What Makes the Identity of a Scientific Method? A History of the "Structural and Analytical Typology" in the Growth of Evolutionary and Digital Archaeology in Southwestern Europe (1950s–2000s)

Sébastien Plutniak

Centre Émile Durkheim – UMR 5116, Université de Bordeaux, Bordeaux, France
Laboratoire TRACES – UMR 5608, Université Toulouse Jean Jaurès, Toulouse, France
sebastien.plutniak@posteo.net

[Author version of: Sébastien Plutniak [2022], "What makes the Identity of a Scientific Method? A History of the 'Structural and Analytical Typology' in the Growth of Evolutionary and Digital Archaeology in Southwestern Europe (1950s–2000s)," *Journal of Paleolithic Archaeology*, 5, 10: *Cultural Taxonomies in the Palaeolithic. Old Questions, Novel Perspectives*, ed. by Felix Riede and Shumon T. Hussain, DOI: 10.1007/s41982-022-00119-7.]

Contents

1 Introduction: Lithic typologies in the 2sd half of 20th century
- 1.1 Typologies in the history of lithic studies . . . . . .
- 1.2 A case of social and linguistic obfuscation . . . . . .
- 1.3 On the identity of scientific methods . . . . . .

2 Changing names, same method?
- 2.1 Naming the method . . . . . .
- 2.2 Naming the method's vocabulary . . . . . .

3 Changing contents: the versions of the TA vocabulary
- 3.1 The multiple versions of the TA vocabulary . . . . . .
- 3.2 Properties of the versions . . . . . .

4 A specific mode of representation: the TA notation system
- 4.1 The development of the notation and its components . . . . . .
- 4.2 The collective use and development of the TA notation system . .

5 **Specific reasoning: the TA analytical procedures**
5.1 Measuring the properties of a set of objects: the "industrial complex" and "structure" concepts . . . . . .
5.2 Comparing the properties of sets of objects . . . . . .
5.3 Measuring the individual properties of objects . . . . . .

6 **Conceptual background: TA, dialectics, and structuralism**
6.1 References to structuralism and the methodological status of the structure concept . . . . . .
6.2 Dialectics and TA: a metaarchaeological function . . . . . .

7 **Discussion**
7.1 What makes the identity of a scientific method? . . . . . .
7.2 A continuation of evolutionary approaches in French archaeology
7.3 Early development of "computational" archaeology . . . . . .

Abstract

Usual narratives among prehistoric archaeologists consider typological approaches as part of a past and outdated episode in the history of research, subsequently replaced by technological, functional, chemical, and cognitive approaches. From a historical and conceptual perspective, this paper addresses several limits of these narratives, which 1) assume a linear, exclusive, and additive conception of scientific change, neglecting the persistence of typological problems, 2) reduce collective developments to personal work (e.g., the "Bordes'" and "Laplace" methods in France), and 3) presuppose the coherence and identity of these "methods" over time. It explores the case of the "Structural and analytical typology" method, developed in France, Spain, and Italy from the 1950s to the 2000s by Georges Laplace and his collaborators for lithic implements. This paper 1) provides a detailed historical account of the evolving content of this collective endeavour over five decades, 2) it addresses the epistemological question of what makes the identity and unity of a scientific method, demonstrating that the core component of the "analytical typology" lies in its particular way to represent real-world phenomena through its notation system, and 3) it reveals how this little-known but significant episode of advances in the methods and theory of archaeology, contemporary but independent of the "New Archaeology" trend in English-speaking archaeology, was instrumental in the continuation of evolutionary perspectives in France and in the development of quantitative and formal methods in archaeology in south-western Europe, foreseeing crucial knowledge representation issues raised today by digital methods in archaeology and data curation.

Keywords: history of archaeology, lithic typology, notation system, digital archaeology, evolutionary archaeology

1 Introduction: Lithic typologies in the 2^{sd} half of 20th century

1.1 Typologies in the history of lithic studies

Since the 19th century, typological and taxonomical approaches were essential in the study of prehistoric lithic objects. From the 1940s, North American archaeology was galvanised by in-depth debates on the type concept (Krieger 1944, Ford 1954). In Western Europe, the apex of research in lithic typology happened in the 1960s, with the publication of several ambitious typologies, encompassing large spatial and chronological scales (de Sonneville-Bordes 1960, Bordes 1961, Tixier 1963, Laplace 1966b), raising intense debates and producing critical literature (de Heinzelin de Braucourt 1962, Brézillon 1968, Merino 1969).

Common accounts of the history of archaeological research consider that typological approaches were a moment in the history of research, gradually supplanted by a methodological diversification in lithic studies from the 1970s, including, for example, technological, cognitive, and raw material approaches (Nowell and Davidson 2010). However, this linear view of history is misleading. Historians and sociologists of science have long shown how disciplinary histories play more functions than developing knowledge about the past of a discipline: "legitimating "political" interests often pursued by the authors of such histories themselves", supporting particular approaches and delegitimising other ones, what can be done by extending the present as far as possible into the past, by establishing figures of heroes and pioneers, etc. (Lepenies and Weingart 1983). The history of archaeology and lithic studies in particular are no exceptions. In fact, in English speaking as in French-speaking archaeology, the "typological debates" never ceased after their moment (Wylie 2002, Hussain 2019).

In the English-speaking literature, this continuity was first made by "New Archaeologists", through a particular emphasis on systematics and numerical taxonomy (Clarke 1968, Dunnell 1968, Litvak King et al. 1972). It was later perpetuated by the evolutionary archaeologists, still active today, who reassessed the type problem (O'Brien and Lyman 2002, O'Brien and Lyman 2003) and the methods of classification (O'Brien, Darwent, et al. 2001). In addition, more than a century of research on lithic typologies also generated critical literature and synthesis books (Whallon and Brown 1982, Klejn 1982, W. Y. Adams and E. W. Adams 1991).

In Western Europe, and in France in particular, the persistence of typological lithic studies is illustrated by the work by Georges Laplace[1] (1918–2004) and the "*Groupe international de typologie*" (International research group in typology) he organised from 1969 to 1989. The participants of this group were committed to improving a method called "*typologie analytique*" ("analytical typology", hereafter TA), which illustrates the uninterrupted interest in typology and taxonomy among French, but also Swiss, Spanish, and Italian archaeologists, mainly specialised in Palaeolithic and Mesolithic periods (Livache 1976, Cavaillès 1984, Laplace 1987a). However, although this was a significant episode in the history of research in

[1]About Laplace's scientific career and research, see Plutniak 2017a and Plutniak 2017b. Note that from 1949 Laplace signed his publications as Laplace-Jauretche (adding his first wife's surname); then, from 1958 onwards, he signed as Laplace.

prehistoric archaeology with regard to typology, the introduction of mathematics and formal approaches, and methodological creativity, the TA experience remains poorly known, especially outside France, Spain and Italy, and in the international literature.

1.2 A case of social and linguistic obfuscation

The TA case is a good example of social and linguistic obfuscation in science: 1) in France, it has been shadowed by rival approaches which became the mainstream, including Bordes' typology, Leroi-Gourhan's school, and Tixier's lithic technology; 2) given that TA-related researches primarily occurred in south-western Mediterranean Europe (south of France, Spain, Italy) and published in Romance languages, it remains virtually unknown in the English and international literature[2].

In the last decades of the 20th century, English became the hegemonic language in prehistoric archaeology at the international scale. Consequently, the available literature in English about the TA has become a determining factor of its international reception and status in the history of archaeology. Significantly, the American authors of a book on archaeological typologies admitted to not considering research published in languages other than English, due to their "unfamiliarity with the literature" (W. Y. Adams and E. W. Adams 1991, p. 266). Publications in English about the TA are rare and depreciative, and either authored by French researchers (with no specific discussion, e.g., Audouze and Leroi-Gourhan 1981, p. 172, Cleuziou et al. 1991, p. 102) or by Italian archaeologist, who developed detailed arguments (Bietti 1990, p. 122, 147, Bietti 1991, p. 276-277). This has important effects on the reception of the TA in the English-speaking literature. For example, in a critical study of Bordian typology, an American archaeologist (Bisson 2000, p. 10) dismissed without discussion the "abstruse 'analytical typology'" only based on the authoritarian statement made in Audouze and Leroi-Gourhan 1981. The harmful effects of monolingualism are well known and are similar to those already summarised in 1969 by Michel Brézillon[3] about lithic typology in his book *La dénomination des objets de pierre taillée*:

> It is surprising how often, in the field of prehistoric typology, the same studies have been repeated, the same mistakes made, failing to utilise an already considerable knowledge, albeit one scattered in extensive literature.[4] (Brézillon 1968, p. 139.)

This comment made fifty years ago is still relevant today. Fundamental issues in lithic typology are similar through time, as well as their envisioned solutions: 1) a better consideration for previous research, 2) better dissemination of the data in the scientific community, and 3) the collective use of improved and interoperable descriptive standards. The generalised use of personal computers and, more

[2] It is noteworthy that, after his death in 2004, tributes to Georges Laplace were only published in Italy, Basque Country, Catalonia, and not even in France.

[3] Brézillon (1924–1993) is another example of a researcher forgotten after having been used and shadowed by a prominent actor, namely Leroi-Gourhan.

[4] "*Il est surprenant de constater combien souvent, dans le domaine de la typologie préhistorique, les mêmes recherches ont été entreprises, les mêmes erreurs commises, faute de profiter d'un acquis déjà considérable mais dispersé dans une abondante littérature.*"

recently, the promotion of open access data publishing, are considered instrumental in recent studies on lithic taxonomies to make the third point an aspiration (Reynolds and Riede 2019). For example, Shea identifies the naming of lithic taxa, and in particular their construction from toponyms, as one of the key obstacles to the progress of research in lithic typology (Shea 2014). Yet, this issue was exactly the problem targeted by Georges Laplace in the early 1950s, and the grounding intuition of his collective research programme for five decades. Shea rejects the use of systematics as a method, while ultimately calling for the use of "better ways of expressing lithic variation" and "more nuanced measures of lithic variability": in other words, what systematics can provide and what Laplace and his collaborators carried out for decades. It is noteworthy that Shea does not even mention the TA.

The TA case is a striking example of the loss of key research insights due to the sociological and linguistic segmentation of the research community. It also illustrates the process of oversimplification by which a scientific proposal is discredited due to 1) a lack of information about it, and 2) its reduction to supposedly individual authorship, considering "Laplace's TA" where it was instead a collective endeavour. In this situation, history of science investigations contribute to clarifying what actually happened, beyond partisan views and historiographies, to leverage the loss of past research results, and to use specific cases to address general issues in the historical and philosophical study of science. Consequently, this paper is not intended to defend the use of TA by today's archaeologists but rather to re-examine its motivational, conceptual and formal foundations in order to benefit current and future archaeological studies addressing similar problems. In addition, the fact that the TA has been oversimplified and reduced to individual work raises more general conceptual questions about what makes the identity and unity of a scientific method.

1.3 On the identity of scientific methods

Drawing on archives[5], publications and interviews, the historical examination of the TA presented in this paper reveals how it was the evolving product of a living, and sometimes conflictual, scientific and collective endeavour. This challenges the idea that the TA was one singular and monolithic method, addressing its identity through the different contexts in which the TA occurred. From the perspective of the history and philosophy of science, establishing the identity of a method and what constitutes its unity, is a non-trivial issue. It relates to the problems about the nature and structure of scientific theories, considering their historical dimension (Vorms 2011).

Following previous calls by archaeologists (Murray 2013, Embree 1992) and philosophers of science (Ankeny et al. 2011) to combine the (historical) study of scientific practices and theoretical inquiry, this paper addresses what ultimately

[5]Georges Laplace's files at the *Musée National de Préhistoire*, Les Eyzies-de-Tayac, France (hereafter abbreviated MNP); Jean-Claude Gardin's files at the Maison Archéologie-Ethnologie, Paris X University, Nanterre, France (MAE); Henri Breuil's files at the *Muséum national d'histoire naturelle* in Paris, France (MNHN); Hallam Movius files at the Peabody Museum of Archaeology and Ethnology, Harvard University (Peabody); archives of the *Fondation de la Maison des sciences de l'homme*, Paris, France (MSH); Bordes files at the *Service régional de l'archéologie de Nouvelle-Aquitaine*, Bordeaux, France (SRA).

makes the identity and unity of a scientific method. Using the TA case, five possible aspects are examined:

1. naming is a way to identify something, so the different names which were given to what I referred to by "TA" until now will be considered.

2. Although the name can be stable, changes in methods' definition are common in science and challenge their unity. This will be illustrated by studying the multiple versions of the TA's taxonomy.

3. The identity of a method is also related to the specific way it represents real-world phenomena. In the TA case, it was done through its formal notation system.

4. Methods might also be characterised by the specific reasoning they typify or are embedded in. The statistical methods articulated by the TA will be examined.

5. Finally, the unity and identity of methods might be found within the particular set of concepts they embedded. The status of dialectics and structuralism in TA will be discussed.

These five aspects are discussed in the last part of the paper, leading to a reconsideration of the status of the TA in the development of prehistoric archaeology in south-western Europe, where it played an underappreciated role in the cultivation and continuation of evolutionary approaches and in the development of computational archaeology.

2 Changing names, same method?

Two aspects of naming are addressed in this section: first, the different names given to the method throughout its history; second, the names used to refer to the descriptive vocabulary of the TA.

2.1 Naming the method

From 1955 to 2000, Laplace and his collaborators used six different names to refer to their method. The first form was "*typologie statistique*" (statistical typology), identified in a report by Laplace during fieldwork he conducted in Tunisia in 1955[6]. The next year, he used this name in the first publication on his method (Laplace-Jauretche 1956). One year later, he changed its name to "*typologie analytique*" (analytical typology) (Laplace-Jauretche 1957), while "*typologie statistique*" then referred to the more general class of methods to which the *typologie analytique* belonged to: "In fact, in prehistory, there is no statistical method as such, but rather research methods that were born from the use of statistics."[7] (Laplace-Jauretche

[6] Laplace Georges, *Campagne de recherches en Tunisie. November 1955*, p. 1, manuscript dated from November 1955, Mnp.

[7] "*En fait, en préhistoire, il n'y a pas une méthode statistique, mais des méthodes de recherches qui sont nées de l'utilisation de la statistique.*"

1957, p. 2). From this moment, "*typologie analytique*" has been the most stable name given to the method, being later used in the title of the journal published by Laplace and his collaborators, *Dialektikê. Cahiers de typologie analytique*[8]. Later, Laplace explained the reasons why he chose the name *typologie analytique*, for example in a letter sent to the archaeologist Jean-Georges Rozoy (1922–2019):

> As you can see, I came up with the expression "analytical typology" deliberately, consciously, intentionally, wilfully, and for good reason, on the model of "analytical psychology", "analytical geometry", and "analytical function".[9]

The form *typologie analytique* will constitute the core of the next names of the method, to which several adjectives were added to reflect its different improvements.

In 1973, Laplace added the adjective "*structural*". This change can be observed in a letter to the archaeologist Henri Delporte (1920–2002):

> Since the beginning of autumn, when the excavations were complete, I've been working tirelessly on putting together a review article on my research into structural typology.[10]

The paper Laplace mentioned is the publication of the presentation he gave one year earlier at the conference "*Les banques de données en archéologie*" (Data banks in archaeology) held at Marseilles[11]. Since then, Laplace used the name "*typologie analytique et structurale*" (Laplace 1974). Some years later, Michel Livache, one of Laplace's closest collaborator, added the idea of dynamics, using the form *typologie analytique dynamique et structurale* (Livache 1980, p. 23). In addition, an abbreviated form, "*l'Analytique*", was also occasionally used[12], summarising the most specific aspect of the method according to the practitioners, i.e. its emphasis on the analytical operation.

I used the form "TA" by convenience. However, this should not overlook that these different linguistic forms to name the method reflect its transformations through time. The naming of one component of the TA, its vocabulary, reveals a similar history.

---

[8]First *Cahiers de typologie analytique* in 1972, then *Dialektikê. Cahiers de typologie analytique* from 1973 to 1987. For a history of this publication, see Plutniak 2019 and Plutniak 2020b; a digital version of the journal is available at `https://lithictypes.hypotheses.org/187`.

[9]"*Apprenez que j'ai créé l'expression "typologie analytique" délibérément, consciemment, intentionnellement, volontairement, et pour cause, sur le modèle de "psychologie analytique", de "géométrie analytique", et de "fonction analytique".*". Typed letter by G. Laplace to J.-G. Rozoy, 16-9-1982, MNP.

[10]"*Depuis le début de l'automne, les fouilles terminées, j'ai travaillé d'arrache-pied à l'élaboration d'un article de synthèse concernant mes recherches de typologie structurale.*". Letter from G. Laplace to H. Delporte, 1-12-1973, MNP.

[11]Note that the title of the oral presentation indicated on the conference's program did not yet contain the word "structural": "*La typologie analytique : base rationnelle d'étude des industries lithiques et osseuses*", box JCG 130-2, MAE.

[12]For example, in J. Delfaud 1973, p. 8, during an interview with the Catalan archaeologist Eudald Carbonell i Roura (16-11-2015), and in two letters sent to Laplace: from M. Livache (25-6-1971) and from another Catalan archaeologist, Josep Maria Fullola i Pericot, 18-3-1980, MNP.

2.2 Naming the method's vocabulary

As other typologies for manufactured lithic objects, the TA included a vocabulary to name the different types. The different names given to this vocabulary reflect more general conceptual changes in the use of typological reasoning.

First, Laplace adopted the common concept used by prehistoric archaeologists in the 1950s, i.e. the "*liste-type*"[13], or "*liste typologique*"[14] (type list). It referred to the simple finite lists of types used by contemporary archaeologists to build their typology, such as Max Escalon de Fonton (1920–2013) and Henri de Lumley (born 1934) (Escalon de Fonton and de Lumley 1955) or François Bordes (1919–1981) and Maurice Bourgon (1907–1951) (Bordes and Bourgon 1951).

The first significant change was the definition of a "*liste des types primaires*" (list of primary types), based on the new concept of "*type primaire*" (primary type) introduced by Laplace in a publication in 1957. This change draws on a critical reappraisal of the inconsistent and changing ways lithic types were named:

> Thus, the typological disorder born of the confusion between the general and the specific, of the existence of names sometimes based on form and other times on a hypothetical function or on the relative size of the objects, prompted us to create an original typological system. [...] This involved drawing up a long list and forming tables into which we grouped the forms with common morphological and technical characteristics.[15] (Laplace-Jauretche 1957, p. 135-136.)

In addition, Laplace defined the primary type concept against the notion of *fossile directeur* (index fossil). For him, the difference relied in the mode of definition of the concepts, qualitative for the *fossile directeur*, and quantitative and statistical for the primary types:

> For some time now, we have tried to express the frequency of recognised types in percentages, but due to a lack of clear definitions and an adequate methodology, these efforts have failed to connect with each other, and are therefore now futile. However, foundations were laid for quantitative definitions and, subsequently, new qualitative definitions of a higher order than those of *fossiles directeurs*.[16] (Laplace-Jauretche 1956, p. 272.)

The third important move made by Laplace was the introduction of hierarchy in the construction of the typology. Primary types are "primary" in the sense they

[13] A first occurrence of Laplace's use of this concept is observed in a letter sent to the archaeologist, and Laplace's friend, François Bordes, 14-2-1954, BOR33, SRA.

[14] For example in a letter from G. Laplace to his mentor Henri Breuil, 1-2-1955, BR35, MNHN.

[15] "*C'est ainsi que le désordre typologique né de la confusion du général et du particulier, de l'existence de dénominations basées tantôt sur la forme tantôt sur une hypothétique fonction ou sur la grandeur relative des pièces, nous a conduit à créer un système typologique original. [...] Ce faisant, nous dressions une longue liste et des tableaux où nous groupions les formes présentant des caractères communs morphologiques et techniques.*"

[16] "*Depuis longtemps, on a tenté d'exprimer en pourcentages la fréquence des types reconnus, mais faute de définitions précises et de méthode adéquate, ces essais sont demeurés sans liaison entr'eux, donc sans lendemain. Cependant la voie était ouverte à des définitions quantitatives et par l'intermédiaire de celles-ci, à de nouvelles définitions qualitatives d'un ordre supérieur à celles des fossiles directeurs.*"

are part of a hierarchical structure of concepts, as illustrated in a letter Laplace sent to Bordes in 1957:

> As I've written, I've carried out all of my counts according to secondary types, of which there are well over one hundred. Experience has nevertheless taught me that essential variations occur when I focus on my primary types and typological groups and classes.[17]

In the following decades, the *liste des types primaires* (list of primary types) was the most frequent name given to the TA's vocabulary, with the form *liste typologique analytique* also occasionally used (Laplace 1964a, p. 22).

The second important change in the naming of the vocabulary was the adoption of the notion of "*grille*" (grid). Its first occurrence was in a theoretical paper in 1973 (J. Delfaud 1973, p. 9) but its use was generalised later, from a publication in 1981 in which Laplace started to refer to the *grille des thèmes morphotechniques* (grid of morphotechnical patterns) (Laplace 1981, p. 16). Contrary to what happened before with the primary types, this change in the name did not reflect a particular and precise conceptual innovation. However, it was part of a more general tendency to consider the relationships between prehistoric archaeology and the formal sciences[18]. This is reflected by the titles of the two papers cited, the first, by the geologist Jean Delfaud (1939–) was entitled "*Quelques réflexions sur les rapports entre la Typologie analytique et l'informatique*" (Some thoughts on the relationship between Analytical Typology and computer science) and the second, by Laplace, addressed statistical questions under the title "*Algorithme de segmentation de la matrice d'homogénéité*" (Homogeneity matrix segmentation algorithm). In the following years, different adjectives were added to refer to the *grille typologique* (Laplace 1987b), *grille de caractères* (Livache 1989) or *grille analytique* (Laplace and Sáenz de Buruaga 2000). Since the TA was an international research initiative, the grid concept was also used in other languages. For example, in a synthesis published in Spanish in 2013, the grid was described as the core of the "*praxis analítica*" (Fernández Eraso and García Rojas 2013, p. 489).

In summary, changes in the naming of the method or its components can be more or less directly related to conceptual changes in the contents of the method. The next sections will address the transformation in the contents of different aspects of the TA between the 1950s and the early 2000s. I will first look at the different versions of the TA's vocabulary.

---

[17] "*J'effectue, comme je l'ai écrit, tous mes décomptes suivant les types secondaires et ceux-ci dépassent largement la centaine. L'expérience m'a néanmoins appris que les variations essentielles s'effectuaient suivant mes types primaires et suivant mes groupes et classes typologiques.*". Letter from G. Laplace to F. Bordes, 2-1-1957, BOR33, Sra.

[18] The concept of grid was then used in formal linguistics, although it was not very frequent. For example, in his course at the *Institut d'art et d'archéologie* in Paris, the mathematician Mario Borillo (1934–2013) defined the grid as the "set of semantic and/or syntactic notions that constitute the D.L. [descriptive language]" "*l'ensemble des notions de nature sémantique et/ou syntaxique qui constituent le L.D. [langage descriptif]*") (Borillo, M., 1970, *Problèmes de méthode liés à la mise en œuvre de procédures formelles et de techniques de traitement de l'information en archéologie*, 1C1 box 38, Msh). Borillo was then a member of the *Centre d'analyse documentaire pour l'archéologie* in Marseilles, a research centre directed by Jean-Claude Gardin (see Moscati 2016, Plutniak 2021b, p. 522).

3 Changing contents: the versions of the TA vocabulary

3.1 The multiple versions of the TA vocabulary

In the course of its development over fifty years, many versions of the TA's vocabulary were defined. In a letter he sent to Delporte in 1967, Laplace wrote that he had elaborated about 25 lists[19]. Later, Delfaud wrote that there were a dozen versions (J. Delfaud 1973, p. 9). In 1997, Laplace mentioned that 14 "analytical typology grids" ("*grilles de typologies analytique*") were defined between 1953 and 1963. The first stabilised version was published in 1964, which was then adapted in two subsequent versions, for a total of 17 versions (Laplace 1997, p. 223). These different and contradictory numbers show, at the very least, that the TA was grounded on a very changing fundamental vocabulary.

In the period 1954–2000, I have identified at least then different versions to name TA's vocabulary[20]. All were built as a hierarchical vocabulary, but the number and the names of the hierarchical levels were different. They are summarised in Table 1: five levels are distinguished, from the more general (1) to the more specific (5), and the number of concepts related to each level is indicated for ten versions of the vocabulary. Only the hypernym-hyponym relationships are considered, with no attention to the names given to the levels, which are summarised in Table 2. Producing these tables implied defining the equivalences between the different names given to the same hierarchical levels in the different versions: for example, considering the third level, the names "*classes*", "*classes typologiques*" and "*thèmes morphologiques basaux*" all correspond to the same conceptual level of description.

Table 1: Number of concepts by hierarchical levels in ten versions of the TA's vocabulary. Dashes indicate when a level does not exist in the version.

Level	1954	1956	1957	1960	1964	1968	1972	1974	1986	2000
1	–	–	5	–	5	4	6	6	5	5
2	10	11	12	14	14	15	16	16	16	21
3	–	22	–	–	–	37	51	52	50	56
4	56	49	60	80	82	85	105	104	59	85
5	–	–	–	–	–	–	–	–	–	13
Σ	66	82	77	94	101	141	178	178	130	180

3.2 Properties of the versions

The total number of concepts by version increased over time (Table 1). By contrast, the number of hierarchical levels changed only slightly from 1954 to 1964 until stabilising to the same four levels as in the 1968 version. The relative importance

[19] Letter from G. Laplace to H. Delporte, 15-11-1967, MNP.

[20] 1954: Laplace-Jauretche 1954; 1956: Laplace-Jauretche 1956; 1957: Laplace-Jauretche 1957; 1960: Laplace 1960; 1964: Laplace 1964d; 1968: Laplace 1968; 1972: Laplace 1972; 1974: Laplace 1974; 1986: Laplace 1987b; 2000: Laplace and Sáenz de Buruaga 2000, p. 268 and 302–303.

Table 2: Names of the hierarchical levels in ten versions of the TA's vocabulary.

version	level 1	level 2	level 3	level 4	level 5
1954	–	groupes	–	types	–
1956	–	groupes typologiques	classes	types primaires	–
1957	familles typologiques	groupes typologiques	classes	types primaires	(types secondaires)
1960	–	groupes typologiques	–	types primaires	–
1964	[unnamed]	groupes typologiques	–	types primaires	(types secondaires)
1968	ordres modaux	groupes typologiques	classes typologiques	types primaires	–
1972	ordres typologiques	groupes typologiques	classes typologiques	types primaires	–
1974	ordres typologiques	groupes typologiques	classes typologiques	types primaires	–
1986	ordres typologiques	groupes typologiques	thèmes morphologiques basaux	thèmes morphologiques dérivés	–
2000	ordres	groupes typologiques	–	types primaires	types secondaires

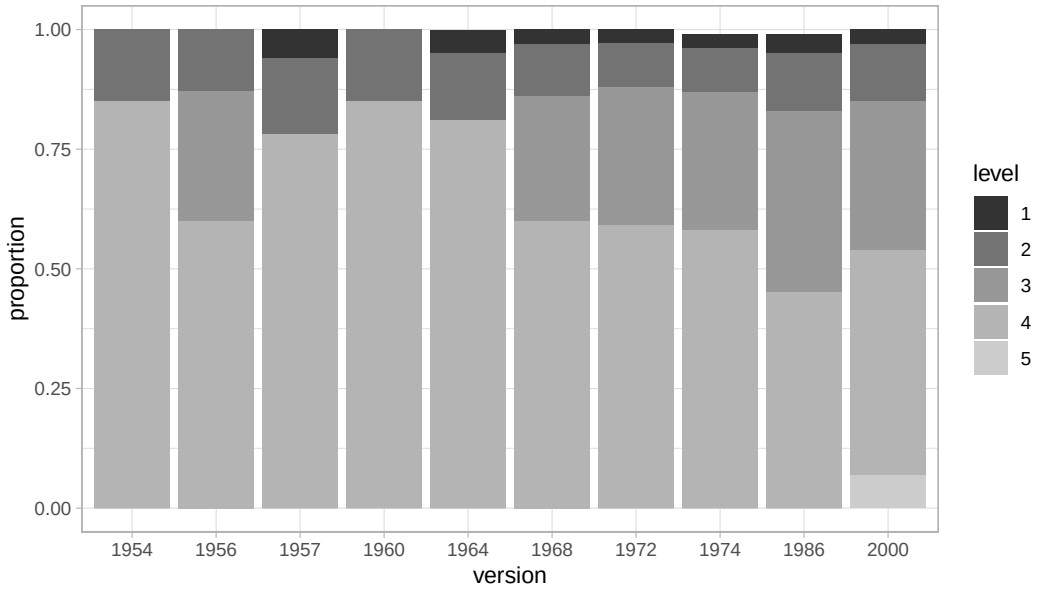


Figure 1: Proportion of concepts by hierarchical level by version of the TA taxonomy.

of the levels is represented in Figure 1. The lowest and most specific hierarchical levels (levels 4 and 5) tend to have a decreasing importance over time, except in the last version, reflecting a move of the archaeologists' attention towards the general properties of the lithic objects.

Being hierarchically structured, these vocabularies can be represented using graph theory: the nodes represent taxonomical concepts and directed edges represent hypernym relationships (Figure 2). The resulting graphs are directed trees, a graph in which the directed edges will never form a closed loop (also called directed acyclic graphs). The structural properties of the resulting graphs can then be characterised using graph theory measures[21]. The degree of a node is the number of edges that are incident to this node. This measure can be summarised at the scale of the entire graph using a "centralisation" measure, which reflects the extent to which the graph structure is polarised around few very central nodes or not[22].

[21]Computations were made using the *igraph* R package (Csárdi and Nepusz 2006). See supplementary material at `https://doi.org/10.5281/zenodo.6307350`.

[22]Centralisation measures are summary methods based on node centralisation measures (Freeman 1979). The measurement can be normalised to facilitate the comparison between graphs.

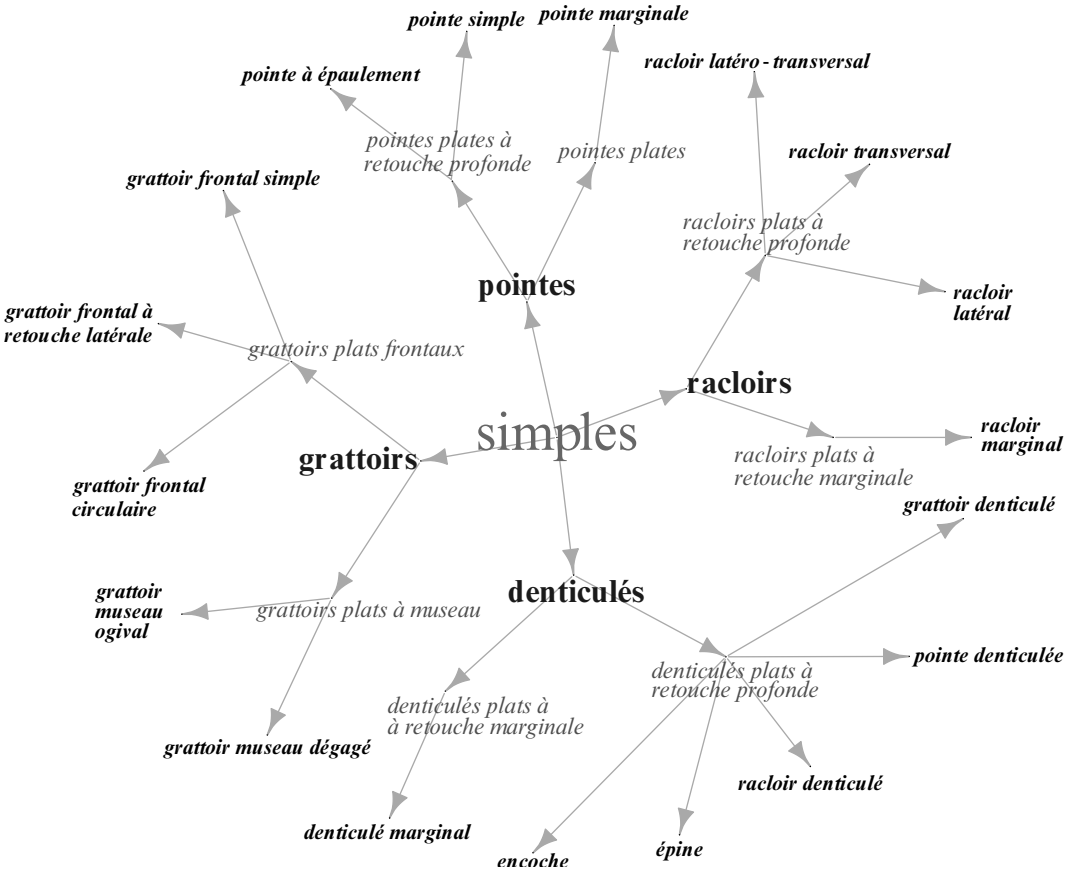


Figure 2: Representation of the TA taxonomy by a directed graph. Partial example from the 1974 version: only the sub-graph corresponding to the "simple" order is represented, with its classes, families, and primary types.

Measuring degree centralisation on the different versions of the TA taxonomy demonstrates a decreasing centralisation of the vocabulary structure over time (Figure 3), especially from the 1968 version onwards, reflecting a more balanced distribution of the concepts in the different hierarchical levels of the taxonomy.

The changes detected with these quantitative measures can be related to the history of the development of the TA. For example, the stabilisation observed from the 1968 version corresponds to the social stabilisation of the research group by Laplace, marked by the creation of the "International research group in typology". Their first meeting was celebrated in 1969 in Arudy (French Pyrenees) and then continued yearly until 1988. Conversely, the latest versions of 1986 and 2000 reintroduced an instability, corresponding to the final period of the TA development, the absence of the yearly seminar and Laplace working alone or with only a handful of collaborators such as Andoni Sáenz de Buruaga. This stresses the importance of collective work in the development of the TA.

This approach heralded by the TA was claimed to be universal and adaptable to lithic industries from all contexts, contrary to rival typological systems. Consequently, TA practitioners adapted it to their analytical needs and those changed over time and with regard to research contexts and interests. For example, the Catalan archaeologist Josep Maria Fullola i Pericot proposed to include new pri-

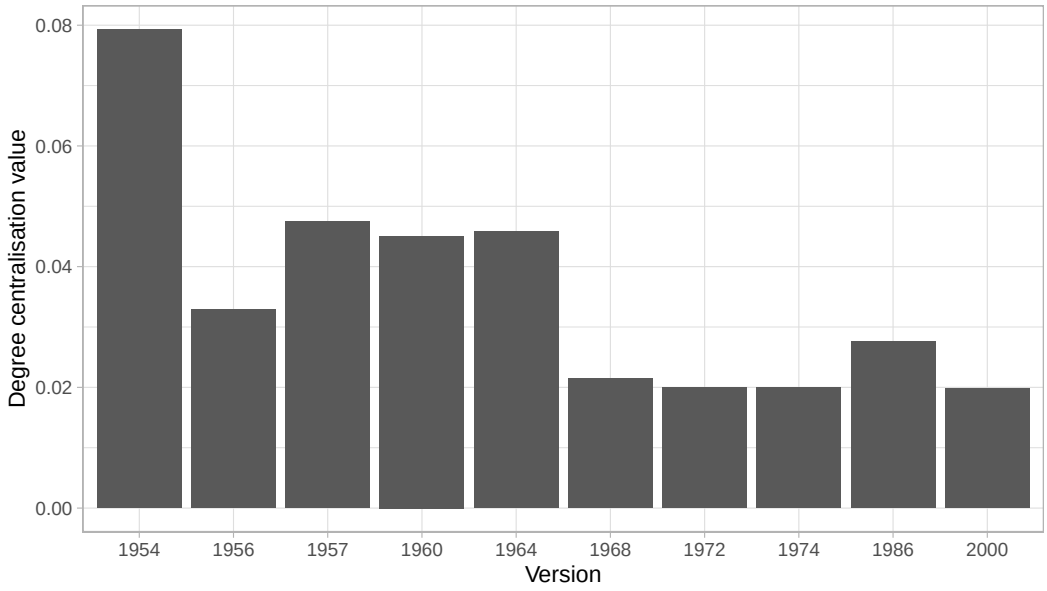


Figure 3: Degree centralisation value of the structure of the TA taxonomy by version.

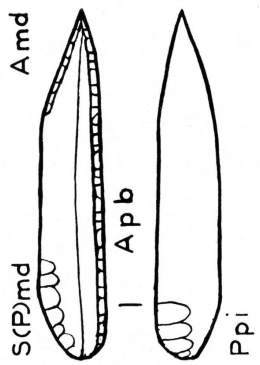
mary types in the "backed points" and "backed blades" typological groups (Fullola i Pericot 1976). Similarly, Hélène Crémillieux and Michel Livache included three new "typological classes" in the "*écaillés*" *group* (H. Crémillieux and Livache 1976), and Francesc Gusi i Jener and Carme Olària proposed the "double bevel-edged geometric pieces" typological group (*geométricos en doble bisel*) including 3 classes and 9 types (Gusi i Jener and Olària 2006). Some of these changes were integrated in the next version of the TA vocabulary, others not. For example, the 1986 version included an update concerning the *écaillés* group. By contrast, and notably, a more recent presentation of the TA considers the 1986 version as the last reference version, without including later changes (Fernández Eraso and García Rojas 2013, p. 490).

The practitioners assigned different status and importance to the versions, considering the 1964, 1972, and 1986 versions as the major landmarks. This can be demonstrated by the examination of the use of the different versions and by what practitioners wrote about them. However, the identification of significant versions was not always consistent, and this included Laplace himself. In 1981, he identified the 1964, 1972 and 1974 as landmarks (Laplace 1981, p. 16) but, some years later, he instead selected the 1964, 1972 and 1986 versions (Laplace 1997, p. 223), even though the 1986 version was considered not to be a new grid but only a new way to write the previous version (Laplace 1987b, p. 16).

The proliferation of the versions of the vocabulary led some archaeologists to define equivalences between the different versions. For example, such an equivalence table for the 1964 and 1972 versions was presented by the Basque archaeologist José María Sánchez Merino (1922–?), in the second edition of his book *Tipología Lítica* (Merino 1980, p. 232).

This illustrates the collective development of the TA through the satisfaction of a practical requirement, namely ensuring that all practitioners used compatible

Pièce longue, pointe distale droite à dos profond total, dextre, façonné par une retouche biface rectiligne. Elle porte des retouches complémentaires : plate profonde inverse de la base, surimposée au dos ; abrupte marginale directe de la partie distale du bord réservé ; simple marginale directe, tendant vers plate, de la partie proximale du bord réservé.



1974 formula:

$$\overline{\text{PD23}}\ \text{dist dext droit}\ \left[\text{Apb rect}\right]\ /\ =\ \text{Ppi prox}\ .\ \text{S(P)md prox}\ --\ \text{Amd dist}$$

1968 formula:

$$\overline{\text{pD4}}\ \text{dext rect}\ \left[\text{Apb}\right]\ /\ =\ \text{Ppi base}\ .\ \text{Amd dist}\ --\ \text{S(P)md prox}$$

Figure 4: Example of textual, graphic, and coded representations of a lithic piece. Two versions of the TA formula are presented (Laplace 1974, p. 136 for the text and the 1974 formula, and Laplace 1968, p. 58 for the 1968 formula).

vocabularies. This was also an important function of the notation system.

4 A specific mode of representation: the TA notation system

4.1 The development of the notation and its components

Since the 19th century, lithic pieces were represented in two principal ways: 1) by a description in natural language (using relatively systematised technical lexicons, raising translation issues between the different languages), and 2) by drawing them (Figure 4). Laplace complemented these two modes of representation by a third mode, representing a lithic piece by a coded character string, as illustrated in Figure 4[23].

The first two versions of the TA lexicon (published in 1954 and 1956) were organised as a finite list of *types*, each being associated with a number. In 1957, Laplace defined a set of "symbols" formed by one or two letters, to denote the "typological groups". The primary types belonging to a typological group were noted by complementing the corresponding group symbol with a number[24]: for example, G1 for the "*grattoir long*" primary type (long scraper) or B7 for the hooked burin (*burin busqué*). From 1964, Laplace further systematised this notation (Laplace

[23]This section draws and extends a previous study about the material and typographical aspects of this notation system (Plutniak 2020b).

[24]Laplace-Jauretche 1957, p. 138.

Table 3: Summary of the "analytical signs" (Laplace 1968, p. 57).

Sign	Utterance	Signified
‾	overline	blade feature
—	simple dash	continue adjacency on the same edge
— —	double dash	discontinue adjacency on the same edge
=	duplicated dash	overlapping adjacency on the same edge
·	point	opposition
+ or ∩	plus or union	composition
( )	parentheses	tendency
[ ]	brackets	technical characteristics
/	stroke	complementarity

1964a, p. 70-71). He distinguished:

- elementary symbols based on the previous rules for the notation of the primary types;
- five basic graphic symbols to specify the properties of a primary type or the association between adjacent primary types on the same object;
- four supplementary graphic symbols (referring to the technical properties of an object, or expressing the combination of primary types on the same object;
- three sets of supplementary abbreviations to describe the retouch[25].

A difference was made between the "symbols" (alphanumerical or typographical) and the "abbreviations" of natural language words by apocope: for instance, *dext(re)*, *dist(al)*, *prox(imal)* (see the formulas in Figure 4).

From 1968, the character strings generated with this method, which Laplace described as a "concise notation system" (Laplace 1966a, p. 201), were called "analytical formulas" (*formules analytiques*, Laplace 1968, p. 56-57). These formulas had to be constructed using a specific syntax, such as:

$$\text{TPx location shape (T'P'y)} \left[\text{technical symbols}\right] \text{ / additional retouches}$$

TPx and *T'P'y* were chosen from the set of primary type symbols. *T'P'y* was optional and used to complement the first symbol when two primary types could only ambiguously describe the object under study. A lithic piece can have multiple additional retouched edges and a set of operators made possible to describe their relative locations on a lithic piece (Table 3).

Analysing a lithic piece and describing it using the TA notation system implied to hierarchically arrange its properties[26]. Livache illustrated the relationship

[25]In archaeological analysis of stone knapping, retouch refers to "all forms of intentional secondary modification", including edge-limited and large removals (Odell 2004, p. 65).

[26]On the purpose of this hierarchical feature, see Livache 1976. Odell stressed that the TA was one of the rare quasi hierarchical lithic typologies, and also suggested that their weakness lies in the fact that "archaeological types are usually non-hierarchical – essentially because the contributions of underlying attributes to the type structure are relatively unknown" (Odell 2004, p. 104).

Table 4: Illustration of how features related to different levels of analysis are summarised and synthesised in TA. From Livache 1974, p. 18.

Hierarchical level of analysis		Common feature	Formula
Order:	Abrupt	Abrupt retouch	A
Group:	Backed point	Abrupt retouch forming a point	pteA
Class:	Deep backed point	Deep abrupt retouch forming a point	pteAp
Type:	Total deep backed point	Deep abrupt retouch all along the edge forming a point	pteAp tot
Variety:	Total straight deep backed point with flat inverted retouch at the base	Deep abrupt retouch all along the edge forming a point, covered by a flat indirect retouch at the basal extremity	pteAp tot /= Pi prox

between the hierarchical levels of the TA taxonomy and the syntax of the formula from the case of a "classical" type in lithic typology: the "Vachons" point, type number 50 in Denise de Sonneville-Bordes (1919–2008) and Jean Perrot's (1920–2012) typology, where it was defined as a backed point with a low angle inverse retouch at one or both extremities (de Sonneville-Bordes and Perrot 1956, p. 547). This example shows how the description was built by the addition of criteria (Table 4).

The application of the TA principles were not always rigid and were to some extent subject to the archaeologist's interpretation. This is illustrated by two different formulas describing the same lithic object (Figure 4). There are two reasons for these differences: first, the changes made in the different versions of the TA vocabulary (e.g., the primary type "complete backed point" (*pointe à dos total*) had the symbol "pD4" in 1968 and "PD23" in 1974); second, differences in the analysis and description of a lithic piece. Despite being systematised, the use of the TA notation and the writing of a formula is a matter of interpretation. For example, in 1968 the "rectilinear" property was considered an attribute of the primary type (backed point), whereas in 1974 it became one of the additional "technical properties". Other changes can be observed in the description of the spatial relationships of the retouched edges (coded with the use of the symbols "." and "——"). This highlights an important aim pursued in developing this notation: to offer a descriptive tool flexible enough for being widely adopted and applied to different types of lithic industries.

4.2 The collective use and development of the TA notation system

The notation system was instrumental in making the TA a collective tool, shared by different practitioners as a "common language". Laplace himself referred to the notation system as a language, as reflected by the linguistic vocabulary used in Table 3 (sign, utterance, signified) or in his publications:

> Thus, we obtain an analytical formula, a genuine syntagma formed of significant units, i.e. elements carrying morphotechnical information

which is the only type of information relevant in typology.[27] (Laplace 1968, p. 57.)

Determining the epistemological status of this notation, and whether it can be described as a language, is out of the scope of this study. However, these references to language reflect the importance of linguistics as a scientific model, in a period in which structuralist approaches were influential in several scientific fields[28]. In the context of the TA research group, this is illustrated by linguists such as Alain Nouvel (1942–2000) and Christian Baylon participating in the Arudy seminars and publishing in *Dialektikê* (Baylon 1977, Nouvel 1978), which also included other papers related to language, such as a linguistic analysis of typological concepts in archaeology (Cavaillès 1987).

The notation system was the basis for several innovations developed by TA practitioners, including the creation of the *Archivio di tipologia analitica* journal, published from 1973 to 1998. The 21 issues of this journal included what could be called "supplementary materials" today, namely the lithic objects discussed in authors' other publications, represented as lists of TA formulas. About 60,000 objects were described and published[29], illustrating how the notation became the base of a collective effort. Another example relates to an attempt, published in *Archivio*, to record formulas in a computer (Livache 1997). For the needs of this operation, Livache proposed to redefine and disambiguate some abbreviations whose meaning is clear for an archaeologist but undecidable for a computer. For example, the abbreviation "con" could correspond to "convex" and "convergent".

Livache was also the source, together with Laplace, of another improvement about notation in TA, related to the concept of "structural sequences". The structural sequence of a given archaeological layer was defined by the ordered numbers of pieces classified by taxonomical categories (e.g., "order" or "group", see Table 2). "Discontinuities" in the sequence were first defined between adjacent values being more than twice as large (Broglio and Laplace 1966, p. 343). Later, statistical procedures were used to define discontinuities (Phi coefficient, chi-squared, see Laplace 1981, p. 16-17). A notation was introduced to represent graphically these differences, using obliques to note their degree of significance (/, //, ///), parentheses to group associated classes, and equal signs to mark equivalent classes (Laplace and Livache 1975, p. 13-14). This method made possible comparisons between archaeological layers, as illustrated by three layers from Gatzarria cave (Table 5). The use of a notation system was therefore not only applied to the representation of lithic objects but was also used to represent the results of analytical procedures, which are addressed in the next section.

5 Specific reasoning: the TA analytical procedures

In broad terms, analytical procedures refer to the operations used to transform scientific data and generate new knowledge about it. The name of the TA, in itself,

[27] "*Ainsi, nous aboutissons à une formule analytique, véritable syntagme, formée d'unités significatives, c'est-à-dire d'éléments porteurs d'information morphotechnique seuls pertinents en typologie.*"

[28] Beyond the TA group, this is illustrated by the work by Jean-Claude Gardin (1925–2013) at the crossroad between archaeology and semiotics (Gardin and Peebles 1992).

[29] Plutniak 2020b, p. 289-291.

Table 5: Structural sequences of three layers from the Gatzarria cave (Cjn2, Cjn1, Cbf). The table gives the number of objects by typological order ("S" stands for "simple", "B" for "burin", etc.). Obliques mark the differences between values (adapted from Laplace and Livache 1975, p. 14).

Layer	Typological orders												Σ
	S	/	A	///	B		SE	///	E	=	P		
Cjn2	132		93		26		19		0		0		270
	S	///	A		SE	/	(B		(E)		P)		
Cjn1	70		25		21		6		3		0		125
	S	///	(SE		(E)		A)	///	B	/	P		
Cbf	216		76		52		42		8		0		394

reflects the importance played by analytical procedures in this approach. This is also illustrated in a letter where Laplace answered the critical review of this book by Delporte (Delporte 1967):

> Let's be objective: Leroi [-Gourhan] does not offer a method but rather an eclectic vocabulary; the Sonneville-Bordes-Perrault system simply represents a codification of the traditional ordered morphology, as do the all too similar systems of Escalon-Lumley and Tixier, according to a stratigraphic criterion; as for the studies of Bohmers and Vértes, the analytical typology is reminiscent of others in the same framework.[30]

About fifteen years later, Laplace conveyed a similar argument to Rozoy: "Furthermore, in 1968, Brézillon, in line with his master's approach [André Leroi-Gourhan], achieved the undue distinction of their method by reducing the project of analytical typology to the dimensions of a coded language!"[31]. The claim that the TA was a method, for Laplace, was neither grounded in the definition of a vocabulary or the processes of coding, nor in the application of ordering relations to the data or the use of mere statistics. For him, what made the TA a method was the relationships defined between multiple analytical procedures, forming a set whose consistency is related to a specific knowledge aim. This section does not focus on the definition and change in this knowledge aim from the 1950s to the 2000s but instead examines the different analytical procedures included in the TA and their articulations.

I distinguish between three types of procedures, respectively related to: 1) the measurement of the properties of individual objects (here, lithic objects), 2) the

[30] "*D'ailleurs, soyons objectifs : Leroi[-Gourhan] ne propose pas une méthode mais un vocabulaire éclectique ; le système Sonneville-Bordes-Perrault ne représente qu'une codification de la morphologie traditionnelle ordonnée, comme dans les systèmes similaires d'Escalon-Lumley et de Tixier, selon un critère stratigraphique ; quant aux recherches de Bohmers et Vértes, la typologie analytique en conduit de semblables dans son propre cadre.*" Letter from G. Laplace to H. Delporte, 15-11-1967, Mnp.

[31] "*Enfin, en 1968, Brézillon, dans le droit fil de la démarche de son maître [André Leroi-Gourhan], achève le démarquage en réduisant le projet de la typologie analytique aux dimensions d'un langage codé !*" Typed letter from G. Laplace to J.-G. Rozoy, 16-09-1982, Mnp. Laplace probably referred to Brézillon 1968, p. 43.

properties of a set of objects, and 3) the quantitative comparison between sets of objects. The distinctions between these three levels are related to two other distinctions, between:

- two subfields in prehistoric archaeology, namely typometry and typology;
- two knowledge aims, related to, on one hand, a single object and its (static) integration into a classification of objects and, on the other hand, to the description of the (dynamic) changes between different states of sets of objects over time.

The procedures related to these three levels of generality were gradually introduced in TA. Chronologically, procedures related to sets of objects (2) were first introduced, then comparison procedures (3), and finally procedures about individual properties (1). Chronological order is followed in this section, rather than the logical order related to the levels of generality.

5.1 Measuring the properties of a set of objects: the "industrial complex" and "structure" concepts

The analysis of the properties of a set of lithic objects was what Laplace claimed as one of his major conceptual innovations. He introduced the concept of *industrial complex*, which was said to be characterised by a *structure*:

> the qualitative notion of "structure", based on the study of the quantitative relationships between "typological families", "typological groups" or "primary types".[32] (Laplace-Jauretche 1957, p. 163.)

Studying these quantitative relationships was made by computing *indices* and representing them with diagrams. Laplace defined indices for each hierarchical level of the taxonomy (primary type index, typological group index, etc., see Table 1) and for "technical" aspects (e.g., the proportion of laminar or microlithic pieces in a set of objects)[33]. The graphical representation of quantitative data was a major aspect of the typological controversies between archaeologists in the 1950s. François Bordes proposed the use of percentage histograms (Bordes 1950b) and "cumulative diagrams" (Bordes and Bourgon 1951). Laplace, who was not the only one to criticise Bordes' cumulative diagrams (see also Cheynier 1957, Kerrich and Clarke 1968, Kolpakov and Vishnyatsky 1989, Bisson 2000), defended the use of "*bloc-indices*"[34] to visualise the numerical values of the indices he defined and determine the structure of a set of objects, namely:

> a type of balance which we call the *specific structure* of the intended group of industries. It is the *specific structure* that grants diagrams their original appearance. This observation brings us to introduce

[32] "*la notion qualitative de "structure", fondée sur l'étude des rapports quantitatifs existant entre les "familles typologiques", les "groupes typologiques" ou les "types primaires".*"

[33] From an arithmetical perspective, these "indices" were actually quotients. This approach was not a novelty, other authors already defined similar computations (e.g., Malvesin-Fabre 1952, p. 59, Bordes 1950b, p. 410).

[34] In actual terminology, Laplace's "*bloc-indices*" correspond to categorical bar charts.

> a new notion: the *industrial complex*. All industries with the same structure make up an industrial complex.[35] (Laplace-Jauretche 1957, p. 145-146.)

According to Laplace, the study of structures and industrial complexes made the difference between the TA and other contemporary statistical approaches. After his 1957 paper, this concept remained fundamental in the TA and was occasionally redefined with minor changes[36]. Laplace also used the structure concept to define thirteen other concepts: e.g., the *morphological*, *technical*, *typometrical*, *elementary* structures, etc. In addition, the concept of *structural sequence*, already discussed, was an important innovation[37].

5.2 Comparing the properties of sets of objects

Comparing sets of objects by computing (similarity or dissimilarity) distances between the properties of these objects relate to the highest level of abstraction in TA. As summarised by Laplace and José María Merino in a later article, the sets of objects can be defined in various ways, including the time dimension or not:

> While comparative structural analysis studies the relationships between several industrial complexes from different sites, the analysis of structural dynamics studies the relationships between industrial complexes in the same stratigraphic sequence.[38] (Laplace and Merino 1979, p. 395.)

Analytical procedures related to this level of generality were included early in the TA, from the 1957 seminal paper, in which the evolution of industrial complexes was addressed. An important step was the 1974 paper "*De la dynamique de l'analyse structurale ou la typologie analytique*" (On the dynamics of structural analysis, or analytical typology) (Laplace 1974). The concept of "structural dynamics" was defined and, as suggested by the title, the TA and the study of these dynamics were considered equating to each other. Laplace had a lasting interest in determining and naming evolutionary processes and the analysis of structural dynamics aimed at describing these processes with quantitative methods. Two types of methods can be distinguished: those created by the TA practitioners, and those imported from statistical publications.

The first category is illustrated, for example, by Laplace's definition of an *instability coefficient* used to order a set of structural sequences (Laplace 1974, p. 139). From the time when the collective development of the TA started (from the first

[35] "*une sorte d'équilibre que nous appelons* structure spécifique *du groupe d'industries envisagé. C'est la* structure spécifique *qui donne aux diagrammes leur physionomie originale. Cette constatation nous amène à introduire une nouvelle notion : celle de* complexe industriel. *Toutes les industries qui présentent la même structure forment un complexe industriel.*"

[36] For example, the structure concept was occasionally presented in an organicist perspective (Broglio and Laplace 1966, p. 343).

[37] In addition to the procedures related to the lithic types, few procedures were applied to morphometrical data measured on sets of objects, e.g. linear regression (Laplace 1977a).

[38] "*Alors que l'analyse structurale comparée étudie les rapports entre plusieurs ensembles industriels provenant de sites divers, l'analyse de la dynamique structurale étudie les rapports entre les ensembles industriels d'une même séquence stratigraphique.*"

typology seminar at Arudy in 1969), the practitioners contributed by importing statistical methods. Laplace introduced the use of the chi-square distance (Laplace 1974) and chi-squared test (Laplace 1975), the taxonomy method based on the ultrametric distance (Laplace 1975), and Fisher's exact test (Laplace 1978).

The introduction of concepts from information theory from the late 1970s provides a good illustration of the collaborative dimension in methodological innovation among TA practitioners. A first example is the test of independence based on the 2Î statistical dispersion index[39]. In 1975, Jean Lesage examined this test in detail after Laplace mentioned it to him. Lesage implemented it in 1978 in a program for the HP67 pocket calculator[40]. The same year, Laplace used this test and published Lesage's programming code in a paper about the analysis of the discontinuities in structural sequences (Laplace 1978, see also Table 5). Other examples include the measure of the "*Lien*" between features[41] (Laplace 1980), and the use of Shannon's entropy concept by Jacques-Élie Brochier and Michel Livache, who applied it to compare stratigraphically ordered structural sequences (Brochier and Livache 1982).

Lesage played a significant role in introducing more sophisticated statistical procedures in the TA collective. He contributed, in particular, by writing programs for programmable handheld calculators, recorded on magnetic cards and exchanged between the participants of the Arudy typology seminar. During the 1978 seminar, Lesage presented several algorithms he implemented, including the chi-square distance, the Mann-Whitney test, the Kruskall-Wallis test, correspondence analysis[42]. Correspondence analysis was first introduced in 1977 among the TA practitioners. The first known application was made by the statistician Éliette Laborie, a student of Henri Caussinus in Toulouse[43], then working at Pau University, in the Pyrenees. Laplace gave classes at this university from its first year of activity in 1971. Laborie signed the mathematical appendices of a paper by Laplace on the lithic industry from an Italian site in "*Il Riparo Mochi ai Balzi Rossi di Grimaldi (Fouilles 1938–1949). Les industries leptolithiques*" (Laplace 1977b). She also performed computations for the study of the lithic material from Provence (Brochier and Livache 1978) and some Basque sites (Laplace and Merino 1979, p. 707-708). In the 1980s, the sophisticated computations required for correspondence analysis were done by the archaeologists themselves, using Lesage's programs.

[39]The 2Î test is a less know alternative to the chi-squared test, with the advantage not to have a constraint on the minimal number of individuals by class. This test is based on the work by the American mathematician Solomon Kullback (1907–1994) in information theory (Kullback 1959). In France, the 2Î measure and 2Î test were introduced by the mathematician and agronomist Pierre Arbonnier (1918–2006) (Arbonnier 1966). However, Laplace discovered this method from Lothar Sachs' statistics handbook (Sachs 1969).

[40]Letters from J. Lesage to G. Laplace, 24-10-1975 and 17-9-1978, Mnp.

[41]Developed by the economist and statistician Michel Volle the *Lien* ("bond" in French) is a "measure of the information gain resulting from the knowledge of the content of a table" when the margin frequencies are already known (Volle 1981, p. 62).

[42]Letter from J. Lesage to G. Laplace, 17-9-1978, Mnp.

[43]Laborie defended her PhD in 1971 under Caussinus' direction, *Recherches sur un problème d'analyse multidimensionnelle* (Research on a multidimensional analysis problem).

5.3 Measuring the individual properties of objects

Analysis procedures related to the lowest level of generality (single objects and their properties) were the last to be addressed by the TA practitioners. This aspect was gradually introduced in TA under the name of "typometry", referring to the application of metric measurements to archaeological objects to determine description categories and types.

Laplace's interest in typometry originated in his scientific exchanges with Dutch archaeologist Johan Christiaan Assien Böhmers (1912–1988)[44]. In a harsh critical note from 1959, D. de Sonneville-Bordes accused Bohmers of having unduly claimed scientific priority over François Bordes for the application of statistics in prehistoric archaeology (de Sonneville-Bordes 1959). Bohmers sent a copy of his answer to Laplace, providing evidence to refute this accusation[45]. During the next decades, Laplace never ceased to defend Bohmers' priority on typometry against Bordes (although considering at the same time that the *name* of this concept was his personal contribution, e.g., Laplace 1982, p. 30). During the 1950s and the 1960s Laplace was not especially interested in typometry. In the 1957 "*Typologie analytique*" paper, he did not address the individual properties of lithic objects and their quantification. The only occurrence of this aspect in his PhD dissertation was the definition of a "typometric carination index"[46], which was completed in 1968 by a "lengthening index" (Laplace 1968, p. 20-21). These two indices were computed as simple ratios between two metric values.

The development of typometry in TA occurred later, in the 1970s and 1980s, through a deepening of the geometrical aspects of lithic study. This emphasis on geometry was part of a shared interest in the *compagnonnage*, a movement and network of transmission and practice of craftsmanship, widely developed in France since the eighteenth century (Plutniak 2017b, p. 134-137). This new interest is illustrated by astonishing differences between two important papers: "*Recherches de typologie analytique 1968*" (Laplace 1968) and "*La typologie analytique et structurale : base rationnelle d'étude des industries lithiques et osseuses*" (Laplace 1974). The second paper is mainly an update of the first one, but with significant changes in the section "*Typométrie de l'éclat*" (Flake typometry). Laplace introduced a set of new measurements: the old carination and lengthening indices were replaced by a set of "modules" defined from the Fibonacci sequence (Laplace 1974, p. 101-103). Other examples include a geometrical method for the tridimensional analysis of lithic objects (Thomas 1974), a paper about the orientation of lithic objects in space before measuring them (Laplace 1976, p. 30); a study about the optimal determination of the minimal reference rectangle in which locating an object before measuring it (Laplace 1977c); a study of the angle measurement and the thresholds to distinguish between different types of lithic implements (scrapers, points, backed points, truncation, etc.) by comparing "results obtained from a methodical approach with the spontaneous inductions of empirical knowledge"[47] (Laplace

[44]During WWII, Böhmers changed his name as Assien Bohmers, in relation with his activities at the SS Ahnenerbe. See the recent biography, Carmiggelt 2019.

[45]Letter from A. Bohmers to G. Laplace, 20-10-1959, MNP.

[46]Laplace 1961. Laplace also used this index in Laplace 1964a, p. 31 and in the publication of his PhD dissertation Laplace 1966b, p. 48.

[47]"*des résultats obtenus par une démarche méthodique avec les inductions spontanées de la connais-*

1982, p. 30). As suggested by this quote, these improvements in methods were motivated by theoretical concerns. This brings us to an examination of the status of the dialectics and structure concepts in TA.

6 Conceptual background: TA, dialectics, and structuralism

Scientific methods do not exist by their own, but draw on and refer to other methods and concepts. In this section, the conceptual background of the TA is discussed with reference to two major theoretical frameworks in French humanities and social sciences in the 1950s–1970s, namely structuralisms[48] and Marxist dialectics.

6.1 References to structuralism and the methodological status of the structure concept

The post-WWII period was characterised by a will to modernise archaeology and strengthen its scientific ground, in the USA (Willey and Phillips 1958) as well as in France (Laming 1952b). As mentioned earlier, from its first occurrence in 1957, the concept of structure played a crucial role in TA, strengthened in 1973 by its introduction into the very name of the method ("Analytical and structural typology"). I will examine the extent to which what is now described as "generalised structuralism", namely the multiple adaptations and forms of a "structural" approach (Léon 2013), was instrumental in the modernisation of archaeology as seen by Laplace and the TA practitioners. I show that although they kept at bay structuralist references and claimed for a concept of structure particular to archaeology, the position they defended shared more general aspects in common with other structuralist approaches.

6.1.1 A definition of structure particular to archaeology

Two periods can be distinguished considering the references to structuralism in general in TA. References were absent during the first period, from 1957 to 1968. A change happened in 1968 with the paper "*Recherches de typologie analytique 1968*" (Research in Analytical Typology 1968) in which Laplace denied any influences from linguistic and ethnological structuralisms on his own work:

> In 1956, irrespective of the research carried out in linguistics and ethnology, we came upon the concept of structure, the only notion that grants access to the coherent and specific definition of an industrial complex. Since then, we have fully established that the study of the structural variations of different industrial complexes uniquely en-

sance empirique".

[48]Plural is required, due to the many different practices which were associated with this term. See for example Lamy 2016 on Marxism and structuralism in France, and the other chapters of this collective volume.

> riches our knowledge regarding the quantitative and qualitative phenomena that so characterise their future.[49] (Laplace 1968, p. 53.)

Laplace so defended the idea of a specific development and relevance of the concept of structure in archaeology[50]. Laplace's refusal to consider his use of the structure concept with exogenous and extra-disciplinary references was repeated in a different publication, some years later (Laplace 1974, p. 137), in which he employed a typical scheme of a multiple discovery narrative in the history of science[51]. What is currently known about the composition of Laplace's personal library does not either support or refute this statement of absence of influence from other structuralist work. However, it is certain that the idea of Laplace's opposition to structuralism was acknowledged by other archaeologists. For example, in his PhD dissertation, the Swiss archaeologist Jean-Louis Voruz considered that the three authors inspiring his work – Alain Gallay, Jean-Claude Gardin and Georges Laplace – "all raised against the tendency of using simplistic comparatism and structuralism which characterise archaeology during the 1960s"[52] (Voruz 1984, p. 28).

Even if no other structuralist approaches might have directly influenced the development of the TA, the use of "structural" reasoning by these archaeologists recalls the general trend of referring to this idea, which was a major aspect of the scientific and intellectual atmosphere during the 1960s. There is a fuzzy frontier between the explicit "structuralist" approaches and the uses of the structure concept which contributed to the general structuralist climate. In particular, Laplace himself occasionally established general similarities between the TA and some components of the generalised structuralism.

6.1.2 Relationships between archaeology and generalised structuralism

When the defence of the scientific principles of the TA was at stake, Laplace had no problem referring to structuralism. This is illustrated, for example, in a letter sent to Henri Delporte:

> Hermetic method that's difficult to use. Really? No more so than the methods recommended by Benvéniste in linguistics and by Lévi-Strauss in anthropology. Does analytical typology better account for

[49] "*En 1956 nous parvenions, indépendamment des recherches effectuées en linguistique et en ethnologie, au concept de structure, seule notion qui permette d'accéder à la définition cohérente et spécifique de complexe industriel. Depuis, nous avons amplement établi que l'étude des variations structurales des divers complexes industriels aboutit à un singulier enrichissement de notre connaissance des phénomènes quantitatifs et qualitatifs qui caractérisent leur devenir.*"

[50] This illustrates, once again, the importance of priority claims for discoveries in archaeology, not only about sites or outstanding remains, but also about conceptual and methodological innovations. See the cases of typometry and use of statistics in prehistoric archaeology discussed above. Laplace seemed to have been very sensible to priority issues, inspired by the sociology of science readings. See his pamphlet Laplace 1987a and its republishing and discussion in Plutniak 2020a.

[51] However, in this writing, Laplace did not show signs of *adumbrationism*, namely what the sociologist Robert Merton defined as "the practice of claiming to find dim anticipations of current scientific discoveries in older, and preferably ancient, work by the expedient of excessively liberal interpretations of what is being said now and of what was said then." (Merton 1961, p. 485).

[52] "*tout trois élevés contre la tendance au comparatisme primaire et au structuralisme qui caractérisait l'archéologie des années 1960.*"

> reality than other typological systems? That's the one, and only, question. Everything else is simply a matter of study and training.[53]

Laplace compared the TA with two major declinations of structuralism, namely in linguistics and in anthropology, thus assuming a degree of similarity between them, referring to notions of clarity, systematicity, realism, and progress of knowledge.

In addition, let us consider the TA according to one major aspect of structuralism: its genericity and the constant expansion of its domains of applications. The TA was initially, and above all, a method to study manufactured stones from the Late Palaeolithic and Mesolithic. However, one of the main characteristics claimed to distinguish the method was its genericity and possible universal application to diverse contexts: aiming to replace the numerous local typologies, the TA method was considered relevant for and applicable to African lithic objects as well as Italian and Pyrenean material[54]. Considering geographic scope, the study by André Crémillieux (1937–2018) of stone implements from Easter Island is a striking example of the possibility to adapt and apply the TA to other contexts (A. Crémillieux 1987). In addition, the "analytical approach" was also adapted in order to help studying other types of archaeological objects, including bone industries (Voruz 1978, 1984), faunal remains (Estévez 1977), rock art (J. Delfaud and L. Delfaud 1974), Neolithic pottery (Vital 1981), and stratigraphic successions (Sáenz de Buruaga 1996). In addition, attempts to extend the domain of application of the TA went beyond prehistoric archaeology. For example, it was applied to manufactured stones found in a medieval settlement in the Basque Country (Fernández Eraso 2013) and, more generally, to cultures as studied by anthropology: for a while Livache had "the (crazy) ambition of an analytical typology of cultures"[55], which merely resulted in the publication of a bibliographical review of the definitions of anthropological concepts, including "culture" (Livache 1981b). A last example, although anecdotal, is about dry stone constructions. This is illustrated by a talk given by A. Crémillieux entitled "*Propositions pour la mise en chantier d'une typologie analytique de la cabane en pierre sèche*" (Proposals for the development of an analytical typology of dry stone huts) in 2002 at the *Fédération de la pierre sèche* seminar (Dry Stone Federation)[56].

It must be stressed that these studies were marginal and had only a small impact on the growth of the TA, which was mainly about lithic objects. However, they all explicitly referred to the method and illustrate an ambition for universality, which is a general feature shared with other structuralist developments, assuming that this sort of reasoning helps to inform various phenomena. Nevertheless, while considering the concept of structure as essential, the main theoretical reference of TA practitioners was Marxism rather than structuralism, as illustrated by

[53]"*Méthode hermétique et difficilement utilisable. Vraiment ? Pas plus que les méthodes préconisées par Benvéniste en linguistique et par Lévi-Strauss en anthropologie. La typologie analytique rend-elle mieux compte du réel que les autres systèmes typologiques ? La question est exactement là et seulement là. Tout le reste n'est qu'affaire d'étude et d'entraînement.*" Letter from G. Laplace to H. Delporte, 15-11-1967, MNP. In this letter, Laplace answered to Delporte's review of his book (Delporte 1967).

[54]This feature of the TA was also stressed in Giannichedda 2021, p. 77-80.

[55]"*l'ambition (folle) d'une typologie analytique des cultures*". Letter from M. Livache to G. Laplace, 11-5-1977, MNP.

[56]This seminar was held at Saint-Germain de Calberte (Lozère, France), 17–19 September 2002.

this interview excerpt with Livache:

> **M.L.**: With Laplace, structurally, we think in hierarchical levels. Today, we're discovering… there's general history, and we're talking about microhistory, which has nothing to do with general history, and we find it surprising [that different scales of observation bring about different observations]. We have to decide at which level… Those dealing with prehistory today following the Bordes method –or any other one–, are working at a flat level. Example: in economics, from a general level, humanity has never been more prosperous. On individual levels, some are getting along fine and others are suffering, some people are really unhappy. It all depends on the level of analysis, if it's general… That was inherited from structuralism.
>
> **S.P.**: From Lévi-Strauss?
>
> **M.L.**: No, Levi-Strauss didn't… You tell me, in the 1960s everything was structuralist, and maybe none of it was connected. There was a good book by Edgar Morin on it. Laplace's references were often Marxist.[57]

6.2 Dialectics and TA: a metaarchaeological function

The concept of dialectics, as the concept of structure, were widely shared ideas in the 1960s. As such, TA's practitioners also referred to dialectics, gradually considering it as a ground for their method and a conceptual cement strengthening its consistency. In this section I address the changes in the references to this concept and its status, demonstrating that, more than an epistemological principle implemented in actual analytical procedures, it was part of the meta-discourse archaeologists developed at the time about their scientific practice.

In the first occurrence of the concept of dialectics in Laplace's work, he framed it as a means to rethink the type concept:

> The notion of industrial ensemble, which remains our research base, involves the only qualitative definition of "characteristic form". The new analysis method, using all types of statistical reports, including the simplest ones, creates a quantitative definition. Looking beyond these two definitions, moving dialectically, we come to a new qualitative definition: that of industrial complex, where the characteristic forms and structures can be considered in their interrelations.[58] (Laplace-Jauretche 1957, p. 146.)

[57] Interview with M. Livache.

[58] "*La notion d'ensemble industriel qui demeure notre base de recherches fait intervenir la seule définition qualitative de 'forme caractéristique'. La nouvelle méthode d'analyse, utilisant les rapports statistiques de toutes les formes, y compris les plus humbles, crée une définition quantitative. Dépassant ces deux définitions, nous parvenons par un mouvement dialectique, à une nouvelle définition qualitative : celle de complexe industriel, où les formes caractéristiques et les structures peuvent être considérées dans leurs relations réciproques.*"

After this first occurrence in 1957, the idea of dialectics is absent until the publication of his PhD. dissertation in 1966 in which Laplace included a short paragraph about the "dialectical method". Answering Bordes' criticisms[59], Laplace reused and enhanced this paragraph in his later publications, where he considered dialectics as the fundamental ground of his approach[60]. Laplace was explicit about the use of dialectics as a unification principle in a 1967 letter to Henri Delporte, who also criticised his work:

> Thus, forming an original totality, based on dialectical rationalism, the analytical typology cannot fall into any kind of syncretism without ultimately denying itself. The value of a method is judged by the results obtained, how much it allows knowledge to progress by combining flexibility and rigour.[61]

In this excerpt, he made clear his view on what gives a method its scientific value: its unity, its capacity to generate new knowledge, and the consistency of its form of reasoning. In this case, this consistency was said to be grounded in dialectical rationalism. It appears that Laplace articulated both aspects, dialectics and rationalism, considering them as complementary[62]. For example, in a 1974 letter to J.-G. Rozoy, Laplace presented the TA as a specific application of the general dialectical method:

> analytic typology is nothing but the negation and overcoming of traditional empirical typology by applying the dialectical method to typological research.[63]

However, in the title of a paper published the same year, he chose the adjective "rational" (and not "dialectical") to characterise this particular typological approach (Laplace 1974). In a later correspondence with Rozoy, Laplace suggested that what made the difference between the TA and the other typological approaches was the use of the dialectical method, which he tried to clarify using a synthetic model of scientific change:

> Finally, a diagram, inspired by Gallay[64], shows the fundamental difference between the spontaneous or empirical typology of "list-types"

[59] Bordes 1965.

[60] The gradual importance of dialectics can be observed by comparing: Laplace 1966b, p. 28-29, Laplace 1968, p. 11-14, Laplace 1974, p. 3-4, and the section "*Question de méthode*" (Methodological issues) in Laplace 1997, p. 234-235.

[61] "*Ainsi, constituant une totalité originale, basée sur le rationalisme dialectique, la typologie analytique ne saurait entrer dans un quelconque syncrétisme sans se nier elle-même. La valeur d'une méthode se juge aux résultats obtenus, aux progrès de la connaissance qu'elle permet en alliant souplesse et rigueur.*" Letter from G. Laplace to H. Delporte, 15-11-1967, Mnp.

[62] Laplace was a member of the *Union rationaliste*, and made many references to French rationalists philosophers and scientists in his archaeological publications, including for example Gaston Bachelard and Ernest Kahane. See also Merino and Izaga 2004, p. 145.

[63] "*la typologie analytique n'est que la négation et le dépassement de la typologie empirique traditionnelle par l'application de la méthode dialectique à la recherche typologique.*" Letter from G. Laplace to J.-G. Rozoy, 12-3-1974, Mnp.

[64] Alain Gallay (1938–), Swiss prehistoric archaeologist with interest in theoretical issues, as illustrated by the paper which probably inspired Laplace (Gallay 1980).

> and analytical typology, a logical, intelligible, coordinated and open system based on the dialectical method[65]:
>
> - Each list-type constitutes a rigid A framework, such as: $A + X = X^A$... a new discovery X questioning the A framework results in X equated to A: we force the discovery into the theoretical system.
> - Analytical typology, however, is defined by a real equation: $XA = A'$... the interaction between the new discovery X and the existing framework of understanding leads to the creation of a new reference grid, a new theoretical framework for grasping reality (evolving open grid).[66]

The combination of dialectics and rationalism originated in Laplace's interest in epistemological, theoretical, and Marxist studies. This interest was fed through his intellectual friendship with the Marxist philosopher Henri Lefebvre (1901–1991) who published several books on dialectics[67]. As Laplace, Lefebvre was from the Béarn Pyrenean region. They met on a regular basis, Lefebvre visited Laplace's excavations and participated in the second Arudy seminar in 1970.

These seminars strengthened the collective development of the TA and favoured the appropriation of dialectics and rationalism. Other practitioners acknowledged dialectics as a specific property of the TA. For example, Delfaud stressed that Laplace has

> drawn up, in 30 years of practice, a dozen typological lists, in a series of dialectical movements between the concrete and the theoretical.[68] (J. Delfaud 1973, p. 9.)

Spanish archaeologists, in particular, integrated the reference to dialectics in their own research. For example, the Catalan archaeologists Eudald Carbonell and Rafael Mora, and the French Michel Guilbaud, published an "*Application de la méthode dialectique à la construction d'un système analytique pour l'étude des matériaux du Paléolithique inférieur*" (Application of the dialectical method to the construction of an analytical system for the study of Lower Palaeolithic materials) (Carbonell, Guilbaud, et al. 1982). Drawing on the TA and extending it further,

[65] Significantly, Laplace borrowed the three properties characterising science according to Ernest Kahane in a paper on "rationalism" published in *Raison présente*, the journal of the *Union rationaliste* (Kahane 1980).

[66] "*Pour terminer, un schéma, inspiré de Gallay, rend compte de la différence fondamentale entre la typologie spontanée ou empirique des 'listes-types' et la typologie analytique, système logique, intelligible, coordonné et ouvert fondé sur la méthode dialectique : Chaque liste-type constitue un cadre rigide A tel que : $A + X = X^A$ ... une nouvelle découverte X remettant en question le cadre A aboutit à X assimilé à A : on fait entrer de force la découverte dans le système théorique. La typologie analytique, au contraire, se définit par une véritable équation :*
$XA = A'$ ... l'interaction entre la nouvelle découverte X et le schéma de compréhension existant alors provoque la création d'une nouvelle grille de référence, d'un nouveau cadre théorique d'appréhension de la réalité (grille ouverte évolutive)." Letter from G. Laplace to J.-G. Rozoy, 16-09-1982, MNP.

[67] Namely, *Logique formelle, logique dialectique* (Formal logic, dialectical logic, Lefebvre 1969) and *Le matérialisme dialectique* (Lefebvre 1962, translated into English as Lefebvre 1968).

[68] "*[Laplace a] élaboré, en 30 ans de pratique, une douzaine de listes typologiques, dans une suite de mouvements dialectiques entre le concret et le théorique.*"

these authors later developed the "*Sistema Lògic Analític*" (Logical Analytical System) for the study of lithic implements (Carbonell, Mosquera, et al. 1992). In a tribute monograph to Laplace, two other Catalan archaeologists entitled their contribution "*La fuerza de la contradicción interna*" (The Strength of Internal Contradiction), in reference to Laplace's taste for dialectics (Vila and Estévez 2006). Another group of researchers, from the Basque Country, extended the TA dialectical approach to stratigraphy. Developing what they coined "*Estratigrafía Analítica*" (Analytical stratigraphy) (Sáenz de Buruaga 1996, Sáenz de Buruaga 2006), they founded the *Krei* journal publishing on related topics[69].

However, despite the claims of the TA practitioners, the idea of a crucial status and function of dialectics in TA is questionable[70]. In a short paper entitled "*La typologie analytique, une dialectique*" (Analytical Typology, a Dialectic), Livache summarised the dialectical aspect of the TA:

> Analysing, developing a reasoning, formulating hypotheses upon said analysis and reasoning, returning to the analysis and modifying it according to the hypotheses, modifying the reasoning to come up with new hypotheses… this is the dialectical work of the Analytical Typology.[71] (Livache 1989, p. 30.)

As illustrated by this quotation the reference to dialectics was very general, as outlined by Laplace in his exchange with Rozoy. The reference to dialectics by TA practitioners falls under what Lester Embree called "metaarchaeology" (Embree 1992), namely historical or philosophical discourses *about* archaeology, rather than being essential to the methods they developed and applied to actual data[72].

***

Taken together, the notion of structure played an important role in the organisation of data and the definition of the analytical procedures of the TA. Similarly, the concept of dialectics was instrumental in TA practitioners' metaarchaeology. However, whether this meta-discourse was a proper, distinct and necessary part of the TA is uncertain given that practising the TA approach did not require specific reference to dialectics. This leads us to our final question: what was the core of the TA, its minimal and necessary components which ensured its unity and identity?

[69]About this group, in the context of the history of stratigraphic methodological innovations in the Pyrenees region, see Plutniak 2021a, p. 88-89.

[70]For an in-depth discussion and defence of the dialectical aspects of Laplace's TA, against the Logical Analytical System promoted by Catalan archaeologists, see Sáenz de Buruaga 2005.

[71]"*Analyser, développer un raisonnement, énoncer des hypothèses en fonction de cette analyse et de ce raisonnement, revenir à l'analyse et la modifier en fonction des hypothèses, modifier le raisonnement pour aboutir à de nouvelles hypothèses… voilà le travail dialectique de la Typologie Analytique.*"

[72]For a different and unrelated dialectical approach in lithic typology, see the philosophically grounded perspectives developed in W. Y. Adams and E. W. Adams 1991.

7 Discussion

7.1 What makes the identity of a scientific method?

Multiple aspects of the TA have been identified and discussed in this paper. Considering the TA while virtually subtracting each aspect is a good way to test whether this aspect is a necessary component of the TA. 1) The names of the method and of its vocabulary are obviously not essential for their definition and application. 2) The use of a vocabulary is necessary for typological analysis. However, as demonstrated by the changes in the different versions of the TA's vocabulary, the contents of the vocabulary are not essential to the method (although they reflect a "dialectical praxis"). 3) The use of statistical methods also cannot be considered as the core of the TA, considering that most of these methods were generic and not created especially to be used in the TA and prehistoric archaeology. 4) The TA practitioners considered dialectical reasoning as the main and distinctive feature of their approach. I have argued that this is questionable since the importance of this concept increased gradually over time. Consequently, it was possible to practise the TA approach with no reference to dialectics, which was part of the meta-discourse about the TA rather than part of the methods being applied to data. 5) Finally, subtracting the notation system makes it impossible to use the TA, neither to represent the data nor to analyse them: without the notation, the representation is not substantially different from representations based on alternative methods, and the analysis would become the simple application of standard statistical methods. Consequently, I argue that the essential and necessary component of the TA lies in its notation system[73]. Because this notation includes both a conventional set of signs *and* a syntax, it was more than a mere naming method: it implemented a specific way to determine relationships between real-world phenomena and their scientific representation, grounding the methodological unity of the TA.

This feature supported a particular way to consider and practise science, of which two aspects must be emphasised with significant consequences for today's archaeology: its link with evolutionary archaeology, on the one hand, and with computational archaeology, on the other hand.

7.2 A continuation of evolutionary approaches in French archaeology

In the 1950s, adopting an evolutionary perspective was a common view among French archaeologists. The conclusion of a book edited by Annette Laming about the new advances in archaeological methods illustrates this orientation:

> The prehistorian is not a historian. They are not on the lookout for events that they will never be able to trace. They attempt to find general laws, a general sense of biological and cultural evolution.[74] (La-

[73]Note that ultimately this argument is consistent with the common view shared by archaeologists who, not practising the TA, identified it with its notation system and overlooked the TA's other components and their relationships.

[74]"*Car le préhistorien n'est pas un historien. Il n'est pas à la recherche des événements dont, de toutes façons il ne pourra jamais retracer la chaîne. Il essaie de retrouver des lois générales, un sens général d'une évolution biologique et culturelle.*"

ming 1952a, p. 301.)

At that time, French archaeologists were continuing an older trend rooted in the work of 19th century researchers, such as Gabriel de Mortillet (1821–1898). However, evolutionary research aims, scales of analysis, and methods were gradually less used in the next decades. Laplace and his closest collaborators maintained an interest in evolutionary aims throughout the second half of the 20th century, as illustrated, for example, in a paper published by Laplace in 1997:

> Indeed, the evolution of an industrial complex can rationally be approached from a resolutely biological point of view. According to this hypothesis, said evolution can be considered that of a "cladogenetic complex" (from the Greek, *klados*, "branch") with differential anageneses, an anagenesis being a continuum of industrial units succeeding one another over time.[75] (Laplace 1997, p. 231.)

Research aims related to evolution and anthropology were replaced by aims related to history and ethnography, e.g., palaeo-ethnography (influenced by the late André Leroi-Gourhan) and lithic technology (influenced by Jacques Pélegrin, Jacques Tixier and others). TA practitioners criticized several aspects of this trend, including the ambition to reconstruct past societies, the introduction and use of anthropological concepts in archaeology (e.g., the culture concept[76]), and strong assumptions on past humans' intentionality.

However, TA practitioners had interestingly almost no relationship and contact with US and UK research and researchers pursuing similar goals and subscribing to similar research interests (for example, references to Alfred Spaulding, Lewis Binford, and the New Archaeology are absent). Two exceptions can be mentioned. Laplace had relationships with the American archaeologist Hallam Movius (1907–1987), who excavated the site of Abri Pataud from 1953 to 1964 and contributed to the development of "attribute analysis" as a method for the analysis of lithic stone tools (Movius et al. 1968). However, they did not exchange or collaborate on methodological issues, as revealed by their friendly correspondence[77]. In addition, Laplace later suggested that Movius' "attribute analysis" was a plagiarism of his 1957 paper[78]. A second exception is his indirect relationship with the British archaeologist David Clarke (1937–1976), through a translation in *Dialektikê* of a paper criticising Bordes' use of statistics[79]. Consequently, the TA experience appears as a little-known attempt at maintaining large-scale evolutionary archaeology research aims in France.

---

[75] "*En effet, l'évolution d'un complexe industriel peut être rationnellement abordée d'un point de vue résolument biologique. Dans cette hypothèse, cette évolution peut être considérée comme celle d'un* complexe cladogénétique *(du grec* klados *'rameau')* à anagenèses différentielles*, l'anagenèse étant un continuum d'ensembles industriels se succédant dans le temps.*"

[76] For a critical review of the many definitions of the culture concept by a TA practitioner see Livache 1981a.

[77] Held at Mnp and Peabody.

[78] Laplace-Jauretche 1957. More precisely, Laplace accused Movius of "cryptomnesia" (Laplace 1987a, p. 35), that is, according to sociologist Robert Merton's word, the " *'submerged or subliminal memory of events forgotten by the supraliminal self', as in forgetting the source of an idea one takes to be newly one's own*" (Merton 1965, p. xxiii).

[79] Kerrich and Clarke 1968 translated as Kerrich and Clarke 1976.

This led to particular research methods and results, in particular about 1) taxonomies and 2) evolutionary processes. About taxonomy, Laplace determined an Epigravettian industry in Italy, posterior to the Gravettian (Laplace 1958). Later, he demonstrated a genetic relationship between the Gravettian and Epigravettian industries ("cladogenetic complexes" in his terms) and accordingly renamed the Epigravettian in Tardigravettian[80]. Similarly, he also introduced two changes in the model proposed for the Upper Palaeolithic by Dorothy Garrod (1892–1968), determining a "*Protoaurignacien*" industry between the Chatelperronian and Aurignacian industries (Laplace 1965), and a "*Tardi-Aurignacien*" posterior to the Gravettian (Laplace 1970).

Laplace addressed or defined multiple evolutionary processes. With reference to Bordes' argument about "*buissonnante*" (ramified) evolution (Bordes 1950a), Laplace discussed the orthogenetic or polygenetic nature of the evolution of different industries including the "Capsian" and blade and bladelets industries from the Cantabro-Pyrenean region (Laplace-Jauretche 1957). He proposed an in-depth discussion of these aspects in his PhD dissertation[81] grounded on Alberto Carlo Blanc's "cosmolysis" evolutionary theory (Blanc 1956). Other processes include the *leptolithisation* (referring to the development of blade-shaped lithic pieces[82]), *denticulation* (referring to the "regressive invasion phenomenon of denticulated and abrupt forms [...], which can be seen in all Palaeolithic, Leptolithic and Neolithic industrial complexes"[83] Laplace 1964b, p. 61), or the process he called *substrate inflation* (referring to the "the regressive evolutionary process characterised by the multiplication, in an industry, of the elementary and archaic forms that make it up"[84] (Laplace 1964a, p. 61).

TA practitioners also contributed to the research on evolutionary processes. Livache interpreted statistical similarity as phylogenetic relationship[85] and sought to identify "homomorphism" similarities in unrelated series of industries (e.g., from different sites) at any taxonomic hierarchical level, even if the date, origin, and transformations of the series were different (Livache 1974, p. 20). This concept was later completed with the "homodynamism" concept, characterising series of industries featuring similar evolutionary changes (without assuming contemporaneity) (Livache and Brochier 1996, p. 27-28). The Catalan archaeologists Eudald Carbonell and Jordi Estévez, who participated in the Arudy seminar, developed a theory of hominisation coined "bidirection theory" (*teoría de la bidirección*), criticising environmental determinism and stressing the ability of humans to transform their environment (Carbonell and Estévez 1978).

[80]See: Broglio, Laplace, and Zorzi 1963, Laplace 1964c, Laplace 1977b, and a synthesis in Laplace 1997.

[81]Laplace 1961. See also the published version, Laplace 1966b, p. 261-274.

[82]Laplace 1966b, p. 265 and 279–281; this concept was also used by other authors, e.g., Escalon de Fonton and de Lumley 1955.

[83]"*phénomène régressif d'envahissement des formes denticulées et abruptes de l'infrasubstrat, pouvant se manifester dans tous les ensembles industriels paléolithiques, leptolithiques et néolithiques.*"

[84]"*processus évolutif régressif caractérisé par la multiplication, dans une industrie, des formes élémentaires et archaïques qu'il comprend.*"

[85]About the relationships between evolutionary aims and statistical method sin TA, see the section "Comparing the properties of sets of objects" above.

7.3 Early development of "computational" archaeology

The use of statistics and both manual and automatic computations by TA practitioners were discussed above and are the most obvious aspect which can be related to what is now called "computational" or "digital" archaeology. However, the most fundamental relationship between this current trend in archaeology and TA lies in the TA's notation system. From a historical perspective, efforts made to standardise and formalise the description of lithic objects in TA must be considered vis-à-vis the long-term process of standardisation of symbolic representations, including the long history of scientific notations, the standardisation of typography resources[86] and the standardisation of computer and digital formats. The TA was part –although as a minor player– of the development of formal and semi-formal representation systems which span the second half of the 20th century, mostly for the purpose of automatic data processing with mechanical and, later electronic, computers.

In France, several researchers were active in this field, such as Maurice Coyaud (1934–2015), Maurice Gross (1934–2001), and the linguist and archaeologist Jean-Claude Gardin who was among the first researchers committed to the application of automatic information systems to the humanities and social sciences[87]. From the late 1950s, Gardin and his collaborators developed multiple "codes" to represent the description of texts, images, and material objects, intended to store and retrieve this information automatically[88]. Engineer Louis Bourrelly (1938–2015) was, from the early 1960s, among Gardin's close collaborators at the *Centre d'automatique documentaire pour l'archéologie* (Cada) in Marseille. From 1970, he participated in a project with the archaeologists Henry de Lumley (born 1934) and Henriette Camps-Fabrer (1928–2015) about the automatization of the treatment of excavation data[89]. In June 1972, Laplace was invited to an international conference organised by the Cada on data banks in archaeology (Laplace 1974). Following this meeting, Bourrelly contacted Laplace to participate in the typology summer seminar in Arudy[90], where he presented the principles of formal documentation languages. In the subsequent publication of his talk at this meeting (Bourrelly 1973, p. 5), he illustrated how the TA vocabulary can be formalised: a lithic implement described as an

> *outil à retouche marginale (M) directe (D) ou inverse (I) sur le bord latéral droit (LD) dont la longueur (L) est supérieure à 40 mm*

would be represented using symbols, logical connectors, and nested parentheses as:

(((M and (D or I) and LD) and L>40).

[86]The typographical aspects of the TA, and the relationships between publishing material constraints and scientific thought, were addressed in a previous publication (Plutniak 2020b).

[87]About Gardin's early commitments to information systems, automatic documentation, and language processing, see Plutniak 2017a, Dallas 2015, Moscati 2016, Léon 2021.

[88]For a detailed analysis of their analysis of Akkadian cuneiform tablets, see Plutniak 2021b. About Gardin's later research on data representation in archaeology, see Gardin and Peebles 1992.

[89]"Rapport préparatoire à la réunion du Comité de Direction le 24 Janvier 1970", 05-01-1970, box JCG 1, Mae.

[90]Letter from L. Bourrelly to G. Laplace, 21-06-1972, Mnp.

This example illustrates how the development of the TA took place in the context of the growth of documentation languages and systems, including some occasional direct involvements[91]. Like the systems developed by Gardin and his collaborators, the TA notation system aimed at facilitating the communication and data exchange between archaeologists by establishing a description standard. Over the years, multiple authors argued that the TA notation was too complex, limiting its use[92]. It is out of the scope of this paper to address the properties of the TA notation system, to determine if it was a code, a "language" and, if so, what sort of language (A "documentation" language? A "formal" or "semi-formal" language?), and to measure and compare its complexity. However, these issues continue to be addressed in archaeology today, in particular through the lens of formal ontologies[93] and this suggests changing the perspective on the status of the TA in the recent history of archaeology. Some decades later, the complexity of the TA now appears much less important than the complexity of contemporary computer-based data structure representation schemes (e.g., Linked Open Data and Semantic web formats, such as the CIDOC-CRM used in archaeology and heritage management). Consequently, the TA must be seen as a noteworthy experience and episode in the growth of computer-based methods in archaeology in the second part of the 20th century.

Conclusion

Based on the thorough investigation of what has come to be known as the "Structural and analytical typology", this paper shows how archaeology can benefit from historical and conceptual inquiries *on* archaeological practice itself. Considering the history of archaeology in France, it offers a detailed account of the TA: the changing product of a collective scientific endeavour over fifty years rather than a monolithic work of a single researcher. Correcting this bias in the history of archaeology is also a call to avoid political uses of disciplinary history. In addition, this paper demonstrates how the TA enterprise was one of the few attempts to continue evolutionary research in French archaeology during the second part of the 20th century. This recognition has consequences for the status of archaeological research in France in the context of the discipline's global history: it leads to qualify the narrative of a great divide between French and US/UK archaeologies (Hussain 2019), demonstrating that research similar to "New Archaeology" research was carried out in France over the same period, although independently. This paper also demonstrates how the TA endeavour was part of the development of formal approaches in archaeology, including not only the use of statistics but also, and more importantly the creation of abstract and formal methods to represent data. The problems and solutions addressed by the TA practitioners are fundamentally no different to those raised in current research in digital archaeology and data heritage management. Consequently, and given the persistence of these fundamental issues in archaeology (Gardin and Peebles 1992), it is not surprising that

[91]For a larger history of computer-based treatments of TA formulas see, Plutniak 2020b, p. 291-292.

[92]Bordes 1965, p. 372, Nenquin 1969, p. 205, Odell 2004, p. 104-105, Demars 2011, p. 128.

[93]Dallas 2009, Niccolucci et al. 2015, Cardinal 2019.

the examination of the different aspects of the "Structural and analytical typology" leads us to acknowledge its notation system as its core component. The identity and unity of this method is its specific way to represent the analysis of real-world phenomena, namely some old lithic stone implements.

Acknowledgements

This paper was written during a research stay at the *Fondation des Treilles*, in France, that I thank for this opportunity. I also thank Shumon Hussain and Felix Riede, the four reviewers and their useful comments on this paper and, finally, Shannon McPherron for his supporting effort during the editorial process.

Funding

Not applicable.

Disclosure statement

No potential conflict of interest was reported by the author.

Availability of data and material

Supplementary material (data and R code to generate the tables and figures) is available at: https://doi.org/10.5281/zenodo.6307350.

References

Adams, William Yewdale and Ernest Wilcox Adams [1991], *A Dialectical Approach to Artifact Classification and Sorting. Archaeological Typology and Practical Reality*, Cambridge: Cambridge University Press, 427 pp.

Ankeny, Rachel, Hasok Chang, Marcel Boumans, and Mieke Boon [2011], "Introduction: Philosophy of Science in Practice," *European Journal for Philosophy of Science*, 1, p. 303-307, DOI: 10.1007/s13194-011-0036-4.

Arbonnier, Pierre [1966], "L'analyse de l'information : aperçu théorique et application à la loi multinomiale," *Annales des sciences forestières*, 23, 4, p. 949-1017.

Audouze, Françoise and André Leroi-Gourhan [1981], "France: a Continental Insularity," *World Archaeology*, 13, 2: *Regional Traditions of Archaeological Research I*, ed. by Bruce Trigger and Ian Glover, p. 170-189, DOI: 10.1080/00438243.1981.9979824.

Baylon, Christian [1977], "L'analyse sémique," *Dialektikê. Cahiers de typologie analytique*, 5, p. 1-7, DOI: 10.5281/zenodo.2584028.

Bietti, Amilcare [1990], "The Late Upper Paleolithic in Italy: An Overview," *Journal of World Prehistory*, 4, 1, p. 95-155, DOI: 10.1007/BF00974820.

Bietti, Amilcare [1991], "Normal Science and Paradigmatic Biases in Italian Hunter-Gatherer Prehistory," in *Perspectives on the Past. Theoretical Biases in Mediterranean Hunter-Gatherer Research*, ed. by Geoffrey A. Clark, Philadelphia: University of Pennsylvania Press, p. 258-281, DOI: 10.9783/9781512801811-016.

Bisson, Michael S. [2000], "Nineteenth Century Tools for Twenty-First Century Archaeology? Why the Middle Paleolithic Typology of François Bordes Must Be Replaced," *Journal of Archaeological Method and Theory*, 7, p. 1-48, DOI: 10.1023/A:1009578011590.

Blanc, Alberto Carlo [1956], "L'évolution humaine et la doctrine des centres génétiques – Cosmolyse et évolution humaine," in *Problèmes actuels de Paléontologie*, Paris, Apr. 18-23, 1955, ed. by Jean Piveteau, Colloques internationaux du Centre national de la recherche scientifique, 60, Paris: Éditions du Centre national de la recherche scientifique, p. 123-134.

Bordes, François [1950a], "L'évolution buissonnante des industries en Europe occidentale. Considérations théoriques sur le Paléolithique ancien et moyen," *L'Anthropologie*, 54, p. 393-420.

Bordes, François [1950b], "Principes d'une méthode d'étude des techniques de débitage et de la typologie du Paléolithique ancien et moyen," *L'Anthropologie*, 54, p. 19-34.

Bordes, François [1961], *Typologie du Paléolithique ancien et moyen*, 2 vols., Bordeaux: Imprimerie Delmas, 85–216 p.

Bordes, François [1965], "À propos de typologie," *L'Anthropologie*, 69, 3–4, p. 369-377.

Bordes, François and Maurice Bourgon [1951], "Le complexe moustérien," *L'Anthropologie*, 55, p. 1-23.

Bourrelly, Louis [1973], "Automatisation de l'étude des sites. Une méthode," *Dialektikê. Cahiers de typologie analytique*, 1, p. 1-7, DOI: 10.5281/zenodo.2583834.

Brézillon, Michel [1968], *La dénomination des objets de pierre taillée. Matériaux pour un vocabulaire des préhistoriens de langue française*, Paris: Éditions du CNRS, 416 pp.

Brochier, Jacques-Élie and Michel Livache [1978], "Le niveau C de l'abri no 1 de Chinchon à Saumanes de Vaucluse : analyse des correspondances et ses conséquences quant à l'origine des complexes du Tardiglaciaire en Vaucluse," *Géologie Méditerranéenne*, 5, 4, p. 359-369, DOI: 10.3406/geolm.1978.1056.

Brochier, Jacques-Élie and Michel Livache [1982], "L'entropie analogique relative comme mesure de la diversité des complexes industriels," *Dialektikê. Cahiers de typologie analytique*, 9, p. 1-6, DOI: 10.5281/zenodo.2584174.

Broglio, Alberto and Georges Laplace [1966], "Études de typologie analytique des complexes leptolithiques de l'Europe centrale. II. Les complexes gravettiens de la Basse-Autriche : Willendorf II," *Rivista di scienze preistoriche*, 21, 2, p. 303-364.

Broglio, Alberto, Georges Laplace, and Francesco Zorzi [1963], "I depositi quaternari del Ponte di Veia. Le industrie," *Memorie del Museo Civico di Storia Naturale di Verona*, 11, p. 325-367.

Carbonell, Eudald and Jordi Estévez Escalera [1978], "Avanç de la teoria de la bidirecció," *Cypsela. Revista de prehistória i protohistória*, 2, p. 1-5.

Carbonell, Eudald, Michel Guilbaud, and Rafael Mora [1982], "Application de la méthode dialectique à la construction d'un système analytique pour l'étude des matériaux du Paléolithique inférieur," *Dialektikê. Cahiers de typologie analytique*, 9, p. 7-23, DOI: 10.5281/zenodo.2584168.

Carbonell, Eudald, Marina Mosquera, Andreu Ollé, Xose Pedro Rodríguez, Robert Sala, Manuel Vaquero, and Josep María Vergès [1992], *New Elements of the Logical Analytic System. First International Meeting on Technical Systems to Configure Lithic Objects of Scarce Elaboration*, Cahier noir, 6, Tarragona: Reial Societat Arqueològica Tarraconense, p. 5-61.

Cardinal, J. Scott [2019], "Sets, Graphs, and Things we Can See: A Formal Combinatorial Ontology for Empirical Intra-Site Analysis," *Journal of Computer Applications in Archaeology*, 2, p. 56-78, DOI: 10.5334/jcaa.16.

Carmiggelt, Arnold [2019], *Geheimzinnigheid is zijn fort. Assien Bohmers (archeoloog), 1912–1988*, Utrecht: Eburon, 692 pp., DOI: 10.33612/diss.98705556.

Cavaillès, Bernard [1984], "L'écart : taxinomie et obstacle en science préhistorique," *Dialektikê. Cahiers de typologie analytique*, 10, p. 32-39, DOI: 10.5281/zenodo.2584399.

Cavaillès, Bernard [1987], "La permanence nominative des concepts chrono-archéologiques en science préhistorique," *Dialektikê. Cahiers de typologie analytique*, 11, p. 1-7, DOI: 10.5281/zenodo.2585697.

Cheynier, André [1957], "À propos des courbes cumulatives statistiques appliquées à la préhistoire," *Bulletin de la Société préhistorique de France*, 54, 3–4, p. 211-215, DOI: 10.3406/bspf.1957.5988.

Clarke, David Leonard [1968], *Analytical Archaeology*, London: Methuen, xx–684 p.

Cleuziou, Serge, Anick Coudart, Jean-Paul Demoule, and Alain Schnapp [1991], "The Use of Theory in French Archaeology," in *Archaeological Theory in Europe. The Last 3 Decades*, ed. by Ian Hodder, trans. by Sander E. van der Leeuw, London: Routledge, p. 91-128.

Crémillieux, André [1987], "Contribution de la typologie analytique à l'identification de quelques types morpho-techniques parmi des obsidiennes taillées de l'île de Pâques," *Journal de la Société des océanistes*, 84, 1, p. 73-82, DOI: 10.3406/jso.1987.2564.

Crémillieux, Hélène and Michel Livache [1976], "Pour le classement des pièces écaillées," *Dialektikê. Cahiers de typologie analytique*, 4, p. 1-5, DOI: 10.5281/zenodo.2583970.

Csárdi, Gábor and Tamás Nepusz [2006], "The igraph Software Package for Complex Network Research," *InterJournal*, 1695, 5, p. 1-9, http://igraph.org.

Dallas, Costis [2009], "From Artefact Typologies to Cultural Heritage Ontologies: or, an Account of the Lasting Impact of Archaeological Computing," *Archeologia e Calcolatori*, 20, p. 205-222.

Dallas, Costis [2015], "Jean-Claude Gardin on Archaeological Data, Representation and Knowledge: Implications for Digital Archaeology," *Journal of Archaeological Method and Theory*, 23, 1, p. 305-330, DOI: 10.1007/s10816-015-9241-3.

De Heinzelin de Braucourt, Jean [1962], *Manuel de typologie des industries lithiques*, Bruxelles: Institut royal des Sciences naturelles de Belgique, 74 pp.

Delfaud, Jean [1973], "Quelques réflexions sur les rapports entre la Typologie analytique et l'Informatique," *Dialektikê. Cahiers de typologie analytique*, 1, p. 8-12, DOI: 10.5281/zenodo.2583848.

Delfaud, Jean and Liliane Delfaud [1974], "Première ébauche d'une analyse typologique des gravures rupestres du Sud-Oranais (Algérie)," *Dialektikê. Cahiers de typologie analytique*, 2, p. 37-42, DOI: 10.5281/zenodo.2583916.

Delporte, Henri [1967], "Laplace (G.) Recherches sur l'origine et l'évolution des complexes leptolithiques. 1. vol. de 586 p. 25 pl. 21 tabl. E. de Boccard, Paris, 1966," *L'Anthropologie*, 71, p. 291-301.

Demars, Pierre-Yves [2011], "François Bordes versus Georges Laplace : deux visions de l'outillage lithique," in *François Bordes et la Préhistoire*, Colloque international François Bordes Bordeaux, Apr. 22-24, 2009, ed. by Françoise Delpech and Jacques Jaubert, Documents préhistoriques, 29, Paris: Éditions du Comité des travaux historiques et scientifiques, p. 125-131.

De Sonneville-Bordes, Denise [1959], "Bohmers (A.) et Wouters (Aq.). Statistics and graphs in the study of flint assemblages (Statistiques et graphiques dans l'étude des outillages en silex). Palaeohistoria, vol. V, 1958, Groningen, 38 p., 7 fig., 2 pi.," *Bulletin de la Société préhistorique de France*, 56, 3–4, p. 178-180.

De Sonneville-Bordes, Denise [1960], *Le Paléolithique supérieur en Périgord*, forew. by Jean Piveteau, Bordeaux: Imprimerie Delmas, 558 pp.

De Sonneville-Bordes, Denise and Jean Perrot [1956], "Lexique typologique du Paléolithique supérieur : Outillage lithique (suite et fin) - V Outillage à bord abattu - VI Pièces tronquées VII Lames retouchées - VIII Pièces variées - IX Outillage lamellaire. Pointe azilienne," *Bulletin de la Société préhistorique de France*, 53, 9, p. 547-559, DOI: 10.3406/bspf.1956.3374.

Dunnell, Robert C. [1968], *Systematics in Prehistory*, New York: The Free Press, 256 pp.

Embree, Lester [1992], "The Future and Past of Metaarchaeology," in *Metaarchaeology. Reflections by Archaeologists and Philosophers*, ed. by Embree Lester, Boston Studies in the Philosophy and History of Science, 147, Dordrecht: Springer Netherlands, p. 3-50.

Escalon de Fonton, Max and Henry de Lumley [1955], "Quelques civilisations de la Méditerranée septentrionale et leurs intercurrences (Épipaléolithique, Leptolithique, Épileptolithique)," *Bulletin de la Société préhistorique de France*, 52, 7, p. 379-394, DOI: 10.3406/bspf.1955.3223.

Estévez Escalera, Jordi [1977], "Analyse structurale et analyse palethnologique de la faune provenant de gisements préhistoriques," *Dialektikê. Cahiers de typologie analytique*, 5, p. 15-31, DOI: 10.5281/zenodo.2584042.

Fernández Eraso, Javier [2013], "La tipología analítica aplicada al estudio de materiales líticos de época histórica," in *Métodos y Técnicas de análisis y estudio en arqueología prehistórica. De lo técnico a la reconstrucción de los grupos humanos*, ed. by Marcos García Diez and Lydia Zapata Peña, Bilbao: Servicio Editorial de la Universidad del País Vasco, p. 167-178.

Fernández Eraso, Javier and Maite García Rojas [2013], "Tipología analítica," in *Métodos y Técnicas de análisis y estudio en arqueología prehistórica. De lo técnico a la reconstrucción de los grupos humanos*, ed. by Marcos García Diez and Lydia Zapata Peña, Bilbao: Servicio Editorial de la Universidad del País Vasco, p. 479-497.

Ford, James A. [1954], "On the Concept of Types: the Type Concept Revisited," *American Anthropologist*, 56, 1, p. 42-53, DOI: 10.1525/aa.1954.56.1.02a00050.

Freeman, Linton C. [1979], "Centrality in Social Networks I: Conceptual Clarification," *Social Networks*, 1, p. 215-239, DOI: 10.1016/0378-8733(78)90021-7.

Fullola i Pericot, Josep Maria [1976], "De nouveaux types primaires," trans. by Merche de Hériz, *Dialektikê. Cahiers de typologie analytique*, 4, p. 6-9, DOI: 10.5281/zenodo.2584000.

Gallay, Alain [1980], "Réflexion sur le concept d'ethnoarchéologie," *Les Nouvelles de l'archéologie*, 4, p. 34-42, DOI: 10.3406/nda.1980.1969.

Gardin, Jean-Claude and Christopher Spalding Peebles (eds.) [1992], *Representations in Archaeology*, Bloomington (Ind.): Indiana University Press, ix–394 p.

Giannichedda, Enrico [2021], *Fulmini e spazzatura. Classificare in archeologia*, Temi e luoghi del passato e del presente, 23, Bari: Edipuglia, 292 pp., DOI: 10.4475/968.

Gusi i Jener, Francesc and Carme Olària [2006], "Propuesta de clasificación de las piezas geométricas de doble bisel," in *Dialektikê. Cahiers de typologie analytique 2006. Hommage à Georges Laplace*, ed. by Francesc Gusi i Jener, Castelló de la Plana: Diputació de Castelló, Servei d'Investigacions Arqueològiques i Prehistòriques, p. 106-107.

Hussain, Shumon [2019], *The French-Anglophone Divide in Lithic Research: A Plea for Pluralism in Palaeolithic Archaeology*, PhD thesis, Universiteit Leiden, 470 pp., HDL: 1887/69812.

Kahane, Ernest [1980], "Rationalisme," *Raison présente*, 55, 2: *Raisons rationalités rationalismes*, https://www.persee.fr/doc/raipr_0033-9075_1980_num_55_1_2077.

Kerrich, John Edmund and David Leonard Clarke [1968], "Notes on the Possible Misuse and Errors of Cumulative Percentage Frequency Graphs for the Comparison of Prehistoric Artefact Assemblages," *Proceedings of the Prehistoric Society*, 33, p. 57-69, DOI: 10.1017/S0079497X00014043.

Kerrich, John Edmund and David Leonard Clarke [1976], "Remarques sur le mauvais usage possible et sur les erreurs des diagrammes de fréquences cumulées pour la comparaison des ensembles industriels préhistoriques," trans. by Denyse Aghion, *Dialektikê. Cahiers de typologie analytique*, 4, p. 14-29, DOI: 10.5281/zenodo.2583972.

Klejn, Leo S. [1982], *Archaeological Typology*, trans. by Penelope Dole, BAR International Series, 153, Oxford: Archaeopress, 382 pp.

Kolpakov, Eugene M. and Leonid B. Vishnyatsky [1989], "The Bordes method?" Trans. by Sarah Wright, *Norwegian Archaeological Review*, 22, 2, p. 107-118, DOI: 10.1080/00293652.1989.9965497.

Krieger, Alex D. [1944], "The Typological Concept," *American Antiquity*, 9, 3, p. 271-288, DOI: 10.2307/275785.

Kullback, Solomon [1959], *Information Theory and Statistics*, New York: John Wiley & Sons, xvii–395 p.

Laming, Annette [1952a], "Conclusion," in *La découverte du passé. Progrès récents et techniques nouvelles en préhistoire et en archéologie*, ed. by Annette Laming, Paris: Picard, p. 299-302.

Laming, Annette (ed.) [1952b], *La découverte du passé. Progrès récents et techniques nouvelles en préhistoire et en archéologie*, Paris: Picard, 363 pp.

Lamy, Jérôme [2016], "Marxisme et structuralisme. Les querelles des anthropologues français," in *Résonances des structuralismes*, ed. by Jean-François Bert and Jérôme Lamy, Paris: Éditions des archives contemporaines, p. 33-53.

Laplace-Jauretche, Georges [1954], "Application des méthodes statistiques à l'étude du Mésolithique," *Bulletin de la Société préhistorique de France*, 51, 3–4, p. 127-139, DOI: 10.3406/bspf.1954.3074.

Laplace-Jauretche, Georges [1956], "Typologie statistique et évolution des complexes à lames et lamelles," *Bulletin de la Société préhistorique de France*, 53, 5–6, p. 271-290, DOI: 10.3406/bspf.1956.3334.

Laplace-Jauretche, Georges [1957], "Typologie analytique. Application d'une nouvelle méthode d'étude des formes et des structures aux industries à lames et lamelles," *Quaternaria*, 4, p. 133-164.

Laplace, Georges [1958], "Recherches sur l'origine et l'évolution des complexes leptolithiques. Le problème des Périgordiens I et II et l'hypothèse du Synthétotype aurignaco-gravettien. Essai de typologie analytique," *Quaternaria*, 5, p. 153-240.

Laplace, Georges [1960], "Liste des types primaires et des groupes typologiques," *Bulletin de la Société d'études et de recherches préhistoriques*, 10, p. 152-154.

Laplace, Georges [1961], *Recherches sur l'origine et l'évolution des complexes leptolithiques. Le problème des Périgordiens I et II et l'hypothèse du Synthétotype aurignaco-gravettien. Essai de typologie analytique*, PhD thesis, Poitiers: Université de Poitiers, 88 pp.

Laplace, Georges [1964a], *Essai de typologie systématique*, Annali dell'Università di Ferrara. Nuove serie, Sezione XV, Paleontologia Umana et Paleontologia, 1, Supplemento 2, Università degli Studi di Ferrara, 86 pp.

Laplace, Georges [1964b], “Le problème de l’origine de l’Aurignacien à la lumière des fouilles de la Grotte de Gatzarria,” *Bulletin de la Société des Sciences, Lettres et Arts de Pau*, 24, p. 24-26.
Laplace, Georges [1964c], “Les subdivisions du Leptolithique italien. Étude de typologie analytique,” *Bullettino di Paletnologia Italiana. Nuova serie XV*, 73, p. 25-63.
Laplace, Georges [1964d], “Lexique de typologie analytique,” *Bulletin de la Société d’études et de recherches préhistorique et Institut pratique de préhistoire*, 14, p. 111-128.
Laplace, Georges [1965], “Le niveau de Châtelperron de la Grotte de La Chèvre à Bourdeilles (Dordogne). Analyse typologique et statistique de l’outillage,” in *Miscelánea en homenaje al Abate Henri Breuil (1877–1961)*, ed. by Eduardo Ripoll Perelló, Barcelona: Instituto de Prehistoria y Arqueología, vol. 2, p. 5-30.
Laplace, Georges [1966a], “Le Magdalénien du Grand Abri Charasse à Entrechaux (Vaucluse),” in *In memoriam do Abade Henri Breuil*, Separata da Revista da Faculdade de Letras de Lisboa, Lisboa: Universidade de Lisboa, vol. 9, p. 3-30.
Laplace, Georges [1966b], *Recherches sur l’origine et l’évolution des complexes leptolithiques*, forew. by Jean Bayet, Mélanges d’archéologie et d’histoire, 4, Paris: De Boccard, xii–586 p. www.persee.fr/doc/efr_0000-0000_1966_mon_4_1.
Laplace, Georges [1968], “Recherches de typologie analytique 1968,” *Origini. Preistoria e protostoria delle civiltà antiche*, 2, p. 7-64.
Laplace, Georges [1970], “Les niveaux aurignaciens et l’hypothèse du synthétotype,” in *L’homme de Cro-Magnon. Anthropologie et archéologie. 1868–1968*, Les Eyzies-de-Tayac, July 15-17, 1968, Paris: Centre de Recherches Anthropologiques, Préhistoriques et Ethnographiques. Conseil de la Recherche en Algérie. Arts et Métiers Graphiques, p. 141-164.
Laplace, Georges [1972], “Liste typologique 1972,” *Cahiers de typologie analytique*, 1, p. 9-27, DOI: 10.5281/zenodo.2583794.
Laplace, Georges [1974], “La typologie analytique et structurale : base rationnelle d’étude des industries lithiques et osseuses,” in *Les banques de données archéologiques*, Colloque national “Les banques de données archéologiques” Marseille, June 12-14, 1972, ed. by Mario Borillo and Jean-Claude Gardin, Colloques nationaux du Centre national de la recherche scientifique, 932, Paris: Éditions du CNRS, p. 91-143.
Laplace, Georges [1975], “Distance du Khi 2 et algorithme de classification hiérarchique. Formule du Khi 2,” *Dialektikê. Cahiers de typologie analytique*, 4, p. 22-37, DOI: 10.5281/zenodo.2583950.
Laplace, Georges [1976], “Notes de typologie analytique : anatomie et orientation de l’éclat brut ou façonné,” *Dialektikê. Cahiers de typologie analytique*, 5, p. 30-34, DOI: 10.5281/zenodo.2584013.
Laplace, Georges [1977a], “Application de la Phytocinétique biogéographique de Paul Rey à la géologie dynamique du Quaternaire : le cyclothème ombrothermique. Approche écologique de l’homme fossile,” *Bulletin de l’Association française pour l’Étude du Quaternaire. Supplément*, p. 251-257, DOI: 10.5281/zenodo.2586761.
Laplace, Georges [1977b], “Il Riparo Mochi ai Balzi Rossi di Grimaldi (Fouilles 1938–1949). Les industries leptolithiques,” *Rivista di scienze preistoriche*, 32, 1–2, p. 3-131.
Laplace, Georges [1977c], “Notes de typologie analytique. Orientation de l’objet et rectangle minimal,” *Dialektikê. Cahiers de typologie analytique*, 6, p. 32-53, DOI: 10.5281/zenodo.2584046.
Laplace, Georges [1978], “Analyse matricielle de la contingence. Niveaux et réseaux d’homogénéité,” *Dialektikê. Cahiers de typologie analytique*, 7, p. 7-27, DOI: 10.5281/zenodo.2584073.

Laplace, Georges [1980], "Le 'Lien' comme mesure de l'information dans un tableau de contingence," *Dialektikê. Cahiers de typologie analytique*, 8, p. 1-15, DOI: 10.5281/zenodo.2584115.

Laplace, Georges [1981], "Algorithme de segmentation dans la matrice d'homogénéité," *Dialektikê. Cahiers de typologie analytique*, 9, p. 15-28, DOI: 10.5281/zenodo.2583950.

Laplace, Georges [1982], "Sépultures et rites funéraires préhistoriques en Vallée d'Ossau (Ursari)," in *Hil Harriak*, Colloque international sur la stèle discoïdale Musée Basque, Bayonne, July 8-10, 1982, Bayonne: Société des amis du Musée Basque, p. 21-70.

Laplace, Georges [1987a], "Autorité et tradition en taxinomie," *Antiquités Nationales*, 18–19, p. 33-37.

Laplace, Georges [1987b], "Un exemple de nouvelle écriture de la grille typologique," *Dialektikê. Cahiers de typologie analytique*, 12, p. 16-21, DOI: 10.5281/zenodo.2585701.

Laplace, Georges [1997], "Gravettien, Épigravettien et Tardigravettien," *Rivista di scienze preistoriche*, 48, p. 223-237.

Laplace, Georges and Michel Livache [1975], "Précisions sur la démarche de l'analyse structurale," *Dialektikê. Cahiers de typologie analytique*, 3, p. 8-21, DOI: 10.5281/zenodo.2583942.

Laplace, Georges and José María Merino [1979], "Application de la Typologie analytique et structurale à l'étude du 'Processus d'azilianisation' : la série phylétique de la grotte Urtiaga en Pays Basque," in *La fin des temps glaciaires en Europe. Chronostratigraphie et écologie des cultures du Paléolithique final*, Talence, May 24-28, 1977, ed. by Denise de Sonneville-Bordes, 2 vols., Colloques Internationaux du Centre National de la Recherche Scientifique, 271, Paris: Éditions du CNRS, p. 694-710.

Laplace, Georges and Andoni Sáenz de Buruaga [2000], "Application de la typologie analytique et structurale à l'étude de l'outillage moustéroïde de l'abri d'Olha 2 à Cambo (Kanbo) en Pays Basque," *Paleo*, 12, p. 261-324.

Lefebvre, Henri [1962], *Le matérialisme dialectique*, 5th ed., Nouvelle encyclopédie philosophique, Paris: Presses universitaires de France, 153 pp.; trans. 1940.

Lefebvre, Henri [1968], *Dialectical Materialism*, trans. by John Sturrook, London: Jonathan Cape, 171 pp.; trans. 1940.

Lefebvre, Henri [1969], *Logique formelle, logique dialectique*, 2nd ed., Paris: Anthropos, liii–291 p. Trans. 1947.

Léon, Jacqueline [2013], "Historiographie du structuralisme généralisé. Étude comparative," *Les dossiers de HEL*, 3: *Les structuralismes linguistiques : problèmes d'historiographie comparée*, HDL: 10670/1.a4i5fk.

Léon, Jacqueline [2021], "Automatic Documentation and Automatic Discourse Analysis : Specificity of Harris's Reception in France," in, *Automating Linguistics*, History of Computing, New York: Springer International Publishing, p. 121-139, DOI: 10.1007/978-3-030-70642-5_9.

Lepenies, Wolf and Peter Weingart [1983], "Introduction," in *Functions and Uses of Disciplinary Histories*, ed. by Loren R. Graham, Wolf Lepenies, and Peter Weingart, Dordrecht: D. Reidel, p. ix-xx, DOI: 10.1007/978-94-009-7035-9.

Litvak King, J., Moll, and Roberto García Moll [1972], "Set Theory Models: an Approach to Taxonomic and Locational Relationships," in *Models in Archaeology*, ed. by David Leonard Clarke, London: Methuen and Co. Ltd., p. 735-755.

Livache, Michel [1974], "Les familles sérielles de complexes industriels et leurs homomorphies en typologie analytique," *Dialektikê. Cahiers de typologie analytique*, 2, p. 15-22, DOI: 10.5281/zenodo.2583933.

Livache, Michel [1976], "Les fins opératives de la hiérarchie en taxonomie lithique," *Dialektikê. Cahiers de typologie analytique*, 4, p. 35-38, DOI: 10.5281/zenodo.2584022.

Livache, Michel [1980], "Le lien calculé à partir des données des niveaux de l'Abri no 1 de Chinchon à Saumane-de-Vaucluse," *Dialektikê. Cahiers de typologie analytique*, 7, p. 16-24, DOI: 10.5281/zenodo.2584126.

Livache, Michel [1981a], "Culture, acculturation, tribu… Des définitions des ethnologues à leur usage en préhistoire," *Dialektikê. Cahiers de typologie analytique*, 8, p. 29-44, DOI: 10.5281/zenodo.2584152.

Livache, Michel [1981b], *Le gisement de la Font Pourquière (Lacoste-Vaucluse) et le processus tardigravettien en Vaucluse*, Diplôme d'études approfondies.

Livache, Michel [1989], "La typologie analytique, une dialectique," in *Le temps de la préhistoire. La découverte du temps. Succession des systèmes appliqués*, 23e Congrès préhistorique de France Paris, Nov. 3-6, 1989, ed. by Jean-Pierre Mohen, Dijon and Paris: Archeologia and Société préhistorique de France, vol. 1, p. 30.

Livache, Michel [1997], "Exploitation d'une base de données de typologie analytique par un programme informatique simple. Codage et utilisation," *Archivio di tipologia analitica*, 20, p. 133-136.

Livache, Michel and Jacques-Élie Brochier [1996], "Deux processus évolutifs de complexes industriels en provence au pléni et tardiglaciaire würmien," *Préhistoire Européenne*, 8, p. 27-48.

Malvesin-Fabre, Georges [1952], "Essai de discrimination des bifaces abbevilliens et acheuléens par un indice numérique," *Bulletin de la Société préhistorique de France*, 45, 1–2, p. 58-63, DOI: 10.3406/bspf.1948.7994.

Merino, José María [1969], *Tipología Lítica*, Munibe, suplemento, 21 (1-2-3), San Sebastián: Sociedad de Ciencias Aranzadi, 326 pp.

Merino, José María [1980], *Tipología Lítica*, 2nd ed., Munibe, suplemento, 4, San Sebastián: Sociedad de Ciencias Aranzadi, 515 pp.

Merino, José María and Carmen Izaga [2004], "José María Merino, 'En arqueología me gustaba ver cómo era el hombre del paleolítico con respecto al hombre de hoy'," *Aranzadiana*, 125, p. 142-145.

Merton, Robert K. [1961], "Singletons and Multiples in Scientific Discovery: a Chapter in the Sociology of Science," *Proceedings of the American Philosophical Society*, 105, 5, p. 470-486.

Merton, Robert K. [1965], *On the Shoulders of Giants. A Shandean Postscript*, New York: Free Press, ix–289 p.

Moscati, Paola [2016], "Jean-Claude Gardin and the Evolution of Archaeological Computing," *Les Nouvelles de l'archéologie*, 144: *Jean-Claude Gardin (1925–2015)*, p. 10-13, DOI: 10.4000/nda.3457.

Movius, Hallam L., Nicholas C. David, Harvey M. Bricker, and R. Berle Clay [1968], *The Analysis of Certain Major Classes of Upper Palaeolithic Tools*, ed. by Hugh Hencken, Bulletin of the American School of Prehistoric Research, 26, Cambridge (Mass.): Peabody Museum, 58 pp.

Murray, Timothy [2013], "Why the History of Archaeology is Essential to Theoretical Archaeology," *Complutum*, 24, 2, p. 21-31, DOI: 10.5209/rev_CMPL.2013.v24.n2.43364.

Nenquin, Jacques [1969], "Georges Laplace, Recherches sur l'Origine et l'Évolution des Complexes leptolithiques. Paris, E. de Boccard, 1966. 1 vol., 22,5 x 28 cm, xii–586 pp., 39 figg., 24 tableaux, 25 planches. (École Française de Rome, Mélanges d'Archéologie et d'Histoire, Supplément no 4)," *Helinium*, 8, 2, p. 204-206.

Niccolucci, Franco, Sorin Hermon, and Martin Doerr [2015], "The Formal Logical Foundations of Archaeological Ontologies," in *Mathematics and Archaeology*, ed. by Juan A. Barceló and Igor Bogdanovic, Boca Raton (Fla.): CRC press, p. 86-99, DOI: 10.1201/b18530-7.

Nouvel, Alain [1978], "Les vestiges linguistiques pré-indo-européens en Occitanie," *Dialektikê. Cahiers de typologie analytique*, 6, p. 28-37, DOI: 10.5281/zenodo.2584101.

Nowell, April and Iaain Davidson [2010], "Introduction and Overview," in *Stone Tools and the Evolution of Human Cognition*, ed. by April Nowell and Iaain Davidson, Boulder: University Press of Colorado, p. 1-11, https://muse.jhu.edu/book/779.

O'Brien, Michael J., J. Darwent, and R. Lee Lyman [2001], "Cladistics is Useful for Reconstructing Archaeological Phylogenies: Paleoindian Points from the Southeastern United States," *Journal of Archaeological Science*, 28, 10, p. 1115-1136, DOI: 10.1006/jasc.2001.0681.

O'Brien, Michael J. and R. Lee Lyman [2002], "The Epistemological Nature of Archaeological Units," *Anthropological Theory*, 2, 1, p. 37-56, DOI: 10.1177/1463499602002001287.

O'Brien, Michael J. and R. Lee Lyman [2003], *Cladistics and Archaeology*, forew. by Robert D. Leonard, Salt Lake City (Utah): University of Utah Press, xxiii–280 p.

Odell, George H. [2004], *Lithic Analysis*, Manuals in Archaeological Method, Theory and Technique, New York: Springer Science & Business Media, 262 pp., DOI: 10.1007/978-1-4419-9009-9.

Plutniak, Sébastien [2017a], "L'innovation méthodologique, entre bifurcation personnelle et formation des disciplines : les entrées en archéologie de Georges Laplace et de Jean-Claude Gardin," *Revue d'histoire des sciences humaines*, 31: *Faire science*, ed. by Camila Orozco Espinel and Yann Renisio, p. 113-139, DOI: 10.4000/rhsh.435, HDL: 10670/1.rw3o20.

Plutniak, Sébastien [2017b], "The Professionalisation of Science – Claim and Refusal: Discipline Building and Ideals of Scientific Autonomy in the Growth of Prehistoric Archaeology. The Case of Georges Laplace's Group of *Typologie Analytique*, 1950s–1990s," *Organon*, 49: *Approche historique des structures de l'archéologie préhistorique et protohistorique aux XIXe–XXe siècles*, ed. by Arnaud Hurel, p. 105-154, HDL: 10670/1.y5rnm6.

Plutniak, Sébastien [2019], "Quinze ans de théorie et de méthodologie archéologique francophone : un retour sur les rapports entre science, politique, et édition, à l'occasion de la diffusion numérique de la revue *Dialektikê. Cahiers de typologie analytique* (1972–1987)," *Les Nouvelles de l'archéologie*, 155, p. 36-41, DOI: 10.4000/nda.5861, HDL: 10670/1.aewuj5.

Plutniak, Sébastien [2020a], "De l'usage des *science studies* dans les controverses scientifiques : une illustration archéologique. Suivi de : Georges Laplace, 'Autorité et tradition en taxinomie'," *Zilsel. Science, technique, société*, 7, p. 389-413, DOI: 10.3917/zil.007.0387, HDL: 10670/1.1igaes.

Plutniak, Sébastien [2020b], "The Effects of Publishing Processes on Scientific Thought. Typography and Typology in Prehistoric Archaeology (1950s–1990s)," *Science in Context*, 33, 3, p. 273-297, DOI: 10.1017/S0269889721000053, HDL: 10670/1.6uwjmh.

Plutniak, Sébastien [2021a], "Abstraction in Archaeological Stratigraphy: a Pyrenean Lineage of Innovation (late 19th–early 21th century)," in *New Advances in the History of Archaeology*, International Union of Prehistoric and Protohistoric Sciences 18th World Congress Paris, June 4-9, 2018, ed. by Sophie A. de Beaune,

Alessandro Guidi, Oscar Moro Abadía, and Massimo Tarantini, 978-16, Oxford: Archaeopress, p. 78-92, DOI: 10.31235/osf.io/2pgak, HDL: 10670/1.m6bprs.

Plutniak, Sébastien [2021b], "Assyrian Merchants meet Nuclear Physicists: History of the Early Contributions from Social Sciences to Computer Science. The Case of Automatic Pattern Detection in Graphs (1950s–1970s)," *Interdisciplinary Science Reviews*, 46, 4: *Computing in the World*, ed. by Mario Verdicchio, p. 547-568, DOI: 10.1080/03080188.2021.1877502.

Reynolds, Natasha and Felix Riede [2019], "House of Cards: Cultural Taxonomy and the Study of the European Upper Palaeolithic," *Antiquity*, 93, 371, p. 1350-1358, DOI: 10.15184/aqy.2019.49.

Sachs, Lothar [1969], *Statistische Auswertungsmethoden*, Berlin: Springer, xxx–677 p.

Sáenz de Buruaga, Andoni [1996], "Apuntes provisionales sobre la historia y el concepto de la Estratigrafía Analítica," *Krei. Círculo de Estratigrafía Analítica*, 1, p. 5-20, HDL: 10670/1.y5an81.

Sáenz de Buruaga, Andoni [2005], "¿Tipología hoy? Algunas reflexiones sobre la sistemática analítica laplaciana: una reafirmación de la 'dialéctica de causalidad' en los sujetos industriales," *Krei*, 8, p. 79-94, HDL: 10670/1.y9wgxd.

Sáenz de Buruaga, Andoni [2006], "Estratigrafía Analítica: una profundización de la sistemática laplaciana en el movimiento estratigráfico," in *Dialektikê. Cahiers de typologie analytique 2006. Hommage à Georges Laplace*, ed. by Francesc Gusi i Jener, Castelló de la Plana: Diputació de Castelló, Servei d'Investigacions Arqueològiques i Prehistòriques, p. 126-139.

Shea, John J. [2014], "Sink the Mousterian? Named Stone Tool Industries (NASTIES) as Obstacles to Investigating Hominin Evolutionary Relationships in the Later Middle Paleolithic Levant," *Quaternary International*, 350, p. 169-179, DOI: 10.1016/j.quaint.2014.01.024.

Thomas, Gérard [1974], "Nouveaux éléments pour servir à l'analyse typologique des objets lithiques taillés dans les trois dimensions," *Dialektikê. Cahiers de typologie analytique*, 2, p. 23-33, DOI: 10.5281/zenodo.2583938.

Tixier, Jacques [1963], *Typologie de l'Épipaléolithique du Maghreb*, Mémoires du Centre de recherches anthropologiques, préhistoriques et ethnographiques d'Alger, 2, Paris: Arts et métiers graphiques, 209 pp.

Vila i Mitjà, Assumpció and Jordi Estévez Escalera [2006], "Georges Laplace. La fuerza de la contradicción interna," in *Dialektikê. Cahiers de Typologie Analytique 2006. Hommage à Georges Laplace*, ed. by Francesc Gusi i Jener, Castelló de la Plana: Diputació de Castelló, Servei d'Investigacions Arqueològiques i Prehistòriques, p. 140-161, https://ddd.uab.cat/record/110577.

Vital, Joël [1981], "Typologie et industrie céramique," *Dialektikê. Cahiers de typologie analytique*, 8, p. 45-52, DOI: 10.5281/zenodo.2584160.

Volle, Michel [1981], *Analyse des données*, 2nd ed., Collection Économie et statistiques avancées. École nationale de la statistique et de l'administration économique et Centre d'études des programmes économiques, Paris: Economica, 317 pp.; trans. 1976.

Vorms, Marion [2011], *Qu'est-ce qu'une théorie scientifique ?* Paris: Vuibert, 217 pp.

Voruz, Jean-Louis [1978], "Typologie de l'industrie en matières dures animales. Essai d'extension de la typologie analytique. Première étape : le langage descriptif," *Dialektikê. Cahiers de typologie analytique*, 6, p. 38-61, DOI: 10.5281/zenodo.2584107.

Voruz, Jean-Louis [1984], *Outillages osseux et dynamisme industriel dans le Néolithique jurassien*, PhD thesis, Toulouse: Ehess, 574 pp.

Whallon, Robert and James A. Brown (eds.) [1982], *Essays on Archaeological Typology*, Kampsville Seminars in Archeology, 1, Evanston (Ill.): Center for American Archeology Press, xix–200 p.

Willey, Gordon R. and Philip Phillips [1958], *Method and Theory in American Archaeology*, Chicago (Ill.): University of Chicago Press, 270 pp.

Wylie, Alison [2002], "The Typology Debate," in, *Thinking from Things. Essays in the Philosophy of Archaeology*, Berkeley (Calif.): University of California Press, p. 42-56.