

PREHISTORIC FOOD BEHAVIOURS AND PHYSICAL ANTHROPOLOGY IN THE NORTHWESTERN MEDITERRANEAN

Comportamientos alimenticios prehistóricos y Antropología Física en el Mediterráneo Noroccidental

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ABSTRACT This paper aims to give an overview (non-exhaustive) of the application of biogeochemical methods, particularly stable isotopes, to understand human palaeodiet, its modifications along times and according to environment and cultural choices. Food study is a favoured way to understand human societies and their behaviours, and past populations must be studied by a variety of methods and disciplines. Most commonly, human palaeodietary study is carried out through to anthropological remains (*eg.* specific pathologies, health status) and archaeological material but for few decades now, biogeochemical analyses, specifically stable isotope ones, are routinely included in numerous researches. In the Mediterranean, a lot of studies have focused on Prehistoric periods. Among other things, the application of biogeochemical methods have highlighted the diversity of environments exploited by Palaeolithic hunter-gatherers, the dietary changes occurring during the Mesolithic-Neolithic in coastal areas, the development of agricultural practices during the Neolithic, as well as the variability of food choices according to regions and the introduction of millet in Bronze Age human and animal diet.

Key words: Prehistory, Mediterranean, Europe, Diet, Physical Anthropology, Stable Isotopes.

RESUMEN Este artículo tiene el objetivo de proporcionar una visión general (no exhaustiva) de la aplicación de métodos biogeoquímicos, concretamente de isótopos estables, a la comprensión de la paleodieta humana, sus modificaciones a lo largo del tiempo y en relación al medio ambiente y las opciones culturales. El estudio de la dieta es un camino privilegiado a la comprensión de las sociedades humanas y sus comportamientos, y las poblaciones del pasado deben ser estudiadas por una combinación de diferentes métodos y disciplinas. Generalmente, el estudio paleodietético humano se ha llevado a cabo gracias a los restos

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antropológicos (patologías concretas, nivel de salud) y al material arqueológico pero, desde hace pocas décadas, los análisis biogeoquímicos, concretamente el de isótopos estables, se han incluido de forma habitual en numerosas investigaciones. En el Mediterráneo, una gran cantidad de estudios se ha centrado en periodos prehistóricos. Entre otras cosas, la aplicación de métodos biogeoquímicos ha destacado la diversidad medioambiental explotada por los cazadores-recolectores paleolíticos, los cambios dietarios a lo largo de las regiones costeras del Mesolítico-Neolítico, el desarrollo de las prácticas agrícolas y las opciones alimenticias según las regiones durante el Neolítico y la introducción del mijo en la dieta humana y animal en la Edad del Bronce.

Palabras clave: Prehistoria, Mediterráneo, Europa, Dieta, Antropología Física, Isótopos estables.

INTRODUCTION

Food study is a favoured way to understand human societies and its behaviours, whatever the time period considered. Relationships between dietary habits and cultural and economic choices are extremely strong. Food origin, environment exploited, cooking way reflect ancient or recent traditions, religious recommendations, medical treatments, taboos, for example. Some current examples illustrate this assumption: in Mauritania, women force-feeding still an important practice to show wealth and opulence. Individual dietary habits could be also modified according to social or economical circumstances as food shortage (due to environmental conditions or social crisis as war) or production cost increase of staple food (*eg.* meat, cereal). The understanding of human dietary practices mainly lies in which, how much, how and why. Which aliments are consumed, how important they are in the diet, how they are cooked or which part is eaten, and are these practices linked to specific factors. Past populations, as current ones, must be studied by a combination various methods and disciplines in order to get the widest database possible. For a few decades now, archaeology and physical anthropology have been applied different methodologies from environmental and physical sciences, among other things. It concerns all archaeological materials from ceramics and organic residue analysis to different biological remains as soft tissue or coprolite for example. With time, improving techniques have made these technologies more precise and to require smaller samples. Among these methods, biogeochemical analysis of bone remains allow getting specific information on individual diet, whatever the species considered, human or animals. Compared to archaeological (as funeral practices) and environmental data (*eg.* archeobotanic, archaeozoology) these analysis bring essential datasets in palaeodietary and human/environment relationship studies.

As for other regions, Northwestern Mediterranean area is the subject of specific dietary research from the eighties, a period from which physical anthropological studies and “anthropologie de terrain” has been significantly developed (Formicola, 1986; Formicola *et al.*, 1987). New bioarchaeological methods, osteological analysis and biogeochemical applications lead to an integrated way of research (Francalacci, 1988, 1989; Francalacci *et al.* 1988).

This paper presents an overview of different specific palaeodietary studies and the use of biogeochemical methods performed in the Northwestern Mediterranean from the Upper Palaeolithic to the Bronze Age. Considering the substantial development

of this approach within the last years, this presentation is not exhaustive but aims to highlight the importance of data combination and the consideration of environment in palaeodietary researches and also presents some studies conducted recently.

ANTHROPOLOGICAL METHODOLOGIES

Human remains and dietary evidences

Most commonly, human palaeodietary study is carried out through archaeological material (*eg.* ceramics, textual and iconographic sources, faunal and botanical remains. When human remains (burial or non burial) are present at an archaeological site, it allows getting other dataset giving complementary information for an individual and a group (Larsen, 1997; Duda, 2006).

In most cases, archaeological human remains consist in hard tissues, i.e. bone and teeth. When preservation conditions are optimal, these remains can pass information on health status, sometimes in relation with food habits and/or dietary disorders. Oral health status is one of the most conclusive. Teeth, oral pathologies and growth disorders are direct witnesses, as caries, calculus and periodontal damage favoured by and developed due to food intake (*eg.* carbohydrates and alkaline food). Enamel hypoplasia, growth cessation of dental enamel production visible on the crowns, could also be linked to diet disruption (Goodman and Rose, 1991; Aufderheide *et al.*, 1998; Lieverse, 1999; Esclassan *et al.*, 2009).

Tooth wear, evaluated by different method, usually using the degree of occlusal surface abrasion (*eg.* Smith, 1984), is a good indicator of the abrasive food consumed, as cereal (more or less abrasive according to the grinding millstone). Indeed, vegetal has phytoliths, specific according to the species, which leave traces identifiable by scanning electron microscopy (SEM). The SEM is also used by anthropologists to highlight other microgrooves left by meat consumption for example (Molleson and Jones, 1991). Bones also bring much information potentially linked to diet. As hypoplasia, Harris lines are non specific stress markers, visible by radiography on long bones, which could be increased by nutritional deficiencies (starvation, malnutrition).

On the cranium, bone porosities located in the orbits and/or on the vault are called respectively cribra orbitalia and cranial porotic hyperostosis. These bone modifications could result from iron and vitamins B12 deficiencies in relation to infectious diseases, poor sanitation and/or malnutrition as animal products deficiencies (Stuart-Macadam, 1985; Walker and Hewlet, 1990; Aufderheide *et al.*, 1998). A few other severe vitamin deficiencies leave specific marks on bones. This is the case of the lack of vitamin-D and vitamin-C, still present in numerous current populations from developing nations. Deformed and bowed lower limb long result from calcification defect due to vitamin-D deficiency, and subperiosteal hemorrhages as well as tooth loss testify of vitamin-C one (Aufderheide *et al.*, 1998). Moreover, general health status determined by a thorough examination of the whole skeleton and its pathologies could inform on social status, activities and possible food patterns (*eg.* DISH could be linked to meat and

fat consumption sometimes visible on remains from ecclesiastic context (*eg.* Waldron, 1985; Villotte and Kacki, 2009).

To supplement these data, palaeoparasitology, more routinely developed from ca. 20 years ago, allows reconstructing the evolution of relationships between human and parasites and thus provide information on diet, cooking modes and health conditions (Harter and Bouchet, 2002; Carvalho Gonçalves *et al.*, 2003). Indeed, several parasites (*eg.* *Taenia*) found in evacuations or burial soils for example, revealed the consumption of infected food, more often caprid/pig meat or fish (Bouchet, 2002). Finally, in specific cases of body preservation, food habits can be documented thanks to stomach content.

Dietary practices and biogeochemical studies

From the last decades stable isotope analysis from bone and dental remains is routinely included in numerous anthropological and archaeological studies. The measurement of stable isotope ratios in bone and teeth notably showed successful results to determine individually the protein and total energy consumed by animal species including human. The bone and teeth are composed of both organic (mainly collagen) and inorganic matter (mainly hydroxyapatite) with specific stable isotope ratios according to the environment exploited and the type of food consumed (Ambrose, 1993). The protein fraction of the diet is recorded in collagen through carbon ($\delta^{13}\text{C}_{\text{coll}}$), nitrogen ($\delta^{15}\text{N}$), and sulphur isotope ratios ($\delta^{34}\text{S}$). The total energy consumed is recorded in mineral part mainly through carbon isotope ratios ($\delta^{13}\text{C}_{\text{ap}}$) (Ambrose, 1990, 1993). When hard tissues remains are well preserved, the use of these isotopes can provide information on different dietary sources exploited to feed human, human group and livestock. Bone and teeth have different growth patterns (Hillson, 1996; Scheuer and Black, 2000). Stable isotope ratios measured in bone tissues give information on the last years of individual's life (ca. 15 years) while those measured in tooth correspond to a specific growth period (*i.e.* childhood). Indeed, bone has a permanent turnover with a decreasing rate according to the age and health status. On the other hand, once formed, teeth do not modify their tissues and record biogeochemical information at specific times during infancy and childhood. These growth particularities allow answering specific issues as weaning and breastfeeding (*eg.* Herrscher, 2013).

Carbon, nitrogen and sulphur stable isotopes from collagen inform about individuals' protein intake, but are not able to distinguish different protein sources issued from the same species (*eg.*, meat proteins vs. milk proteins). Vegetables at the base of the food chain have isotopic values that vary in accordance to the type of photosynthesis, the environment and the species. These isotopic differences have an impact throughout all the food chain, as there is a fractionation along the food chain in favour of the heavy isotope. The differences observed in the collagen of two individuals from two consecutive trophic levels (*eg.*, between prey and predator) are usually between +0.0 to +1.0‰ for $\delta^{13}\text{C}$ and +3.0 to 5.0‰ for $\delta^{15}\text{N}$ (De Niro and Epstein, 1978; Minagawa and Wada, 1984; Bocherens and Drucker, 2003). The relevance and reliability of the interpretation of the results require characterizing beforehand the isotopic environment of the human population. It is therefore essential to characterize the isotopic signal range of known

diet species (eg., plant consumers) for each specific archaeological environment (eg. Bösl *et al.*, 2006; Herrscher and Le Bras-Goude, 2010). The isotopic signature of sulphur ($\delta^{34}\text{S}$) is conditioned in vegetables by the levels of soil sulphites, which vary in accordance to the geological background, erosion and microbial soil activity, and by the local atmosphere (eg. Sea spray). Isotopic fractioning between the soil sources and vegetables, as between any of the links in the food chain, is considered negligible. Sulphur values ($\delta^{34}\text{S}$) are relatively high in the sea environment (ca. +20.0‰) and more variable in a land and freshwater environments (-10.0‰ to +20.0‰) (Nehlich and Richards, 2009). Consequently, measured in collagen, $\delta^{34}\text{S}$ informs on local habitat, distinguishing between those coming from a sea environment and those further inland, as well as different geographic origins, if the geological regions were isotopically different (Vika, 2009). Unlike carbon from collagen (linked to protein intake), those from bone and tooth calcium carbonate ($\delta^{13}\text{C}_{\text{ap}}$) is a useful indicator of the whole diet, allowing the distinction between energy coming from C_3 or C_4 /marine environments (Ambrose, 1993). Combined to collagen isotopic data, $\delta^{13}\text{C}_{\text{ap}}$ provide complementary information on dietary patterns variability and origin of food consumed (eg. Ambrose *et al.*, 2003; Kellner *et al.*, 2007; Lee-Thorp, 2008; Froehle *et al.*, 2012). The application of multi-isotope analysis is particularly relevant when studying Mediterranean populations during the introduction of new resources as millet, a C_4 plant cultivated from the Bronze Age in France and Italy for example. Bone and tooth apatite analysis allow as well the record of $\delta^{18}\text{O}$ in both calcium phosphate and calcium carbonate. Oxygen stable isotope in human remains is mainly used to determine geographic origin and mobility as it is linked to drinking water and thus to various environmental conditions influencing water sources (eg. altitude, seasons; White *et al.*, 1998).

Measured in mineral fraction of bone and tooth, other isotopes, as calcium ($\delta^{44}\text{Ca}$) (Reynard *et al.*, 2011), iron ($\delta^{56}\text{Fe}$), copper ($\delta^{65}\text{Cu}$) or zinc ($\delta^{66}\text{Zn}$) (Jaouen *et al.*, 2012) were recently studied. Based on the assumption that dairy products are impoverished in ^{44}Ca compared to other food sources of calcium, a few studies were performed in order to track milk consumption in ancient populations (Reynard *et al.*, 2011). First results were not those expected and underline the necessity to carry out further works on calcium biological process. Iron, copper and zinc isotopes are developing in anthropological studies as shown in Jaouen *et al.* (2012). Their work have demonstrated ^{56}Fe increase and ^{65}Cu decrease in women bones compared to men's ones. However, these results stem more from biological sex differentiation more than diet. Finally, another is the study of trace elements concentration in bone and tooth mineral. Some elements are less than 0.01% in this biological fraction, and thus considered as "traces" (eg. strontium, lead, zinc). Measured with other elements as calcium and barium (for Sr), trace elements concentration provide information on diet when apatite is well preserved and not chemically modified by diagenesis factors. Most of studies using trace elements concentration focused on Sr/Ca and Ba/Ca ratios, as they are trophic level markers (Balter, 2001; Polet and Orban, 2001).

Material sampling must be conducted according to specific issues (eg. diet, human intravariability, weaning), and specific care should be done on old osteological collections due to the possible presence of exogenous organic components (Goude *et al.*, 2011). Interpretation of stable isotope data is also closely linked to environmental

and archaeological contexts. For this reason palaeodietary studies should ideally be carried out on well documented materials. Biological parameters like age-at-death, sex, stature, health conditions, as well as social information like grave goods and/or funeral practices are essential to the interpretation of isotopic variation and differences between and within populations.

FOOD BEHAVIOURS DURING PREHISTORIC TIMES

The Mediterranean region has been widely studied by archaeologists and anthropologists for decades, and the application of biochemical methods on archaeological remains from this region occurred quite early in the discipline's history. A lot of studies have focused on Prehistoric periods. The Upper Palaeolithic and Mesolithic-Neolithic transition as well as food changes of coastal populations were, and still are, favoured research areas.

The Palaeolithic: opportunist hunter-gatherers

The use of stable isotope method to study palaeodiet of hunter-gatherers revealed new and complementary data to understand Palaeolithic food acquisition and their environmental origin. Indeed, the mobility of Upper Palaeolithic groups allows exploitation of different resources according to the season and mobility patterns. In Northwestern Mediterranean, studies mainly focused on Italian sites (Pettitt *et al.*, 2003; Vercellotti *et al.*, 2008; Craig *et al.*, 2010; Mannino *et al.*, 2011a, 2011b; Gazzoni *et al.*, 2013). The presence of well preserved burials and osteological remains in this region allowed several isotopic studies which have shown various exploitation modes of the local and sub-local environments. At Riparo Tagliente (Verona, Italy), one young male and several faunal remains, dated between 16634 to 15286 cal BP were recently analyzed (Gazzoni *et al.*, 2013). Isotopic values would indicate an origin of proteins from terrestrial herbivores and high trophic level species, as carnivore or more probably fish from local freshwater sources. This dietary pattern (protein from mixed sources) is similar to one proposed by Craig *et al.* (2010) for an Upper Palaeolithic individual at Grotta del Romito (13915±70 BP, Southern Italy) and by Pettit *et al.* (2003) for the “Principe” at the Arene Candide (23440±190 BP, Liguria). In Liguria, analysis performed on the Gravetian young male highlight the consumption of ca. 25% of marine food, probably from the local coastal environment (*ibid.*). These results contrast with the next period, where, in this region, Mesolithic hunter-gatherers seem turned toward a more specialized diet, dominated by terrestrial protein intake as shown at Villabruna (12140±70 BP, Vercellotti *et al.* 2008), Grotta del Romito (11340±90 BP and 10862±70 BP; Craig *et al.* 2010) Mezzocorona (7424–6,662 cal BP), Vatte di Zambana (7943±46 BP) and Mondeval de Sora (7425±55 BP) (Northern Italy Gazzoni, 2011). The dietary shift observed could be partially explained by climate: an opportunistic food supply during the Upper Palaeolithic cold climate and resources supplied by terrestrial mammals hunting during the climate improvement at the Mesolithic (*ibid.*). In Sicily, Upper Palaeolithic dietary patterns seem more diversified according to site location.

Despite the proximity to the sea (Mannino *et al.*, 2011b, 2012) have highlighted that humans from Grotta di San Teodoro (15232–14126 cal. BP) and Grotta Addaura Caprara (16060–15007 cal. BP) mainly have terrestrial mammals protein intake. The study of Grotta della Molarà (Sicily) supports results directly obtained from stable isotope analysis, showing a minor contribution of marine food to the human diet (Mannino *et al.*, 2011b). However, according to the authors, in the North East of the Island aquatic resources, as anadromous fish, would contribute to protein consumed contrary to the Northwestern part of the region. Orographic components would have a major impact on food choices during this period and within insular context. In Spain, the site of Balma Guilanya delivered few Upper Palaeolithic human remains (13380-12660 cal. BP and 12380-10990 cal. BP) located in Catalanian Mountains. Stable isotope analyses conducted on both human and faunal bone collagen have shown that neither marine nor freshwater foods were consumed by these individuals (Garcia Guixé *et al.*, 2009). On the other hand, herbivores as red deer, wild goat and even rabbits would supply the major part of the proteins consumed (*ibid.*).

The Mesolithic: the marine issue

The Mesolithic-Neolithic transition and the evolution of food practices is one of the earliest issues on Prehistoric time addressed by biogeochemical methods. One of the first applications of stable isotopes to archaeological human remains was carried out by Tauber (1981) in Denmark. It has shown the successful use of such analysis to detect dietary modification between Mesolithic hunter-gatherers and Neolithic farmers-herders. From this research, many other studies were developed, mainly along coastal environments. They have shown the rapid transition between a Mesolithic diet dominated by marine food to a Neolithic terrestrial based one, especially in Northwestern Europe and Atlantic coast (Lubell *et al.*, 1994; Richards and Hedges, 1999, 2003; Schulting and Richards, 2001). Inland, close to freshwater resources access, dietary shift seems to take place slower (*eg.* Bonsall *et al.*, 1997; Bonsall *et al.*, 2004), supporting the idea of different acculturation models according to region and environment. Conversely, in the Mediterranean, dietary change pattern is more complex. A few Mesolithic human remains were analyzed in Spain, Italy and more rarely in France. On the Spanish coastal site of El Collado (7500 BP; Valencia), a part of the individuals had 25% marine protein intake (Garcia Guixé *et al.*, 2006), however it's less important than for Atlantic Mesolithic groups. Recent works published by Fernández-López de Pablo *et al.* (2013) and Salazar-García *et al.* (2014) show the same trend in this Spanish region. On three sites (Cingle del Mas Nou; Coves de Santa Maira; Peya del Comptador), where the relationship with the coastal environment is attested (*eg.* lithic and marine resources), isotopic data indicate a protein intake dominated by C₃ environmental resources, but marine resources intake is also proposed, up to 25%, for some individuals (Salazar-García *et al.*, 2014). The analysis performed by Fernández-López de Pablo *et al.* (2013) on the Late Mesolithic site of Casa Corona presents, in this case, a human diet only based on terrestrial resources. The same observation was made in South of Corsica on the coastal sites of Araguina Sennola and Monte Leone where two individuals

were analyzed (Pouydebat, 1997). Results indicate an important contribution of rabbit (*Prolagus sardus*) in diet instead of marine food (ca. 25-30%). Other Mesolithic examples show a diet based on terrestrial proteins despite the proximity to the sea as in Croatia (Lightfoot *et al.*, 2012) and in Sicily at Grotta dell'Uzzo (Francalacci, 1988). On this latest site, the stable isotopes from thirteen individuals suggest a consumption of red deer, and the shellfish evidences would testify only a seasonal exploitation of marine environment (Mannino *et al.*, 2008). The different contribution of marine food between Mediterranean and Atlantic coast could be justified by a difference of bio-availability of resources and fish quantity between the two maritime regions.

The Neolithic: toward an agricultural development

The Neolithic period was widely studied throughout the Mediterranean (Tykot *et al.*, 1999). From this time, the way of life and production economy provide to populations an important parameter in food acquisition: social behaviours. Thus, human diet is dictated by various cultural choices in combination with climatic and environmental changes along time. Biogeochemical studies was used in this context in order to determine, among other things, 1) the environment exploited, especially along the shore (marine vs. terrestrial food resources), 2) the type of food production (agriculture vs. herding), and 3) intra- and interpopulation differences, related to biological/social distinctions. One of the earliest works was conducted by Francalacci in Italy (Francalacci, 1988, 1989). Then, numerous studies were carried out in Mediterranean area, specifically in Italy and France (Goude, 2007) and some in Spain. From these researches we know that the lack of marine resources in coastal populations' diets is visible in southern France, as well as in Spain, on the sites of Costamar and La Vital for example (Salazar-García, 2009, 2011), or in Croatia (Lightfoot *et al.*, 2012), even at the beginning of the Neolithic (Goude, 2007; Le Bras-Goude, 2008). On the other hand, the recent data published by Lelli *et al.* (2012) are one of the few testimonies of sea exploitation by Neolithic populations in Italy (7th-6th mill. BC). The authors demonstrate the relationship between distance to the sea and marine food consumption comparing coastal and inland sites in Marche and Apulia. Coastal populations would have consumed 5% to 30%, even more, of marine fish, and inland ones would not show clear marine protein intake (*ibid.*).

These results contrast with those from other Italian sites in southern peninsula: Samari, Ripatetta, Catignano, Latronico and Trasano (7th-6th mill. BC), where dietary pattern seems dominated by terrestrial animal and also plant protein intake as proposed by Giorgi *et al.* (2005). However, recent data of $\delta^{34}\text{S}$ measured on bone collagen from individuals of Samari would suggest, contrary to carbon and nitrogen values, a contribution of coastal environment in diet (Lelli *et al.*, 2012). In the light of these new information, it seems necessary as from now to combine several biogeochemical markers to better understand the part of different environments in human foodstuff. These remarks are also available for the study of humans from Brochtorff Circle (Malta), where social particularities could lead to misinterpretation of food choices of insular populations (Richards *et al.*, 2001), and for the study of Spanish sites where marine protein intake are suspected for few individuals (Salazar-García, 2009). These

last years, several research programmes led to the development of stable isotope studies on Neolithic populations in France and Liguria dated from Early to Recent Neolithic (eg. Goude, 2007; Goude *et al.*, in press). In Southern part, human groups analyzed (ca. 5500-3400 BC) show that in Eastern Provence and in Liguria, there is obviously a certain homogeneous dietary pattern all along the Neolithic, with a subsistence economy strongly turned toward herding for meat and milk (Le Bras-Goude *et al.*, 2006, 2010; 2013; Le Bras-Goude, 2011) (fig. 1). Some individuals differ, with less animal protein consumption, but these results would be linked to specific conditions (eg., trauma or disease) or status. Similar data were obtained in Spain, at Cova de la Pastora, where McClure *et al.* (2011) observe no significant marine resource consumption among humans and a homogeneous terrestrial diet all along the period studied (from the late

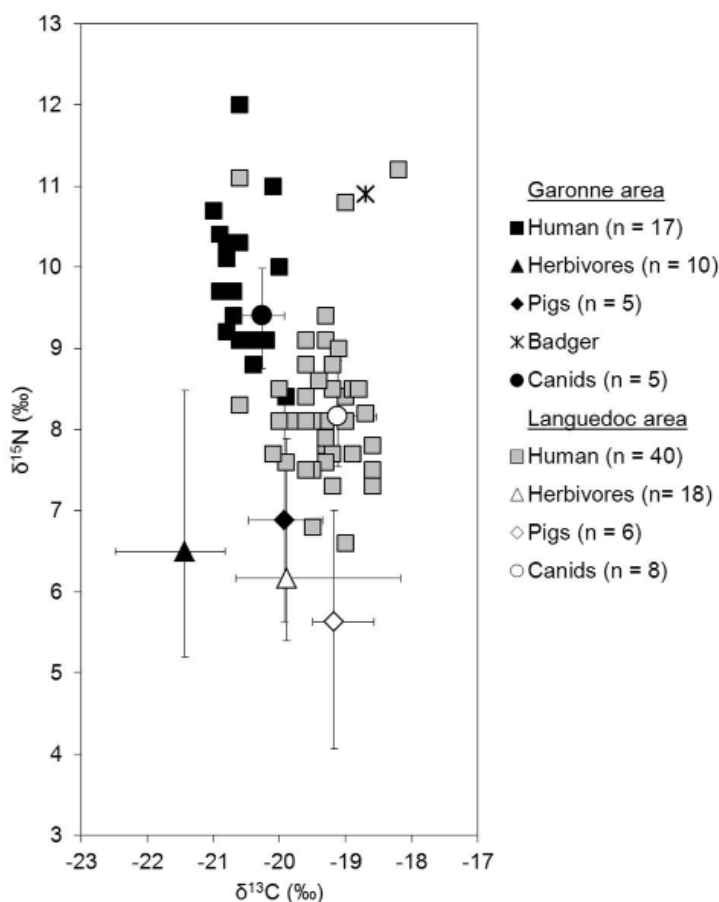


Fig. 1.—Stable isotope (C, N) dataset from Neolithic humans and animals in Southern France (from Herrscher and Le Bras-Goude, 2010). Results show regional differences in dietary patterns.

Neolithic to the Bronze Age, ca. 3800-1500 BC; McClure *et al.*, 2011); results also observed in the study of Lai *et al.* (2007), on Sardinian populations dated from 4th to 2nd mill. BC. Other dietary patterns were proposed, based on results from several sites dated from Middle Neolithic (mainly 2nd half of 5th mill. BC) in Southwestern region. Indeed, it appears that the human diet is diversified with an animal protein intake variability 1) according to the area (Herrscher and Le Bras-Goude, 2008, 2010; Le Bras-Goude and Claustre, 2009), and 2) according to the social/funeral context (Le Bras-Goude *et al.*, 2013). Once again, no marine food consumption was detected in bone collagen, and biological data, as sex, age-at-death, or stature, do not correlate with carbon and nitrogen isotope data. Consumption of freshwater fish and/or young animals (not weaned) is however proposed for some specific individuals. The isotopic variability observed within these human groups should be linked to other factors (*eg.*, social distinctions) not clearly highlighted by archeological evidence (Le Bras-Goude *et al.*, 2009). These studies also demonstrate the wide variability of $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ among females 'groups more than males' ones, suggesting possible exogamy practices. Some strontium isotope analysis were undertaken to test this hypothesis, but preliminary results do not clearly support women migratory pattern (Goude *et al.*, 2012). Finally, regional comparisons carried out in southern France allowed proposing hypothesis on link between societies and environment. They mainly suggest regional trends in subsistence economy patterns: on one hand, human groups rather inland, living in hilly/semi-mountainous landscape, more mobile and consuming more wild resources (aquatic/terrestrial), considered as herders, and, on the other hand, human groups rather located in plain landscape, more sedentary, consuming no/few wild resources, considered as farmers (Herrscher and Le Bras-Goude, 2010).

The Bronze Age: hierarchy, trade and new resources

Contrary to previous periods and cultures, Bronze Age is more recently studied and researches develop exponentially from last years. In the Northwestern Mediterranean area, studies focus mainly in Italy and few have started in France by Goude *et al.* (2011). Two issues interest more specifically anthropologists applying biogeochemical methods: firstly, potential link between hierarchical assertion and diet and secondly, diffusion, cultivation and consumption of millet. Indeed, Bronze Age is, among other things, characterized by technical innovations, linked to metallurgy (copper alloys), and thus by trade development and new social organization. Moreover, it is from this period that archaeology shows in Western European areas first evidences of the introduction and cultivation of millet (*Panicum miliaceum/Setaria italica*), a C_4 plant coming from eastern regions. The consumption of such food is clearly visible in human and animal bone collagen and apatite as millet has higher $\delta^{13}\text{C}$ values than C_3 plants usually consumed (*i.e.* wheat, barley). The work performed by Tafuri *et al.* (2009), on Bronze Age sites in Italy, paves the way for study of cereal consumption and economic development during this period. Indeed, analysis performed on human and coeval fauna from the Early to Late Bronze Age sites of Olmo di Nogara (1600-1200 BC), Sedegliano (North), Topo Daguzzo and Lavello (1600-1200) (South), have highlighted that millet

was commonly consumed by humans and used as animals fodder in the North from Early Bronze Age. Conversely, southern human groups and animals do not show such food specificity (*ibid.*).

Authors show for the first time the diffusion path of this cereal and its economic importance according to geographical location in Italy. However, more recent study carried out on another Northern Italian site (Arano di Cellere, Early Bronze Age), would lead to a more complex food pattern in this area, as neither human, nor animal, isotopic data would support that millet was a common resource in daily diet (Varalli, 2011). Ample multi-isotope analyses (C, N, S) are currently in progress (Varalli, 2013) and will help to better understand millet diffusion/consumption phenomenon as well as social and economic food patterns in different Italian regions. This issue has also been addressed in France, where millet carpological remains were found in some sites from Middle Bronze Age. Stable isotope measurements performed on human and animal bone collagen, located in South (Languedoc) and Central areas (Auvergne), do not show any consumption of such plant during Early Bronze Age (Goude *et al.*, 2011). More research should be performed on more recent populations to track if botanic remains found are link to a real economic and diet modification (Goude ongoing works; Goude *et al.*, in press). Hierarchy and social distinctions seem to gain in importance through this period. Several evidences, as funeral practices, would show, for example, sex/gender differentiations or specific social status: *eg.* grave goods opposition between male (*eg.* swords) and female (*eg.* ornaments) or between elite (?) and commoners (?) would reflect social distinction, but no link was currently found with specific food choices and stable isotope data (Tafari *et al.*, 2009; Goude *et al.*, 2011).

CONCLUSION

Biogeochemical analyses, specifically stable isotope, are now considered as common and indivisible tools to physical anthropology studies. Recent technical development allows us to routinely use these analyses in order to study human palaeodiet and migration. However, it is important to remind that these topics must be studied with a pluridisciplinary approach, including faunal, botanical and environmental data. In like manner, human behaviours researches cannot be conducted without integrating material culture; a particular attention should be brought to funeral practices for example. Moreover, other bioarchaeological information (*eg.* health status, sex, age, stature, or even artefact residue analysis) are essential to understand the variability of food choices within a group and between groups. The synthetic overview presented in this paper has shown both the dietary variability of Prehistoric populations and points of mutual interest in the Mediterranean areas. Among many issues addressed: environmental exploitation, marine food attraction/rejection, cereal diffusion/consumption and intra- and inter-group dietary variability, would need to be still studied (1) with multi-analyses approach and (2) on more ample sites, particularly in areas where only a few data are available.

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