ANTHROPOLOGICA ET PRAEHISTORICA

Bulletin de la
Société royale belge d'Anthropologie
et de Préhistoire

Bulletin van de
Koninklijke Belgische Vereniging
voor Antropologie en Prehistorie

131 / 2020

Ce volume a été publié
grâce à l'appui de
et grâce au soutien financier de

Deze bundel werd gepubliceerd
met de steun van
en met de financiële steun van

l'Institut royal des Sciences naturelles de Belgique • het Koninklijk Belgisch Instituut voor Natuurwetenschappen

et

l'Association pour la Diffusion de l'Information archéologique

2022

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Anthropologica et Præhistorica, 131/2020 (2022) : 79-96
https://doi.org/10.57937/ap.2022.004

The diet of Late Neolithic individuals from Hastière Caverne M in the Belgian Meuse basin

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Abstract

Nearly 80% of prehistoric burials of the Belgian Meuse basin date to the Late Neolithic period. To explore whether temporal differences characterize these Late Neolithic farmers, an intersite comparison is made. The main site of the present study is Hastière Caverne M (8 individuals), dated to circa 4,350 years before present (BP). Two additional sites from the Final/Late Neolithic period are also included, i.e. the rockshelter of Bois Madame in Arbre (12 individuals) dated between 4,075 and 3,910 years BP, and the cave of Sclaigneaux (15 individuals), dated to circa 4,155 years BP. The last site considered is Caverne de la Cave at Maurenne (18 individuals) associated with three Final/Late Neolithic dates spanning from 4,160 to 3,830 years BP and one Middle Neolithic date of circa 4,635 years BP. Comparative samples include Epipaleolithic and Holocene foragers, farmers and herders (173 individuals). Molar Phase II facets on dental casts were scanned via white-light confocal microscopy, and subjected to dental microwear texture analysis. This yielded complexity (Asfc), describing the degree of hard object consumption, and anisotropy (epLsar) which characterizes the patterning of microwear. Compared to other Neolithic Belgian sites, individuals of Hastière Caverne M exhibit significantly greater anisotropy with a large effect size suggesting a smaller amount of foraged foods was consumed. Complexity of Hastière Caverne M is elevated but is not significantly different from the other Meuse basin sites. During the Final/Late Neolithic period, just prior to the Bronze Age, wild plant foods may have been an important component of the diet in the Meuse basin. This could have stemmed from either domestic food scarcity, cultural traditions or other societal factors.

Keywords: *Caverne de la Cave at Maurenne, Bois Madame, Sclaigneaux, dental microwear texture analysis, paleodiet.*

Résumé

Près de 80 % des sépultures préhistoriques du bassin mosan belge datent du Néolithique final. Pour explorer si des différences temporelles caractérisent ces agriculteurs du Néolithique final, une comparaison inter-site a été menée. Le site principal de cette étude est la Caverne M d'Hastière (8 individus), datée d'environ 4350 ans avant le présent (ca. 3000 Cal BCE). Deux sites supplémentaires du Néolithique final sont également inclus, à savoir l'abri sous roche de Bois Madame à Arbre (12 individus), datant d'entre 4075 et 3910 ans avant le présent (ca. 2700-2500 Cal BCE), et la grotte de Sclaigneaux (15 individus), datant d'environ 4155 ans avant le présent (ca. 2800 Cal BCE). Le dernier site pris en compte est celui de la Caverne de la Cave à Maurenne (18 individus) associée à trois dates du Néolithique final couvrant la période 4160-3830 ans avant le présent (ca. 2750-2450 Cal BCE) et une date du Néolithique moyen d'environ 4635 ans avant le présent (ca. 3400 Cal BCE). À cela s'ajoutent des échantillons comparatifs comprenant des cueilleurs, des agriculteurs et des éleveurs épipaléolithiques et holocènes (173 individus). Les facettes sur molaires de phase II observées sur les moulages dentaires ont été scannées par microscopie confocale à lumière blanche et soumises à une analyse texturale des micro-usures dentaires. Dès lors, la complexité (Asfc), décrivant le degré de consommation d'objets durs, et l'anisotropie (epLsar), caractérisant la structuration des micro-usures, peuvent être discutées. Comparativement aux autres sites néolithiques belges, les individus de la Caverne M d'Hastière présentent une anisotropie significativement plus grande avec un grand effet de taille suggérant qu'une plus petite quantité d'aliments fourragers a été consommée. La complexité de la Caverne M d'Hastière est élevée, mais n'est cependant pas significativement différente des autres sites du bassin mosan. Au cours du Néolithique final, juste avant l'âge du Bronze, la consommation de végétaux sauvages semble avoir été une composante importante de l'alimentation dans le bassin de la Meuse. Cela pourrait s'expliquer par une pénurie d'aliments cultivés, par des traditions culturelles différentes, voire d'autres facteurs sociétaux.

Mots clés : Caverne de la Cave de Maurenne, Bois Madame, Sclaigneaux, analyse texturale des micro-usures dentaires, paléodiet.

1. INTRODUCTION

The Late Neolithic site of Hastière Caverne M from Hastière rockshelter is situated along the fertile waterways of the Meuse basin in Belgium. Hastière Caverne M is among the earliest collective burials attributed to the Late Neolithic period, an interval of time in northwest Europe that preceded the massive demographic shifts associated with the Bronze Age. The site is close to more than 250 other collective burials settled in caves and rockshelters, the great majority of which have been radiocarbon dated to the Late Neolithic period (BRONK-RAMSEY *et al.*, 2002; DUMBRUCH, 2003; DE PAEPE & POLET, 2007; TOUSSAINT, 2007). However, there is variation among these sites with respect to chronology, and many larger collective burials can be dated to the Final/Late Neolithic beginning after circa 4,200 years before present (BP) (TOUSSAINT, 2007). It is expected that the Final/Late Neolithic sites should resemble one another and contrast with Hastière Caverne M which is earlier. Compared to Hastière Caverne M, the Final/Late Neolithic sites should exhibit evidence of more intensive farming and the abandonment of wild foods like elsewhere during the European Bronze Age transition (DICKINSON, 2006; CHIU *et al.*, 2012; DE GREGORY, 2012). This central question is examined by inferring the dietary signal of Hastière Caverne M using dental microwear texture analysis (DMTA) vis-à-vis previously published data from three Final/Late Neolithic caves of the Belgium Meuse basin (WILLIAMS *et al.*, 2020). Additional comparative samples come from seven Epipaleolithic and Holocene foragers, farmers and herders (KARRIGER *et al.*, 2016; SCHMIDT *et al.*, 2016, 2020; DA-GLORIA & SCHMIDT, 2020). To infer the diet of individuals interred in Hastière Caverne M, we chose subsistence patterns from American and Eurasian peoples that vary in intensity of wild plant food exploitation and degree of processing.

1.1. The Late Neolithic Period in the Belgian Meuse basin

The Late Neolithic to Bronze Age transition in northern Europe occurred roughly 3,300 years BP, known principally from burials radiocarbon dated from circa 4,350 to 3,850 years BP (TOUSSAINT *et al.*, 2001, 2003; TOUSSAINT, 2007). These Late Neolithic burials of the Belgian Meuse basin were often found in collective internments nested within karstic valley crevices, caverns, rockshelters and caves (TOUSSAINT *et al.*, 2001; TOUSSAINT, 2007; POLET, 2011). Hastière Caverne M was an early Late Neolithic burial, found in the 'Haute Meus' region of Wallonia, Belgium. The Haute Meuse witnessed an increasing intensification of collective internments during the Late Neolithic period, reflecting a common pattern noted elsewhere in Eurasia (SUBIRÀ *et al.*, 2014; WATERS-RIST *et al.*, 2016; LÓPEZ-ONAINDIA *et al.*, 2018; SARASKETA-GARTZIA *et al.*, 2018; SILVESTRI *et al.*, 2020).

To provide a Neolithic context for Hastière Caverne M, we included three assemblages from the Meuse basin, radiocarbon dated to circa 4,635-3,830 years BP (WILLIAMS *et al.*, 2020). These are (1) Caverne de la Cave at Maurenne, dated to 4,635 ± 45 years BP, 4,160 ± 45 years BP, 3,950 ± 70 years BP and 3,830 ± 90 years BP (BRONK-RAMSEY *et al.*, 2002; TOUSSAINT, 2007); (2) the rockshelter of Bois Madame in Arbre associated with two dates, 4,075 ± 38 years BP and 3,910 ± 40 years BP (BRONK-RAMSEY *et al.*, 2002; DUMBRUCH, 2003, 2007); and (3) the cave of Sclaigneaux, dated to 4,155 ± 35 years BP (Fig. 1; DE PAEPE, 2007; DE PAEPE & POLET, 2007). All of these cave burials have been associated with at least one Final/Late Neolithic date. In a previous study, no statistical differences in complexity or anisotropy between these three Final/Late Neolithic caves were found (WILLIAMS *et al.*, 2020). This provides a justification for grouping them together to compare to Hastière Caverne M, which is chronologically earlier than the others. Two caveats must be mentioned concerning this Final/Late Neolithic group. One is a single Middle Neolithic date for Maurenne (TOUSSAINT, 2007). The other is the fact that much of the fauna associated with Maurenne is classified as Middle Neolithic (BOCHERENS *et al.*, 2007). Nevertheless, Maurenne does not significantly differ from Bois Madame and Sclaigneaux in complexity or anisotropy (WILLIAMS *et al.*, 2020).

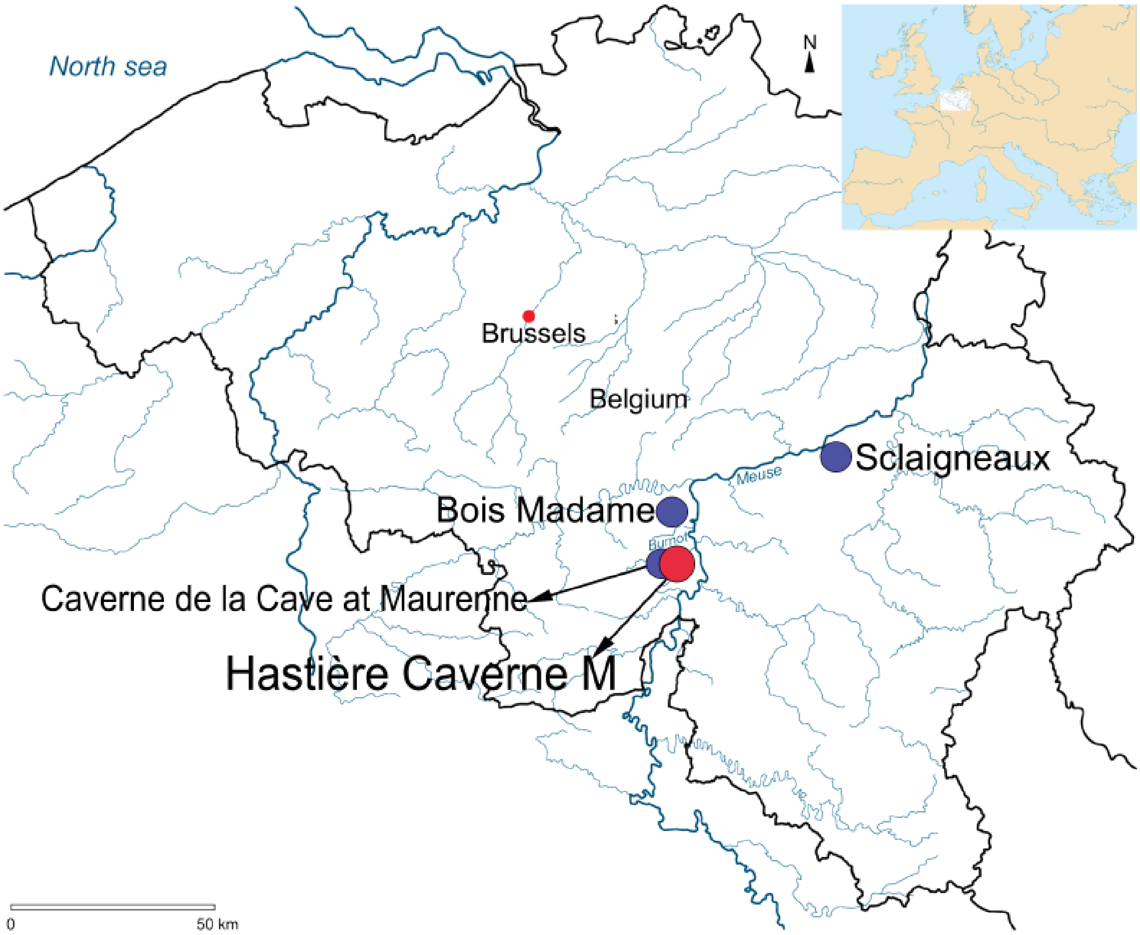

Fig. 1 – Location of Neolithic collective burials from Belgium including Hastière rockshelter, which is adjacent to Caverne de la Cave at Maurenne; these two sites are about 12 km south of Bois Madame rockshelter and circa 35 km west of the cave of Sclaigneaux; inserted map shows approximate location of Belgium (white rectangle) in northwest Europe.

Fig. 1 – *Localisation des sépultures collectives néolithiques de Belgique comprenant l'abri sous-roche d'Hastière, qui est adjacent à la Caverne de la Cave de Maurenne ; ces deux sites sont à environ 12 km au sud de l'abri sous-roche Bois Madame et à environ 35 km à l'ouest de la grotte de Sclaigneaux; la carte insérée montre l'emplacement approximatif de la Belgique (rectangle blanc) dans le nord-ouest de l'Europe.*

1.2. Hastière Caverne M

Hastière rockshelter was first excavated from 1867 to 1879, and the burials span the entirety of the Neolithic period in the Belgian Meuse basin. The rockshelter is situated in a dense cluster of Late Neolithic sites of the Haute Meus along the Lesse River and close to the medieval citadel of Dinant (BOCHERENS *et al.*, 2007). Hastière rockshelter yielded some of the oldest Neolithic burials from the Meuse basin the same year it was first excavated. These include Hastière Caverne B, dated to 5,180 ± 45 (OxA-9021) years BP and Hastière Caverne L, dated to 5,070 ± 60 (OxA-9088) years BP (ORBAN *et al.*, 2000; TOUSSAINT, 2007). These two Middle Neolithic sites are earlier than multiple bone caches within Hastière rockshelter dated to the Late Neolithic period. The earliest of these Late Neolithic sites is Hastière Caverne M, dated to 4,345 ± 60 (OxA-6852) years BP, followed by Hastière Petite Caverne, which dates to 4,300 ± 50 (OxA-6852) years BP and Hastière Le cimetière, dated to 4,280 ± 50 (OxA-6951). These three sites, together with Hastière Trou

Garçon C dating to 4,220 ± 45 (OxA-6853) years BP, can be categorized as early Late Neolithic. The Final/Late Neolithic is also represented at Hastière rockshelter, namely by Hastière Trou Fanfan, dated to 4,155 ± 50 (OxA-6854) years BP, which was among the first of the Hastière collective burials to be unearthed in 1867.

The inhabitants of Hastière Caverne M are estimated to have been of short stature based on regression estimates derived from the first metatarsal and isolated long bones (ORBAN *et al.*, 2000). The individuals interred at Hastière Caverne M, as well as at Maurenne, are estimated to have been shorter than those of Hastière Trou Fanfan, Hastière Petite Caverne and Hastière Trou Garçon C (ORBAN *et al.*, 2000). The individuals from Sclaigneaux are estimated to have been taller than those from the Haute Meus (DE PAEPE & POLET, 2007). However, it is possible that the Haute Meus postcranial remains are predominantly from females (ORBAN *et al.*, 2000), which might explain the smaller stature of individuals from Hastière Caverne M and Maurenne. These stature differences also could have resulted from nutritional deficiencies, genetic differences or other factors.

Cultural or kin traditions of extended families could additionally affect dietary choices. Although preserved material culture from the burial sites is limited, the degree of relatedness among Late Neolithic sites has been preliminarily explored using dental morphology. For instance, in a study of deciduous molars, dental remains from Hastière Caverne M feature Carabelli's trait and a protostylid in greater frequencies than is expressed by individuals of the Final/Late Neolithic sites (WILLIAMS *et al.*, 2018). In permanent maxillary molar crown shape, individuals from Hastière Caverne M are distinctive when compared to those from the Final/Late Neolithic cave burials and appear as outliers in plots of principal components scores from amplitudes of the harmonics derived from elliptical Fourier analysis (BRYAN & WILLIAMS, 2021). Permanent mandibular molars from Hastière Caverne M are also partly distinct from Final/Late Neolithic sites when elliptical Fourier shape descriptors are considered (WILLIAMS *et al.*, 2021). Although dental morphology suggests individuals from Hastière Caverne M are relatively distinct vis-à-vis the Final/Late Neolithic sites, the overwhelming signal in all of these studies highlights considerable variation existing both within and between groups.

In addition, no clear differentiation exists in isotopic signatures between Late Neolithic cave burials (BOCHERENS *et al.*, 2007). A study of carbon and nitrogen stable isotopes compared several collective burials from Hastière rockshelter and found that generally Late Neolithic diets could be characterized as similar to those of terrestrial carnivores. However, the lower nitrogen isotopic values could be indicative of the consumption of substantial plant resources (BOCHERENS *et al.*, 2007). Evidence signaling the consumption of fish was weak from the nitrogen isotopes (BOCHERENS *et al.*, 2007). However, it should be mentioned that freshwater nitrogen isotopes are highly variable relative to marine resources, and low nitrogen isotopic values do not automatically exclude freshwater fish consumption (GUIRY, 2019). Specifically, in freshwater environments, food chains are sometimes shorter and baseline foods are more depleted in δ^{15}N, resulting in lower nitrogen isotopic values being transmitted throughout the food chain (GUIRY, 2019). However, this is less true for temperate climates typical of northwest Europe.

Previous dental microwear analyses have found evidence of coarse scratches and other microwear features in the Late Neolithic sites of the Belgian Meuse basin. These features have been attributed to fish scales or some other abrasive animal or plant adherent or part (SEMAL *et al.*, 1999; GARCÍA MARTIN, 2000; TOUSSAINT *et al.*, 2001; SHERRILL & WILLIAMS, 2019). The faunal remains from the Final/Late Neolithic site of Bois Madame included both wild animals and domestics, such as horses, non-ruminant artiodactyls (suids), bovids, ovicaprids, cervids, carnivores (including dogs), feral and domestic cats, lagomorphs, insectivores, birds and amphibians (DUMBRUCH, 2003). Although pathological conditions were observed on Middle and Late Neolithic internments from the Meuse basin, there were low frequencies of nutritional insults occurring during growth and development, suggesting good health overall (POLET, 2011).

These previous studies have provided important insights into the diet of the prehistoric farmers of Belgium. However, the foods consumed at Hastière Caverne M have not been specifically reconstructed. Given that Hastière Caverne M is one of the earliest Late Neolithic collective burials of the Meuse basin, it is expected that the dietary signal will differ from the Final/Late sites situated closer to the Bronze Age transition. To examine dietary patterns of these Neolithic sites and comparative samples, we examined the microtopography of molar occlusal surfaces using dental microwear texture analysis (DMTA).

1.3. Diet reconstruction using DMTA

Dental microwear texture analysis is based on the principle that food items (as well as adherent sediment) damage the enamel in ways that can be characterized as complex, less complex and patterned or less patterned (SCOTT *et al.*, 2005, 2006, 2012; KRUEGER *et al.*, 2008, 2017, 2019; EL ZAATARI *et al.*, 2011, 2016; UNGAR *et al.*, 2012; KARRIGER *et al.*, 2016; REMY & SCHMIDT, 2016; SCHMIDT *et al.*, 2016, 2019, 2020; ESTALRRICH *et al.*, 2017; WILLIAMS *et al.*, 2019, 2020; DA-GLORIA & SCHMIDT, 2020). Complexity in DMTA is calculated in several ways. The preferred method for DMTA is to use a fractal-based computation known as area-scale fractal complexity (Asfc) in which the contours of the surface are compared to a flat plane of the same area, at different scales (SCOTT *et al.*, 2006). When complexity is low, the diet includes few, if any, hard objects that pit the enamel surface (e.g., seeds, shells, nut casings, sand, phytoliths, grit of various sizes and hard or brittle foods) (SCOTT *et al.*, 2012; CALANDRA *et al.*, 2012; DESANTIS *et al.*, 2013; SCHMIDT *et al.*, 2020). When complexity is high, the surface is roughened and the texture can be described as exhibiting a large number of micro-features that are of different dimensions and elevations.

Changes to occlusal surfaces, particularly from hard particles that are drawn along the teeth, can result in striations or scratches. Striations may be oriented, or patterned, in a similar direction, particularly when the mandible moves primarily in a side-to-side motion. Alternatively, they can be of a haphazard nature when the consumption of many different kinds of foods necessitates the movement of the mandible in multiple directions, including vertical movements (see FIORENZA *et al.*, 2020). Striations in many directions lead to low anisotropy values, which are measured using exact proportion length-scale anisotropy of relief (epLsar). A high value for anisotropy signals a diet concentrating on foods that are tough, like certain plant tissues, or homogenous such as in pre-industrial agricultural diets that were masticated using similarly oriented jaw movements (SCOTT *et al.*, 2006, 2012; EL ZAATARI, 2010; SCHMIDT *et al.*, 2016, 2019, 2020). Tough food items can leave large scratches too, particularly when they are contaminated by exogenous grit. In the end, food and contaminants capable of breaking the protein bonds that secure enamel crystallites will generate microwear features (e.g., HUA *et al.*, 2015). Contaminants may be sediment adhering to collected foods, windborne particles, or grit introduced through processing with stone tools (see UNGAR, 2009).

1.4. Expectations

We aim to infer the diet of the individuals from Hastière Caverne M by comparing their complexity and anisotropy values to those of the Final/Late Neolithic caves of the Meuse basin, represented by Maurenne, Bois Madame and Sclaigneaux. Previously, we found that the dietary signal of the Final/Late Neolithic caves of Belgium was more similar to hunter-gatherers from the Americas than to Holocene farmers (WILLIAMS *et al.*, 2020). Hastière Caverne M is expected to follow this pattern as well.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Collective burials from the Late Neolithic of the Belgian Meuse basin

A total of 134 isolated Neolithic alveolar remains with permanent molars including 50 partial maxilla and 84 mandibular fragments from the Belgian Meuse basin were examined at the Laboratory of Anthropology and Prehistory of the Royal Belgian Institute of Natural Sciences in Brussels (Belgium). Out of the 134 alveolar remains, 53 permanent molars exhibited well-preserved dental microwear on the enamel surface, originating from Hastière Caverne M (n = 8), Maurenne (n = 18), Bois Madame (n = 12) and Sclaigneaux (n = 15) (Tab. 1). Only molars within their respective alveoli were examined.

Sites and samples[1]	*Study area*[2]	*Sex*	*Age*	*Description*
Hastière CM (n = 8; MNI = 24)[3]				
Hastière 2	LLM1		Subadult >15 years	Nearly complete mandible
Hastière 15	LLM1		Adult	Mandibular fragment
Hastière 16	LRM1	Male	Adult	Corpus fragment
Hastière 25	URM1		Subadult 11-13 years	Right hemi-maxilla
Hastière 31	ULM2		Subadult 16-17 years	Maxillary fragment
Hastière 34	ULM1		Juvenile 10-12 years	Maxillary fragment
Hastière 35	ULM1		Subadult 12-13 years	Maxillary fragment
Hastière 36	ULM1		Subadult 12-13 years	Maxillary fragment
Maurenne (n = 18; MNI = 34)[4]				
Maurenne 1	LLM1	Male	Adult	Nearly complete mandible
Maurenne 4	ULM2		Older adult	Maxillary alveolus
Maurenne 6	ULM1		Near adult 17-18 years	Lower maxillary fragment
Maurenne 7	LRM1	Male	Adult	Nearly complete mandible
Maurenne 8	URM1		Subadult ~16 years	Left maxillary fragment
Maurenne 10	LRM2	Male	Older adult	Right hemi-mandible
Maurenne 11	ULM1		Subadult ~15 years	Left maxillary fragment
Maurenne 15	LRM1		Near adult 17-18 years	Mandibular corpus fragment
Maurenne 15	ULM1		Adult	Maxillary fragment
Maurenne 17	URM1		Older adult	Maxillary fragment
Maurenne 26	LLM2	Female	Adult	Left hemi-mandible
Maurenne 29	LLM1	Female	Adult	Mandibular fragment/ramus
Maurenne 31	LLM1	Female	Adult	Mandibular fragment
Maurenne 32	LRM2	Female	Young adult 18-25 years	Mandibular corpus fragment
Maurenne 34	LRM2	Female	Adult	Right hemi-mandible
Maurenne 39	LRM2		Subadult ~12 years	Mandibular fragment
Maurenne 43	LRM1	Male	Adult	Mandibular fragment
Maurenne 65	LLM1		Subadult 12-13 years	Left mandibular fragment
Bois Madame (n = 12; MNI = 32)[5]				
Bois Madame md 1	LLM2		Older adult	Nearly complete mandible
Bois Madame md 2	LRM1	Male	Older adult	Nearly complete mandible
Bois Madame md 4	LRM2	Female	Older adult	Nearly complete mandible
Bois Madame mx 5	ULM1		Young adult 17-25 years	Maxillary fragment
Bois Madame mx 6	URM2		Adult	Maxillary fragment
Bois Madame md 6	LRM1	Male	Older adult	Mandibular corpus fragment
Bois Madame mx 9	ULM1		Adult	Maxillary fragment
Bois Madame mx 16	URM1		Older adult	Maxillary fragment
Bois Madame md 20	LLM2	Male	Adult	Left ramus and corpus
Bois Madame md 21	LLM2	Male	Older adult	Mandibular corpus fragment
Bois Madmae md 29	LLM1		Juvenile 6-7 years	Mandibular fragment
Bois Madame mx 97	URM1		Juvenile 7 years	Maxillary fragment

Sites and samples[1]	*Study area*[2]	*Sex*	*Age*	*Description*
Sclaigneaux (n = 15; MNI = 44)[6]				
Sclaigneaux 1	LRM1	Male	Subadult 12-13 years	Nearly complete mandible
Sclaigneaux 11	LRM1	Female	Older adult	Partial mandible
Sclaigneaux 34	LRM1	Male	Older adult	Left hemi-mandible
Sclaigneaux 35	LRM1		Subadult ~12 years	Mandibular corpus fragment
Sclaigneaux 46	LLM1		Subadult 14-15 years	Mandibular corpus
Sclaigneaux 47	LLM1	Male	Young adult 19-20 years	Mandibular corpus
Sclaigneaux 59	LLM2		Adult	Small corpus fragment
Sclaigneaux 63	LLM2	Female	Near adult 17-25 years	Mandibular corpus fragment
Sclaigneaux 66	LLM1		Adult	Small corpus fragment
Sclaigneaux 91	URM2		Adult	Partial maxilla
Sclaigneaux 92	URM1		Young adult 17-25 years	Maxillary fragment
Sclaigneaux 93	URM1		Subadult 14-18 years	Lower maxillary fragment
Sclaigneaux 97	URM1		Young adult 17-25 years	Maxillary fragment
Sclaigneaux 98	URM1		Young adult 17-25 years	Maxillary fragment
Sclaigneaux 108	ULM1	Female	Adult	Maxillary fragment

[1] N = number of individuals; MNI = minimum number of individuals with well-preserved *in situ* permanent molars.

[2] Code abbreviations for study area include mandibular (L), maxillary (U), followed by left (L) and right (R), and M1 (first molar) and M2 (second molar).

[3] 4,345 ± 60 years BP (AMS OxA-6558) (BRONK-RAMSEY *et al.*, 2002).

[4] 4,635 ± 45 years BP (AMS OxA-9025); 4,160 ± 45 years BP (AMS OxA-9026); 3,950 ± 70 years BP (Lv-1483); 3,830 ± 90 years BP (Lv-1482) (BRONK-RAMSEY *et al.*, 2002; TOUSSAINT, 2007).

[5] 4,075 ± 38 years BP (AMS OxA 10831); 3,910 ± 40 years BP (AMS OxA 10830) (DUMBRUCH, 2003).

[6] 4,155 ± 35 years BP (GrA-32975) (DEPAEPE & POLET, 2007).

Tab. 1 – Description of individuals examined.
Tab. 1 – *Description des individus examinés.*

Standard osteological techniques were used to estimate age and sex for all 53 alveolar fragments examined (Tab. 1) (BUIKSTRA & UBELAKER, 1994). For adults, standard age categories were used. These included "young adult" with M3 only recently erupted and with a dental wear score of 3 (SMITH, 1984); "adult" with full eruption of the molars and associated with dental wear scores of 4-5 (SMITH, 1984); and "older adult" exhibiting dental wear scores of 5-6 (SMITH, 1984). Although the sample was primarily composed of subadults and young adults, 11 Final/Late Neolithic older adults with crown margins and islands of occlusal enamel showing well-preserved dental microwear were also included (Tab. 1). These cave and rockshelter collective burials of the Meuse basin have been studied in detail elsewhere (VANDERVEKEN, 1997, 2007; SEMAL *et al.*, 1999; GARCÍA MARTIN, 2000; TOUSSAINT *et al.*, 2001, 2003; DUMBRUCH, 2003, 2007; DE PAEPE, 2007; DE PAEPE & POLET, 2007; TOUSSAINT, 2007; POLET, 2011).

2.1.2. Comparative samples

Complexity and anisotropy descriptive statistics were incorporated from three forager groups, three farming societies and a pastoralist sample (n = 173). These dental casts were assessed using the same instrumentation and protocol at the University of Indianapolis as described below in greater detail for the Late Neolithic caves of the Meuse basin. The means and standard deviations for these groups were culled from multiple publications (KARRIGER *et al.*, 2016; SCHMIDT *et al.*, 2016, 2019, 2020; DA-GLORIA & SCHMIDT, 2020).

The three hunter-gatherer samples from different continents and with diverse patterns of subsistence were chosen (Tab. 2). One of these groups of foragers is from the Archaic period of Indiana, United States (n = 34) and dates to 3,500-5,500 years BP (SCHMIDT *et al.*, 2019). These archaic foragers relied heavily on woodland plant and animal species, and engaged in low levels of horticulture. This group was included because the individuals are associated with the remains of both wild and domestic species (CHAPMAN & WATSON, 1993; YARNELL, 1993; SCHMIDT *et al.*, 2020). Similarly, both wild and domestic animals are associated with the Late Neolithic burials of the Belgian Meuse basin (DUMBRUCH, 2003; BOCHERENS *et al.*, 2007). We included foragers from Lagoa Santa Brazil (n = 23) dating to 11,000-7,000 years BP (DA-GLORIA & SCHMIDT, 2020), as well as sedentary Natufian foragers from present-day Israel, dated to 14,000-10,000 years BP (KARRIGER *et al.*, 2016). These hunter-gatherer societies provide examples of variation in forager dietary resources, particularly the latter who subsisted on cereals that were later domesticated (Tab. 2).

From Schmidt *et al.*, (2016), we considered Xiongnu pastoralists (n = 49) from the Late Bronze / Early Iron Age of Mongolia, roughly 1000-400 BCE to 2010 ± 35 uncal. BP (MAKAREWICZ, 2011; MACHICEK & ZUBOVA, 2012). These herder societies were included to assess how the dietary signature of Late Neolithic inhabitants from the Belgian Meuse basin compared to individuals whose diet included minimal amounts of wild plant foods (Tab. 2). Xiongnu pastoralists consumed a soft diet that likely included large amounts of meat and animal products. Although evidence exists that wild animals and plants were consumed, the main vegetable contribution to the diet was millet, which was traded for flesh, dairy, fiber and hides to farmers (MAKAREWICZ, 2011; MACHICEK & ZUBOVA, 2012; SCHMIDT *et al.*, 2019).

Group	*Area*	*Date*
Natufian sedentary foragers, Israel	Southwest Asia	14,000-10,000 years BP
Neolithic farmers, Israel	Southwest Asia	12,500-10,250 years BP
Lagoa Santa paleoforagers, Brazil	South America	11,000-7,000 years BP
Early Bronze Age England farmers	Northern Europe	4,500-3,500 years BP
Archaic Indiana forager/farmers	North America	3,500-5,500 years BP
Bronze/Iron Age Greece farmers	Southern Europe	~3,500-2,900 years BP
Xiongnu pastoralists, Mongolia	Central Asia	~3,000-2,000 years BP

Tab. 2 – Epipaleolithic and Holocene comparative groups.
Tab. 2 – *Groupes comparatifs épipaléolithique et holocène.*

From Karriger *et al.* (2016), we included three farming societies. One of these groups, from Early Bronze Age England (n = 21) dated to 4,500-3,500 years BP overlaps the radiocarbon dates of the Late Neolithic Meuse basin sites (Tab. 1). Other farming societies included Late Bronze Age / Early Iron Age Greece, dated to circa 3,500-2,900 years BP (n = 15) and Neolithic Israel, 12,500–10,250 years BP (n = 16). Domesticates for all of these societies and presumably for the Late Neolithic period of the Belgian Meuse basin included barley, wheat, emmer and legumes as well as cattle, sheep and goats (FAGEN, 1995; DICKINSON, 2006; SCHMIDT *et al.*, 2011; CHIU *et al.*, 2012; DE GREGORY, 2012; KARRIGER *et al.*, 2016).

2.2. Methods

The occlusal surface of the molars was first cleaned with cotton balls and isopropyl alcohol, and then coated with a thin layer of medium-bodied polyvinylsiloxane (Coltène/Whaledent) at the Royal Belgian Institute of Natural Sciences. The molds were cast using epoxy resin and hardener (Buehler) at the Bioarchaeology Laboratory of Georgia State University. These cured for at least 24 hours prior to removal from the dental impressions.

Dental microwear observed on the dental casts was scanned using the “Indie” white-light confocal microscope system (Sensofar Plμ, Solarius Development Inc.) at the University of Indianapolis. For each individual, four adjoining scans were taken at 100x magnification. We focused on Phase II wear facets corresponding to facets x, 9 and 10n (MAIER & SCHNECK, 1982; KRUEGER *et al.*, 2008). The four scans were subsequently stitched together using an automated function to create a single data cloud for each individual of 242 by 182 μm (SCHMIDT *et al.*, 2019). Prior to analysis, SolarMap 5.1.1 was employed to delete dust particles from the data clouds and to level the scans using a least-squares algorithm. To corroborate initial observations that the surface included only microwear resulting from mastication rather than *postmortem* factors, two- and three- dimensional surface reconstructions were created (Fig. 2, Fig. 3). To extract the two variables widely used in dental microwear texture analysis, complexity and anisotropy, the scans were subjected to scale-sensitive fractal analysis which involved the use of two programs, Sfrax® and Toothfrax® to estimate Afsc and epLsar, respectively (SCOTT *et al.*, 2006, 2012; UNGAR *et al.*, 2012; ARMAN *et al.*, 2016; SCHMIDT *et al.*, 2016, 2019, 2020).

The data were initially subjected to Kolmogorow-Sminov and Shapiro-Wilk tests of normality, both including and excluding the categorical factor of membership (Hastière *versus* all other Meuse basin sites), followed by the calculation of the mean, standard deviation and confidence intervals. Hastière Caverne M was then compared directly to the Final/Late Neolithic burials using a t-test, with effect size estimated using Cohen's d, and by presenting complexity (Asfc) and anisotropy (epLsar) in a bivariate framework using 95% confidence ellipses around site centroids. To explore the relationship between complexity and anisotropy further, we applied a linear regression and bivariate correlation to these two variables. The linear regression estimated the relationship between complexity and anisotropy, explained the distribution of individuals across both axes, and helped to visualize the extent to which the variation can be found within the 95% confidence limits and prediction intervals. We use a bivariate correlation to evaluate the strength of this relationship. To contextualize the dietary signal of Hastière Caverne M, the means and 95% confidence intervals for the Late Neolithic cave burials of the Meuse basin were compared to the Epipaleolithic and Holocene human societies included in the comparative samples. These are presented separately for complexity and anisotropy.

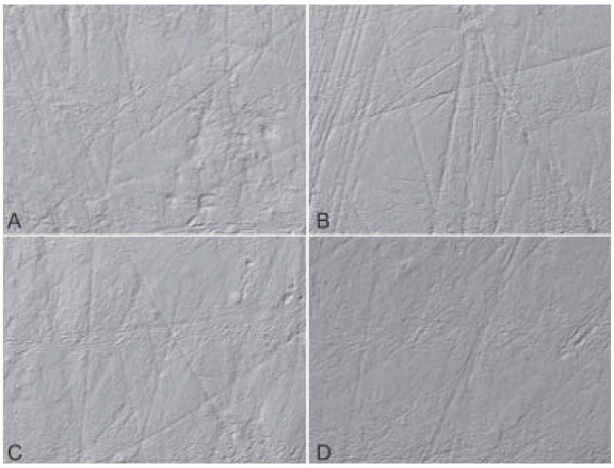

Fig. 2 – Two-dimensional image reconstructions of Hastière 15 (A), Sclaigneaux 91 (B); Bois Madame BM Mx 5 (C); and Maurenne 4 (D).
Fig. 2 – *Reconstitutions d'images bidimensionnelles de Hastière 15 (A) ; Sclaigneaux 91 (B) ; Bois Madame BM Mx 5 (C) ; et Maurenne 4 (D).*

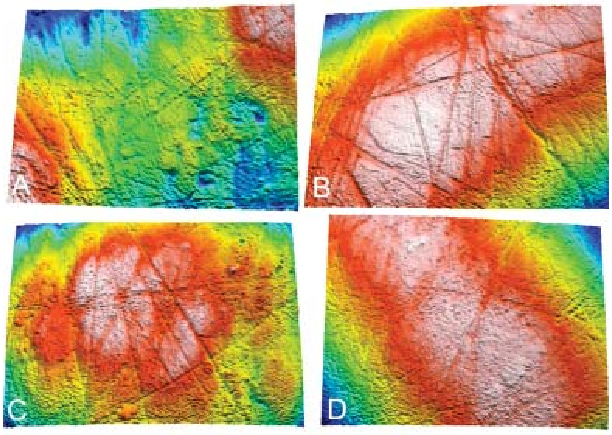

Fig. 3 – Three-dimensional image reconstructions of Hastière 15 (A), Sclaigneaux 91 (B); Bois Madame BM Mx 5 (C); and Maurenne 4 (D).
Fig. 3 – *Reconstitutions d'images tridimensionnelles de Hastière 15 (A) ; Sclaigneaux 91 (B) ; Bois Madame BM Mx 5 (C) ; et Maurenne 4 (D).*

3. RESULTS

Kolmogorov-Smirnov and Shapiro-Wilk tests of normality exhibit non-significant *p* values (Tab. 3). This is true both when membership categories are used as a factor and when they are not (Tab. 3). Therefore, the null hypothesis of non-normality can be rejected.

There is extensive variation in the Final/Late Neolithic sites. Maurenne exhibits the greatest degree of variation in complexity (Asfc), whereas Bois Madame presents the highest standard deviation for anisotropy (epLsar) (Tab. 4, see also Fig. 4). Hastière Caverne M has the highest mean for complexity and anisotropy. The standard deviation for Hastière Caverne M is relatively small for complexity, and comparatively large for anisotropy (Tab. 4). Despite this variation, Hastière Caverne M exhibits significantly higher anisotropy compared to the Final/Late Neolithic sites ($p = 0.038$) using a t-test (Tab. 5). The effect size for this significant difference is large as indicated by a Cohen's d of 0.789 (Tab. 5). Although the mean complexity is higher for Hastière Caverne M (Tab. 4), there is no significant difference between this cave burial and the Final/Late Neolithic sites ($p = 0.427$). However, the effect size associated with this t-test, as estimated using Cohen's d, suggests that the difference between groups is low medium (0.318). Therefore, the higher mean complexity of Hastière Caverne M compared to the Final/Late Neolithic sites is likely to reflect an important distinction (Tab. 5).

		Kolmogorov-Sminov			*Shapiro-Wilk*		
		Test	n	p value	Test	n	p value
Complexity	Hastière Caverne M	0.205	8	0.20	0.930	8	0.514
(Asfc)	Final/Late Neolithic sites	0.123	45	0.09	0.953	45	0.066
	All	0.097	57	0.20	0.967	57	0.120
Anisotropy	Hastière Caverne M	0.226	8	0.20	0.909	8	0.349
(epLsar)	Final/Late Neolithic sites	0.098	45	0.20	0.970	45	0.284
	All	0.083	57	0.20	0.972	57	0.211

Tab. 3 – Kolmogorov-Sminov and Shapiro-Wilk tests of normality results.
Tab. 3 – *Résultats des tests de normalité de Kolmogorov-Smirnov et Shapiro-Wilk.*

	Complexity (Asfc) Mean (N)	*SD*	*95% CI*	*Anisotropy (epLsar) Mean (N)*	*SD*	*95% CI*
Hastière Caverne M[1]	1.67 (8)	0.395	1.34-2.00	0.0027 (8)	0.0085	0.0020-0.0034
Maurenne[2]	1.55 (18)	0.738	1.18-1.91	0.0019 (18)	0.0010	0.0014-0.0024
Bois Madame[2]	1.34 (12)	0.470	1.07-1.67	0.0018 (12)	0.0095	0.0012-0.0024
Sclaigneaux[2]	1.53 (15)	0.529	1.23-1.82	0.0018 (15)	0.0011	0.0013-0.0024
Lagoa Santa[3]	2.45 (23)	1.020	2.01-2.89	0.0029 (23)	0.0015	0.0023-0.0035
Archaic Indiana[4]	1.26 (34)	0.471	1.01-1.42	0.0026 (34)	0.0011	0.0022-0.0030
Natufian. Israel[5]	1.41 (15)	0.645	1.08-1.74	0.0038 (15)	0.0017	0.0029-0.0047
Neolithic. Israel[5]	1.34 (16)	0.811	0.94-1.74	0.0034 (16)	0.0017	0.0026-0.0042
Early Bronze Age England[5]	1.34 (21)	0.443	1.13-1.54	0.0041 (21)	0.0016	0.0034-0.0048
Late Bronze / Iron Age Greece[5]	1.14 (15)	0.294	0.99-1.29	0.0036 (15)	0.0015	0.0028-0.0044
Pastoralists[6]	0.92 (49)	0.311	0.83-1.01	0.0034 (49)	0.0017	0.0029-0.0039

[1] Original results from this study
[2] Williams *et al*. (2020)
[3] Da-Gloria & Schmidt (2020)
[4] Schmidt *et al.* (2020)
[5] Karriger *et al*. (2016)
[6] Schmidt *et al*. (2016)

Tab. 4 – Descriptive statistics for the Belgian Late Neolithic sites (above) and comparative samples (below).
Tab. 4 – *Statistiques descriptives des sites belges du Néolithique récent (en haut) et échantillons comparatifs (en bas).*

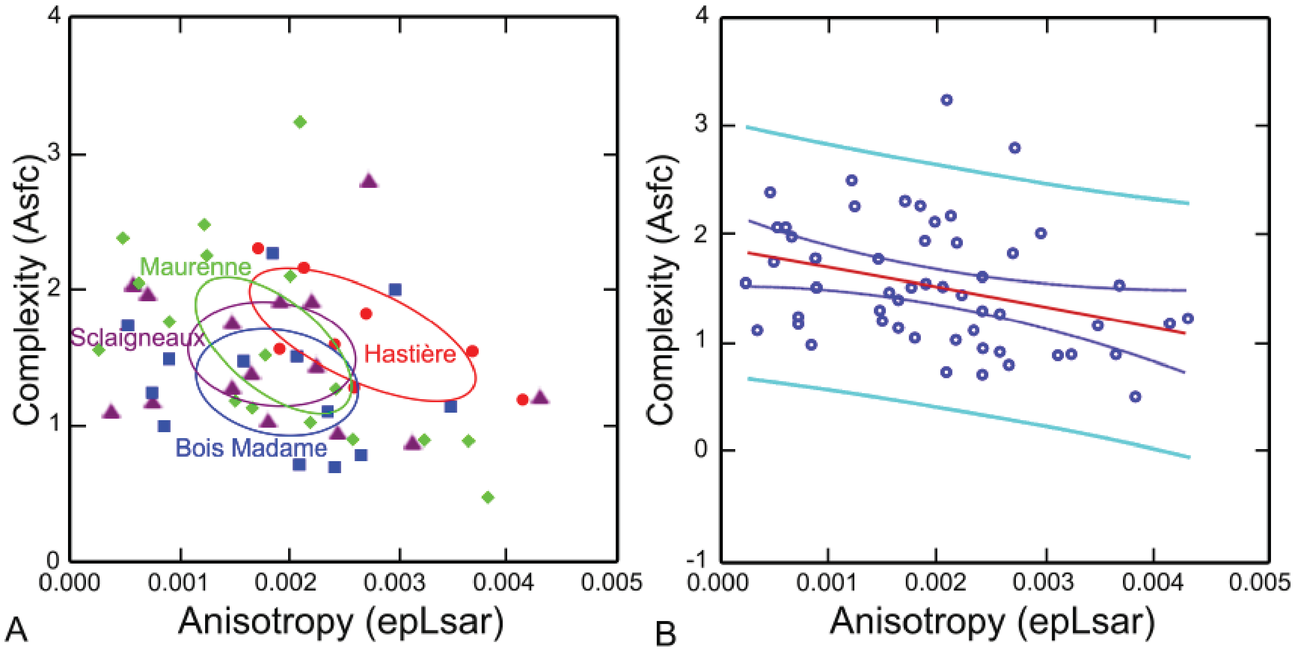

Fig. 4 – Bivariate plot contrasting complexity *versus* anisotropy: shown with 95% confidence ellipses around site centroids (A); a least-squares linear regression shows a significant indirect relationship between complexity and anisotropy demarcated by 95% confidence intervals (blue line) and the inner and outer predication intervals (turquoise line) (B).

Fig. 4 – *Graphique bivarié montrant la complexité par rapport à l'anisotropie : illustré avec des ellipses de confiance à 95 % autour des centroïdes du site (A) ; une régression linéaire des moindres carrés montre une relation indirecte significative entre la complexité et l'anisotropie délimitée par des intervalles de confiance à 95 % (ligne bleue) et les intervalles de prédiction interne et externe (ligne turquoise) (B).*

	t	*df*	*p value*	*Cohen's d*
Complexity (Asfc)	0.801	51	0.427	0.318
Anisotropy (epLsar)	2.128	51	0.038	0.789

Tab. 5 – Results of t-tests and effect size using Cohen's d.
Tab. 5 – *Résultats du test t et de la taille de l'effet à l'aide du D de Cohen.*

3.1. Bivariate comparison of Hastière Caverne M with the Final/Late Neolithic Belgian sites

The 95% confidence ellipse for the site centroid of Hastière Caverne M is relatively distinct from the Final/Late Neolithic sites, particularly compared to that for Bois Madame (Fig. 4). This distinction is borne primarily from the higher anisotropy of Hastière Caverne M. However, the single highest anisotropy is demonstrated by Sclaigneaux 66, followed closely by Hastière Caverne M 31, while Maurenne 34 and Maurenne 29 also present elevated values (Fig. 4). Differences in complexity between the Belgian Meuse basin sites is less convincing, particularly between Maurenne and Hastière Caverne M.

A linear regression using least-squares estimates the degree to which complexity is a function of anisotropy (Tab. 6). The regression is demarcated by 95% confidence intervals and only two individuals fall outside the outer prediction interval, Maurenne 11 and

	B	*Standard error*	*t*	*p value*
Constant	1.876	0.167	11.213	<0.001
Coefficient	-180.316	75.252	-2.396	0.020

Tab. 6 – Constant and coefficient estimates for a linear regression of complexity compared to anisotropy.
Tab. 6 – *Estimations d'une constante et d'un coefficient pour une régression linéaire de complexité par rapport à l'anisotropie.*

Sclaigneaux 92 (Fig. 4). There is a weak negative but significant correlation between complexity and anisotropy (*r* = -0.292; *p* = 0.02) (Fig. 4). This indirect relationship suggest individuals with high complexity will also have low anisotropy, and conversely, individuals with lower complexity will also tend to exhibit a greater patterning of microtopographical striations, which yields high anisotropy (SCOTT *et al.*, 2006; SCHMIDT *et al.*, 2016, 2019). In contrast to Hastière Caverne M, only individuals from the Final/Late Neolithic sites, and particularly Bois Madame, have low values for both complexity and anisotropy.

3.2. Late Neolithic Belgian sites and comparative samples

The Late Neolithic collective burials exhibit higher complexity values than most foragers excepting Lagoa Santa (Fig. 5). However,

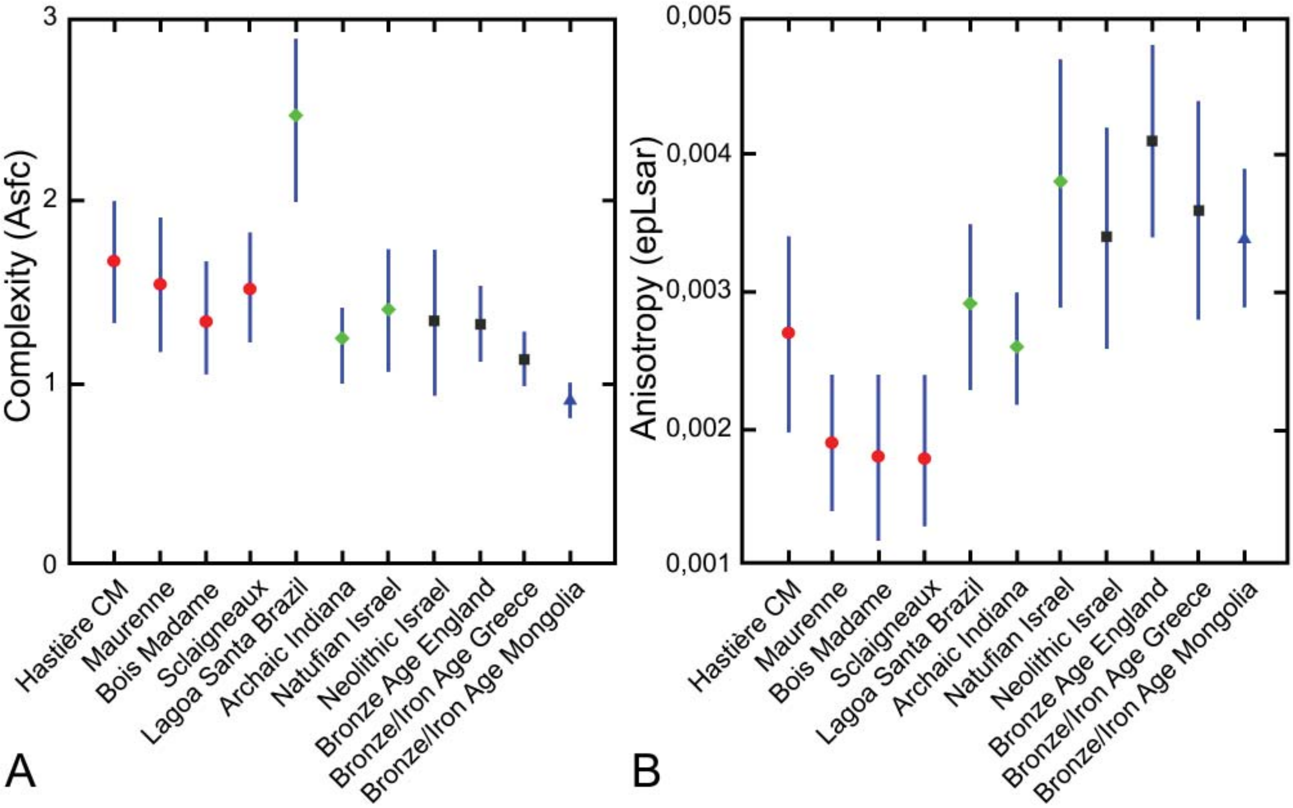

Fig. 5 – Means of complexity (A) and anisotropy (B) with 95% confidence intervals for Belgian Late Neolithic sites (red circles), hunter-gatherers (green diamonds), farmers (black squares) and pastoralists (blue triangles).
Fig. 5 – *Moyennes de complexité (A) et d'anisotropie (B) avec des intervalles de confiance à 95 % pour les sites belges du Néolithique récent (cercles rouges), les chasseurs-cueilleurs (losanges verts), les agriculteurs (carrés noirs) et les bergers nomades (triangles bleus).*

the Belgian Meuse basin sites vary in complexity. Hastière Caverne M has the highest and Bois Madame has the lowest complexity of the Neolithic sites from the Meuse basin. Foragers generally have higher complexity than do farmers (Fig. 5). However, the Belgian Late Neolithic burials surpass the complexity of most food producers.

Regarding anisotropy, the Final/Late Neolithic sites of the Belgian Meuse exhibit relatively low values compared to farmers and pastoralists, as well as sedentary Natufian foragers (Fig. 5). The anisotropy of Hastière Caverne M and of Amerindian foragers of Indiana and Lagoa Santa, falls between these two extremes. Although the mean is lower, the 95% confidence interval for Hastière Caverne M overlaps with those of farmers from Early Bronze Age England, Late Bronze Age / Early Iron Age Greece and Neolithic Israel. The 95% confidence interval for Hastière Caverne M overlaps those of all foragers. However, the 95% confidence intervals for the Final/Late Neolithic sites from the Belgian Meuse basin only show overlap with the paleoforagers of Lagoa Santa and Archaic Indiana, and not with sedentary Natufian foragers with much higher anisotropy.

4. DISCUSSION

The complexity of Hastière Caverne M is higher than observed in the Final/Late Neolithic period. Although the difference is not significant—perhaps from the limited number of individuals available—the effect size can be described as low medium, suggesting a distinction might exist between Hastière Caverne M and the Final/Late Neolithic sites. The relatively low complexity of the Final/Late Neolithic sites could derive from limited domesticated food availability, reduced access to food processing technology or a combination of the two. The enamel complexity characterizing Hastière Caverne M does not approach that of Lagoa Santa paleoforagers who consumed a broad-based diet with no domesticates (DA-GLORIA & SCHMIDT, 2020). However, complexity at Hastière Caverne M is still higher than the food producers and other foragers sampled. Hastière Caverne M is most similar to Sclaigneaux and Maurenne, which have lower means but include outliers that exceed the values associated with Hastière (Fig. 4, Fig. 5).

Considering all of the seven comparative samples, the hardness of the diet of Hastière Caverne M most closely resembles sedentary Natufian foragers (Fig. 5). It might be expected that Early Bronze Age England would be similar to the Final/Late Neolithic burials from the Meuse basin since they are coincident temporally and close geographically. However, the Final/Late Neolithic sites from the Meuse basin are distinct from their neighbors in Britain who had already embraced a Bronze Age diet (MAHONEY *et al.*, 2019; WILLIAMS *et al.*, 2020).

The anisotropy of Hastière Caverne M is significantly elevated compared to those from the Final/Late Neolithic sites of the Meuse basin suggesting different movements of the jaws characterized the two groups. This difference likely reflects a reduced exploitation of wild plant foods at Hastière Caverne M. The extremely low anisotropies of the Final/Late Neolithic sites suggest the inhabitants were not fulltime farmers but instead consumed a great variety of wild plant foods (WILLIAMS *et al.*, 2020). In contrast, Hastière Caverne M falls within the low end of the range of foragers. Hastière Caverne M most closely resembles paleoforagers of Lagoa Santa and forager/farmers of Archaic Indiana rather than farmers, herders and sedentary Natufian foragers with much higher anisotropy (Fig. 5). These results suggest the diet at Hastière Caverne M could be characterized as intermediate between the low anisotropies of foragers and the elevated anisotropies of farmers. The diet signal of Hastière Caverne M is dissimilar in anisotropy to Early Bronze Age England in mean values, although the 95% confidence intervals slightly overlap (Fig. 5).

The significant negative correlation between Asfc and epLsar suggests that as complexity increases, anisotropy decreases (Fig. 4). This relationship also exists between foragers with high complexity and low anisotropy, and farmers with lower Asfc and higher epLsar (SCOTT *et al.*, 2006; SCHMIDT *et al.*, 2016, 2019). This indirect relationship may exist because of the underlying properties of the food. For instance, hard or round items will leave highly complex and low anisotropic surfaces because they are crushed, whereas tough, flat or smoother foods will result in lower complexity and higher anisotropy as they are dragged across the tooth during mastication. The cave burials of the Late Neolithic sites of Belgium correspond to this trend. However, the individuals from these sites resemble foragers more than food producers, suggesting the Late Neolithic societies of the Meuse basin may not have been practicing agriculture as a full-time subsistence practice. The presence of terrestrial domestic mammal remains in such cave burials as Bois Madame (DUMBRUCH, 2003) suggests animal husbandry was most likely practiced. However, investments in the farming of vegetable crops may have been limited or episodic. The inhabitants of the early Late Neolithic site of Hastière Caverne M may have regularly practiced plant agriculture to a greater extent than subsequent Final/Late Neolithic peoples. Settling crop fields in the Belgian Meuse basin is most feasible on the plateaus, and these may have been limited. Alternatively, those interred at the Late Neolithic sites of the Meuse basin may have been involved in a food exchange system with neighboring farmers, whereby wild plants and animals were bartered for agricultural staples.

In addition to terrestrial carnivores, isotopic evidence points to a Late Neolithic diet also overlapping that of suids (BOCHERENS *et al.*, 2007). Wild boars and domestic pigs both yield high carbon and nitrogen isotope values, although the nitrogen values of canids are even higher in temperate habitats such as northwest Europe. Carnivores are generally more enriched than prey in ^{15}N given their higher trophic level. Late Neolithic peoples from the Meuse basin exhibit nitrogen isotope values consistent with that of terrestrial carnivores suggesting much of the protein in the diet derived from ungulates and other land mammals (BOCHERENS *et al.*, 2007). Mean nitrogen values in the Middle/Late and Late Neolithic are much lower than at Mesolithic Belgian sites, although Middle Neolithic burials exhibit the highest values (BOCHERENS *et al.*, 2007). These differences have been interpreted as the result of a greater consumption of freshwater fish and invertebrate resources during the Middle Neolithic compared to the Middle/Late and Late Neolithic where nitrogen values are lower and commensurate with suids. Suids consume tubers, fruits, herbs, seeds and other high quality plant foods, small prey items such as rodents, reptiles and birds, as well as carrion, suggesting that Late Neolithic peoples of the Belgian Meuse basin were heavily reliant on foraged foods.

5. CONCLUSION

Previous studies suggest the diet of Hastière Caverne M included terrestrial mammals, very little freshwater fish or shellfish and a large amount of plant foods. Our study indicates the diet was a mix of foods harder than that of many intensive farmers but with an anisotropy that is conceivably from a farming group. Thus, they appear to have a mixed diet that included both wild and domesticated foods. The inhabitants of Hastière Caverne M differed from Final/Late Neolithic peoples who probably had an even larger proportion of gathered plant foods in the diet as deduced from a significantly lower anisotropy.

The inhabitants of Hastière Caverne M generally masticated slightly harder and coarser resources than in the Final/Late Neolithic, although a few individuals from Maurenne and Sclaigneaux matched or even exceeded the complexity values found at Hastière. In fact, the variation at Maurenne and Sclaigneaux in complexity is extensive. However, the trend toward lower anisotropy values for the Final/Late Neolithic suggests that agricultural foods, at least the cereals, were difficult to acquire, perhaps because of societal perturbations associated with the onset of the northern European Bronze Age. Individuals of Hastière Caverne M existed prior to this time frame and escaped, at least in part, local constraints on food production, such that the inhabitants were able to depend on domestic agricultural products to a greater extent, albeit with wild plant foods still forming a large part of the vegetable dietary component. Another possibility is that active foraging could have been a regular subsistence activity in the Meuse basin during the Late Neolithic as it was in other locations such as Neolithic Greece (DICKINSON, 2006). Wild plant foods must have become particularly important during the Final/Late Neolithic.

Acknowledgments

We wish to thank Patrick Semal, Chief of the Scientific Heritage Service, at the Royal Belgian Institute of Natural Sciences Brussels, for generously allowing access to these Neolithic remains. At the Royal Belgian Institute of Natural Sciences, we gratefully acknowledge the important contribution of Caroline Polet who provided literature and osteological expertise to the study. We additionally thank Laurence Cammaert who expertly created the map of Belgium modified for Figure 1. We are grateful to Bernard Spenlé for corrections to the French translation. Funding for this project was received from Fulbright-Belgium and the Commission for Educational Exchange between the United States, Belgium, and Luxembourg, and the US National Science Foundation (BCS 0922930).

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