Prehistoric human migrations: a prospective subject for modelling using geographical information systems

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Researchers in many fields have discovered the advantage of using geographical information systems (GIS), spatial statistics and computer modelling, but these techniques are only sparingly applied in archaeological research. Writing 30 years ago, Castleford (1992) noted the considerable potential of GIS, but he also felt that its then atemporal structure was a serious flaw. It is clear that the study of dynamic processes suffers if past events cannot be linked to each other, or to the present, but today's powerful tools have overcome this drawback. Importantly, with location and time as key indices, hypotheses about early human population dynamics can be tested and visualized in ways that can potentially reveal hidden relationships and patterns.

The current view of human prehistory is reminiscent of a vast jigsaw puzzle. Although pieces are missing, or still turned over, many are beginning to fall into place as archaeology, anthropology, osteology and climatology converge in the unravelling of our earliest history. Radiocarbon dating has supplied much information since it started to be broadly used after World War II. However, the recent success in extraction and sequencing of DNA from archaic biological has revolutionized the study of how primitive hominin species (defined as those closer to modern-day humans than to chimpanzees) relate to each other. Importantly, phylogenetic data not only specify individuals but also indicate how long ago two species diverged from a common ancestor. The reason for the latter is that genetic sequences mutate at a relatively constant rate whereby the accumulation of DNA differences functions as a clock indicating how different hominins fitted into the chain leading to modern-day humans. All the various hominin species evolved exclusively in Africa over a period exceeding 6 million years, with some having a long record and others becoming extinct after a short run, eventually leading to the emergence of *Homo sapiens* around 300,000 years ago.

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The geospatial approach

Climate, operating within a geographical framework, may be the strongest driver of human evolution. In this connection, GIS software offers new and exciting ways of integrating applicable approaches enabling researchers to identify patterns or trends and make informed decisions in order to gain deeper insights into the past by: i) improving the distinction of multiple layers of data, including topography, soil composition, elevation and other records and analyzing the spatial relationships between artifacts; ii) tracking large-scale changes by applying the data reduction possibilities offered by principal component analysis (PCA); and iii) creation of maps, diagrams and three-dimensional models of archaeological sites;

The roots of GIS reach all the way back to Hippocrates (400 BC), who drew attention to the spatial component in the spread of diseases, a fact famously brought home by Dr John Snow's observations of a cholera epidemic in 18th century London (Snow, 1855). The onward route from there takes us first to Roger Tomlinson (1974) who coined the term GIS for the capture, integration and visualization of spatial data when presenting his doctoral thesis, and then on to its commercialization. In 1982, the Environmental Systems Research Institute (ESRI) released an application based on vector graphics together with maps in raster format, but it was the explosive advance of computer systems coupled with the Internet and the global positioning system (GPS) in the 1990s that changed everything (https://gisgeography.com/what-is-arcgis/). With data capture no longer limited to terrestrial data collection but also coming from satellite-borne sensors and with access to a plethora of GIS software, almost anybody armed with a laptop and Internet connection can produce results straight from the back of beyond.

GIS and population dynamics

The study of human prehistory has utilized geospatial technology for mapping settlement sites in order to gain insight into how past human populations interacted with their environments. Hilpert *et al.* (2008) developed a hierarchical GIS model for the transfer of data between different scale levels where settlement sites expressed by point data were transformed into two-dimensional expressions (isolines). In a European study area, they noted an increase of cultivated areas from the Neolithic to Roman times leading to an understanding of population densities as an exponent of agricultural progress. Working with a similar focus but at a much earlier time (6000–3500 years ago), Zhang *et al.* (2010) explored the transition between gathering practices and agriculture in ancient China using PCA to order and reduce the high number of data collected. They found that the varying conditions of the natural environment around each site explained patterns of wild food collection, with social and cultural factors being the keys to the initiation and growth of farming. Focusing on an even earlier time, Banks *et al.* (2021) examined the archaeological record of a naturally constrained region of Western Europe between 82,000 and 60,000 years ago. Applying ecological niche modelling for illuminating the role of the environment in the growth and decline of different populations, they found that the range of suitable habitats exploited by a Neanderthal population contracted and shifted in line with temperature changes, as reflected by Marine Isotope Stage 4 (MIS4), *i.e.* a set of oxygen isotope data in deep sea core samples corresponding to the middle of the latest Ice Age.

The exact route and timing of human entry into the Americas remains a matter of debate. A new study of the impact of climate conditions based on MIS data provides support for coastal migration from north-western Asia (Praetorius *et al.*, 2023). Their computer simulations of the prevailing temperatures in the Late Pleistocene epoch indicated two intervals (between 24,500 to 22,000 and 16,400 to 14,800 years ago) that could have helped the first immigrants to travel along the Pacific coast by the frozen sea. This was felt preferable to the mountainous land route between Asia and North America, which was then open thanks to the low sea levels caused by the massive binding of water to land during the Ice Age.

Out of Africa and beyond

Both *H. sapiens* and earlier hominins made numerous advances into Asia via Sinai and the Red Sea, perhaps reaching Southeast Asia as early as 1.8 million years ago (Husson *et al.*, 2022). Although most migrations were initially successful, they generally failed, even after various hominin groups had become established, and the current consensus is that the total world population emanates from one or several groups of *H. sapiens* crossing the Red Sea in the period between 70,000 and 50,000 years ago (Schaebitz *et al.*, 2021; Soares *et al.*, 2012; Tierney *et al.*, 2017). This hypothesis is supported by archaeological evidence and by a significant deterioration of the African climate change coinciding with the prevailing low sea levels due to the Ice Age, which turned the southern part of the Red Sea into a narrow strait. The 'out of Africa doctrine' remains correct even if *H. erectus* might have remained for more than a million years in Southeast Asia and possibly interbred with various hominins, which we know was the case between *H. sapiens* and *H. neandertalis* and *H. denisova* (Callaway, 2016).

According to MIS data from Greenland ice cores, the Pleistocene epoch ended with a few cataclysmic temperature swings followed by rapid warming that marked the start of the Holocene epoch with its stable, long-term, higher temperatures (Figure 1). This led to increased dispersal of *H. sapiens* throughout the European continent, and the first habitation of Scandinavia after the Ice Age. However, the most well-documented settlements from that time are in the eastern Italian Alps, where Caracausi *et*

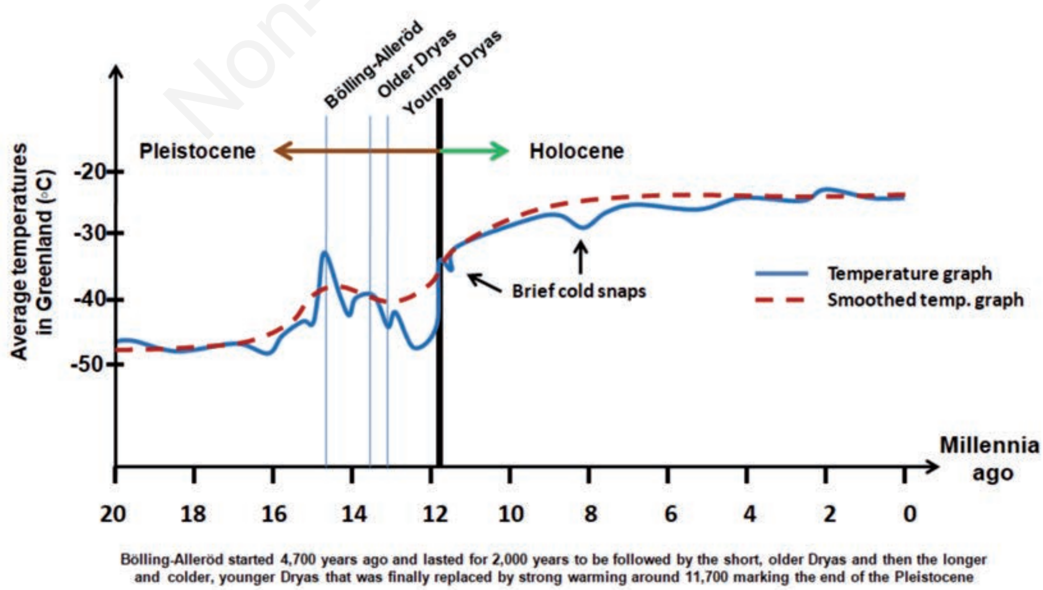

Figure 1.

al. (2018) developed a GIS-based predictive model that identified new archaeological sites based on long-term data from around 11,000 years ago. Similar work, but focusing more on dispersal rather than settlements, was published by Guiducci *et al.* (2016), who suggested that GPS-assisted navigation systems can also be used for the study of ancient human mobility. They produced a model focusing on the role of geographical structures for migration, which might also indicate trade routes and provide insights into the development of long-distance economic relationships.

Using genome-wide, ancient DNA studies supported by PCA, Brace *et al.* (2019) reported that mesolithic Britons clustered with West-European and Scandinavian hunter-gatherers, while those entering later than 6,000 years ago clustered with neolithic individuals emanating from Aegean farmers moving into Iberia and central Europe via the Mediterranean route. The original peopling of Scandinavia occurred through the merger of one population migrating around the Scandinavian North Atlantic coast from north-eastern Eurasia, with another ascending along the west coast of present-day Sweden (Günther *et al.*, 2018). The former study includes Cheddar Man from Somerset, England who has become well-known after a model was built based on his DNA showing a relatively short, young man with dark skin and blue eyes. The oldest human remains in Scandinavia are from the 'Österöd woman', named after the place where her skeleton was found in a shale bank on the Swedish west coast (Ahlström & Sjögren, 2006). Incidentally, both the Österöd woman and Cheddar Man were found the same year (1903), and both are estimated to also have died at a similar time about 10,200 years ago. It would be interesting to know if the Österöd woman also had Cheddar Man's dark skin and blue eyes or if she already had received genes from the more light-skinned incoming population from the Northeast, but so far it has not been possible to extract her DNA for sequencing.

Several major questions associated with a spatial component, remain, *e.g.*, how strongly has topography governed the routes of migration?; how were remote islands in the Pacific reached?; and to what extent did early human migration influence the dispersal of plant and animal species? Other issues regard the interbreeding between different human species after coming out of Africa, and whether this occurred already during the long time the human species were confined to the African continent.

References

Ahlström T, Sjögren K-G, 2006/2007. Kvinnan från Österöd – ett tidig-mesolitiskt skelett från Bohuslän. In Situ, 7:47–64, Göteborg (abstract in English – full text in Swedish).

Banks WE, Moncel MH, Raynal JP, Cobos ME, Romero-Alvarez D, Woillez MN, Faivre JP, Gravina B, d'Errico F, Locht JL, Santos F, 2021. An ecological niche shift for Neanderthal populations in Western Europe 70,000 years ago. Sci Rep 11:5346.

Brace S, Diekmann Y, Booth TJ, van Dorp L, Faltyskova Z, Rohland N, Mallick S, Olalde I, Ferry M, Michel M, Oppenheimer J, Broomandkhoshbacht N, Stewardson K, Martiniano R, Walsh S, Kayser M, Charlton S, Hellenthal G, Armit I, Schulting R, Craig OE, Sheridan A, Parker Pearson M, Stringer C, Reich D, Thomas MG, Barnes I, 2019. Ancient genomes indicate population replacement in Early Neolithic Britain. Nat Ecol Evol 3:765-71.

Callaway E, 2016. Evidence mounts for interbreeding bonanza in ancient human species. Nature 1476-4687.

Caracausi S, Berruti GLF, Daffara S, Bertè D, Borel FR, 2018. Use of a GIS predictive model for the identification of high altitude prehistoric human frequentations. Results of the Sessera valley project (Piedmont, Italy). Quat Int 490:10-20.

Castleford J, 1992. Archaeology, GIS and the time dimension: an overview. In CAA91 Computer Applications and Quantitative Methods in Archaeology 1991. Available from: https://proceedings.caaconference.org/files/1991/13_Castleford_CAA_1991.pdf.

Guiducci D, Burke A, 2016. Reading the landscape: Legible environments and hominin dispersals Evol Anthropol 25:133-41.

Günther T, Malmström H, Svensson EM, Omrak A, Sánchez-Quinto F, Kılınç GM, Krzewińska M, Eriksson G, Fraser M, Edlund H, Munters AR, Coutinho A, Simões LG, Vicente M, Sjölander A, Jansen Sellevold B, Jørgensen R, Claes P, Shriver MD, Valdiosera C, Netea MG, Apel J, Lidén K, Skar B, Storå J, Götherström A, Jakobsson M, 2018. Population genomics of Mesolithic Scandinavia: Investigating early postglacial migration routes and high-latitude adaptation. PLOS Biology 16:e2003703.

Hilpert J, Wendt KP, Zimmermann A, 2008. A Hierarchical Model of Scale Levels for Estimations of Population Densities. Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Berlin, Germany, April 2–6, 2007.

Husson L, Salles T, Lebatard A-E, Zerathe S, Braucher R, Noerwidi S, Aribowo S, Mallard C, Carcaillet J, Natawidjaja DH, Bourlès D, ASTER team2022. Javanese Homo erectus on the move in SE Asia circa 1.8 Ma Sci Rep 12:19012

Praetorius SK, Alder JR, Condron A, Mix AC, Walczak MH, Caissie B, Erlandson J, 2023. Ice and ocean constraints on early human migrations into North America along the Pacific coast. Proc Natl Acad Sci USA 120:e2208738120.

Schaebitz F, Asrat A, Lamb H, Cohen A, Foerster V, Duesing W, Kaboth-Bahr S, Opitz S, Viehberg FA, Vogelsang R, Dean J, Leng MJ, Junginger A, Bronk Ramsey C, Chapot MS, Deino A, Lane CS, Roberts HM, Vidal C, Tiedemann R, Trauth MH, 2021. Hydroclimate changes in eastern Africa over the past 200,000 years may have influenced early human dispersal. Commun Earth Environ 2:123

Snow J, 1855. On the mode of communication of cholera. 2nd ed. John Churchill, London, England.

Soares P, Alshamali F, Pereira JB, Fernandes V, Silva NM, Afonso C, Costa MD, Musilová E, Macaulay V, Richards MB, Cerny V, Pereira L, 2012. The expansion of mtDNA Haplogroup L3 within and out of Africa. Mol Biol Evol 29, 915–27.

Tierney JE, deMenocal PB, Zander PD, 2017. A climatic context for the out-of-Africa migration. Geology 45:1023–6.

Tomlinson RF, 1974. Geographical information systems, spatialdata analysis and decision making in government. Accessed 3 April 2023. Available from: http://discovery.ucl.ac.uk/id/eprint/1563584

Zhang H, Bevan A, Fuller D, Fang, Y-M, 2010. Archaeobotanical and GIS-based approaches to prehistoric agriculture in the upper Ying valley, Henan, China. J Archaeol Sci 37:1480-9.