From observed successions to quantified time: formalizing the basic steps of chronological reasoning

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EXTENDED ABSTRACT

There is not a unique conception of archaeological time, which could be a common base for the discipline. Archaeological time is a heterogeneous construction which mobilizes several chronological scales and conceptions, widely borrowed from natural and other social sciences: from stratigraphical time related to the formation of sites, to great chrono-cultural sequences, including also functional time (stages of production and use of objects and structures), relative serial time of typochronological models and their statistical developments, and “absolute” quantified time, recorded in historical sources or supplied by laboratory dating methods.

These various representations of time are of a different nature (discursive or formalized, discrete or continuous, relative or "absolute"...), so that their integration within the same whole chronological reasoning is not a simple or obvious matter. However, if there is a lot of references about each of those approaches of time, an issue is quite less studied: how to link these different times, in a way enough explicit to be formalized.

It is specially true about a basic step of archaeological chronologies making: dating (i.e. positioning in the quantified time) the discrete units of relative chronology which archaeologists identify in order to analyze the formation of an archaeological site, or to analyze the chronological and functional path of an object or a structure.

Actually, on one hand, it is not useless to remind that important conceptual and practical progress have been made for the past decades about the analysis of relative discrete chronologies, including for instance formalization of the stratigraphic analysis (following the works of E.C. Harris [1]), analysis in terms of chaînes opératoires derived from the anthropology of technical systems and applied to the processes of artifacts production and use [3][4], or, on a wider scale, settlement evolution analysis in terms of spatial and functional entities, linked to GIS conception [4]. These approaches have in common a precise definition of discrete units of time (that are also characterized by a spatial location and a functional, cultural or social interpretation) and a precise definition of chronological order relationships (which are observed material interfaces in the case of stratigraphic analysis, or succession constraints in other cases) between these units.

On the other hand, it is well known that the possibilities to get “absolute” (more exactly: quantified) indications of time about archaeological remains have been in constant progress for the past sixty years, thanks to the laboratory dating techniques. But these quantified time indications, as well as those provides by more classical chronometric (historical, numismatic, etc.) sources, are not direct solutions to the problem of relative chronological units dating. They are only parameters of this problem.

Actually, this double progress of relative chronologies analyses and dating techniques still leave a dark zone in the chronological reasoning: as some authors said (e.g. [5]), archaeological discourses are widely implicit and sometimes ambiguous about this transfer from a relative to a quantified chronological frame, whereas the quality of the next steps of these discourses (for instance building chrono-typologies) depends on it. The only roughly explicit notions usually (but not always) mobilized at this stage – terminus post quem and terminus ante quem – are useful but not sufficient, as it will be exposed.

So, how to define more explicitly the range of quantified time corresponding to a relative succession, with taking into account incompleteness, inaccuracy and uncertainty which affect the available data? The proposed paper will discuss this matter of transfer from discrete relative chronology to a quantified frame of time. It will expose the present state of a work in progress [6][7][8] to make more explicit and rigorous the dating of stratigraphic and other chronological discrete units by simple formalized ways, and to get computerized tools using these ways.

A first point of this work is to use an algorithm derived from graph theory and its applications in operational research (more precisely from the Critical path and graphe MPM methods, which were developed in the 1950s in order to design production processes). It calculates relative time distances between the units of the studied relative chronology, from the set of the observed units and succession constraints (constituting a partially ordered set). This algorithm also provides a graph
displaying the relative chronology, corresponding to a Harris Matrix in the case of a stratigraphic chronology; but the same process may be applied to other sorts of discrete relative chronologies (chaines opératoires for instance).

The second point is to adapt the quantified frame of time used in the industrial applications of graph theory mentioned above. This frame includes only four main variables: the beginning $B_i$ of a chronological unit $i$, the end $E_i$ of this unit, the duration $D_i$ of this unit, and the duration $D_{ij}$ allocated to the order relationship (if it exists) between a unit $i$ and a unit $j$ (which may be zero if the succession is immediate). These variables are linked by basic equalities; e.g.:

$$E_i = B_i + D_i$$
$$B_j = E_i + D_{ij}$$

This simple frame is necessary but not sufficient to deal with archaeological data, because our quantified time indications, with few exceptions, do not directly provide values to the variables. However, these quantified time indications can always be used as limits of inaccuracy intervals including each basic variable: [at the earliest, at the latest] intervals for the moments (beginnings and ends), [at the shortest, at the longest] intervals for the durations. Then, a four intervals and height limits system is obtained, that is no more than a generalization of this principle of inaccuracy intervals, already but incompletely used by archeologists in the form of the [terminus post quem, terminus ante quem] interval above mentioned which corresponds only to the [earliest date for the end, latest date for the end] interval for a unit, and not to the beginning or duration intervals of this unit.

Then, relative chronology relationships and distances as well as quantified inaccuracy intervals may be integrated in a whole system of inequations, with its unknown values (the basic variables of quantified time for each unit and relationship) and its valued parameters (the limits of inaccuracy intervals, provided by dating indication or by default values previously defined to include the whole period concerned). The algebraic processing of this inequations system results in the best possible reduction of the inaccuracy intervals. It gives, for each unit, a slot of “possible time”, and in favorable cases (if the latest date for the beginning of the unit is before the earliest date for the end) a slot of “certain time”. An intermediary “estimate time” may be processed and obtained if a status distinction between “certain” and “estimate” data is introduced into the system; the advantage is a more flexible process, able to take in account uncertain observations or qualitatively heterogeneous documentation; the inconvenient is a more complex double system of intervals. The latest progress state of this work, concerning the integration of inclusion relationships into this formalized system, in order to process chronological scaling (grouping of chronological units) will be discussed.

The final part of the proposed paper will show short examples, allowing to expose the present state of the computerized tools resulting from this work (application Le Stratifiant to process relative chronology data, application Chronophage to process inaccuracy intervals of quantified time). Two practical and methodological points will be also discussed through these examples: the distinction between the units marked by a duration of formation (like a stratigraphic unit stricto sensu) from those marked by a duration of cultural use or “life” (like a functional structure or entity), and the consideration of dating indications from different sources (for instance archaeological indications and historical mentions) in terms of different limits informed in the same set of intervals.

REFERENCES