Introduction.
Chronometric Data for History and Archaeology of Iberian Peninsula

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Seventy years have passed since the first publication of the theoretical bases of radiocarbon dating by Willard Libby and his collaborators [And47, Gro47], and little less since the first experimental application of the method on known age samples [Arn49]. The prospect of being able to date ancient materials to "absolute" dates has quickly been embraced by researchers driven by the energy of the incipient scientific revolution in archaeology, although not without critical voices who for too long have insisted on rejecting the reliability of the method [Mil57, Mil59]. The institutionalization of isotopic clocks in contemporary archaeological research is evident. Among them perhaps the most popular is the radiocarbon method. Today 150 laboratories worldwide [Lab17] offer radiocarbon dating service. There have been several updates to the method throughout these years, mainly improving in two aspects: the technical and the mathematical. In the technical sense, measurement accuracy has been increased and the quantity of sample required for analysis has been reduced. On the other hand, complex mathematical methods have been developed for converting the presence of a particular isotope into the probabilistic estimation of a historical date. These technical advances have had the transcendental influence in the development of a theory of time in archaeology, and in increasing the possibilities of its interpretation based on chronometric information. As a result, there has been a proliferation of archaeological sites dating from different chronologies, but there has also been a boost of different ways of publishing and interpreting radiocarbon dates. The problems of using chronometric data in historical interpretation are the same as those affecting other sources necessary for contemporary archaeological research, increasingly based on distributed computing technologies. Data dispersion, lack of formalization and systematization, as well as limited public access to information are some of the most acute problems.

At the end of 2015, we invite researchers from Spain, Portugal, Gibraltar and Andorra, specialized in any historical period, to meet in Barcelona a year later, and present the latest novelties in the application of isotopic clocks in archaeology and to discuss the possibility of the collective creation of a radiocarbon date database for the whole Iberian Peninsula (Iber-Chrono). Such a database should be built for multiple purposes:

- propose standardized protocols for the application of the method, from sampling to data submission;
- provide a durable and secure repository of formalized and structured data, using Blockchain distributed registry technologies, thus ensuring preservation of documentary heritage;
- give way to the creation of applications for public access to chronometric knowledge through different data formats and tools for:
    - Heritage management
    - teaching
    - the dissemination of historical knowledge
    - the progress of archaeological and chronometric research on the peninsula.

In this sense, the general and integrated database constitutes a response to the urgent need to update and share the chronometric foundations of the history of a geographical entity such as the Iberian Peninsula and Islands, from prehistoric times to the present, ignoring the barriers that have forced us to work in closed territories.

The Proceedings

The Barcelona meeting -the IberCrono congress, held at the Autonomous University of Barcelona from 17 to 19 October 2016- was a great success. Inaugurated by the Vice-rector of the University, the Dean of the Faculty of Arts and Humanities and the Director of the Department of Prehistory, it was attended by more than 200 researchers. For three days, 16 posters could be seen and discussed, 40 papers were presented in plenary format, and three guest lectures were given by guest speakers who offered brilliant master classes: Joao Zilhao introduced us to the problems of precision, association and meaning in C14 dating responding to archaeological problems, Caitlin Buck who has offered the basic concepts of Bayesian modeling as a manual, and Alex Bayliss who has presented a practical guide to C14 dating and Bayesian chronological modeling. In addition, a round table was organized with the participation of the representative of the Beta Analytic laboratory, where practical and institutional problems regarding radiometric data were discussed, laying the foundations for the future chronometric database project in the Iberian Peninsula. In the days following the congress, a monographic course on chronometric methods was organized by 14 experts, attended by more than 40 students from all the mainland regions. None of this would have been possible without the enthusiastic support and collaboration of researchers from the Laboratory of Quantitative Archaeology at the Autonomous University of Barcelona, and dozens of students from the Autonomous University of Barcelona, the University of Barcelona and other universities and research centers in Andalusia, Castilla-León, Catalonia, Valencia, Galicia and Madrid.

This publication brings together a selection of contributions to the congress. It features 23 articles covering a wide chronological scale, from the final Mesolithic to the medieval period. The applications of chronometric methods in historically recent contexts are particularly important because they show that not only written documents can make history, but that the methods and characteristics of archaeology and text-based history must be integrated. The contributions to the congress that referred to methodological issues have been selected for another publication that emerges from the course of chronometric methods, in textbook format, given their interest and repercussion.

Among the papers analyzing single-site C14 date series and those analyzing a regional chronology (Fig. 1), these proceedings mention more than 2300 data, some of which were previously known, but many published here for the first time. We believe this close link between published and unpublished data is particularly important, because the large amount of chronometric information that has been generated over 70 years of research must be reused and critically analysed in the light of new results.

Figure 1 - Archaeological sites and study areas presented in the Proceedings.

The historical problems dealt with by the authors in their studies are diverse. In the absence of contributions on the beginnings of human occupation in the Iberian Peninsula and on the development of hunter-gatherer societies, this publication begins with a series of works on the chronology of the transition from hunter-gatherer to agricultural and livestock, as well as on the Consolidation of agricultural and livestock societies. The work of Salvador Pardo-Gordó and collaborators analyzes the stratigraphy of Cueva de la Cocina, discussing the Mesolithic occupation of the cave throughout the recent Mesolithic period, emphasizing the different cultural phases (Geometric A and B) and their chronological ranges. Alberto Mingo and collaborators approach the topic of Neolitization in the centre-south of the Iberian Peninsula (Albacete), providing unpublished data obtained by radiocarbon, thermoluminescence and racemization of amino acids on organic and inorganic samples of different nature. Bogdanovic et al present the first results of the excavations in the Coves del Fem (Tarragona), with evidence of well-dated human occupations radiometrically in the transition from the seventh to the sixth millennium before our era. Javier González and others deal with the consolidation of the first agro-livestock companies, placing the epicardial phase in time. Ferran Antolín and his research group focus on the so-called Middle Neolithic, proposing an in-depth study of the temporal sequence at the Can Sadurní field (Barcelona), using statistical analysis methods.

The consolidation of agricultural and livestock farming societies is also analyzed by Juan Cano Pan and his collaborators, who deal with the chronometry of Galician megalithic monuments, by Alberto Mingo et al, who propose new dates for these periods on the southern plateau (Albacete) and by Xavier Clop and Tona Majó, who deal with the megalithism of the northeastern peninsula.

Entering already in the first societies that used metallic objects, José L. Caro investigates the chronometry of the ditch enclosures of the southwest of the peninsula, while Gabriel García Atiénzar provides new chronological information on the peninsular east. In his analysis of the first complex societies of the southeastern peninsular Vicente Lull and his collaborators offer us two communications, in the first one they chronologically locate an instrument as characteristic and historically relevant, as the halberds. In their second work they detail an important methodological problem: the importance of the multiple dates of the same archaeological entity (in this case, a skeleton), and the errors that can be made when dating the argaric tombs. In the same vein, Giacomo Capuzzo and his collaborators contribute with their respective discussions on the chronology of cultural markers characteristic of the so-called Bronze Age in the Northeast of the Iberian Peninsula: ceramic vessels with button-grip handles and burial graves characteristic of the phenomenon of the "urns fields".

Antonio Uriarte and his team present IDEArq-C14, a spatial database for radiocarbon chronology in the Iberian Peninsula. The importance of this communication is obvious, given the widespread interest in having a database that integrates all the data obtained with isotopic watches and other chronometric methods for the prehistory and history of the Iberian Peninsula. Partially related to this, is the work of Pablo Atoche and Ängles Ramírez, who offer us an integrating perspective of all the data available for the recent prehistory of the island of Lanzarote (Canary Islands).

The chronology of the most recent periods of prehistory is dealt by Guy de Mulder et al, in his work on the limestone burials of the Balearic Islands. Antonio M. Monge Soares and Ana Margarida Arruda also address recent periods of difficult radiometric dating, such as the orientalizing period in Portugal. Alejandro Parga and his collaborators refer to the fortified enclosures of the Iron Age in Galicia, while Eduardo Carmona and Cristina Vega provide new dates of these recent periods in Cantabria.

The dating of archaeological contexts of historical epoch, that is to say, those also known by contemporary written sources, is approached by Cristian Folch and Jordi Gibert, in their study of Catalan archaeological sites from the 5th to 11th centuries of our era. Finally, Jorge Sanjurgo-Sánchez and his collaborators show us how to use innovative chronometric techniques to estimate historic buildings.

Iber-Crono. The project of an Integrated Chronometric Database for History and Archaeology of the Iberian Peninsula

The response of peninsular archaeologists to the proposal to address the creation of conditions for a platform that could integrate chronometric databases is favourable. Several papers were presented at the congress referring to the Register, Formalization and Presentation of chronometric data and temporal inferences, among which it is worth highlighting: the contribution of the members of the Quantitative Archaeology Lab of the Autonomous University of Barcelona on the formalisation of spatial-temporal relations in the chronometric databases; the IDEArq-C14 database of the working group of the History Institute of the CSIC led by Juan Vicent and with the collaboration of Antonio Gilman; the database of radiocarbon data from the Recent Prehistory of the Southern Iberian Peninsula (CRONLOOGEA), presented by the team of the University of Granada under the direction of Gonzalo Aranda and Águeda Lozano; the radiocarbon data base on Mesolitic and Neolithic in the Iberian Peninsula, developed by the University of Valencia team coordinated by Joan Bernabeu and Salvador Pardo-Gordó; the Galician IDEPatri System, designed by Emilio Abad and collaborators. It is also worth mentioning the complete list of dates for the Canary Islands presented by Pablo Atoche and for the Balearic Islands by Rafael Micó.

We do not yet have an open-access computer tool containing the thousands of dates that have been obtained in 65 years of application of the radiocarbon method in peninsular and insular archaeology, as well as in the bordering and historically connected regions, and which is based on an adequate systematic description of the archaeological contexts from which the analyzed samples originate. However, from the discussions in Congress we know what we need and how we should approach that project:

1) Systematization and formalization of the chronometric elements of the Prehistory, Antiquity and Middle Ages of the Iberian Peninsula, Islands and bordering regions, through the creation of a database using advanced computer technology.
2) Development of new computer methodologies for the intelligent indexing and consultation of chronometrically dated archaeological contexts contained in the database. We intend to use cutting-edge technologies in the field of cloud storage, using XML technology for cloud computing. The purpose is to combine technological advances with the essence of the concept of documentary heritage and the objectives of Digital Humanities. The user-friendly web platform ensures that researchers in history and humanities and other professionals with no computer skills can use the tool to their advantage. The simplicity of use of the platform for non-experts in these areas, for users of knowledge, configured for example as a virtual museum, is achieved by providing the system with powerful hardware and software resources as well as great computing power.

3) Development of new analytical methods based on statistical and artificial intelligence techniques, to process chronometric data and formulates hypotheses about the time duration of historical events.
4) Development of new analytical methods, based on statistical techniques and artificial intelligence, to make paleodemographic estimates from large series of radiocarbon data.
5) Development of new methods based on knowledge engineering to create ontologies as well as to study, analyse and extract information or knowledge based on the information collected, systematised and stored in these data warehouses.
6) Protection of heritage.
7) Dissemination of heritage using the Internet and graphic viewers.
8) Use in heritage management as a discursive tool and basic element for the construction of immersive experiences and virtual reality for the dissemination of knowledge of history.

The first two objectives are closely related. The construction of archaeological knowledge requires the systematization and structuring of information from many sources. The third and fourth objectives are also related. We are so used to consider the method of 14C or other comparable methods such as Uranium-Torio, Thermoluminescence, etc. as "absolute dating" procedures that we forget the uncertainties involved in converting a chemical-physical measurement into a temporal reference represented by any dating system such as the Roman, Julian or Gregorian calendar. This conversion is not precise as it involves not only the very random nature of the isotopic process, but also measurement, processing and calibration errors. Time-based estimation of the temporal position is a probabilistic process that minimizes the effects of apparently aberrant data on punctual events, recognizing them as extreme values of a probability distribution, or excluding the least likely parts of the resulting range and concentrating where the greatest probability is concentrated. There is a growing agreement in the scientific community that calibrated data can only be reliably expressed in terms of non-symmetric probability intervals, which take into account both the uncertainty and error inherent in radiocarbon measurement, as well as the effects derived from the reliability of the calibration curve over a given period and the irregularity, non-linearity and non-monotony of the calibration curve. We cannot expect a single value to deliver satisfactory results. Within the calibration interval, two dates are indistinguishable and there is no reason to think that one is better than the other, simply because it is in the center of the interval. This interval does not have a symmetrical probability density distribution, but is characteristically multi-modal.

Therefore, we believe that it is necessary to develop an advanced data ontology in order to integrate historical, geographical, archaeological and/or art history information. Current research in Temporary GIS and temporary databases will form the basis. Our purpose is not only to apply cutting-edge technology, but to advance the development of such technology. For example, we hope to advance in the development and operationalization of Allen's algebras and other formal systems to document complex temporal relationships through the development and experimentation of statistical methodologies and artificial intelligence for defining chronological phases. On the other hand, it is proposed to study variability in the frequency of contexts dated by time interval, in order to establish paleodemographic hypotheses and cultural dynamics over time. Once again, the information technology competition as well as high computing capacity and graphic resources allow for a high quality and long range of analysis and research by experts, which would not be possible otherwise. Specifically, we hope to be able to develop Bayesian statistical methodologies, space-time interpolation methods based on neural networks and other algorithms characteristic of modern research in data mining and automatic learning. We are particularly interested in investigating statistical methods that integrate aspects of fuzzy logic and uncertainty weighting.

The debates in the congress regarding the nature and requirements of such a consultation and research tool have allowed us to discuss some of the fundamentals on which the chronometric database that we intend to build together should be based. First of all, we must start from the fact that databases are a fundamental element for the management of archaeological heritage, for its recording, preservation, study and creation of knowledge. The same element is also fundamental for the presentation and public dissemination of archaeological knowledge and historical heritage, for its social use. The advances in the application of computational technologies in research are enormous and the production of the various databases is intense. However, the problem inherited from the documentation and publication of narratives on paper persists and is reflected in the fragmentation and lack of communication between small information and knowledge units. Without formalised, ordered and structured data, without different related databases and without their integration into an operational network, the construction of archaeological knowledge and the resolution of specific questions using advanced scientific methodologies and procedures is impossible. The work involved in developing the computer system for the complete management of archaeological knowledge is extraordinarily complex, immense and cannot be tackled on all fronts at the same time. But its modulation will facilitate gradual and efficient growth, both in structure and in the empirical basis.

As a starting point, the concept of event is proposed as a basic analytical unit that is configured at different levels of archaeological research [Bar13]. The event is a profoundly spatial-temporal category and can therefore be defined as ***a spatial-temporal unit represented by specific materiality***. The materiality of an event is represented in the archaeological record and will vary qualitatively and quantitatively according to a hierarchy of levels, starting with a natural occurrence (e. g.., a flood that has left a specific sediment, or the death of an organism), through individual or collective action

directly involved in the material transformation (flat size or hut construction, deforestation), to historical phenomena that are intended to date (such as social transitions, technological changes or climate change).

In any case, the dating process must follow the chronological inference chain, which begins with the smallest unit: with the sample representing an *isotopic event* (ei). The sample provided by the C14 range is related in a degree of reliability to its immediate context which is the individual or collective action represented by *depositional event* (ed). Discovering then the relationship of particular actions with the *archaeological event* (ea), we can define time space and content of what has generated material residue collected in the archaeological record. Following the path of discovery of significant causal relationships in macro resolution, we can define space, time, content and dynamics of the processual categories, of the social or technological transformations contained in *historical events*.

Therefore, chronological inference should follow the ontological chain of events (Fig. 2):

Isotopic event → depositional event → archaeological event → social event → historical event.

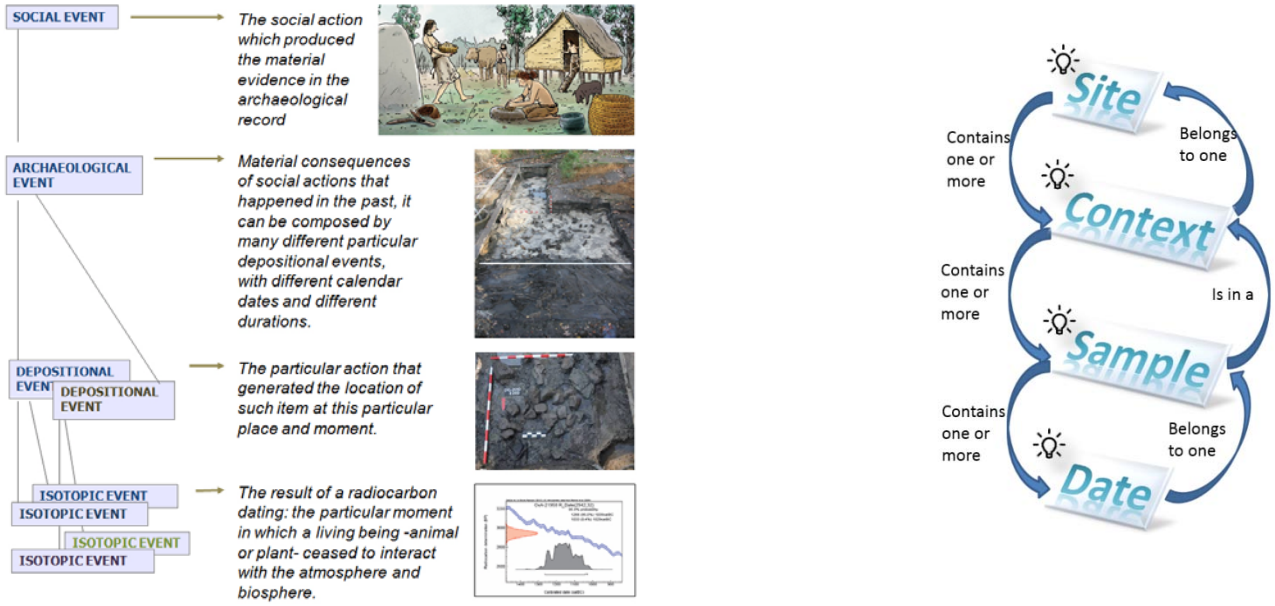

Figure 2 - General diagram of the chronological inference chain of events applied as follows the ontological structure of the database

The definition of each type of event or event should be made by means of the characteristic relationships of a relational model, since in reality they should be considered logically as datasets or "tuples". We conceptualize each relationship more easily in the form of an ontology composed of operationally linked conceptual units.

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The most relevant result of the last peninsular congress Chronometry for the history of the Iberian Peninsula - IberCrono, apart from a great deal of data and knowledge contributed, has been the express desire of the peninsular scientific community to take synchronized actions in the direction of the strategic points discussed and agreed upon in their general features. Synergies have been created to continue building this fundamental module of the archaeological knowledge resource system and its management tools. The selection of articles in front of you brings new facts and new knowledge and, above all, expresses in different ways the need to solve indicated problems, drawing clear directions of the steps to follow.

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