerfeldt, 2009; Sjögren, 2003; Weiler, 1994). Systematic studies of the associated burials have been ongoing since 1860 with a particular focus on the passage graves and the Middle Neolithic period (Anderbjörk, 1932; Hildebrand, 1864; Montelius, 1873; Persson & Sjögren, 2001; Retzius, 1899; Sahlström, 1932; Shanks & Tilley, 1982; Sjögren, 2003; 2008), while only a few studies have dealt with the gallery graves and the Late Neolithic in the area (Algotsson, 1996; Anderbjörk, 1932; Blank, 2016, 2017; Stensköld, 2004; Weiler, 1994).

The Scandinavian Late Neolithic (2350–1700 BC) has been described as a period of increased social complexity, growing population density, and stronger reliance on agriculture (Apel, 2001; Artursson, 2009; Lekberg, 2002; Vandkilde, 1996; Kristiansen & Larsen, 2005). Most of the research is based on artefact studies; however, it may be useful to consider whether there is any bioarchaeological evidence of population increase, higher mobility, changes in subsistence, or increased nutritional access in the Late Neolithic megalithic population compared to the megalithic Middle Neolithic population in Falbygden.

The calcareous soils of Falbygden have promoted excellent bone preservation, allowing osteological studies, radiocarbon dating, and stable isotope analyses of skeletal remains. The geology of the region is dominated by Cambrosilurian sedimentary rock (550–400 Ma), which differs from the Precambrian crystalline bedrock (1.86–0.9 Ga) in the surrounding areas (Figure 1), and thus increases the likelihood of detecting mobility through strontium isotope analysis. The human and animal remains from Middle Neolithic passage graves and settlements have been subjected to thorough osteological investigations (Ahlström, 2001, 2009). A number of isotope studies measuring \(^{14}C\), \(^{13}C\), \(^{15}N\) values and \(^{87}Sr\)/\(^{86}Sr\) ratios in human and animal remains from this area have been conducted (Hinders, 2011; Lidén, 1995; Persson & Sjögren, 1995; Sjögren, 2011, 2017; Sjögren & Price, 2006, 2013a, 2013b; Sjögren et al., 2009). These publications all discuss the Middle Neolithic period, while isotopic studies of the Late Neolithic are still few (Blank, in press; Blank, Knipper, in press).

This study presents new knowledge about the Late Neolithic population buried in megalithic graves by focusing on the bone material found in the gallery grave at Falköping stad 5 in Falbygden. It addresses this subject through analyses of the time of use of the gallery grave, as well as the health, paleodemography, diet and subsistence, and mobility of the individuals buried there, and compares these results with previously published studies of the Late and Middle Neolithic in Falbygden, as well as from other south Scandinavian regions.

2 Background

2.1 Archaeological Background

The Scandinavian Late Neolithic is a period defined by new types of materials, complex flint-working techniques, the appearance of gold and copper artefacts, and long distance trading networks (Apel, 2001; Ling et al., 2014; Kristiansen & Larsen, 2005; Vandkilde, 1996). The first part (2350–1950 BC) of the Scandinavian Late Neolithic is contemporary with the later years of the Beaker phases in the British Isles and the Rhine delta and the Early Bronze Age in Central Europe, while the second part (1950–1700 BC) overlaps with the Wessex I phase in the British Isles, the barbed-wire Beaker phase in the Rhine delta, and the Únetice phase in central Europe (Vandkilde, 1996). Influences from these culture complexes are visible in the rather homogenous Scandinavian Late Neolithic material (Apel, 2001; Iversen, 2015; Vandkilde, 1996).

In Scandinavia, the period is also associated with the constructions of gallery graves. It is likely that only part of the population during the Late Neolithic were buried in gallery graves and that other burial practices were in use, although they are not common in the archaeological record. In some parts—for
example, in Scania—, inhumation burials in flat graves occur (Bergerbrant et al., 2017; Tornberg, 2017). In Falbygden, on the other hand, only gallery graves have been found to date.

In Sweden, gallery graves are concentrated in western Sweden and Småland, southern Sweden. The graves in western Sweden are generally larger than the ones found in Denmark, Scania in southernmost Sweden, and eastern Sweden (Iversen, 2015, p. 123f; Weiler, 1994, p. 56). The emergence of gallery graves has been explained by influences from Denmark, which in turn have been explained by a development of the Single grave culture stone cists in Jutland (Ebbesen, 2004, p. 23; Iversen, 2015, p. 124; Janson, 1938, p. 321). It has also been suggested that the larger graves are inspired by burials in northern France and central Germany, considering the apparent resemblances to allées couvertes/allées sépulcrales and the concentration of gallery graves with portholes in western Sweden (Ebbesen, 2004, p. 62; Janson, 1938, p. 330ff). Anderbjörk (1932, p. 26ff) and Montelius (1905, p. 170ff), however, also underline the continuation of the megalithic tradition and the resemblances with the earlier passage graves in Falbygden.

Falbygden is a 50 × 30 km sedimentary rock area (Figure 1) where 255 passage graves, 125 gallery graves, 2 dolmens, and 115 megalithic graves of unknown types have been documented (Persson & Sjögren 2001, p. 6). Only a small number of the graves have been excavated, most only partially, and the methods vary according to the excavation standard of the time (Blank, 2016, p. 52; Weiler, 1994; Sjögren, 2003). One of these is the gallery grave Falköping stad 5, also known as Fredriksberg, located in the limestone area between the mountains Mösseberg and Ålleberg, in the south-western part of Falbygden (Figure 1). Falköping parish is the densest area of gallery graves in Sweden, with one grave per 0.5 km² (Weiler, 1994). In 1973, after being damaged by construction work, Falköping stad 5 was excavated and restored (Weiler, 1977).

Figure 1. The location of Falbygden and Falköping stad 5. 1: Mösseberg, 2: Ålleberg, 3: Billingen, 4: Varvsberget, 5: Gerumsberget.
The grave was placed on a small ridge and dug into flat ground. It was constructed of limestone slabs and consisted of a chamber and antechamber, 5.3×2 m large slightly trapezoid and orientated NNE-SSW (Figure 2). Roof slabs that had collapsed into the grave were found in the chamber. These slabs were covered by a stone packing mixed with soil. The floor consisted of flat limestone slabs. The chamber and antechamber were separated by two limestone slabs with a slit at the top. The antechamber was somewhat lower than the chamber (Weiler, 1977). The size, orientation, and construction details reflect the common characteristics of gallery graves in south-western Sweden (Weiler, 1994).

During excavation the grave was divided in different sections and layers and the finds were documented in these units. The bone material lacking stratigraphic and spatial information derives from the top layer (Weiler, 1977, p. 12). Both the antechamber and the chamber contained artefacts as well as human and animal skeletal remains, although most of the material was found in the chamber. The majority of the bones derived from human burials, but remains from cattle, sheep/goat, pike, fox, rodent, and dove were also found (Weiler, 1977). Almost all of the artefacts were found in the bottom layers and consisted of remains from a decorated ceramic vessel, a flint dagger, seventeen flint flakes, six amber pendants, a slate whetter, a round and flat bone bead, two bone needles, a bone awl, and a bone artefact interpreted as a flute (SHM 32384). The skeletons were commingled and in a fragmentary state, suggesting they were moved to make room for new burials. Successive burials are supported by the presence of different and small bone elements which is consistent with recent research of the megalithic graves of Falbygden suggests (Ahlström, 2009; Sjögren, 2003). There were no signs of later activities in the grave (Weiler, 1977).

Compared to other excavated gallery graves in the surrounding area, Falköping stad 5 did not contain a lot of artefacts, even though it did not show any trace of looting or later reuse as many other megalithic graves in the area do (Weiler, 1977). It contained amber pendants, bone needles, and awls, which are common in both passage and gallery graves. The pottery found in Falköping stad 5 consisted of a rim sherd of a vessel with an estimated rim diameter of 10 to 15 cm. The rim is flared and the sherd is decorated by uneven rows of small pointed impressions. This type of ware and decoration is commonly found in Late Neolithic gallery graves in western Sweden and south Scandinavia, even though the sherd is relatively thin (5mm) (Anderbjörk, 1932, p. 38; Stilborg, 2002, p. 78). The shape of the sherd indicates an s-shaped vessel with a pronounced profile. The amber beads are not well preserved, but an oval pendant and two pendants of unknown shape with double holes can be identified. Amber pendants are common in megalithic graves both during the Middle and Late Neolithic. The flat and round bone bead is not a common find in the
gallery graves of western Sweden. However, this kind of artefact can have been easily missed due to its small size (6mm in diameter) and can only be expected to be preserved in certain environments. Bone implements are common both in passage and gallery graves, even though bone needles (dress needles) are mostly associated with the Late Neolithic. The bone needles in Falköping stad 5 are simple and lack ornamentation. However, one of the needles could be identified as type A:4 according to Hjärthner-Holdar’s typology (1978, p. 236). A flint dagger of Lomborg type IIB had been placed in the chamber (Lomborg, 1973, p. 44). This type is not so common in the gallery graves in Falbygden, and is generally dated to the Late Neolithic I (Apel, 2001).

An osteological analysis was conducted by Iregren (1977), who estimated a minimum number of individuals (MNI) of thirty—ten children and twenty adults. The adult MNI was estimated by the presence of left distal humerus. Iregren (1977) reported ten males and six females based on characteristics of the pelvis. Five of the individuals were 14C dated when the gallery grave was excavated in 1973 (Weiler, 1977, p. 23). These analyses were performed by the Laboratory of Radioactive Dating in Stockholm with the conventional method (St-5149 to 5153 and 5157) (Weiler, 1977, p. 23). The dates imply that the grave was already in use during the Middle Neolithic B (2800–2350 BC) (Figure 3). Based on demographic calculations made by Jan Grandell (in Iregren, 1977, p. 62ff), Iregren suggests that the grave was in use for about one-hundred years and that it is most likely that the site was a family grave (Iregren, 1977, p. 51). As seen in Figure 3, the uncertainties of these dates are too significant to say anything more than that the grave was in use during the Late Neolithic.

2.2 Isotope Analysis

Carbon (δ13C) and nitrogen (δ15N) isotope values in human bone collagen can be used to evaluate prehistoric food consumption (Sealy, 1986, 2001). For example, δ13C distinguishes terrestrial or marine diets, as marine organisms exhibit higher δ13C values (Sealy, 1986). In the Atlantic/North Sea region, terrestrial mammals have δ13C end values of bone collagen ranging from -20‰ to -21‰, whereas the marine end value is about -12‰. Intermediate δ13C would thus reflect a combination of marine and terrestrial proteins. In the Baltic region, the terrestrial δ13C values are similar whereas the marine end values are -14‰ to -15‰ (Lidén & Nelson, 1994). Nitrogen, which is absorbed by humans through consumed proteins, is also useful when the diet of prehistoric humans is investigated. Delta15N values have generally been suggested to increase along the food chain by about 3 to 5‰ per trophic level (Hedges & Reynard, 2007). In a terrestrial food web, this standard model implies δ15N values of 3‰ in plants, 6‰ in herbivores, and 9‰ in carnivores. Thus, bone collagen in human consumers of terrestrial plants and animals should have δ15N values between 6 and
10‰. However, recent data implies higher enrichment rates and variation within and between species, and enrichment up to 6‰ has been suggested (O’Connell et al., 2012). This range of values has been considered in several recent papers (see Hedges & Reynard, 2007; Sjögren & Price, 2013b; Wilhelmson, 2017b). Thus, the interpretation of the origin of the protein might differ depending on which fractionation level is considered. Consumers of fresh water and marine fish and other aquatic predators show δ15N values of up to 15 to 20‰ as aquatic food webs have generally longer food chains than land-based webs (Eriksson, 2013; Schoeninger et al., 1983, p. 130). The Baltic Sea has varied substantially in salinity through history (Emeis et al., 2003). Since different species need different salinity to thrive the variation in salinity is connected to a variation in occurring species and probably also number of levels in the food chain. This variation should be taken into consideration when interpreting δ15N values in comparison with other published data from eastern Sweden. Delta15N values can also be affected by breastfeeding and the consumption of juvenile herbivores as these are one trophic level above their mothers. Physiological stress, famine, climate, elevation, and the intake of manured crops are other factors which can elevate δ15N values in human bones (Eriksson, 2013, p. 130, 36; Fraser et al., 2011; Hedges & Van Klinken, 2002).

Different bone tissues reflect different components of the diet. Bone collagen mainly reflects protein intake, while bone and enamel carbonate (apatite) mirrors overall dietary components (protein, carbohydrates, and fats) (Ambrose & Norr, 1993, p. 121–55). The difference between the δ13C in apatite and the δ15N in collagen (the collagen-apatite spacing) observed in carnivores is smaller than in herbivores, while collagen-apatite spacings of 6.8±1.4‰ for herbivores, 5.2±0.8‰ for omnivores, and 4.3±1.0‰ for carnivores have been suggested (Hedges & Van Klinken, 2002; Lee-Thorp et al., 1989).

Strontium originates from weathering rock minerals and the element passes through soils and water into the biosphere, travelling through the food chain into the human skeleton with minimal isotope fractionation (Bentley, 2006). Hence, the 87Sr/86Sr ratio is effective for identifying human and animal mobility. The bio-available strontium isotope signature largely reflects geology, as 87Sr/86Sr ratios in rocks and minerals depend on their original Rb/Sr ratio as well as their geological age (87Rb radioactively decays to 87Sr) (Faure, 1986). However, in regions with loess or glacial deposits, the isotope ratio of the bio-available strontium can be very different from the underlying geology. Furthermore, various minerals weather at different rates and have different strontium concentrations and isotope ratios. The isotope signal can also be affected by sea spray, heavy rain, and atmospheric dust (Bentley, 2006).

Hence, the strontium isotope signals in humans mirror the bio-available signal where they have resided. This approach assumes that the water and food which humans consumed were procured locally (Montgomery, 2010, p. 325). In humans, plants are the main contributors to strontium uptake, while meat contributes less and the importance of drinking water has been debated (Bentley, 2006, p. 154; Frei & Frei, 2013, p. 158; Montgomery, 2010, p. 329). For mobility studies, a consideration of diet is relevant, as considerable portions of marine food can shift the isotopic signal towards the seawater ratio of 0.7092 (Bentley, 2006).

When sampling skeletal remains, tooth enamel is often preferred, as it is less susceptible to diagenesis and contamination (Bentley, 2006; Montgomery, 2010, p. 329). Bone undergoes continuous chemical and structural turnover during life, while enamel forms in infancy, childhood and youth (depending on the kind of tooth) and remains unchanged thereafter. The recognition of specific events of mobility based on enamel analyses is therefore restricted to the childhood and youth of the sampled individuals (Hillson, 1996). It can take several years before the enamel is completely crystallized (Hillson, 1996) and the measured ratio is a mean value of the isotope signals incorporated during this time. If a person moves to a new location with a different geology after the tooth enamel has formed, the strontium isotopic ratio from their enamel will differ from the bio-available strontium isotope signal from that location, and register as non-local. However, if the range of 87Sr/86Sr ratios in the different locations is the same, it is not possible to identify non-local individuals.

In Sweden, baseline ranges have been determined only in a few restricted areas, mostly in connection to specific archaeological sites (Arcini et al., 2015; Blank & Knipper, in press; Eriksson et al., 2016; Fornander et al., 2015; Frei, 2009; Price, 2013; Sjögren et al., 2009; Sjögren & Price, 2012; Sjögren & Price,
2006; Wilhelmson & Ahlström, 2015; Wilhelmson & Price 2017; Price et al., 2017). A preliminary overview of strontium isotope ratios in south-western Sweden has been published by Blank and Knipper (in press). However, the isotope signal of the bio-available strontium in Falbygden is relatively well known. In previous research, seventy-eight samples from domestic and wild animals and eighty-two humans from southwest Sweden, mainly from the area of Falbygden, were analysed (Sjögren et al., 2009; Sjögren & Price, 2012). These studies show a clear division of the Cambro-Silurian area (Falbygden) and the surrounding Precambrian provinces (Figure 1). Based on previous and ongoing studies, the isotope signal of the bio-available strontium in Falbygden ranges from 0.713 to 0.716, with higher ratios ranging from 0.717 to 0.726 in the surrounding Precambrian areas (Sjögren et al., 2009; Sjögren & Price, 2012). These ranges can be confirmed in a thorough baseline study of inland western Sweden (Blank et al., in press).

3 Material and Methods

The Falköping stad 5 gallery grave was chosen for this study for several reasons: it is well documented and not disturbed by later activity, it contained a substantial number of well-preserved human remains suitable for osteological and isotope analyses, and the results from previous analyses needed reevaluation. The gallery grave contained burials from at least twenty-eight individuals, including nine children and nineteen adults (MNI). Iregren (1977) estimated MNI to be thirty, based on twenty distal adult humeri and ten juvenile mandibles. In the current osteological analysis by Tornberg, only fifteen adult distal humeri were detected. One humerus was sent in for radiocarbon dating in the 1970s, but the remaining absence of four humeri cannot be explained further. The high adult MNI calculated through the presence of left tali (n=19) and calcanei (n=18) is the same in both studies. In the present study, MNI is estimated through the presence of mandibles divided in six different age categories and through the number of left adult tali. When comparing current osteological analysis to Iregren’s report, mandibles from F142, F85, F38, F123 and F122 are missing. However, three mandibles not present in Iregren’s report, that could not be associated to any of the other mandibles, were documented in the current study (F 129 V:2, F 139 VII:2 and F 134). It is possible that differences in calculations of the MNI are partly due to further fragmentation caused by insufficient packaging in the museum storage, and partly to inter-observer error. It should be noted that these calculations are the minimum number of individuals buried in Falköping stad 5 and that it is possible that more individuals were actually buried. This approach to the number of buried individuals is however necessary since the grave contains no articulated individuals.

To evaluate the frequency of dental caries and dental calculus, a total number of 287 permanent, erupted teeth were analysed. Eighty-eight teeth were incisors and canines and 199 teeth were premolars and molars, from both the upper and lower dentition. Seven teeth, including five incisors, one canine, and one premolar, could not be observed for carious lesions due to fragmentation. Therefore, 280 teeth are included in this study, including eighty-two incisors and canines and 198 premolars and molars.

A maximum of separate individuals based on teeth were sampled for isotope analyses of both enamel and collagen. In this case, molars (mostly second molars, which are suitable for strontium isotope analysis) from the lower dentition were selected from twenty-one individuals (Table 1). The enamel was used for \(^{87}\text{Sr}/^{86}\text{Sr}\) and \(\delta^{13}\text{C}\) analysis, and the root of the tooth was used for \(^{14}\text{C}, \delta^{13}\text{C}\) and \(\delta^{15}\text{N}\) analysis.

Sex has been assessed through morphological characters on the os ilium and os pubis when applicable. Since the skeletal remains cannot be deduced to articulated individuals, it has been necessary to use secondary morphological characteristics of the skull and mandible as indicators of sex in the tooth-sampling procedure for stable isotopes and dental calculus analyses.

Adult age has been assessed using degenerative features of the pubic and auricular facets, as well as transition analysis (TA) when possible (Boldsen et al., 2002). Transition analysis is based on Bayesian modelling where population demographic patterns are used as prior information. The TA was carried out using the ADBOU software (Boldsen et al., 2002, available at http://math.mercyhurst.edu/~sousley/Software/) with an archaeological population of unknown ancestry as a model. In the sampling procedure for stable isotopes, an approximate age based on dental wear (Brothwell, 1981) was assessed. Juveniles have been aged using traditional
osteological analysis of dental eruption and epiphyseal fusion. Demography has been analysed using a Siler-competing hazard model (Ahlström, 2015; Siler, 1979, 1983; Wood et al., 2002). The model is based on three components of human mortality. The first (immature) component refers to the high but decreasing infant and early child mortality. The second (residual) component is a constant-age, non-specific mortality hazard (e.g. accidents, violence, etc.), and the third (senescent) component is related to the increased risk of dying with increased age. The Siler model has five parameters that models mortality: $\alpha_1$=immature mortality rate, $\beta_1$=the rate of immature mortality decline, $\alpha_2$=residual mortality, $\alpha_3$=the initial adult mortality rate, and $\beta_3$=the rate of adult mortality increase. The Siler analysis was carried out using the free statistical software R386 version 3.1.3. Adults that could not be aged more precisely aged (n=7) were weighted and divided between age spans so that the analysed sample would include the complete MNI, as leaving these individuals out would have biased the sample towards higher child mortality in relation to the whole population.

Table 1. Individuals sampled for isotope analysis.

<table>
<thead>
<tr>
<th>Ind. No.</th>
<th>Context</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>F83II:1</td>
<td>Layer 1, northern part of chamber</td>
<td>M2, mandibula, sin</td>
</tr>
<tr>
<td>F139II:2</td>
<td>Layer 2, northern part of chamber</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F90</td>
<td>Upper part, northern part of chamber</td>
<td>dpm2, mandibula, dexter</td>
</tr>
<tr>
<td>F115VII:2</td>
<td>Layer 2, southern part of chamber</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F132VI:3</td>
<td>Layer 3, southern part of chamber</td>
<td>M2, mandibula, sin</td>
</tr>
<tr>
<td>F117</td>
<td>Layer 4, northern part of chamber</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F108IV:3</td>
<td>Layer 3, northern part of chamber</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F98</td>
<td>Layer 2, northern part of chamber</td>
<td>dpm2, mandibula, dexter</td>
</tr>
<tr>
<td>F147VI:4</td>
<td>Layer 4, southern part of chamber</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F123</td>
<td>Upper part, unknown</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F122</td>
<td>Layer 4, southern part of chamber</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F119</td>
<td>Layer 3, northern part of chamber</td>
<td>dpm2, mandibula, dexter</td>
</tr>
<tr>
<td>F121</td>
<td>Layer 3, southern part of chamber</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F134</td>
<td>Layer 3, southern part of chamber</td>
<td>M1, mandibula, sin</td>
</tr>
<tr>
<td>F69</td>
<td>Upper part, southern part of chamber</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F124</td>
<td>Layer 3, northern part of chamber</td>
<td>M2, mandibula, dexter</td>
</tr>
<tr>
<td>F118</td>
<td>Layer 3, northern part of chamber</td>
<td>M1, mandibula, dexter</td>
</tr>
<tr>
<td>F88</td>
<td>Ante chamber</td>
<td>dpm2, mandibula, dexter</td>
</tr>
<tr>
<td>F129V2:2</td>
<td>Layer 2, under roof slab western part</td>
<td>M1, mandibula, dexter</td>
</tr>
<tr>
<td>F128</td>
<td>Layer 3, northern part of chamber</td>
<td>M3, mandibula, dexter</td>
</tr>
<tr>
<td>F120+132</td>
<td>Layer 3, southern part of chamber</td>
<td>M1, mandibula, dexter</td>
</tr>
</tbody>
</table>

Stature estimations were based on the maximum length of the femur (Martin 1) (Martin & Saller, 1957) and calculated using the Sjøvold (1990) model. Paleopathological features were studied macroscopically under a bright light and registered, together with a description, as present, absent, or non-observable. Dental caries was investigated macroscopically under a bright light, with a magnifying glass when necessary. Only real cavities were registered as dental caries, while discolorations or initial enamel demineralization was not considered as dental caries. Dental caries was registered as: 1=occlusal surface, 2= interproximal, 3=smooth surface, 4=cervical caries, 5=root caries, 6=large caries with unknown origin, 7=non-carious pulp exposure, 0=non detectable and 9=non observable. Dental calculus was scored 1–3 (slight, medium, severe), absent (0) and non-observable (9).

Dating and analyses of stable carbon and nitrogen in collagen were conducted at the 14Chrono Centre in Belfast. Collagen was extracted through a modified Longin method (Longin, 1971), developed by Brown.
et al. (1988). The samples were pretreated using a simple ABA treatment, followed by gelatinization and ultrafiltration with a Vivaspin filter cleaning method (Reimer et al., 2015). The $^{13}$C/$^{12}$C and $^{14}$C/$^{12}$C ratios were measured by accelerator mass spectrometry (AMS) on an NEC 0.5 MV compact accelerator. The sample $^{13}$C/$^{12}$C was background corrected and normalised to the HOXII standard (SRM 4990C). The radiocarbon ages were corrected for isotope fractionation using the AMS measured $\delta^{13}$C. A Thermo Flash 1112 elemental analyser coupled to a Thermo Delta V mass spectrometer (EA-IRMS) were used to measure %C, %N, $\delta^{13}$C and $\delta^{15}$N within the sample. Samples and standards were sealed into tin capsules and combusted in the elemental analyser, which yields %C and %N, and C:N ratios were calculated from these values. The EA was connected to the IRMS for the stable isotope analysis. Three blanks were measured at the start of the run followed by three standards of Nicotinamide for the %element values. The samples were run in duplicate (Reimer et al., 2015).

For stable carbon isotope analyses of bioapatite, 800 to 850 µg of enamel powder were balanced into borosilicate exetainers, which were closed with silicone rubber septa. After flushing with helium, the samples were reacted with concentrated phosphoric acid for 2 h at 70°C. The isotope composition of the resulting CO$_2$ was measured using a GasBench II coupled to an isotope ratio mass spectrometer (Thermo Finnigan MAT 253) at the Institute of Geosciences, Department of Applied and Analytical Palaeontology at the University of Mainz, Germany. The isotope data were calibrated against the internal IVA-Carrara marble standard with $\delta^{13}$C = 2.01 ‰, and the measurement quality checked against NBS 19. Average internal precision (1σ) was better than 0.04 for $\delta^{13}$C.

Enamel sample preparation and strontium isotope analysis were carried out at the Curt Engelhorn Center for Archaeometry in Mannheim, Germany following Knipper et al. (2012). Enamel chips were cut from complete teeth using a diamond-coated dental cutting disc. Adhering dentin and all surfaces were thoroughly removed, and the chips ground in an agate mortar. Pretreatment of the powders included soaking in de-ionized water in an ultrasonic bath, followed by the same procedure with 0.1 M acetic acid buffered with Li-acetate (pH 4.5) and three rinses with de-ionized water. Samples were dried overnight and ashed. Strontium separation with Eichrom Sr-Spec resin was carried out in clean laboratory facilities. Strontium concentrations were determined using a Quadrupole-Inductively Coupled Plasma-Mass Spectrometry (Q-ICP-MS) and the $^{87}$Sr/$^{86}$Sr ratios using a High Resolution Multi Collector-ICP-MS (Neptune). Raw data were corrected according to the exponential mass fractionation law to $^{87}$Sr/$^{86}$Sr = 8.375209, to correct for isotope fractionation during measurement.

The statistical analyses were performed using the software SPSS version 23. The data evaluation included descriptive statistics and significance tests. As a normal distribution cannot be ascertained in all cases, the non-parametric Mann-Whitney U-test (MWU-test) was used to examine whether the observed differences were statistically significant at the 5% level. In the Mann-Whitney U-test, distributions are compared across groups.

4 Results

4.1 Osteology

The MNI calculated for the present study is twenty-eight. Based on mandibles, tooth eruption, and dental wear, the age distribution of the sample is presented in Figure 4. It included nine children and subadults of up to 18 years of age and eighteen adult individuals of different age groups. One adult individual lacked a mandible which could be assessed to age.

Based on morphological characters of the os ilium and os pubis six females or probable females and eight males or probable males were buried. Figure 5 shows the age-at-death distribution for each sex.

Since traditional osteological methods for age estimation is known to mimic the age distribution of the reference sample and work poorly for old ages (Bocquet-Appel & Masset, 1982), twelve adult individuals could also be aged using Transition Analysis (TA) (Boldsen et al., 2002). It is evident that the oldest individuals gain substantially higher values when using TA in relation to traditional osteological methods. Point-value ages with the lowest and the highest end value is given in table 2.
Figure 4. Age-at-death distribution based on tooth eruption using Schour and Massler (1941), available in Hillson (1996, p. 143), and on dental wear (Miles, 1962).

Figure 5. Adult age-at-death distribution divided by sex, based on the degeneration of the auricular facet as suggested by Lovejoy et al. (1985).

Table 2. Age-at-death distribution using Transition Analysis.

<table>
<thead>
<tr>
<th>Point value</th>
<th>Low</th>
<th>High</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.0</td>
<td>15.0</td>
<td>26.2</td>
<td>M</td>
</tr>
<tr>
<td>20.0</td>
<td>15.0</td>
<td>26.2</td>
<td>M</td>
</tr>
<tr>
<td>20.0</td>
<td>15.0</td>
<td>28.0</td>
<td>F</td>
</tr>
<tr>
<td>20.0</td>
<td>15.0</td>
<td>28.0</td>
<td>F</td>
</tr>
<tr>
<td>26.5</td>
<td>26.5</td>
<td>58.0</td>
<td>F</td>
</tr>
<tr>
<td>35.2</td>
<td>15.2</td>
<td>69.9</td>
<td>M</td>
</tr>
<tr>
<td>43.0</td>
<td>21.8</td>
<td>77.3</td>
<td>F</td>
</tr>
<tr>
<td>75.3</td>
<td>45.3</td>
<td>90.3</td>
<td>M</td>
</tr>
<tr>
<td>75.3</td>
<td>45.3</td>
<td>90.3</td>
<td>M</td>
</tr>
<tr>
<td>72.8</td>
<td>30.3</td>
<td>90.0</td>
<td>F</td>
</tr>
<tr>
<td>78.1</td>
<td>44.9</td>
<td>92.5</td>
<td>M</td>
</tr>
</tbody>
</table>
There is a difference in age-at–death values between the sexes, but this difference is not statistically significant (MWU-test, p=0.2796). The distribution suggests that the mean age at death was 33.7 years for females and 50.7 years for males. It is possible that this difference reflects the hazard of child birth in the population. The demographic pattern of Falköping 5 was further analysed using a Siler model.

![Survivorship Graphs](image)

**Figure 6.** Result of the Siler model for survivorship for Falköping stad 5 (a), Karataş, Turkish Bronze Age 2500–2300 BC (b) (Angel, 1969, available in Weiss & Wobst, 1973), nomadic Saami (c), and settled Saami 1796–1840 (d) (Wahlund, 1932).

The survival function of Falköping stad 5 is presented in Figure 6 and the Siler parameters in Table 3. The Siler graph of Falköping stad 5 shows tendencies towards a type I survivorship with a high mortality risk in the younger years (<15) and a high age non-specific (residual) mortality. The pattern in Falköping stad 5 is similar to that of Bronze Age Turkey; however, evidence from the Falköping stad 5 material suggests individuals there reached an older age, while also demonstrating a later onset of senescent mortality. This distinction is probably due to differences in aging methods where traditional osteological methods are unable to detect old individuals. There is a large difference, however, to both Saami populations where infant mortality is similar to that of Falköping stad 5, but with a low age-independent mortality hazard. The high number of young adults in the sample is often discussed as an “accident-bump”. This bump is a widely known phenomenon, but it is considered too detailed for paleodemographers to possibly analyze.
and is usually not further investigated (Wood et al., 2002). The demographic data of Falköping 5 does not resemble those of late Mesolithic Skateholm or Middle Neolithic foragers from the island of Gotland (Ahlström, 2015), who present very low child mortality rates. High juvenile mortality is primarily due to infectious disease in the world today (Black et al., 2010; Roberts & Manchester, 2005). It is possible that early weaning would also influence child mortality negatively (Howcroft et al., 2012). Developmental defects in tooth enamel have sometimes been discussed as a result of insufficient weaning foods (Corruccini et al., 1985). However, the duration of the growth disturbance is difficult to assess (Hilson & Bond, 1997) and teeth have different predisposition for enamel defects. This relationship has therefore been questioned (Blakely et al., 1994; Bennike et al., 2007). The relationship between weaning and child mortality is yet not definitely settled. Traditionally, a lack of juveniles in archaeological assemblages is considered to be the result of taphonomy. However, Ahlström (2015) interprets the low number of juveniles in the Skateholm and Gotlandic material as depending on a low population density, minimizing the risk of infectious disease, sensu lato child mortality. The higher child mortality in the Falköping 5 material might therefore reflect a high population density or a high mobility in the area, which makes the population more at risk for infectious disease.

Table 3. Siler models with parameters from Falköping stad 5, Bronze Age population of Karataş (Angel, 1969, available in Weiss & Wobst (1973) and church records of Saami populations (Wahlund, 1932).

<table>
<thead>
<tr>
<th>Population</th>
<th>Parameters for Siler model</th>
<th>$\alpha_1$</th>
<th>$\beta_1$</th>
<th>$\alpha_2$</th>
<th>$\alpha_3$</th>
<th>$\beta_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falköping stad 5</td>
<td></td>
<td>1.323036e-01</td>
<td>1.453876e+00</td>
<td>2.508339e-02</td>
<td>4.581383e-11</td>
<td>2.976407e-01</td>
</tr>
<tr>
<td>Karataş</td>
<td></td>
<td>0.021103057</td>
<td>0.517287341</td>
<td>0.005052553</td>
<td>0.005605995</td>
<td>0.082126280</td>
</tr>
<tr>
<td>Nomadic Saami</td>
<td></td>
<td>3.138836e-01</td>
<td>5.241204e+00</td>
<td>6.908124e-03</td>
<td>1.136060e-08</td>
<td>2.284405e-01</td>
</tr>
<tr>
<td>Settled Saami</td>
<td></td>
<td>1.297838e-01</td>
<td>1.274081e+00</td>
<td>6.267815e-03</td>
<td>1.104711e-10</td>
<td>2.936886e-01</td>
</tr>
</tbody>
</table>

Only two femora from definitely different individuals could be measured for calculation of stature. Both individuals were evaluated as males based on sexual dimorphism. This classification was done by applying an iterative discriminant analysis on three different measurements of robusticity (Tornberg, 2018). The maximum femoral lengths were 44.3 and 48.9 cm correlating with a stature of 165.9 and 178.4 using Sjøvold’s model (Sjøvold, 1990). The mean male stature in south Swedish Late Neolithic is 173.5 (n=8) in LNI and 173.2 in LNII-EBA (n=15) (Tornberg, 2018). Bennike (1985) reports mean stature for Denmark somewhat higher, equaling 176.2 cm in the Late Neolithic (n=50). Even if the estimates are based on different models, the results only differ marginally (=1 cm higher for the Trotter and Gleser 1952 model used by Bennike).

In the 152 non-molar teeth, only one cariogenic lesion could be detected, on a second lower premolar. In the 128 registered molars dental caries were present in fifteen cases, which adds up to a caries frequency of 11.7% in molars. The frequency of caries seen in all registered teeth was 5.7%, and in post-canine teeth 8%. These numbers are similar to those at the Late Neolithic-Early Bronze Age site of Abbekås, southernmost Sweden, where 6.9% of post-canine teeth were affected (Tornberg, 2013), and substantially higher than reported from Swedish Middle Neolithic skeletal assemblages (Ahlström, 2003). Dental caries appear to have been more frequent in Denmark, where a decline in affected individuals from 25% to 14.9% is reported between the Middle and Late Neolithic (Bennike et al., 2007). Since the skeletal material from Falköping stad 5 is commingled, as is some of the material from Abbekås, frequencies based on individuals, such as those calculated by Bennike et al. (2007), have not been possible. The most common location of dental caries in Falköping 5 is interproximal (n=8) followed by the occlusal surface (n=5). Only one example of root caries and one example of a large cavity of unknown origin is represented. The sample is regarded as too small to evaluate if there are differences in the frequency of...
caries and their location related to age. However, the individual suffering from root caries also exhibits one of the highest attrition scores (25/40) of the second molar among the affected teeth.

*Enamel hypoplasia* is due to disturbance of the enamel formation during tooth development in childhood, and is considered as a sign of general malnutrition and childhood illness (Hillson, 1996; King et al., 2005). Eleven teeth from eight individuals were documented with enamel hypoplasia in the Falköping 5 material. This correlates to a frequency of 28.6% of the total number of individuals of twenty-eight. The majority of individuals with enamel defects survived into adulthood, but two individuals did not survive past 12 years of age. All but one of the cases had enamel defects in the form of linear grooves, and the last case was in the form of a single pit. Canines were most commonly affected, followed by incisors. This phenomenon is common, possibly reflecting the fact that canines are more prone to develop hypoplasias, and its appearance could depend on local nutritional deficiency or lack of space in the jaw (Bennike et al., 2007). However, most individuals seem to have developed these disturbances around the age of 3–4 years, which is in accordance with site mortality.

To further evaluate signs of malnutrition, the frequency of *cribra orbitalia* was registered. Cribra orbitalia, or pitting of the orbital roof, is generally considered a sign of iron deficiency anemia, caused by expansion of the bone marrow (Waldron, 2009). However, in contrast to genetically induced anemia, such as sickle-cell anemia and thalassemia, iron-deficiency anemia generally causes little or no expansion of the bone marrow, which is why this hypothesis has been questioned. Instead, vitamin–C- and vitamin–D-deficiency-caused hematomas have been put forward as possible explanations (Walker et al., 2009; Wapler et al., 2004). In this study, a total of nineteen frontal orbits from both sides were registered. One orbit derived from a child, three from adolescents or young adults, and the remaining from adults with different degrees of cranial suture synostosis. None of the orbits showed any signs of active or healed cribra orbitalia. There is no correlation between the presence of enamel hypoplasia and cribra orbitalia in the sample. Either individuals affected by cribra orbitalia lived long enough for the feature to heal out completely, or cribra orbitalia and enamel hypoplasia have different etiologies, with only that of enamel hypoplasia affecting the individuals in Falköping 5. The latter is considered more probable.

### 4.2 Dating

The radiocarbon analyses included in this study were conducted at the 14Chrono Centre in Belfast. The Belfast lab employs more developed methods, with several cleaning steps including ultrafiltration and AMS measurements, compared to the earlier-performed conventional dating at the Laboratory in Stockholm. Therefore, the uncertainties of the new dates are smaller and the dates are here considered more reliable (Figure 7, Appendix). Furthermore, the reported C:N ratios from the samples analysed in Belfast indicate well-preserved collagen (Appendix).

A total of twenty individuals were 14C dated (Figure 7, Appendix). Most of the samples were dated to the transition between Late Neolithic I and II (2sigma, 95.4%). Five of them were most probably from the Late Neolithic I (2sigma), while three individuals could be dated to the Late Neolithic II (2sigma, 95.4%) (Figure 7). Unlike previous dates, no Middle Neolithic date was observed. The 14C analyses suggest a use-time of the grave between about 100 and 550 years (2sigma, 95.4%). The main phase of the burials is concentrated to about 2000 cal BC. The series indicates a continuous use, even though two or three shorter phases might also be possible.

The osteological results indicate successive burials. The distribution of the 14C-dated bones was investigated stratigraphically and spatially in ArcGIS (10.1). Over all, there was no apparent pattern of where the skeletal remains were found according to their 14C dates, although the three latest buried individuals (F83III:1, F90 and F123) were found in the upper layers (Appendix, Weiler, 1994, pp. 12, 15).
4.3 Carbon and Nitrogen Stable Isotopes for Dietary Reconstruction

In this study, teeth from twenty-one individuals of different age and sex were sampled (Table 1, Appendix). In contrast to bones, the turnover of tooth dentine is insignificant and therefore corresponds to the formation time of the tooth root. The teeth included in this study offer an average of the food intake during the childhood and early youth (Hillson, 1996, p. 155). No quantitative diet reconstruction was possible due to the lack of relevant reference samples. The available δ¹³C and δ¹⁵N measured in animals and plants are either dated to other time periods or originate from other regions, which might have very different subsistence strategies and environmental conditions. However, to be able to include also the carbohydrate
and fat contribution to the diet, the results of δ13C and δ15N analyses of dentin collagen are presented and discussed, along with the δ13C data of enamel apatite (Appendix, Table 4).

The δ15N values of the four deciduous teeth, mean value of 10.4±0.4‰ (1SD), were significantly higher than those of the permanent teeth (n=17), mean value of 9.3±0.8‰ (1SD) (MWU-test, p=0.031). These elevated values are likely caused by breastfeeding and deciduous teeth were therefore excluded from further evaluation regarding dietary composition. The roots of the first molars begin forming at the age of three years and thus could also be affected by breast feeding (Hillson, 1996). However, no statistically significant increase of the δ15N values could be noted. Therefore, the first molars are included in the diet analysis.

Table 4. Summary statistics of light stable isotope data from Falköping stad 5, with and without the outlier (collagen apatite spacing) F122.

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>Mean δ15Ncollagen ± 1 SD (‰)</th>
<th>Mean δ13Ccollagen ± 1 SD (‰)</th>
<th>Mean δ13CEnamel ± 1 SD (‰)</th>
<th>Collagen-apatite spacing ± 1 SD (‰)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All sampled teeth</td>
<td>21/20</td>
<td>9.5±0.8</td>
<td>-20.8±0.4</td>
<td>-14.6±0.9</td>
<td>6.2±0.8/6.1±0.5</td>
</tr>
<tr>
<td>All excluding deciduous</td>
<td>17/16</td>
<td>9.3±0.8</td>
<td>-20.9±0.3</td>
<td>-14.5±1.0</td>
<td>6.3±0.9/6.2±0.5</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>9.5±0.9</td>
<td>-20.9±0.5</td>
<td>-14.8±0.8</td>
<td>6.1±0.5</td>
</tr>
<tr>
<td>Male</td>
<td>11/10</td>
<td>9.3±0.8</td>
<td>-20.9±0.3</td>
<td>-14.3±1.1</td>
<td>6.6±1.0/6.3±0.5</td>
</tr>
</tbody>
</table>

The average δ15N of 9.3±0.8‰ and the δ13C mean value of -20.9±0.3‰ (1SD) in dentin collagen (Table 4) reflect a terrestrial diet (Schoeninger et al., 1983). The mean δ13C value in apatite is -14.5±1.0 (1SD). The relatively low δ15N values indicate a minimal consumption of freshwater fish and no reservoir effect is suspected. The standard deviation of the δ15N values mirrors their high variation, while the standard deviation of the δ13C in collagen is relatively low (Table 4). There is a slight difference, although not statistically significant (MWU-test, p=0.441), of δ15N between the sexes, showing lower δ15N values and higher collagen apatite spacing for males (Table 4).

The mean value of the collagen-apatite spacing is 6.3±0.9‰ (1SD). However, in this case there is an outlier, F122, with a very high collagen-apatite spacing (9.1‰) (Figure 8). If this individual is excluded the mean value and standard deviation of the collagen-apatite spacing are slightly lower (Table 4). In both cases the collagen-apatite spacing results correspond better to herbivores and omnivores than carnivores (Lee-Thorpe, 1989, p. 590), suggesting a substantial intake of plant foods such as cereals and vegetables.

When the collagen-apatite spacing is plotted in three different phases, two outliers appear (Figure 8). A probable male who died at the age of 40–50 years, F122, shows the highest collagen-apatite spacing. The same individual also has a rather low δ15N value (8.3‰) (Figure 8, Appendix), which could indicate a high intake of plant food. The sample with the lowest collagen-apatite spacing (5‰), F134, belongs to a young adult (Figure 8; Appendix). If these two outliers are omitted, some slight differences in the collagen-apatite spacing over time can be observed, with the lowest median value in the earliest phase and the highest median value in the later phases (Figure 8).

Figure 9 shows two data clusters, which probably reflect different diets. The smaller group has δ15N values indicating a higher consumption of protein from a higher trophic level than the larger group. These differences do not correspond to sex, strontium isotopes, or radiocarbon dating. It might reflect differences in subsistence strategies or in social status.

There is no obvious correlation between the δ13C and δ15N values in collagen and the 14C dates (Figure 9), and the sample size in some of the phases are too small for any statistical significance tests. However, a small tendency for higher δ15N values can be observed in the individuals buried in the first part of the Late Neolithic (Figure 10).
Figure 8. Collagen-apatite spacing from the 17 individuals in Falköping stad 5, included in the diet investigation. Boxplot with line: median, box: 25th-75th percentile, whisker: ca 95% of the data. LNI: Late Neolithic I, LNII: Late Neolithic II.

Figure 9. δ¹³C and δ¹⁵N values in collagen from the 17 sampled teeth from Falköping stad 5, included in the diet investigation. LNI: Late Neolithic I, LNII: Late Neolithic II.
4.4 Results of Strontium Isotope Analysis

Based on earlier and ongoing research, the isotopic signal of the bio-available in Falbygden is suggested to range from 0.713 to 0.716 (marked with dashed lines in figures 11, 12, 13 and 15), and in the limestone area where Falköping stad 5 is located ratios around 0.714 are very likely (Blank et al., 2018; Blank & Knipper, in press; Sjögren et al., 2009; Sjögren & Price, 2012). In a nearby passage grave, Falköping stad 3, measurements from two rodents showed ratios of 0.714 (Sjögren et al., 2009). Ratios ranging between 0.719 and 0.726 are interpreted here as signals which could originate from different locations in the surrounding Precambrian areas in inland-western Sweden, while even higher ratios can be expected in the eastern or northeastern part of Sweden (Åberg & Wickman, 1987, pp. 36–37; Eriksson et al., 2016; Lindström, 2009; Price et al., 2017; Sjögren et al., 2009). Ratios between 0.717 and 0.719 (marked with dashed lines in figures 11, 12, 13 and 15) are more difficult to interpret and several explanations are plausible. The ratios are found in areas about 30 km south and 20 km northwest of Falbygden but can also be expected for areas surrounding Falbygden (Blank et al., 2018; Blank & Knipper, in press; Frei, 2009; Sjögren et al., 2009; Sjögren & Price 2012). However, these ratios could also be mixed signals from Falbygden and the surrounding Precambrian areas for reasons discussed in more detail below. In this paper, the clearly delimited Cambrosilurian area of Falbygden is defined as local, whereas both the closest surrounding Precambrian region and areas of further distances are considered non-local. Thus, movements within the 50 × 30 km extended Falbygden region, as well as movements between Falbygden and other areas with similar strontium isotope signals, cannot be detected.

In the following section, the strontium isotope ratios incorporated during childhood and early youth of the buried individuals are discussed. The terms local and non-local refer here to isotope signals and not to the origins of individuals (see above and discussion). In four cases, deciduous teeth (dpm) are included, which gave $^{87}$Sr/$^{86}$Sr ratios of between 0.717 and 0.726 (Appendix). The enamel of these teeth starts to develop before birth and is completely crystalized at the age of 6 to 9 months (Hillson, 1996). Hence, the strontium isotope ratio also mirrors the whereabouts of the mother carrying the unborn/infant child. Of all
the sampled individuals only six (29%), show a local signal with signals close to 0.715 (mean 0.7150±0.0005) while seven (33%) fall into the more ambiguous range from 0.717 to 0.719, and eight individuals (38%) most likely spent part of their childhood outside of the sedimentary area of Falbygden. In three individuals (F83III:1, F90 and F123), ratios higher than 0.726 were measured. F123, a probable female, who died when she was over 40 years of age, has a very high ratio (0.733), which is not a likely signal from western Sweden. The frequency of buried individuals with non-local signals is higher in this grave than what is generally found in the Late Neolithic megalithic population of Falbygden (Locals: 42%, Ambiguous: 29%, Non-locals: 29%, Blank & Knipper, in press).

Figure 11. Strontium isotope ratios of the buried individuals in Falköping stad 5 in chronological order (histogram and a scatter plot). A: Local 87Sr/86Sr ratios, B: non-local/mixed 87Sr/86Sr ratios, C: non-local 87Sr/86Sr ratios, see text above. The local and non-local signals of Falbygden are based on earlier and ongoing research. LNI: Late Neolithic I, LNII: Late Neolithic II.

There is no apparent correlation between the strontium isotope ratios and the 14C dates in the first phase, when most of the individuals were buried in this grave (Figure 11). As can be observed in figure 10, the youngest burials—the individuals dated to the Late Neolithic II (F123, F83III:1 and F90)—have significantly higher (MWU-test, p=0.002) strontium isotope values than the rest of the individuals investigated (Appendix). The adult man (F83III:1) and the child (F90) have very similar strontium isotope ratios and δ15N values, which could indicate a common origin. A plausible explanation is that these three individuals belong to a later burial phase associated with a non-local group.

As can be observed in Figure 12, there is no correlation between sex and strontium isotope ratios. In figure 12, it seems like there are no women with ratios in the range between 0.716 and 0.719, but a more accurate description is that there are no adults of female sex with these ratios. However, the ratios from two children where enamel formed in utero or as infants fall into this range, and the ratio 0.7263 is also represented in the enamel of another child in the sample (Figure 13). At such an age, babies share the isotopic signal of their mothers at that specific time.

5 Discussion

In this part, the results obtained from the gallery grave Falköping stad 5 are placed within their wider geographical and chronological framework.

5.1 Time of Use

Previous research revealed that dolmens and passage graves were built over a relatively short period at the transition between the early and the middle Neolithic, 3300–3000 cal BC, in the cultural setting of the
Figure 12. Histogram of strontium isotope ratios compared to sex, Falköping stad 5. A: Local $\text{Sr}^{87}/\text{Sr}^{86}$ ratios, B: non-local/mixed $\text{Sr}^{87}/\text{Sr}^{86}$ ratios, C: non-local $\text{Sr}^{87}/\text{Sr}^{86}$ ratios, see text above. The local and non-local signals of Falbygden are based on earlier and ongoing research.

Figure 13. Histogram of strontium isotope ratios of children and juveniles with unknown sex, Falköping stad 5. A: Local $\text{Sr}^{87}/\text{Sr}^{86}$ ratios, B: non-local/mixed $\text{Sr}^{87}/\text{Sr}^{86}$ ratios, C: non-local $\text{Sr}^{87}/\text{Sr}^{86}$ ratios, see text above. The local and non-local signals of Falbygden are based on earlier and ongoing research.
Funnel Beaker Culture (Persson & Sjögren, 1995, 2003, 2011). The chronology of the gallery graves is still not addressed in a sufficient way, but indications of Middle Neolithic gallery graves have been suggested (Algotsson, 1996; Blank, 2016). There have been several attempts to date the different kinds of gallery graves found in Sweden by analysing their construction, but this method has turned out to be complicated (Anderbjörk, 1932; Johansson, 1961; Montelius, 1905, etc). A previous study of the use and reuse of megalithic graves in Falbygden, based on new ^14C analyses and relative dating of artefacts revealed that the most intense period of use for the gallery graves, as well as the most intense period of reuse of passage graves, was the second half of the Late Neolithic (Blank, 2016). Most of the Danish stone cists seem to have been in use in the transition between Late Neolithic I and II and in Late Neolithic II, based on dagger types found in the graves (Ebbesen, 2004, p. 23).

New radiocarbon dating of human remains show that gallery graves in Falbygden were used for successive burials into the Early Bronze Age period II/III (Blank, 2017). Moreover, a relatively large quantity of ^14C dates of skeletal remains from Scania, southern Sweden, show that gallery graves were intensely used at least into the Early Bronze Age period II in this region as well (Bergerbrant et al., 2017; Tornberg, 2017).

In the second part of the Scandinavian Late Neolithic, daggers also become more common and metal objects begin appearing in graves in south-west Sweden (Apel, 2001; Vandkilde, 1996; Weiler, 1994). The lack of metal objects and later dagger types, along with the ^14C dates, indicates that this grave was used for a rather limited period around 2000 cal BC with a few individuals buried later in the beginning of LNII. No slate pendants, which are very common in gallery graves in southern Scandinavia, were found in this grave. Anderbjörk (1932, p. 32) argues that slate pendants can be dated to the later part of Late Neolithic as they occur with the later dagger types. Falköping stad 5 can thus be considered to be a rather early gallery grave (Late Neolithic I) with no burials later than the Late Neolithic II. Furthermore, there is nothing that suggests that this is a Middle Neolithic grave, which one could suspect based on the earlier radiocarbon dates.

Considering the ^14C-dates, the gallery grave appears to have been continuously used, although use in two or three different phases in close succession is also possible. The majority of the burials are dated to LN I and the transition between the LNI–LNII. This commingled bone material indicates successive use, with skeletal remains moved to make way for new burials. On the other hand, the three individuals dated to Late Neolithic II were all found in the upper layers (see above). In Falbygden, several phases of burials in numerous gallery and passage graves have been observed and discussed (Ahlström, 2009; Sjögren, 2003; Weiler, 1997). The individuals included in the latest burial phase all have strontium isotope signals distinct from the others, suggesting they may have travelled a long distance to reach the area. Such evidence could indicate an influx of people from new areas. Possibly a non-local group settling and reusing the grave, or non-local people integrating to the group using the grave.

5.2 Health and Demography

The Falköping stad 5 gallery grave displays a high child mortality rate, with one third of the skeletons representing individuals who did not reach an adult age. Even though this is suggested to be an expected frequency (Lewis, 2007), it has recently been questioned for prehistoric populations (Ahlström, 2015). Further, half of the adults that could be aged using transition analysis (n=6) died before the age of 30, and the majority of these (4/6) were female. The high female mortality during childbearing years is probably due to hazards in relation to childbirth. Half of the adult males, as well as females who survived their childbearing years, lived into their seventies. A high number of juveniles within a sample is often associated with a population increase (Wood et al., 1992). Since the risk of infectious disease and childhood mortality are closely connected, Ahlström (2015) suggests that the invisibility of children in Stone Age materials does not merely reflect taphonomic loss, but also a low population density. It is probable that low visibility of children in the material is affected by both. The high childhood mortality in the Falköping stad 5 gallery grave might reflect a rather high population density and/or mobility in the area during the Late Neolithic. Weiler (1994, p. 66) suggests that the sex and age distribution in the grave indicates a family grave, and demographic calculations made by Grandell (in Iregren, 1977, p. 62ff) have been used to support this idea. This assessment is reasonable; however, considering a seemingly high population density and usage under
an apparently short time span, one could argue it is more likely to be a grave for individuals living in the vicinity, and while it is possible that some individuals did belong to the same family, it is unlikely they all belonged to one specific family. Further, there remains the question of how one defines a family. The definition of a Neolithic family has been discussed, and the characterisation of megalithic graves as family graves has been rejected by Ahlström (2009, p. 135ff.), who argues that the large size variation in Falbygden Middle Neolithic passage graves indicates that a number of families joined together in the construction and use of the grave. Similar size variation is also seen in Late Neolithic gallery graves.

Growth and stature are closely connected to health. Generally, osteologists and archaeologists have suggested that stature increases in the south Scandinavian Late Neolithic. This conclusion is partly confirmed by Tornberg (2018), who states that stature is high in the Late Neolithic, but this substantial increase in stature is associated with the Battle Axe Culture in Middle Neolithic B. The two males from Falköping stad 5 measured 165.9 and 178.4 cm in stature using Sjøvold’ s model (Sjøvold, 1990), which is considered consistent with a mean male stature in the south Swedish Late Neolithic of 173.5 (n=8) in LNI and 173.2 in LNII–EBA (n=15) (Tornberg, 2018). It is difficult to draw any conclusions regarding health based on only two individuals, since the genetic component of stature becomes too dominant; however, there is no evidence of growth stunting, indicating sufficient nutrition and moderate disease rates during adolescence when much of adult stature is determined.

The frequency of enamel hypoplasia is relatively high (28.6%) in relation to the Late Neolithic-Early Bronze Age locality of Abbekås in southern Sweden (15%) (Tornberg, 2013), but lower than in Middle and Late Neolithic Denmark (40%) (Bennike et al., 2007). The location of the enamel defects shows that nutritional stress or illness commonly affected children around the age of 3–4, often attributed to an increased risk of diseases associated with weaning. However, it might also depend on tooth morphology, where earlier enamel hypoplasia is undetectable macroscopically (Lewis, 2007). However, most of the individuals exhibiting enamel hypoplasia (6/8) survived into adulthood. It is probable that the high child mortality, high mortality among females of reproductive age, and the frequency of enamel hypoplasia together display a population at high risk for infectious disease due to a relatively high population density, and possibly also at risk of infections associated with close contact with animals (Roberts & Manchester, 2005, p. 23).

There is no evidence of Cribra orbitalia. Bennike (1985) states that cribra orbitalia is present in approximately 50% of the children and 10–20% of the adults in prehistoric Denmark. In the Abbekås material, 77% of the individuals were affected (Tornberg, 2013). The aetiology of cribra orbitalia is somewhat unclear, but iron deficiency anaemia and/or vitamin C or D deficiency are probable causes. Although it is probable that the pathological features of cribra orbitalia are multi-causal, Tornberg in this study favours the vitamin C/D deficiency hypothesis since bone-marrow hypertrophy related to iron-deficiency is low. It would be beneficial for future research to further investigate a possible correlation between cribra orbitalia and other signs of vitamin C and vitamin D deficiency. However, with unclear aetiology of cribra orbitalia, it seems to have been entirely absent in Falköping stad 5.

5.3 Diet and Subsistence

According to previous research (Blank, in press; Sjögren & Price, 2013b; Sjögren, 2017), agriculture was already well established in Falbygden during the Middle Neolithic. Pollen analysis indicates that pasture land increased during the Late Neolithic in southern Scandinavia (Holm et al., 1997, p. 216). Furthermore, shafts hole axes, which appear in the Late Neolithic period, are associated with the clearance of woodland (Holm et al., 1997, p. 216). During the Scandinavian Late Neolithic, an increased population density can be observed, which often has been interpreted as a consequence of an intensified agriculture, in turn resulting in the spread of the gallery graves in the landscape. Gallery graves in Falbygden were placed in the same areas as the passage graves but are situated in other areas too providing a higher variation of the topographical distribution of the graves.

Evidence of agricultural activities in Late Neolithic Falbygden includes, for example, flint tools used for harvesting and a few seed impressions on ceramic vessels (Hjelmquist, 1955; Weiler, 1994). Animal bones in
gallery graves are quite common and mainly derive from domesticated animals such as pigs, cattle, and goats/sheep. These are also the dominant species found in the Middle Neolithic passage graves and settlements (Sjögren et al., in press; Sjögren & Price, 2013b; Sjögren, 2017). Fish remains from the settlements, on the other hand, have been scarce, even though small bones often have been preserved in the calcareous soils (Sjögren, 2017, p. 297; Sjögren et al., in press). Although rare, two fish hooks have been found in a Middle and a Late Neolithic megalithic grave in the area of Falköping stad (SHM: 4840:29-32, SHM: 4034: a). In the Falköping stad 5 grave, a few pike bones were found. These bones might belong to the Late Neolithic period, but they could also be a result of later animal activity since bones from two foxes were identified (Weiler, 1977, p. 54). It is likely that fish was consumed, even if only marginally as indicated by the low δ15N values. Bones from different birds have been excavated at a Middle Neolithic settlement not far from Falköping stad, although they did not represent a large part of the bone material (Sjögren et al., in press). Today, the Falbygden area is known for its rich birdlife and the many small lakes and streams were probably also a favourable environment for birds during the Neolithic. Some consumption of birds and eggs would be expected.

The mean values of δ15N and δ13C (9.3‰ and -20.9‰) measured in collagen in buried individuals in Falköping stad 5 reflect a terrestrial diet and are similar to values in other Late Neolithic individuals, both from Falbygden and from the island of Öland, in southern Sweden (Blank, in press; Eriksson et al., 2008). Unlike in Öland, in Falbygden the δ15N and δ13C values from the earlier megalithic population are similar to the Late Neolithic individuals (Blank, in press; Eriksson et al., 2008; Sjögren & Price, 2013b). Previous studies of the Middle Neolithic population in Falbygden revealed rather homogenous δ13C values around -21‰ and δ15N values around 10.5‰, which can be expected for an inland population with a terrestrial diet (Blank, in press; Hinders, 2011; Lidén, 1995; Sjögren & Price, 2013b). These values are consistent with other Middle Neolithic megalithic populations from southern Sweden, Denmark, and Germany where δ15N values between 10 and 11‰ and δ13C values around -20 to -21‰ were observed (Sjögren, 2017, p. 297).

Table 5. Summary statistics of light stable isotopes from megalithic populations in Falbygden. MN: Middle Neolithic, LN: Late Neolithic, EBA: Early Bronze Age.

<table>
<thead>
<tr>
<th>Period</th>
<th>Location</th>
<th>Bone element</th>
<th>N</th>
<th>Mean δ15N (‰) 1 SD</th>
<th>Mean Collagen apatite spacing (‰) 1 SD</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>MN</td>
<td>Falbygden</td>
<td>teeth</td>
<td>21</td>
<td>10.4±0.4</td>
<td>6.2±0.8</td>
<td>Hinders 2011; Sjögren, Price 2013b</td>
</tr>
<tr>
<td>MN</td>
<td>Falbygden</td>
<td>teeth</td>
<td>8/5</td>
<td>10.4±0.5</td>
<td>6.2±0.2</td>
<td>Blank in press</td>
</tr>
<tr>
<td>LN/EBA</td>
<td>Falbygden</td>
<td>teeth</td>
<td>16</td>
<td>9.9±0.7</td>
<td>6.1±0.7</td>
<td>Blank in press</td>
</tr>
<tr>
<td>LN</td>
<td>Falköping stad 5</td>
<td>teeth</td>
<td>17/16</td>
<td>9.3±0.8</td>
<td>6.3±0.9/6.2±0.5</td>
<td>This study</td>
</tr>
</tbody>
</table>

The tendency of higher δ15N values and lower collagen-apatite spacing observed in the Falköping 5 material in the earlier burials could indicate a greater consumption of protein from higher trophic levels and a lower intake of plant food than in the later part of the Late Neolithic. However, in general the collagen-apatite spacing of the individuals from Falköping stad 5 is similar to findings in Middle Neolithic megalithic populations and other Late Neolithic/Early Bronze Age individuals from Falbygden (Table 5). The high standard deviation of the δ15N values in Falköping stad 5 corresponds better to the LN/EBA than to the MN values of Falbygden (Table 5). In figure 14, the δ15N values from Falköping stad 5 are presented with previous results associated with permanent teeth from megalithic graves in Falbygden (Blank, in press; Hinders, 2011). The δ15N values are more varied and lower in the Late Neolithic than in the Middle Neolithic—a difference that is significant (MWU-test, p=0.003).

The lower δ15N values during the Late Neolithic compared to the Middle Neolithic period could indicate a decrease in the intake of animal-derived foodstuffs, such as meat or dairy products, or an increased consumption of protein from a lower trophic level, such as plant food. This interpretation is however contradicted by the fact that the plant food intake does not seem to increase if the collagen-apatite spacing is taken into consideration. Instead, similar values can be observed during the Late Neolithic and the Middle Neolithic. Caries frequency is slightly higher in Falköping stad 5 than in contemporary Scania (Tornberg, 2013, 2017) and substantially higher than in Middle Neolithic Falbygden (Ahlström, 2003). The caries
frequency supports an increased reliance on carbohydrates, but could possibly also depend on hereditary factors or different tooth brushing.

Figure 14. $\delta^{15}N$ from megalithic individuals in Falbygden (teeth). Boxplot with line: median, box: 25th-75th percentile, whisker: ca 95% of the data. MN: Middle Neolithic, LN/EBA: Late Neolithic / Early Bronze Age.

Analysis of ancient protein preserved in dental calculus from six individuals in Falköping stad 5 provides evidence supporting dairy consumption (Fotakis et al., in preparation). A milk protein, beta-lactoglobulin, was previously identified in archaeological dental calculus dating from the Bronze Age onwards (Warinner et al., 2014). The oldest milk residues in Sweden were found in a ceramic vessel dated to the Early Neolithic (4000–3350 cal BC) (Isaksson & Hallgren, 2012). In Falbygden, traces of milk products have been found in Middle Neolithic pottery (Kaldhussæter Lindboek, 2014). The result from Falköping stad 5 is amongst the earliest evidence for direct consumption of dairy in Sweden (Fotakis et al., in preparation). Currently, in individuals from Falköping stad 5, there is no molecular evidence supporting the presence of the genetic mutation responsible of lactase persistence (LP), i.e. the ability for adults to digest lactose (a milk sugar). This trait emerged as a consequence of a relatively recent genetic mutation, supposedly related to the practice of dairying (Sverrisdóttir et al., 2014; Hollox et al., 2001; Itan et al., 2009; Bersaglieri et al., 2004; Leonardi et al., 2012; Ségurel & Bon 2017), and so far absent or detected at low frequency in the Early to Middle Neolithic (Burger et al., 2007; Malmström et al., 2010; Allentoft et al., 2015). The timing and circumstances leading to the selection of traits linked to LP is still not fully understood, but increased access to liquids (Hollox et al., 2001) and the important source of D-vitamin (Itan et al., 2009) have been put forward as explanations. However likely to have been suffering from some stomach ache, there are examples of non LP regular milk-drinkers as well (Ségurel & Bon, 2017). Lactose reduces when milk is processed into cheese or yoghurt (Leonardi et al., 2012), which were probably also the first kinds of dairy consumed. It is possible that the evidence of dairy consumption in all sampled individuals is a sign of a surplus in dairy products related to a change towards a focus on secondary products, i.e. the Secondary Products Revolution (Sherratt, 1981). The ceramic ware of the Late Neolithic is substantially different from the pottery from the earlier periods. Hulthén (2013) argues that Late Neolithic pottery is adapted for keeping liquids cold and is suitable for souring them. If cribra orbitalia is due to vitamin D deficiency, it is interesting that there is no registered case in the population, where dairy, rich in vitamin D, was been consumed on a regular basis.

The lower $\delta^{15}N$ values found in individuals from Falköping stad 5 than those associated with earlier populations could indicate a greater dependence on cattle than pigs, as pigs in general eat from a higher
trophic level than cattle. A greater dependence on cattle could indicate a focus on secondary products such as milk or blood (Evans-Pritchard, 1937, p. 223ff.; Sherratt, 1981). This suggestion would, however, have to be confirmed by isotope analyses on pig and cattle remains themselves. However, the previously analysed sheep, cattle, and pig remains from the Middle Neolithic show similar δ¹⁵N values (Sjögren, 2017, p. 299). The levels of δ¹⁵N could also be affected by differences in agro-pastoral strategies. The δ¹⁵N values of the animals can change depending on how they are held and fed, and the δ¹⁵N values of crops can vary depending on if and how the fields are manured and used, etc.

The higher variability during the Late Neolithic could indicate specialisation. The distribution of gallery graves in different topographical areas could also indicate increased variation in subsistence strategies. However, it is important to acknowledge that nitrogen isotope fractionation is complex and not completely understood, and it seems like there is a rather high variability of δ¹⁵N values among individuals with a similar diet (Deniro & Schoeniger, 1983; O’Connell et al., 2012). In this particular study differences in fractionation could not be the only explanation since the same variation is not seen in the Middle Neolithic population. The higher variability could indicate an increased stratification of society where the access to different foods varied in different social strata or a generally higher human mobility with influx of people with different backgrounds (Blank & Knipper, in press; Tomberg, 2017).

5.4 Human Mobility

The majority (71%) of the buried individuals have non-local strontium isotope signals, i.e. ⁸⁷Sr/⁸⁶Sr signals not present in the Cambrosilurium area of Falbygden (Appendix; Figure 12). This discrepancy is probably due to a high level of mobility among the individuals buried in Falköping stad 5. Since the samples reflect the geological signal associated with childhood locales, the individuals with non-local signals might only have been brought to the Falköping stad area for burial. However, it seems most likely that the megalithic graves of Falbygden were used by local groups living in the vicinity of the graves (Sjögren, 2003; Sjögren et al., in press; this study). In that case, non-local signals would represent people who moved into the area in their younger years and settled for different reasons, including exogamous marriage alliances with groups from outside of Falbygden. Marriage alliances are an effective way of maintaining networks between different groups as well as lowering the risk of inbreeding. Similar propositions have been suggested in published work on the Middle Neolithic population (Sjögren et al., 2009). As in previous studies of both the Middle and Late Neolithic, there is no correlation between sex and non-local strontium isotope signals indicating any specific marriage system (Blank & Knipper, in press; Sjögren et al., 2009).

The strontium isotope signals ranging between 0.716 and 0.719 could be explained by individuals moving in from different locations outside or at the outskirts of Falbygden (Sjögren et al., 2009). It can also be a result of local individuals consuming non-local food, particularly plant food, since plant food is the main contributor to human uptake of strontium (Bentley, 2006). However, the favourable conditions for agriculture with calcareous soils and the easy access to water do not support a large import of plant food. Ratios within this range could also be a result of repeated movement in and out of Falbygden. One reason for such movements could be transhumance—that is, herding of cattle and sheep/goat between different grazing lands between seasons. The distance from Falköping stad 5 to the outskirts of Falbygden is between 6 and 15 km depending on direction. It is possible that seasonal herding was performed, although transhumance can only influence the strontium isotope signal if individuals consumed foodstuffs that were derived along the way and participated in these activities from early childhood. The suggestion of young cattle herders during prehistory has been brought forward by Welinder (1998, p. 192). However, to obtain a strontium isotope ratio above 0.718 you would need to consume a substantial part of your food stuff from the Precambrian areas. Hence, there could have been a lot of movement between the two geological areas that cannot be detected by strontium isotope analysis.

Ratios between 0.719 and 0.726 can be expected in large parts of the Precambrian areas surrounding Falbygden, but are also found in areas further away. Similar ratios are, for example, found in Norway and eastern Sweden ( Lövendahl et al., 1990; Price et al., 2015; Wilhelmson & Ahlström, 2015). The individual with a strontium isotope ratio of 0.733 is not likely to originate from western Sweden and ratios above 0.726
are rare in these parts (Blank & Knipper, in press; Sjögren et al., 2009). Ratios between 0.726 and 0.733 have been observed in the eastern parts of south-central Sweden (Åberg & Wickman, 1987, p. 36f; Eriksson et al., 2016; Lindström, 2009; Price et al., 2017).

There is a distinct increase in human mobility during the Late Neolithic in Falbygden (Blank & Knipper, in press; Sjögren et al., 2009). In the Late Neolithic, individuals with high strontium isotope ratios, not visible in the Middle Neolithic population, are present (Blank & Knipper, in press; Figure 15). Increased mobility, contacts, and interactions between Late Neolithic groups on the island of Öland, southeast Sweden, have also been claimed based on carbon and nitrogen, as well as sulphur isotopes (Linderholm et al., 2014). The increased human mobility could be explained by intensified trade, connected to new artefacts such as flint daggers and new raw materials such as bronze and gold. Long distance networks with Corded Ware and Bell Beaker groups, as well as with the Únétice culture of central Europe, can be observed in the southern Scandinavian Late Neolithic archaeological record (Apel, 2001; Artursson, 2009; Vandkilde, 1996). These cultural influences are also visible in Falbygden (Apel, 2001; Weiler, 1994), and even if the strontium isotope results cannot confirm long distance migration, the higher degree of mobility perhaps indicates increased trade with the surrounding areas which was likely to be connected to long trade networks. The high mobility observed in individuals buried in megalithic graves might indicate that they were a part of the population which was more mobile than others. Falköping stad 5 gallery grave contains a small number of artefacts commonly found throughout southern Scandinavia. Flint does not occur naturally in Falbygden, and the flint found in the grave originates from Scania or Denmark. The dagger is most likely an import from the eastern Danish islands or south-western parts of Scania (Apel, 2001). However, the dagger could also have been produced locally, possibly from a polished flint axe as several flint flakes were found with the dagger. They are of the same raw material and have identical polishing traces (vertical) and patina (Figure 16). The dagger was manufactured by a highly skilled craftsman, and it has been argued that this kind of knowhow could only have been obtained in areas with a lot of flint (Apel, 2001, Apel, 2015). It can also be the remaining belongings of a specialised flint knapper from Scania or Denmark (see Apel, 2015). While there is no evidence of any individual with strontium isotope ratios matching the bio-available signals in Denmark or south-western Scania (see Frei & Frei, 2011 for these ratios), the flint craftsmen working in these regions were not necessarily of local origin. Even though no individuals from southern Scania or Denmark can be traced with strontium isotopes in the Late Neolithic, established contacts with this area are known to have existed in the previous Neolithic periods (Sjögren, 2003). In figure 15, two individuals dated to the previous Battle Axe Culture show strontium isotope ratios of 0.710, indicating that these individuals might have spent their childhood in southern Scania, Denmark or other regions with similar geology or affected by sea spray. The buried individuals in Falköping stad 5 have also been sampled for aDNA in an ongoing research project (The Rise). The results will provide even more information about the buried individuals and the Late Neolithic population.

### 6 Conclusion

This article presents new knowledge about the Late Neolithic megalithic population in Falbygden from an interdisciplinary perspective combining archaeology, osteology, and isotope analyses. Most gallery graves in Southern Scandinavia, including Falbygden, were in use during the Late Neolithic II and Early Bronze Age. In contrast, Falköping stad 5 had already been constructed in the Late Neolithic I. The gallery grave was most probably used for successive burials in a rather short time span of about 150 years, but two different burial phases, with the majority in the Late Neolithic I and later inhumations of three individuals in Late Neolithic II, might also be possible. Considering evidence pointing to high population density and inhumations during a short time frame, it is difficult to conclude if the burial site was used by a single family or by a larger social group. Both are considered possible, even though the high number of non-local $^{87}$Sr/$^{86}$Sr signals might favour the latter.

The demographic analyses indicate a relatively high population density and a possible population increase over time. Stature is similar to Late Neolithic populations in southern Sweden in general. Childhood
Figure 15. Scatterplot of strontium isotope ratios of individuals buried in megalithic graves in Falbygden, based on results from the current study and Blank and Knipper (in press). A: Local $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, B: non-local/mixed $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, C: non-local $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, see text above. Lines mark periods: MN: Middle Neolithic and LN: Late Neolithic.

Figure 16. Flint dagger and flint flakes from Falköping stad 5. Photo by Malou Blank, CC BY.
mortality was around 30% and the risk of dying during childbearing years was high for females, while many males lived into their seventies. This mortality profile might indicate a population at high risk for infectious disease due to high population density and close contact with animals. The high mortality among children might also be related to a relatively high frequency of enamel hypoplasia caused by nutritional stress or bad health around the age of 3–4. Most individuals displaying enamel hypoplasia lived into adulthood.

The isotope values from the buried individuals in Falköping stad 5 indicate a terrestrial diet with a rather high intake of plant foods. Subsistence based on plant cultivation and animal husbandry with elements of hunting and fishing can be expected. Consumption of dairy products has been observed in a number of individuals (all of those sampled) (Fotakis et al, in preparation), probably indicating a heavier reliance on cattle, which could also in turn explain the decreased δ15N values in the Late Neolithic. It is possible that the lack of cribra orbitalia in Falköping stad 5 is connected to milk consumption and a higher availability of vitamin D. Inclusion of fish in the diet would also provide high intake of vitamin D; however, evidence of a high fish contribution to the diet is not present in the stable isotope values observed here. Some of the strontium isotope ratios might be a result of repeated movements in and out of the Falbygden area, possibly related to herding. However, this has to be confirmed by multiple analyses of teeth from the same individuals. The variation of δ15N values in Falköping stad 5 is greater than during the Middle Neolithic, which is also observed in other Late Neolithic samples from the area. The variation in stable isotope values could reflect specialisation and variation in subsistence strategies, but could also depend on social stratification and increased mobility.

The majority (71%) of the buried individuals in Falköping stad 5 have a non-local strontium isotope signal. The specimens with non-local signals associated with the first burial phase probably spent part of their childhood in the outskirts of Falbygden or in the surrounding Precambrian area. The three individuals with the youngest 14C dates have substantially higher strontium isotope ratios and are likely to have spent their childhood years in eastern or more northern parts of Sweden. These strontium isotope ratios are consistent with previous studies where it has been shown that human mobility increased during the Late Neolithic. These results point to increasing population dynamics throughout the Late Neolithic.

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**Abbreviations**

BAR= British Archaeological Reports
VG= Västergötland
SHM= Statens Historiska Museum
SLM= Skaraborgsläns museum

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## Appendix

<table>
<thead>
<tr>
<th>Find No.</th>
<th>Context</th>
<th>Sample</th>
<th>$^{87}$Sr/$^{86}$Sr Ratio</th>
<th>Analytical error ± 2 SD</th>
<th>$^{13}$C Carb. (VPDB) ‰</th>
<th>$^{14}$C Lab. no.</th>
<th>BP</th>
<th>$^{15}$N Collagen (AIR) ‰</th>
<th>$^{13}$C Collagen (VPDB) ‰</th>
<th>Collagen apatite spacing</th>
<th>Sex</th>
<th>Age</th>
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<td>F83III:1</td>
<td>layer 1, northern part of chamber</td>
<td>M2, mandibula, MA-1556000.72645</td>
<td>0.00001</td>
<td>-14.28</td>
<td>UBA-30770</td>
<td>3420±33</td>
<td>3.18</td>
<td>1874-1630</td>
<td>10.6</td>
<td>6.6</td>
<td>Male?</td>
<td>30+</td>
</tr>
<tr>
<td>F139II:2</td>
<td>layer 2, northern part of chamber</td>
<td>M2, mandibula, MA-1556110.71803</td>
<td>0.00002</td>
<td>-14.89</td>
<td>UBA-30764</td>
<td>3598±31</td>
<td>3.18</td>
<td>2031-1886</td>
<td>9.1</td>
<td>6.2</td>
<td>Male</td>
<td>25-35</td>
</tr>
<tr>
<td>F90</td>
<td>upper part, northern part of chamber</td>
<td>dpm2, mandibula, dexter</td>
<td>MA-1556120.72631</td>
<td>0.00001</td>
<td>-13.94</td>
<td>UBA-30758</td>
<td>3500±31</td>
<td>3.24</td>
<td>1910-1704</td>
<td>10.8</td>
<td>6.1</td>
<td>Indet.</td>
</tr>
<tr>
<td>F115VII:2</td>
<td>layer 2, southern part of chamber</td>
<td>M2, mandibula, MA-1556090.71543</td>
<td>0.00002</td>
<td>-13.96</td>
<td>UBA-30763</td>
<td>3654±34</td>
<td>3.16</td>
<td>2137-1940</td>
<td>8.9</td>
<td>6.6</td>
<td>Male</td>
<td>15-20</td>
</tr>
<tr>
<td>F132VI:3</td>
<td>layer 3, southern part of chamber</td>
<td>M2, mandibula, MA-1556020.71424</td>
<td>0.00001</td>
<td>-13.57</td>
<td>UBA-30737</td>
<td>3639±35</td>
<td>3.22</td>
<td>2134-1911</td>
<td>8.9</td>
<td>7.1</td>
<td>Male</td>
<td>25-35</td>
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<td>F117</td>
<td>layer 4, northern part of chamber</td>
<td>M2, mandibula, MA-1556010.71470</td>
<td>0.00002</td>
<td>-14.81</td>
<td>UBA-30766</td>
<td>3679±32</td>
<td>3.16</td>
<td>2190-1961</td>
<td>9.1</td>
<td>5.7</td>
<td>Female?</td>
<td>20</td>
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<td>F108IV:3</td>
<td>layer 3, northern part of chamber</td>
<td>M2, mandibula, MA-1556160.72267</td>
<td>0.00002</td>
<td>-14.40</td>
<td>UBA-30767</td>
<td>3562±49</td>
<td>3.15</td>
<td>2030-1756</td>
<td>10.7</td>
<td>6.6</td>
<td>Male?</td>
<td>45-55</td>
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<td>F98</td>
<td>layer 2, northern part of chamber</td>
<td>dpm2, mandibula, dexter</td>
<td>MA-1556060.71924</td>
<td>0.00003</td>
<td>-14.83</td>
<td>UBA-30774</td>
<td>3640±33</td>
<td>3.22</td>
<td>2134-1916</td>
<td>9.9</td>
<td>6.0</td>
<td>Indet.</td>
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<td>F147VI:4</td>
<td>layer 4, southern part of chamber</td>
<td>M2, mandibula, MA-1555990.71485</td>
<td>0.00001</td>
<td>-14.26</td>
<td>UBA-30745</td>
<td>3624±31</td>
<td>3.21</td>
<td>2121-1896</td>
<td>8.4</td>
<td>6.3</td>
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<td>20-30</td>
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<td>F123</td>
<td>unknown</td>
<td>M2, mandibula, MA-1556100.73269</td>
<td>0.00002</td>
<td>-14.71</td>
<td>UBA-30768</td>
<td>3491±33</td>
<td>3.15</td>
<td>1902-1697</td>
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<td>6.4</td>
<td>Female?</td>
<td>&gt;40</td>
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<tr>
<td>F122</td>
<td>layer 4, southern part of chamber</td>
<td>M2, mandibula, MA-1556050.71675</td>
<td>0.00003</td>
<td>-11.70</td>
<td>UBA-30765</td>
<td>3602±33</td>
<td>3.17</td>
<td>2112-1883</td>
<td>8.3</td>
<td>9.1</td>
<td>Male?</td>
<td>40-50</td>
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<tr>
<td>Find No.</td>
<td>Context</td>
<td>Sample</td>
<td>$^{87}$Sr/$^{86}$Sr Lab. No.</td>
<td>$^{87}$Sr/$^{86}$Sr Ratio</td>
<td>Analytical error ± 2 SD Enamel (VPDB) ℓ%</td>
<td>$^{13}$C Lab. no.</td>
<td>BP</td>
<td>C:N</td>
<td>Cal BC OxCal 4.3, 95.4%</td>
<td>$\delta^{15}$N Collagen (AIR) ℓ%</td>
<td>$\delta^{13}$C Collagen (VPDB)</td>
<td>Collagen apatite spacing</td>
</tr>
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<td>F119</td>
<td>layer 3, northern part of chamber</td>
<td>dpm2, mandibula, dexter</td>
<td>MA-1556130.71720</td>
<td>0.00003</td>
<td>-15.10</td>
<td>UBA-30771</td>
<td>3638±35</td>
<td>3.21</td>
<td>2134-1910 10.4</td>
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<td>F121</td>
<td>layer 3, southern part of chamber</td>
<td>M2, mandibula, MA-1556040.71939 dexter</td>
<td>0.00002</td>
<td>-14.36</td>
<td>UBA-30749</td>
<td>3595±33</td>
<td>3.17</td>
<td>2110-1880 9.3</td>
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<td>Female</td>
<td>35+</td>
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<td>F134</td>
<td>layer 3, southern part of chamber</td>
<td>M1, mandibula, MA-1556150.71870 sin</td>
<td>0.00004</td>
<td>-15.40</td>
<td>UBA-30735</td>
<td>3631±42</td>
<td>3.23</td>
<td>2135-1891 9.3</td>
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<tr>
<td>F69</td>
<td>upper part, southern part of chamber</td>
<td>M2, mandibula, MA-1556070.71582 dexter</td>
<td>0.00002</td>
<td>-14.44</td>
<td>UBA-30742</td>
<td>3642±32</td>
<td>3.18</td>
<td>2134-1921 9.1</td>
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<td>Male</td>
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<td>F124</td>
<td>layer 3, northern part of chamber</td>
<td>M2, mandibula, MA-1556080.71900 dexter</td>
<td>0.00002</td>
<td>-15.45</td>
<td>UBA-30775</td>
<td>3600±33</td>
<td>3.21</td>
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<td>Male</td>
<td>45+</td>
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<td>F118</td>
<td>layer 3, northern part of chamber</td>
<td>M1, mandibula, MA-1556190.71697 dexter</td>
<td>0.00003</td>
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<td>UBA-30769</td>
<td>3560±33</td>
<td>3.15</td>
<td>2018-1774 8.6</td>
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<td>6.2</td>
<td>Male</td>
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<tr>
<td>F88</td>
<td>ante chamber</td>
<td>dpm2, mandibula, dexter</td>
<td>MA-1556140.71883</td>
<td>0.00001</td>
<td>-15.59</td>
<td>UBA-30753</td>
<td>3609±61</td>
<td>3.22</td>
<td>2132-1880 10.5</td>
<td>-21.4</td>
<td>5.8</td>
<td>Indet.</td>
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<td>F129V2:2</td>
<td>layer 2, under roof slab western part</td>
<td>M1, mandibula, MA-1556030.72016 dexter</td>
<td>0.00001</td>
<td>-15.70</td>
<td>UBA-30762</td>
<td>3697±37</td>
<td>3.20</td>
<td>2201-1975 9.5</td>
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<td>5.4</td>
<td>Male?</td>
<td>&gt;40</td>
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<td>F128</td>
<td>layer 3, northern part of chamber</td>
<td>M3, mandibula, MA-1556180.72098 dexter</td>
<td>0.00002</td>
<td>-16.06</td>
<td>UBA-30773</td>
<td>3680±33</td>
<td>3.19</td>
<td>2192-1960 9.9</td>
<td>-21.6</td>
<td>5.5</td>
<td>Female</td>
<td>adult</td>
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<td>F120+132</td>
<td>layer 3, southern part of chamber</td>
<td>M1, mandibula, MA-1556170.7155 dexter</td>
<td>0.00001</td>
<td>-14.03</td>
<td>UBA-30772</td>
<td>3706±36</td>
<td>3.21</td>
<td>2202-1980 10.8</td>
<td>-20.5</td>
<td>6.5</td>
<td>Female?</td>
<td>40+</td>
</tr>
</tbody>
</table>