



HAL
open science

The diet of young Neandertals from France, Pech de l'Azé I and Hortus II, reconstructed using dental microwear texture analysis

Frank L'engle Williams, Christopher W Schmidt, Jessica L Droke, Whitney M Karriger, Gaël Becam, Fred H Smith, Marie-Antoinette de Lumley

► To cite this version:

Frank L'engle Williams, Christopher W Schmidt, Jessica L Droke, Whitney M Karriger, Gaël Becam, et al.. The diet of young Neandertals from France, Pech de l'Azé I and Hortus II, reconstructed using dental microwear texture analysis. *Bulletins et Mémoires de la Société d'anthropologie de Paris*, 2023, 35 (2), 10.4000/bmsap.12074 . hal-04267000

HAL Id: hal-04267000

<https://hal.science/hal-04267000v1>

Submitted on 1 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Copyright

The diet of young Neandertals from France, Pech de l'Azé I and Hortus II, reconstructed using dental microwear texture analysis

Le régime alimentaire des jeunes Néandertaliens de France, Pech de l'Azé I et Hortus II, reconstitué à l'aide de l'analyse de la texture des micro-usures dentaires

Frank L'Engle Williams, Christopher W Schmidt, Jessica L Droke, Whitney M Karriger, Gaël Becam, Fred H Smith et Marie-Antoinette de Lumley



Édition électronique

URL : <https://journals.openedition.org/bmsap/12074>

DOI : [10.4000/bmsap.12074](https://doi.org/10.4000/bmsap.12074)

ISSN : 1777-5469

Éditeur

Société d'Anthropologie de Paris

Référence électronique

Frank L'Engle Williams, Christopher W Schmidt, Jessica L Droke, Whitney M Karriger, Gaël Becam, Fred H Smith et Marie-Antoinette de Lumley, « The diet of young Neandertals from France, Pech de l'Azé I and Hortus II, reconstructed using dental microwear texture analysis », *Bulletins et mémoires de la Société d'Anthropologie de Paris* [En ligne], 35 (2) | 2023, mis en ligne le 13 septembre 2023, consulté le 18 octobre 2023. URL : <http://journals.openedition.org/bmsap/12074> ; DOI : <https://doi.org/10.4000/bmsap.12074>



Le texte seul est utilisable sous licence CC BY-NC-ND 4.0. Les autres éléments (illustrations, fichiers annexes importés) sont « Tous droits réservés », sauf mention contraire.



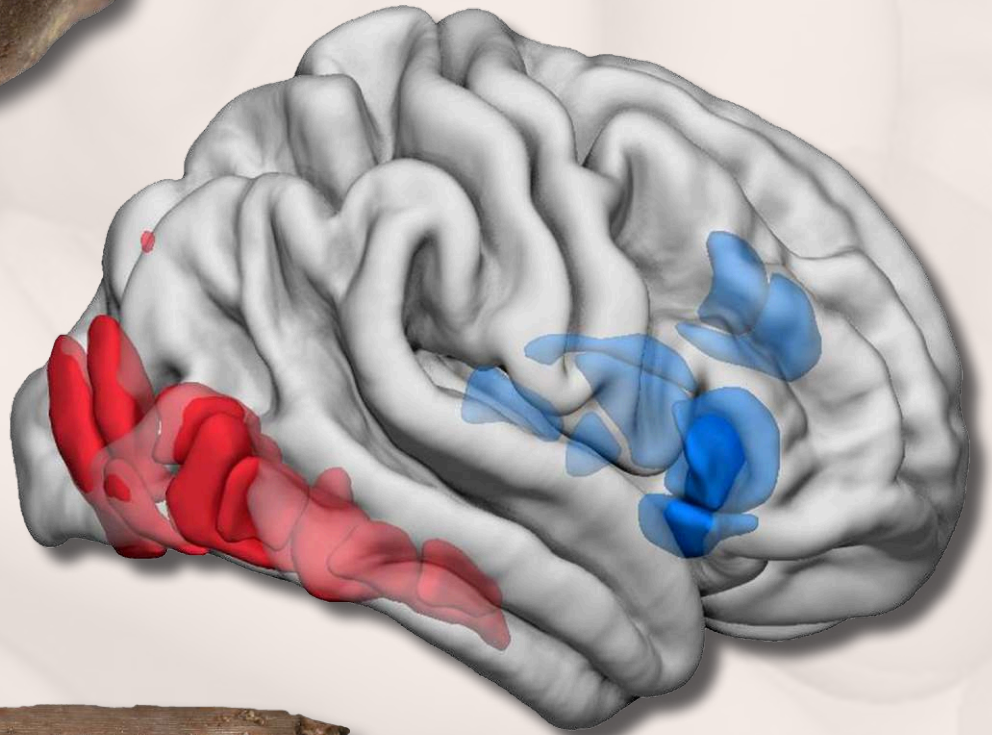
BMSAP

Bulletins et Mémoires de la Société d'Anthropologie de Paris

VOLUME 35 # 2
OCTOBRE 2023

ISSN 0037-8984

Publication fondée en 1859



*Revue soutenue par l'Institut des sciences humaines et sociales (InSHS) du CNRS
2023-2024*

The diet of young Neandertals from France, Pech de l'Azé I and Hortus II, reconstructed using dental microwear texture analysis

Le régime alimentaire des jeunes Néandertaliens de France, Pech de l'Azé I et Hortus II, reconstitué à l'aide de l'analyse de la texture des micro-usures dentaires

Frank L'Engle Williams ^{1*}, Christopher W Schmidt², Jessica L Droke³, Whitney M Karriger⁴, Gaël Becam⁵, Fred H Smith^{6,7}, Marie-Antoinette de Lumley^{5,8}

1. Department of Anthropology, Georgia State University, Atlanta, GA, United States
2. Department of Anthropology, University of Indianapolis, Indianapolis, IN, United States
3. Department of Anthropology, University of Wyoming, Laramie, WY, United States
4. Department of Biomedical Sciences, Edward Via College of Osteopathic Medicine, Auburn Campus, AL, United States
5. Centre Européen de Recherches Préhistoriques de Tautavel, France
6. Department of Sociology and Anthropology, Illinois State University, Normal, IL, United States
7. Department of Anthropology, University of Colorado, Boulder, CO, United States
8. Institut de Paléontologie Humaine, Paris, France

* frankwilliams@gsu.edu

Reçu : 26 janvier 2023 ; accepté : 07 août 2023
Bulletins et Mémoires de la Société d'Anthropologie de Paris

Abstract – Neandertal adults show differences in diet with respect to paleohabitat. To examine whether Neandertal children of France during Marine Isotope Stage 3 also show these dietary distinctions, the deciduous second molars of Pech de l'Azé I, from a cold-temperate period, and Hortus II from Sub-Phase Vb, an extreme cold-arid interval, were examined using dental microwear texture analysis. The comparative sample (n=76) includes deciduous molars from Neolithic forager-farmers of Belgium, including Caverne de la Cave at Maurenne (n=5), Sclaigneaux (n=7) and Bois Madame (n=6), Roman-era farmers from Herculaneum (n=15) and Medieval agriculturalists from Canterbury, England (n=43). When complexity is compared to anisotropy, Pech de l'Azé I exhibits an elevated value from the mastication of plants with hard parts or adherent particles, or the consumption of foods that were poorly processed or grit-laden, whereas Hortus II presents a low value, perhaps from limited access to hard plant parts such as seeds and nuts. However, Pech de l'Azé I and Hortus II resemble each other in having a low value for anisotropy, which is indicative of complicated movements of the jaws during mastication and are dissimilar to Neolithic, Roman and Medieval human children who tend to have higher values. The diets of Neandertal children differ with respect to paleohabitat and typically were more diverse than those of food producers regardless of whether they inhabited wooded or open environments.

Keywords – Maurenne Caverne de la Cave, Sclaigneaux, Bois Madame, Herculaneum, deciduous molars

Résumé – Les adultes néandertaliens présentent des différences de régime alimentaire en fonction de leur paléohabitat. Nous examinons si les jeunes enfants néandertaliens de France datant du stade isotopique marins 3 montrent également ces distinctions alimentaires à partir de l'étude de la texture des micro-usures dentaires des deuxièmes molaires déciduales des individus Pech de l'Azé I, datant d'une phase froide-tempérée, et Hortus II, datant d'une phase froid-aride extrême. L'échantillon comparatif (n=76) comprend des molaires déciduales d'agriculteurs-cueilleurs provenant de trois grottes néolithiques de Belgique, dont Caverne de la Cave à Maurenne (n=5), Sclaigneaux (n=7) et Bois Madame (n=6), ainsi que des agriculteurs de l'époque romaine d'Herculaneum (n=15) et médiévaux de Canterbury, Angleterre (n=43). Lorsque la complexité est comparée à l'anisotropie, Pech de l'Azé I présente une valeur élevée provenant de la mastication de plantes à parties dures ou de particules adhérentes, ou de la consommation d'aliments mal transformés ou chargés de silicates abrasifs. En revanche, Hortus II a une valeur faible, peut-être en raison de l'accès limité aux parties dures des plantes comme les graines et les noix. Toutefois, Pech de l'Azé I et Hortus II se ressemblent en présentant une faible valeur d'anisotropie qui est révélatrice de mouvements complexes des mâchoires

lors de la mastication et sont différents des enfants humains néolithiques, romains et médiévaux qui ont tendance à avoir des valeurs plus élevées. Les régimes alimentaires des enfants néandertaliens diffèrent en fonction du paléohabitat et sont généralement plus diversifiés que ceux des producteurs d'aliments, qu'ils habitent des environnements boisés ou ouverts.

Mots clés – Caverne de la Cave à Maurenne, Sclaigneaux, Bois Madame, Herculaneum, molaires décidentales

Introduction

Several studies have found that Neandertal adult diets vary with respect to climate extremes and paleoecology (El Zaatari et al., 2011, 2016; Fiorenza et al., 2011; Williams et al., 2018). For example, in warmer periods or regions, tree cover was more extensive and the range of plant foods increased, from staples such as grass seeds and underground storage organs to mushrooms, dates, pine nuts and tree moss (Henry et al., 2011; Weyrich et al., 2017). In contrast, under colder climate regimes, Neandertal adults were forced to subsist more exclusively on returns from the hunt and had fewer opportunities to exploit plants, although they still did (Hardy, 2018; Power et al., 2018). For example, Neandertals from Hortus cave Sub-Phase Vb, a colder period with a remarkable dearth of evidence of plant food consumption, differ from slightly warmer-wetter phases of the sequence where a heavier plant food signal is evidenced (Williams et al., 2018). In contrast, Spy I, from a slightly warmer period of Marine Isotope Stage (MIS) 3 albeit on the habitable fringe of northwest Europe, may have consumed plants more extensively than counterparts to the south and east (Williams et al., 2019).

Although ecogeographic distinctions in diet characterize adults, whether such dietary differences exist in Neandertal children is largely unknown. To examine this question further, we chose to investigate the deciduous molars of two Neandertals from disparate locations and climatological conditions of France during MIS 3. These include Pech de l'Azé I, dated to a temperate interval of southcentral France and Hortus II from a particularly cold and arid habitat of the Mediterranean littoral (figure 1). These Neandertal children are compared to the deciduous molars preserved from three Neolithic collective burials of Belgium, the Roman-era fishing village of Herculaneum and Medieval Canterbury, England using dental microwear texture analysis to infer the diet.

Dental microwear texture analysis

Dental microwear texture analysis has aided the reconstruction of dietary behavior in Plio-Pleistocene australopiths (Scott et al., 2005), *Homo erectus* (Ungar et al., 2012), Neandertals (El Zaatari et al., 2011; Karriger et al., 2016; Estalrich et al., 2017; Williams et al., 2018, 2019, 2021, 2022a), Upper Paleolithic Europeans (El Zaatari et al., 2016) and Holocene humans (Remy and Schmidt, 2016; Da-Gloria and Schmidt, 2020; Kelly et al., 2020; Williams et al., 2020, 2022b), and is based on the principle that foods and contaminants damage enamel as angular particles separate enamel crystallites from their adhering protein bonds. The loss of enamel typically is expressed as pit-like features, or linear scratches. These features can be deep or overlaying each other, which creates an uneven surface at microscopic scales. Likewise, the features can be oriented in all directions, or favoring a particular direction. Surface characteristics like these make up surface textures, which vary



Figure 1. Localisation of Pech de l'Azé I and Hortus II caves / Localisation des grottes de Pech de l'Azé I et de l'Hortus II

based on diet, food processing, and masticatory behavior (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 and Schmidt, 2016; Schmidt et al., 2016, 2019, 2020; Estalrich et al., 2017; Da-Gloria and Schmidt, 2020; Kelly et al., 2020). Two textural properties previously used to indicate surface complexity and feature orientation are area-scale fractal complexity (Asfc) and anisotropy (epLsar) (Scott et al., 2005, 2006; Schmidt et al., 2019).

Complexity

Area-scale fractal complexity is the measure of the unevenness of a surface at fine scales. Its calculation stems from a fractal-based computation that compares the overall 3D surface contour to a 2D plane of the same area (Scott et al., 2006). Higher complexities indicate a greater surface relief. Foods that elevate complexity values in human enamel tend to be hard and, at times, brittle. Some are harder than enamel, like opal phytoliths and accidentally ingested particles of sand, silt, and clay; brittle foods such as seeds and nuts, invertebrate exoskeletons, mollusk shell, and certain bones shatter into angular pieces (Scott et al., 2012; Calandra et al., 2012; Schmidt et al., 2020) (figure 2). Brittle foods need not be harder than enamel to remove it if their fragments are angular enough to prize enamel crystallites from their adhering proteins.

Anisotropy

When hard food items are repeatedly drawn across the enamel surface during molar occlusion, the resulting damage consists of scratches or striations. The degree of patterning of these scratches can be estimated using the exact proportion length-scale anisotropy of relief (epLsar), or anisotropy (Scott et al., 2005, 2006, 2012). Striations oriented in a similar direction are indicative of masticatory events involving repetitive chewing, typically in a side-to-side motion of the lower jaw, generating elevated anisotropy values (figure 2). In contrast, when microwear texture striations are patterned such that there is no preferred direction, the anisotropy value is low (Scott et al., 2006; Schmidt

et al., 2019). Tough and fibrous foods tend to render microwear striations that are patterned because they require multiple cycles of directional chewing. Harder foods and/or diverse diets tend to generate non-patterned striations because the jaw moves in multiple directions to break down foods having different mechanical properties. In humans, it is common for foraging groups, who eat a sizable range of foods, to have lower anisotropy and farmers, dependent on tough plant foods that were masticated using uniform movements of the jaws, to yield relatively elevated values (Scott et al., 2006, 2012; El Zaatari, 2010; Schmidt et al., 2016, 2019, 2020).

Deciduous dentition

Pech de l'Azé I and Hortus II are both represented by deciduous molars. Whereas permanent molars have been the focus in studies using dental microwear texture analysis, the deciduous dentition is becoming more frequently addressed (e.g., Mahoney et al., 2016; Remy and Schmidt, 2016; Scott and Halcrow, 2017; Bas et al., 2020; Kelly et al., 2020). Deciduous teeth are less calcified than their permanent counterparts. As a consequence, they are less structurally complex, reduced in mineral density and present greater porosity (Wilson and Beynon, 1989; Lynch, 2013). Permanent molars are calcium and phosphorous rich compared to their deciduous precursors (De Menezes Oliveira et al., 2010). The enamel thickness of permanent molars of 2.58 mm is more than double that of the primary counterparts at an average of 1.14 mm (De Menezes Oliveira et al., 2010). The unerupted crowns of neonatal deciduous molars are more than half to 80% mineralized, representing approximately 6 months of mineralization while permanent molar crowns take 3-4 years to calcify (Hillson, 1996). As a result, permanent molars are 97% mineralized, whereas the deciduous crowns of children range from 82-94% (Wang et al., 2006).

During mastication, the force generated by chewing is lower in children compared to that of adults (Scott and Halcrow, 2017; Kelly et al., 2020). The smaller size of the jaws of children are more constrained in movement potential compared to adults, which decreases chewing efficiency (Kelly et al., 2020). In addition, deciduous teeth may be more prone than the permanent dentition to non-dietary microwear (Bas et al., 2020). Given these caveats, a direct comparison between deciduous and permanent teeth requires careful consideration (Krueger, 2016; Mahoney et al., 2016) and was not attempted here.

Analytic framework

To contextualize the diets of Pech de l'Azé I and Hortus II, deciduous molars from three Neolithic collective burials are utilized as comparative samples. These include Caverne de la Cave at Maurenne and Bois Madame which are 12 km apart, and Sclaigheaux which is 35 km to the west in the Belgian Meuse basin. These three cave burials

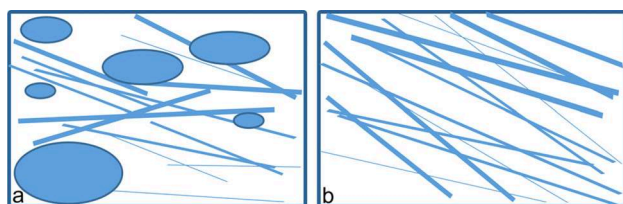


Figure 2. Idealized rendering of surfaces having high complexity (a) and high anisotropy (b) (adapted from Schmidt et al., 2019) / *Rendu idéalisé des surfaces avec une complexité élevée (a) et une anisotropie élevée (b) (adapté de Schmidt et al., 2019)*

were chosen because much is known about the diet from archaeological investigation of the caves and prior isotope and dental microwear texture analyses (Semal et al., 1999; Bocherens et al., 2007; Toussaint, 2007; Williams et al., 2020, 2022b). These Neolithic peoples may have relied extensively on hunting wild fauna with little isotopic evidence indicative of a freshwater fish signal (Bocherens et al., 2007), and appear to have consumed a forager-like diet with respect to the hardness of the plant foods (Williams et al., 2020, 2022b). The differences between Maurenne, Sclaigneaux and Bois Madame, and other comparative samples from Roman-era Herculaneum and Medieval Canterbury, will provide a context for understanding the variation in textural values exhibited between Pech de l'Azé I and Hortus II.

Materials and methods

Materials

Pech de l'Azé I

The right mandibular second deciduous molar (dm_2) of Pech de l'Azé I was molded at the Musée de l'Homme, Paris. Pech de l'Azé I is a relatively complete cranium and mandible. Much of the face is preserved as is the anterior occipital with basilaris *in situ*. However, most of the parietal, frontal and zygomatic regions are absent as are parts of the maxilla (Ferenbach et al., 1970; Minugh-Purvis, 1988). A metopic suture persists dividing the sides of the frontal squama.

All deciduous elements are fully erupted although the maxillary lateral incisors are missing postmortem. The molars are slightly worn, with a Smith (1984) dental wear score of 3 (FLW, unpublished data; figure 3). The M^1 crown is visible on the right and left, angled slightly distally and embedded within the alveolus. Some dentine exposure is visible on the incisal edge of the incisors, but it is minimal (Smith [1984] score of 3). A small crypt exists immediately posterior to i_1 and i_2 where the incisal margin of the left I^1 crown can be observed embedded within the alveolus. Pech de l'Azé I has been aged osteologically to 2.5-3.0 years and using dental calcification scores to 3.0-3.6 years by Minugh-Purvis (1988).

The deciduous molars present a complex morphology and the canines and incisors exhibit shoveling. The mandible presents a low and short corpus coupled with a short, squared mental region. Pech de l'Azé I exhibits a relatively thinner mandibular symphyseal region compared to other Neandertal young children such as Roc de Marsal which presents heavier internal buttressing of the anterior mandible (Tillier, 1996). The inferior corpus base is concave between the mental and gonial regions. The coronoid process is slightly taller than the mandibular condyle. The left side has been reconstructed from i_2 to dm_2 . Therefore, the right side was molded with President Plus regular body polyvinylsiloxane (Coltène-Whaledent).

Hortus II

The right dm_2 of Hortus II (1644) was molded with President Plus regular body polyvinylsiloxane at the Centre Européen de Recherches Préhistoriques de Tautavel. Hortus II is the mandibular remains associated with the Hortus III maxilla, and has been aged to 6.5-7.9 years (Ramirez Rozzi, 2005). The permanent anterior teeth were lost postmortem and are represented by crypts in the mandibular alveolus. The permanent premolars were previously embedded within the alveolus and are now affixed to the mandible. No mental trigone is observable and the mandible exhibits pinched gonial tubercles. The Hortus II mandible includes the right M_1 (1265), left M_1 (1262) which is the best preserved, right dm_2 (1644), left dm_2 (1261) and right dm_1 (1498).

Context of remains from Pech de l'Azé I and Hortus II

Pech de l'Azé I

The young child from Pech de l'Azé I cave was discovered in 1909 (Capitan and Peyrony, 1909) at the bottom-most level of Layer 6, radiocarbon dated to late MIS 3 (Soressi et al., 2007; Jacobs et al., 2016). The child was found with numerous animal bones, including those of wild goats, asses, horses, red deer and, to a lesser extent, reindeer. There has been an acrimonious debate concerning the attribution of the stone tool industry associated with Pech de l'Azé I, with the consensus suggesting it can be described as Mousterian of Acheulean tradition, type B, which is a denticulate heavy industry with a substantial proportion of backed-knives but a limited number of bifaces. Work on a single face characterizes the industry. The presence of some axes that resembled those from the village of Saint-Acheul is the source of the Acheulean attribution. However, the numerous elongated blades that resemble Upper Paleolithic traditions, such as the Châtelperronian, corroborate the mid to late MIS 3 dates (Soressi et al., 2007). The sequence of stone tool layers is roughly replicated at Pech de l'Azé IV, which is possibly earlier but could overlap Pech de l'Azé I (McPherron et al., 2012; Richter et al., 2013). The Mousterian of Acheulean tradition appears to be the final Neandertal toolkit in this part of southwest France (Dordogne) prior to the Upper Paleolithic (Richter et al., 2013).

Layer 6 of Pech de l'Azé I cave has been dated using numerous techniques in deposits believed to be close to the original site of the infant. These include AMS ^{14}C ages, which range from 37.06+0.49/-0.42 to 38.43+0.56/-0.47 Uncal ka before present (BP) to a calibrated date range of 41.7-43.6 ka cal BP. These radiometric dates broadly agree with a Coupled ESR/U-series date of 43+8/-6 ka BP and a mean ESR date of 40±2 ka BP (EU age) with a linear uptake age estimate that is earlier, dating to 47±5 ka BP (Soressi et al., 2007).

The animals preserved suggest the paleoecology was less extreme than that experienced by MIS 4 Neandertals. The majority of the animals are temperate species, suggesting a warmer climate compared to the peak of northern hemispheric glaciation during late MIS 4 (Soressi et al., 2007). Red deer (*Cervus elaphus*) are the most common faunal species preserved at Pech de l'Azé I, accounting for 53.3% of all nonhuman remains, whereas bison (*Bison priscus*) represent 34.9% (Rendu, 2010). Horses comprise a much smaller proportion of the remains, including *Equus caballus* (3%) and wild asses, *E. hydruntinus* (1.2%); goats, suids and a few carnivores are also preserved. Reindeer (*Rangifer tarandus*) are present but in small numbers (1.4%) suggesting a less extreme biome with some cold intervals (Rendu, 2010).

Most of the faunal remains are limb bones, while vertebrae and ribs are scarcely represented at the site. A sizeable proportion of the fauna (>30%) show signs of anthropogenic activity (Rendu, 2010). These include cut marks, notches and the exhaustive destruction of the terminal long bone ends. The over-representation of purposeful breakage of long bones suggests these remains were exploited for marrow and grease in the most prodigious limb bones (Rendu, 2010).

The faunal bones, along with the presence of hearths, stone tools and the infant skeletal elements, imply the remains were brought to the cave by the Neandertals (Rendu, 2010). These characteristics generally describe levels 4 and 7 as the faunal remains from level 6 are largely unidentified (Bordes, 1972; Rendu, 2010). It is the assumption that level 6 would also conform to the patterns present in the other cultural levels. However, an unworn red deer incisor from level 6 suggests the cave was utilized in the mid-summer months or possibly the end of the summer season. The mortality distribution favoring females with the presence of juveniles, however, suggests level 6 records the exploitation of a gregarious matriarchal herd during late spring to early summer (Rendu, 2010).

Pech de l'Azé I served as a hunting base camp (Rendu, 2010). As the cave shrank in size between levels 4 and 7 from collapsing rock walls, the number of individuals using the shelter also decreased and fewer activities, such as the use of ochre pigments, occurred within the cavern during the later intervals compared to earlier ones. The curious abundance of pigment crayons with telltale signs of use that are present in early levels, such as level 4 and level 5, appear only scarcely in level 6. By this time, the cave living space had greatly decreased from rock falls, ultimately closing completely by level 7 (Soressi et al., 2008; Rendu, 2010; d'Errico and Soressi, 2018). The Mousterian of Acheulean tradition type A that was typical in the earlier levels gave way to type B, with fewer bifaces but maintaining the elongated blades that align it with Upper Paleolithic traditions such as the Châtelperronian (Rendu, 2010).

Hortus II

The Hortus Neandertals were excavated between 1960-1963 at l'Hortus cave (Lumley, 1972, 1973), located about 30 km to the northwest of Montpellier, which is situated on the Mediterranean coast of France (figure 1). The remains of 20-33 individuals were discovered *in situ* excepting Hortus VI, which was found in the cave infill out of context in 1964 (Lumley, 1973). Although Mousterian and other Middle Paleolithic tools are found throughout the Hortus sequence, dated from MIS 5e to MIS 3, Neandertal remains are found in only the most recent sub-phases of IVa and IVb as well as Va, Vb and Vc from MIS 3, including the Hortus II child from Sub-Phase Vb.

Hortus Sub-Phase Vb witnessed the most extreme cold and aridity of the cave sequence. The cave was likely a habitation site rather than a hunting or butchering camp during this phase given the variety of activities evidenced, and the preservation of repeatedly reused hearths (Lebègue et al., 2010). Phase V probably represents a self-sufficient seasonal camp in which the preservation of both children and adults indicates a small social unit (Lebègue et al., 2010). Cultural striations and paramasticatory activities are evidenced on the dentition of the Hortus Neandertals (Lumley, 1973; Estalrich and Rosas, 2015).

Sub-Phase Vb exceeded the coldness and dryness of earlier periods (Lumley, 1973). As a consequence, denticulate Mousterian tools were more frequently created in Sub-Phase Vb for the exploitation of smaller game and a more diverse diet compared to earlier intervals (Lumley, 1973). Sub-Phase IVb was slightly warmer and wetter but still colder and more arid than at any time during the Holocene. Climate deterioration continued further in Sub-Phase Va which witnessed a landscape that was more temperate, and perhaps slightly warmer and wetter relative to Sub-Phase Vb. In addition to the Hortus II child, Sub-Phase Vb also yielded Hortus V and Hortus VIII adults (Lumley, 1973; Williams et al., 2018).

Sub-Phase Vb large carnivores include wolves (*Canis lupus*), predatory cats, such as *Felis leo pardus* and *Felis panthera* and cave bears (*Ursus spelaeus*) (Lumley, 1972; 1973). Ungulates such as red deer (*Cervus elaphus*) and reindeer (*Rangifer tarandus*) are present, although more abundant remains are from ibex (*Capra ibex*), bison (*Bos/Bison* sp.), horses (*Equus caballus*) and rhinoceros (*Dicerorhinus* sp.) (Lumley, 1972, 1973; Pillard, 1972). These remains all represent plastic species and suggest a temperate-cold paleoecology with intervals of intense cold and aridity, separated by temperate interstadials typical of MIS 3.

Early in the sequence, red-backed voles (*Clethrionomys glareolus*) signal the presence of forests. However, the preservation of mice, dormouse (*Apodemus sylvaticus*) and *Glis glis* and wood shrews (*Crocidura leocoden*) suggests these forests also contained meadows and prairies. Nonaquatic mollusk shells are found throughout the anthropogenic sequence as are rabbits (*Oryctolagus cuniculus*) which are amply represented, suggestive of frequent exploitation.

During Sub-Phase IVb, *Clethrionomys glareolus* was replaced with the pine vole (*Pitymys duodecimcostatus*), indicative of forest community change. By Sub-Phase Va and Vb, the absence of voles and wood shrews suggests that the forests became increasingly smaller and the open areas larger, while the presence of prairie moles signals a colder and more arid habitat (Pillard, 1972). The continued presence of the lesser white-toothed shrew (*Crocidura suaveolens*) in Sub-Phase Vb, along with *Equus caballus* is suggestive of a disturbed habitat of patchy woodlands and forests interspersed with scrub and open areas (Pillard, 1972; Lumley, 1973).

From the various sub-phases of IV to V, chiropteran and bird remains progressively decline in numbers reflecting a reduction of forest habitats. Analyses of pollen and sediments corroborate the increasing aridity from Sub-Phase IV to V (Lumley, 1972, 1973; Pillard, 1972), while the presence of the large variant of the European rabbit (*Oryctolagus cuniculus cuniculus*), which occurs today in more northerly climates, signals the increasing coldness of Sub-Phase Vb (Pillard, 1972). The rodent and insectivore ecological communities attest to a habitat fundamentally Mediterranean, but one in which intervals of extreme cold and aridity persisted (Lumley, 1972, 1973; Pillard, 1972). During MIS 3, the Mediterranean region was not quite as cold as other parts of Europe to the north and east (Fiorenza et al., 2015). The coldest stadials averaged about -9.3°C during the long winters and up to 17.3°C during the shorter summers (Van Meerbeeck et al., 2009).

Neandertal comparative sample

This is the first attempt to compare the dental microwear texture analysis of Middle Pleistocene deciduous molars to deciduous comparators. However, Neandertal deciduous molars have been subjected to dental microwear texture analysis previously. Pech de l'Azé I was utilized in aggregate in a study of Mediterranean and continent Neandertals (Droke et al., 2020). Similarly, Hortus II was shown with other individuals of Hortus cave to demonstrate climate distinctions with respect to phase (e.g., Williams et al., 2018). Toussaint et al. (2010) conducted the earliest study of Neandertal deciduous dental microwear texture analysis as part of their description of the lower second molar (dm_2) from Trou de l'Abîme at Couvin, Belgium. However, permanent molars from the Yamana of Terra de Fuego and the Khoe-San from southern Africa were compared to the Couvin child (Toussaint et al., 2010 SOM; El Zaatari et al., 2007). Differences in the analysis between the Couvin child texture analysis and that conducted for Pech de l'Azé I and Hortus II precludes a direct comparison of the data without the use of metrological filters (e.g., Arman et al., 2016). However, since there are so few Neandertal deciduous molar data available in the published literature, the Couvin child values are compared broadly to those from Pech de l'Azé I and Hortus II, primarily via plots of relative texture characteristics. This is accomplished by comparing a

schematic representation of the general tendency of the variables from Pech de l'Azé I and Hortus II to the complexity and anisotropy for the Couvin child from Toussaint et al. (2010) with the 95% confidence intervals from Fuegians and Khoe-San (Toussaint et al., 2010, SOM; El Zaatari, 2007). The Couvin child is aged to be between 3-8 years (Toussaint et al., 2010) although the limited degree of wear (Skinner, 1997) and intricate occlusal morphology are suggestive of a very young child.

Recent human comparative sample

Data from five discrete cultural groups ($n=76$) are used to contextualize the dietary signatures of Pech de l'Azé I and Hortus II. These include children from three Neolithic collective burials from the Meuse river system of Belgium, radiocarbon dated to 4.6 to 3.8 ka BP. Two additional studies of dental microwear texture analysis of human deciduous molars have been conducted. One of these is from the Roman site Herculanum, which was destroyed by Mount Vesuvius in A.D. 79 (Remy et al., 2014; Remy and Schmidt, 2016). The other is a Medieval cemetery population from Canterbury, England (Mahoney et al., 2016).

Neolithic cave burials of the Belgian Meuse River basin

Out of approximately 200 known cave burials, the three Neolithic sites selected for analysis are among the largest collective internments known from the Meuse river tributary system in Belgium. Beginning in the middle Neolithic, but becoming more extensive in the Late Neolithic, caches of fragmentary human remains were concealed in crevices, natural pockets in cave walls and within nearly inaccessible reaches of rockshelters along the karstic system of the Belgian Meuse basin (Toussaint et al., 2001; Toussaint, 2007). Since open air sites are rarely found, the cave burials provide valuable information about this formative period just before the onset of the Bronze Age, when the differences between foragers and farmers may not have been discrete. Most of the cave burials have little to no artifacts beyond human remains, although with some exceptions such as Bois Madame (Dumbruch, 2003, 2007).

The three Neolithic sites comprise the Middle to the final/late Neolithic collective burial of Caverne de la Cave at Maurenne ($n=5$), and the final/late Neolithic internments of Sclaigneaux ($n=7$) and the rockshelter of Bois Madame ($n=6$). The dental remains were molded at the Laboratoire de Anthropologie et Préhistoire at the Royal Belgian Institute of Natural Sciences in Brussels, Belgium. Caverne de la Cave at Maurenne has been dated four times by two labs. There is a single Middle Neolithic date from Maurenne, $4,635\pm 45$ years BP and much of the faunal material is from this earlier period (Bronk-Ramsey et al., 2002; Bocherens et al., 2007; Toussaint, 2007). However, three dates from two labs ($4,160\pm 45$ years BP; $3,950\pm 70$ years BP and $3,830\pm 90$ years BP) may suggest most of the human remains derive from the final/late Neolithic (Bronk-Ramsey et al., 2002;

Toussaint, 2007). Sclaigneaux cave is situated along the Meuse river between Namur and Liège, and has been dated once to 4,155±35 years BP (De Paepe, 2007; De Paepe and Polet, 2007), corresponding to the final/late Neolithic period of Belgium. Bois Madame rockshelter of the Burnot valley, located along the 'Haut Meuse' river basin of Belgium, is a final/late Neolithic collective burial, extensively studied by Dumbruch (2003, 2007). Two radiocarbon dates are available for Bois Madame, and indicate an age of 4,075 ±38 years BP and 3,910±40 years BP (Bronk-Ramsey et al., 2002).

Iron Age Herculaneum

The excellent preservation of food remains discovered at Herculaneum allows for a detailed reconstruction of Roman subsistence during the 1st century AD. The children, represented by deciduous molars (n=15), were found in the storage structures, often called boathouses, along with adults attempting to escape the cataclysmic eruption (Remy and Schmidt, 2016; Remy, 2016). The subsistence record points to both wild and domesticated plants and animals on the Roman menu, although for most people, cereal grains, ground with basalt millstones and querns, and wild foods made up the bulk of their diet. Meat was more commonly a dietary staple by those with greater wealth, and fish was primarily consumed as a sauce, garum (Prowse et al., 2004). A study of Herculaneum dental microwear texture indicates that hard foods were widely consumed, supporting the subsistence evidence for the consumption of seed and nut-bearing plants like walnut, fig, lentil, olive, and chickpeas (Frayn, 1975; Prowse et al., 2004; Remy et al., 2014). Overall, the Herculaneum molar microwear texture signature indicates a diet that is hard compared to some farmers, but distinguishable from hard food foragers; its anisotropy is relatively high and similar to other agricultural peoples in Europe (Schmidt et al., 2016, 2019).

Medieval Canterbury

Mahoney et al. (2016) conducted a dental microwear texture analysis of children between the ages of 1 and 8 years from St Gregory's Priory and Cemetery of Canterbury, southeast England, dated from the 11th to 15th or

16th centuries (n=43). Medieval agrarian diets of the era were heavily reliant on wheat flour, eggs, milk, butter, bread, broth and domestic animals. The flour was milled using sandstone or limestone querns that added residual inclusions such as grit into the diet (Mahoney et al., 2016). It is expected that Medieval Canterbury will differ markedly from Neandertals from MIS 3 with the caveat that a hard diet with extraneous grit may derive either from direct exploitation or through the processing of plant foods (table 1).

Scanning

The dental molds for the Neandertals (n=2) and the Neolithic Belgian sites (n=18) were cast with epoxy resin mixed with hardener (Buehler) at Georgia State University, while descriptive statistics from Herculaneum (n=15) and Canterbury (n=43) were obtained from published sources (Remy, 2016; Remy and Schmidt, 2016; Mahoney et al., 2016). Standard methods were employed to create the dental casts from Herculaneum and Canterbury which were analyzed using the same profiler and software programs as were used for the Neandertal and Neolithic sites (Remy, 2016; Remy and Schmidt, 2016; Mahoney et al., 2016). Data collection for all individuals used a white-confocal profiler (Sensofar Plμ) at the University of Indianapolis. The procedures entailed collecting data at 100X magnification with an emphasis on facet 9 and other Phase II facets (figure 3) that reflect the grinding action of the power stroke during masticatory behavior (Krueger et al., 2008). The total study area approximated 242 × 182 μm; datapoint spacing was 0.17 microns in the X-Y plane and 0.20 microns in the Z plane. Leveling used the least squares algorithm, and there was no S or L filtering. The subsequent data clouds for each individual were "cleaned" of surface debris in SolarMap 5.1.1. Two and 3-dimensional surface reconstructions were carefully evaluated to remove from the sample any occlusal surface that presented postmortem artifacts. When the quality of the surface was evaluated as free of taphonomic defects, it was included (figure 4) and subjected to scale-sensitive fractal analysis using Sfrax and Toothfrax (Scott et al., 2006, 2012; Ungar et al., 2012; Schmidt et al., 2016, 2019). This study focused on complexity and anisotropy.

Assemblage and location	Context	Dating BP	N	Subsistence
Maurenne Caverne de la Cave, Belgium ^a	Middle and final/late Neolithic	4.6-3.8 ka	5	Forager-farmers
Sclaigneaux, Belgium ^a	Final/late Neolithic	4.2 ka	7	Forager-farmers
Bois Madame, Belgium ^a	Final/late Neolithic	4 ka	6	Forager-farmers
Roman-era Herculaneum, Italy ^b	Iron Age	2 ka	15	Fisher-farmers
Canterbury, England, UK ^c	Medieval	1-0.5 ka	43	Agriculturalists

^aCompared in aggregate in Williams et al. (2020); ^bRemy et al. (2014), Remy (2016), Remy and Schmidt (2016); ^cMahoney et al. (2016) / ^d'après Williams et al. (2020); ^bRemy et al. (2014), Remy (2016), Remy and Schmidt (2016); ^cMahoney et al. (2016)

Table 1. Comparative samples of human deciduous molars / *Échantillons comparatifs de molaires déciduales humaines*

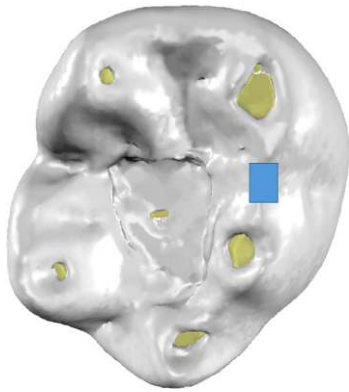


Figure 3. Representation of a right dm_2 indicating the location of microwear texture data collection for Pech de l'Azé I [the blue rectangle] (image from 3D Tooth Atlas 9, 2018, eHuman, Inc.) / Représentation d'un dm_2 droit indiquant l'emplacement de la collecte des données de texture de micro-usure pour Pech de l'Azé I [le rectangle bleu] (image de 3D Tooth Atlas 9, 2018, eHuman, Inc.)

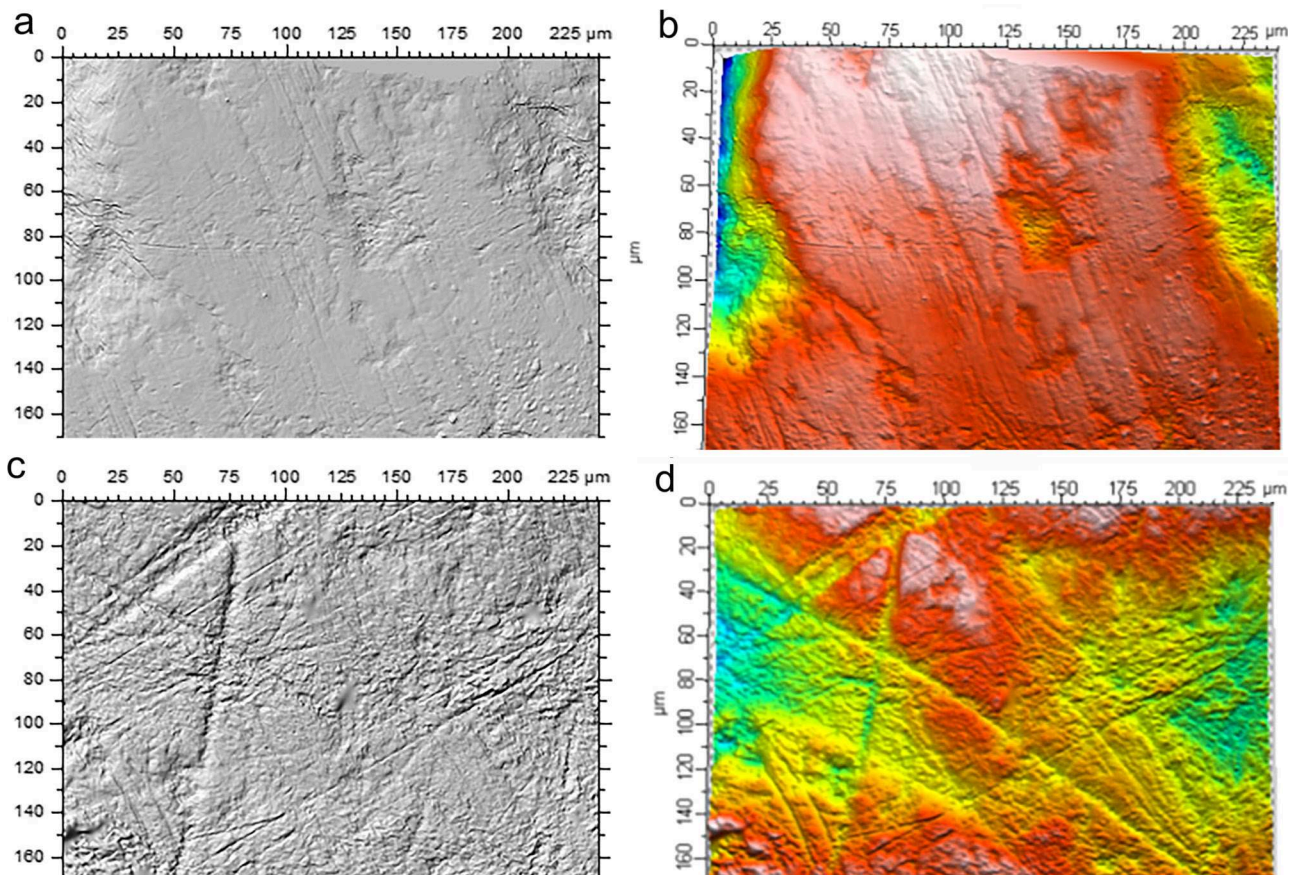


Figure 4. Two- and three-dimensional reconstructions of the enamel surface of Pech de l'Azé I (a & b) and Hortus II (c & d) / Reconstructions bi- et tridimensionnelles de la surface de l'émail de Pech de l'Azé I (a & b) et l'Hortus II (c & d)

Analytical methods and expectations

A comparison of complexity and anisotropy is shown to demonstrate the degree of separation of the 100% convex hulls between the Neolithic sites and the variation in Neandertal deciduous molars, with the expectation that the groups will differ in these dietary indicators. To infer the degree to which life cycle age, estimated using standard osteological techniques (Buikstra and Ubelaker, 1994), is associated with complexity and anisotropy for the Neolithic Belgian sites ($n=18$), a least-square linear regression was applied to the sample and shown with Pech de l'Azé I and

Hortus II. Further inferences are gleaned from schematic representations of Pech de l'Azé I and Hortus II compared to the published values for the Neandertal child from Couvin, Belgium, along with the original comparative populations from Toussaint et al. (2010). Pech de l'Azé I and Hortus II are additionally shown with respect to the 95% confidence intervals for the Neolithic sites of Maurenne, Sclaigneaux and Bois Madame, as well as Iron Age Herculaneum and Medieval Canterbury, for complexity and anisotropy. It is expected that the Neandertals will be more similar to Neolithic forager-farmers than to more recent human agrarian societies.

Results

Bivariate comparison of complexity and anisotropy

Both Pech de l'Azé I and Hortus II are completely outside of the 100% convex hull representing the deciduous molars from these three Neolithic sites (figure 5). Pech de l'Azé I exhibits an extremely elevated complexity value compared to Hortus II. Although the complexity of Pech de l'Azé I is higher than most of the Neolithic children, a single individual from Maurenne approximates and one from Sclaigneaux surpasses the Neandertal value (figure 5; table 2). Hortus II, in contrast, has an exceptionally low complexity signal, which is only approached by a single individual from Bois Madame (figure 5; table 2). The other Neolithic deciduous molars sampled are distinct from the two extremes represented on the high end by Pech de l'Azé I and on the low extreme by Hortus II (figure 5).

With respect to anisotropy, the Neandertals are again unique (figure 5). Both Pech de l'Azé I and Hortus II exhibit very low anisotropic surfaces, with only a single child from Bois Madame and another from Sclaigneaux approaching the Neandertal low values. There is extensive variation in the Neolithic samples. Both Maurenne and Sclaigneaux are distributed from relatively low to relatively high values, while the Bois Madame children cluster on the lower end of the range of anisotropy, closer to the Neandertals. The Neolithic sites overlap greatly, whereas the Neandertal children are practically indistinguishable from one another for anisotropy (figure 5).

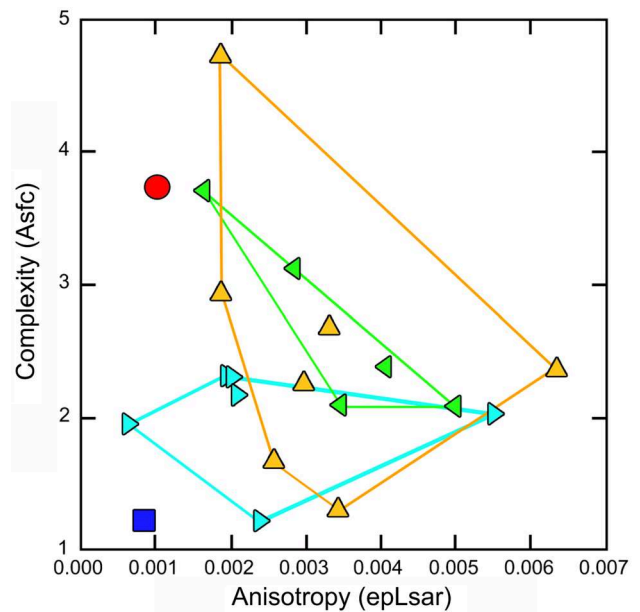


Figure 5. Pech de l'Azé I (red circle) and Hortus II (blue square) are compared to the deciduous molars texture data from Neolithic Maurenne (green left-pointing triangles), Sclaigneaux (orange isosceles triangles) and Bois Madame (teal right-pointing triangles) / Pech de l'Azé I (cercle rouge) et Hortus II (carré bleu) sont comparés aux données de texture des molaires déciduales du Néolithique de Maurenne (triangles verts pointant vers la gauche), Sclaigneaux (triangles isocèles oranges) et du Bois Madame (triangles bleu sarcelle pointant vers la droite)

	Complexity	Anisotropy	Age (years)	Age midpoint
Neandertals				
Pech de l'Azé I LRdm2 ^a	3.73	0.0010	3.0-3.6	3.3
Hortus II LRdm2	1.22	0.0009	6.5-7.9	7.2
Maurenne				
Maurenne 21 ULdm2	2.09	0.0035	5.5-6.5	6
Maurenne 22 URdm1	3.70	0.0016	2.5-3.5	3
Maurenne 23 URdm2	2.08	0.0050	7-8	7.5
Maurenne 26 ULdm2	2.38	0.0041	4-5	4.5
Maurenne 91 LRdm2	3.11	0.0029	6-7	6.5
Sclaigneaux				
Sclaigneaux 115 URdm2	2.36	0.0063	4.5-5.5	5
Sclaigneaux 116 ULdm1	1.30	0.0034	2.5-3.5	3
Sclaigneaux 117 ULdm1	2.92	0.0019	2.5-3.5	3
Sclaigneaux 119 ULdm2	1.66	0.0026	6-7	6.5
Sclaigneaux 120 ULdm1	4.73	0.0019	5-6	5.5
Sclaigneaux 122 ULdm2	2.24	0.0030	4-5	4.5
Sclaigneaux 125 URdm2	2.67	0.0033	5-6	5.5
Bois Madame				
BM Md 30 LRdm2	2.31	0.0019	4.5-5.5	5
BM Md 31 LLdm2 ^b	2.16	0.0021	5.5-6.5	6
BM Md 32 LLdm2	1.95	0.0006	7-8	6.5
BM Md 33 LLdm2	1.22	0.0024	5.5-6.5	6
BM Md 37 LRdm2	2.02	0.0055	3-4	3.5
BM Md 38 LRdm2 ^b	2.30	0.0020	5.5-6.5	6

^aL=lower (mandibular), U=upper (maxillary); L=left, R=right; dm=deciduous molar; ^bIt is possible that BM Md 38 and BM Md 31 are the right and left isomers of the same individual / ^aL=inférieure (mandibulaire), U=supérieure (maxillaire); L=gauche, R=droite; dm=molaire déciduale; ^bIl est possible que BM Md 38 et BM Md 31 soient les dents isomères droite et gauche du même individu

Table 2. Complexity, Anisotropy and estimated age / Complexité, anisotropie et âge estimé

Complexity and anisotropy compared to age

When complexity is compared to age, there is a slightly negative slope, suggesting a decrease with respect to maturation. Pech de l'Azé I is above this regression while Hortus II is below. For anisotropy the slope is closer to zero, implying age does not have a strong influence on the distribution of Neolithic children. Both Pech de l'Azé I and Hortus II are found below the regression (figure 6; table 3).

	Complexity	Anisotropy
Multiple r from bivariate correlation	0.148	0.119
Regression constant (y-intercept)	2.850	0.00364
Standard error of the constant	0.779	0.00138
Lower boundary for the constant	1.199	0.00025
Upper boundary for the constant	4.502	0.00072
Regression coefficient (slope)	-0.086	-0.00012
Standard error of the coefficient	0.144	0.00023
Lower boundary for the coefficient	-0.391	-0.00066
Upper boundary for the coefficient	0.219	0.00656

Table 3. Bivariate correlation and regression analysis of complexity and anisotropy of deciduous molars from Neolithic Belgian sites (n=18) compared to estimated age / *Résultats de la corrélation bivariable et de l'analyse de régression de la complexité et de l'anisotropie des molaires déciduales des sites néolithiques belges (n=18) par rapport à l'âge estimé*

Neandertal children vis-à-vis the 95% confidence intervals for comparative samples

When the 95% confidence intervals for complexity in Iron Age Herculaneum and Medieval Canterbury as well as the Neolithic sites of Maurenne, Sclaigneaux and Bois Madame are considered, Pech de l'Azé I exceeds all of the groups examined (figure 7). Hortus II falls within the 95% confidence interval for Bois Madame. The closest groups to Pech de l'Azé I are Maurenne and Sclaigneaux from the Neolithic period.

For anisotropy, Pech de l'Azé I falls within the 95% confidence interval for Bois Madame, while Hortus II falls just outside of this range with its extreme low value (figure 7; table 2). With the exception of Bois Madame, human subsistence groups relying solely or in part on a monotonous agrarian diet are distinct from Middle Paleolithic foragers represented by Pech de l'Azé I and Hortus II, suggesting anisotropy is reflecting the degree of dietary diversity (figure 7).

Pech de l'Azé I and Hortus II compared to Trou de l'Abîme at Couvin, Belgium

The deciduous Neandertal molar from Trou de l'Abîme at Couvin presents an extremely low complexity (Tous-saint et al., 2010), similar to that of Hortus II and certainly substantially lower than exhibited by Pech de l'Azé I. With respect to anisotropy, the Couvin child is similar to Pech de l'Azé I and Hortus II. All three Neandertal children exhibit relatively low anisotropy (figure 8).

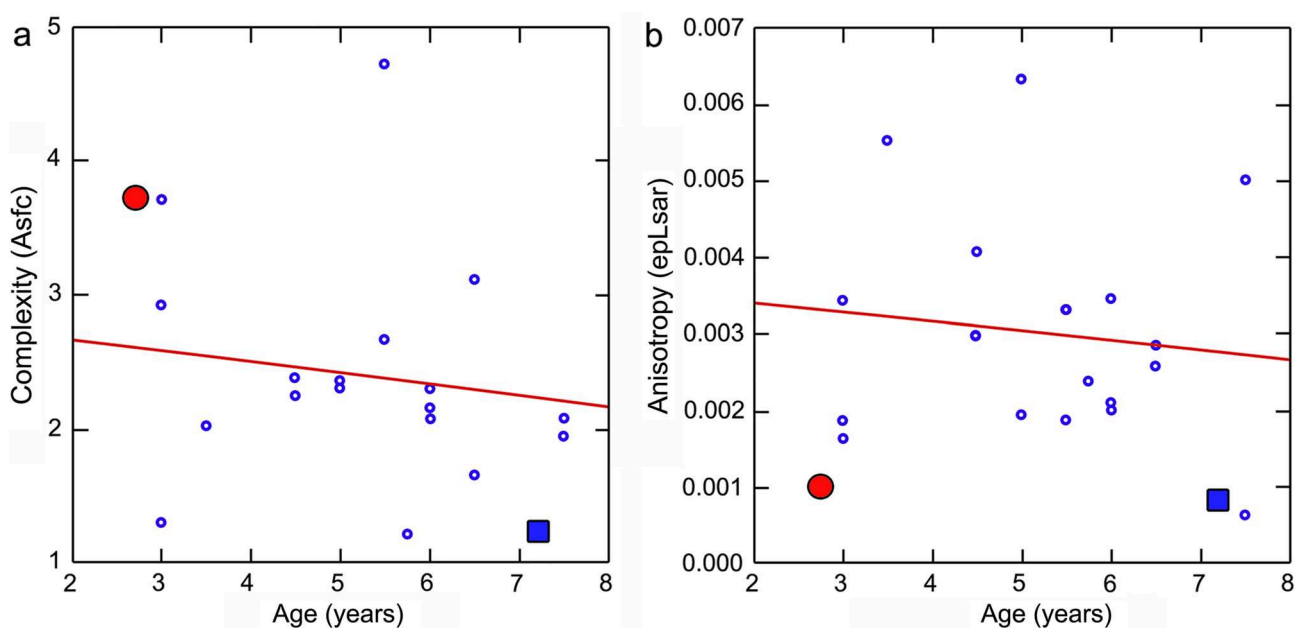


Figure 6. Pech de l'Azé I (red circle) and Hortus II (blue square) compared to deciduous molars from Neolithic forager-farmers from Belgium (open blue circles), regressed against age for (a) complexity: $Y=2.85 - 0.086 * X$ and (b) anisotropy: $Y=0.00364 - 0.00012 * X$ / *Pech de l'Azé I (cercle rouge) et Hortus II (carré bleu) comparés aux molaires déciduales des cueilleurs-agriculteurs néolithiques de Belgique (cercles bleus ouverts), régressés en fonction de l'âge pour (a) complexité : $Y=2,85 - 0,086 * X$ et (b) anisotropie : $Y=0,00364 - 0,00012 * X$*

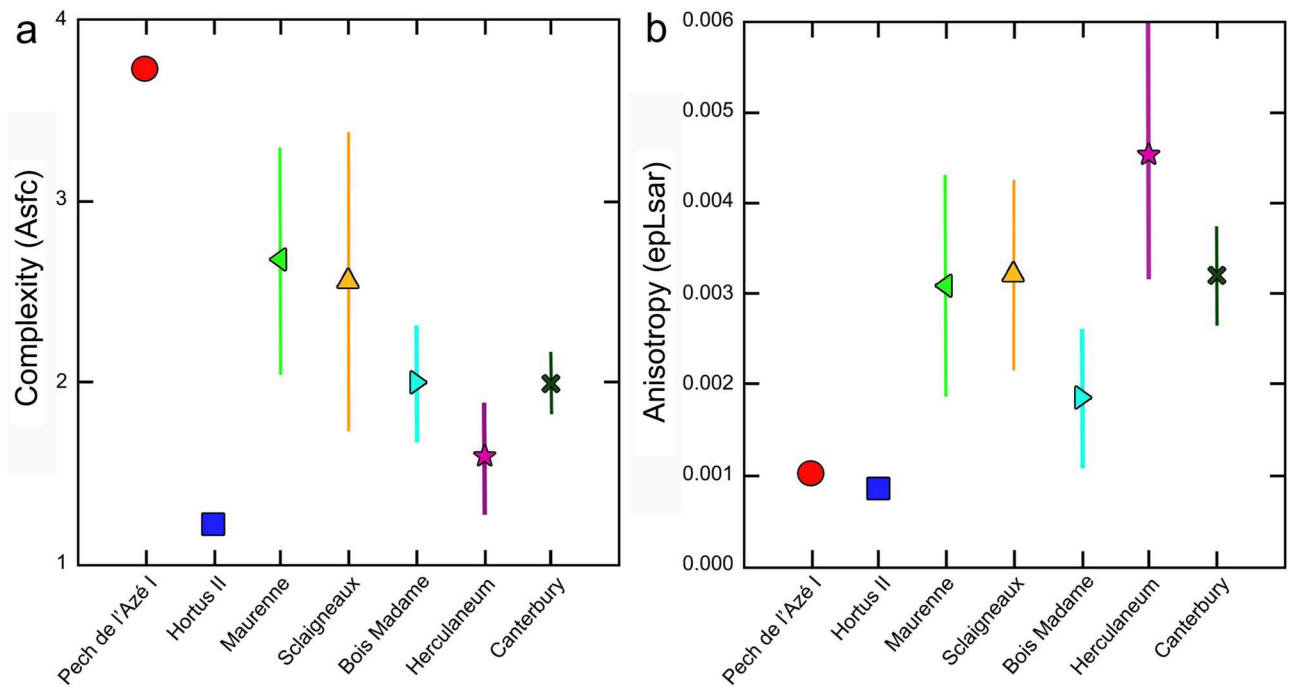


Figure 7. Comparison of Pech de l'Azé I (red circle) and Hortus II (blue square) to the 95% confidence intervals and means of the Belgian Neolithic sites of Maurenne (green left-pointing triangle), Sclaigneaux (orange isosceles triangle) and Bois Madame (teal right-pointing triangle), as well as Roman-era Herculaneum (purple star) and Medieval Canterbury, England (dark purple X) in complexity (a) and anisotropy (b) / *Comparaison de la complexité (a) et de l'anisotropie (b) de Pech de l'Azé I (cercle rouge) et Hortus II (carré bleu) aux intervalles de confiance à 95 % et moyens des sites Néolithique belge de Maurenne (triangle vert pointant vers la gauche), Sclaigneaux (triangle isocèle orange) et du Bois Madame (triangle bleu sarcelle pointant vers la droite), ainsi que Herculaneum de l'époque romaine (étoile violette) et Canterbury de l'époque médiévale, Angleterre (X violet foncé)*

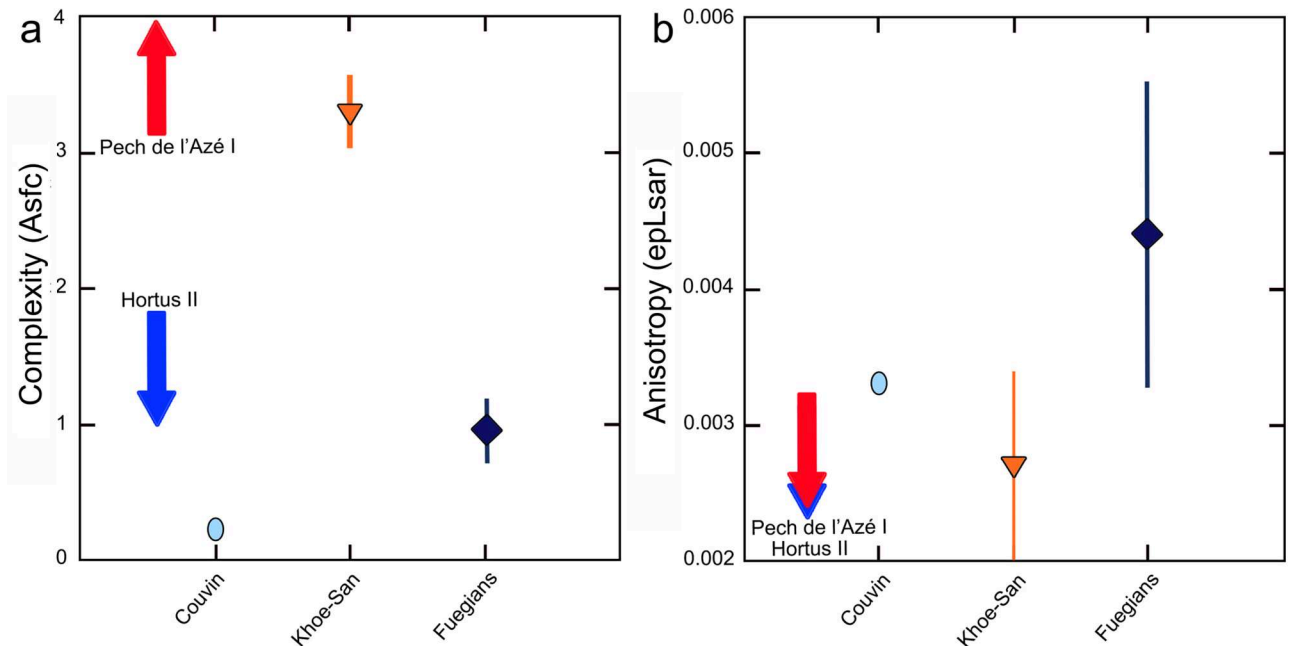


Figure 8. Schematic representation showing the general tendencies of Pech de l'Azé I and Hortus II in comparison to the Neanderthal deciduous molar from Trou de l'Abîme at Couvin, Belgium and adult human foragers from Toussaint et al. (2010) and El Zaatari (2007) / *Représentation schématique montrant les tendances générales de Pech d'Azé I et d'Hortus II comparées à la molaire déciduale néandertalienne du Trou de l'Abîme à Couvin, Belgique et aux adultes humains cueilleurs de Toussaint et al. (2010) et El Zaatari (2007)*

Discussion

Complexity

Neandertal adults have been noted to exhibit paleoecological differences in diet with respect to microwear and macrowear signatures (El Zaatari et al., 2011, 2016; Fiorenza et al., 2011; Krueger et al., 2019). We asked whether Neandertal children, represented by deciduous molars, also show differences in diet with respect to paleoecology. Pech de l'Azé I was from a warmer temperate environment where reindeer were scarce and much of the hunted remains consisted of roe and red deer. In contrast, the animal bones found at Hortus cave, Sub-Phase Vb included much more reindeer, as well as numerous other cold-temperate ungulates such as ibex, bison and horse, and the micromammals corroborate the frigid temperatures experienced by these Neandertals. The elevated complexity of Pech de l'Azé I in contrast to the extremely low value for Hortus II does indeed suggest that an environmental signal exists in the microwear texture that is likely predicated on the degree of plant food exploitation (figure 5). If complexity values are reflecting primarily the mastication of grit (van Casteren et al., 2018), then the degree of plant food consumption would still explain the disparity between Pech de l'Azé I and Hortus II. Extraneous silicates and phytoliths may account for some of the dental microwear, although the Pech de l'Azé I complexity value indicates microwear features formed by hard and brittle seeds and nuts typical of the kinds of plant foods exploited by Neandertals (e.g., Lev et al., 2005).

In fact, Pech de l'Azé I has a complexity value that is exceptionally high. Grit is known to be a major catalyst for microwear and macrowear of the occlusal surface (van Casteren et al., 2018, 2020). The elevated complexity of Pech de l'Azé I may have resulted from the purposeful or accidental ingestion of grit. Intentional ingestion of grit, dirt and clay, or geophagia, is noted among nonhuman primates, particularly leaf eating monkeys, to assist in the detoxification of secondary compounds in low-quality plant foods (Fashing, 2009). In humans, geophagia has been observed in both children and adults in response to acute starvation, mineral deficiencies and, in the case of clays, for dysentery and other gastrointestinal complications (Huffman, 2009). Accidental ingestion of grit may have occurred in Pech de l'Azé I from a lack of experience in food processing or from poor hygiene. The young age of Pech de l'Azé I hints at both the potential of intentional or accidental grit ingestion, although the former may have been more important if mortality of the child was influenced by a lack of food.

At this time, however, we surmise that food consumption generated the bulk of the microwear features exhibited by these individuals. Plant foods contribute to the production of dental microwear in increasingly predictable ways; for example, Holocene pastoralists, with plant-poor diets, have low complexity values, compared to farmers and foragers,

since their diets have few, if any, seeds or nuts (Schmidt et al., 2016, 2019). Hortus II probably had access to fewer woodland plant resources compared to Pech de l'Azé I from a more temperate interval. Although the kinds of plants used by Neandertals differed by region – for example, the consumption of wild dates and mushrooms by Neandertals in Iraq and Spain, respectively – evidence from dental calculus shows a rather consistent use of starches from grass seeds and underground storage organs in a wide range of habitats (Madella et al., 2002; Henry et al., 2011, 2014; Hardy et al., 2012; Hardy, 2018, Power et al., 2018). Additional plant foods consumed during the Middle Paleolithic, primarily charred, include hackberry (*Celtis* sp.) (Hardy, 2018); stone pine nuts (*Pinus pinea*), wild olives (*Olea* sp.) and *Pistacea* sp. (Barton et al., 1999); common hazel (*Corylus avellana*), Cornelian cherry (*Cornus mas*) and linden tree (*Tilia*) fruits (Richter, 2016); a great diversity of legumes (Papilionaceae) as well as pistachios (*Pistacia atlantica*), acorns (*Quercus* sp.), vetch (*Vicia* sp.) and other seeds (Lev et al., 2005); bitter-tasting medicinal plants (Hardy et al., 2012); stone seeds/field gromwell (*Lithospermum arvense*) (Tsartsidou et al., 2015); and possibly chyme from hunted or scavenged herbivores (Speth, 2017). The diet of Pech de l'Azé I probably included at least some of these items. However, they may have been coupled with adhering grit or seed casings to account for the elevated enamel surface complexity of the young child.

An additional possibility is that the elevated complexity signal obtained from Pech de l'Azé I could have stemmed from the processing of bone ends and diaphyseal marrow deposits, such as that noted at Pech de l'Azé IV cave (Hodgkins et al., 2016). A comparison of Pech de l'Azé IV and Roc de Marsal showed that during colder intervals there was a greater tendency toward more intensive processing of the ends of long bones for marrow extraction (Hodgkins et al., 2016). Pech de l'Azé IV is thought to correlate temporally with Pech de l'Azé I (McPherron et al., 2012). The observed increase in the processing of remains, such as percussion flakes, at the various levels of Pech de l'Azé IV cave suggests an increasingly difficult acquisition of foods, particularly hunted remains. As animals became more difficult to acquire, the Neandertals at Pech de l'Azé I, including the young child, could have become more dependent on processing hard foods, such as bone ends (Rendu, 2010) or eating grit-laden or hard, unprocessed plant foods prior to a premature mortality.

Complexity and age

The complexity of Pech de l'Azé I exceeds most of the Neolithic children with the exception Sclaigneaux 120 and Maurenne 22 (figure 5; table 2). Both Pech de l'Azé I and Maurenne 22 are close to 3 years and the latter is the youngest individual in the Neolithic assemblages included, while Sclaigneaux 120 is estimated to be approximately 5.5 years (table 2). It is possible that Pech de l'Azé I has a complexity value that is elevated because it is young and

Hortus II has a lower one given its older age. However, a bivariate correlation between complexity and estimated age for the Neolithic deciduous molars is weak ($r=0.148$) and, coupled with a regression slope of -0.086 (table 3), suggests a lack of a strong inverse relationship that could explain the position of Pech de l'Azé I compared to Hortus II. In addition, the Neandertal deciduous molar from Couvin, Belgium exhibits an extremely low complexity value (figure 8) which could be indicative of a reliance on meat (Toussaint et al., 2010) a lack of plant food, or alternatively could indicate a child still heavily dependent on lactation. If the Couvin child is older, then perhaps an inverse relationship characterizes complexity in Neandertals with respect to life cycle age. However, if the child was still nursing and closer to 3 years, there is less support for age influencing the degree of complexity.

The young child from Pech de l'Azé I was at least partially weaned and was eating some adult foods. Complexity values can be higher in children than adults because of the limited jaw movement (Scott and Halcrow, 2017; Kelly et al., 2020). However, in this case the very high value is likely a combination of chewing mechanics and hard food consumption. The area was forested, and the complexity value is likely reflecting evidence of eating forest foods, like pine nuts or seeds and acorns. The low anisotropy may support this conclusion.

Anisotropy

Pech de l'Azé I and Hortus II both express extremely low anisotropy. The same is probably true of the Neandertal child from Couvin (figure 8). The deciduous molars from one of the Neolithic sites, Bois Madame, is the closest to the Neandertal children and a single individual approximates the anisotropy of Pech de l'Azé I and Hortus II (figure 5). However, the agrarian communities from Herculaneum, Canterbury and the Neolithic period of Belgium generally have much higher anisotropy than the Neandertal children (figure 7), which replicates the distinction between foragers and food producers in permanent molars (Schmidt et al., 2016, 2019).

Conclusion

The young child from Pech de l'Azé I represents one of the most complete Upper Pleistocene cranium and mandible known. Aged at approximately 3 years, the young child is often attributed to the Neandertals (Tillier, 1996). Furthermore, the tool tradition discovered at Pech de l'Azé I has been described as Mousterian but approximating some aspects of the Upper Paleolithic, suggesting increasingly greater technological skill applied to improving efficiency in food acquisition and processing (Soressi et al., 2007). The primary hunted fauna recovered from the site include red and roe deer, suggesting a temperate habitat. In contrast, Hortus II, a child between the ages of 6.5 and 7.9 years, lived in an extremely cold and arid phase of MIS 3.

We expected the two Neandertal children from different paleoecological conditions to exhibit differing dietary signatures and this is shown to be the case for textural complexity of the occlusal surface. Pech de l'Azé I presents a much higher value for complexity than does Hortus II which resembles other individuals from the cold and arid Sub-Phase Vb of Hortus cave (Williams et al., 2018). The high complexity of Pech de l'Azé I could have derived from purposeful or accidental geophagia or the consumption of hard plants, bone ends, poorly processed foods or a combination of factors.

Although the complexity varies greatly between the two Neandertal young children examined, the anisotropy of both Pech de l'Azé I and Hortus II is low compared to most of the food producers sampled and corresponds to what was observed for the Neandertal child from Couvin, Belgium (Toussaint et al., 2010). Pech de l'Azé I and Hortus II resemble Neolithic forager-farmer children from Belgium more than later agrarian societies from the Iron Age and the Medieval period. The low anisotropy of the Neandertal children corresponds to a heterogeneity of jaw movement typical of human forager adults (Schmidt et al., 2019).

Acknowledgments

We are extremely grateful to the museum curators who kindly allowed access to remains featured in this study, including Aurélie Fort and Liliana Huet at the Musée de l'Homme (Paris), Tony Chevalier at the Centre Européen de Recherches Préhistoriques de Tautavel and Patrick Semal, Chief of the Scientific Heritage Service, Institut Royal des Sciences Naturelles de Belgique (Bruxelles). Funding for this project was generously received by Fulbright-Belgium, the Commission for Educational Exchange between the United States, Belgium, and Luxembourg and the National Science Foundation (BCS 0922930).

References

- Arman SD, Ungar PS, Brown CA, et al (2016) Minimizing inter-microscope variability in dental microwear texture analysis. *Surface Topography: Metrology and Properties* 4:024007 [<http://doi:10.1088/2051-672X/4/2/024007>]
- Barton RNE, Carrant AP, Fernandez-Jalvo Y, et al (1999) Gibraltar Neanderthals and results of recent excavations in Gorham's, Vanguard and Ibex Caves. *Antiquity* 73:13-23
- Bas M, Le Luyer M, Kanz F, et al (2020) Methodological implications of intra- and inter-facet microwear texture variation for human childhood paleo-dietary reconstruction: insights from the deciduous molars of extant and medieval children from France. *Journal of Archaeological Science: Reports* 31:102284 [<https://doi.org/10.1016/j.jasrep.2020.102284>]
- Bocherens H, Polet C, Toussaint M (2007) Palaeodiet of Mesolithic and Neolithic populations of Meuse Basin (Belgium): evidence from stable isotopes. *Journal of Archaeological Science* 34:10-27 [<https://doi.org/10.1016/j.jas.2006.03.009>]
- Bordes F (1972) *A Tale of Two Caves*. New York, Harper and Row, 169 p

- Bronk-Ramsey C, Higham TFG, Owen DC, et al (2002) Radiocarbon dates from the Oxford AMS system: datelist 31. *Archaeometry* 44(3) Supplement 1:1-149
- Buikstra JE, Ubelaker DH (1994) Standards for Data Collection from Human Skeletal Remains: proceedings of a Seminar at the Field Museum of Natural History. Fayetteville, AR, Arkansas Archeological Survey Research Series No 44
- Calandra I, Schulz E, Pinnow M, et al (2012) Teasing apart the contributions of hard dietary items on 3D dental microtextures in primates. *Journal of Human Evolution* 63:85-98 [<http://10.1016/j.jhevol.2012.05.001>]
- Capitan L, Peyrony D (1909) Deux squelettes humains au milieu des foyers de l'époque moustérienne. *Revue de l'École d'Anthropologie de Paris* 19:402-409
- Da-Gloria P, Schmidt CW (2020) Dental Microwear Texture Analyses of the Paleoamericans of Lagoa Santa, Central-Eastern Brazil. In: Schmidt CW, Watson JT (eds) *Dental Wear in Evolutionary and Biocultural Contexts*. Springer, New York, pp 243-262 [<https://doi.org/10.1016/B978-0-12-815599-8.00011-3>]
- De Menezes Oliveira MAH, Torres CP, Gomez-Silva JM, et al (2010) Microstructure and mineral composition of dental enamel of permanent and deciduous teeth. *Microscopy Research and Technique* 73:572-577 [<http://doi.org/10.1002/jemt.20796>]
- De Paepe M (2007) Studie van de laat-neolithische menselijke resten uit een collectief graf te Sclaigneaux (provincie Namen, B.). MA thesis, Universiteit Gent
- De Paepe M, Polet C (2007) 'Numerous and tall': a revision of the Late Neolithic human remains found in a collective burial site at Sclaigneaux (prov. Namur), Belgium. *Notae Præhistoricæ* 27:163-168
- d'Errico F, Soressi M (2018) Appendix A: manganese-rich lumps from Pech de l'Azé IV: a preliminary analysis. In: Dibble HL, McPherron SJP, Goldberg P, et al (eds) *The Middle Paleolithic Site of Pech de l'Azé IV*. Springer International Publishing AG, pp 229-236
- Droke J, Schmidt CW, Williams FL, et al (2020) Regional variability in diet between Northern European and Mediterranean Neandertals: evidence from dental microwear texture analysis. In: Schmidt CW, Watson JT (eds) *Dental Wear in Evolutionary and Biocultural Contexts*. Springer, New York, pp 225-242 [<https://doi.org/10.1016/B978-0-12-815599-8.00010-1>]
- Dumbruch I (2003) Étude du site de l'abri-sous-roche du "Bois-Madame", Néolithique, à Arbre, dans la vallée du Burnot (Province de Namur). Étude anthropologique et archéologique, Volume I et II. Mémoire de licence, Université Libre de Bruxelles
- Dumbruch I (2007) Le site de l'abri-sous-roche du "Bois-Madame" à Arbre (Province de Namur, Belgique). *Archæologia Mosellana* 7:609-612
- El Zaatari S (2007) Ecogeographic variation in Neandertal dietary habits: evidence from microwear texture analysis. PhD dissertation, Stony Brook University, NY
- El Zaatari S (2010) Occlusal microwear texture analysis and the diets of historical/prehistoric hunter-gatherers. *International Journal of Osteoarchaeology* 20:67-87 [<http://doi.org/10.1002/oa.1027>]
- El Zaatari S, Grine FE, Ungar PS, et al (2011) Ecogeographic variation in Neandertal dietary habits: evidence from occlusal microwear texture analysis. *Journal of Human Evolution* 61: 411-424 [<http://doi.org/10.1016/j.jhevol.2011.05.004>]
- El Zaatari S, Grine FE, Ungar PS, et al (2016) Neandertal versus modern human dietary responses to climatic fluctuations. *Public Library of Science One* 11:e0153277 [<https://doi.org/10.1371/journal.pone.0153277>]
- Estalrriich A, Rosas A (2015) Division of labor by sex and age in Neandertals: an approach through the study of activity-related dental wear. *Journal of Human Evolution* 80:51-63 [<http://dx.doi.org/10.1016/j.jhevol.2014.07.007>]
- Estalrriich A, El Zaatari S, Rosas A (2017) Dietary reconstruction of the El Sidrón Neandertal familial group (Spain) in the context of other Neandertal and modern hunter-gatherer groups. A molar microwear texture analysis. *Journal of Human Evolution* 104: 13-22 [<https://doi.org/10.1016/j.jhevol.2016.12.003>]
- Fashing PJ (2009) African colobine monkeys. In: Campbell CJ, Fuentes A, MacKinnon KC, et al (eds) *Primate Behavioral Ecology*, 2nd edition, pp 203-228
- Ferenbach D, Legoux P, Fenart R, et al (1970) L'enfant du Pech de l'Azé. *Archives de L'Institut de Paléontologie Humaine* 33. Paris, Masson, 180 p
- Fiorenza L, Benazzi S, Tausch J, et al (2011) Molar macrowear reveals Neandertal eco-geographic dietary variation. *Public Library of Science One* 6:e14769 [<https://doi.org/10.1371/journal.pone.0014769>]
- Fiorenza L, Benazzi S, Henry AG, et al (2015) To meat or not to meat? New perspectives on Neanderthal ecology. *American Journal of Physical Anthropology* 156:43-71 [<https://doi.org/10.1002/ajpa.22659>]
- Frayn JM (1975) Wild and cultivated plants: a note on the peasant economy of Roman Italy. *The Journal of Roman Studies* 65:32-39
- Hardy K, Buckley S, Collins MJ, et al. (2012) Neanderthal medics? Evidence for food, cooking, and medicinal plants entrapped in dental calculus. *Naturwissenschaften* 99:617-626 [<https://doi.org/10.1007/s00114-012-0942-0>]
- Hardy K (2018) Plant use in the Lower and Middle Palaeolithic: food, medicine and raw materials. *Quaternary Science Reviews* 191:393-405 [<https://doi.org/10.1016/j.quascirev.2018.04.028>]
- Henry AG, Brooks AS, Piperno DR (2011) Microfossils in calculus demonstrate consumption of plants and cooked foods in Neanderthal diets (Shanidar III, Iraq; Spy I and II, Belgium). *Proceedings of the National Academy of Sciences of the United States of America* 108:486-491 [<http://www.pnas.org/cgi/doi/10.1073/pnas.1016868108>]
- Henry AG, Brooks AS, Piperno DR (2014) Plant foods and the dietary ecology of Neanderthals and early modern humans. *Journal of Human Evolution* 69:44-54 [<https://doi.org/10.1016/j.jhevol.2013.12.014>]
- Hillson S (1996) *Dental Anthropology*. Cambridge, Cambridge University Press, 373 p
- Hodgkins J, Marean CW, Turq A, et al (2016) Climate-mediated shifts in Neandertal subsistence behaviors at Pech de l'Azé IV and Roc de Marsal (Dordogne Valley, France). *Journal of Human Evolution* 96:1-18 [<https://doi.org/10.1016/j.jhevol.2016.03.009>]

- Huffman MA (2009) Primate self-medication. In: Campbell CJ, Fuentes A, MacKinnon KC, et al (eds) *Primate Behavioral Ecology*, 2nd edition, pp 563-575
- Jacobs Z, Jankowski NR, Dibble, et al. (2016) The age of three Middle Palaeolithic sites: single-grain optically stimulated luminescence chronologies for Pech de l'Azé I, II and IV in France. *Journal of Human Evolution* 95:80-103 [<http://dx.doi.org/10.1016/j.jhevol.2016.03.010>]
- Karriger WM, Schmidt CW, Smith FH (2016) Dental microwear texture analysis of Croatian Neandertal molars. *PaleoAnthropology* 2016:172-184
- Kelly CD, Schmidt CW, D'Anastasio R (2020) Dental microwear texture analysis in deciduous teeth. In: Schmidt CW, Watson JT (eds) *Dental Wear in Evolutionary and Biocultural Contexts*. Springer, New York, pp 169-186 [<https://doi.org/10.1016/B978-0-12-815599-8.00008-3>]
- Krueger KL, Scott JR, Kay RF, et al (2008) Technical note: dental microwear textures of "Phase I" and "Phase II" facets. *American Journal of Physical Anthropology* 137:485-490 [<http://doi.org/10.1002/ajpa.20928>]
- Krueger KL (2016) Dental microwear texture differences between permanent and deciduous enamel. *American Journal of Physical Anthropology Supplement* 62:198
- Krueger KL, Ungar PS, Guatelli-Steinberg D, et al (2017) Anterior dental microwear textures show habitat-driven variability in Neandertal behavior. *Journal of Human Evolution* 105:13-23 [<https://doi.org/10.1016/j.jhevol.2017.01.004>]
- Krueger KL, Willman JC, Matthews GJ, et al (2019) Anterior tooth-use behaviors among early modern humans and Neandertals. *Public Library of Science One* 14:e0224573 [<https://doi.org/10.1371/journal.pone.0224573>]
- Lebègue F, Boulbes N, Gregoire S, et al (2010) Systèmes d'occupation, exploitation des ressources et mobilité des Néandertaliens de l'Hortus (Hérault, France). In: Conard NJ, Delagnes A (eds) *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age*, volume 3. Kerns Verlag, Tübingen, pp 455-484
- Lev E, Kislev M, Bar Yosef O (2005) Mousterian vegetal food in Kebara cave. Mt. Carmel. *Journal of Archaeological Science* 32: 475-484 [<http://doi.org/10.1016/j.jas.2004.11.006>]
- de Lumley H (1972) La grotte moustérienne de l'Hortus. Étude Quaternaire, mémoire no 1. Provence, Université de Provence, France, 668 p
- de Lumley M-A (1973) Anténéandertaliens et Néandertaliens du bassin méditerranéen occidental européen. Études Quaternaires, mémoire no 2. Provence, Université de Provence, France, 604 p, et index
- Lynch RJM (2013) The primary and mixed dentition, post-eruptive enamel maturation and dental caries: a review. *International Dental Journal* 63:3-13 [<http://doi.org/10.1111/idj.12076>]
- Madella M, Jones MK, Goldberg P, et al (2002) The exploitation of plant resources by Neanderthals in Amud cave (Israel): the evidence from phytolith studies. *Journal of Archaeological Science* 29:703-719 [<https://doi.org/10.1006/jasc.2001.0743>]
- Mahoney P, Schmidt CW, Deter C, et al (2016) Deciduous enamel 3D microwear texture analysis as an indicator of childhood diet in medieval Canterbury, England. *Journal of Archaeological Science* 66:128-136 [<https://doi.org/10.1016/j.jas.2016.01.007>]
- McPherron SP, Talamo S, Goldberg P, et al (2012) Radiocarbon dates for the late Middle Palaeolithic at Pech de l'Azé IV, France. *Journal of Archaeological Science* 39:3436-3442 [<https://doi.org/10.1016/j.jas.2012.05.017>]
- Minugh-Purvis N (1988) Patterns of craniofacial growth and development in Upper Pleistocene hominids. PhD dissertation, University of Pennsylvania, Philadelphia
- Pillard B (1972) La faune des grands mammifères du Würmien II. In: de Lumley H (ed) *La grotte moustérienne de l'Hortus. Étude Quaternaire*, Université de Provence, France, pp 163-206
- Power RC, Salazar-García DC, Rubini M, et al (2018) Dental calculus indicates widespread plant use within the stable Neanderthal dietary niche. *Journal of Human Evolution* 119: 27-41 [<https://doi.org/10.1016/j.jhevol.2018.02.009>]
- Prowse T, Schwarcz HP, Saunders S, et al (2004) Isotopic paleodiet studies of skeletons from the Imperial Roman-age cemetery of Isola Sacra, Rome, Italy. *Journal of Archaeological Science* 31: 259-272 [<https://doi.org/10.1016/j.jas.2003.08.008>]
- Ramirez Rozzi F (2005) Âge au décès de l'enfant néandertalien de l'Hortus. *Bulletins et mémoires de la Société d'anthropologie de Paris* 17:47-55 [<https://doi.org/10.4000/bmsap.911>]
- Remy AJ, Schmidt CW, D'Anastasio R, et al (2014) Dental microwear texture analysis of the people of Herculaneum. *American Journal of Physical Anthropology Supplement* 58:220
- Remy AJ (2016) Diet among the people of Herculaneum via dental microwear texture analysis. MS Thesis, University of Indianapolis, Indianapolis, IN
- Remy AJ, Schmidt CW (2016) What did ancient people eat? *Physics Today* 69:78-79 [<https://doi.org/10.1063/PT.3.3148>]
- Rendu W (2010) Hunting behavior and Neandertal adaptability in the Late Pleistocene site of Pech-de-l'Azé I. *Journal of Archaeological Science* 37:1798-1810 [<https://doi.org/10.1016/j.jas.2010.01.037>]
- Richter D, Dibble H, Goldberg P, et al (2013) The late Middle Palaeolithic in Southwest France: new TL dates for the sequence of Pech de l'Azé IV. *Quaternary International* 294: 160-167 [<https://doi.org/10.1016/j.quaint.2012.05.028>]
- Richter J (2016) Leave at the height of the party: a critical review of the Middle Paleolithic in Western Central Europe from its beginnings to its rapid decline. *Quaternary International* 411: 107-128 [<https://doi.org/10.1016/j.quaint.2016.01.018>]
- Schmidt CW, Beach JJ, McKinley JJ, Eng JT (2016) Distinguishing dietary indicators of pastoralists and agriculturalists via dental microwear texture analysis. *Surface Topography: Metrology and Properties* 4:014008 [<http://doi.org/10.1088/2051-672X/4/1/014008>]
- Schmidt CW, Remy A, Van Sessen R, et al (2019) Dental microwear texture analysis of *Homo sapiens sapiens*: foragers, farmers, and pastoralists. *American Journal of Physical Anthropology* 169:207-226 [<https://doi.org/10.1002/ajpa.23815>]
- Schmidt CW, El Zaatari S, Van Sessen R (2020) Dental microwear texture analysis in bioarchaeology. In: Schmidt CW, Watson JT (eds) *Dental Wear in Evolutionary and Biocultural Contexts*. Springer, New York, pp 143-168 [<https://doi.org/10.1016/B978-0-12-815599-8.00007-1>]
- Scott RM, Halcrow SE (2017) Investigating weaning using dental microwear analysis: a review. *Journal of Archaeological*

- Science: Reports 11:1-11 [<https://doi.org/10.1016/j.jasrep.2016.11.026>]
- Scott RS, Ungar PS, Bergstrom TS, et al (2005) Dental microwear texture analysis shows within-species diet variability in fossil hominins. *Nature* 436:693-695 [<http://doi.org/10.1038/nature03822>]
- Scott RS, Ungar PS, Bergstrom TS, et al (2006) Dental microwear texture analysis: technical considerations. *Journal of Human Evolution* 51(4):339-349 [<https://doi.org/10.1016/j.jhevol.2006.04.006>]
- Scott RS, Teaford MF, Ungar PS (2012) Dental microwear texture and anthropoid diets. *American Journal of Physical Anthropology* 147:551-579 [<https://doi.org/10.1002/ajpa.22007>]
- Semal P, García Martín C, Polet C, et al (1999) Considération sur l'alimentation des Néolithiques du Bassin mosan : usures dentaires et analyses isotopiques du collagène osseux. *Notae Præhistoricae* 19:127-135
- Skinner M (1997) Dental wear in immature Late Pleistocene European hominines. *Journal of Archaeological Science* 24: 677-700
- Smith BH (1984) Dental attrition in hunter-gatherers and agriculturalists. *American Journal of Physical Anthropology* 63:39-56
- Soressi M, Jones HL, Rink WJ, et al (2007) The Pech-de-l'Azé I Neandertal child: ESR, uranium-series, and AMS 14C dating of its MTA type B context. *Journal of Human Evolution* 52(4): 455-466 [<https://doi.org/10.1016/j.jhevol.2006.11.006>]
- Soressi M, Rendu W, Texie J-P, et al (2008) Pech de l'Azé I (Dordogne, France) : nouveau regard sur un gisement moustérien de tradition acheuléenne connu depuis le XIXe siècle. In: Jaubert J, Bordes J-G, Ortega I (eds) *Les sociétés Paléolithiques d'un grand Sud-Ouest: nouveaux gisements, nouvelles méthodes, nouveaux résultats*. Société Préhistorique Française, Mémoire, 47, pp 95-132
- Speth JD (2017) Putrid meat and fish in the Eurasian Middle and Upper Paleolithic: are we missing a key part of Neandertal and modern human diet? *PaleoAnthropology* 2017:44-72
- Tillier A-M (1996) The Pech de l'Azé and Roc de Marsal children (Middle Paleolithic, France): skeletal evidence for variation in Neandertal ontogeny. *Human Evolution* 2:113-119
- Toussaint M, Orban R, Polet C, et al (2001) Apports récents sur l'anthropologie des Mésolithiques et des Néolithiques mosans. *Anthropologica et Præhistorica* 112:91-105
- Toussaint M (2007) Les sépultures Néolithiques du bassin mosan Wallon et leurs relations avec les bassins de la Seine et du Rhin. *Archaeologia Mosellana* 7:507-549
- Toussaint M, Olejniczak AJ, El Zaatari S, et al (2010) The Neandertal lower right deciduous second molar from Trou de l'Abîme at Couvin, Belgium. *Journal of Human Evolution* 58:56-67 [<http://doi.org/10.1016/j.jhevol.2009.09.006>]
- Tsartsidou G, Karkanias P, Marshall G, et al (2015) Palaeoenvironmental reconstruction and flora exploitation at the Palaeolithic cave of Theopetra, central Greece: the evidence from phytolith analysis. *Archaeological and Anthropological Science* 7:169-185 [<http://doi.org/10.1007/s12520-014-0183-6>]
- Ungar PS, Krueger KL, Blumenshine RJ, et al (2012) Dental microwear texture analysis of hominins recovered by the Olduvai Landscape Paleoanthropology Project, 1995-2007. *Journal of Human Evolution* 63:429-437 [<https://doi.org/10.1016/j.jhevol.2011.04.006>]
- Van Casteren A, Lucas PW, Strait DS, et al (2018) Evidence that metallic proxies are unsuitable for assessing the mechanics of microwear formation and a new theory of the meaning of microwear. *Royal Society Open Science* 5:171699 [<http://dx.doi.org/10.1098/rsos.171699>]
- Van Casteren A, Strait DS, Swain MV, et al (2020) Hard plant tissues do not contribute meaningfully to dental microwear: evolutionary implications. *Scientific Reports* 10:582 [<https://doi.org/10.1038/s41598-019-57403-w>]
- Van Meerbeeck CJ, Renssen H, Roche DM, et al (2011) The nature of MIS 3 stadial-interstadial transitions in Europe: new insights from model-data comparisons. *Quaternary Science Reviews* 30:3618-3637 [<https://doi.org/10.1016/j.quascirev.2011.08.002>]
- Wang LJ, Tang R, Bonstein T, et al (2006) Enamel demineralization in primary and permanent teeth. *Journal of Dental Research* 85: 359-363 [<https://doi.org/10.1177/154405910608500415>]
- Weyrich LS, Duchene S, Soubrier J, et al (2017) Neandertal behaviour, diet, and disease inferred from ancient DNA in dental calculus. *Nature* 544:357-361 [<https://doi.org/10.1038/nature21674>]
- Williams FL, Droke J, Schmidt CW, et al (2018) Dental microwear texture analysis of Neandertals from Hortus cave, France. *Comptes rendus Palevol* 17:545-556 [<https://doi.org/10.1016/j.crpv.2018.04.003>]
- Williams FL, Schmidt CW, Droke J, et al (2019) Dietary reconstruction of Spy I using dental microwear texture analysis. *Comptes rendus Palevol* 18:1083-1094 [<https://doi.org/10.1016/j.crpv.2019.06.004>]
- Williams FL, Schmidt CW, Droke JL (2020) The diet of Late Neolithic farmers of the Belgian Meuse basin inferred using dental microwear texture analysis. *Anthropologica et Præhistorica* 129:73-86
- Williams FL, Schmidt CW, Droke JL, et al (2021) Reconstructing the diet of Kůlna 1 from the Moravian karst (Czech Republic). *Journal of Paleolithic Archaeology* 4:21 [<https://doi.org/10.1007/s41982-021-00099-0>]
- Williams FL, Schmidt CW, Henry AG, et al (2022a) The Ice Age diet of the La Quina 5 Neandertal from southwest France. *L'anthropologie* 126:103056 [<https://doi.org/10.1016/j.anthro.2022.103056>]
- Williams FL, Schmidt CW, Droke JL (2022b) Inferring the diet of Late Neolithic Hastière Caverne M from the Meuse basin of Belgium. *Anthropologica et Præhistorica* 131:79-96 [<https://doi.org/10.57937/ap.2022.004>]
- Wilson PR, Beynon AD (1989) Mineralization differences between human deciduous and permanent enamel measured by quantitative microradiography. *Archives of Oral Biology* 34:85-88



BMSAP

Bulletins et Mémoires de la Société d'Anthropologie de Paris