Radiocarbon dates and Bayesian modeling support maritime diffusion model for megaliths in Europe

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There are two competing hypotheses for the origin of megaliths in Europe. The conventional view from the late 19th and early 20th centuries was of a single-source diffusion of megaliths in Europe from the Near East through the Mediterranean and along the Atlantic coast. Following early radiocarbon dating in the 1970s, an alternative hypothesis arose of regional independent developments in Europe. This model has dominated megalith research until today. We applied a Bayesian statistical approach to 2,410 currently available radiocarbon results from megalithic, partly premegalithic, and contemporaneous nonmegalithic contexts in Europe to resolve this long-standing debate. The radiocarbon results suggest that megalithic graves emerged within a brief time interval of 200 y to 300 y in the second half of the fifth millennium calibrated years BC in northwest France, the Mediterranean, and the Atlantic coast of Iberia. We found decisive support for the spread of megaliths along the sea route in three main phases. Thus, a maritime diffusion model is the most likely explanation of their expansion.

Significance

For thousands of years, prehistoric societies built monumental grave architecture and erected standing stones in the coastal regions of Europe (4500–2500 calibrated years BC). Our understanding of the rise of these megalithic societies is contentious and patchy; the origin for the emergence of megalithic architecture in various regions has been controversial and debated for over 100 y. The result presented here, based on analyses of 2,410 radiocarbon dates and highly precise chronologies for megalithic sites and related contexts, suggests maritime mobility and intercultural exchange. We argue for the transfer of the megalithic concept over sea routes emanating from northwest France, and for advanced maritime technology and seafaring in the megalithic Age.

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megalithic sequence as precisely as possible, we adopted a Bayesian modeling approach, which is applied here to a wide region, using the program OxCal 4.1 (11, 12). We combined measurements with archaeological information relating to stratigraphical contexts, associated cultural material, and information on the burial rites, to narrow the time intervals for the calibrated ranges. In a first important step, we reviewed critically the 2,410 samples, including measurements from the 1960s up to the present, to determine the quality and reliability of the sample contexts. For each site with available radiocarbon results and a suitable sequence, we constructed one-phased or multiphased models with phase boundaries (Datasets S2 and S3) taking into consideration the detailed stratigraphic information (13). The posterior density estimates expressed as probability distributions in the text and in the figures are given by convention in italics to distinguish them clearly from simple calibrated radiocarbon dates.

Results

The radiocarbon dates suggest that the first megalithic graves in Europe were closed small structures or dolmens built above-ground with stone slabs and covered by a round or long mound of earth or stone. These graves emerge in the second half of the fifth millennium calibrated years (cal) BC within a time interval of 4794 cal BC to 3986 cal BC (95.4%; 4770 cal BC to 4034 cal BC, 68.2%) (Dataset S3, M7-2 to M7-7). Among the earliest megalithic grave chambers in Brittany, such as Tumiac, Kervinio, Castellic, St. Germain, Manio 5, Mané Hui, and Kerlescan (14–16), emerge within this horizon as an architectonic feature of monumental long and round mounds. For these early megaliths, no radiocarbon determinations are available. It is only possible to limit the time interval of construction to the Ancient Castellic horizon based on the typochronological considerations of the grave goods and according to the Ancient Castellic contexts with associated radiocarbon results ranging from 4794 cal BC to 3999 cal BC (95.4%; 4770 cal BC to 4034 cal BC, 68.2%) (Dataset S3, M7-2 to M7-7).

In Catalonia, in the Tavertet region, early megaliths emerged during the same time interval, even contemporaneous with the graves in Brittany. A reevaluation of the available radiocarbon results yielded a dating of the construction of these graves not before 4722 cal BC to 4068 cal BC (95.4%; 4581 cal BC to 4267 cal BC, 68.2%) (Dataset S3, M24-33). A part of these data exhibit an inbuilt age (Dataset S3, M24-28 to M24-32) (ref. 13, p. 128). On the northeastern side of the Pyrenees in southern France, early megaliths are either isolated in the landscape or arranged in necropolises as at Najac and Camp del Ginébre. The unmodeled ranges of three radiocarbon results for human bones from the necropolis of Najac 4328 cal BC to 3979 cal BC (95.4%; 4318 cal BC to 3995 cal BC) (Dataset S1, 830 to 832) suggest burials within this time horizon. Along the central Mediterranean coast and north Mediterranean islands of Sardinia and Corsica, small necropolises are found with early megalithic graves. The grave-goods from the Li Muri necropolis on Sardinia are attributed to the Late Neolithic San Ciriaco horizon, and, according to the radiocarbon results from the San Ciriaco layers in the settlement of Contraguda, it is possible to limit the emergence of these graves to a time interval from 4733 cal BC to 3986 cal BC (95.4%; 4771 cal BC to 4005 cal BC, 68.2%) (Dataset S3, M29-1 to M29-4). There are further clusters with potential early megalithic graves documented in the central Mediterranean in northern Italy, for example, in La Vela-Trento, or Maddalena di Chiomonte-Torino and possibly Apulia (6). However, for these, there are no radiocarbon dates available yet. Based on the archaeological material, they are likely dated to the second half of the fifth millennium cal BC. From the southwest Iberian Peninsula in Andalusia, the Algarve, and the Alentejo, we find more of these possible early megaliths (17–19).

In the northern half of the western Iberian Peninsula, there are early megaliths, concentrated mainly in Galicia. So far, these...
have been dated to the very end of the fifth millennium cal BC, if not later. Most of these dates are from charcoal, and many represent \textit{termini post quos} values due to the inbuilt age of the wood or unsure contexts. From Chan de Cruz 1, a possible construction or usage date from \( \sim 4080 \) cal BC (CSIC-642, 5210 ± 50 BP, 4144 cal BC to 3961 cal BC, 68.2%; 4230 cal BC to 3947 cal BC, 95.4%) (Dataset S1, 2014) is available.

Small stone chambers with no access and single or double inhumations are diagnostic for the early megalithic stage in the fifth millennium cal BC. In the last third of the fifth millennium, the earliest chambers with access are attested as dolmens and passage graves (Fig. 4). These graves could be reopened for repeated burials, and this marks the beginning of a new practice for the whole of Europe: the construction of graves for successive depositions of human remains over centuries. The earliest known accessible megalithic grave with reliable radiocarbon dates is located in central western France in the necropolis of Prissé-la-Charrière, Deux-Sèvres. The beginning of burial activities at this dolmen is calculated at 4371 cal BC to 4263 cal BC (95.4%; 4358 cal BC to 4275 cal BC, 68.2%) (Dataset S3, M20-2). Structures transitional to passage graves are documented for Brittany and for the long tumulus \textit{or tertre} of Lanec er Gadouer with a radiocarbon sequence which pinpoint this transition to 4503 cal BC to 4103 cal BC (95.4%; 4432 cal BC to 4233 cal BC, 68.2%) (Dataset S3, M5-8). Contemporaneous accessible megalithic graves are known from northern Corsica on the Monte Revincu dated at 4327 cal BC to 4266 cal BC (95.4%; 4302 cal BC to 4273 cal BC, 68.2%) (Dataset S3, M27-5).

On the western Iberian Peninsula, date ranges for the onset of accessible structures are calculated for the Estremadura at 3844 cal BC to 3383 cal BC (95.4%; 3658 cal BC to 3432 cal BC, 68.2%) (Dataset S3, M33-1), for the Alentejo at 3743 cal BC to 3521 cal BC (95.4%; 3673 cal BC to 3567 cal BC, 68.2%) (Dataset S3, M34-5), and for Beira at 3883 cal BC to 3782 cal BC (95.4%; 3837 cal BC to 3796 cal BC, 68.2%) (Dataset S3, M35-19). Similarly, the earliest megaliths with entrance in Britain and Ireland are also calculated to the first half of the fourth millennium cal BC. The earliest known megalithic grave in southeast England, Coldrum, is calculated at 3971 cal BC to 3805 cal BC (95.4%; 3960 cal BC to 3880 cal BC, 68.2%) (20), and Parknabinnia on the Burren in Ireland at 3885 cal BC to 3440 cal BC (95.4%; 3715 cal BC to 3530 cal BC, 68%) (21).

The subsequent centuries are a time of megalithic stasis and reuse of ancient megalithic graves. With the exception of the gallery graves in Belgium, there is no evidence for movements or new megalithic regions added at this time.

Finally, an even later megalithic expansion occurred in the second half of the fourth millennium in northern Germany and southern Scandinavia (22–24). In the Mediterranean, there is a megalithic revival in the second millennium cal BC in the
Balearic Islands, Apulia, and Sicily. These are associated with the Bronze Age and/or with the Bell Beaker phenomena (25).

**Discussion**

The radiocarbon results suggest that megalithic graves emerged within a time interval of 200 y to 300 y in the second half of the fifth millennium cal BC in northwest France, the Mediterranean, and the Atlantic coast of the Iberian Peninsula. Northwest France is, so far, the only megalithic region in Europe which exhibits a premegalithic monumental sequence and transitional structures to the megaliths, suggesting northern France as the region of origin for the megalithic phenomenon. For the remaining regions with an early megalithic proliferation in the fifth millennium cal BC (such as Catalonia, southern France, Corsica, Sardinia, and probably the western Iberian Peninsula and Italian mainland), megaliths are found occurring in small clusters. These are exceptional grave forms for this period in their respective regions, at a time when subterranean cists, pit burials and hypogea (dug-out subterranean burial chambers) were still the most common burial rites. A fresh expansion occurred during the first half of the fourth millennium cal BC when thousands of passage graves were built along the Atlantic coast of the Iberian Peninsula, Ireland, England, Scotland, and France. Their distribution emphasizes the maritime linkage of these societies and invites the opening of a new scientific debate regarding the maritime mobility and organization of Neolithic societies, the nature of these interactions through time, and the rise of seafaring.

Fig. 4. Map showing dates estimated for the start of accessible megaliths as dolmens and passage graves in the different European regions, with 95% probability (68% probability in brackets). Italic bold type is used for date ranges of the posterior density estimates based on samples from accessible megalithic graves, regular bold type is used for simple calibrated radiocarbon dates from accessible megalithic graves, and regular italic type is used for the probabilities of the posterior density estimates associated with the earliest cultural material in dolmen or passage graves.
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