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1 **The Grandeur of Death – Monuments, Societies, and Diets in Middle** 2 **Neolithic Paris Basin**

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4 Christina Cheung^{1,2*}, Estelle Herrscher², Guy Andre², Lisandre Bedault³, Lamys Hachem^{3,4},
5 Annelise Binois-Roman^{5,6}, Daniel Simonin⁷, Aline Thomas^{1*}

6
7 ¹ EA – Eco-anthropologie (UMR 7206), Muséum National d'Histoire Naturelle, CNRS, Université Paris Diderot,
8 Paris, France

9 ² UMR 7269, LAMPEA, Aix-Marseille Université, CNRS, Minist Culture, Aix-en-Provence, France

10 ³ UMR 8215 Trajectoires – De la sédentarisation à l'Etat, CNRS/Université Paris 1 Panthéon Sorbonne, Paris,
11 France

12 ⁴ INRAP – Institut National de Recherches Archéologiques Préventives

13 ⁵ Université Paris 1 Panthéon Sorbonne, Paris, France

14 ⁶ ArScAn - Archéologies et Sciences de l'Antiquité (UMR 7041), Nanterre, France ”

15 ⁷ Musée de Préhistoire d'Île-de-France, Nemours, France

16
17 * Corresponding authors

18 Email: christina.cheung@mnhn.fr (CC); aline.thomas@mnhn.fr (AT)

19 20 **Abstract**

21 This study investigates the relationship between monumental funerary structures, social
22 organizations, and diets in Middle Neolithic France. Focusing on the Cerny culture based in the
23 Paris Basin region, we analysed and compared bone collagen stable carbon, nitrogen, and sulfur
24 isotope values of 113 individuals from three different types of Cerny cemeteries: the Passy type
25 (Cerny STP), slab burials (Cerny Slab), and burials without major superstructure (Cerny Flat).
26 Published stable isotopic data from one other Cerny Flat and two contemporaneous non-Cerny
27 cemeteries (n=140), together with new and published faunal isotopic data (n=267) from across
28 six different river valleys in the region are also included in the analysis. The results of this study
29 have shown that 1) the Cerny diet was likely rich in animal protein; 2) comparing to all other
30 cemetery types, Cerny STP sites were considerably homogenous isotopically and culturally, and
31 3) individuals buried in aberrant funerary arrangements tend to have outlying isotopic
32 compositions, suggesting strong correlations between diets and burial practices. Interestingly, as
33 oppose to the distinctly sex-related funerary arrangements, no obvious pattern can be observed in
34 the isotopic compositions between males and females in Cerny cemeteries.

35 36 37 **Keywords**

38 Cerny culture; Neolithic; Passy-type monument; Slab burials; Stable isotope analysis

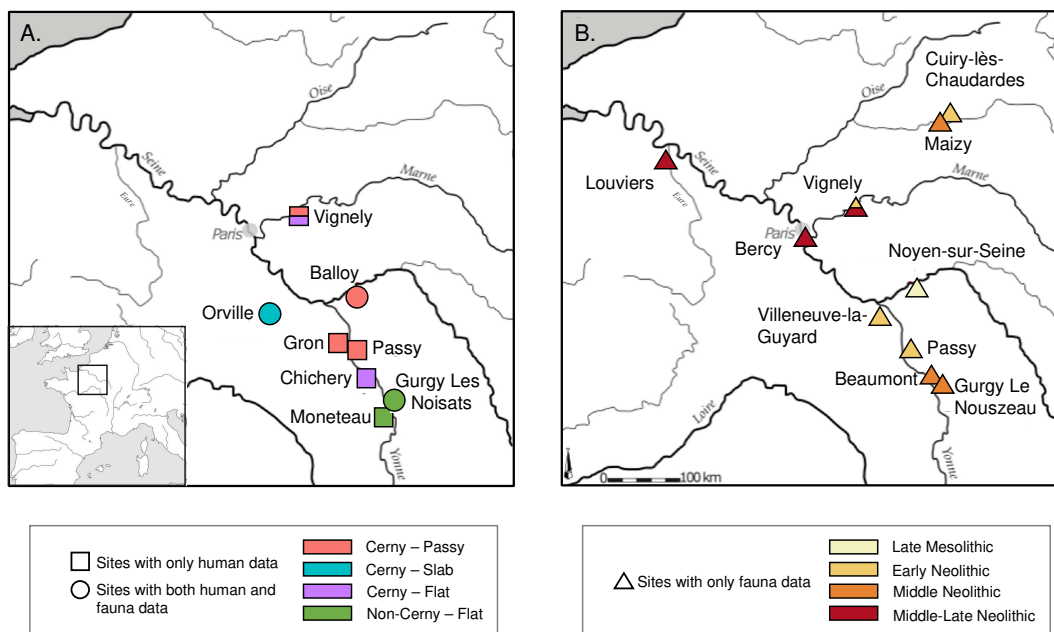
39

1 **1. Introduction**

2 The Paris Basin (*Bassin parisien*) is an intracratonic basin located in the northern part of
3 France, encompasses all or parts of several modern French administrative regions, including
4 Normandy, Pays de la Loire, Centre–Val de Loire, Île–de–France, Hauts–de–France, Grand Est,
5 and Bourgogne–Franche–Comté (Figure 1). Supported by an expansive river system, together
6 with favourable climatic conditions, fertile soil, and gentle relief (Jones 1947), the Paris Basin
7 region has been occupied by human settlers as early as the Palaeolithic and Mesolithic periods
8 (Bodu, et al. 2014; Leroi-Gourham and Brézillon 1972; Pigeot 2004; Valentin, et al. 2013). By
9 the end of the 5th millennium BC, the Paris Basin region appeared to be a crossroads between
10 two main routes of Neolithic dissemination in Western Europe (e.g.(Manen and Hamon 2018)).
11 While many sites in the area had Danubian roots, the region received further influences from the
12 Mediterranean Neolithic sphere in terms of material culture (Constantin and Vachard 2004;
13 Lichardus-Itten 1986) as well as genetic signatures (Rivollat, et al. 2015). These interactions
14 have created remarkable cultural diversity in the Paris Basin area during the Middle Neolithic
15 period (c. 4700 – 3500 BC), in a scale that is observed neither in the preceding nor following
16 periods (Chambon and Leclerc 2003; Chambon, et al. 2013). One particularly notable
17 observation is the emergence of the first monumental cemeteries in western Europe (Chambon
18 and Thomas 2010). From massive, earthen long–barrows up to 300 m in length, to large stone
19 slabs weighing several tonnes, these labour intensive, physically imposing ceremonial structures
20 are seen by many as a tell–tale sign that communities are moving away from simple, egalitarian
21 structures to more stratified, hierarchal social systems during this period (Duhamel and Midgley
22 2004; Midgley 2005). At the same time, these monumental graves stood in stark contrast to their
23 contemporary modest counterparts – cemeteries without superstructure, or the “flat” cemeteries
24 (Thomas, et al. 2011b). Based on burial arrangements and recovered ceramics, the monumental
25 cemeteries are all considered part of the Cerny Culture, while the flat cemeteries can be further
26 divided into three major groups under varying degrees of Cerny influence: major (Bostyn, et al.
27 2018; Chambon, et al. 2010), minor (Chambon, et al. 2006), and completely absent (Augereau
28 and Chambon 2011; Constantin, et al. 1997; Rottier, et al. 2005). These contrasting cemetery
29 architectures are further complicated by other differing but correlated burial traditions such as
30 body positions (flexed vs. supine) (Chambon, et al. 2007) and compositions of grave goods
31 (Thomas 2011). Thus, during the Middle Neolithic period, in a small area of about 100 km in
32 radius around the Seine–Yonne confluence (Figure 1), several types of stylistically distinctive
33 cemeteries coexisted.

34 Focusing on the Cerny groups, this study examines the relationship between subsistence
35 economy, burial rites, cultural affiliations, and social organization by reconstructing and
36 comparing the palaeodietary and funerary patterns of eight Cerny sites with two “Non-Cerny”
37 sites (cemeteries with no significant Cerny features) in the Paris Basin area. Using a multi–
38 isotope approach, we present the stable carbon (C), nitrogen (N), and sulfur (S) isotopic
39 compositions of a total of 113 humans and 90 animals from the area. In addition, published C, N,
40 and S isotope measurements of a total of 140 humans and 177 animals from contemporaneous or

1 near contemporaneous sites are included to provide additional insights into the regional isotopic
 2 variations (Balasse 1999; Bocherens, et al. 2005; Bocherens, et al. 2011; Drucker, et al. 2018;
 3 Naito, et al. 2013; Rey, et al. 2017; Rey, et al. 2019). The main objectives of this study are
 4 threefold: 1) to advance our current understanding of the subsistence economy of populations
 5 living in the Paris Basin region during the Middle Neolithic period, when funerary
 6 monumentalism began to emerge in western Europe, 2) to investigate whether there was any
 7 difference in the subsistence economy between the Cerny and non-Cerny groups, and 3) to
 8 explore connections between funerary monumentality and social differentiations (e.g. gender,
 9 social-economic status, etc) among Cerny sites.



10
 11 *Figure 1 Maps of the Paris Basin showing locations of all sites mentioned in this study, with reference to the modern city of Paris.*
 12 *A: ■ corresponds to sites with only human data; ● corresponds to sites with human and corresponding faunal data. B: ▲*
 13 *corresponds to sites with faunal data not directly associated with the humans analysed in this study.*

14 2. The Cerny Culture

15 2.1 The Cerny way of death

16 The Cerny culture was a Middle Neolithic culture that flourished between 4700 and 4300
 17 BC in the Paris Basin region, also refer to as the Cerny territory *stricto sensu* (Constantin, et al.
 18 1997). In the general absence of residential sites, most of our knowledge of the Cerny social
 19 organisation comes from its cemeteries (Thomas 2011). Although first identified and defined by
 20 its unique ceramic style (Bailloud 1964), today, the Cerny culture is possibly best known for
 21 building some of the first monumental cemeteries in Western Europe (Midgley 2005;
 22 Wunderlich, et al. 2019). In the Paris Basin region, there are three major varieties of Cerny
 23 cemeteries: two monumental types and one without superstructure or “flat”. A brief description
 24 of these cemetery types is provided below.

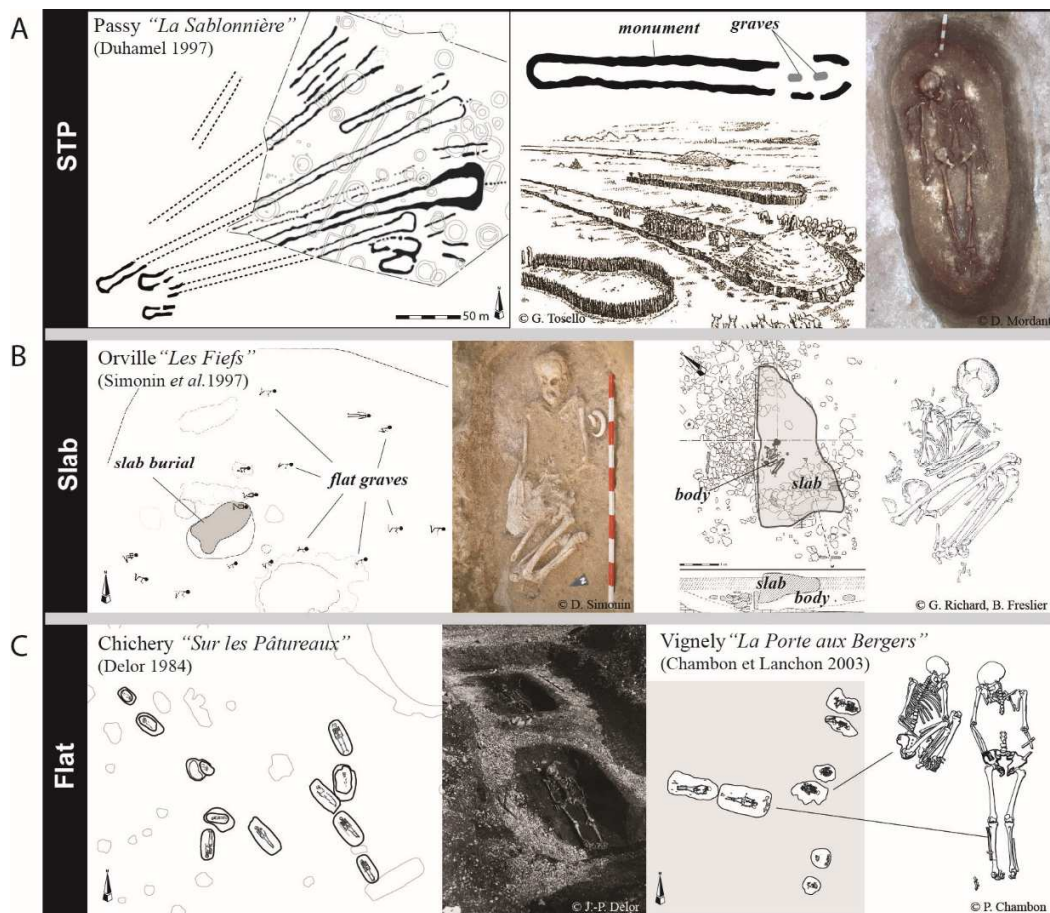
1
2 *Cemeteries with Passy-type structures (Structures de Type Passy, or STP – Figure 2A):* named
3 after the eponymous cemeteries in Passy (Duhamel 1997), this type is possibly the most famous
4 of all Cerny cemetery types. STP cemeteries are consisted of long barrows constructed out of
5 timber and earth, where the total lengths of each structure can vary from 25 to 300 m (Duhamel
6 and Mordant 1997). Only a few individuals were buried within each monument, and in some
7 cemeteries, some individuals were buried outside. There appeared to be certain rules about social
8 identities (most apparent categories are sex and age) and burial locations, where only certain
9 individuals were allowed to be buried within, or even associated with the monuments (Chambon
10 1997; Thomas, et al. 2011a; Thomas, et al. 2011b). Most of the individuals were buried in the so-
11 called Balloy-type graves, which is consisted of a coffin placed inside a vault, where the body is
12 laid in an extended supine position (Chambon, et al. 2007; Chambon and Thevenet 2014). In this
13 study, five sites, namely Balloy “Les Réaudins” (BLR), Vignely “La Noue Fenard” (VNF), Gron
14 “Les Sabons” (GLS), Passy “La Sablonnière” (PLS), and Passy “Richebourg” (PR), belong to
15 this category. A total of 70 individuals from these five sites are analysed. A variation of STP
16 cemeteries is the so called Rots-type cemeteries. These cemeteries have monuments similar to
17 those of STP cemeteries, but are only found in Normandy, which is generally considered as
18 Cerny sphere *lato sensu* (Desloges 1997; Ghesquière, et al. 2019). As it is located outside of our
19 concerned area, groups buried in this type of cemeteries are not addressed in this paper.

20
21 *Cemeteries with “slab” burials, or the Malesherbes-type (Figure 2B):* “Slab” burials are burials
22 marked by a megalith, either a flat stone (slab) or standing stone (menhir). These types of burials
23 are often found in the western part of the Paris Basin region, along the banks of the Essonne. In
24 this study, we analysed a total of 20 individuals from Orville “Les Fiefs” (OLF), the biggest
25 “Slab” cemetery found thus far. In OLF, the slab burial is the key grave surrounded by at least 21
26 flat burials (Simonin, et al. 1997). All but one individual from this site were buried in a flexed
27 position, most of them on the left side.

28
29 *Flat cemeteries (Figure 2C):* as suggested by the name, these types of cemeteries have no major
30 superstructure. Most of the individuals were buried in an extended supine position inside a
31 Balloy-type grave, only few were buried in flexed position on the side (Bostyn, et al. 2018;
32 Chambon, et al. 2010). Two sites associated with this cemetery types are Vignely “La Porte aux
33 Bergers” (VPB) and Chichery “Sur les Pâturaux” (CLP). A total of 30 individuals from VPB
34 are analysed. Isotopic measurements of eight individuals from CLP are obtained from a recently
35 published report (Rey, et al. 2019). Note that even though both cemeteries are categorized as
36 “Cerny flat”, VPB is considered more closely related to STP cemeteries than CLP (Thomas
37 2014a).

38
39 While most Cerny cemeteries in the Paris Basin region show connections with cultural spheres
40 from north-eastern France, such as the Rössen Culture, within the same temporal and

1 geographical framework, there are also cemeteries that bear components of other cultures, such
 2 as the Chasséen Culture from southern France. Two of such cemeteries included in this study are
 3 Gurgy “Les Noisats” (GLN) (Rottier, et al. 2005) and Monéteau “Macherin” (MON) (Augereau
 4 and Chambon 2011). GLN and MON are located in the Yonne river valley, about 10 km south of
 5 the Cerny flat cemetery of CLP (Figure 1A). With more than 180 burials in total, most of the
 6 burials from these two sites carried no clear Cerny components, and were buried in a flexed
 7 position, mainly on the left side. Other than burial positions, individuals from GLN and MON
 8 were buried in several grave types that are distinct from the typical Balloy-type seen in most
 9 Cerny cemeteries (Chambon, et al. 2013). Interestingly, three individuals in MON (#02–685;
 10 #04–89; #04–99) show evidence of affiliation with the Cerny culture, where they were buried in
 11 a Balloy-type grave (Chambon, et al. 2006). For the purpose of this study, these two cemeteries
 12 are categorized as “non-Cerny”. A total of 132 C, N, and S isotope measurements from GLN and
 13 MON are obtained from two recently published reports (Rey, et al. 2017; Rey, et al. 2019).
 14



15
 16 Figure 2 The three major types of Cerny cemeteries in Paris Basin, monumental (STP, Slab) and flat, also showing the typical
 17 burial positions of the deceased seen in the three types of cemeteries, respectively.

1 **2.2 The Cerny way of life**

2 Unfortunately, so far, residential sites from the Cerny contexts remain few and far in
3 between (Bostyn, et al. 2016; Last 2013; Mordant and Simonin 1997). As a result, relatively little
4 is known about the details of their lifeways. Based on limited archaeological evidence and
5 research on related neighbouring sites, it is generally agreed that the Cerny subsistence economy
6 was based primarily on agriculture (agronomy and animal husbandry), supplemented by some
7 limited hunting activities. In terms of staple crops, the Cerny people grew both hulled (emmer
8 wheat: *Triticum dicoccum* and einkorn wheat: *Triticum monococcum*) and naked (likely bread
9 wheat: *Triticum aestivum*) varieties of wheats (Bakels 1999; Bakels 2009). Other crops exploited
10 include barley (*Hordeum vulgare*), pea (*Pisum sativum*), and poppy (*Papaver somniferum*)
11 (Bakels 2009). Zooarchaeological assemblages are composed predominantly of domestic animals,
12 with cattle being the most numerous, followed by pigs and sheep/goats (Bostyn, et al. 2016;
13 Colas, et al. 2018; Hachem 2010; Hachem 2011; Sidéra 2000; Tresset 1997). Thus far there is no
14 direct evidence for dairying from the Cerny contexts. However, evidence of dairying was present
15 at a nearby Middle Neolithic site Bercy, (Balasse, et al. 2012), therefore, it is possible that the
16 Cerny groups exploited cattle and sheep/goat for both their meat and dairy products. Other than
17 domestic animals, wild animals such as red deer, wild boars, and aurochs were also consumed –
18 albeit to a much lesser extent (Bostyn, et al. 2016; Tresset 1997). Furthermore, despite the lack
19 of fish bones in the Cerny zooarchaeological assemblages, based on the proximity of Cerny sites
20 to the rivers, the occasional discovery of fishing related artefacts such as hooks in these sites
21 (Bostyn, et al. 2018:276), as well as the continuous practice of fishing throughout earlier and
22 later periods in the region (Augereau and Chambon 2011; Clavel and Arbogast 2005; Dauphin
23 1989; Drucker, et al. 2018; Naito, et al. 2013), it is safe to assume freshwater resources were
24 utilized to a certain extent.
25

26 **3. Methods and materials**

27 **3.1 Principles of stable isotope analysis**

28 Stable isotope analysis is a well-established methodology for reconstructing past
29 lifeways, allowing archaeologists to address different archaeological questions, including but not
30 limited to topics such as lifestyles, food technology, socio-economic organizations, trading
31 networks, and many more (Katzenberg 2008; Makarewicz and Sealy 2015; Schwarcz and
32 Schoeninger 2012).. Traditionally, the most common isotopes used by archaeologists are those of
33 carbon ($^{13}\text{C}/^{12}\text{C}$) and nitrogen ($^{15}\text{N}/^{14}\text{N}$), but recently the suite has grown to include more
34 elements, such as oxygen ($^{18}\text{O}/^{16}\text{O}$), sulfur ($^{34}\text{S}/^{32}\text{S}$), and strontium ($^{87}\text{Sr}/^{86}\text{Sr}$), allowing
35 archaeologists to draw from a wider range of assessments, thus improving the resolution of the
36 analysis. Among these elements, the isotopic analyses of C, N, and S isotopes reveal primarily
37 diet-related information, while those of O and Sr often relayed information regarding to
38 seasonality and/ or mobility. As this study mostly concerns the palaeodietary practices of the
39 Cerny people, the stable isotopes of C, N, and S are analysed.

1 Stable carbon isotope analysis (expressed as $\delta^{13}\text{C}$) is primarily used to identify the
2 consumption of food groups with distinctive $\delta^{13}\text{C}$ values, most commonly between C_3 plants, C_4
3 plants, the marine system, and/ or the terrestrial system (Boutton 1991; Chisholm, et al. 1982;
4 van der Merwe 1982). As both native and cultivated flora of continental Europe during this
5 period are predominately C_3 (Ehleringer and Cerling 2002; Motuzaite-Matuzeviciute, et al. 2013),
6 and our study area is at least 200 km away from the closest coastline, the diets of those involved
7 in this study are likely predominantly based on C_3 -based terrestrial resources. Thus, $\delta^{13}\text{C}$ values
8 will be mainly used to identify individuals with unusual dietary components that have carbon
9 isotope signatures deviate from those of the main food source groups, such as freshwater
10 resources, or wild games. Stable nitrogen isotope analysis (expressed as $\delta^{15}\text{N}$) is typically used to
11 infer trophic positions of consumers within a biological system (Hedges and Reynard 2007;
12 O'Connell, et al. 2012). In this study, $\delta^{15}\text{N}$ values will be primarily used to evaluate animal
13 protein intake among different social groups. Comparing to the stable isotopes of carbon and
14 nitrogen, the stable isotopes of sulfur (expressed as $\delta^{34}\text{S}$) are more tied to the geology, and can
15 vary greatly from area to area, especially in freshwater systems (Nehlich 2015). With adequate
16 baseline information, $\delta^{34}\text{S}$ values can help to detect the consumption of freshwater resources
17 (Drucker, et al. 2018; Nehlich, et al. 2010; Privat, et al. 2007), as well as mobility (Cheung, et al.
18 2017a; Richards, et al. 2001) among past populations. In this study, $\delta^{34}\text{S}$ values will be used
19 alongside $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, to help elucidate the dietary practices of these Cerny groups.
20

21 **3.2 Methods and Instrumentation**

22 All bone samples were prepared at the Preparation Laboratory at UMR 7269 LAMPEA,
23 Aix-en-Provence (France), and the extracted collagen were analysed at Iso-Analytical Limited
24 (U.K.). Bone collagen was extracted following a modified ABA procedure combining the
25 methodologies outlined in Brock et al. (2010) and Szpak et al. (2017a): bone samples were
26 demineralized in 0.5M HCL solution at 4°C in chunks (solution changed ever 2–3 days, until
27 bones were fully demineralized); demineralized bones were then placed in 0.125M NaOH at
28 room temperature for successive 30-minute sessions (until solution stopped changing colour);
29 followed by a 0.5M HCL treatment at room temperature for 1 hour. Samples were thoroughly
30 rinsed with deionized water in between each change of solution. The samples were then
31 gelatinized in pH3 solution (10^{-3}M HCL) at 75°C for 48 hours. The resultant soluble collagen
32 was filtered with Ezee filtersTM and subsequently lyophilized.

33 At Iso-Analytical, samples were analysed with a Europa ScientificTM elemental analyzer,
34 coupled to a mass spectrometer. One in every five samples were measured in duplicates.
35 Precision of measurements were further monitored using an in-house lab standard that has been
36 extracted alongside the archaeological bone samples (CC_REF – cattle bone collage). Reported
37 carbon and nitrogen isotope values are reported in “per mil (‰)” and are calibrated to VPDB and
38 AIR, respectively, using IA-R068, IA-R038, IA-R069, and a mixture of IA-R046 and IAEA-
39 C7 are used as control check standards. IA-R068, IA-R038, and IA-R069 are calibrated and

1 traceable to the international standards IAEA-CH-6 and IAEA-N-1. IA-R046 is calibrated
2 against and traceable to the international standards IAEA-N-1 and IAEA-C7.

3 For sulfur isotope analysis, all measurements are reported in “per mil (‰)”. Results are
4 calibrated to VCDT using IA-R061. IAEA-SO-5, IA-R068, and IA-R069 are used as control
5 check standards. IA-R061 is calibrated against and traceable to the international standards NBS-
6 127 and IAEA-S-1. IA-R068 and IA-R068 are calibrated against and traceable to the
7 international standards NBS-127 and IAEA-SO-5.

8 Based the formulae provided in Szpak, et al. (2017b)’s paper, the precision ($u(R_w)$) of the
9 measurements is determined to be $\pm 0.07\text{‰}$, $\pm 0.10\text{‰}$, and $\pm 0.24\text{‰}$, for $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$,
10 respectively, on the basis of repeated measurements of calibration standards, check standards, in-
11 house lab standard, and sample replicates. Accuracy or systematic error ($u(bias)$) is determined
12 to be ± 0.14 for $\delta^{13}\text{C}$, and ± 0.15 for $\delta^{15}\text{N}$, and ± 0.33 for $\delta^{34}\text{S}$, on the basis of the difference
13 between the observed and known δ values of the check standards and the long-term standard
14 deviations of these check standards. The total analytical uncertainty was estimated to be ± 0.16
15 for $\delta^{13}\text{C}$, and ± 0.18 for $\delta^{15}\text{N}$, and ± 0.41 for $\delta^{34}\text{S}$. The formulae sheet with details of all
16 measured standards are provided in the supplement S1.

17 The quality of the collagen is assessed using the conventional criteria: %collagen
18 between 0.5% and 22% by weight, %C between 15.3% and 47%, %N between 5.5% and 17.3%,
19 %S between 13% and 35%, atomic C/N ratio between 2.9 and 3.6, atomic C/S ratio between 300
20 and 900, and atomic N/S ratio between 100 and 300 (Ambrose 1990; Bocherens, et al. 2011;
21 DeNiro 1985; Harbeck and Grupe 2009; Nehlich and Richards 2009; van Klinken 1999). Only
22 samples with elemental compositions within these ranges are accepted for analysis.

24 3.3 Materials

25 This study examines the bone collagen C, N, and S isotope compositions of humans from
26 10 Middle Neolithic sites, as well as fauna from 13 contemporaneous or roughly
27 contemporaneous sites in Paris Basin. Skeletal remains from a total of 119 humans and 104
28 faunas are analysed. An additional 140 humans and 177 faunas from published reports are
29 included for comparison. Not all reports published their data along with collagen quality
30 indicators, for those that do, only data from samples with well-preserved collagen (see previous
31 section for detailed criteria) are included.

32 All humans have been osteologically analysed, detailed results are described in Thomas’
33 (2011:83-103) report, and general information of each analysed individual is provided in
34 supplement S2. Age-at-death are determined by established methods (Moorrees, et al. 1963;
35 Scheuer and Black 2000; Schmitt 2005). Sex identification are conducted using the morphology
36 and morphometry of the mature *ossa coxae* (Bruzek 2002; Murail, et al. 2005).

37 Table 1 summarizes the principal data of each site where human samples are obtained,
38 listing the major archaeological cultural affiliations, types of cemetery, major burial
39 arrangements, and references for published data.

1 *Table 1 Summary of sites where human samples were obtained. N refers to total number of individuals analysed.*

River Valley	Site Code	Site	Culture	Cemetery type	Cemetery category	Body position and grave type	N	Reference for isotopes	
Essonne Valley	OLF	Orville “Les Fiefs”	Cerny	Monumental	Slab	Predominately flexed bodies	18	This study	
Seine Valley	BLR	Balloy “Les Réaudins”	Cerny	Monumental	STP	Supine bodies in Balloy type graves	36		
Marne Valley	VNF	Vignely “La Noue Fenard”	Cerny	Monumental	STP	Supine bodies in Balloy type graves	4		
	VPB	Vignely “La Porte aux Bergers”	Cerny	Flat	STP Associated	Predominately supine bodies in Balloy type graves	29		
Yonne Valley	GLS	Gron “Les Sablons”	Cerny	Monumental	STP	Supine bodies in Balloy type graves	5		
	PLS	Passy “La Sablonnière”	Cerny	Monumental	STP	Predominately supine bodies in Balloy type graves	10		
	PR	Passy “Richebourg”	Cerny	Monumental	STP	Predominately supine bodies in Balloy type graves	11		
	CLP	Chichery “Sur Les Pâtureaux”	Cerny	Flat		Predominately supine bodies in Balloy type graves	8	(Rey, et al. 2019)	
	MON	Monéteau “Macherin”	Non-Cerny (Chasséen + some Cerny component)	Flat		Predominately flexed bodies	45		
	GLN	Gurgy “Les Noisats”	Non-Cerny	Flat		Flexed bodies	87	(Rey, et al. 2017; Rey, et al. 2019)	

2
3
4 As all the human samples come from cemeteries, faunal samples directly associated with
5 the humans are not found at all sites. Thus, when directly associated faunal samples are not
6 available, faunal samples from roughly contemporaneous period in the area are used to establish
7 the regional isotopic baseline. Despite not examining any human data from the northern part of
8 the Paris Basin, faunal samples from the Aisne valley: Maizy “Les Grands Aisements” (Le
9 Bolloch, et al. 1986) and Cuiry-lès-Chaudardes “Les Fontinettes”(Ilett and Hachem 2001), and
10 Eure valley: Louviers “La Villette” are included to provide a clearer picture of the overall
11 isotopic variability within the region. Table 2 provides the principal data of each site where
12 faunal samples are obtained, listing the major archaeological cultural affiliations, periods, and
13 references for published data.

14 *Table 2 Summary of sites where faunal samples were obtained. N refers to total number of individuals analysed. For*
15 *archaeological cultures, RFBS stands for Rubané final du bassin de la Seine, BVSG stands for Blicquy/Villeneuve-Saint-Germain.*
16 *For periods, Late Mesolithic period corresponds to c. 7000-5000 BC; Early Neolithic corresponds to c. 5000-4700 BC; and*
17 *Middle Neolithic corresponds to c. 4700-3500 BC.*

River Valley	Site code	Site	Culture	Period	N=	Reference
Aisne Valley	CCF	Cuiry-lès-Chaudardes “Les Fontinettes”	RFBS	Early Neolithic	24	(Balasse 1999)
	MGA	Maizy “Les Grands Aisements”	Michelsberg	Middle Neolithic	14	
Eure Valley		Louviers “La Villette”	Chasséen	Middle Neolithic	34	(Bocherens, et al. 2005)
Essonne Valley	OLF	Orville “Les Fiefs”	Cerny	Middle Neolithic	9	This study
Marne	VNF	Vignely “La Noue	Michelsberg	Middle Neolithic	5	

Valley		Fenard"				
	VPB	Vignely "La Porte aux Bergers"	RFBS-BVSG	Early Neolithic	26	
Seine Valley	BLR	Balloy Les Réaudins"	Cerny	Middle Neolithic	24	
		Paris Bercy	Chasséen	Middle Neolithic	9	(Balasse, et al. 1997)
		Noyen-sur-Seine "Hauts des Nachères"		Late Mesolithic	36	(Bocherens, et al. 2011; Drucker, et al. 2018; Naito, et al. 2013)
Yonne Valley	VLG	Villeneuve-la-Guyard		Early Neolithic	7	This study
	PAS	Passy "La Sablonnière"	BVSG	Early Neolithic	20	
	GLN	Gurgy "Les Noisats"		Early/Middle Neolithic	18	(Rey, et al. 2017; Rey, et al. 2019)
	NZ	Gurgy "Le Nouveau"	Cerny	Middle Neolithic	5	(Rey, et al. 2019)
	BMT	Beaumont "Le Crôt aux Moines"	Chasséen	Middle Neolithic	37	

1

2 **3.4 Statistical methods**

3 All statistical tests are performed using R version 3.6.0 (R Core Team 2019) with RStudio
4 (RStudio Team 2018). Data are visualized using the package 'ggplot2' (Wickham 2016) and
5 'ggpubr' (Kassambara 2020). Distribution normality is tested using a Shapiro-Wilk test.
6 Variance equality is tested using the Levene's test. For groups with normally distributed data
7 and/or sufficient sample size ($n > 15$), the parametric tests, unpaired independent 11Student's t
8 tests and one-way ANOVA, are used to determine differences between group means for $\delta^{13}\text{C}$,
9 $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ values. For groups where data are not normally distributed and/or have small
10 sample size ($n < 15$), the non-parametric Wilcoxon and Kruskal-Wallis tests are used. For
11 ANOVA, when differences are detected, post-hoc comparisons are conducted using the Tukey
12 honest significant difference (HSD) tests. For Kruskal-Wallis, when differences are detected,
13 post-hoc comparisons are conducted using the Dunn's test using the package 'dunn.test' (Dinno
14 2017). A 0.05 probability ($p < 0.05$) is considered significant.

15 Bivariate standard ellipses are created using the package 'SIBER' (Jackson, et al. 2011),
16 with p value set at 66% (for visualization purpose). Variability of different groups are quantified
17 using the following area metrics: convex hull areas (TA), standard ellipse areas (SEA), standard
18 ellipse areas corrected (SEA_C), and standard ellipse areas with Bayesian estimate (SEA_B)
19 (Jackson, et al. 2011). 3-dimensional graphics are created using the packages 'Rcmdr' (Fox, et al.
20 2015) and 'Rgl' (Adler, et al. 2015). Ellipsoids representing the point concentration of each
21 group has the expected proportion (α) of multivariate-normal observations set as 0.5. Example
22 scripts for the statistical analyses and graphical visualisations of the results are provided in
23 supplement S3.

24

25 **3.5 Adjustment for regional pattern in isotopic baselines**

26 The sites in this study are scattered across six different river valleys. In order to ensure
27 differences in the isotopic compositions of the humans were due to actual differences in dietary

1 practices but not geographical factors, faunal isotopic data are used to establish the local
2 isotopic baseline of each valley. If a regional pattern in an isotopic system is observed, the
3 following equation is used to estimate the weighted overall shift in the baseline value of the
4 valley relative to the whole region:

$$5 \quad \text{baseline_shift} = \sum_{i=1}^y \left((\mu_{\text{site}_i} - \mu_{\text{overall}_i}) \left(\frac{n_i}{N} \right) \right) \quad (1)$$

6

7 where y is the number of taxa involved, i refers to each individual taxon, μ is the mean isotopic
8 value of a particular taxon (site of interest or overall), n is the number of samples of each taxon
9 from the site of interest, and N is the total number of samples from the site of interest.

10 Equation (1) is designed so that only selected taxa are considered, and that likes are
11 compared with likes. Archaeologists are encouraged to select taxa most commonly consumed at
12 site/region based on other archaeological evidence. The shift is weighted by the proportion of
13 each taxon among the total assemblage, hence taxa with higher sample numbers (i.e. with better
14 represented means) will contribute heavier towards the offset calculation. The resulting offset
15 (%) can then be applied to address the shift in human isotopic compositions caused by
16 geographical differences in isotopic baseline values. This adjustment only shifts the isotope data
17 of the concern site(s) along the x- and/or y- axis(axis) to allow better inter-site comparisons.
18 However, it does not change the relative variability of the data. Therefore, the internal spatial
19 patterns of the biplot remain unaltered for intra-site analyses.

20

21 **4. Results**

22 The summary statistics of all humans and faunas are provided in Table 3. The detailed
23 contextual information and elemental compositions of all analysed specimens are provided in
24 supplement S2.

25

26

Table 3 Summary statistics of all human and faunal data discussed in this study, including both original and published data. *N* refers to the total number of accepted data. The human data from the two Marne sites has not been adjusted for the baseline shift. A key for the site codes is provided in Table 1.

Valley	Site	$\delta^{13}\text{C}$						$\delta^{15}\text{N}$						$\delta^{34}\text{S}$					
		Min	Max	Mean	Median	SD	N=	Min	Max	Mean	Median	SD	N=	Min	Max	Mean	Median	SD	N=
Essonne	OLF	-21.2	-20.3	-20.7	-20.7	0.3	18	+9.7	+12.9	+10.4	+10.2	0.7	18	+6.4	+10.1	+8.3	+8.4	1.0	15
Marne	VNF	-21.2	-20.9	-21.0	-21.0	0.1	4	+11.6	+13.0	+12.0	+11.7	0.6	4	+6.1	+8.1	+7.3	+7.5	0.9	4
	VPB	-22.7	-20.8	-21.2	-21.0	0.5	29	+11.1	+15.5	+12.5	+12.2	1.0	29	+5.4	+9.6	+7.6	+7.8	1.2	20
Seine	BLR	-21.5	-20.4	-21.0	-20.9	0.3	36	+9.5	+14.7	+11.2	+11.0	1.1	36	-1.1	+9.7	+5.8	+5.9	2.6	22
Yonne	CLP	-20.9	-20.2	-20.6	-20.7	0.3	8	+10.5	+11.6	+10.9	+10.9	0.4	8	+2.3	+6.3	+4.5	+4.8	1.5	6
	GLN	-21.3	-20.3	-20.7	-20.7	0.2	87	+9.9	+13.4	+11.7	+11.6	0.5	87	+0.2	+6.3	+3.3	+3.4	1.4	27
	GLS	-21.1	-21.0	-21.0	-21.0	0.1	5	+11.3	+11.5	+11.4	+11.4	0.1	5	+7.1	+9.6	+8.4	+8.4	0.9	5
	MON	-21.2	-19.8	-20.6	-20.7	0.3	45	+8.7	+12.1	+10.8	+11.0	0.8	45	+1.6	+10.0	+5.2	+4.9	2.3	17
	PLS	-21.6	-20.7	-21.2	-21.2	0.3	10	+10.2	+14.9	+11.6	+11.4	1.2	10	+4.7	+8.9	+7.4	+7.8	1.4	8
	PR	-21.2	-20.8	-21.0	-21.0	0.1	11	+9.7	+14.4	+11.6	+11.5	1.4	11	+7.5	+10.3	+8.7	+8.7	0.9	9
Total		-22.7	-19.8	-20.8	-20.8	0.3	253	+8.7	+14.9	+11.3	+11.3	0.9	253	-1.1	+10.3	+6.1	+6.4	2.5	133
	Fauna																		
Aisne		-24.5	-20.2	-22.9	-23.0	1.0	38	+5.1	+9.2	+6.7	+6.8	1.0	38	—	—	—	—	—	—
Eure		-24.6	-20.3	-22.0	-22.1	1.0	34	+4.6	+10.8	+7.2	+7.0	1.4	34	—	—	—	—	—	—
Essonne		-22.7	-19.1	-20.3	-19.6	1.5	9	+5.0	+10.9	+8.2	+9.0	2.2	9	+7.2	+11.1	+9.7	+10.1	1.5	5
Marne		-23.8	-19.0	-21.6	-21.9	1.2	31	+4.9	+13.8	+8.3	+7.8	1.9	31	+2.0	+11.8	+8.2	+8.4	2.4	16
Seine		-26.7	-19.1	-22.5	-22.7	1.6	68	+3.4	+12.4	+7.2	+6.8	2.0	68	-19.0	+10.1	+2.3	+4.4	7.0	31
Yonne		-23.7	-19.3	-21.7	-21.6	1.3	87	+3.3	+11.0	+6.9	+6.8	1.3	87	-10.0	+15.1	+5.8	+6.8	5.6	34
Total		-26.7	-19.0	-22.1	-22.3	1.4	267	+3.3	+13.8	+7.2	+6.9	1.6	267	-19.0	+15.1	+5.2	+6.4	+6.0	86

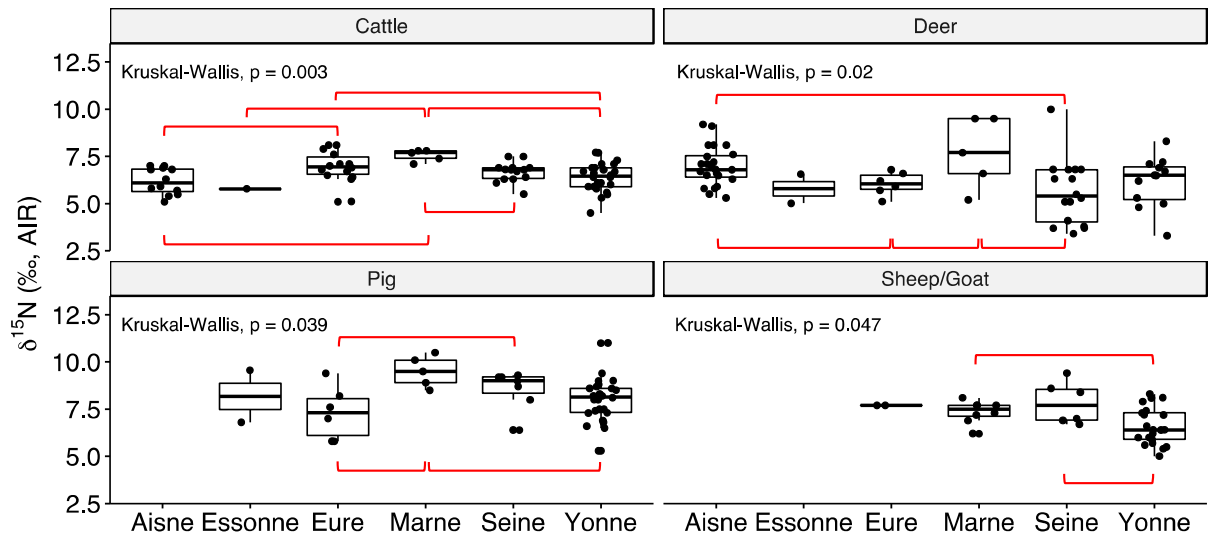
1 **4.1 Faunal data**

2 Out of the 104 faunal samples analysed, 90 samples have produced well preserved collagen for
3 isotopic analysis. Including the 177 additional previously published fauna data from
4 neighbouring sites, the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for all faunas range from -26.7‰ to -19.0‰ and
5 $+3.3\text{‰}$ to $+13.8\text{‰}$, respectively (n=267). The $\delta^{34}\text{S}$ values of all faunas range from -19.0‰ to
6 $+15.1\text{‰}$ (n=86). As a vast majority of the faunal samples are not directly associated with the
7 human analysed, the faunal isotopic values will only be used to establish regional isotopic
8 baselines, and will not be used to evaluate husbandry practices at these sites.

9 The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ baselines of the six river valleys are examined based on the four most
10 common faunal species found in the region: cattle (n=70), deer (n=64), pig (n=46), and
11 sheep/goat (n=37). Kruskal-Wallis tests reveal that differences in $\delta^{15}\text{N}$ values among the six
12 valleys are statistically significant in all four species (cattle: $p = 0.0031$; pig: $p = 0.039$;
13 sheep/goat: $p = 0.047$; deer: $p = 0.021$), while differences in $\delta^{13}\text{C}$ values are only significant in
14 sheep/goat ($p = 0.015$). Post-hoc Dunn-tests confirm that faunas from the Marne valley have
15 higher mean $\delta^{15}\text{N}$ value than those from other valleys (Figure 3). The strongest difference is
16 observed between the $\delta^{15}\text{N}$ values of cattle from the Marne and the Yonne valleys ($\Delta_{\text{mean}} = 0.9\text{‰}$,
17 $p=0.0007$), and the biggest difference is observed between the $\delta^{15}\text{N}$ values of deer from the
18 Marne and the Seine valleys ($\Delta_{\text{mean}} = 2.1\text{‰}$, $p=0.0079$). In terms of $\delta^{13}\text{C}$ values, sheep/goat from
19 the Seine valley have relatively negative $\delta^{13}\text{C}$ values compare to all other valleys ($\Delta_{\text{means}}: 0.7 -$
20 1.3‰ ; $p < 0.01$).

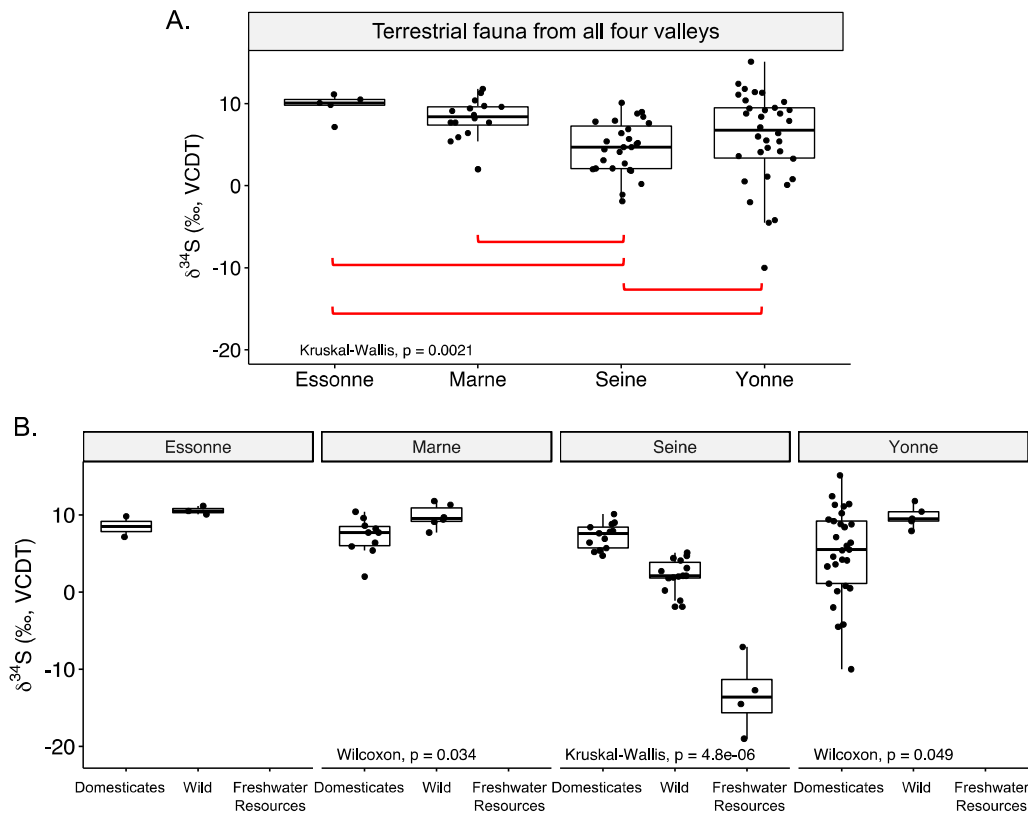
21 In general, the differences in $\delta^{13}\text{C}$ values among the six valleys are relatively small. Thus,
22 for the purpose of this study, we will consider the regional differences in $\delta^{13}\text{C}$ baseline negligible.
23 For $\delta^{15}\text{N}$ values, fauna from the Marne valley consistently produce the highest mean values
24 (except for sheep/goat), therefore it is possible that the $\delta^{15}\text{N}$ baseline in Marne valley is higher
25 than the other valleys in the region. Equation (1) is used to calculate the difference in the basal
26 $\delta^{15}\text{N}$ values between Marne Valley and the general region. The four most abundant species:
27 cattle, pig, sheep/goat, and deer are used (see supplement S4 for a detailed breakdown of the
28 calculations). Note that despite the small sample size, the faunal samples from the Marne valley
29 come from two different sites, one pre-dating and one post-dating the Cerny period, thus we
30 believe the isotopic ranges shown in these faunas should adequately encapsulate the baseline of
31 the region.

32 According to Equation (1), the $\delta^{15}\text{N}$ baseline of the Marne Valley is about 1.0‰ higher
33 than that of the general Paris Basin region. This adjustment will be applied to all of the humans
34 from the Marne Valley (VPB and VNF) for subsequent analysis, unless noted otherwise.



1
 2 *Figure 3 A comparison of the $\delta^{15}\text{N}$ values of the four most common species of animals found in the area: cattle, deer, pig, and*
 3 *sheep/goat. Red brackets indicate pairings with statistically significant differences as determined by post-hoc Dunn tests. Data*
 4 *included both original and published data. For references of published data please refer to Table 2.*

5
 6 Stable sulfur isotope data are only available from four river valleys: Essonne, Marne,
 7 Seine, and Yonne. Based on the $\delta^{34}\text{S}$ values of all terrestrial animals, some regional patterns in
 8 $\delta^{34}\text{S}$ values can be observed among the four different valleys (Figure 4A). The strongest
 9 differences are observed between Seine and Essonne (Δ_{mean} : 5.1‰; $p = 0.0012$), and Seine and
 10 Marne (Δ_{mean} : 3.5‰; $p = 0.0013$) valleys. The terrestrial faunal $\delta^{34}\text{S}$ baseline at the Yonne valley
 11 is particularly variable, ranging from -10.0‰ to $+15.1\text{‰}$, interestingly, both are pigs from
 12 Beaumont (Rey, et al. 2019). Apart from the Essonne valley, where the sample size is too small
 13 for meaningful statistical analysis, the domesticates from all three valleys have statistically
 14 significant differences in their mean $\delta^{34}\text{S}$ values comparing to the wild animals (Figure 4B:
 15 $\Delta_{\text{mean_Marne}}$: 2.6‰; $\Delta_{\text{mean_Seine}}$: 5.0‰; $\Delta_{\text{mean_Yonne}}$: 4.7‰). S isotope measurements from freshwater
 16 resources are only available from the Seine valley. Figure 4B shows that at the Seine valley, the
 17 mean $\delta^{34}\text{S}$ value of the freshwater resources are significantly negative comparing to the
 18 terrestrial fauna.



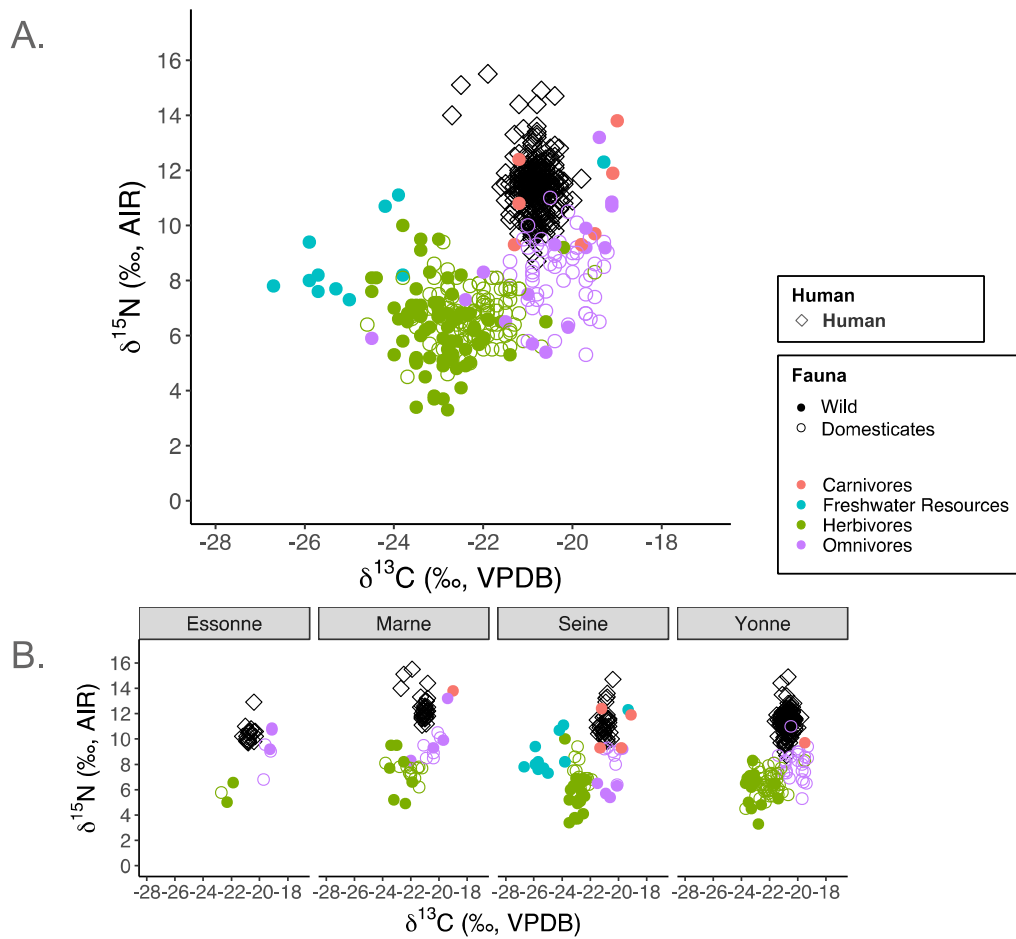
1
2 *Figure 4* $\delta^{34}\text{S}$ values from fauna from the Paris Basin region. A. boxplot comparing the $\delta^{34}\text{S}$ values of all terrestrial fauna. Red
3 brackets indicate pairings with statistically significant differences as determined by post-hoc Dunn tests. B. boxplot comparing
4 the $\delta^{34}\text{S}$ values of all domesticated vs. wild fauna from four river valleys, and freshwater resources from the Seine valley. Data
5 included both original and published data. For references of published data please refer to Table 2.

6

7 **4.2 Human data**

8 A total of 119 human samples are analysed, of which 113 have yielded well preserved collagen
9 for isotopic analysis. Including the 140 published human data from related sites, all humans have
10 $\delta^{13}\text{C}$ values ranging from -22.7 to -19.8 ‰, $\delta^{15}\text{N}$ values range from $+8.7$ ‰ to $+15.5$ ‰ ($n=253$),
11 and $\delta^{34}\text{S}$ values range from -1.1 ‰ to $+10.3$ ‰ ($n=132$). In total, 66 individuals come from Cerny
12 STP contexts, 18 individuals come from Cerny Slab context, 37 individuals come from Cerny
13 Flat contexts, and 132 individuals come from non-Cerny contexts. The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of
14 all human and faunal data are plotted in Figure 5. Note that in this figure, the human data from
15 the Marne valley have not been adjusted for the baseline shift.

1



2

3 *Figure 5 Overall human and fauna (baseline shift for the Marne Valley not applied). Data included both original and published*
 4 *data. For references of published data please refer to Table 1 (for human data) and Table 2 (for faunal data). VNF and VPB data*
 5 *are not adjusted for the baseline shift in $\delta^{15}\text{N}$ values.*

6

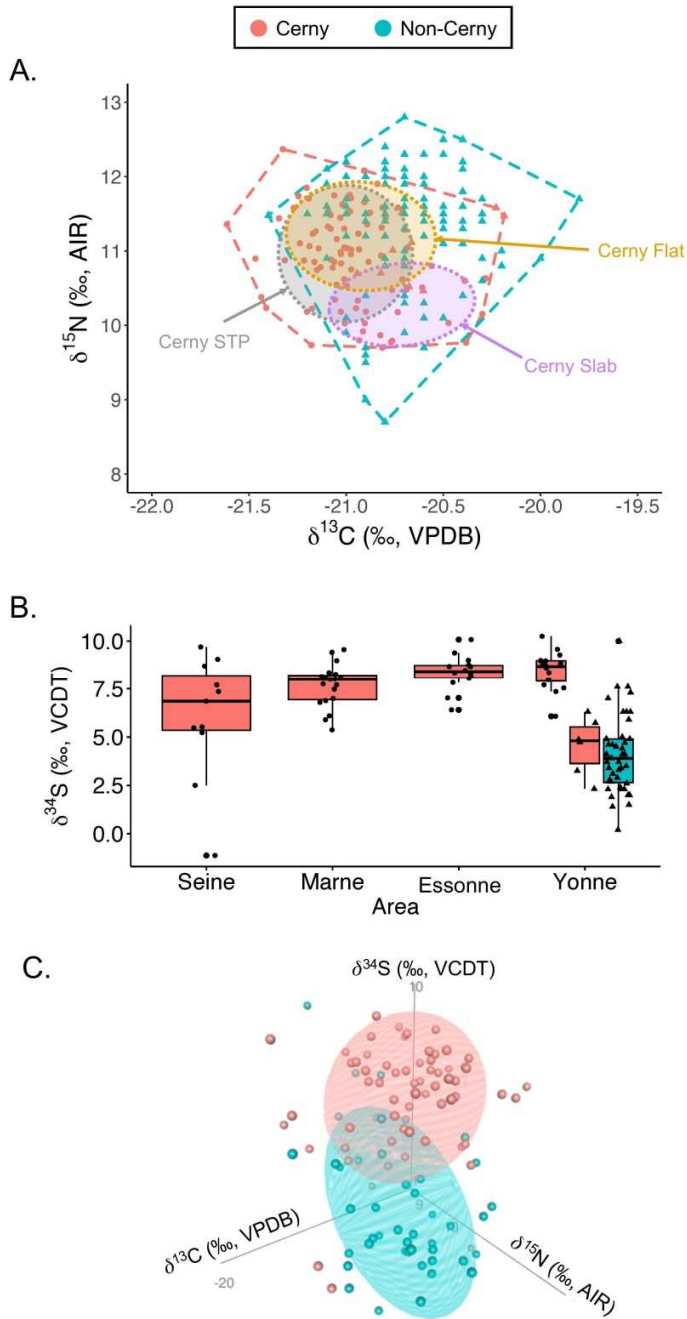
7 Individuals under the age of 4 have relatively elevated $\delta^{15}\text{N}$ values ($+12.5 \pm 1.4\text{‰}$)
 8 comparing to those above the age of 4 ($+11.3 \pm 0.8\text{‰}$). This is likely due to the breastfeeding
 9 effect in very young children (Dupras, et al. 2001; Fuller, et al. 2006; Herrscher, et al. 2017). In
 10 order to focus our analysis on social organisations, all individuals under the age of 4 ($n= 35$) are
 11 excluded in subsequent analyses.

12

13 **4.2.1 Inter-site comparisons**

14 Hereinafter, all human data from the Marne Valley has been adjusted for the baseline shift in
 15 $\delta^{15}\text{N}$ values. Comparing to those from non-Cerny contexts, ANOVA tests reveal that the humans
 16 from the Cerny contexts have slightly lower mean $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values ($\Delta_{\text{mean}} \delta^{13}\text{C} = 0.2\text{‰}$, $p <$

1 0.001; $\Delta_{\text{mean}} \delta^{15}\text{N} = 0.4\text{‰}$, $p < 0.001$) (Figure 6A), and a higher mean $\delta^{34}\text{S}$ value ($\Delta_{\text{mean}} \delta^{34}\text{S} =$
 2 3.4‰ ; $p < 0.001$) (Figure 6B).



3
 4 *Figure 6 Comparing human data by culture. A: stable carbon and nitrogen isotope compositions of the two cultural groups, each*
 5 *group described by a convex hull (outer dotted line). Cemetery types are described by bivariate standard ellipses (shaded area);*
 6 *B: stable sulfur isotope compositions of two cultural groups, organized by river valleys; C: 3D plot comparing all three isotope*
 7 *measurements between the two cultural groups. In A, “Cerny STP” refers to samples from BLR, GLS, PLS, PR, VNF; “Cerny*
 8 *Flat” refers to samples from CLP and VPB; “Cerny Slab” refers to samples from OLF; and “Non-Cerny” refers to samples*

1 from GLN and MON. In A and B, ● corresponds to original data from this study; ▲ corresponds to data obtained from
 2 published reports. VNF and VPB data have been adjusted for the baseline shift.

3
 4 The sites are further divided into four groups based on the cemetery types: Cerny STP,
 5 Cerny Slab, Cerny Flat, and non-Cerny (Figure 6A). One-way ANOVA tests reveal statistically
 6 significant differences between the means of all three measurements ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$) ($\delta^{13}\text{C}$:
 7 $p < 0.001$; $\delta^{15}\text{N}$: $p < 0.001$; $\delta^{34}\text{S}$: $p < 0.001$). In terms of $\delta^{13}\text{C}$ values, the strongest difference is
 8 observed between non-Cerny and Cerny STP groups ($\Delta_{\text{mean}} = 0.3\text{‰}$, $p < 0.001$). For $\delta^{15}\text{N}$ values,
 9 the strongest difference is observed between non-Cerny and Cerny Slab groups ($\Delta_{\text{mean}} = 1.1\text{‰}$, p
 10 < 0.001). For $\delta^{34}\text{S}$ values, the strongest difference is observed between non-Cerny and Cerny
 11 Slab groups ($\Delta_{\text{mean}} = 4.3\text{‰}$, $p < 0.001$). Overall, the non-Cerny group stands out the most, not
 12 only in terms of its mean $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ values, but also in terms of its range and overall
 13 variability in isotopic compositions (Table 4).

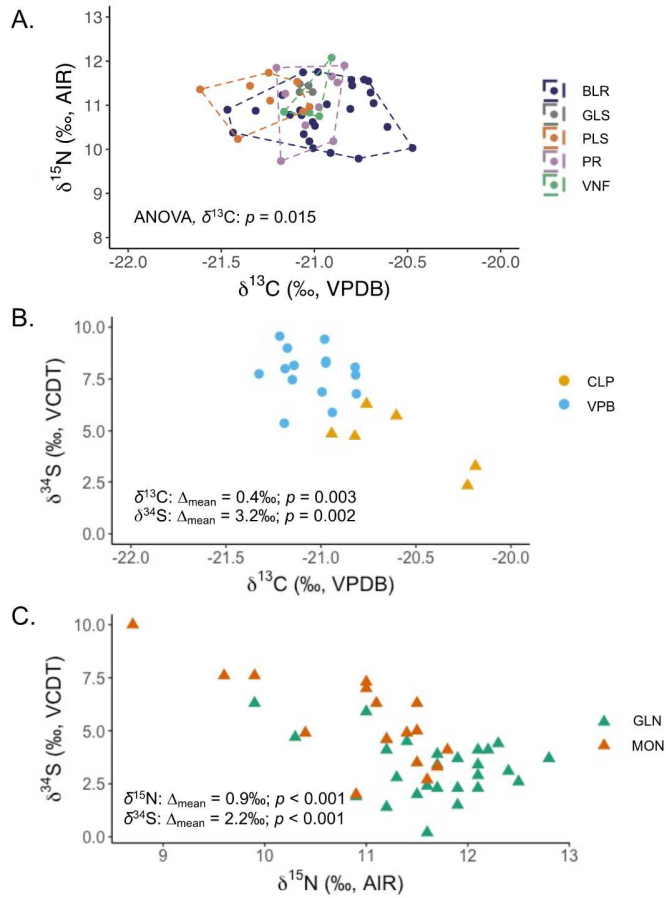
14
 15 Table 4 Area metrics based only on carbon and nitrogen isotope compositions of all humans above the age of 5 ($n=218$). TA
 16 refers to convex hull areas; SEA refers to standard ellipse areas; SEAc refers to standard ellipse areas corrected, and SEAb
 17 refers to standard ellipse areas with Bayesian estimate. See Figure 6A for the visualisation of the convex hulls and standard
 18 ellipses described by these metrics.

	<i>Cerny STP</i> ($n=51$)	<i>Cerny Slab</i> ($n=17$)	<i>Cerny Flat</i> ($n=32$)	<i>Non-Cerny</i> ($n=118$)
TA	1.995	0.872	1.515	3.465
SEA	0.465	0.306	0.405	0.608
SEAc	0.474	0.326	0.418	0.614
SEAb.modes	0.456	0.276	0.390	0.604

19
 20 Despite having the highest number of sites ($n=5$), and distributed over three river valleys
 21 (Seine, Marne, and Yonne), Cerny STP is relatively homogenous in terms of isotopic
 22 compositions (ANOVA; $\delta^{13}\text{C}$: $p = 0.018$; $\delta^{15}\text{N}$: $p = 0.352$; $\delta^{34}\text{S}$: $p = 0.090$) (Figure 7).
 23 Individuals from PLS have a slight but significantly lower mean $\delta^{13}\text{C}$ value than those from BLR
 24 (ANOVA: $\Delta_{\text{mean}} = 0.3\text{‰}$, $p = 0.006$) (Figure 7A).

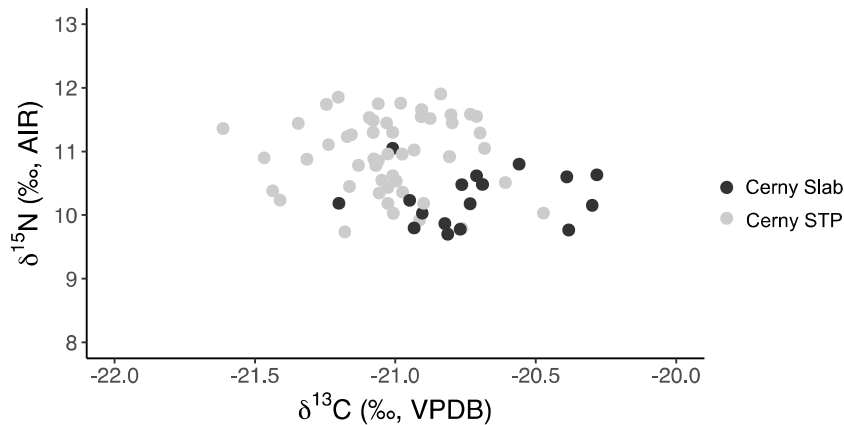
25 Among the Cerny Flat group (VPB and CLP), the two sites show significant disparity in
 26 the means of $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values (t-tests; $\delta^{13}\text{C}$: $p = 0.003$; $\delta^{15}\text{N}$: $p = 0.127$; $\delta^{34}\text{S}$: $p = 0.002$).
 27 Individuals from VPB have lower mean $\delta^{13}\text{C}$ ($\Delta_{\text{mean}} = 0.4\text{‰}$) and higher mean $\delta^{34}\text{S}$ ($\Delta_{\text{mean}} =$
 28 3.2‰) values than those from CLP (Figure 7B). Generally speaking, VPB is more isotopically
 29 similar to other Cerny sites than CLP, while CLP shares more affinity with the non-Cerny group
 30 in all C, N, and S isotope values.

31 Among the non-Cerny group (GLN and MON), despite the two sites are located in close
 32 proximity to each other ($< 3\text{km}$), there are strong differences in the means of $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$
 33 values between the two sites (t-tests; $\delta^{13}\text{C}$: $p = 0.097$; $\delta^{15}\text{N}$: $p < 0.001$; $\delta^{34}\text{S}$: $p = 0.001$).
 34 Individuals from GLN have higher mean $\delta^{15}\text{N}$ ($\Delta_{\text{mean}} = 0.9\text{‰}$) and lower mean $\delta^{34}\text{S}$ ($\Delta_{\text{mean}} =$
 35 2.2‰) values than those from MON (Figure 7C).



1
 2 *Figure 7 Significant isotopic comparison within groups: A. Comparison between the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of individuals from the*
 3 *Cerny STP sites; B. Comparison between the $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values of individuals from the Cerny Flat sites; C. Comparison*
 4 *between the $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$ values of individuals from the non-Cerny sites. ● corresponds to original data from this study; ▲*
 5 *corresponds to data obtained from published reports. VNF and VPB data have been adjusted for the baseline shift.*

6 Results show that all $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ values in humans are significantly different
 7 among the two types of Cerny monumental necropolises, Cerny STP and Cerny Slab (Figure 8).
 8 Comparing to those buried in Cerny STP cemeteries (i.e. BLR, VNF, PR, PLS, GLS), those
 9 buried in Cerny Slab (i.e. OLF) have significantly elevated mean $\delta^{13}\text{C}$ (t -test: $\Delta_{\text{mean}} = 0.3\text{‰}$, $p <$
 10 0.001) and $\delta^{34}\text{S}$ values (t -test: $\Delta_{\text{mean}} = 0.9\text{‰}$, $p = 0.049$), and relatively depleted mean $\delta^{15}\text{N}$ value
 11 (t -test: $\Delta_{\text{mean}} = 0.7\text{‰}$, $p < 0.001$).

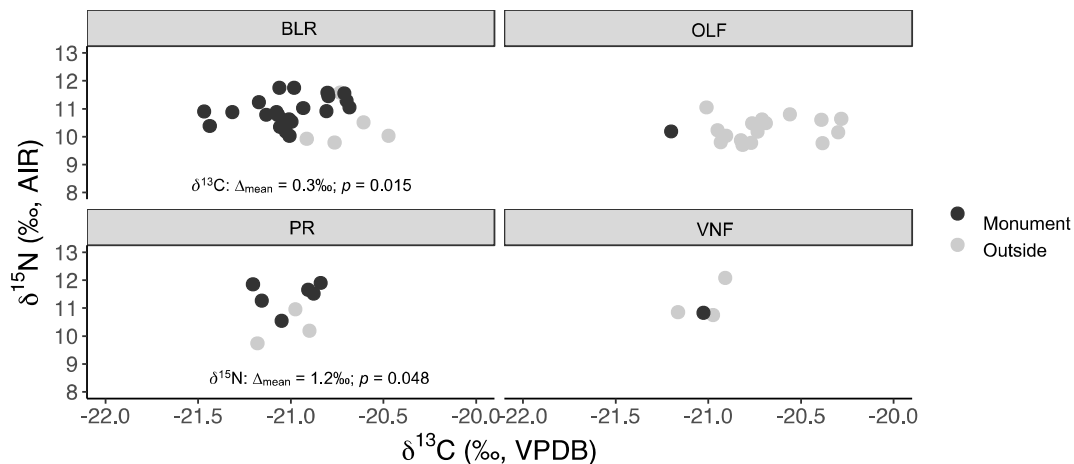


1
2 Figure 8 Comparisons between the two types of monumental necropolises in Paris Basin. Cerny Slab refers to OLF, Cerny STP
3 refers to BLR, VNF, PR, PLS, and GLS. All data are original data from this study. VNF data have been adjusted for the baseline
4 shift.

5
6 **4.2.2 Intra-site comparisons**

7 Location of burials

8 A total of six monumental cemeteries (STP or Slab) are involved in this study. For four of these
9 cemeteries (BLR, OLF, PR, and VNF), some burials are located outside of the monumental
10 structures. We compare the C, N, and S isotope compositions among individuals being buried
11 within and outside of the monumental structures from these four sites, respectively (Figure 9).
12 There is statistically significant difference in the mean $\delta^{13}\text{C}$ values between those buried within
13 and outside of monumental structures in BLR (Wilcoxon; $p = 0.02$), as well as in $\delta^{15}\text{N}$ values in
14 PR (Wilcoxon; $p = 0.05$). No difference can be observed in the mean $\delta^{34}\text{S}$ values between the
15 two groups at all four sites.

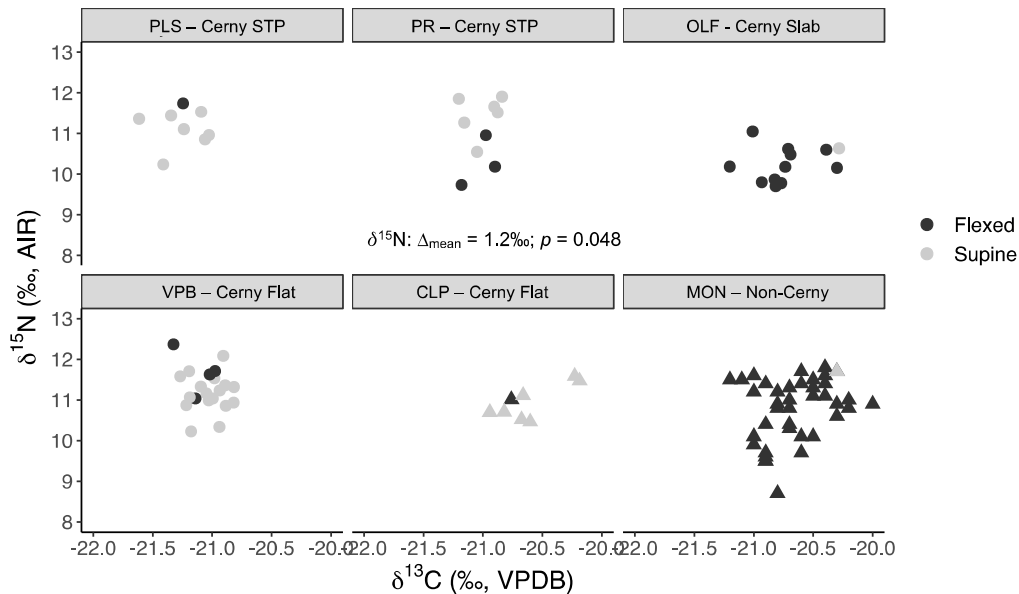


16
17 Figure 9 Comparisons between locations of burial in regard to monumental structure(s) in each cemetery. All data are original
18 data from this study. VNF data have been adjusted for the baseline shift.

1 Burial positions

2 No difference can be observed in the mean $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values between the two types of burial
3 positions (supine vs. flexed) at all six sites. However, in PR, those buried in a flexed position
4 have statistically lower mean $\delta^{15}\text{N}$ values than those buried in a supine position (Wilcoxon; Δ_{mean}
5 = 1.2‰, $p = 0.048$) (Figure 10). Note that the individual buried in supine position in MON is the
6 individual buried in a Balloy-type grave (#04-99).

7



8

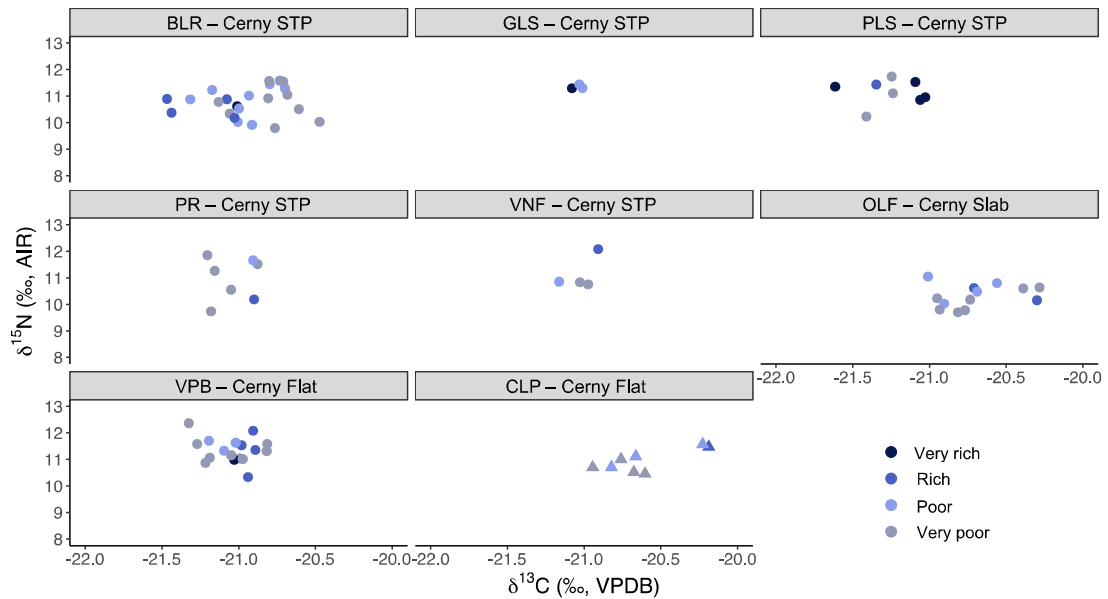
9 *Figure 10 Comparisons between burial positions in each cemetery. ● corresponds to original data from this study; ▲*
10 *corresponds to data obtained from published reports. VPB data have been adjusted for the baseline shift.*

11

12 Burial goods

13 Following the discussions on the symbolic meanings of Neolithic grave goods in Europe
14 (Augereau and Chambon 2003; Salanova 1998), individuals are categorized into four groups
15 according to the quantity and quality of (non-perishable) burial goods (Thomas 2011:577-579;
16 Thomas and Chambon 2018). Only Cerny sites are considered for this analysis. Quality of burial
17 goods can be divided in two broad groups: “common” and “precious”, according to the energy
18 required to procure the object (i.e. labour-intensive production, or involve exotic raw materials)
19 and the rarity of the object among Cerny burials generally. Common objects include flint blades,
20 raw flakes, and bone awls. While precious objects include complete ceramics, ornament made
21 from bones of wild animals (e.g. bear, wolf, boar, deer), and a type of triangular bone spatula
22 found uniquely in STP burials called the “Eiffel tower” spatula. The four categories are roughly
23 as follow: very rich (5 or more common goods or at least one precious object), rich (3 to 5
24 common objects or at least one object made of multiple elements, e.g. neckless made of
25 numerous beads), poor (less than 3 common objects), and very poor (no grave good). For more
26 detailed descriptions of grave goods found with each individual, please refer to Supplement S5.

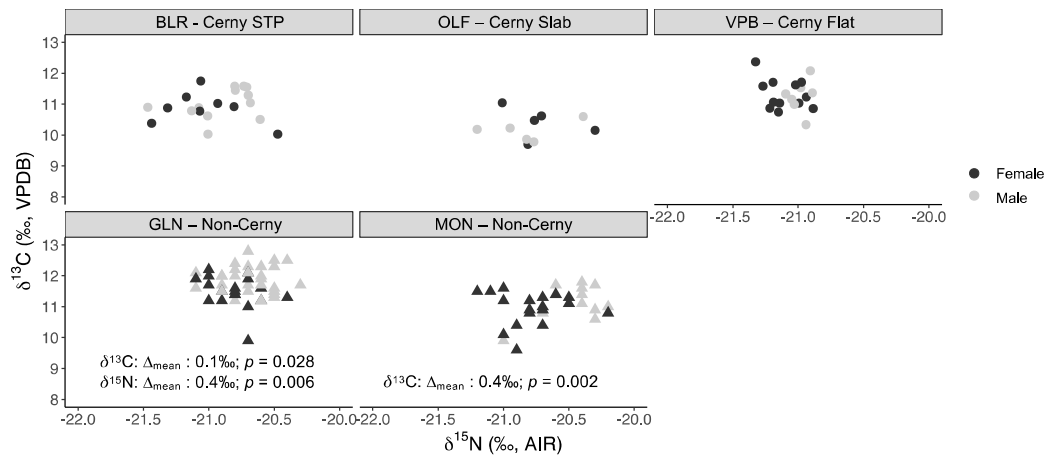
1 As shown in Figure 11, there is no obvious trend observed among those buried in varying
 2 degrees of grave good richness, except for BLR (Kruskal-Wallis $\delta^{13}\text{C}$: $p = 0.016$), where a post-
 3 hoc Dunn's test reveals that the strongest difference is observed between the rich and the very
 4 poor ($\Delta_{\text{mean}} = 0.5\text{‰}$, $p = 0.003$). No difference can be observed in the mean $\delta^{34}\text{S}$ values among
 5 all level of burial good richness at all seven sites.
 6



7
 8 *Figure 11 Comparisons among individuals with varying degree of burial good richness in each cemetery. ● corresponds to*
 9 *original data from this study; ▲ corresponds to data obtained from published reports. VNF and VPB data have been adjusted*
 10 *for the baseline shift.*

11
 12 Sex

13 Only sites with at least 5 of each sex are considered in this comparison. Wilcoxon tests reveal
 14 that statistically significance differences in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values are only observed in the two
 15 Non-Cerny sites (Figure 12). No difference can be observed in the mean $\delta^{34}\text{S}$ values between the
 16 two sexes at all five sites.
 17



1
2 Figure 12 Comparisons between the two sexes in each cemetery. ● corresponds to original data from this study; ▲ corresponds
3 to data obtained from published reports. VPB data have been adjusted for the baseline shift.

4 5 5. Discussion

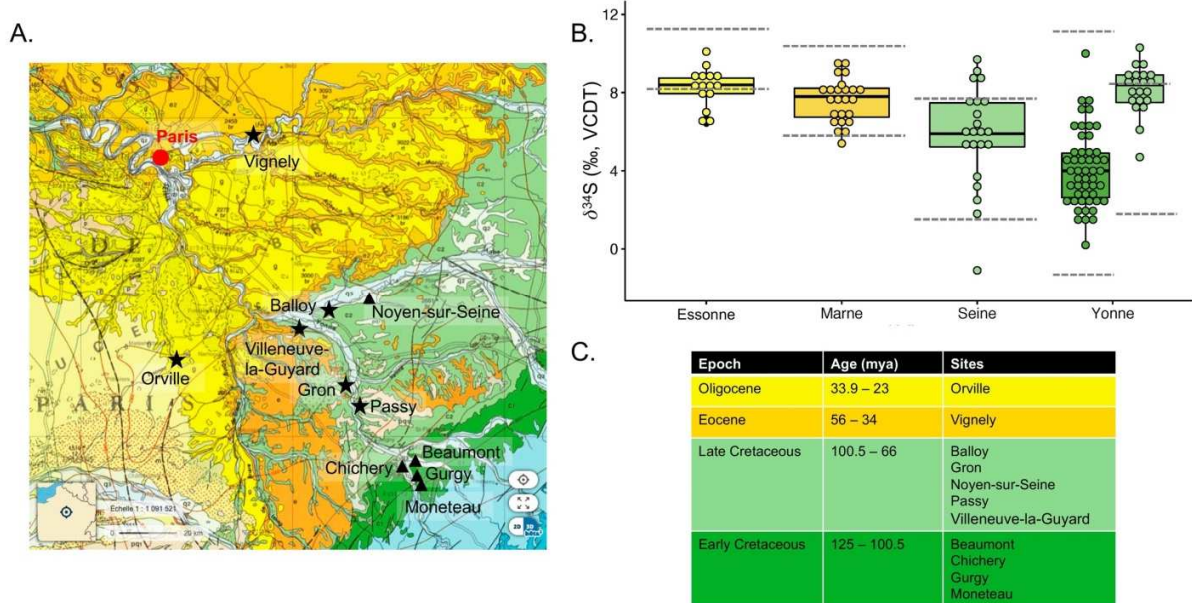
6 5.1 $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ baselines

7 While it is possible to separate the fauna by general feeding patterns (i.e. herbivory, omnivory,
8 and carnivory), most of the species have significant overlapping $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ values
9 (Figure 5). Accordingly, it is not possible to qualify or quantify the proportion of different
10 animal species in the human diets. Hence, the subsequent discussion of human dietary patterns
11 will refrain from making specific inferences about the respective proportion of each dietary
12 component. A comparison of faunal isotope measurements from 14 Mesolithic and Neolithic
13 sites from six river valleys suggested that the geographic variability in the $\delta^{13}\text{C}$ baseline in Paris
14 Basin is relatively limited. Some regional patterns can be observed in the $\delta^{15}\text{N}$ values, notably
15 from Marne valley (Figure 3). This issue should be rectified after applying the baseline
16 adjustment on the human data from the Marne valley as calculated by Equation (1). Hence, all
17 differences observed in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of humans presented in this study should reflect
18 actual differences in dietary patterns.

19 The $\delta^{34}\text{S}$ baseline of the region is much more complicated. At first glance, there is no
20 apparent pattern observed when only terrestrial faunal $\delta^{34}\text{S}$ values are considered (Figure 4A).
21 However, when all human and (terrestrial) faunal data are plotted together, it appears that the
22 terrestrial $\delta^{34}\text{S}$ baseline does roughly corresponds with the underlying geological formations
23 (Figure 13). The bedrocks of the region are mostly consisted of later Mesozoic (Cretaceous) and
24 early Cenozoic (Eocene and Oligocene) formations. Figure 13 shows that elevated $\delta^{34}\text{S}$ values
25 are associated with younger bedrocks, where more depleted $\delta^{34}\text{S}$ values are associated with older
26 bedrocks.

27 Therefore, the difference in mean $\delta^{34}\text{S}$ values observed between Cerny and non-Cerny
28 groups (Figure 6B) was likely due to geological, rather than cultural factors. While all sites in the

1 Yonne valley are located on Cretaceous age bedrock, the sites in the upper Yonne valley (CLP,
 2 BMT, GLN, and MON) are situated on older formations than those in the lower Yonne valley
 3 (VLG, GLS, PR, PLS) (Figure 13). This also explains how CLP, a Cerny Flat site located on the
 4 same geological formation as the non-Cerny sites, has mean $\delta^{34}\text{S}$ value more similar to those
 5 from the non-Cerny sites than those from the Cerny sites (Table 3).



6
 7 *Figure 13 Establishing a sulfur baseline for the Paris Basin region: A. geological map of the region obtained from Géoportail*
 8 *(<https://www.geoportail.gouv.fr/>), indicating the locations of sites mentioned in this study with reference to the modern city of*
 9 *Paris. ★ corresponds to sites with original sulfur data, ▲ corresponds to sites with sulfur data from published reports. B.*
 10 *boxplot showing $\delta^{34}\text{S}$ values of humans from the four valleys, colour coded by the underlying geology of each respective site.*
 11 *Grey dotted lines indicate the range of standard deviations from the means of terrestrial faunal data from each valley. C. table*
 12 *showing the age of the four major types of bedrock in concern. For references of published data please refer to Table 1 (for*
 13 *human data) and Table 2 (for faunal data).*

14
 15 While the differences in $\delta^{34}\text{S}$ values between domestic and wild animals (Figure 4B) in
 16 three of the four valleys are significant, the largely overlapping ranges made it difficult to use it
 17 to detect casual consumption of wild animal protein. However, this observation may offer a
 18 novel avenue to examine animal husbandry practices in the region. For example, the ranges of
 19 $\delta^{34}\text{S}$ values observed among the domesticates (Figure 4A) could indicate different husbandry
 20 regimes: those characterised by a smaller range of $\delta^{34}\text{S}$ values among the domesticates, such as
 21 BLR (σ : 1.7‰) could indicate a relatively heavy-handed management approach, while sites with
 22 larger $\delta^{34}\text{S}$ ranges (e.g., σ_{BMT} : 7.8‰; σ_{GLN} : 3.9‰) may be indicative of a “free-range” approach,
 23 where livestock were raised over a larger area, potentially crossing over to regions with different
 24 geological bedrocks (Rey, et al. 2019). While current evidence is only limited to stable sulfur
 25 isotope data, and that not all faunal remains were directly associated with the cultural groups
 26 analysed, this interpretation remains speculative, but more research on this topic may yield
 27 further insight into animal husbandry practices in the region.

1 In theory, this pattern in $\delta^{34}\text{S}$ baseline should allow us to identify possible non-locals
2 based on outlying $\delta^{34}\text{S}$ values in humans. Unfortunately, S isotope measurements are only
3 available from freshwater resources from the Seine River. $\delta^{34}\text{S}$ values in freshwater systems are
4 known to be extremely variable and fluctuate greatly depending on seasonality, geology, and
5 proximity to other water sources. For example, the $\delta^{34}\text{S}$ values of a 1,050 km stretch of the
6 Danube water can range from +2.8 to +17.1‰ (Nehlich, et al. 2010; Pawellek, et al. 2002). A
7 much smaller river, the river Arno (~240km) in northern Tuscany, Italy, has $\delta^{34}\text{S}$ values between
8 -10.9 and +16.3‰ (Cortecci, et al. 2002). In the Seine River, even just within the small stretch
9 between BLR and Noyen-sur-Seine (< 20km), the mean $\delta^{34}\text{S}$ values of freshwater resources is
10 quite large (Noyen-sur-Seine: $-15.4 \pm 3.2\text{‰}$; BLR: -7.1‰). Thus, without S isotope
11 measurements from other rivers in the region, we remain sceptical regarding using $\delta^{34}\text{S}$ values to
12 evaluate palaeomobility activities within the Paris Basin region. Having said that, Figure 4B and
13 Figure 5B show that freshwater resources in the Seine have evidently more negative $\delta^{13}\text{C}$ and
14 $\delta^{34}\text{S}$ values than those from the terrestrial systems. Therefore, it is possible to argue that
15 relatively negative $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values in humans may be indicative of freshwater resources
16 consumption, at least in sites along the Seine River.

17

18 **5.2 Subsistence economy and general dietary patterns in the Paris Basin region**

19 Generally speaking, the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of all humans fall within the expected range
20 of groups that subsisted primarily on C_3 terrestrial resources (Figure 5). Constrained by the lack
21 of baseline data from the Essonne, Marne, and Yonne rivers, the consumption of freshwater
22 resources can only be evaluated at BLR. The extremely tight range in the $\delta^{13}\text{C}$ values of the BLR
23 community ($\delta^{13}\text{C}$: $-21.0 \pm 0.3\text{‰}$) suggested that the group likely obtained most of their dietary
24 protein from a restrictive source, which likely came from the terrestrial ($\delta^{13}\text{C}$: $-22.1 \pm 1.2\text{‰}$)
25 rather than freshwater system ($\delta^{13}\text{C}$: $-24.7 \pm 2.0\text{‰}$). A weak correlation between the $\delta^{13}\text{C}$ and
26 $\delta^{34}\text{S}$ values ($R = 0.45$, $p = 0.17$) further substantiated the proposition that freshwater resources
27 likely did not constitute a major component of the BLR diet.

28 A comparison between the dietary breadths of the Cerny and non-Cerny groups suggested
29 that the dietary practices of the Cerny groups were more standardized. As shown in Figure 5 and
30 Table 4, despite occupying a much smaller geographical range, the isotopic variation of the Non-
31 Cerny group is considerably larger than those of the Cerny group. One explanation is that the
32 Cerny groups were more socially and economically organized than the non-Cerny groups. By
33 definition, the practice of agriculture directs all (or most) food production labour into producing
34 a smaller range of food products (plants and animals) more efficiently. As a result, agricultural
35 societies tend to enjoy improved quantity, but reduced diversity of food (Dudley and Alexander
36 2017). Thus, the relatively homogeneity in isotopic composition among the Cerny sites may have
37 reflected a standardized dietary pattern associated with an agricultural-dependent lifestyle. This
38 pattern is especially stark among the Cerny STP group, as comparing to inter-group differences
39 among the Cerny flat and non-Cerny groups (Figure 7). This suggests that despite being scattered
40 across three river valleys, the Cerny STP group is strongly connected through burial practices,

1 social organizations, as well as subsistence economy. Moreover, isotopic evidence agrees with
2 other archaeological evidence, that among the Cerny flat group, VPB was likely more closely
3 associated with the Cerny STP group than CLP.

4 While it is not possible to further quantify the specific dietary components of these
5 Middle Neolithic communities, a general comparison between the mean $\delta^{15}\text{N}$ values of the Cerny
6 humans ($+11.5 \pm 1.2\text{‰}$; baseline adjustment for the Marne humans not applied) and those of the
7 overall fauna revealed that the humans have comparable mean $\delta^{15}\text{N}$ value with those of the
8 carnivores ($+11.0 \pm 1.6\text{‰}$), and much higher than those of the omnivores ($+8.2 \pm 1.5\text{‰}$) and
9 herbivores ($+6.6 \pm 1.2\text{‰}$). Considering that the diet–tissue trophic enrichment factor is typically
10 assumed to be around 3–5‰ per trophic level (Bocherens and Drucker 2003; Hedges and
11 Reynard 2007), the large spacing between the mean $\delta^{15}\text{N}$ values of human and fauna suggested
12 that all these communities consumed a considerable amount of animal protein.

13 Furthermore, a study that looked at the oral health of a total of 10 Cerny sites in the Paris
14 Basin region (n=160) revealed the raw frequency of carious teeth among the Cerny population is
15 more in line with hunter-gatherer groups (Thomas 2011:522). Dental caries is often associated
16 with a high consumption of cariogenic foods, such as cereals (Gupta, et al. 2013; Lingstrom, et al.
17 2000; Moynihan 2016; Selwitz, et al. 2007; Tayles, et al. 2009). Therefore, it is argued that the
18 occurrence of dental caries tends to be higher in agricultural populations than in hunter-gatherer
19 groups (Cohen and Armelagos 1984; Larsen 1995; Powell 1985; Temple and Larsen 2007). The
20 overall prevalence of dental caries among the Cerny groups is relatively low (4.1%) comparing
21 to agricultural populations (3 – 40%), and is more comparable with hunter-gatherer populations
22 (0.1 – 8%) (Caselitz 1998; Larsen, et al. 1991; Walker and Hewlett 1990). Thus, the Cerny
23 groups were likely agricultural groups that relied heavily on animal protein.
24

25 **5.3 Inter-site comparisons**

26 Regarding the two different types of monumental Cerny sites, other than the types of
27 funerary monuments, the most significant distinction between Cerny STP and Cerny Slab burials
28 are the burial positions. Burials in Cerny STP sites are typically buried in a supine position,
29 where burials in Cerny Slab sites are typically buried in a flexed position. Many archaeologists
30 working in the region agree that the supine position likely reflected incoming influence from the
31 Rhine basin's *Mittelneolithikum* cultures (Boës 2003; Chambon, et al. 2007; Chambon and
32 Thevenet 2016; Jeunesse 1997; Mordant 1997; Simonin, et al. 1997), while the flexed burial
33 position could be attributed to several cultures, based on the similarity in burial practices and
34 other archaeological evidence, some archaeologists believe that there are links between the
35 Cerny Slab site of OLF with those from the local Early Neolithic Blicquy/Villeneuve-Saint-
36 Germain (BVSG) cultures (Simonin, et al. 1997). As shown in Figure 8, individuals buried in
37 Cerny Slab (i.e., OLF) have very different isotopic compositions comparing to those buried in
38 Cerny STP (i.e. BLR, VNF, PR, PLS, GLS). While differences in $\delta^{34}\text{S}$ values can be explained
39 by geology (Figure 13), differences in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values are likely related to diets. The
40 difference in the mean $\delta^{15}\text{N}$ values between the two groups suggested the Cerny Slab group

1 either consumed less animal protein, or that their dietary protein was obtained from lower trophic
2 animals (i.e. herbivores), than those from Cerny STP sites (Figure 8). Without the $\delta^{13}\text{C}$ baseline
3 of all major food groups, especially those from plants, the difference in $\delta^{13}\text{C}$ values is harder to
4 explain. Nevertheless, based on isotopic evidence, it is clear that the two groups had
5 systematically distinctive dietary practices. Thus, if burial positions are in fact indicative of
6 cultural origins, our results would suggest that these two lines of cultural origins also differ
7 strongly in terms of subsistence economy. Even though our current data cannot fully explain the
8 difference in isotopic compositions between the two types of Cerny sites, the observation is
9 nonetheless thought-provoking, and raise further questions about the current cultural
10 categorizations of communities in Middle Neolithic Paris Basin. What does being part of the
11 Cerny culture really mean? An osteological study done by Thomas (2011) reported that
12 individuals from the Cerny Slab contexts (OLF + Malsherbes “La Chaise” + Malesherbes “Les
13 Marsaules”) were taller than the rest of the Cerny populations (Cerny STP + Cerny Flat). Further
14 distinctions in skull morphology were also observed and confirmed with multivariate statistical
15 analyses (Thomas 2011:494-501). All these seem to suggest that other than dietary and burial
16 practices, individuals from the Cerny Slab context may also be biologically different than those
17 from other Cerny contexts.

18

19 **5.4 Intra-site comparisons**

20 It is presumed that sites with monumental structures, i.e. Cerny STP and Cerny Slab, would have
21 stronger social differentiations than those without, i.e. Flat sites (with or without Cerny
22 component). In many archaeological cultures, hierarchy in socio-economic status is sometimes
23 reflected in dietary patterns. A common phenomenon is that individuals of higher socio-
24 economic status – as represented by richer grave goods and/or elaborate tomb structures –
25 consume a higher proportion of animal protein, and hence have higher $\delta^{15}\text{N}$ values than those
26 from a lower social class (Ambrose, et al. 2003; Cheung, et al. 2017b; Le Huray and
27 Schutkowski 2005; Pearson, et al. 2013). However, this is not the case here. As shown in Figure
28 9 and Figure 11, the relationships between $\delta^{15}\text{N}$ values and funerary arrangements are erratic,
29 suggesting that social differentiation at Cerny sites were not necessarily related to the amount of
30 animal protein intake. Another interesting observation is that individuals who were buried in a
31 “special arrangement” – whether it be buried within the monuments (Figure 9) or buried in a
32 position that was not the “norm” within the site (Figure 10) – also have distinctive isotopic
33 compositions comparing to the rest of the group. While the sample sizes of these aberrant burials
34 are generally too small for the difference to be picked up by statistical tests, the pattern is
35 unmistakable. These burial arrangements clearly reflected certain aspects of the buried
36 individual’s background, including diets, were different from the rest of the group. Nevertheless,
37 it is important to stress that in the Middle Neolithic Paris Basin, social-economic status, as
38 reflected by the variety of the burial features, cannot be merely explained, nor described by the
39 quantity of animal protein intake, but the association between social groups and dietary practices
40 was both complex and contentious.

1 Furthermore, there is no consistent pattern in the isotopic compositions of individuals
2 buried in different burial positions within sites (Figure 10). For example, both PLS and PR are
3 Cerny STP sites, where individuals were predominately buried in a supine position. However,
4 the flexed burial in PLS has the highest $\delta^{15}\text{N}$ value among all, while those from PR has
5 statistically significant lower $\delta^{15}\text{N}$ values than the rest of the community (Figure 8). The sample
6 size of our dataset is too small to draw any definite conclusions, however it is possible that the
7 factors involved in determining burial positions could be different on the intra- and inter-site
8 levels.

9 The individual (adult male) from MON buried in a Balloy-type grave (supine position;
10 #04-99) had relatively elevated $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values comparing to the rest of the MON
11 population (Figure 10). However, his isotopic measurements are completely outside of the
12 “Cerny” convex hull (Figure 6A). This suggested that his diet was not particularly similar to
13 those coming from the Cerny groups. More isotopic as well as archaeological evidence will be
14 needed to better explain this individual’s particular burial arrangement.

15 Last but not the least, it is important to point out that while there is no difference
16 observed in the dietary patterns between the two sexes in any of the Cerny sites, the opposite is
17 observed in the two Non-Cerny sites (Figure 12). Even though the original report stated that the
18 differences between the sexes are not clearly distinct but only showed “a slight tendency” (Rey,
19 et al. 2019), statistical tests revealed that the differences are indeed significant, which is
20 particularly notable given the isotopic variations of all food sources in this region are rather
21 limited. This difference is surprising in two ways. First, Thomas (2014b) reported that funerary
22 arrangements in Cerny STP sites were highly gendered: monumental structures were sex-specific,
23 and certain grave goods, specifically hunting equipment, were always associated with males.
24 Thus, some differences in the dietary patterns between the two sexes among the Cerny sites are
25 expected. The fact that there is no discernible distinction between the isotopic compositions of
26 the two sexes in any Cerny sites suggests that the “gendered” treatment of males and females did
27 not extend to diets. This is further supported by oral health data, which revealed that males and
28 females in Cerny sites suffered similar level of dental pathologies (Thomas 2011). Thus, among
29 Cerny groups, the two sexes may have different treatments/ status after death, but in life, the two
30 sexes received similar sustenance, at least in terms of macronutrients intake. Secondly, the
31 differences observed between the males and females in GLN are mostly in $\delta^{15}\text{N}$ values, while the
32 differences in MON are mostly in $\delta^{13}\text{C}$ values (Figure 12). Note that GLN and MON are located
33 within 3km from each other with overlapping chronologies (Chambon, et al. 2004). Thus, the
34 differing isotopic compositions in male vs. female diets in non-Cerny sites are clearly not
35 geological, but reflected differences in dietary compositions between the two sexes at these sites.
36 Unfortunately, with current data it is not possible to make explicit inferences about the dietary
37 differences of the two sexes at these sites.

1

2 **Conclusion**

3 This study uses stable carbon, nitrogen, and sulfur isotope analysis to reconstruct and compare
4 the past dietary patterns of individuals from 10 Middle Neolithic sites in Paris Basin. Eight of the
5 sites belong to the predominant culture in the region, the Cerny culture, where two of the sites
6 show significant non-Cerny components. Due to the lack of samples from certain key source
7 groups (i.e. plants and freshwater resources), we are not able to evaluate the subsistence
8 economy of both Cerny and non-Cerny groups in more specificity. Nevertheless, our results have
9 showed that comparing to the non-Cerny groups, Cerny groups, especially STP groups, had
10 relatively standardized diets. In addition, all groups consumed a considerable amount of animal
11 protein. The accessibility of animal protein, therefore, likely explain why the amount of animal
12 protein consumed was not related to one's social-economic standing.

13 Furthermore, our results have demonstrated that during the Middle Neolithic period, the
14 Paris Basin region was a highly dynamic and culturally diverse region. While the cultural sphere
15 was dominated by Cerny culture during this time, it is important to stress that "Cerny culture"
16 was consisted of a number of subgroups, notably expressed through different funerary
17 arrangements. Of the four main types of groups analysed in this study, the Cerny STP group
18 (BLR, VNF, GLS, PLS, PR) stood out as a tight knitted group with relatively standardized burial
19 practices, social organizations, and dietary practices. For the Cerny Flat group, VPB is
20 isotopically and archaeologically more similar to the STP group than CLP. The two "Non-Cerny"
21 sites (GLN, MON) shown strong intra-group differences, suggesting this group was less strictly
22 organized. Moreover, the Cerny Slab group was unique in many ways. Despite being categorized
23 as a Cerny site, most of the individuals were buried in a flexed position – an unusual practice
24 among Cerny cemeteries. Previous published osteological evidence also put forward the
25 proposition that Cerny Slab group were likely culturally and biologically different from the other
26 Cerny groups. Our stable isotope data from OLF, a Cerny Slab site, also shows statistically
27 significant distinctions comparing to other Cerny sites. Future works comparing other aspects of
28 the Cerny Slab group with other Neolithic populations will allow a more comprehensive
29 evaluation of the nature of this group.

30 On an intra-site level, we observed that most of the aberrant burials – burials that do not
31 conform to the general funerary pattern at a particular site – have outlying stable isotope
32 measurements. However, there is no clear pattern between burial patterns and dietary practices.
33 Therefore, it is not clear how do all these different burial patterns translate in terms of social
34 organization. Nevertheless, it is clear that certain lifestyles (i.e. expressed in outlying stable
35 isotope compositions) and distinctions were carried through after one's death and expressed as
36 differing burial patterns. Interestingly, there is no sex-based difference in all three stable isotope
37 measurements observed among all Cerny groups. This shows that even though Cerny men and
38 women were treated differently after death, they likely had similar access to food resources in
39 life. The opposite is observed in the non-Cerny groups.

1 This study has provided a basis for examining the social-cultural diversity in Middle
2 Neolithic Paris Basin within the interconnecting spheres of culture, geography, and biology.
3 Future studies should try to establish a more comprehensive baseline database of the region, or
4 even consider additional analytical approaches, such as dental wear, strontium isotope ($^{87}\text{Sr}/^{86}\text{Sr}$),
5 or compound specific isotope analyses, to better elucidate the relationship between dietary
6 practices and social organizations in these sites.
7

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18
19

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