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Reconstructing the diet of Late Neolithic farmers of Belgium from dental microwear features

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1. Introduction

Throughout the Neolithic, farmers inhabiting northern Europe continued to make use of the wealth of natural caves and caverns as burial grounds and many were repeatedly used, possibly for centuries. This project examines five such sites in central Belgium, including the two early late Neolithic sites of Hastière Caverne M and Hastière Trou Garçon C, two final late Neolithic cave burials of Sclaigneaux and Bois Madame, as well as Maurenne Caverne de la Cave which has been radiocarbon dated to the Middle and *final late* Neolithic (Vanderveken, 1997; Bronk-Ramsey *et al*., 2002; Dumbruch, 2003, 2007; De Paepe, 2007; Toussaint, 2007; Fig. 1). These cave burials are among the largest and most complete collective internments known from the Neolithic period in Belgium.

The Late Neolithic of northern Europe witnessed an interval of intense change for small-scale farmers as the time period prior the Bronze Age coincided with an increase in population density, culture contact and trade. Although human remains have been recovered from more than 250 caves in Belgium dating from the Middle Paleolithic to the beginning of the historical age, at least 200 of these sites derive from the Late Neolithic suggesting a socially-intensive use and reuse of collective burial locations (Semal *et al*., 1999; Toussaint *et al*., 2001; Toussaint, 2007; Polet, 2011; Williams & Polet, 2017; Williams *et al*., 2018). Some sites may have been in use for over 800 years as suggested by the four radiocarbon dates obtained from Maurenne Caverne de la Cave, including 4,635 ± 45, which is Middle Neolithic, as well as 4,160 ± 45, 3,950 ± 70 and 3,830 ± 90 years BP which can be considered *final late* Neolithic (Bronk-Ramsey *et al*., 2002; Toussaint, 2007). Most represent a single burial event or a few events within a relatively short time frame, perhaps over several generations, such as at Bois Madame which is dated from 4,075 ± 38 to 3,910 ± 40 years BP (Fig. 2). Hastière Caverne M, Hastière Trou Garçon C and Sclaigneaux are dated to 4,345 ± 60, 4,220 ± 45 and 4,155 ± 35 years BP, respectively (Fig. 1, Fig. 2).

Fig. 1 – Map of Belgium showing the location of Hastiere rock shelter (Hastière Caverne M, Hastière Trou Garçon C and Maurenne Caverne de la Cave), Sclaigneaux and Bois Madame.

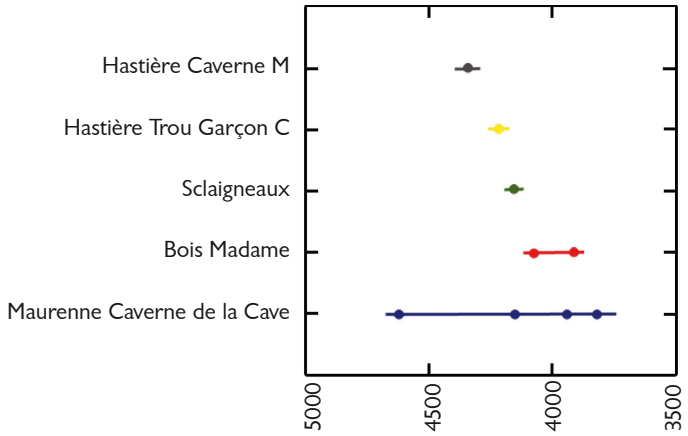

Fig. 2 – Radiocarbon dates for Hastière Caverne M, Hastière Trou Garçon C, Sclaigneaux, Bois Madame and Maurenne Caverne de la Cave represented by min-max values (lines) and average (circles) compared to years before present. The two dates from Bois Madame and four dates for Maurenne Caverne de la Cave are each joined by a spline regression.

It is possible that Maurenne Caverne de la Cave represents a communal burial ground for several local groups over multiple generations. Alternatively, it may be that Maurenne Caverne de la Cave records the burial practices of a population distinct from other Neolithic groups in terms of dietary proclivities, perhaps implying a single cultural entity that utilized the same cave site as a burial chamber for over 800 years. This hypothesis would be supported if individuals from Maurenne Caverne de la Cave cluster together and are separate from the other groups in microwear features. It is expected that the early late Neolithic cave burials of Hastière Caverne M and Hastière Trou Garçon C will be more similar to each other than either is to the *final late* Neolithic sites of Sclaigneaux and Bois Madame, which are anticipated to resemble one another, and secondarily, Maurenne Caverne de la Cave (Fig. 2).

1.1. Dental microwear of use-wear features

Dental microwear features have been utilized previously to detect distinct dietary signatures (Godfrey *et al*., 2004; Semprebon *et al*., 2004; Williams & Patterson, 2010; Williams & Holmes, 2011; Williams & Geissler, 2014). Use-wear features, such as pits, are caused by punctures on the occlusal surface from the penetration of hard objects, such as grains of grit, seed coats, shells, phytoliths and other biomechanically resistant particles (Sanson *et al*., 2007; Ungar, 2015). Scratches result from hard particles being dragged along the enamel surface corresponding to masticatory regimes often involving unidirectional movements and rotary chewing (Schmidt *et al*., 2016).

Dental microwear of the buccal surface in individuals from the Belgian Neolithic caves demonstrated a remarkable uniformity of use-wear scars across sites (Semal *et al*., 1999; Garcia Martin, 2000). Given these earlier observations, only a limited degree of variation in dietary signals is expected between the cave burials. However, Maurenne Caverne de la Cave may exhibit a greater degree of variation compared to the other four sites considering the large range of radiocarbon dates associated with this site (Fig. 2).

2. Materials and Methods

2.1. Materials

The samples included in this study are high-fidelity epoxy resin casts (Buelher) created from polyvinylsiloxane molds (Coltène-Whaledent President Plus) of *in situ* molars within the fragmentary gnathic remains preserved from each cave burial. The molds were collected by one of us (FLW) at the Laboratoire d'Anthropologie et Préhistoire, Institut royal des Sciences naturelles de Belgique and casts were created at the Bioarchaeology Laboratory of Georgia State University. A total of 158 individuals were investigated from the five sites. Out of these, only 66 dental casts were both adult and suitable for microwear analysis (Tab. 1). Dental casts were selected by the amount of visible,

diagnostic microwear and the absence of postmortem taphonomy or casting defects consisting of irregular features atypical of ante-mortem use-wear.

2.2. Methods of data collection

The presence of dental microwear was observed at 35 x on the paracone of maxillary molars and the protoconid of mandibular molars when available. When these cusps did not exhibit discernable use-wear, adjacent phase II facets were investigated. The use of a movable external light source allowed for the three-dimensional visualization of the use-wear features (Semprebon *et al*., 2004).

Diagnostic microwear features include fine scratches, coarse scratches, hypercoarse scratches, small pits, large pits and puncture pits. Fine scratches typically appear in clusters among the samples examined (Fig. 3). They are thinner and shallower than coarse scratches, and therefore more refractive. Coarse scratches are deep lines and less refractive; however, they are narrower than hypercoarse scratches. Hypercoarse scratches appear as wide, deep, straight, trench-like lines. Small pits are shallow and therefore highly refractive (Fig. 3). Large pits are nonrefractive but smaller than puncture pits and approximately twice the size of small pits (Williams & Geissler, 2014). Puncture pits appear as large, deep, nonrefractive indentations on the enamel surface, and these were only rarely observed in the Neolithic dental casts.

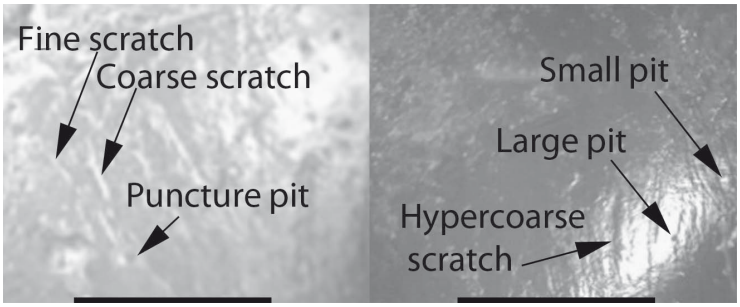

Fig. 3 – Dental micrograph indicating fine scratches, small pits, coarse and hypocoarse scratches and a large pit. Maurenne Caverne de la Cave 1 at 40 x. Scale bar approximates 0.2 mm.

Counts of dental microwear features were created using an ocular reticle of 0.4 mm^2. For each individual, microwear was observed on two different areas of the paracone or protoconid, and the two trials were averaged as a sampling strategy, and subsequently utilized for statistical analysis. The first molar from each individual was included unless it was not preserved or the dental microwear was obscured by postmortem processes. In these cases, the second molar was observed.

Dental microwear features can be caused by a variety of sources. Therefore, there does not exist a 1-1 correlation between a specific substance and a given microwear feature. However, heavier microwear is associated with the consumption of harder foods or an abundance of grit contaminating the food (Walker *et al*., 1978; Williams & Holmes, 2011; Williams & Geissler, 2014). The frequencies of each of these features indicate the kinds of foods consumed by an organism within the final weeks and days before death.

The presence of pitting may be the result of the consumption of particles mechanically harder than the human enamel matrix, such as seeds, seed coats, shells and grit (Williams & Geissler, 2014). Increased consumption of grains during the Neolithic period could also contribute to dental microwear from food processing. For example, the presence of pitting could be caused by small stone particle inclusions from grinding tools used to pound grain into flour or to remove the tough outer shell (Wright, 1994; Weiss *et al*., 2004). High frequencies of fine scratches could suggest a homogeneous pattern of mastication typical of consumers of tough foods which must be chewed thoroughly before ingestion. Such foods would have been chewed in a rotary or repeated fashion, although it is possible

that they also utilized the teeth as tools to braid grasses or some other paramasticatory activity (Power & Williams, 2018). Conversely, high frequencies of heavy microwear would indicate a diet of harder foods with less processing. Scanning electron microscopy of buccal microwear from several Neolithic sites expanded the dietary inferences from isotope results (Semal *et al*., 1999; Bocherens *et al*., 2007). Microwear features were heavier than expected, though the authors interpret the high scratch frequency as the result of the ingestion of fish scales (Semal *et al*., 1999). Based on previous studies, it is expected that dental microwear patterns will be homogeneous within and between the sites due to the proximity of the burials in time and ecogeography (Fig. 1, Fig. 2).

2.3. Statistical Analyses

In addition to descriptive statistics, a One-Way analysis of variance (ANOVA) was performed to ascertain whether significant differences exist between the caves for each use-wear feature, and a Tukey's post-hoc test is included to locate pair-wise distinctions between sites. To examine the degree to which individuals from the five caves could be correctly classified, a discriminant function analysis was conducted using all of the microwear features, and only the conservative jackknifed classifications were considered. The resulting first two canonical scores axes with 95 % confidence ellipses around group centroids demonstrate the distribution of individuals per cave burial. To show overall trends in microwear features between the cave deposits, the means for each microwear feature per cave burial were compared in a cluster analysis using a single linkage of Euclidean distances.

3. Results

All of the caves exhibit high numbers of fine scratches and small pits, and much fewer hypercoarse scratches and puncture pits, suggesting similar dietary proclivities across sites (Tab. 1). However, Maurenne Caverne de la Cave exhibits a much higher frequency of fine scratches than do the other caves (Tab. 1). A One-Way ANOVA for each microwear feature indicates greater between-group than within-group variation for large pits (F = 1.720), puncture pits (F = 2.023) and fine scratches (F = 3.444) (Tab. 2). However, only the fine scratches category is significant (p = 0.014). Tukey's post-hoc test indicates a significant difference in the frequency of fine scratches exists only between Maurenne Caverne de la Cave and Sclaigneaux (p = 0.014).

Neolithic cave burial	*Fine scratches*	*Coarse scratches*	*Hypercoarse scratches*	*Small pits*	*Large pits*	*Puncture pits*
Hastière "Caverne M"[1] (n = 8)	11.813 (3.686)	1.375 (0.876)	0.500 (0.463)	11.625 (3.739)	3.000 (1.195)	0.375 (0.443)
Hastière "Trou Garçon" C[1] (n = 2)	13	1.250 (0.354)	0	11 (2.828)	4	0.500 (0.707)
Sclaigneaux[2] (n = 18)	9.861 (2.689)	1.361 (0.982)	0.556 (0.482)	12.361 (4.777)	3.806 (2.263)	0.306 (0.425)
"Bois Madame"[2] (n = 15)	12.600 (5.033)	1.400 (0.949)	0.500 (0.681)	12.500 (5.092)	2.840 (1.528)	0.200 (0.368)
Maurenne "Caverne de la Cave"[3] (n = 16)	15.153 (5.098)	1.219 (0.730)	0.625 (0.904)	12.438 (4.037)	2.381 (1.743)	0.063 (0.171)

[1] early/late Neolithic; [2] final/late Neolithic; [3] middle and final/late Neolithic

Tab. 1 – Number of individuals examined from each cave burial and statistical mean (standard deviation) for each of the dental microwear features.

With regards to the multivariate results, nine of the 16 individuals from Maurenne Caverne de la Cave were correctly classified giving the highest correct classification score of 56 %. The next highest classification rate was for Hastière Caverne M (38 %) and Sclaigneaux (33 %). However, neither of the two Hastière Trou Garçon C individuals was correctly classified. Individuals from Bois Madame were also misclassified, with six grouped as Hastière Caverne M, five as Maurenne Caverne de la Cave, five as Sclaigneaux, and one as Hastière Trou Garçon C.

Dental microwear features	*F value*	*p value*
Fine scratches	3.444	0.014
Coarse scratches	0.220	0.926
Hypercoarse scratches	0.521	0.721
Small pits	0.126	0.972
Large pits	1.720	0.158
Puncture pits	2.023	0.140

Tab. 2 – One-Way ANOVA with Tukey's Post-Hoc Test.

As shown on Figure 4, Canonical Scores Axis 1 explains 81.3 % of the total variation within and between groups where Axis 2 explains 12.1 %. In total, these axes account for 93.4 % of all variation in dental microwear features among the caves burials. On Axis 1, Maurenne Caverne de la Cave is separated Sclaigneaux; Bois Madame is found between these extremes. The large confidence ellipse for Hastière Caverne M overlaps the other caves and extends further in a negative direction indicative of several outliers. Hastière Trou Garçon C is found within the confidence ellipse for Hastière Caverne M albeit the two individuals represented fall at opposite extremes of the distribution (Fig. 4).

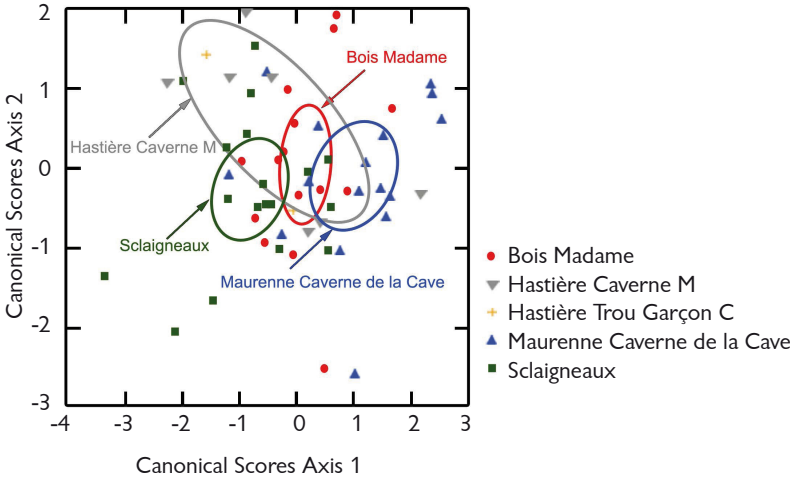

Fig. 4 – Canonical scores axes with 95 % confidence ellipses around group centroids demarcating cave burials representing more than two individuals and thus excluding Hastière Trou Garçon C.

A cluster analysis shows that the greatest similarity exists between Hastière Caverne M and Bois Madame which are secondarily joined to Hastière Trou Garçon C separated by a relatively short branch length (Fig. 5). These three are joined to Maurenne Caverne de la Cave by a rather long branch length. Sclaigneaux is the least similar of the cave burials, and also the most geographically separated from the others.

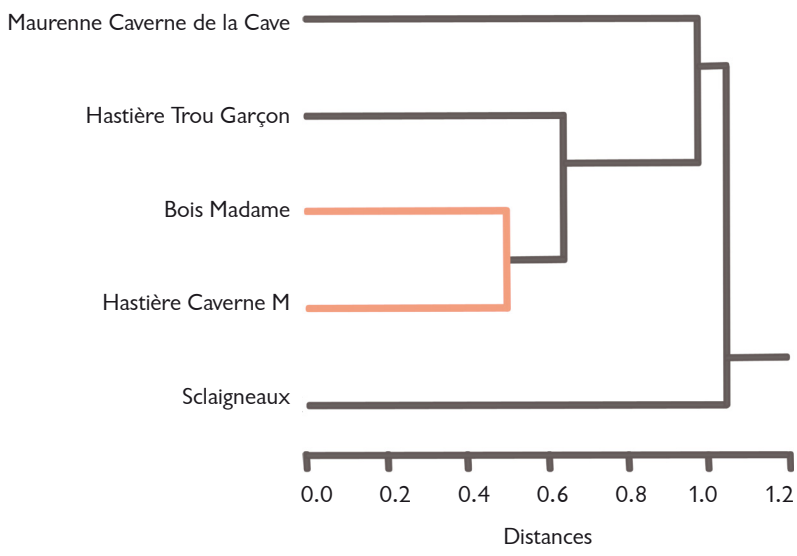

Fig. 5 – Cluster analysis.

4. Discussion and Conclusions

Maurenne Caverne de la Cave appears to exhibit the most distinctive microwear pattern given its higher rate of classification of 56 % compared to than the other sites. Sclaigneaux is also distinctive perhaps

reflecting geographic distance from the other collective burials which would entail subtle differences in ecology and thus the availability of foods (Fig. 1). The other caves show considerable variation, such as Bois Madame, where individuals are classified across the sites and the early late Neolithic cave burials of Hastière Caverne M and Hastière Trou Garçon C, both of which include outliers (Fig. 4). It is noteworthy that Sclaigneaux and Maurenne Caverne de la Cave differ significantly from one another with respect to the frequency of fine scratches (Tab. 2). This distinction implies differences in dietary or paramasticatory behavior patterns between the most cohesive site of Maurenne Caverne de la Cave and the most geographically distant cave of Sclaigneaux.

The most common use-wear features across all groups are fine scratches and small pits (Tab. 1). The abundance of these "lighter" microwear features in Neolithic Belgium appears to be consistent with early farming populations worldwide (Pinhasi & Stock, 2011). Fine scratches indicate a diet rich in fibrous terrestrial plants, likely domesticated cereal grains. Another common feature, small pits, can possibly be attributed to the presence of small stone particle inclusions that infiltrated into grain flour during grinding and pounding. By comparison, an abundance of large pits, puncture pits, coarse scratches and hypercoarse scratches are not observed suggesting "dirty" food such as freshly-pulled underground storage organs, and abrasive seeds, seed coats and grit consumed by hunter/gatherers were less often consumed. The presence, frequency, and distribution of these light features across cave burials suggest that the inhabitants of the Meuse river region maintained an agricultural subsistence strategy throughout the terminus of the Neolithic period, from ~4,600 to ~3,800 years BP (Semal *et al.*, 1999).

Across continental Europe, Neolithic peoples consumed grain crops and dairy, although populations adapted to these imported foods to varying degrees contingent on location, population density and ecosystem. From Denmark to Ukraine, freshwater and terrestrial animals (wild and domesticated) continued to be utilized as staple foods from the Mesolithic through the Neolithic, augmented by dairy and cereal grains (Lillie, 1996; Richards *et al.*, 2003; Nystrom, 2008; Nehlich *et al.*, 2014). Similarities in farming practices reconstructed archaeologically suggest cultural affinities, or at least a measure of contact between nearby settlements wherein cultural information was exchanged (Ammerman & Cavalli-Sforza, 1971; Golitko, 2015). As Neolithic groups became increasingly reliant on crops and livestock, they settled down in villages on arable land with a fresh water source. Small settlements sprang up along the Meuse river, the Danube (Květina & Hrnčíř, 2013), Körös rivers (Gyucha *et al.*, 2013) and other locations, and neighboring communities were increasingly in contact with each other compared to nomadic foragers. These contacts and trade relationships allowed for further exchanges in technology and culture (Gabel, 1958; Golitko, 2015). Nevertheless, it is possible that each village had its own burial ground, although they were in close enough proximity to share burial practices and grave goods as evidenced by the continuity of comingled bones, lithics, pottery, and isolated gnathic remains among the sites.

We hypothesized that if Maurenne Caverne de la Cave did represent a single cultural group which utilized the deposits repeatedly over an 800 year span, individuals would cluster together in comparison to the other sites. Although Maurenne Caverne de la Cave is partly distinct in terms of classification, the extent of overlap with the other cave burials is substantial. The similarities between sites outweigh any between-group differences, with the exception of the prevalence of fine scratches between Maurenne Caverne de la Cave and Sclaigneaux. It is possible that the individuals sampled from Maurenne Caverne de la Cave were primarily derived from the Middle Neolithic period or perhaps mostly from the terminus of the *final late* Neolithic. However, temporal differences do not necessarily differentiate the early late Neolithic sites of Hastière Caverne M and Hastière Trou Garçon C from the *final late* Neolithic cave burials

of Sclaigneaux and Bois Madame in any discernable way. The large number of fine scratches on the molars from Maurenne Caverne de la Cave suggests an intensive use of tough foods with adhering grit or stalks of grasses with phytoliths. Although geography does not explain the differences between the early late Neolithic sites with Maurenne Caverne de la Cave, since they all derive from the Hastière rockshelter, the fact that Sclaigneaux differs from the other cave burials (Fig. 5) does imply that ecogeography may help explain at least some of the variation among individuals.

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Abstract

The karstic caves of the Meuse River Basin of Belgium yielded the remains of nearly 200 burials from the Late Neolithic period, many of which have been radiocarbon dated. Isolated mandibular and maxillary remains of adults represent a substantial portion of these burials and offer an opportunity to explore the dietary proclivities of the inhabitants from the microscopic use-wear features of the resources consumed. Dental microwear analysis was conducted to reconstruct the dietary patterns of 59 individuals excavated from five of these Neolithic collective cave burials. These include Hastière Caverne M (n = 8), Hastière Trou Garçon C (n = 2), Sclaigneaux (n = 18), Bois Madame (n = 15) and Maurenne Caverne de la Cave (n = 16). The sites span the temporal range of the Late Neolithic, although one of four dates for Maurenne Caverne de la Cave is from the Middle Neolithic and this collective burial includes both the earliest and latest radiocarbon dates (4,635-3,830 years before present). Microwear patterns across sites reveal a mixed diet of farmed and foraged foods consistent with other Late Neolithic dietary reconstructions throughout Europe. Univariate and multivariate statistical analyses of dental microwear features indicate significant differences in fine scratches between Maurenne Caverne de la Cave and Sclaigneaux ($p = 0.014$) suggestive of distinctions in dietary proclivities. Although Maurenne Caverne de la Cave has the widest disparity of dates, this collective burial has the highest classification rate suggesting a more cohesive grouping of dietary proclivities than is observed for the other sites. Geographic proximity appears to explain some of the variation in dietary habits, although the mechanical properties of the foods consumed remained fairly consistent during the Late Neolithic.

Keywords: Neolithic, River Meuse Basin (BE), paleodiet, dental microwear.

Résumé

Les grottes karstiques du bassin de la Meuse en Belgique ont livré les vestiges de près de 200 sépultures de la fin du Néolithique, dont beaucoup ont été datées au radiocarbone. Les restes de mandibules et maxillaires isolés d'adultes représentent une partie substantielle de ces sépultures et offrent une opportunité d'explorer les tendances alimentaires de ces individus néolithiques à partir des microtraces d'usure causées par les ressources consommées. Une analyse par microtraces dentaires a été réalisée pour reconstituer les habitudes alimentaires de 59 sujets provenant de cinq de ces sépultures collectives néolithiques en grotte. Il s'agit de Hastière Caverne M (n = 8), Hastière Trou Garçon C (n = 2), Sclaigneaux (n = 18), Bois Madame (n = 15) et Maurenne Caverne de la Cave (n = 16). Les sites couvrent la période du Néolithique récent, bien que l'une des quatre dates de Maurenne Caverne de la Cave soit du Néolithique moyen et que cette sépulture collective comprenne les dates radiocarbone les plus anciennes et les plus récentes (4635-3830 années avant le présent). Les *patterns* de micro-trace de tous les sites révèlent un régime alimentaire mixte composé d'aliments d'élevage et d'aliments récoltés compatibles avec d'autres reconstitutions alimentaires réalisées dans le Néolithique récent en Europe. Les analyses statistiques univariées et multivariées des caractéristiques des micro-traces dentaires indiquent une différence significative dans les fines stries sur la surface des dents entre Maurenne Caverne de la Cave et Sclaigneaux (p = 0,014), ce qui suggère des différences dans les habitudes alimentaires. Bien que Maurenne Caverne de la Cave ait la plus grande disparité de dates, cette sépulture collective présente le taux de classification le plus élevé, ce qui suggère un regroupement plus cohérent des tendances alimentaires que celui observé pour les autres sites. La proximité géographique semble expliquer certaines des variations dans les habitudes alimentaires, bien que les propriétés mécaniques des aliments consommés soient restées relativement constantes au Néolithique récent.

Mots-clés : Néolithique, Bassin mosan (BE), paléonutition, micro-traces dentaires.

Samenvatting

In de karstgrotten van het stroomgebied van de Maas in België werden de overblijfselen van bijna 200 begravingen uit de late neolithische periode opgegraven, waarvan er vele werden gedateerd op basis van koolstofdatering. Geïsoleerde overblijfselen van volwassen kaakbeenderen vormen een belangrijk deel van deze begravingen en bieden de mogelijkheid om het dieet van deze individuen te onderzoeken, aan de hand van microscopische gebruiksslijtage op het glazuuroppervlak. Er werd een analyse uitgevoerd van de microslijtage op de tanden uitgevoerd om de voedingspatronen te reconstrueren van 59 individuen, die werden opgegraven in vijf van deze Neolithische collectieve graven uit grotten. Deze omvatten Hastière Caverne M (n = 8), Hastière Trou Garçon C (n = 2), Sclaigneaux (n = 18), Bois Madame (n = 15) en Maurenne Caverne de la Cave (n = 16). De sites overspannen het volledige late neolithicum, hoewel een van de vier dateringen voor Maurenne Caverne de la Cave afkomstig is uit het Midden-Neolithicum en deze collectieve begraving omvat zowel de oudste als de jongste radiokoolstofdatering (4635-3830 BP). Patronen van microslijtage op de tanden van alle grotten wijzer op een gemengd dieet van geteeld en gemalen voedsel, vergelijkbaar met andere laat-neolithische dieetreconstructies daarheen Europa. Univariate en multivariate statistische analyses van alle kenmerken van microslijtage duiden op een significant verschil in fijne krassen tussen Maurenne Caverne de la Cave en Sclaigneaux (p = 0,014), wat wijst op verschillen in voedsel consumptie. Hoewel Maurenne Caverne de la Cave de grootste chronologishe verspreiding vertoonde heeft, deze collectieve begraving de hoogste classificatie die een meer samenhangende groepering suggereert dan werd waargenomen voor de andere sites. Geografische nabijheid lijkt een deel van de variatie in voedingsgewoonten te verklaren, hoewel de mechanische eigenschappen van de geconsumeerde voedingsmiddelen relatief gelijk bleven gedurende het Laat-Neolithicum.

Trefwoorden: Neolithicum, Maas stroomgebied (BE), paleodieet, microslijtage op tanden.

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