Time, memory and alterity in prehistoric lithic technology: Synthesis and perspectives of the French technogenetic approach

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Abstract:

The technogenetic approach in the field of prehistoric lithic technology studies originated in the late 1980s. Traditional approaches, such as typology and production technology, have tended to approach prehistoric lithic objects through their socio-cultural and economic dimensions, without really considering the existence of a technogenesis prior to these contingencies. The apprehension of this technogenetic dimension in prehistory will call upon both the philosophy and the anthropology of techniques to lead to a double approach of the artefacts: a technogenetic approach of the lithic object according to the technical criteria of its genesis; and a psychosocial approach of the object according to the criteria proper to its artisanal production within a major technical system. The objective of this article is to identify two fundamental existences constituting the technical object, one internal (technogenetic) with technical lineages and the other external (psychosocial) with technical trajectories. The spatio-temporal distribution of prehistoric technical otherness on different continents has logically led to new questions, findings and new criteria of analysis. On this basis, our approach will aim to revisit the main conceptual axes of the foundations of the technological approach, to clarify old questions while developing new expertise. Through the application of key concepts such as time, memory and otherness, an overall methodology will also be discussed and will help proposing its epistemological line.

Keywords: technogenetic approach; psycho-social approach; prehistoric lithic technology; epistemology; technical memory; time; structure; technical object

1. Introduction and background

In the general context of an anthropology of techniques with a long tradition, the 1980s saw the emergence of the first methodological efforts focused on the study of flaked lithics.

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At the same time, lithic experimentation offered a heuristic power never seen before in the definition of diagnostic criteria and experimental protocols. These efforts would lead, years later, to the definitive adoption of the *chaîne opératoire*, a concept and theoretical-methodological tool proposed by A. Leroi-Gourhan (1964), capable of reading the manufacturing processes of prehistoric lithic industries, through the use of refits and diacritical patterns. In this disciplinary context, focused mainly on the synchronicity of lithic production, the Lower and Middle Paleolithic industries of the Old World offered the possibility of a diachronic study that considered the technicofunctional dynamics of prehistoric tools on different time scales. At the end of the 1980s, new problems began to emerge, related to the transformation cycles of lithic industries over long time, mainly from Simondon's philosophy of techniques and some recent theoretical and exegetical developments around it, in France and elsewhere (*e.g.*, Simondon 2004: 57-63; 2005: 77-103; 2006: 175-350; 2008: 139-184; 2010: 235-244; 2012: 9-60; 2013: 511-530; 2014: 27-130; 2015: 128-152; 2016: 447-462; 2017: 15-52; 2018: 15-36; see also, Bardin 2013: 25-44; Barthélémy 2005a: 80-121; 2005b: 10-38; 2008: 11-36; Chabot 2003: 32-58; 2013: 9-22; Chateau 2008: 10-49; Combes 2013: 1-24; Guchet 2010: 133-256; Heredia 2017: 351-390; Hottois 1994: 119-136; Krell 2018: 158-172; Lindberg 2019: 299-310; Loeve *et al.* 2018: 237-256; Stiegler 1994: 115-144; 1998: 241-256; Vaccari 2010: 153-165).

Some aspects of these developments have been considered by what is currently known in the humanities and social sciences as the turn towards material culture, materiality, materials and material ecology, and their role in the constitution of the individual and society (*e.g.*, Dobres & Hoffman 1994; Ingold 2007; de Marrais *et al.* 1996; Miller 1987: 19-43; 2005: 1-50; Miller & Tilley 1996; Olsen 2007; Olsen & Witmore 2015; Olsen *et al.* 2012: 196-210; Thomas 2000; 2006; Tilley 2007; Witmore 2015). Nevertheless, the theoretical and methodological approach presented in this article does not have its roots in, nor is it inspired by, this ontological and epistemological turn that has occurred, especially in the English-speaking world, since the 1990s and continues, with multiple divergences, to the present (see a summary of these approaches and their potential applications to prehistoric archaeology in Hussain & Will 2020; Nativ & Lucas 2020).

The approach presented here, called technogenetic because it combines technology with a genetic ontology, acquires a formal date of birth in prehistory in 1997 with the application of Simondon's system of interpretation to the study of lithic production systems (Boëda 1997: 26-33). More than twenty years of application of this approach by different prehistorians, at different times and in different spaces, now allows us to take stock of the main conceptual axes of this approach, to clarify the old questions and to develop the new.

The more complex aspects of diachrony and synchrony must therefore be constantly revisited in order to obtain a scientific discourse that is increasingly close to prehistoric technicity (*sensu* Simondon 2012: 223; Stiegler 1994: 95) “one of the two fundamental phases of the mode of existence of the whole constituted by man and the world (...) the phase that balances technicity is the religious mode of being” (Simondon 2012: 178). Without wishing to cover all the concepts and methodological practices of the technogenetic approach, this work concentrates on the discussion of three concepts that seem to us fundamental in its development: time, memory and otherness. These three concepts are the pillars that support the whole epistemological construction of the technogenetic approach, and therefore, they run through the other concepts and criteria that have given shape to it during these years.

2. New questions in French prehistoric technology

In our discipline, the object of prehistory has rarely been thought of in itself, it has always been thought by what exists outside of it, that is to say in its socio-cultural and economic dimensions. It is, to this extent, a problem of epistemological incongruity: how to perceive a cultural phenomenon from objects like this one, of which one ignores everything? In fact, the quality of the information dries up as one goes back in time. Nevertheless, the stone, since it keeps in memory the gestures of the operator (or at least partially), allows the analysis of aspects that go beyond the classical form-function diptych and to short time scales.

Until the end of the 1980s, the technical archaeological reality, that is to say the artefacts, were and continue to be studied from their modes of production, outside of any material structure of the object. The functional dimension, internal to the object in its genesis, which implies its function and its operation, does not receive as much attention, whatever the academic tradition of the researchers. One can wonder about the real possibility of approaching the functional dimension of objects by lithic technology.

Between the 1980s and 1990s, important methodological and interpretive advances took place within the French school of prehistoric technology, notably through techno-economic and cognitive approaches (Audouze & Karlin 2017). However, if these studies were preferentially oriented towards production technology, a methodological impasse remained with respect to the problematic of the prehistoric tool: "Why (and for what purpose) did a prehistoric tool exist" (Boëda 1986: 29)? While trying to overcome the classical question of the manufacture of an artefact, this questioning initiated by one of us, then relaunched the debate by pursuing a remark formulated by Perlès (1983: 161): "One speaks about chains of operation as if there were not, at the origin, a need. In reality, they take place according to a need". It is by taking into account this "need" that it was necessary to question in depth the objectives of the operating chains and to make room for what Tixier (1963: 17) had called the vast field of investigation of the functional prehistory.

Thus, the current project that animates our research team AnTET (Anthropology of Techniques, Space and Territories during the Pliocene and Pleistocene) anchored in the French tradition, consists in moving away from the external approach of the object and its methodology turns only towards the production aspect of the artefact, in favour of the technicofunctional aspect. The objective is to get closer to the nature of the object, what is its genesis and the temporal evolution of the technical object. This approach consists of a new epistemology that studies the historical and cultural conditions of technical phenomena through the functional information contained in the archaeological object. In other words, it is a question of questioning, first of all, the principles of functioning to which the whole of the elements that configure the volumetric structure of the tool respond.

3. A new epistemology

We propose a new epistemology that would start from the phenomenal manifestation of technical objects and not only from the appearing object, *i.e.,* such as it is intended by the analyst. From a methodological point of view, this translates into the concrete application of functional technology. The main objective of this method aims at the analysis and the deciphering of the principles of operative functioning that the artefact possessed in its time (Boëda 1997: 7).

Thus, the conception of the technical system in both the French and the English-speaking traditions is still studied on the basis of external principles: cultures, productive forces, environment, know-how, *etc.*, which are of course quite valid, but in a dimension that is not essential to the technique. It was thus necessary to perceive its primary reality: the technical object as an individual. From there, the technical object is fundamentally understood as a mode of technical relations, not simply as an economic or cultural object, or, as it is usual to say in the manner of Mauss, a social fact. Without denying the human origin of the technical object, and without denying either the validity of its anthropological apprehension, the philosophy of Simondon (2014: 52) launches a call to the recognition of a fundamental reality proper to the technical objects which was not yet perceived or observed.

This perspective inevitably leads us to a genetic anthropology of techniques or technogenesis (Boëda 1997: 111-142). The term genetic takes here the sense of temporal evolution. It is thus an anthropology of techniques centered on the temporal evolution of prehistoric objects, recognized and developed by the AnTET team within the framework of a research program aiming at a genetic ontology of techniques (Boëda 2013: 170-217; Forestier 2019; Pérez & Boëda 2019; Ramos & Boëda 2019). Indeed, it is not only a question of reconstituting the methods of production of the tool, but also of understanding the historical conditions of its existence, starting from the detailed analysis of its operative functioning (Boëda 1991; 1997: 7-12; 2013: 39-41; Forestier 2010: 125-130).

In the technogenetic approach, the technical object is, fundamentally, a materialized temporal product (*i.e.,* an artefact), that is, the physical manifestation of a set of technical operations. Consequently, the knowledge of artefacts is understood as a temporary location in technical systems and more essentially within technical lineages and trajectories. We will see later why the technical lineage is defined as a set of objects that have evolved, responding to the same function and the same stable operating principle, while the technical trajectory is defined as a set of objects that have undergone transformations in response to local or specific socio-economic conditions.

Since almost nothing of the technical system of a society survives the passage of time (much less the social and symbolic aspects, *i.e.,* cultural memory), we decided to concentrate on the memory conveyed by the object itself, *i.e.,* a technical memory (Boëda 2013: 171). This is also why the question of the why of the functional existence of the prehistoric tool acquires a scientific importance, as well as a broader perspective of reflection on past behaviours. This question can then be rephrased as follows: What is it about the prehistoric tool that makes it prehistorically useful, while justifying its necessary existence as well as its need to exist?

Consequently, in order to access technical operations, it is necessary to locate technical phenomena in terms of their own evolution. This own evolution is the true meaning of research into "that of which there is genesis" (Simondon 2007: 42). It is a long path of research, since there are no shortcuts or detours. The analyst always remains in the same reality of the objects. It is only at a second stage that human reality will be approached, starting from the analysis of the socio-economic context of production of the objects.

That being said, the question of why is related to the question of what prehistory are we talking about? What is prehistory as we speak of it the history of (Boëda 2013: 171; Canguilhem 2015: 9)? What is the technical genesis of the tool? Where does it come from? What are the technical conditions by which the object acquires the status of a social object, that is, an object produced by an environment or a social context? These new questions do not eliminate the validity of the traditional questions (what, when, how), but rather update them by integrating them into an "epistemology of relations" (*sensu* Bontems 2008). This epistemology follows closely Simondon's proposal of a realism of the relations, which exceeds a phenomenology or a naive realism of the technical objects and is situated in a genetic ontology whose main epistemological postulate is that "the relation between two relations is itself a relation" (Simondon 2013: 83). Simondon thus gives a value of being to the relation. A practical example given by Bontems will help to better understand the general idea of this epistemology:

"The glass on the table is no longer a static reality, identical to itself, not only is it the result of a technical process of transformation, but, in addition, its amorphous nature means that unlike the crystal, on another time scale, it does not cease to evolve, to flow very slowly" (Bontems 2008: 5).

This means that a technical object is not only the product of an instrumental relation between the human being and the environment, but that, more fundamentally, the technical object, the human being and the environment are three terms of a relation of technicality, where none of them is in supremacy over the other. More importantly, this technical relationship between the three terms also has the character of a term, and defines what is called technical genesis (Figure 1).

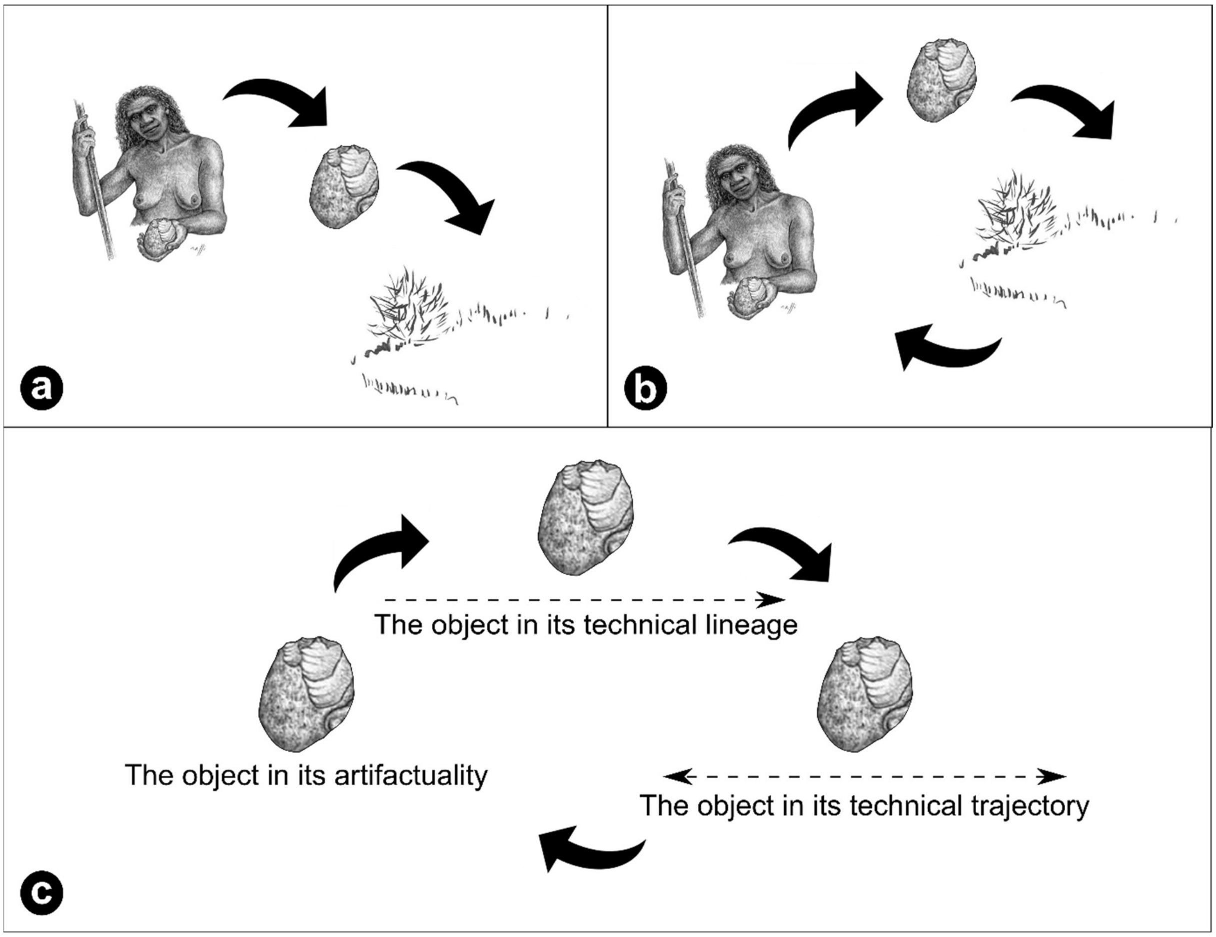


Figure 1. Different types of relationships between humans, artefacts and the environment: (a) the usual case of epistemologies in anthropology that consider the human being as the master and owner of nature. In this conception, the object is only an intermediary between the human being and the environment. (b) The more recent case of certain epistemologies in anthropology that consider a symmetrical relationship between the human being, the object and the environment. (c) The case of the epistemology of relational realism, proposed in this article. In prehistory, in the absence of living individuals, the object enters into a symmetrical relationship with its technical lineage and with its technical trajectory, thus defining, all three, a technical genesis. The object exists not only because it was produced by human beings, but also because it is in constant technical evolution (lineages) and in constant historical evolution (trajectories). In other words, the object that we perceive is nothing more than the stable manifestation of a set of unstable technical relations of a much more fundamental character. We also refer to this set of relationships as "technicality". The drawings were made by Maxence Raffi.

Thus, what we study are the technical relations, understood as the whole of the technical structures and the operations, carried by the matter. The structures and the operations integrate *de facto* technical relations. However, the structures are visible after technicofunctional analysis whereas the operations are not. To make them visible, we must go further, and use, on the one hand, data from the technicofunctional analysis to trace technical lineages and, on the other hand, use data from other types of analysis (traceology, archaeometry, analysis of associated elements in the archaeological context, *etc.*) to trace technical trajectories. Figure 2 shows a representation of the temporal density of prehistoric objects, and their different statuses or epistemological identities at each stage of the technologist's analysis: artefact, structure, technical object and historical object. An artefact consists of any mineral material transformed by humans. A structure (productional or functional) consists of any mineral matter organized through a set of elements or technical criteria established by humans. A technical object consists of any structure situated in its own technical evolution, that is to say in its technical lineage. Finally, a historical object consists of any technical structure situated in its historical evolution, that is to say in its technical trajectory.

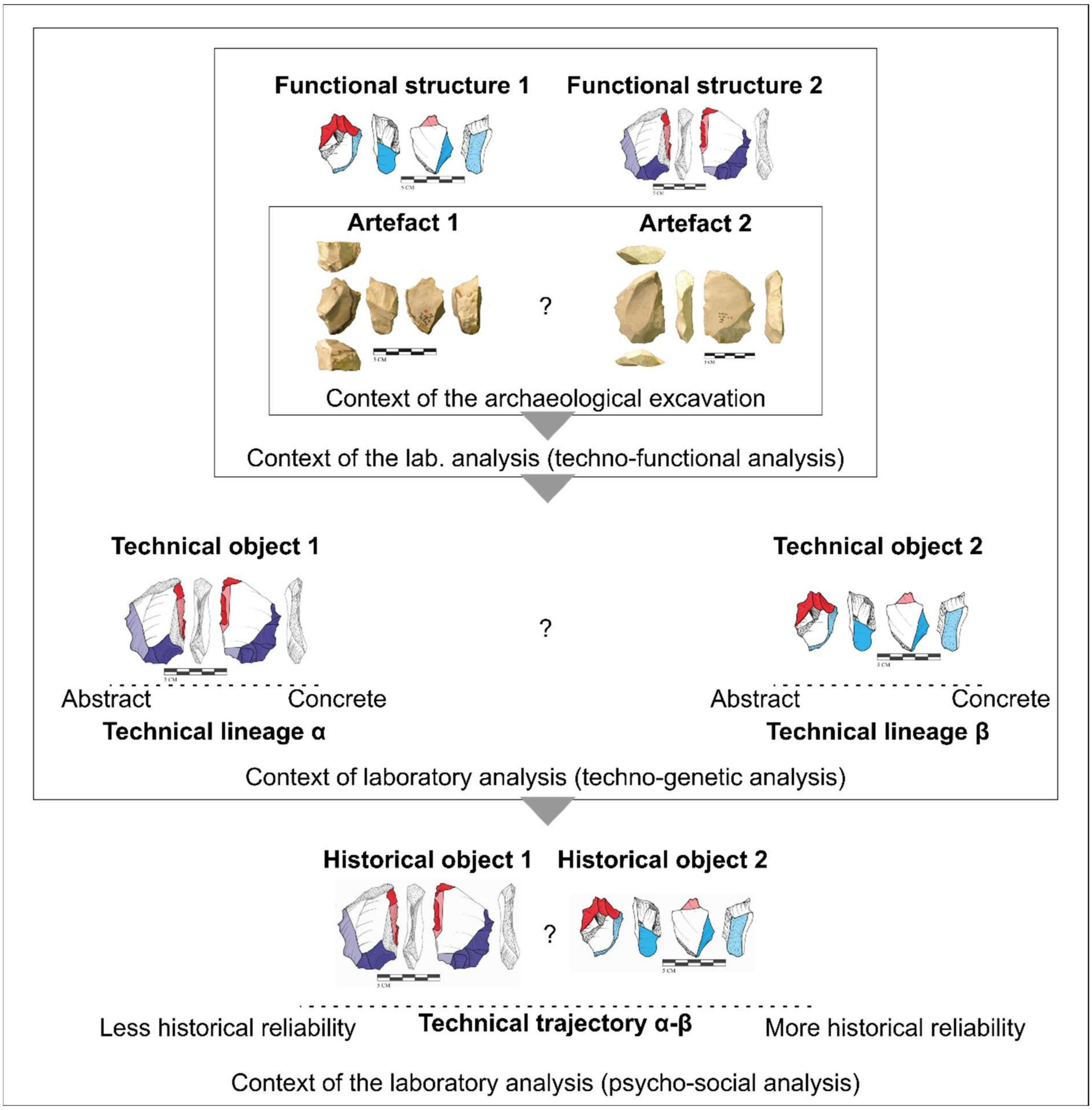


Figure 2. Technical relations between structures and operations, *schéma(s) opératoire(s)* and *schème(s) opératoire(s)*, in prehistoric technology.

In Simondon's language, technical structures constitute the individuality of the object, while technical operations constitute both individualization and transindividuation (Simondon 2012: 27-44; 2013: 285-296). The term individualization is used by Simondon to designate an aspect of the technical evolution (more precisely, of the process of concretization) by which the technical object needs an associated medium to function (Simondon 2012: 75-76). In this sense, individualization constitutes the continuous constitutive dephasing between the technical object and its medium, and thus, the very condition of the technical evolution. The term transindividuation is not used originally by Simondon. This term was proposed by Stiegler (1994: 45-51), declining the term transindividual of Simondonian origin. In Simondon (2013: 29), "the transindividual" is defined as "the systematic unity of the interior (psychic) individuation, and of the exterior (collective) individuation", that is to say as the process of production (Simondon uses the term "regime") at the same time psychic and social of the individual, the psychosocial personality of the individual. This concept goes beyond a simple inter-individuality or inter-subjectivity, since it is not a simple sum of individuals that form a social whole, instead it is formed by the sum of individuals and their associated environments, both in permanent relation. Taking that into account, the term of ransindividuation designates these functional psychosocial dynamics by which the individual (living or technical) is never a given and closed result, but always in permanent transformation, in a constitutive relation to the techniques. In other words, the transindividuation consists of a triple process of psycho-collective-technical individuation (Stiegler 1994: 145-162; 1998).

We consider that the two processes or regimes, individualization and transindividuation, can be approached in Prehistory, because of the dimension of the long time with which it works and the type of technical materiality which is its object of study. Thus, underlying the notion of technical lineage is the notion of individualization, while underlying the notion of technical trajectory is the notion of transindividuation. Obviously, we will never be able to address the totality of technical individualization and transindividuation in prehistory, but it is possible to trace lineages and trajectories by taking into account these two regimes as instruments of archaeological interpretation. This allows us to say that if in Leroi-Gourhan's work, technology was at the heart of the anthropological description (Métais & Lenay 2016); for us, technology is at the heart of the ontogenetic description.

In this perspective, it should be noted that the expression prehistoric object does not carry the same meaning as prehistoric technical object. The prehistoric object is defined by a material structure that we recover from a certain archaeological context, while on its side, the prehistoric technical object constitutes the object situated in its own field of technical evolution. In a certain sense thus, the technical object is a kind of avatar of the time and the space: the rational materialization of the creative instability of the human being since Prehistory (Forestier & Boëda 2018).

3.1. Prehistoric objects as technical structures

The prehistoric object can be defined in two ways: structurally and operationally. Structurally, as we explained earlier, the prehistoric object is an artefact, a natural volume constructed by human hands. This notion of artefact allows us to understand other manifestations that result from scientific study (Figure 3). Thus, the technical product is an artefact within a technical system (*sensu* Lemonnier 2010), and more precisely the result of a chain of operations (Geneste 2010). The tool is an artefact in a toolkit, which implies that the artefact must also have had a pattern of use (Rabardel 1995: 80). Finally, the core is an artefact within a set of production structures, which imposes a volume and one or more useful surfaces, a concept (Boëda 1986: 30) and one or more methods (Tixier 1980: 37). One can thus qualify this artificial character of the object-artifice as its first temporality.

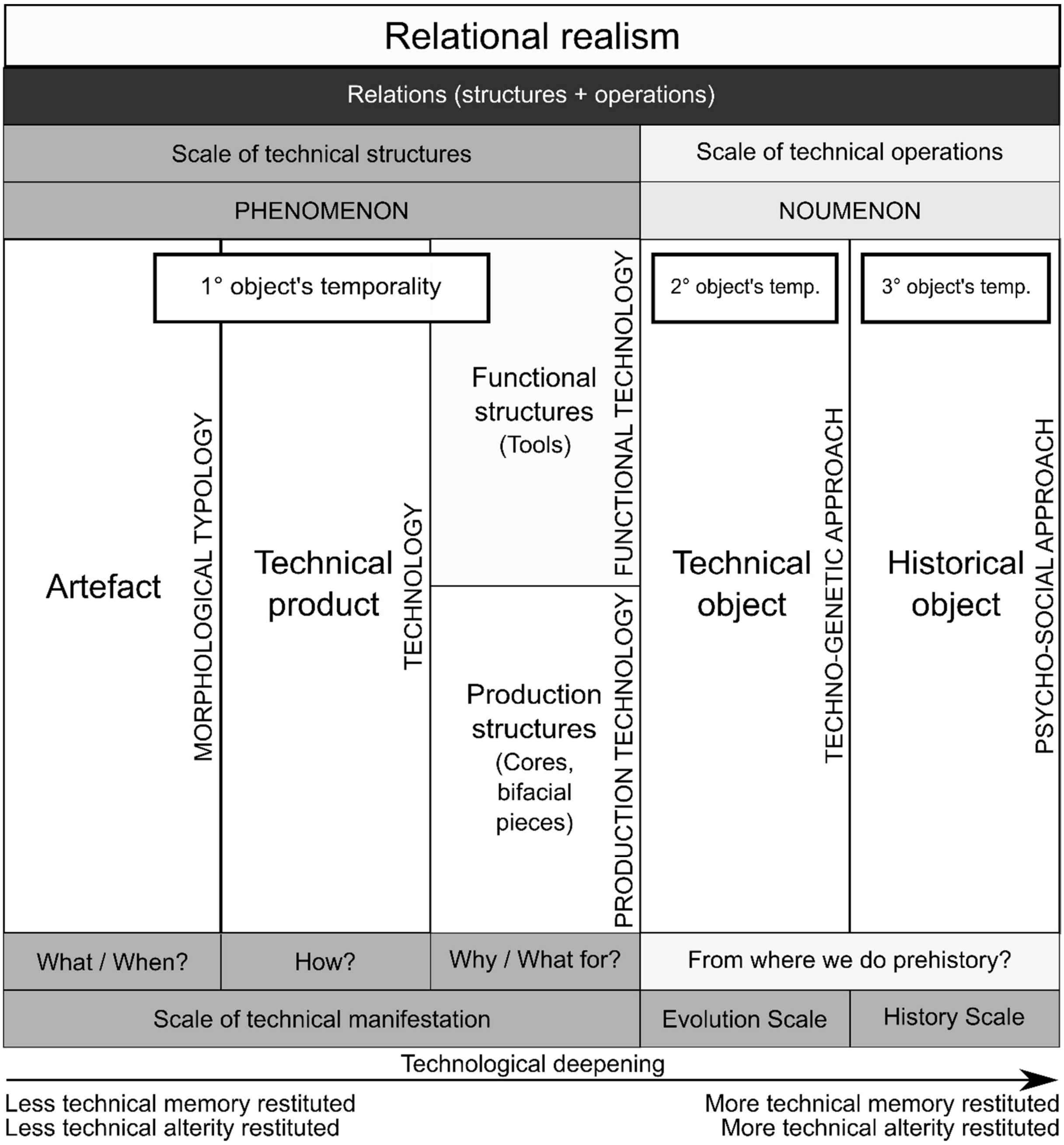


Figure 3. Categorial diagram in prehistoric technology based on an epistemology of relational realism.

As for morphological typology, it approaches the artefact as a morphotype of a determined, fixed and standardised lithic industry. It therefore remains within the contour of the object. While production technology detaches itself from this by considering the artefact as a technical product within a technical system (*i.e.,* it analyses the *dintorno* of the object), functional technology understands the artefact as a tool or a functional structure (Figure 4).

In the technogenetic approach, a technical structure, whether productive or functional, is a form that integrates and hierarchizes a set of technical properties that result in a defined volumetric composition (Boëda 1997: 27). In other words, a technical structure is a set of technical properties materialized by a visible form and volume. These structures correspond to technical phenomena that the technologist can grasp through his sensitive perception. But there is a certain gradation in this sensitive perception -narrowly linked to the methodological tools available at each period of Prehistory-, since the form "is the beginning of the discovery of the structure, which is given by a learned perception, deepening, and which defines the mode of organization" (Simondon 2018: 59) of the object. This sentence of Simondon speaks in reality about the passage of the sensitive perception (the form) to an intelligible perception (the structure). The structure is not perceptible by the sense, but by an intellection.

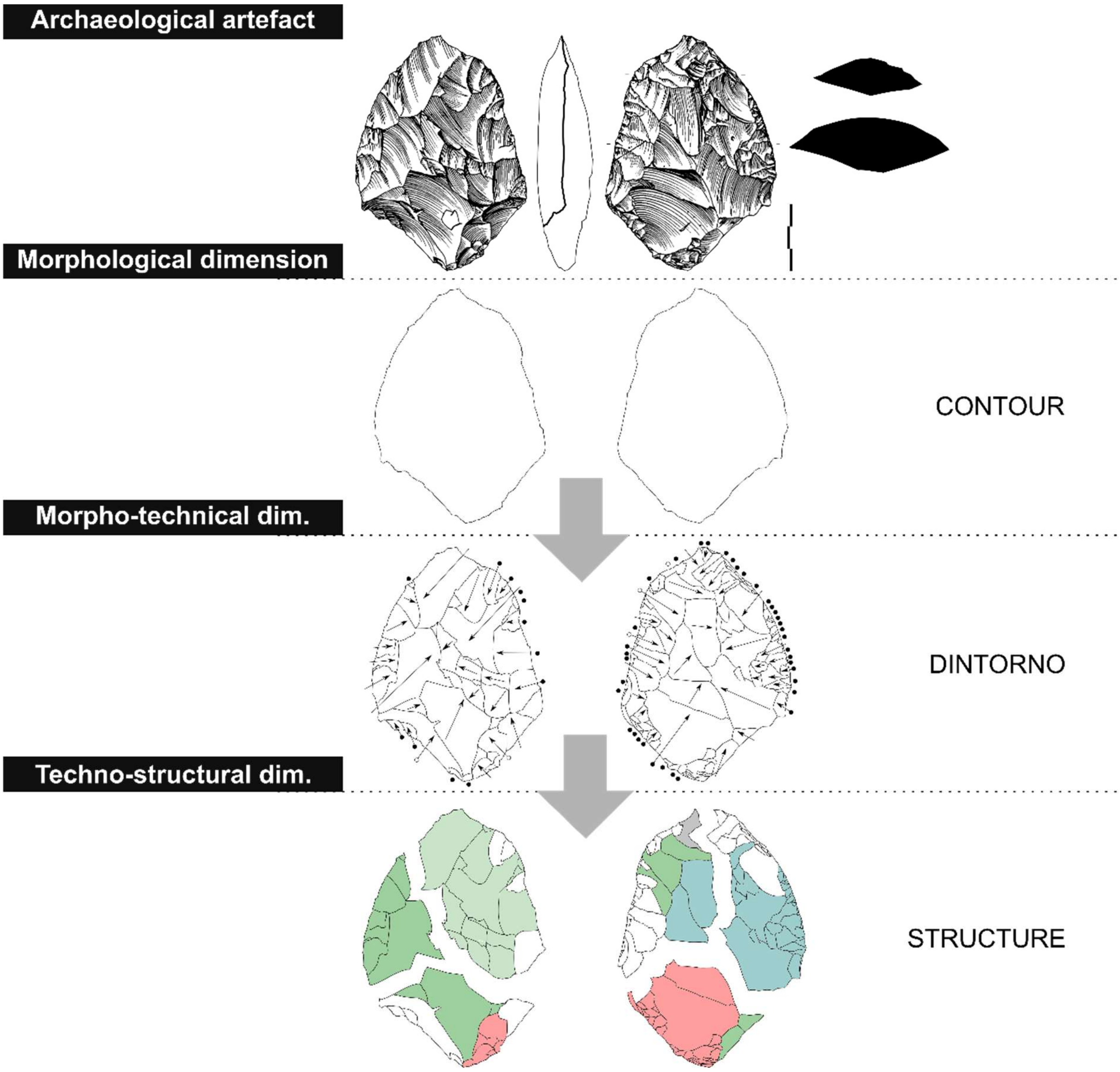


Figure 4. Example of the different analytical dimensions of an artefact depending on the approach used. What we call artefact corresponds to the object immediately found during archaeological excavations. Morphological typology favours an analysis of the contour of the object. This analysis often provides relevant information, but it must be taken into account that the contour (or what is generally called form) is only one of the technical criteria that make up the structure of the lithic piece. Technology, on the other hand, favours the study of the production of the artefact, *i.e.,* its *dintorno*, the production processes contained in its outline and which gave it form. Finally, functional technology starts from the analysis of the *dintorno* to identify the structure of the artefact, the functional areas that allow its operative functioning.

3.2. Prehistoric objects as technical operations

Technical operations are not visible (in themselves), because they are not in a stable material state, as structures as hierarchical and meaningful entities can be. This is why it is possible to identify structural invariants within technical events. Technical operations refer to technical objects and historical objects. In this sense, technical operations constitute the principles of causality that define technical structures. When we talk about historical objects, we refer to objects that, once produced, enter into a relationship with their users. In other words, they enter into an external dimension that is not essential to them, that is, it does not refer to the internal or properly functional dimension.

In terms of operations, the prehistoric object, as an individual, is an artefact and an associated environment (Simondon 2012: 75). Thus, the object is a system that has internal elements that configure a particular organization, established by the hand of the human being in its first temporality. This individual character is the second temporality of the technical object, given by its belonging to a technical lineage. The third temporality of the object is given by its social (economic, political, *etc.*) and symbolic (religious, ritual, *etc.*) dimension. One speaks here, in general, of historical objects. An object in its external life belongs to a technical trajectory, defined by socio-economic criteria which transcend the internal evolutionary logic of the object.

On the structural level, the technical object is defined through its lineage and, on the sociological level, it is defined through the technical trajectory to which it belongs and cannot be extracted. Epistemologically and methodologically, we reconstruct the technical lineage and the technical trajectory from the temporal location of production and functional structures. In the sections on methodology, we will give some examples of lineages and trajectories. Finally, it should be noted that if the technical structures are phenomena in their own right, the operations (lineages and trajectories) correspond to *noumena*, *i.e.,* to entities that the technologist cannot grasp through his sensitive perception (on how phenomena and *noumena* fit into an epistemology of realism of relations, see Simondon 2009: 115-117). But these *noumena* must not be understood as "the past of the object", as it is traditionally understood in prehistory. Lineages and trajectories correspond, because of the temporal rupture of which the archaeological artefact is a mediator, to another past, to other pasts. By forcing the line, we will say that they are technogenetic and psychosocial pasts, that is to say reductive constructions proper to the profession of the prehistorian-technologist.

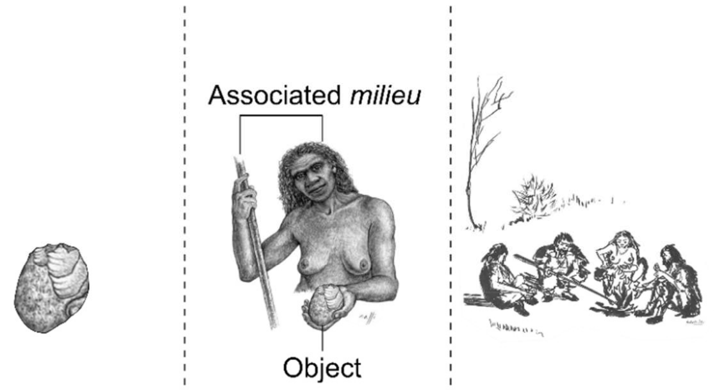
3.3. The associated milieu in prehistoric lithic technology

In the first half of the 20th century, Leroi-Gourhan (1943: 325) proposed the notion of technical milieu to integrate the object into its social group. Internal milieu refers to the technical knowledge of the artisan, and the external milieu refers to the social and environmental constraints. However, this notion assesses technical actions only as the result of an exteriorization of the internal milieu. Thus, Leroi-Gourhan's external milieu is a passive and inert one. This inert external environment constitutes a problematic point in the Leroi-Gourhan's approach, because it inevitably obliges us to reflect on an asymmetrical relationship of adaptability between the tool and its environment, in order to better fulfill its function. This implies assuming a functional determinism that leads to the dangerous notion of "progress" in prehistory. On his side, Simondon (2012: 75-80) proposed the notion of associated milieu. This notion allows to characterize the environment transformed by and also constituting the technical individual, thus allowing its proper functioning. It is a dynamic external milieu, a component of the prehistoric object itself, forming part of its individuality.

In this sense, the associated milieu is a techno-geographical concept allowing to conceive industrial objects, but also prehistoric objects, if we assume that much of this associated milieu does not survive in the archaeological context. This concept cannot be understood solely as the combination of a geographical milieu and a technical milieu, since this milieu is, moreover, produced by and with the creation of the technical individual. This notion was understood, applied and extended to the field of prehistoric lithic technology as part of a techno-logical evolution of cutting tools. The importance of this concept lies in the fact that it allows us to conceive the existence of a technical milieu constituting the objects themselves, at the structural level, thus allowing a finer and more real reading of prehistoric artefacts (Boëda 1997: 5; 2013: 30). Then, at the same time, different groups may have developed a singular milieu, from their geographical and cultural situation, that allows different technical lineages, thus different technical objects. The associated milieu is therefore the fundamental notion that allows us to address Alterity through technical phenomena.

Although the prehistoric object does not have an associated milieu according to Simondon (2012: 71-87), this can be approached from its location within a technical lineage. The notion of associated milieu here is therefore understood as a techno-geographic environment which defines the object at the time of its technical genesis. This is why “technical” is added to “object”.

In prehistory, we do not have the living individual coupled with the technical individual. This is why it may be surprising that Simondon's ontogenetic approach is applied to prehistoric archaeology, a field where one does not work with industrial objects. In this respect, it is necessary to recall that Simondon postulated that technical evolution occurred at three consecutive levels: elements, individuals and technical ensembles (Simondon 2012: 61). Simondon also considered these levels of technical reality as tendency ages of technical progress. However, this should not prevent us from approaching the technical evolution of archaeological artefacts from the same levels of technical reality. The technical elements for Simondon were the tools, the individuals were the machines and the technical ensembles were the industrial factories, to refer only to the prototypical examples given by Simondon himself. For him, the technical evolution goes from the elements to the ensembles. In prehistory, another time scale of technical reality, artefacts can be considered as technical elements. The tool can be considered as what remains of the technical individual, since we do not have the craftsman or the user, who was the main associated environment of the object (without the human being, the object could not function). Finally, the technical activity or production event can be seen as a technical ensemble where various individuals and elements interact to give “birth” to new individuals (Figure 5).



Archaeological categories	Artefact	Tool	Event or activity
Epistemological categories	Technical elements	Technical individual	Technical ensembles

Figure 5. Conceptual correlation between the archaeological and epistemological categories used in the present work. Drawings by Maxence Raffi and Aurore de Dinechin.

In other words, the application of the Simondonian propositions becomes possible from the moment we abandon the hylémorphic approach in favor of a structural approach (centered on the notion of volumetric construction). We see the object as a system made of elements, of relations between these elements, of rules of functioning. An input which is the objective, an output the result, a possible feedback effect not working well, an error, *etc.*

Thus, to understand the human being as the object's associated medium, that is, as part of the object's operative functioning, is to give the object the same epistemological status as the human being. There are of course other possible associated environments, such as the place of activity or another object that comes into contact with the lithic object to function, *etc.* Then, it is through the elucidation of the notion of associated medium that the technical evolution as conceived by Simondon could be applied to prehistory.

Given all of the above, it is not surprising that Simondon analyses a tool (and not an individual, *i.e.,* a machine) as if it were an individual:

"Everything happens as if the tool in its totality were made of a plurality of functionally different zones, welded together. The tool is not only made of form and material; it is made of technical elements elaborated according to a certain scheme of functioning and assembled in a stable structure by the manufacturing operation. The tool gathers in itself the result of the functioning of a technical set. To make a good adze, you need the technical ensemble of the foundry, the forge, the tempering" (Simondon 2012: 89).

In this description of the adze, Simondon gives us precious keys to analyse each object – be it industrial, artisanal, archaeological, *etc.* – from the elements that compose its structure, in relation with the other individuals and elements that allowed it to have this structure. These structural elements, that Simondon also calls "functionally different zones", from our point of view, can be approached from the notion of technico-functional units, defined as the whole of the elements and technical constraints that coexist in a synergy of effects, that is to say in a systemic organization (Boëda 1997: 27-28). Thus, any tool, whatever the period, can be analysed structurally from the technical elements that compose it.

3.4. Technical memory as an epistemological link between technical structures and operations

In summary, the object of prehistory has three temporalities in its structure: the temporality of its structure, the temporality of its technical lineage and the temporality of its technical trajectory (Pérez & Boëda 2019). These temporalities must be studied at the level of the life of an individual or a group, or even of several groups because of the process of transmission. Each of these temporalities incorporates a technical memory, which is essentially an epiphylogenetic memory (Stiegler 2018: 191). This concept was introduced by the philosopher Bernard Stiegler in the early 1990s. For Stiegler, "technique is above all a memory, a third memory, neither genetic nor simply epigenetic. I called it epiphylogenetic, because being the fruit of an experience, it is of epigenetic origin, and because this individual experience being summed up, this technical memory making possible a transmission and an inheritance, a phylum that opens the possibility of a culture, it is also phylogenetic" (Stiegler 1998: 191-192). The italics appear in the text). Simondon called this technical memory "non-living memory" (Simondon 2012: 172).

In this sense, the questions of what, when, how and for what, together, allow us to apprehend a part of this epiphylogenetic memory that the artefact carries, which is only complete when we address the technical and historical dimensions. In other words, the artefact is a mineral volume that memorizes a technical message. Thus, from the artificial object as we see it through its external appearance, we deduce the technical object and its technicality (Boëda 1997: 14). The technicality, as we said before, refers to what we call here the technical relations. Neither the structures nor the operations constitute, in isolation, a prehistoric technical memory. This technical memory is a set of operative schemes, which can be expressed through functional and production schemes (Boëda 1997: 32; 2013: 43). In prehistory, the temporal and spatial distance between the genetic and historical patterns and the productive and functional patterns apprehended by the prehistorian presents different degrees that can be understood as a forgotten, partial and living memory. This is why a "projectile point" is more easily recognized than an artefact with two or three removals. In this sense, technical recurrences constitute an instrument for reading the operations carried out through structures presented to the analyst.

4. A Theoretical framework: The "double approach"

"Therefore, there is a convergence of economic constraints (reduction in the quantity of raw material, work, and energy consumption during use) and purely technical constraints: the object must not be self-destructive, it must remain in stable operation for as long as possible. Of these two types of causes, economic and purely technical, it seems that the latter prevail in technical evolution." (Simondon 2012: 30).

There are thus two fundamental "existences" in the technical object, an internal and external existence, internal or "technogenetic" and external or "psychosocial". The internal dimension is translated by technical lineages; the external, in the technical trajectories (cf. technological trajectories *sensu* Gras 2003: 121-142; 2010). Although the term trajectory comes from the sociology of techniques of Gras, we use the term "technical trajectory" to designate what Deforge (1985: 182-190) called the "avatars of technical lineages", *i.e.,* the paths taken by the internal evolution of objects because of its relation to the anthropological dimension (Boldrini 2012). This double theoretical approach (Figure 6), based on the epistemology of relations explained above, constitutes the necessary material to analyse any object in any historical period, in the short and long term. It allows us to understand technical evolution as the result of a constant "renegotiation" between technical and socio-economic principles, and to study the rhythm between the two dimensions (Manclossi *et al.* 2019). A double approach attenuates the rigid cleavages between these two dimensions: technogenetic (macroevolution) and psychosocial (microevolution) (Boëda 1997: 36-37). Given these two complementary perspectives, our conceptual toolbox is enormously enriched, since we can refer to technical objects, historical objects, and superhistorical objects. Concepts that we will develop below.

One could say that the technogenetic and psychosocial approaches are "two modes of analysis, and that man must learn to deal with problems according to these two processes, extreme modes that make it possible to grasp the limits of the complex domains of reality" (Simondon 2014: 329). Here is the great challenge of prehistory. To answer the question "What kind of history is the prehistory of tools?" is precisely to always keep in mind that these two modes of analysis are not contradictory, but reflect the limits of an extremely complex technical reality. It is not necessary to forget that according to Simondon "the object is the resultant of several constraints: that of the idea of the object, that of its materialization and those of the socio-economic world in which it must be integrated" (Chabot 2003: 234). To have constructed a unilateral scientific discourse, taking into account only one of these constraints, is the great weight that prehistory still carries since its foundation, and from which it must distance itself in order not to fall into bi-substantialist epistemologies.

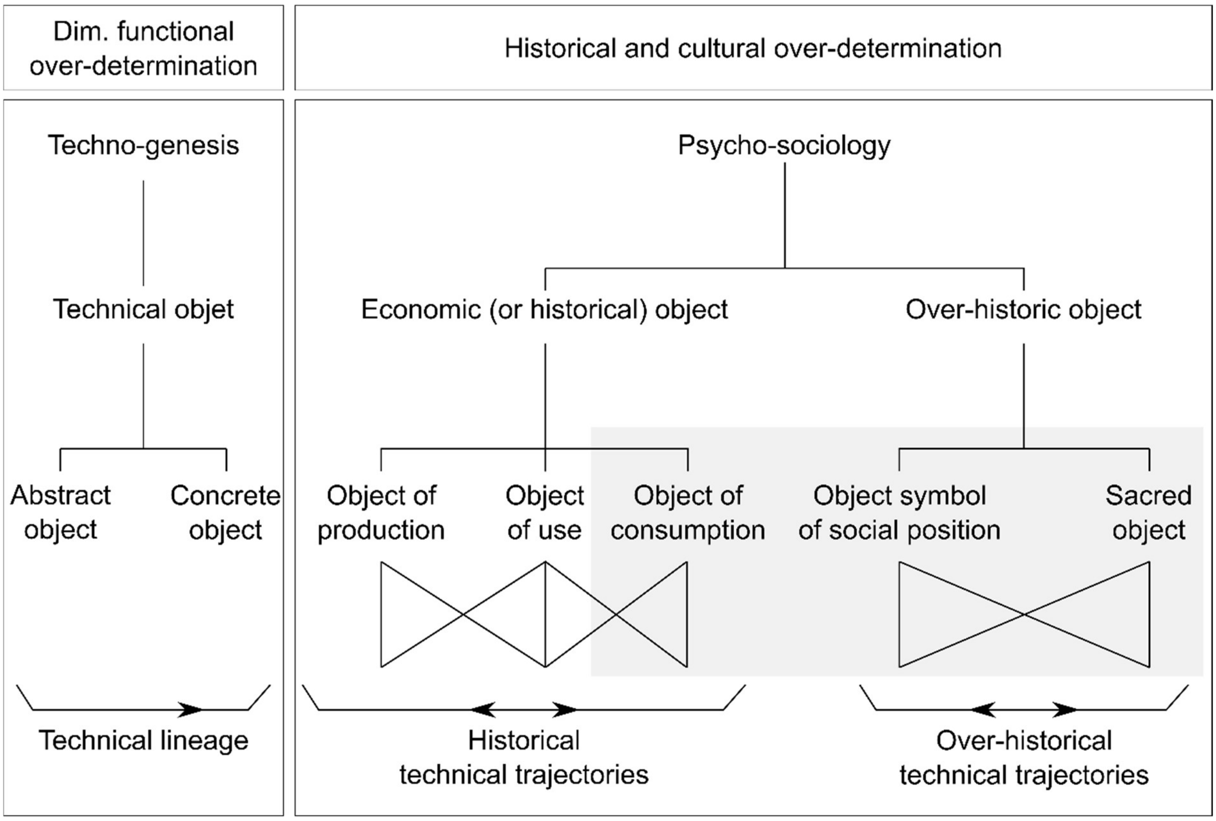


Figure 6. Two complementary perspectives of prehistoric objects. The grey box represents the possible overlap between the historic object and the over-historic object.

4.1. The techno-genetic approach

The technogenetic approach is based on a key notion: “the process of concretization” (Boëda 1997: 75; Simondon 2012: 22). In much of the work devoted to the application of this approach, the term “techno-logic” has been used to refer to it, following Boëda's (2013) proposal about the existence of an internal logic to the technical evolution of lithic objects. In this work, “techno-logic” and “technogenetic” are considered synonymous, due to an easy to understand aspect: “one does not make the tool with just anything” (Simondon 2014: 430). Underlying and due to the cultural dynamics of object production, there is then a logical order in their succession, which does not mean unilinear. Concretization reminds us that the technical object is and can only be understood as a combination of separate elements working together. This combination of elements defines what we previously called the technical structure. Independently of the socio-economic context of production, it is possible to highlight a logical order of succession of these structures. This structural succession is “logical” because we notice a progressive integration of the technical elements internal to each structure with the aim of a better operative functioning. Within a technogenetic approach, the terms “better,” “progress,” “improvement,” or “primitive” are used strictly to qualify the operative functioning of structures, so that their use is far from the socioeconomic connotations that are generally attributed to them in relation to their use. It must be taken into account that, in strict terms, “use is a sociological fact” (Simondon 2014: 377) and not a technological one, and that “human needs diversify infinitely, but the directions of convergence of technical species are finite in number” (Simondon 2012: 26). When it is possible to identify a single operative function shared by a succession of structures with different (or similar) morphologies, we apply the concept of technical lineage (Deforge 1985: 170; Simondon 2012: 23). At the beginning of the lineage, the technical object relays an abstract structure (also called additional structure) which means that each element of the object is independent and determining in the operative functioning. From this stage of technical abstraction, that is to say, of non-integration of the internal elements, a process of concretization will develop, which consists of several recombinations during the evolution of the tool or core. At a certain moment, a better adaptation of the structure to its associated environment will create a new element which will carry in it the operative effectiveness of the two preceding ones. This recombination of said element will logically and systemically lead to the elimination of a previous element within the structure of the object itself. The accumulation of recombination will lead to a so-called "concrete" object (also called concrete structure), whose elements are completely integrated (total synergy), *i.e.,* each element is interdependent and does not exist outside the technical object.

In summary, an abstract structure is a structure made of juxtaposed elements. It represents a composite functional solution. A concrete structure, on the other hand, is a structure made up of elements integrated into each other in a synergy of form, function and operation. From this perspective, technical evolution is a function of the degree of structural synergy in relation to the passage of time: "the technical object progresses by internal redistribution of functions into compatible units, replacing the randomness or antagonism of the primitive distribution; specialization is not function by function, but synergy by synergy" (Simondon 2012: 41). That is to say that the technical object evolves by convergence and by adaptation to itself, by virtue of an internal necessity: it unifies itself internally according to a principle of internal synergy (*i.e.,* coherence) (Simondon 2007: 42).

Simondon offers many examples of the concretization of technical objects in the industrial age. The internal combustion engine is perhaps the most classic (Figure 7A). The philosopher begins by tracing a chronology of these engines from 1900 to 1956. According to him, the 1956 automobile engine is not the descendant of the 1910 engine only because the 1910 engine was produced by people of a different era, nor because the 1956 engine is in a more advanced state in terms of its use. In terms of use, says Simondon, a 1910 engine is indeed superior to a 1956 engine, but in terms of operative functioning, the 1956 engine is the descendant of the 1910 engine. Why? In the 1956 engine (*e.g.,* Sunbeam S7 engine), each internal element - the spark plug, the cylinder head, the fins, the cylinders, the crankcases, *etc.* - is so functionally related to the others that it cannot be other than it is. In Figure 7A we have focused on the case of the cooling fins, because it allows us to explain in a simple way how a technical element that existed in isolation in the 1903 and 1904 Werner engine, will progressively "gain more ground" inside the engine, until it takes up space on the lower crankcases of the 1956 Sunbeam S7 engine. This "gaining ground" is one manifestation of the concretization or integration of the elements that make up the engine. Another manifestation of this evolutionary phenomenon is that the fins themselves will gradually have a dual function. In the Werner four-stroke engine, the fins only perform the function of cooling; whereas in the Zurcher two-stroke engine (*ca.* 1920) the fins begin to approach the cylinder head, like ribs, thus preventing its deformation due to high temperatures, by reinforcing its wall. Thus, the fins-finned become fins-ribs (Simondon 2012: 26). Both manifestations, the invasion of internal space by an element and the multi-functionality are criteria that allow Simondon to qualify the Sunbeam S7 engine as a concrete engine, while four-stroke engines are considered abstract. In this way, a technical lineage is configured around these engines which, despite their different forms, present the same operating principle: internal combustion. This is a case where the historical time coincides with the time of concretization, since we do not observe any technical regressions. This technical evolution from an abstract object to a concrete object has a great consequence: when a technical object is concrete, it has no more way to evolve. It cannot support new technical innovations or these last ones have no more effect on it. Then, in order to evolve, the technical object must be created from a new structure that will start a new lineage.

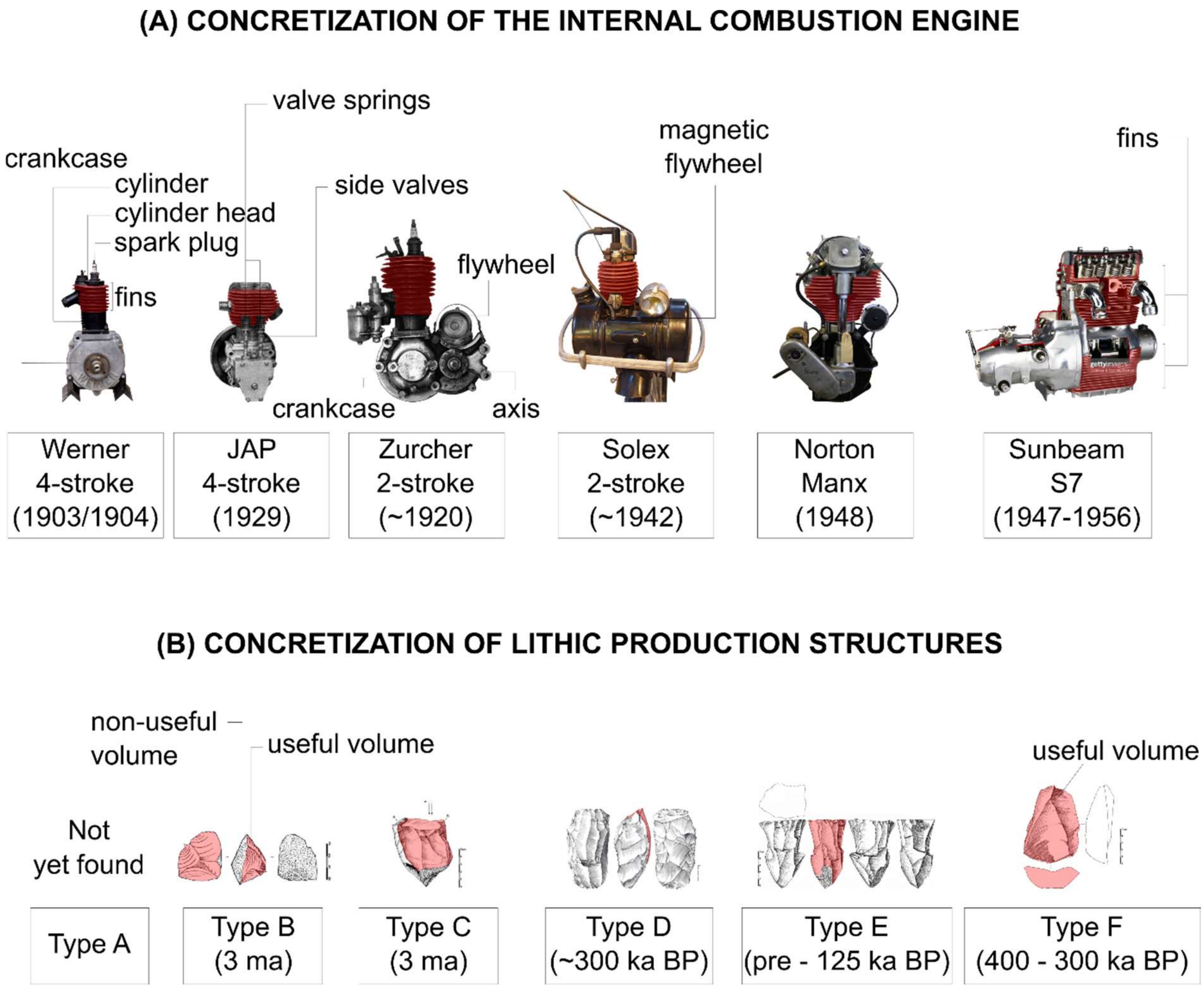


Figure 7. Example of concretisation of technical objects. (A) Concretisation of the internal combustion engine (elaborated from Simondon 2012: 20-26). The area coloured red in each engine corresponds to the fins which, over time, begin to gain more space in the engine structure. In other words, the fins begin to integrate more effectively with the other elements. (B) Concretisation of lithic production structures (elaborated from Boëda 2013: 60-72), using archaeological cores from different archaeological sites. The area coloured red in each core corresponds to the useful volumes (*sensu* Boëda 2013: 89) which, over time, also start to gain more space in the core structure.

This mechanism, called "law of concretization" by Simondon, allows us to think of technical evolution on several scales: short-time based on a specific lineage; long-time based on changes of lineage. This methodological gap is huge for a prehistorian, especially when focusing on technical systems and technical evolution.

In our discipline, this notion is very relevant to study the evolution of the modes of production of debitage or shaping and also the evolution of functional structures (tools). It is important to underline that in the first case, the debitage system is considered as a production structure. Any mode of production, from simple chip cutting to Levallois or laminar production, is governed by technical criteria. The number of these criteria and their combination can be used to define a production structure. One of us has proposed a classification of the different debitage systems using the number and combination of technical criteria used in each system. Six main technical stages (A-F) are defined, in which different types of cores and removals can be found (Boëda 2013: 100) (Figure 7B). In the case of cores, the concretization lies in the progressive integration of two internal technical elements in each core: a useful volume and a non-useful volume. The former refers to the core *sensu stricto*, while the latter refers to the part of the block not invested because not necessary for the production of the removals (Boëda 2013: 89-90). Each debitage concept defines a particular structural organization between these two volumes. Without this organization, media production is not possible, unless the technical criteria that make up the concept are not met. In Figure 7B, we have focused on the useful volume. This allows us to observe that in a long time of three million years, the useful volume begins to "gain ground" within the object. In the first production structures, the useful volume is isolated from the other parts of the block, while in the last ones, as in the case of the F-type structure or Levallois, the useful volume corresponds to the whole block. It should be noted that the non-useful volume is not synonymous with an area with the presence of cortex. In some production structures, such as the one illustrated by type D in Figure 7B, almost the entire block is inverted, but only a portion actually produces the desired media. It is thus primarily the degree of synergy between useful and non-useful volume that allows Boëda (2013: 90) to refer to abstract production structures (types A, B, C, D and subdivisions) and concrete production structures (types E and F, and subdivisions), and thus define a technical lineage around production structures of different shapes, but which follow the same operating principle: the fractionation of hard rock by debitage. Within this more general concretization, there are of course particular cases, such as the laminar production lines (C2, D2, F2, E2), the Levallois production lines (flake, point, blade), among others.

All technical stages are then part of at least two lines of debitage: chip production and blade production. The process of concretization works on the basis of the combination of criteria. The abstract (additional) structures (A-D) involve certain configurations in the preparation of the nucleus, which means that the combination of technical criteria must be recomposed for each flake or after the detachment of some. Only a few parameters are controlled before cutting (length or width for example). Concrete (integrated) structures (E and F) imply a preparation of all technical criteria before the production of the flakes. This means that all components of the flake are checked prior to cutting. This can be seen in the Levallois production and the production of Upper Paleolithic blades. It is obvious from the current state of our research that the number of production lines is finite, and that from this techno-genetic background, human beings will produce accelerations, regressions, borrowings and other phenomena of a psychosocial nature.

4.2. The psycho-social approach

The psycho-social approach is based on a key notion: transformation cycle or evolutionary cycle. This notion has been introduced to refer, on a macroscopic scale, to the passage from an abstract structure to a concrete structure within one or more technical lineages. That is to say that the evolutionary cycle constitutes a transversal concept to the technical lineages, because it allows the human hand to be introduced into its segmentation and its articulation. In this process, the hands of Man operate the changes, Man is then the motor that defines the rhythm, frequency, interruption or resurgence of a technical lineage. It is not enough to describe the passage from an abstract object to a concrete object, but we must look for the causes of this passage in the imperfection of the abstract object, which will inevitably have to reflect on the constraints of the material, and all aspects related to its introduction into the technical future.

When we consider the entry of the human hand as user of the technical object in a certain technical activity, there is a historical dimension and an over-historic dimension in the object. According to Simondon (2014: 54-55), the historical dimension of the technical object corresponds to this cultural and economic space in which the object is “released” once produced. It thus corresponds to a dimension outside the purely functional dimension of the object, and corresponds rather to the use and exchange of the object. For its part, the over-historic dimension of the technical object corresponds to that cultural and symbolic space, where the object is loaded or overloaded with characteristics that are not functional or economic (*i.e.,* aspects inessential to the object), but rather typical of the time, fashion, or personal taste. Simondon offers a very clear example: “If an automobile were conceived as a pure technical object, without over-history, it would be made of stainless-steel sheeting, like the cars of fast trains” (Simondon 2014: 58). This implies considering not only the economic aspects that guide the production of certain objects, but also the symbolism and sacred or deep aspects of technicality (Simondon 2014: 61). We could thus speak of economic objects, symbolic objects and sacred objects, all being “historic objects” (Figure 4). But this trivial classification must be modulated, in the light of a psychosocial perspective of technicity.

From a psychosocial point of view, the historic object has two dimensions, historicity and over-historicity: “The historicity of the object as a utensil is, one could say, a simple historicity, which is reinforced and overdetermined by a cultural historicity” (Simondon 2014: 53). In the historicity dimension, the technical object becomes an object of exchange in the broad sense of the term, more precisely an economic object, which can be an object of use, an object of production or an object of consumption. As for the over-historicity dimension, the economic object is surcharged with a set of extra-economic values, outside of its essential history of exchange good, therefore the object becomes a sign (Figure 4).

Obviously, these two dimensions are complementary, in the sense that neither is unrelated to the other. In fact, it is problematic to some extent to identify the degree of superhistoricity that a consumer object can have in order to define itself as such. There are obvious trade-offs between these dimensions; the technical object goes through different degrees of over-historicity, which in some cases is extremely difficult to recognize; as no object is purely an object of use, it is always partially overdetermined as a psychosocial symbol (Simondon 2014: 29). In prehistoric times, the tool may also have developed those concentric zones that Leroi-Gourhan’s (1943: 325) degrees of the fact have attempted to understand through the idea of accumulation of specificities. This recognition must pass by a topological analysis of the technical object, in its evolution within the psychosocial space. This psychosocial topology makes it possible to identify concentric zones which exceed its individual scale and surround it. However, the approach of Leroi-Gourhan corresponds to a hylemorphic vision of the technical phenomenon, which obliges to conceive the tendency as a functional determinism, without taking into account the internal structure of the objects and the genetic process which made them be born.

The fundamental difference between this approach and technogenetics lies in the fact that from a technogenetic point of view, the tool produced does not really move away from the manufacturing cycle, but is always in constant contact with it, always returns to it (acts of repair, recycling, *etc.*). These concentric zones around a historical object can be applied to the understanding of a tool or a prehistoric tool in the following way (Figure 8):

1. The functional zone, which is the purest zone in functional terms. This zone is composed of aspects essential to the object. It describes the moment before the tool is introduced into the psychosocial space. Obviously, this does not mean that the psychosocial space begins with the act of use, since it is inscribed in the object as soon as it is produced. In any case, it is a second psychosocial space where the object acquires a historical and superhistorical dimension.

2. The utility zone, produced immediately after the act of use. It is the zone of interaction between the tool, the operator and the material to be transformed. It is also the beginning of

an attachment (repair, constant maintenance of the tool) or of a possible participation (personalization of the tool, its total or partial denaturation, abandonment, *etc.*).

3. The zone of psychosocial symbolism or archetypal zone, where real participation occurs. The tool becomes a symbol, in the sense that it represents the position of its user and has no meaning outside of it. This implies endless actions to personalize the tool (identity marks or signatures).

4. The zone of isomorphism between technique and sacredness, or the domain of great works. It is the most contaminated zone for the cultural aspects. The tool becomes the symbol of a technical virtue (artisanal perfection). This includes: the demonstration of technical skills, carved pieces without inherent functionality (functionality acquired only later).

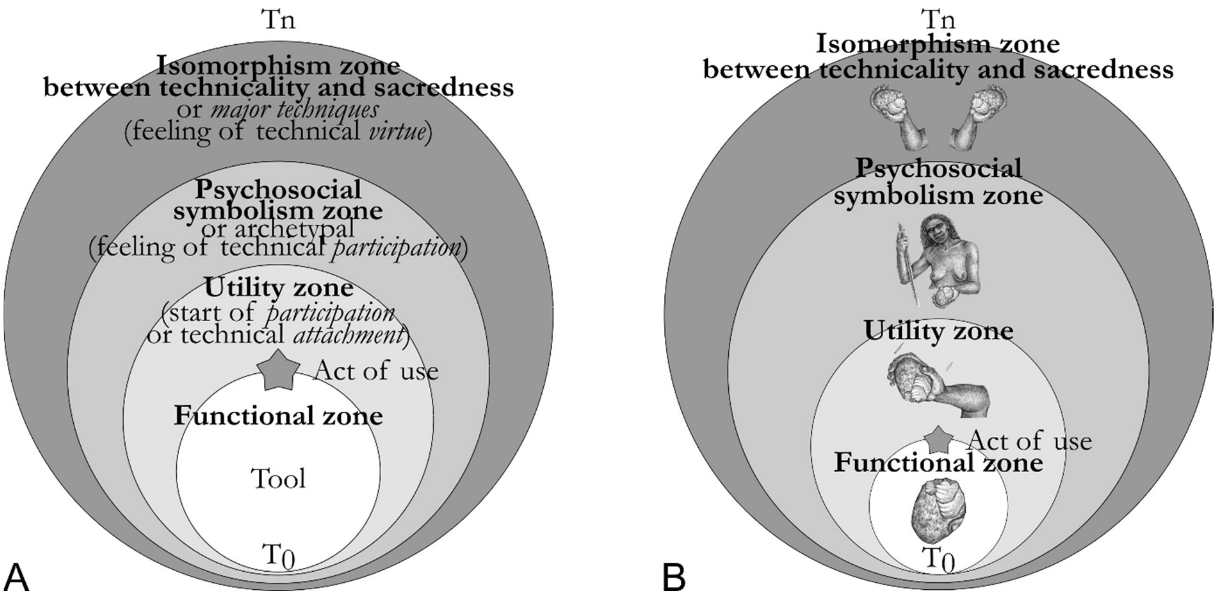


Figure 8. Psychosocial topology of the technical object. Left, concentric zones of industrial objects Simondon (2014: 52-64). Right, our proposal for concentric zones of prehistoric tool. T0, trajectory initial time; Tn, trajectory of final time. Gray levels correspond to the degree of purity (in the sense of technicality) of the object: the grayer the area, the more contaminated (culturally) the technical object is.

These four zones do not constitute all the layers that exist around the tool in its psychosocial trajectory. However, they help to describe the mechanisms that produce ruptures of technical lineages, in the short time scale. The answers concerning prehistoric technicality are not always to be found in long-term evolutionary mechanisms. When this is the case, it is necessary to look for answers in socio-economic, symbolic and sacred contingencies.

5. A methodology

Coupled with the theoretical development that we have just outlined, there is a method that is already well known in the world: the method of technicofunctional analysis (TFA) (Boëda 1991; 1997: 92-110; 2001; 2013: 47-51; Lepot 1993: 25-40; Soriano 2000: 119-136). It is not our intention to review all the details of this method, but to develop a few points that seem essential to us in order to land some of the notions and concepts previously exposed.

5.1. Technicofunctional analysis: beyond the *chaîne opératoire*

Technicofunctional analysis is based on two key notions: the tool and the technicofunctional intentions (Boëda 1991; 1997: 79). If a lithic tool can be considered as the product of a chain of operations, we consider that it is more fundamental to understand the technicofunctional intentions underlying each technical operation. Indeed, we work mainly with objects of which we have no technical memory. The technicofunctional intentions refer to the operative schemes applied by the craftsman to constitute a specific tool structure. Thus, any technogenetic approach starts from a technicofunctional analysis of tools in order to understand their structures. In the case of nuclei or other pieces, the same logic is followed, *i.e.,* a structural analysis of these artefacts is carried out. Thus, the technicofunctional analysis is, strictly speaking, a structural analysis of cutting lithic tools. The determination of the internal structures of the tools logically makes it possible to arrive at an understanding, through an inductive approach, of the technicofunctional intentions sought by the artisan or artisans.

Our objective is not the production processes themselves, but the functional contribution of each production process to the structural constitution of the tool. We do not approach the tools to understand the production processes, but on the contrary, we approach the production processes to understand the tools. It is therefore in essence a functional technology. This approach allows us to conceive of the tool as a mixed entity made up of three components: the object as such, called an artefact, the pattern of use and the energy that keeps it in action (Rabardel 1995: 80). The artefact component is, in turn, subdivided into three technical-functional units (UTF): a prehensive technical-functional unit (UTFp), which receives energy; a technical-functional unit (UTFtr), which transmits energy and transforms the work material (the action takes place here); and a transformative technical-functional unit (UTFt), within which the thread is located (Boëda 1991, 1997: 16-18; Lepot 1993: 29-33). In order to function, the tool, as a functional structure, needs these four units.

Therefore, techno-functional analysis should not be understood as an integration between technological and use-wear observations. The term functional is used in the sense of the structural organization of the artefact due to its function (Figure 9). Thus, this analysis focuses, on the one hand, on the determination of the technicofunctional consequences of each technical operation and, on the other hand, on the determination of the operative patterns applied to produce these technicofunctional consequences.

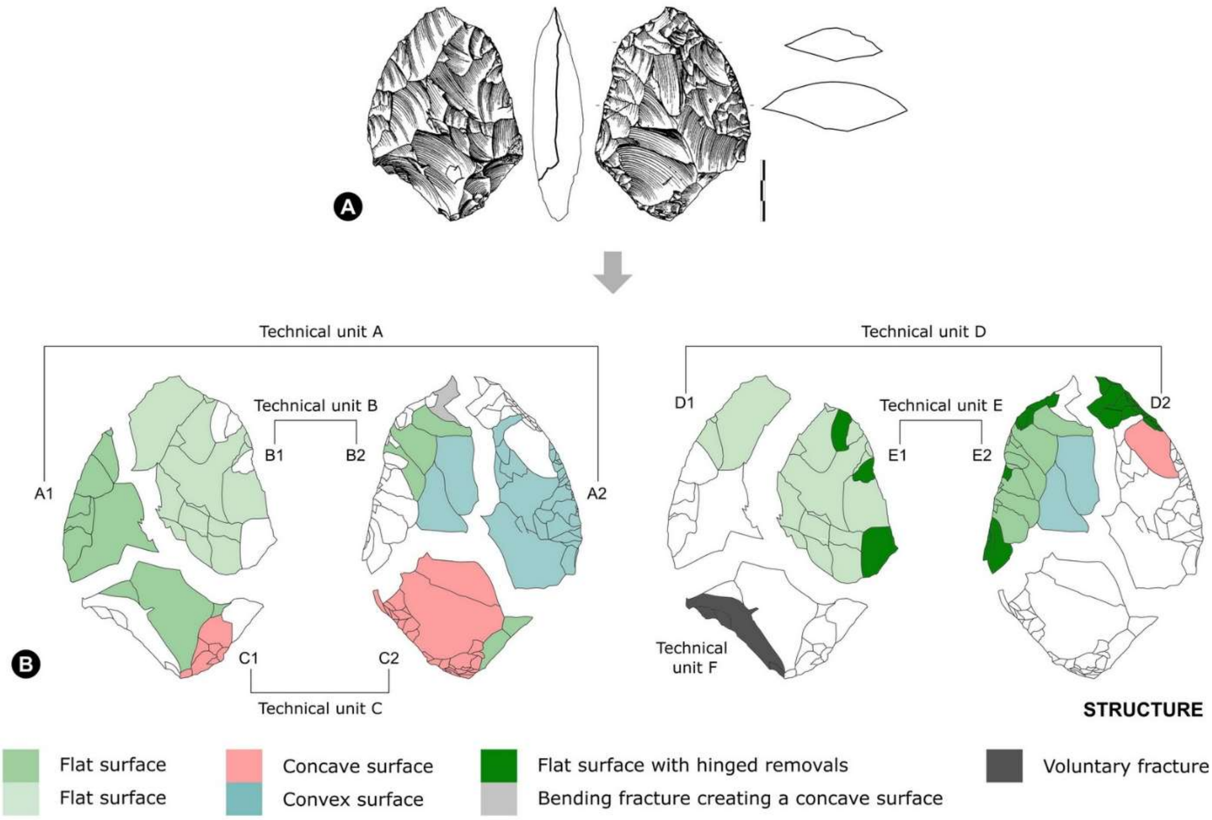


Figure 9. Example of technicofunctional analysis of a bifacial piece from the C'3 base layer of the Barbas I site, Dordogne (Boëda 2001: 63, figs 8 and 9): (A) drawing of the bifacial piece, (B) determination of the technicofunctional units that define the tripartite structure of the bifacial part. Ultimately, at the interpretative level, this structural determination will allow us to define the evolutionary stage (abstract or concrete) to which the piece belongs.

From our perspective, there are three technical operations in the production of stone tools, also called modes of production: affordance, debitage, and shaping (Figure 10).

Affordance refers to the selection of technicofunctional criteria naturally present in the initial block and which will remain in the finished product since they participate in the functionalization of the part (Boëda & Ramos 2017).

Debitage is the fractioning of a volume of material through a range of specific methods, into different units of criteria and technicofunctional volumes (Boëda 2013: 58; Boëda *et al.* 1990).

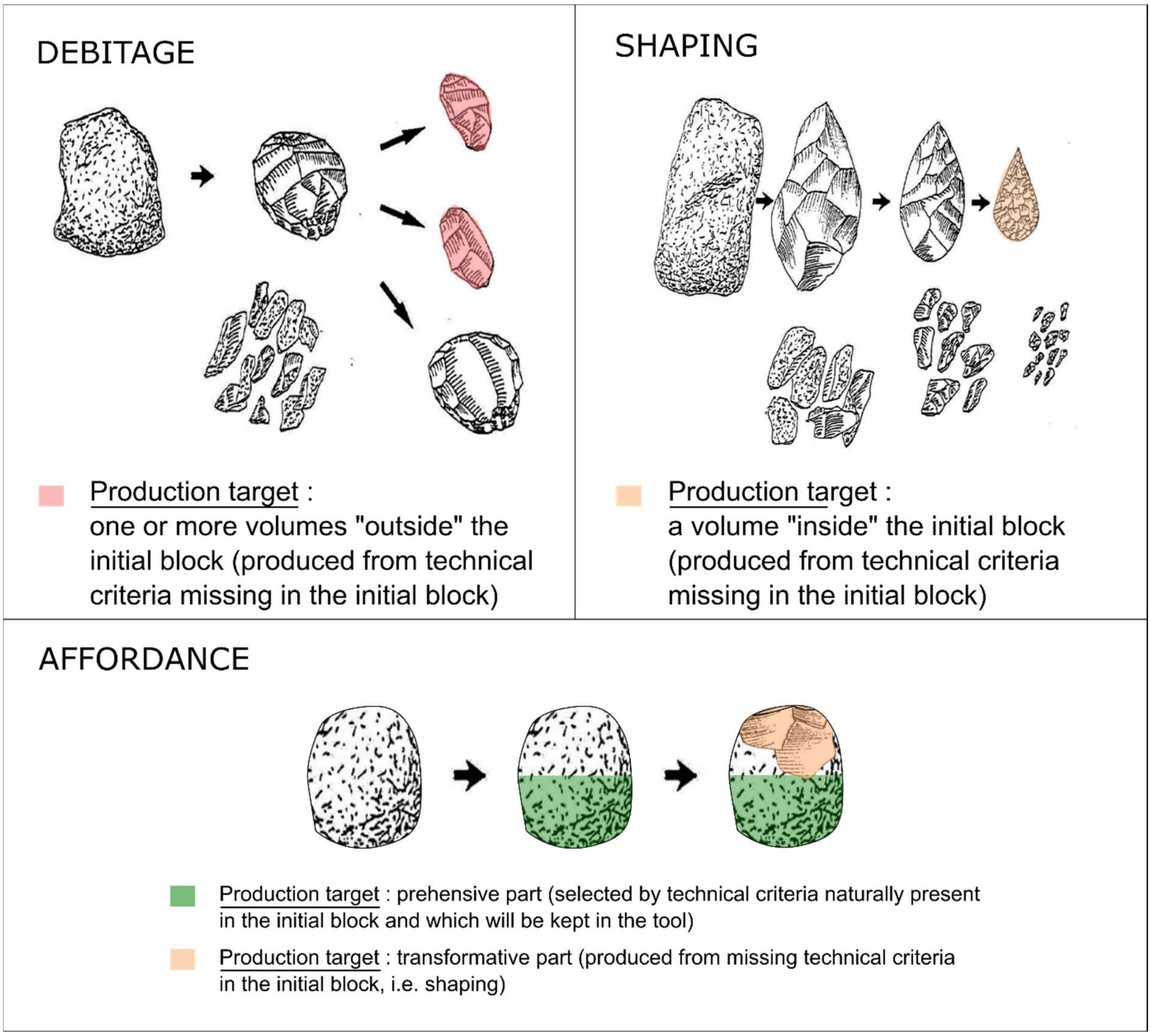


Figure 10. Three technical operations involved in lithic tool production (elaborated from Boëda 1997, fig. 5).

Shaping refers to the configuration of a part, within a mass of material that is worked from the beginning to obtain the techno-functional criteria that are lacking in the initial volume (Boëda *et al.* 1990; Boëda 2013: 58).

The use of the term “retouch” is avoided because of its semantic ambiguity, as it can refer to both technical phases and technical consequences. Any rework is considered a shaping operation.

The technicofunctional consequences include the effects produced by the mentioned technical operations. The consequences are technical in terms of the structural configuration (types of surface highlighted by each removal negative: convex, concave, flat, *etc.*) and functional in terms of the configuration of the transforming part of the tool (cutting edge, bevel, cutting angle, flat surface and bevelled surface) (Figure 11).

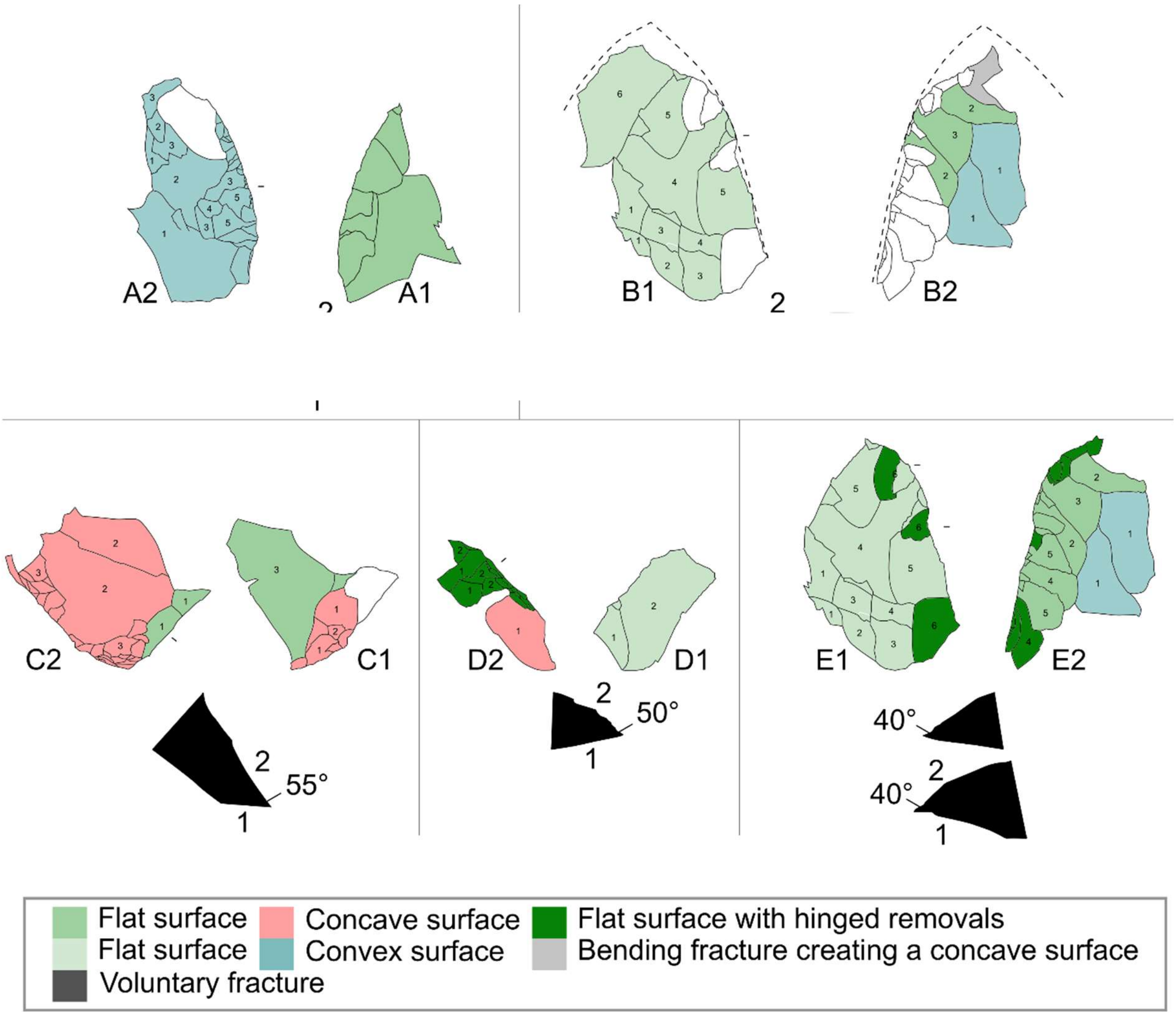


Figure 11. Technical and functional consequences of shaping operations on the bifacial piece from the C'3 base layer of the Barbas I site, Dordogne (Boëda 2001). The technical consequences are shown in frontal standard, while the functional consequences are shown in cross-section.

The determination of the operative patterns applied to produce the technicofunctional consequences on the artefact is carried out by means of a diacritical analysis of the removal negatives and an observation of the abrasion state of the edges. The next step is the individualization of the UTFs (Figure 12), which we had previously equated with functional areas internal to the tool structure. Then, in another level of analysis, the recurrence of these UTFs within the framework of one or more lithic assemblages, will allow us to define techno-functional groups or techno-types. A removal techno-type is a type of support made through a specific debitage system (*e.g.,* Levallois techno-type). A tool techno-type corresponds to a type of tool defined from a particular arrangement of UTFs (*e.g.,* tool techno-type composed by a UTFt opposite a UTFp, tool techno-type composed by a UTFt adjacent to a UTFp, *etc.*).

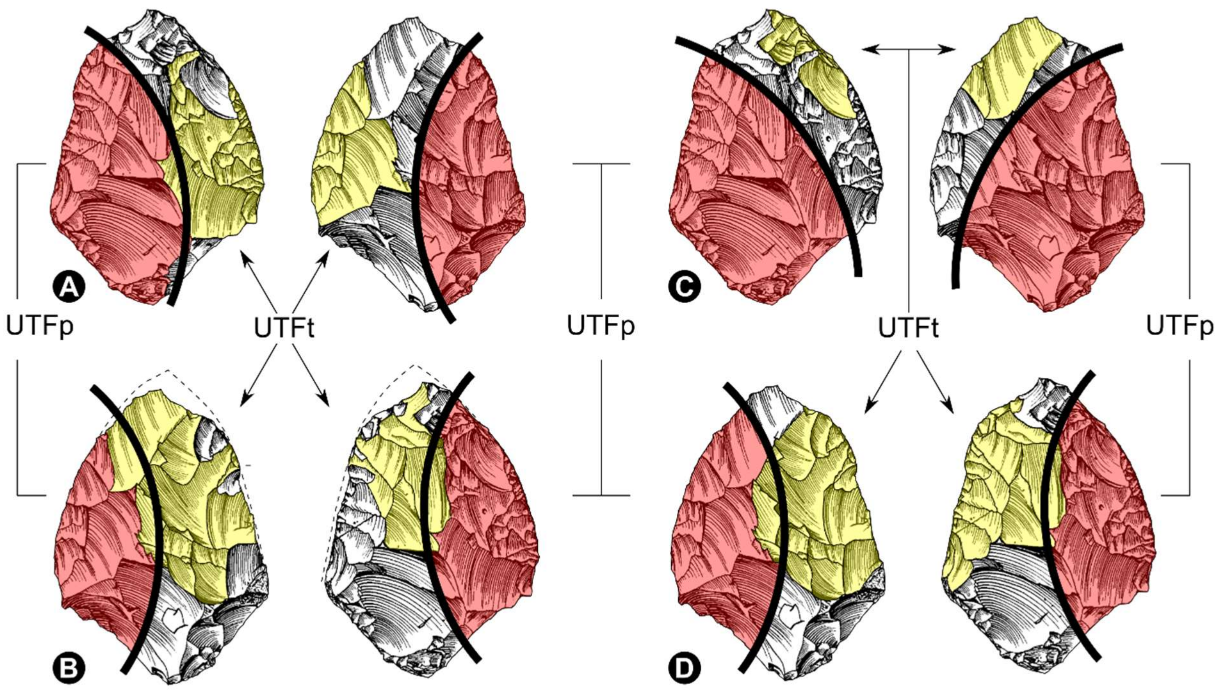


Figure 12. Determination of the technicofunctional units in the structure of the bifacial piece from the C'3 base layer of the Barbas I site, Dordogne. In red, the functional area with a prehensive role (UTFp); in yellow, the functional area with a transformative role (UTFt). The relationship of the two UTFs, assessed at the individual and lithic assemblage level, allowed the identification of four tools (A-D) within the same bifacial piece. As is evident, some areas have a dual function within the same structure (Modified from Boëda 2001: 72, figs 16-19).

Now, each UTF carries constraints that have been integrated to produce an effect, according to a specific operation and mode of action. Thus, the notion of Technico-Functional Unit, synonymous with technical coherence, allows to demonstrate technicofunctional intentions by defining functional criteria for each part, also called instrumentalization criteria. These criteria, put in perspective of the action, restore the object in its functional movement, giving rise to instrumentation hypotheses (movement trajectory, gestures, gripping mode, *etc.*).

As for the terminology used to describe the geometry of UTFt, it comes mainly from the craft sphere, and was introduced mainly by Boëda (1991), Lepot (1993: 25-40), Bourguignon (1997) and Soriano (2000: 119-136). Here we use a recent version of this terminology (Soriano *et al.* 2015), which describes the following components of the transformative part of a tool (Figure 13):

- Beveled surface (top surface): the surface on which the processed material slides, formed in processing action (cutting, scraping, *etc.*).
- Flat surface (bottom surface): the surface that faces the surface of the work area.
- Work surfaces: bevelled and flat surfaces.
- Wire: intersection between the working surfaces.
- Bevel: the body of the tool between the beveled surface and the flat surface.

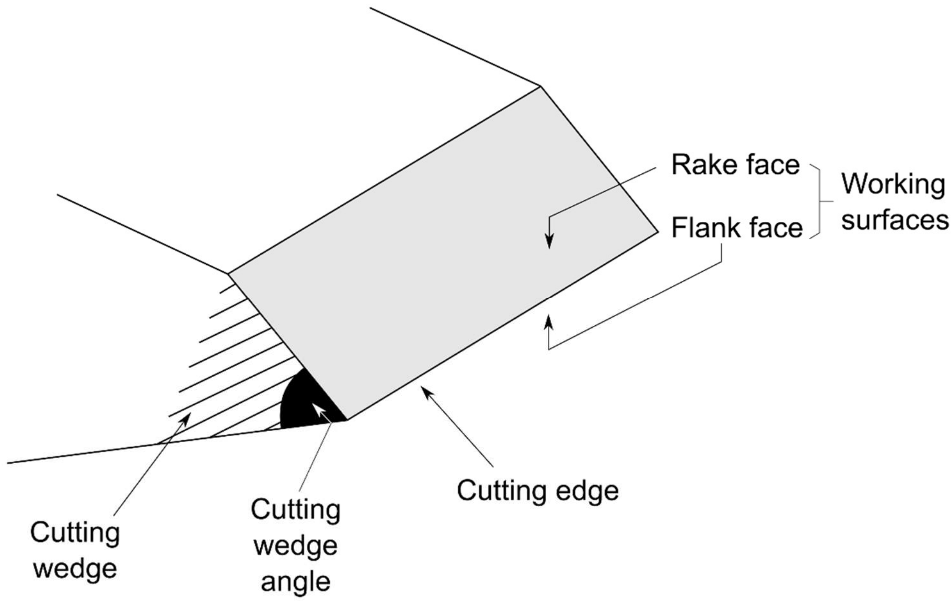


Figure 13. Terms used to describe the geometry of a tool transformative unit (modified from Soriano *et al.* 2015).

It should be noted that instrumentalization phases are also considered, such as grinding or sharpening, among others. Grinding refers to the setting of flat and bevelled surfaces, while sharpening refers to the setting of a sharp edge.

5.2. Prehistoric technical lineages: internal long-term functioning schemes

Since the beginning of this century, the existence of prehistoric technical lineages and technical trajectories has become evident. The work of the AnTET team and its associates has shown this (Bodin 2011; Boëda 1997; 2013; Chevrier 2012; De Weyer 2016; 2020; Forestier 2020a; Hoguin 2013; Manclossi 2016; Nicoud 2011; Rocca 2013). These investigations have allowed us to recognize the usefulness of a Simondonian approach in prehistory. It is therefore important to clarify certain aspects on this point.

Figure 14 summarizes the structure of prehistoric technical lineages within the framework of a fully Simondonian approach, *i.e.,* as a function of time and the degree of concretization of technical structures. The prehistoric object goes through a process of internal concretization, at the elemental level, and a process of external concretization, at the level of the ensembles. At the elemental level, the UTF is the depositary of the technicality. It is important to differentiate a production line from a functional line. The first is characterized by the concretization of the stages and elements of production of the supports, and gives rise to a reduction of the remaining volume compared to the useful volume. As for the functional lineage, this is a tool lineage that is characterized by the integration of its various UTF, creating a dependence between the gestures of use, the elements of the tool and the transformation of materials. At any stage of their development, a production lineage can meet a functional lineage to give rise to what is called technical genesis.

In other words, these functionally different areas or UTFs are the elements that make up the tool. These UTFs are assembled at the level of sets (or groups of individuals), in this case, other tools. Thus, the elements carry technical criteria from the period of manufacture of the tool, where they are grouped in functional synergy.

Consequently, the UTF carries within itself the functional technical reality. This is the epistemological core of technicofunctional analysis in prehistory, understood as the search for a functional logic underlying any technical operation (Soriano 2000: 131). One could thus say that Simondon's three scales of technicality (elements, individuals and ensembles) interact through instrumentation and instrumentalization defined by Rabardel (1995: 70-82). The technical criteria present in the UTF are acquired during instrumentalization (*i.e.,* all the stages of production necessary for the setting up of the technical characteristics of the tool) and are transmitted during instrumentation (the putting into action of the tool by the human operator to act on the material worked on in a place of activity), to the tool or to the technical individual.

The same process of concretization has been observed in prehistoric production structures. At the primary level, a production structure is composed of a useful volume and a non-useful volume. At this level, the reference of technicality is a useful volume. At the individual level, the production structure has as its technical repository the tools associated with the resulting media, and this is why it is possible to speak of predetermination criteria (both for tools and for production structures). On the overall level, the technical repository is the same as for the tools, *i.e.,* the extension and intercommutability of the technical subsystem of production. The prehistoric tools and the structures of production, in their technical evolution, undergo the effects of the law of relaxation defined by Simondon, which in fact is closer to a general principle of functioning than to a law. According to him, prehistoric objects undergo two cycles of evolution, one continuous (minor perfections) and the other discontinuous (major perfections), leading to oriented mutations (Simondon 2012). It is the perfections, discontinuous or major, also classified as structural reforms, that define the technical essence of a lineage. For example, the sliver lineage is marked by the predominance of Levallois structures during the Middle Paleolithic. The structure of Levallois nuclei meets precise technical criteria, which allow for the production of fine flakes with sharp edges. The morphology of the flakes can be controlled by managing the convexities of the debitage surface, as well as the orientation of the striking surface. With this system, it is possible to produce elongated flakes that merge with blades. The changes made to produce blades are minor improvements that do not affect the Levallois production line. When the blade becomes the preferred product of the production system, a new nucleus structure is developed and will completely replace the Levallois structure. This major refinement implies a new structuring of the nuclei, and we thus witness the birth of the laminar production lineage which will be the major production system of the Upper Paleolithic.

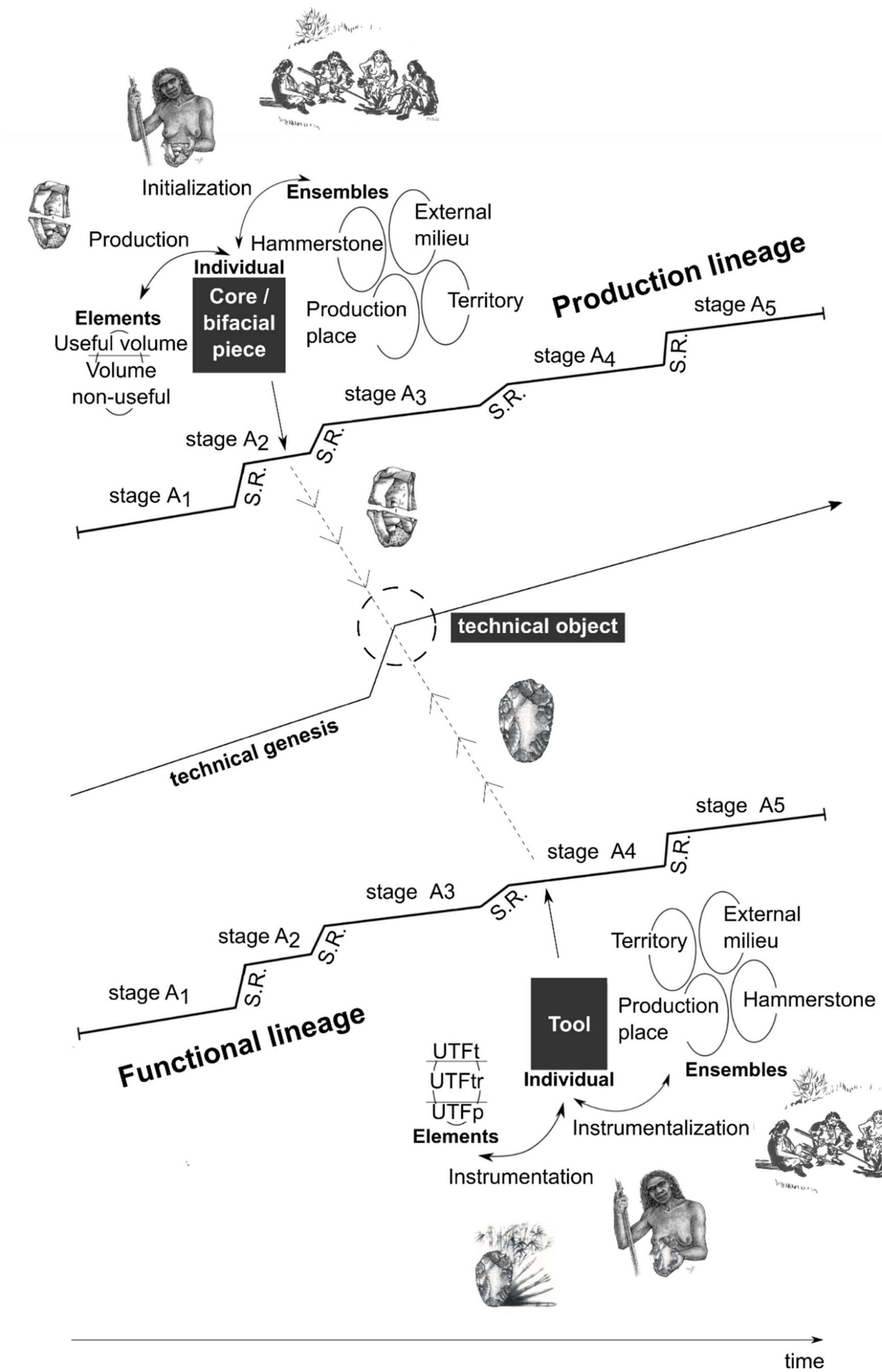


Figure 14. Structure of technical lineages in prehistory: The lineages of production and function are independent at one point in the analysis, but must then be addressed together in an attempt to understand technical genesis. Drawings by Maxence Raffi, Hubert Forestier and Aurore de Dinechin.

5.3. Prehistoric technical trajectories: external short-term functioning schemes

In prehistory, is it possible to study technical evolution on a short time scale (Chevrier 2012: 95-107; Pérez & Boëda 2019)? Is it possible to restore a techno-logic on a short time scale, or are we only subject to a long-time scale? Inevitably, the notion of space must also be introduced as a factor in the temporal subdivision of prehistoric technical trajectories (Bonnemaison 2004; Chevrier 2012; Koehler 2010).

It is only through the inclusion of the notion of space that it is possible, through the application of technical trajectories, to study short time at the techno-logical level. The latter implies, for the most remote times of prehistory (*i.e.,* in a situation of forgotten memory), to observe the recurrences that lie within the limits of a technical trajectory and that are hidden behind the psychosocial aspect of the tools and structures of production. Nevertheless, it is necessary to pay attention to the fact that the perception of a lineage depends on the time in which one lives. The men and women of prehistoric times hardly noticed the passage from one lineage to another. Nowadays, it is possible, thanks to an acceleration of technical innovations.

The concept of technical trajectory was introduced in Prehistory by Forestier in order to address possible responses to these scenarios. It is a concept borrowed from the sociology of technology by Gras (2003: 126; 2010). Forestier (2020a: 82) defines the technical trajectory as a narrow or broad segment of space-time, with a certain beginning and a certain end. A technical trajectory takes into account microevolutionary aspects of varying duration, usually more visible on a short time scale (Forestier 2019; 2020a; 2020b). The rhythm of each technical individualization, of each cycle of structural evolution, may (or may not) define the beginning of a technical trajectory, a rhythm that corresponds to technological or non-technological combinations of the evolutionary cycles of technical lineages.

For example, in a given space, a production structure in an evolutionary stage D (*sensu* Boëda 2013), which remains without significant changes throughout its lineage, succeeds an evolutionary stage B. The configured technical trajectory, among the last instants of stage D and the first instants of stage B can find a logical justification in the possibility that structure D has become a consumer object, degraded, obsolete at the psycho-social level (but not at the techno-genetic level, because in its temporal evolution, structure D is in transition to hypertelia, *i.e.*, structural obsolescence) and, therefore, it is discarded or not used.

This is obviously a working hypothesis that can be verified by analyzing other similar technical trajectories in the same region. The dating of these changes, in the short time, is obviously complicated, even useless, to understand the phenomenon. We do not need the exact date of an event to recognize the change. Of course, we must keep in mind that the more complex the object, the more it is attached to social aspects of use, the more selectively it is dated. A bicycle has a more precise date than a hammer" (Simondon 2014: 53). This complexity is related to the psychosocial charge carried by the tool, which interferes with its techno-logical and economic future, but which is partially independent, as Simondon later points out. This partial independence between historicities is what allows us to perceive change, at the level of technical trajectories.

With respect to the cyclical evolution of technical lineages, at the historical (*i.e.*, economic) level a technical trajectory is a function of time and the "degree of reliability" of a historical object (Simondon 2014: 52) (Figure 15).

One could say that there is a principle of uncertainty or constant tension which consists in the rupture of the linear evolution between objects of use, production and consumption, creating grouped discontinuities which will constitute later a certain technical trajectory. In other words, any techno-logical evolution has a certain range of chance and indeterminacy.

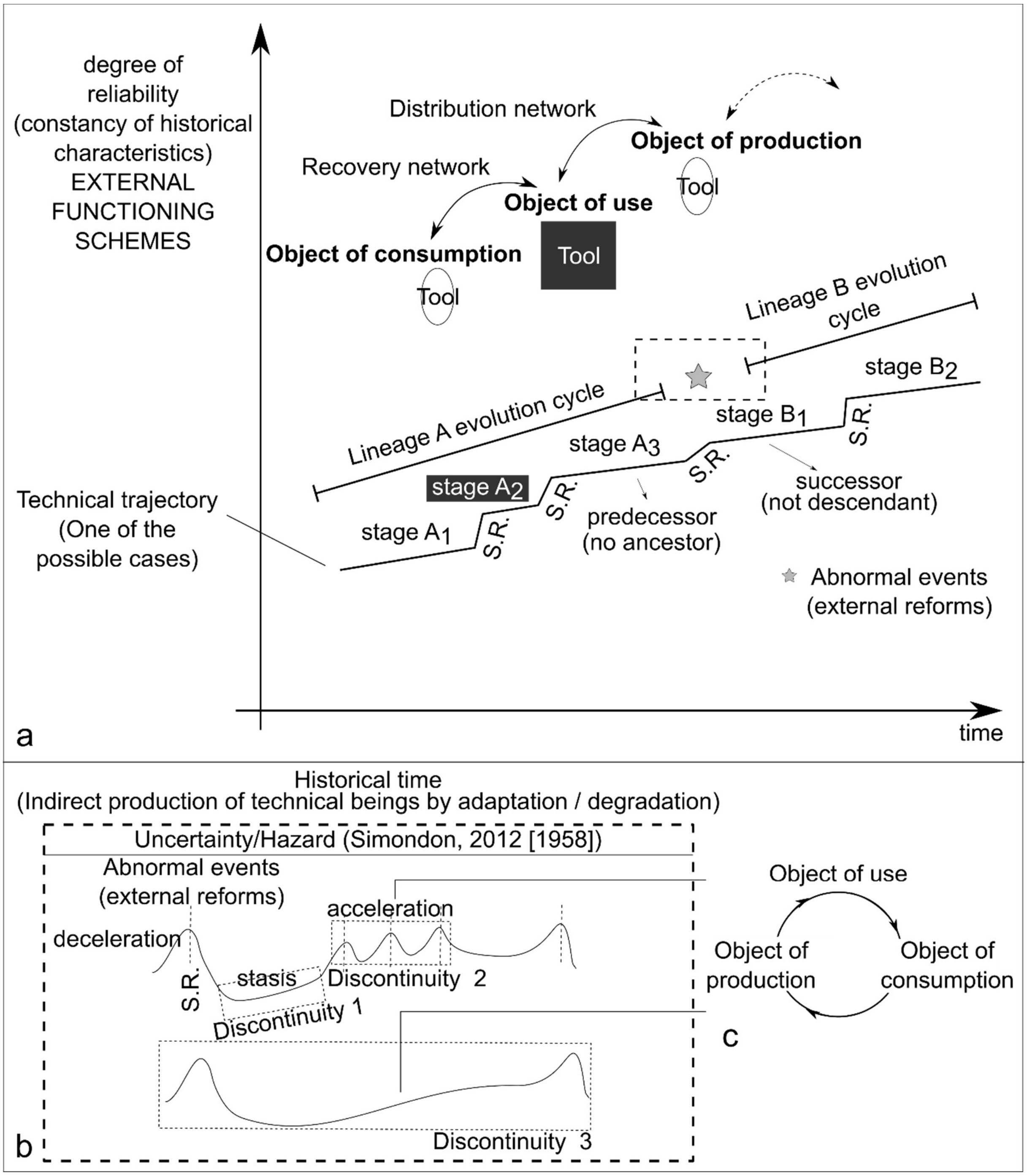


Figure 15. Structure of prehistoric technical trajectories: (a) General definition, (b) role of hazard in internal transformations, (c) psychosocial transformations of structures.

Two quick examples will help explain the notion of technical trajectory. The first is the Hoabinhian period in Southeast Asia. The Hoabinhian technical phenomenon is temporally circumscribed between 40,000 and 10,000 BP and spatially in the caves and rock shelters of Southeast Asia, including present-day Vietnam, Thailand, Laos, Cambodia and Sumatra, mainly. This is a geographical area of nearly two million km^2. Traditionally defined as a static technocomplex as a “pebble culture” among others, *i.e.*, without major technical transformations over time and in a tropical rainforest context, the Hoabinhian is essentially made up of tools shaped unifacially through direct percussion on thick oblong pebbles of limestone, basalt, andesite, and quartz (Forestier 2020a: 33).

The application of techno-functional analysis has made it possible to renew the typological definition of the Hoabinhian from the identification of a plurality of production and functional operating schemes. Nevertheless, over its duration, the Hoabinhian matrix-pebble of asymmetrical design still shows no apparent techno-logical evolution, but rather a technical trajectory composed by portions of different technical lineages (Figure 16). Within the group of production lineages is the F3 (split) debitage lineage, *i.e.,* at the concrete stage. The unifacial shaping lineage in the abstract stage was also determined. In the group of functional lineages, we have a lineage of tools in the concrete stage on split pebbles, a lineage of unifacials in the concrete stage on oblong pebbles, and a lineage of choppers (*i.e.*, single-bevel tools) in the concrete stage on ovoid pebbles. The fact that portions of lineages recur at concrete stages of evolution suggests that the Hoabinhian as a whole appears at a concrete technical stage and then shows almost immediate stagnation. Thus, the technical trajectory of the Hoabinhian, delimited in time between 40,000 and 10,000 BP, corresponds to a technical invention that is not techno-logical in the long term, because if this were the case, it would be necessary to archaeologically observe Hoabinhian structures at the abstract technical stage, which is not the case. Thus, the explanation for the almost immediate appearance of concrete structures, an anomalous event in the history of Southeast Asian techniques, must be sought in the psychosocial dimensions of the Hoabinhian technical phenomenon. Forestier (2020a) shows that part of this explanation lies in the ubiquitous plant world in Southeast Asia. The human groups that made Hoabinhian objects must have understood that only a highly specialized object could exist (*i.e.*, function properly) in this associated plant world. Thus, it is evident that the meaning of the Hoabinhian object lies not only in a well-defined functional zone, but also in a zone of utility and even in a zone of psychosocial symbolism, where the human being and the object are merged to constitute a highly functionally coupled technical individual: one does not exist without the other.

Another example of a technical trajectory is the case of the shift from lithic to metal tool production in the southern Levant during the Chalcolithic to Iron Age transition (Manclossi *et al.* 2019) (Figure 17). At the technogenetic level, the functional lineage of composite tools is found on some occasions in concordance with the production lineage of laminar debitage. In other words, for some time composite tools in the concrete stage correspond to laminar supports in the concrete stage. There is a techno-logic between the two lineages. However, at some point, faced with the impossibility of adapting the concrete laminar production structure to a new functional requirement (creation of long parts with perfect joints at the ends), human groups had two possibilities: (1) return to the production of abstract structures, (2) create a new technical lineage. The first case corresponds to a technical regression, while the second was favored by the invention of metallurgy, which determined the shift to the production of metal objects and the abandonment of the production of lithic objects at the beginning of the 4th millennium B.C., without this meaning the total disappearance of lithic technology. Manclossi *et al.* (2019) show that the adoption of metallurgy, the factor that precipitated the lineage change, was not achieved only because of functional (plasticity and other physicochemical properties) or technoeconomic advantages, but for symbolic-social reasons, probably related to ritual or religious practices. Indeed, copper axes, for example, were not used for functional tasks. In the case of the composite tool lineage, researchers also show that technological changes were conditioned by the emergence of new socio-economic contexts, and not necessarily for purely functional reasons.

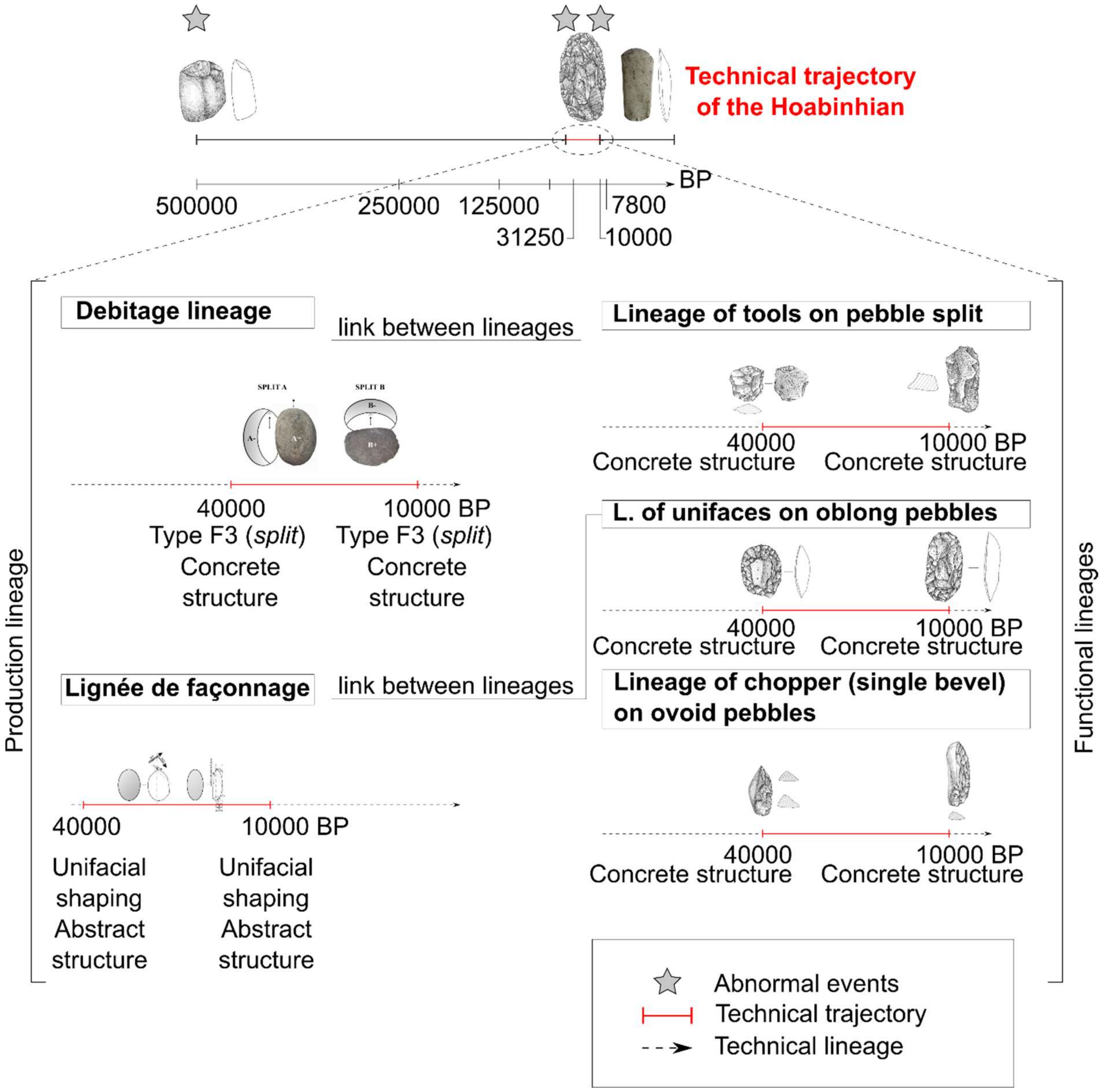


Figure 16. Example of technical trajectory, the case of Hoabinhian culture in Southeastern Asia (elaborated from Forestier, 2020a: 194-200).

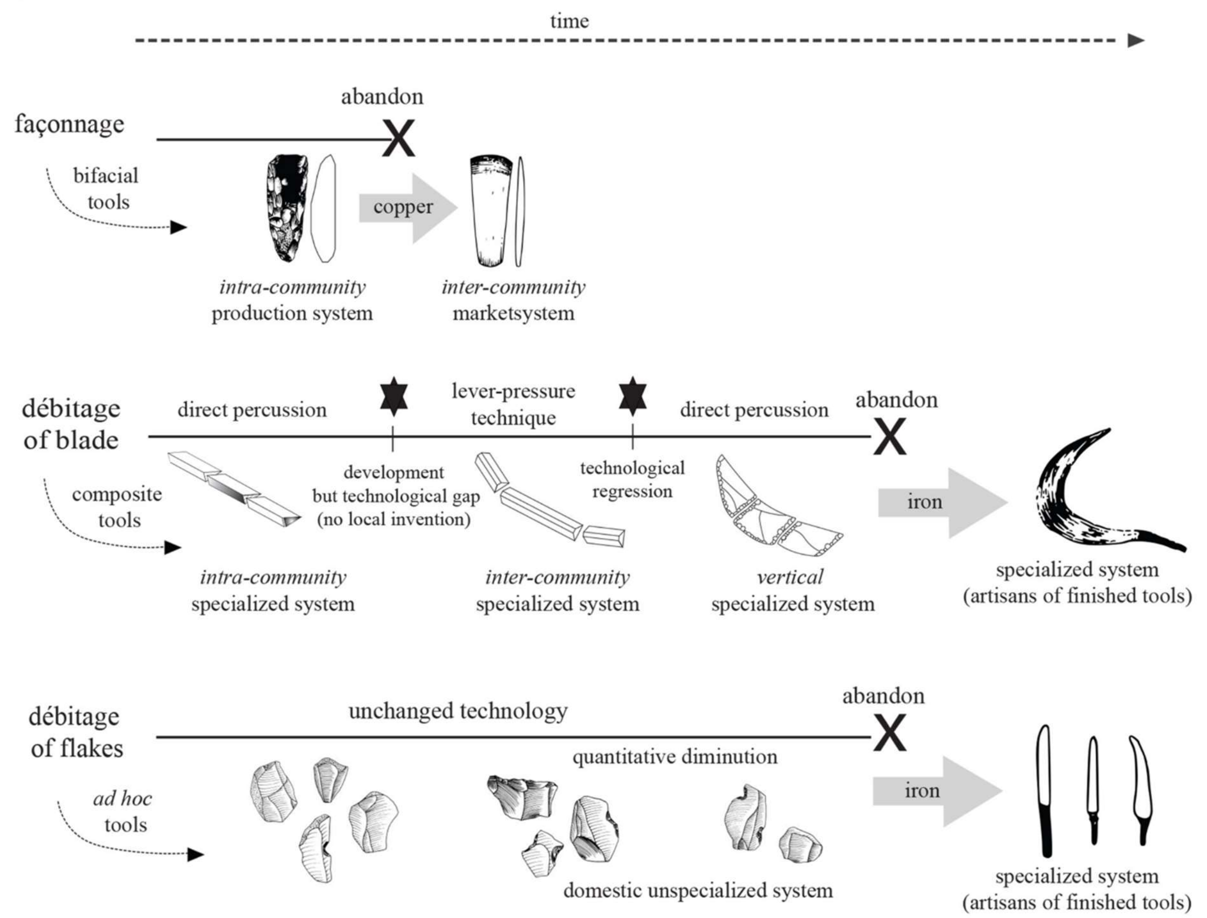


Figure 17. Three different production lineages (shaping, laminar *débitage*, flake *débitage*) that were replaced by metal object lineages, following different trajectories and rhythms (Manclossi *et al.* 2019: fig. 9)

6. Examples and supplementary applications

The temporal density of prehistoric technical objects constitutes the corpus of technical memory that the prehistorian and technologist need to restore in order to access, first, its techno-genetic dimension, and then, its psycho-social dimensions. To access these dimensions is to view the different technical alterities in what they have that is unique. In other words, the Other not as a reflection of me but as a radically different Other (Boëda 2013: 229). Prehistoric technology, in this sense, consists in going towards the others, those who have gone through time leaving artefactual traces of their technical memory.

For instance, if we look into the Lower Paleolithic, which shows the emergence of lithic technical systems through the Old World, several indicators are revealed by the techno-genetic approach. The earliest evidence of stone working is found in East Africa, starting from 3.34 Ma at Lomekwi 3, Kenya (Harmand *et al.* 2015) and extending from 2.6 Ma at Gona, Ethiopia (Semaw 2000) to 1.6 Ma with the emergence of the bifacial lineage (Figure 18a).

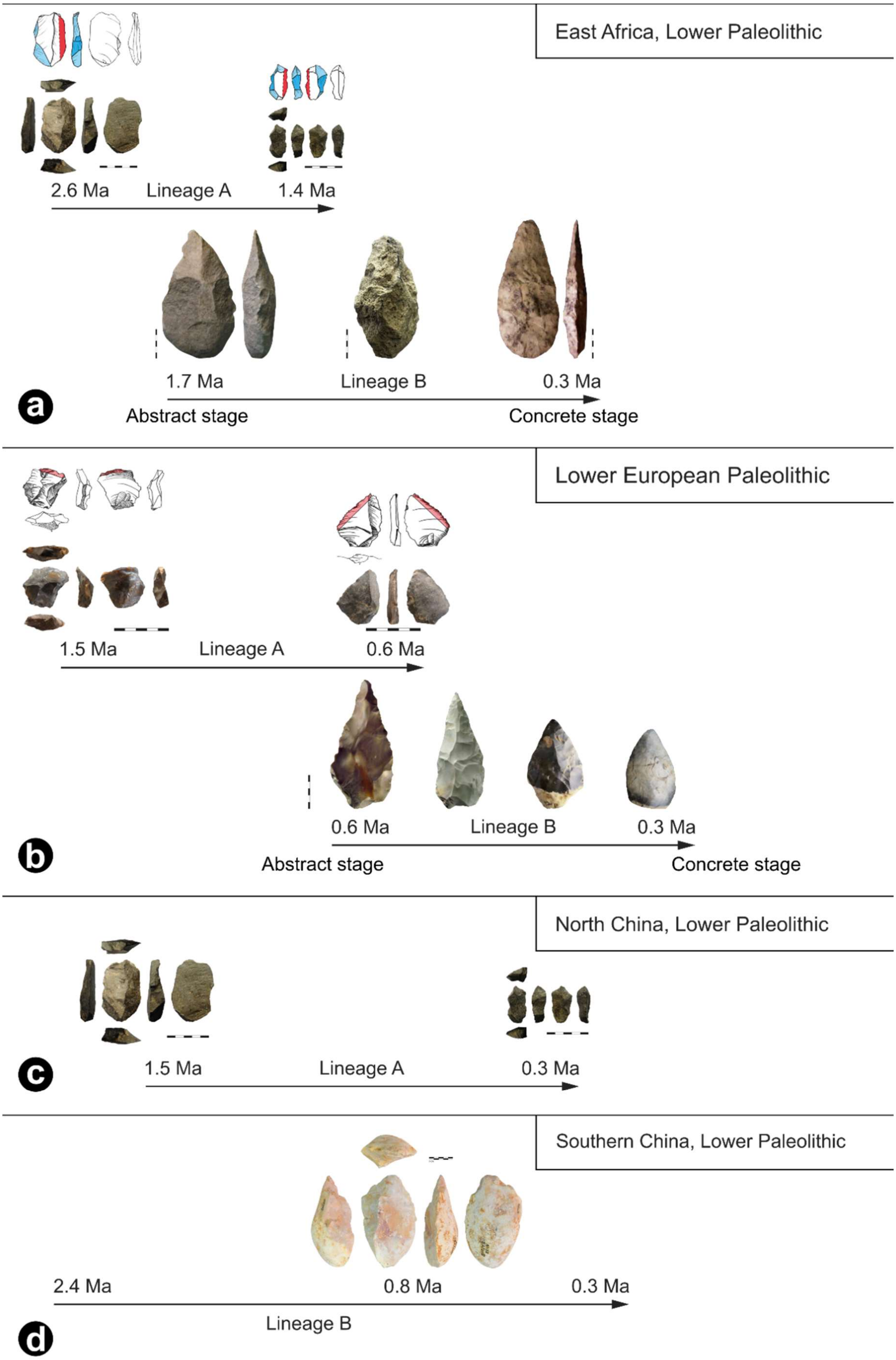


Figure 18. Examples of technical lineages in Africa (a), Europe (b) and Asia (c, d). (5 cm scale bars (1 cm segments).

Taking Europe as a comparison is interesting. The earliest site is Dmanisi in Georgia, dated to 1.81 Ma (de Lumley *et al.* 2002). All the components of the lithic assemblage show a stability and the same technical trends as Oldowan in Africa (Mgeladze *et al.* 2011). There is no known site between Dmanisi and Western Europe. Pirro Nord in Italy, 1.4 Ma (Arzarello *et al.* 2016), and Barranco Leon and Fuente Nueva 3 in Spain, 1.3 Ma (Toro-Moyano *et al.* 2010: 278-279), are also considered as Oldowan-like. The problem is that when this early debitage focused technology appears in Europe, it has already evolved a lot in Africa. The Lower Paleolithic in Europe looks like it starts again the same technical history as Oldowan in Africa, 1 Ma later. Moreover, the Acheulean in Europe does not start before 0.8 Ma, which means the technical dynamics have taken around the same time as in Africa to evolve (Figure 18b).

Then when comparing the technical history of the two continents, it is hard to propose the spread of technical phenomenon outside Africa (since 1 Ma is quite a long time for an idea to spread out somewhere). It is more likely to be a new start of this technical phenomenon. The production methods and techniques start from the beginning that is to say at the same technicity level as at Gona or Lokalelei 1 Ma earlier. This shows clearly that European artisans did not have any epiphylogenetic memory of debitage production, and that a long time was needed to create it and make the technology evolve to bifacial shaping, as it did in Africa long before. Therefore, Alterity is revealed by the enormous period of time separating one place from another in using stone tools. Common interpretations do not take account of this epiphylogenetic memory, and usually conclude with the spread of technology by the “Out of Africa” model, which means that techniques are related to a hominin species. This old paradigm is completely inaccurate today, because several hominin species could have been the Oldowan tool-makers on the one hand, and because very few hominins remain were discovered in Eurasia compared to the archaeological evidence on the other hand. This dispersal model is not relevant anymore and it is time for the community to change the old paradigms (De Weyer 2016: 25-36; 2020: 279-289). Moreover, Europe is not the only evidence of independent emergence of this technical phenomenon.

This emergence phenomenon occurs differently in Eastern Asia. In Asia, two distinct technical lineages split the continent into a northern and a southern part, along the line of the Yellow River in Central China. The northern part is characterized by the emergence of debitage production systems. The technical system is based on the production of sharp flakes from 1.6 Ma in Majuangou (Zhu *et al.* 2004), to 1.1 Ma in Xiaochangliang (Zhu *et al.* 2001). These sites are located in the Nihawan Basin, where many assemblages have been discovered. All of them follow the debitage principle. However, the lithic assemblages are not homogeneous. In Majuangou, a systematic debitage of pebble cores led to a product range dominated by quadrangular semi-cortical flakes, with a sharp edge used without a retouch process. In Xiaochangliang, the blanks are significantly smaller and flakes or small fragments are equally used as blanks and the retouch for tool production (Yang *et al.* 2016). One could consider a technical evolution inside the Nihewan Basin, others could claim a climatic change and a replacement of population. In both cases, this technical difference means a change in the associated milieu, due to climate or cultural change. Starting with the same technical tradition, exploring the same debitage lineage, systemic differences appear very early in the production of a range of tools (De Weyer 2019) (Figure 18c).

The southern part seems completely independent in terms of technical evolution (Figure 18d). The site of Longgupo, in Chongqing Municipality, Central China, is dated to 2.6-2.4 Ma (Boëda & Hou 2011; Han *et al.* 2017). It is the earliest assemblage known outside Africa and it is subcontemporaneous from Gona or Lokalelei 2C, the earliest Oldowan sites in East Africa (Delagnes & Roche 2005; Semaw 2000). Although the dates give a relative synchrony between these extremely distant areas, the technical systems are radically different. In

Longgupo, the tool production is based on a shaping system involving affordance and confection of the UTFt by retouch. Volume selection is strictly systematic with the aim of selecting technical criteria which naturally exist in the blank (the affordance) and lead to a minimal confection phase. As the volume naturally presents the necessary shape and back, only the Transformative UTF has to be shaped (Boëda & Hou 2011).

This shaping process is well known in South East Asia, in Southern China, Viet Nam, and Cambodia for instance. Bose Basin is an example of technical continuity and evolution from the similar technical trends observed in Longgupo, *i.e.,* a technical lineage. Bose Basin assemblages are dated to 0.8 Ma and are usually connected with the Acheulean phenomenon (Xie & Bodin 2007). However, the specificity of Bose Basin and South East Asian industries in this period is to maintain the essential role of affordance in the production process. The volume selection is highly controlled in order to satisfy the majority of technical criteria. The volume shaping phase is then considerably reduced and the confection of transformative UTF is the main operation. Moreover, the volume is systematically organized around a naturally flat surface that leads to the creation of only unifacial tools. This fundamentality of affordance is in opposition with the classical African and European Acheulean, where the shaping phase covers the whole volume and leads to bifacial pieces. Thus, both affordance and shaping seem to be the pillars of the southern Asia technical lineage, as the technical memory implies the capacity of maintaining these criteria.

Comparing southern and northern Asia illustrates the coexistence of at least two technical traditions, with each of them having technical criteria that will remain stable through time and other technical criteria that change around this essential stability. Through two memories identified from a large time-scale, the Alterity is revealed.

On a shorter time-scale, technical changes between the early Holocene and the mid-Holocene in South America are very good examples (Figure 19). The site of Hornillos 2, in the Jujuy region of the Puna, Argentina, has yielded a stratigraphical sequence revealing rapid technical changes (Hoguin 2019; Yacobaccio *et al.* 2013).

At the beginning of the Holocene phase, the technological analysis shows the coexistence of various abstract structures which lead to the production of non-standard blanks. Arrowheads are made through a confection process where recycling is important, while shaped products are rare. The mid-Holocene phase is characterized by an increase in the technical investment to produce arrowheads by the development of the pressure technique for the shaping process. Shaped tools increase very quickly and tool diversity is higher than before. During the latter part of the mid-Holocene, though tool diversity is still high, production processes have changed. Indeed, blade production and centripetal products become the main production sequences, while shaping is progressively decreasing. Arrowheads are now made from blade products.

During this short period, technical systems evolved very quickly. The first phase shows a non-standard debitage production and a confection process to make tools (early Holocene). The tools evolved quickly, leading to an increase of shaping sequences (beginning of mid-Holocene). From this new diversity of tools, debitage follows with a highly diverse range of abstract structures, and then evolves to one blade and discoidal concrete structure, while at the same time shaping production decreases (end of mid-Holocene). This example shows how the evolution and diversification of tool types created the need for a new technical lineage (Hoguin 2019). After a short period of instability, the technical criteria are recombined to create a new debitage lineage that will produce standardized blanks to produce the new tool diversity. In summary, the recombination of technical criteria involves a dormant memory that was mobilized for the initialization of a new technical lineage (Hoguin 2016; 2019). All these observed changes define a coherent (logical) technical trajectory during a relatively short time (*ca.* 6,000 years).

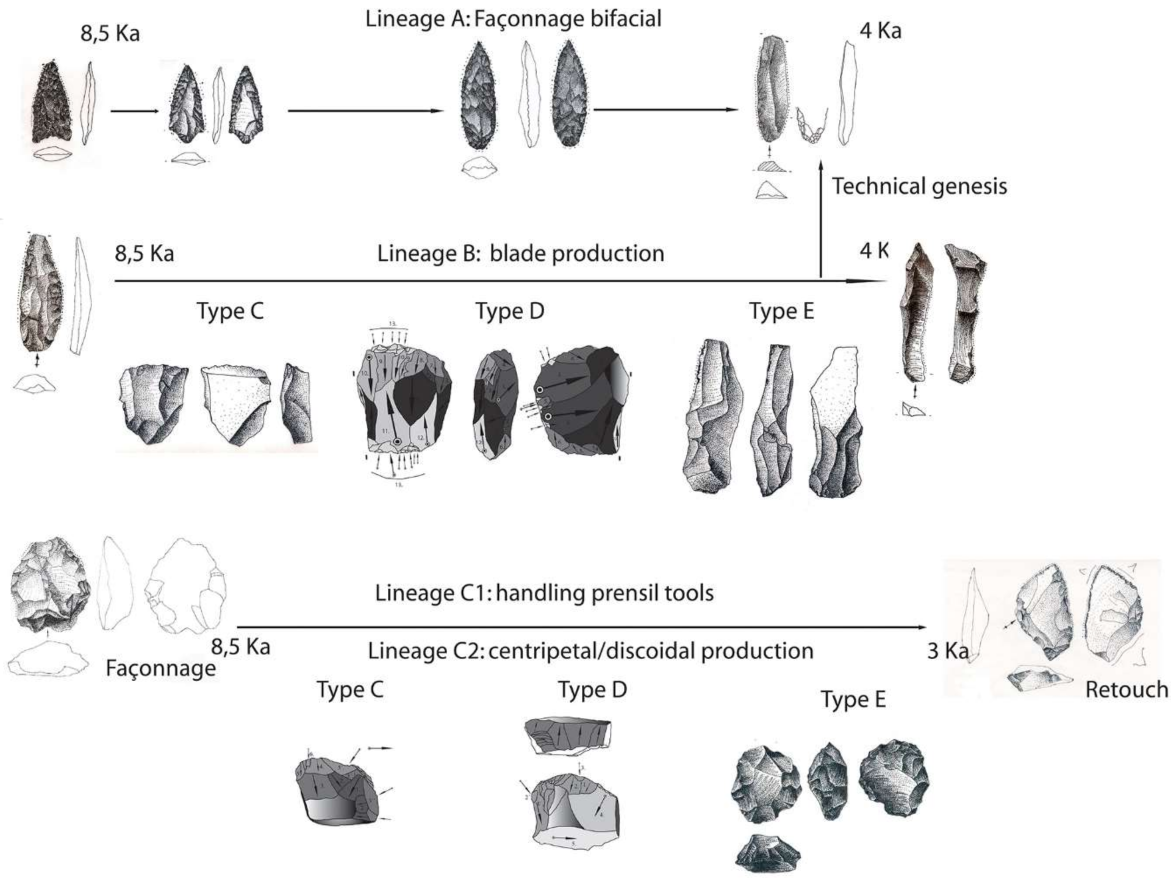


Figure 19. Examples of technical lineages in South America.

7. Conclusion and inconclusive perspectives

All these examples illustrate the fact that there are two tempos of technical evolution and change. Analogies between biological, technical and cultural worlds were often made in archaeological and anthropological research, and seem to be hazardous because of the very different nature of the mechanisms responsible. However, it seems relevant to underline an important similarity with the tempos of the punctuated equilibrium of Eldredge & Gould (1972) in biological evolution. To be clear, the pertinence of this comparison rests on the observed results, not on the causes and mechanisms between biological and cultural (technical in our case) evolution. Moreover, the time scales are very different, from geological speciation to biological speciation, and from the human existence for the technical lineages. But certain facts are interesting, such as how diversity and homogeneity proceed over time, as well as how the two tempos, a fast one and a slow one, can explain biological speciation (Eldredge & Gould 1988; Gould 1989). On another scale, we can see how these observations reflect well what can be observed about the evolution of techniques.

Gould (1989) pointed out interesting explanations for these biological changes, arguing that selective pressures are not uniform over time, such as mass extinction being responsible for major biological changes since life began. He also highlighted the biological potential for Burgess shale fauna to evolve with disparity and diversity, beyond any selective pressure. The explanation to this evolutive phenomenon is that evolutive potential is such that it evolves rapidly and partially protects natural selection (Gould 1989). Equally, mass extinction would be a possible cause for the processes of macroevolution, with different selections over time, alternating between periods of rapid speciation and diversification with period of anatomical stabilization (Gould 1989). We cannot export these explanations from the biological to the cultural or technical sphere, but they can guide our interpretations.

In technical macroevolution, as for biological evolution, we can identify three major events: diversity, homogeneity and rupture or discontinuity. Diversity seems to occur with abstract structures, with sufficient evolutive potential to evolve quickly and in various directions. External and internal environmental factors can be highly dynamic and interrelated. Homogeneity occurs when one specific lineage is prioritized and evolves into a concrete structure. This process can be very long, and is partially impermeable to changes in the external environment. Some abstract structures can persist in more or less important proportions. Finally, rupture in a lineage can occur when there is a saturation of the evolutive potential, a technical locking with incongruences between structures and associated environments, or even caused by a major social change. This is where the phenomena of microevolution come in.

This dual techno-genetic and psychosocial approach requires a functional approach to lithic technology. Over the last twenty years, we have proposed a possible approach. In other parts of the world, research teams have presented perspectives that share this functional approach. For example, Aschero (1973; 1985) and Aschero & Hocsman (2004) have developed the morpho-functional typology – also called macroscopic descriptive-morphological proposal –, whose analysis procedure is adequate to describe and interpret objects starting from the geometry of the bevel and cutting edge, and thus carry out a descriptive segmentation of the different parts that constitute a tool, in the manner of UTF.

Whatever the methodological path taken, it is necessary to reinforce an idea: in a situation of lost technical memory and over a long-time scale. Thus, technological analysis is the instrument that makes it possible to restore part of this memory. Our work as prehistorians is defined by the temporal distance between two "beings": prehistoric man and the prehistorian. We know that we will never achieve the technical reality of prehistory because we find ourselves outside of its technocosm. It is obviously a frustration, which will remain if we do not learn how to adapt our questions to the informative value of each artefact and its techno-genetic echo.

Although we can achieve the technical phenomenon from its materiality, the experience that prehistoric man had of this materiality is inaccessible because it has been lost over time. This experience is unintelligible, while the technical phenomenon can be experienced. It is only after the determination of the technical lineage that we can give sense to the sensible. Since the 1990s, this approach to technical phenomena called "techno-genetic" has been applied by the AnTET team (UMR 7041, Paris Nanterre University), offering positive results and allowing the detection of lineages and technical trajectories in different geographical spaces. It is essentially a different way of asking questions, a new way of questioning lithic material. Therefore, we try to overcome the cumulative knowledge of production technology, through a thought process that would take into account the mode of existence of technical objects, that is to say their evolution.

Our epistemological basis is part of a relational realism which looks at technical structures and operations in combination, and not in opposition. We do not address the artefact by its production chain, but by its functional singularity. The object is not defined by its looks (form and structure), but by the place that its structure occupies in a techno-functional genesis. It is the techno-functional genesis that offers a technical sense to the artefact from which we will initiate a psycho-social research (historical dynamics), often producing trajectories without any predictable direction (blind hazard), in totally heteroclite paths.

This article constitutes a heuristic research agenda, where all human dimensions are considered, rather than a synthesis of the techno-genetic approach. But we consider that without comprehending the primary reality of the object, we cannot aspire to understand the human behavior. The what and how remain in the artefact, the why (and the what for belongs to the artefact-man combination. From this foundation, we introduce the geographical dimension, because there is no culture without space. By combining time and space, on the appropriate scales, prehistory has the keys to human alterity.

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Data accessibility statement

All data used for this paper are inside the paper or quoted and integrated in the reference section

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