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The Last Glacial Maximum in Europe – State of the Art in Geoscience and Archaeology

From the 20th to March 22, 2019, two of us (AM and CM) organized a workshop entitled “The Last Glacial Maximum in Europe – State of knowledge in Geosciences and Archaeology” at Schloss Wiesenthau in the vicinity of Erlangen, generously funded by the Friedrich-Alexander-Universität Erlangen-Nürnberg. Forty scientists from Austria, Belgium, Canada, Czech Republic, France, Germany, Hungary, Italy, Poland, Portugal, Romania, Russia, Serbia, Spain, Switzerland, and Ukraine came together to discuss the current state of knowledge on the Last Glacial Maximum (LGM) in different disciplines and regions (Fig. 1). About 30 and 20 years after the editions of “The World at 18.000 PB” (Gamble and Soffer, 1990) and “Hunters of the Golden Age” (Roebroecks et al., 2000), respectively, the aim of the workshop was to refresh discussions about relations between cultural phenomena and environmental change around this period based on advancements in Geosciences and Archaeology across Europe. The workshop allowed identifying subjects, paths, and perspectives for future research. This special issue is dedicated to disseminate the results initiated during this meeting. Before presenting in short the contributions of this issue, some explanations regarding cultural and environmental terms shall be given, to make the contributions accessible for people from both communities, otherwise maybe not familiar with these terms.

1. Background

While the term Last Glacial Maximum (LGM) is in use already since several decades (Willett, 1950; CLIMAP Project Members, 1976, 1981), its definition has changed with increasing knowledge about dating, proxies and climate archives. Although a detailed review of the LGM goes beyond the scope of this editorial, a few common definitions (among many others) shall be mentioned here, elucidating the various concepts for defining the LGM. Mix et al. (2001), for instance, attribute the LGM to the period with lowest sea level and absence of major climate events such as Heinrich and Dansgaard-Oeschger events. Predominantly based on oxygen isotope records from ice cores and deep sea sediments, they defined a LGM chronozone between 23 and 19 ka BP, or 24–18 ka BP if dating uncertainties are accounted for. On the other hand, Hughes and Gibbard (2015) suggested 27.5–23.3 ka BP the duration of the global LGM coinciding with the Greenland stadial 3 and peak dust concentrations in ice cores from Greenland and Antarctica. It was argued that these chronologies better fulfills the criteria of chronozones, but still based on proxy records that not solely reflect the global maximum glacier expansion. At the same time, also global sea level curves, more directly related to global ice volume, were used for framing the LGM (Clark et al., 2009). Later, an updated sea-level record set the LGM at 30–16.5 ka BP (Lambeck et al., 2014). This LGM definition bases on sea-level data derived from sediment and coral records corrected for isostatic effects. It also covers large parts of the cool Marine Isotope Stage 2, according to deep-sea oxygen isotope records (Lisiecki and Raymo, 2005). The broader time interval encompassed by the LGM based on the sea-level was recently refined and the LGM divided in two phases (LGM-a: 30–21.5 ka BP, LGM-b: 21.5–17 ka BP) (Yokoyama et al., 2018). LGM-b, associated with the lowest global sea-level, is the youngest chronological definition of LGM presented here. The different time frames covered by the mentioned LGM definitions are illustrated in Fig. 2 in comparison to selected records used for deducing them. Independently by the adopted chronological definition, climate also underwent also to regional changes. Regionally, maximum glacier advances may not match with one or another definition, or even with any of the existing LGM definitions, in terms of timing (Heyman et al., 2011; Hughes et al., 2013).

Being aware of the different existing concepts of LGM, in this special issue no a priori definition was given. All authors were called to apply the term LGM depending on the regional context of their studies. This broader view may also challenge to rethink some simplified generalizations of LGM. For instance, there is a quite common view of LGM as a climatically unfavorable period for human populations. However, what is considered favorable frequently cannot be defined objectively and environmental conditions could have differed substantially in the various regions under study.

Between 25 and 20 ka BP, there seems to be a clear distinction in the environmental preferences of hunter-gatherers in Western and Eastern Europe. People in the West preferred locations south of the permafrost line and in parts also south of the timber line, while people in the East apparently preferred the areas north of the permafrost line (Maier et al., 2016; Demidenko, 2018). Adaptation to different ecological niches have also been used as explanations for differences observable in the archaeological record (Banks et al., 2008).

Having that said, LGM has been globally recognized in most regions of Europe as a climatic period characterized by anomalies influencing aeolian activity (Meyer and Kottmeier, 1989; Mayewski et al., 1997; Renssen et al., 2007; Luetscher et al., 2015; Ludwig et al., 2016), precipitation (Florineth and Schlüchter, 2000; Ludwig et al., 2016), and temperature patterns (Kageyama et al., 2006; Schneider von Deimling et al., 2006; Allen et al., 2008; Strandberg et al., 2011; Annan and Hargreaves, 2013; Heyman et al., 2013) in comparison to the previous or following periods. The presence of permafrost is recognized to the north of a line crossing Europe from the Atlantic coast through the south of France to the southern Alpine foreland and along the southern margins of the Carpathian Mountains passing the northern shores of the Black Sea (Baulin et al., 1992; Lindgren et al., 2016).

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The last minimum global sea level was 125–130 m lower than today (Yokoyama et al., 2018) influencing palaeogeography and topography. Large parts of the European continental shelves became exposed, such as the northern Adriatic Sea and the North Sea where the British Isles were connected with the European mainland. The buildup of the British and Fennoscandian ice sheets, roughly between 30 and 25 ka BP (Sejrup et al., 2009), and their advance into the dried North Sea area (Emery et al., 2019), affected the fluvial systems of Europe (Toucanne et al., 2010). Besides large ice build-up of the Fennoscandian Ice Sheet and in the Alps, mountain glaciations did also occur in the Pyrenees, Massif Central, Vosges, Black Forest, Bavarian Forest, and Giant Mountains, although to different extent (Florineth and Schlüchter, 2000; Heyman et al., 2013).

Changing climate during the LGM had a strong influence also on flora and fauna. Besides climatic variables, atmospheric carbon dioxide concentration, soil water capacity and seasonal and diurnal solar insolation intensities were important drivers of regional vegetation variability in Eurasia (Allen et al., 2010). One of the major debates concerning the vegetation during the LGM in Europe is the extent to which trees species could withstand these circumstances and have been present in the landscape (Tzedakis et al., 2013). The timberline, here understood as the northern limit of tree growth, was located roughly at about 45°N between the Atlantic Ocean and the Black Sea (Grichuk, 1992). On a continental scale, the so-called mammoth-steppe was wide-spread and consisted of a “highly heterogeneous vegetation and landscape structure” similar to the present-day Altai-Sayan region (Pavelková Řičánková et al., 2014). Such small-scale differences in climate, vegetation and fauna is also evident in the fossil records (Bennet et al., 1991; Willis et al., 2000; Stewart and Lister, 2001; Taberlet and Cheddadi, 2002; Willis and Van Andel, 2004; Sommer and Nadachowski, 2006; Svenning et al., 2008; Lorenzen et al., 2011; Sommer et al., 2014; Nadachowski et al., 2015; Binney et al., 2016).

The onset of the glacier build-up at around 30 ka BP and the accompanying environmental changes apparently led to a population decline in Europe (Fu et al., 2016) that strongly affected the regions to the north of 50°N. Previously populated areas in Great Britain, the Netherlands, Belgium, Germany and Poland became virtually depopulated (French, 2015; Maier and Zimmermann, 2017). Between 25 and 20 ka BP, however, the situation stabilizes and in Western Europe a renewed population growth is recorded. Populations in eastern Central Europe, however, remained at a very low level (Maier et al., 2016) and it is only with the onset of the re-warming deglaciation phase that populations everywhere in Europe increased substantially (Bocquet-Appel et al., 2005; Kretschmer, 2015; Posth et al., 2016).

From an archaeological point of view, the period between ca. 25 and 20 ka BP seems to be characterized by a decreasing connectivity of long-distance networks and consequently a decrease in inter-group communication. This is indicated by increasing regional idiosyncrasies, reflected in the large number of taxonomic units defined for this period, such as the Solutrean, Salpetrian, Badegoulian, Arenian, Kasovian, Sagvarian, Grubgraben, or Epi-Aurignacian (Fig. 3). The reliability of these taxonomic units and their potential chronological relations is a topic of ongoing debate (e.g. Montet-White, 1994; Terberger and Street, 2002; Reynolds and Riede, 2019).

2. Contributions

The outlined background sets the stage for contributions shedding new light on various aspects of the palaeoenvironmental conditions and human habitats in Europe during the LGM, the topic of this Special Issue. The contributions focus on cultural aspects and life conditions of humans or both. Therefore, we decided to structure the running order of the Special Issue geographically, following a west-to-east direction.

The volume opens with Klein et al. (2021, this volume), who explore the suitability for hunter-gatherer inhabitance in Western and Central Europe during the LGM based on environmental proxies. By calculating the so-called Human Existence Potential, they compare areas with a likely continuous occupation (Core Areas) to those with intermittent use and analyze the connection between Core Areas by estimating the path with the lowest costs between them. Between populations in Western and Central Europe, they identify a significant climatic barrier with important explanatory potential for the observation that the western European Solutrean did not expand beyond 10°E.

Cascalheira et al. (2021, this volume) present an updated review of the evidence of human adaptation to the environmental situation on the Iberian Peninsula during the LGM. The cul-de-sac position at the southwestern end of the European continent and its eco-geographical diversity distinguish Iberia as a key region for the study of the relations between environmental change and human adaptation. This is particularly the case for the period of the LGM, where a series of innovations mark the transitions between the taxonomic categories of the Gravettian, Proto-Solutrean, Solutrean, and Magdalenian. The authors discuss the pronounced inter-regional variability, address unresolved research questions, and point out the most promising research topics for future studies.

Arrizabalaga et al. (2021, this volume) re-evaluate the so-called Basque crossroads on both slopes of the western Pyrenees with regard to its role as the main connecting path between Iberia and the rest of Europe. Here, the authors take into account the environmental heterogeneity of the region and its changes through time from the Gravettian to the Solutrean and incorporate new data on raw material acquisition, the use of rock-shelters and open-air-sites also in high altitudes in contrast to caves, as well as new information of the paleo-environmental situation.

Fig. 1. Participants of the meeting at Schloss Wiesenthau in March 2019, listed in alphabetical order: Natalia B. Akhmetgaleeva, Manuel Alcaraz-Castaño, Mircea Anghelinu, Pierre Antoine, Alvaro Arrizabalaga, Dariusz Bobak, Guillaume Boccaccio, Ariane Burke, João Cascalheira, Laëtitia Demay, Yuri Demidenko, Sylvain Ducasse, Naroa Garcia-Ibaibarriaga, Ulrich Hambach, María-Jose Iriarte-Chiapusso, Susan Ivy-Ochs, Lucas Kämpf, Frank Lehmkuhl, György Lengyel, Patrick Ludwig, Andreas Maier, Slobodan Marković, Christoph Mayr, Olivier Moine, Giovanni Monegato, Petr Neruda, Zdeňka Nerudova, Kerstin Pasda, Marco Peresani, Marta Poltowicz-Bobak, Damien Rius, Petr Škrdla, Christoph Spötl, Philipp Stojakowits, Thomas Terberger, Gábor Újvári, Thorsten Uthmeier, Pavlo Vasilev, Daniel Veres, Bernd Zolitschka.

Ducasse et al. (2021, this volume) present new insights into the Badegoulian in its temporal and spatial extent and relation to the Solutrean. Based on recent analyses of the typo-technological characteristics of assemblages of stratified key-sites containing lithic and organic artefacts as well as faunal remains and personal ornaments, and in light of the archaeostratigraphic re-evaluation and radiometric dating of these assemblages, the authors carve out the Badegoulian characteristics while highlighting also their variability. Eventually, they are able to assess the speed and strength of the changes at the Solutrean-Badegoulian border, identify blind spots in the data structure and lay out potential paths of future research.

The contribution by Boccaccio (2021, this volume) also focusses on the processes that took place towards the end of the Solutrean, but from a different geographical angle. Analyzing sites in the Rhône Valley, the author sheds light on the relation between the Upper Solutrean and following Salpetrian. Despite some notable differences, the Salpetrian also shows signs of continuity in comparison the Solutrean. The article discusses idiosyncrasies of the lithic technology of the Salpetrian, re-evaluates its chronological position and addresses the question of its relations to other regional groups.

The contribution of Stojakowits et al. (2021, this volume) reviews the environmental development towards the LGM in the northern Alps and their foreland. Available evidences for climatic changes from speleothems and sediment deposits for the MIS 3/2 transition (35–25 ka cal BP) are compiled and evaluated. An improved chronological sequence for the glacial advances in the northern Alps and their foreland is presented and the impact of the climatic deterioration on vegetation, soil development, and fauna in the Alpine foreland is discussed.

Ludwig et al. (2021, this volume) explore the climatic conditions during the LGM in the Carpathian basin and adjacent regions using regional climate simulations. They validate the model results with available proxy data and simulate the aeolian dust cycle that led to extensive loess deposits in the area. The results of their atmospheric circulation model allows identifying regional dust sources and prevalent wind directions, and suggest strong seasonal activity changes of the dust cycle during the LGM.

South of the Alps, a vast region existed during the LGM, although its habitability for human groups has long been questioned. Peresani et al. (2021, this volume), examine the physical and ecological features of the Great Adriatic Po Region through a range of palaeogeographic and palaeocological conditions. They explore the relation between these conditions and settlement dynamics of Gravettian and Epigravettian hunter-gatherers and, based on the currently available data coupled with original petroarchaeological evidence achieved from a handful of archaeological sites, demonstrate that this area between the Alpine chain, the Italian Peninsula and the north-western Balkan Peninsula was inhabited by seasonal hunters of bisons and horses at the margins of the great plain and of ibexes and cave bears in some hilly landscapes. Great mobility of groups was favoured by the wide open spaces of the Great Adriatic Po Region in the framework of a cultural identity.

Shifting north, Škrdla et al. (2021, this volume) shed light on LGM settlement strategies in Eastern Central Europe. Applying multivariate spatial statistics, the authors analyze seven key sites of this period with regard to twelve geomorphological characteristics. They find a strong tendency for the selection of sheltered positions for site location. They contextualize their findings with regard to raw material transportation patterns. Škrdla et al. also point out difficulties in regional and supra-regional comparisons of sites of this period and identify demands for future research.

Nerudova et al. (2021, this volume) also address the topic of settlement strategies, but focus exclusively on the area of Moravia, while extending the temporal frame also to the post-LGM period of the Late

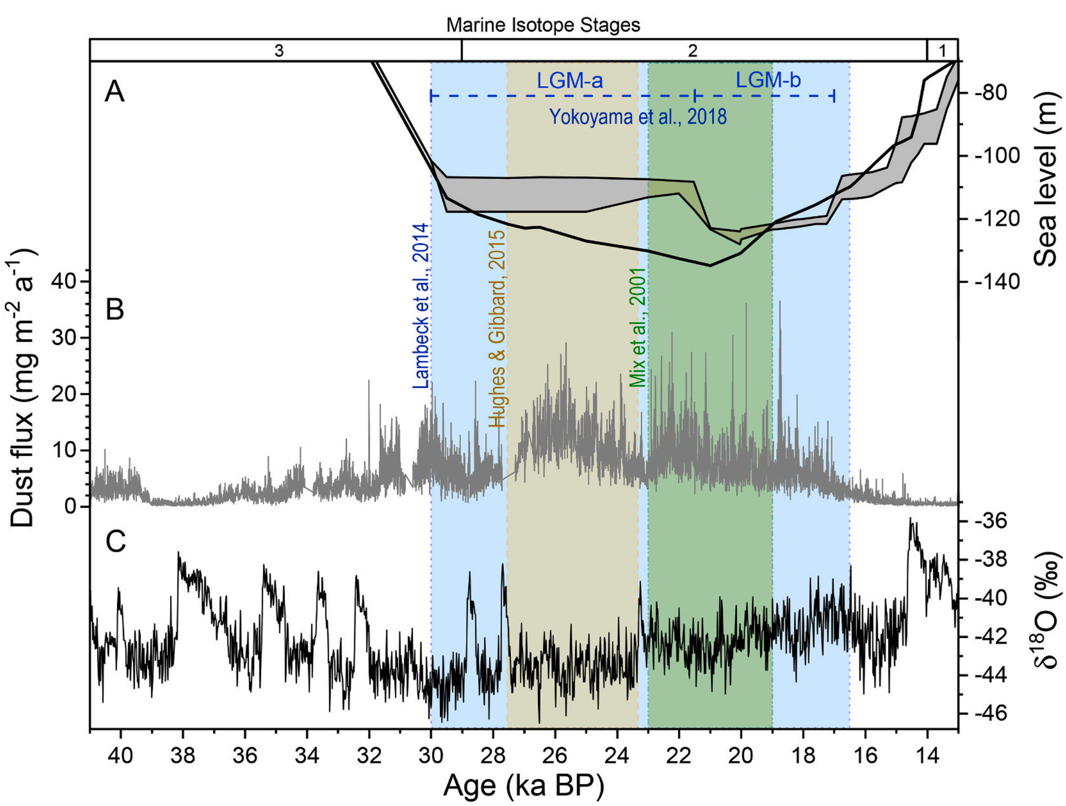

Fig. 2. Schematic overview of different definitions of the LGM. Colored bars represent the definitions by Mix et al. (2001) (green shading), Hughes and Gibbard (2015) (ochre shading), and Lambeck et al. (2014) (blue shading). The LGM subdivision by Yokoyama et al. (2018) is given as dashed blue bars. Selected records used for defining the period of the LGM are given: (A) Global sea level after Lambeck et al. (2014) (bold line) and Yokoyama et al. (2018) (shaded area), (B) dust flux record from the EPICA Dome C record (Lambert et al., 2012), (C) oxygen isotope record from the North Greenland Ice Core Project (Andersen et al., 2006; Svensson et al., 2006). Also shown as bars on top of the graph are the Marine Isotope Stages as defined by Lisiecki and Raymo (2005).

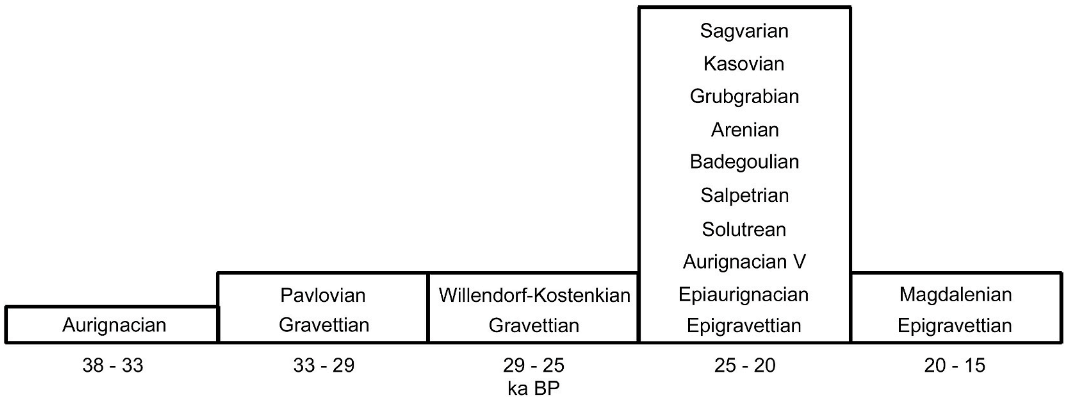

Fig. 3. Schematic overview of archaeological taxonomic units mentioned in the contributions of this SI given in simplifying 5 ka intervals between 38 and 15 ka to highlight the high variability of units between 25 and 20 ka. For references, definitions, and chronological details see the individual contributions.

Glacial. Including 50 sites into their analysis, the authors identify two main strategies for site location, namely at low elevations near larger rivers (usually connected to the Epigravettian) or at higher elevations (usually connected to the Epiaurignacian). The authors critically evaluate their findings and discuss possible implication of the differences between the taxonomic units with regard to chorology, seasonality, and diachronic change.

Staying in the region, Polanská (2021, this volume) provide an in-depth analysis of Gravettian small backed points from Dolní Věstonice II, Unit K11, in Moravia. They show a controlled width and an asymmetric rectilinear edge retouch with the possible presence of inverse retouches on one or both ends. With regard to their small size and the raw material used (chert from Krumlovský les), the artefacts differ from those at other sites of the region related to the Pavlovian sensu stricto, but similarities to Willendorf II, layer 5, are observable.

Polanská et al. (2021, this volume) explore the relation of assemblages from Moravia and Western Slovakia during the Upper and Final Gravettian. The authors critically discuss the significance of shouldered points and Kostienki knives as index fossils for post-Pavlovian assemblages and their taxonomic attribution. In light of new analyses of lithic and osseous artefacts and subsistence strategies, Polanská et al. discuss the effectiveness of traditional index fossils for chronological and chronological questions, point out the significant variability of the assemblages and propose Petřkovice bi-truncated elements as potentially new index fossils.

Maier et al. (2021, this volume) present an attempt to explore patterns of cultural evolution against environmental change in Central Europe in a diachronic approach. Analyzing information of the use periods of lithic and osseous projectiles, the authors identify five instances between 40 and 15 ka, where the evidence suggests higher than average speed of cultural evolution. With regard to environmental data, Maier et al. discuss whether these instances exhibit common characteristics and find that all of them roughly coincide with pronounced and rapid environmental changes, although of different kinds and qualities.

The situation in the Eastern Carpathians is addressed by Anghelinu et al. (2021, this volume). The authors focus on a number of twelve lithic assemblages from six sites in the Bistrița valley that exhibit highly similar litho-stratigraphic sequences and successions of archaeological layers, and are thus particularly suited for to a synthetic discussion. Anghelinu et al. find marked differences between the Late Gravettian and the following Epigravettian assemblages with regard to raw material acquisition and techno-typological characteristics and reflect whether these changes might be related to stochastic effects, adaptation in response to environmental change, or population exchanges.

Demay et al. (2021, this volume) recompile the extensive mammal fauna remains at archaeological sites in the large East European Plain during the late Pleniglacial (31.0–21.5 ka cal BP). By merging these data with occupation seasons, techno-cultural practices and other socio-ecological proxies, they interpret them in terms of Paleolithic human behavior and human-prey relationships. Reindeer, mammoth, horse, and bison were key taxa in the archaeological context, but their relative importance as a game varied both spatially and temporally.

Demidenko (2021, this volume) reflects on the diversity in the archaeological record in the southern part of Eastern Europe (the Great North Black Sea region) during the LGM. Here, the author contrasts ideas on local evolution during the Upper Palaeolithic with a view that puts forward the picture of a punctuated presence of different industries in the area, influenced by the changing palaeoenvironmental conditions around the LGM. Demidenko highlights among others the occurrence of Epi-Aurignacian assemblages only during Heinrich Event 2 and the low degree of similarity between the regional variant of the Epigravettian and the Gravettian or Epigravettian in the central part of Eastern Europe.

Akhmetgaleeva and Burova (2021, this volume) discuss the idiosyncratic character of the site complex of Byki within the mosaic picture of lithic industries in the East European Plain. Dated to between 19 and 21 ka, the assemblages can be divided into two larger groups. The first group is represented by assemblages with lamellar industries and a dominance of burins and backed bladelets, comparable to other LGM sites in the center of Eastern Europe. The second group, in contrast, is characterized by lithic triangles and osseous elongated points, otherwise unknown within European Late Upper Paleolithic industries. The authors discuss their finding against the local environmental background.

3. Concluding remarks

This tour on the eco-cultural relations between human populations and their habitats during LGM in Europe highlights the variability of the currently available records, also acknowledging missing information due to knowledge gaps or inaccessibility of larger patches of now submerged land. Evidence reported in this Special Issue enhances our understanding of how human groups behaved in different ecological contexts, ranging from steppe over boreal open woodland up to the Alpine timberline, or to cold-arid ecotones. Although the major environmental changes and turnovers in material culture are probably known today in their broader outlines, our knowledge on regional differences and high-resolution interaction patterns still remains patchy and blurry for most of Western Eurasia, leaving room for comprehensive perspectives of future multidisciplinary research.

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References

Akhmetgaleeva, N.B., Burova, N.D., 2021. The originality of the Byki sites among known LGM industries in the Russian Plain. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.08.035.

Allen, R., Siegert, M.J., Payne, A.J., 2008. Reconstructing glacier-based climates of LGM Europe and Russia – Part 3: comparison with previous climate reconstructions. Clim. Past 4, 265–280.

Allen, J.R.M., Hickler, T., Singarayer, J.S., Sykes, M.T., Valdes, P.J., Huntley, B., 2010. Last glacial vegetation of northern Eurasia. Quat. Sci. Rev. 29, 2604–2618.

Andersen, K.K., Svensson, A., Johnsen, S.J., Rasmussen, S.O., Bigler, M., Röthlisberger, R., Ruth, U., Siggaard-Andersen, M.L., Steffensen, J.P., Dahl-Jensen, D., Vinther, B.M., Clausen, H.B., 2006. The Greenland Ice Core Chronology 2005, 15–42 ka. Part 1: constructing the time scale. Quat. Sci. Rev. 25, 3246–3257.

Anghelinu, M., Niță, L., Veres, D., Hambach, U., Händel, M., Cordoș, C., Ilie, M., Murătoreanu, G., 2021. Break vs. continuity: techno-cultural changes across the LGM in the eastern Carpathians. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.08.002.

Annan, J.D., Hargreaves, J.C., 2013. A new global reconstruction of temperature changes at the Last Glacial Maximum. Clim. Past 9, 367–376.

Arrizabalaga, A., Iriarte-Chiapusso, M.-J., Garcia-Ibaibarriaga, N., 2021. Gravettian and Solutrean in the Basque Crossroads: climate changes and human adaptations in the western Pyrenees. Quat. Int. 581–582 https://doi.org/10.1016/j.quaint.2020.07.004.

Banks, W.E., d'Errico, F., Peterson, A.T., Vanhaeren, M., Kageyama, M., Sepulchre, P., Ramsteim, G., Jost, A., Lunt, D., 2008. Human ecological niches and ranges during the LGM in Europe derived from an application of eco-cultural niche modeling. J. Archaeol. Sci. 35, 481–491.

Baulin, V.V., Danilova, N.S., Nechayev, V.P., Péwé, T.L., Velichko, A.A., 1992. Glaciation and permafrost – maximum cooling of the last glaciation. In: Frenzel, B., Pecsi, M., Velichko, A.A. (Eds.), Atlas of Paleoclimates and Paleoenvironments of the Northern Hemisphere – Late Pleistocene – Holocene, vol. 49. Gustav Fischer Verlag, Stuttgart.

Bennett, K.D., Tzedakis, P.C., Willis, K.J., 1991. Quaternary refugia of north European trees. J. Biogeogr. 18, 103–115.

Binney, H., Edwards, M., Macias-Fauria, M., Lozhkin, A., Anderson, P., Kaplan, J.O., Andreev, A., Bezrukova, E., Blyakharchuk, T., Jankovska, V., Khazina, I., Krivonogov, S., Kremenetski, K., Nield, J., Novenko, E., Ryabogina, N., Solovieva, N., Willis, K., Zernitskaya, V., 2016. Vegetation of Eurasia from the last glacial maximum to present: key biogeographic patterns. Quat. Sci. Rev. 157, 80–97.

Boccaccio, G., 2021. The Salpetrian culture toward the end of the Solutrean around 23 ka cal BP in the Rhône Valley (France). Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.12.005.

Bocquet-Appel, J.P., Demars, P.Y., Noiret, L., Dobrowsky, D., 2005. Estimates of Upper Palaeolithic meta-population size in Europe from archaeological data. J. Archaeol. Sci. 32, 1656–1668.

Cascalheira, J., Alcaraz-Castaño, M., Alcolea-González, J., de Andrés-Herrero, M., Arrizabalaga, A., Aura Tortosa, J.E., Garcia-Ibaibarriaga, N., Iriarte-Chiapusso, M.-J., 2021. Paleoenvironments and human adaptations during the last glacial maximum in the iberian Peninsula: a review. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.08.005.

Clark, P.U., Dyke, A.S., Shakun, J.D., Carlson, A.E., Clark, J., Wohlfarth, B., Mitrovica, J.X., Hostetler, S.W., McCabe, A.M., 2009. The last glacial maximum. Science 325, 710–714.

CLIMAP Project Members, 1976. The Surface of the Ice-Age Earth. Quantitative geologic evidence is used to reconstruct boundary conditions for the climate 18,000 years ago. Science 191, 1131–1137.

CLIMAP Project Members, 1981. Seasonal reconstructions of the earth's surface at the last glacial maximum. Geol. Soc. Am. Mem. 145, 1–18.

Demay, L., Julien, M.A., Anghelinu, M., Shydlovskyi, P.S., Koulakovska, L.V., Péan, S., Stupak, D., Vasyliev, P.M., Obăda, T., Wojtal, P., Belyaeva, V.I., 2021. Study of human behaviors during the late Pleniglacial in the East European Plain through their relation to the animal world. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.10.047.

Demidenko, Y., 2018. Gravettian in the Great North Black Sea region in the context of East European upper palaeolithic. Stratum Plus 2018/1, 265–283.

Demidenko, Y.E., 2021. Upper paleolithic diversity in the south of eastern Europe around the last glacial maximum. Quat. Int. 581–582, 205–224. https://doi.org/10.1016/j.quaint.2020.07.002.

Ducasse, S., Chauvière, F.-X., Pétillon, J.-M., 2021. Breaking bad? Discarding the solutrean norms: chronology, evolution and geographical extent of the badegoulian phenomenon in western Europe. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.10.063.

Emery, A.R., Hodgson, D.M., Barlow, N.L.M., Carrivick, J.L., Cotterill, C.J., Phillips, E., 2019. Left high and dry: deglaciation of Dogger Bank, North Sea, recorded in proglacial lake evolution. Front. Earth Sci. 7.

Florineth, D., Schlüchter, C., 2000. Alpine evidence for atmospheric circulation patterns in Europe during the last glacial maximum. Quat. Res. 54, 295–308.

French, J., 2015. The demography of the Upper Palaeolithic hunter–gatherers of Southwestern France: a multi-proxy approach using archaeological data. J. Anthropol. Archaeol. 39, 193–209.

Fu, Q., Posth, C., Hajdinjak, M., Petr, M., Mallick, S., Fernandes, D., Furtwängler, A., Haak, W., Meyer, M., Mittnik, A., Nickel, B., Peltzer, A., Rohland, N., Slon, V., Talamo, S., Lazaridis, I., Lipson, M., Mathieson, I., Schiffels, S., Skoglund, P., Derevianko, A.P., Drozdov, N., Slavinsky, V., Tsybankov, A., Cremonesi, R.G., Mallegni, F., Gély, B., Vacca, E., Morales, M.R., Straus, L.G., Neugebauer-Maresch, C., Teschler-Nicola, M., Constantin, S., Moldovan, O.T., Benazzi, S., Peresani, M., Coppola, D., Lari, M., Ricci, S., Ronchitelli, A., Valentin, F., Thevenet, C., Wehrberger, K., Grigorescu, D., Rougier, H., Crevecoeur, I., Flas, D., Semal, P., Mannino, M.A., Cupillard, C., Bocherens, H., Conard, N.J., Harvati, K., Moiseyev, V., Drucker, D.G., Svoboda, J., Richards, M.P., Caramelli, D., Pinhasi, R., Kelso, J., Patterson, N., Krause, J., Pääbo, S., Reich, D., 2016. The genetic history of ice age Europe. Nature 534, 200–205.

Gamble, C., Soffer, O., 1990. The World at 18.000 BP. Unwin Hyman, London.

Grichuk, V.P., 1992. Main types of vegetation (ecosystems) for the maximum cooling of the last glaciation. In: Frenzel, B., Pecsi, M., Velichko, A.A. (Eds.), Atlas of Paleoclimates and Paleoenvironments of the Northern Hemisphere – Late Pleistocene – Holocene. Gustav Fischer Verlag, Stuttgart, pp. 123–124.

Heyman, J., Stroeven, A.P., Caffee, M.W., Hättestrand, C., Harbor, J.M., Li, Y., Alexanderson, H., Zhou, L., Hubbard, 2011. Palaeoglaciology of Bayan Har Shan, NE Tibetan Plateau: exposure ages reveal a missing LGM expansion. Quat. Sci. Rev. 30, 1988–2001.

Heyman, B.M., Heyman, J., Fickert, T., Harbor, J.M., 2013. Paleo-climate of the central European uplands during the last glacial maximum based on glacier mass-balance modeling. Quat. Res. 79, 49–54.

Hughes, P.D., Gibbard, P.L., 2015. A stratigraphical basis for the last glacial maximum (LGM). Quat. Int. 383, 174–185.

Hughes, P.D., Gibbard, P.L., Ehlers, J., 2013. Timing of glaciation during the last glacial cycle: evaluating the concept of a global 'Last Glacial Maximum' (LGM). Earth Sci. Rev. 125, 171–198.

Kageyama, M., Laîne, A., Abe-Ouchi, A., Braconnot, P., Cortijo, E., Crucifix, M., de Vernal, A., Guiot, J., Hewitt, C.D., Kitoh, A., Kucera, M., Marti, O., Ohgaito, R., Otto-Bliesner, B., Peltier, W.R., Rosell-Melé, A., Vettoretti, G., Weber, S.L., Yum, Y., MARGO Project Members, 2006. Last Glacial Maximum temperatures over the North Atlantic, Europe and western Siberia: a comparison between PMIP models, MARGO sea–surface temperatures and pollen-based reconstructions. Quat. Sci. Rev. 25, 2082–2102.

Klein, K., Wegener, C., Schmidt, I., Rostami, M., Ludwig, P., Ulbrich, S., Richter, J., Wenigerd, G.-C., Shao, Y., 2021. Human existence potential in Europe during the last glacial maximum. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.07.046.

Kretschmer, I., 2015. Demographische Untersuchungen zu Bevölkerungsdichten, Mobilität und Landnutzung im späten Jungpaläolithikum. KSPA 6. Marie Leidorf, Rahden.

Lambeck, K., Rouby, H., Purcell, A., Sun, Y., Sambridge, M., 2014. sea level and global ice volumes from the last glacial maximum to the holocene. Proc. Natl. Acad. Sci. Unit. States Am. 111, 15296–15303.

Lambert, F., Bigler, M., Steffensen, J.P., Hutterli, M., Fischer, H., 2012. Centennial mineral dust variability in high-resolution ice core data from Dome C, Antarctica. Clim. Past 8, 609–623.

Lindgren, A., Hugelius, G., Kuhry, P., Christensen, T.R., Vanderberghe, J., 2016. GIS-based maps and area estimates of northern hemisphere permafrost extent during the Last Glacial maximum. Permafr. Periglac. Process. 27, 6–16.

Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic $\delta^{18}O$ records. Paleoceanography 20, PA1003.

Lorenzen, E.D., Nogues-Bravo, D., Orlando, L., Weinstock, J., Binladen, J., Marske, K.A., Ugan, A., Borregaard, M., Gilbert, M.T.P., Nielsen, R., Ho, S.Y.W., Goebel, T., Graf, K.E., Byers, D., Stenderup, J.T., Rasmussen, M., Campos, P.F., Leonard, J.A., Koepfli, K.P., Froese, D., Zazula, G., Stafford, T.W., Aaris-Sorensen, K., Batra, P., Haywood, A.M., Singarayer, J.S., Valdes, P.J., Boeskorov, G., Burns, J.A., Davydov, S.P., Haile, J., Jenkins, D.L., Kosintsev, P., Kuznetsova, T., Lai, X.L., Martin, L.D., McDonald, H.G., Mol, D., Meldgaard, M., Munch, K., Stephan, E., Sablin, M., Sommer, R.S., Sipko, T., Scott, E., Suchard, M.A., Tikhonov, A., Willerslev, R., Wayne, R.K., Cooper, A., Hofreiter, M., Sher, A., Shapiro, B., Rahbek, C., Willerslev, E., 2011. Species-specific responses of Late Quaternary megafauna to climate and humans. Nature 479, 359–364.

Ludwig, P., Schaffernicht, E.J., Shao, Y., Pinto, J.G., 2016. Regional atmospheric circulation over Europe during the last glacial maximum and its links to precipitation. J. Geophys. Res.: Atmosphere 121, 2130–2145.

Ludwig, P., Gavrilov, M.B., Markovic, S.B., Ujvari, G., Lehmkuhl, F., 2021. Simulated regional dust cycle in the Carpathian basin and the Adriatic Sea region during the last glacial maximum. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.09.048.

Luetscher, M., Boch, R., Sodemann, H., Spötl, C., Cheng, H., Edwards, R.L., Frisia, S., Hof, F., Müller, W., 2015. North atlantic storm track changes during the last glacial maximum recorded by alpine speleothems. Nat. Commun. 6, 6344.

Maier, A., Lehmkuhl, F., Ludwig, P., Melles, M., Schmidt, I., Shao, Y., Zeeden, Ch, Zimmermann, A., 2016. Demographic estimates of hunter-gatherers during the Last Glacial Maximum in Europe against the background of palaeoenvironmental data. Quat. Int. 425, 49–61.

Maier, A., Zimmermann, A., 2017. Populations headed south? The Gravettian from a palaeodemographic point of view. Antiquity 91, 573–588.

Maier, A., Stojakowits, P., Mayr, C., Pfeifer, S., Preusser, F., Zolitschka, B., Anghelinu, M., Bobak, D., Duprat-Oualid, F., Einwögerer, T., Hambach, U., Händel, M., Kaminská, L., Kämpf, L., Łanczont, M., Lehmkuhl, F., Ludwig, P., Magyari, E.,

Mroczek, P., Nemergut, A., Nerudová, Z., Niţă, L., Polanská, M., Połtowicz-Bobak, M., Rius, D., Römer, W., Simon, U., Škrdla, P., Úivári, G., Veres, D., 2021. Cultural evolution and environmental change in Central Europe between 40.000 and 15.000 years ago. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.09.049.
Mayewski, P., Meeker, L.D., Twickler, M.S., Whitlow, S., Yang, Q., Prentice, M., 1997. Major features and forcing of high latitude northern hemisphere circulation using a 110000-year-long glaciochemical series. J. Geophys. Res. 102, 26345–26366.
Meyer, H.H., Kottmeier, C., 1989. Die atmosphärische Zirkulation in Europa im Hochglazial der Weichsel-Eiszeit – abgeleitet von Paläowind-Indikatoren und Modellsimulationen. Eiszeitalt. Ggw. 39, 10–18.
Mix, A.C., Bard, E., Schneider, R., 2001. Environmental processes of the ice age: land, oceans, glaciers (EPILOG). Quat. Sci. Rev. 20, 627–657.
Montet-White, A., 1994. Alternative interpretations of the late upper paleolithic in central Europe. Annu. Rev. Anthropol. 23, 483–508.
Nadachowski, A., Lipecki, G., Ratajczak, U., Stefaniak, K., Wojtal, P., 2015. Dispersal events of the saiga antelope (*Saiga tatarica*) in Central Europe in response to the climatic fluctuations in MIS 2 and the early part of MIS 1. Quat. Int. 420, 357–362.
Nerudová, Z., Neruda, P., Hamrozi, P., 2021. Statistical and geographical modelling of moravian (Czech republic) late upper palaeolithic occupation. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.07.003.
Pavelková Řičánková, V., Robovský, J., Riegert, J., 2014. Ecological structure of recent and last glacial mammalian faunas in northern Eurasia: the case of altai-sayan refugium. PloS One 9 (1), e85056.
Peresani, M., Monegato, G., Ravazzi, C., Bertola, S., Margaritora, D., Breda, M., Fontana, A., Fontana, F., Janković, I., Karavanic, I., Komšo, D., Mozzi, P., Pini, R., Furlanetto, G., Giovanni Maria De Amicis, M., Perhoč, Z., Posth, C., Ronchi, L., Rossato, S., Vukosavljević, N., Zerboni, A., 2021. Hunter-gatherers across the great adriatic-Po region during the last glacial maximum: environmental and cultural dynamics. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.10.007.
Polanská, M., 2021. Gravettian backed points from unit K11 of Dolní Věstonice II (south Moravia, Czech republic). Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.09.028.
Polanská, M., Hromadová, B., Sázelová, S., 2021. The upper and final gravettian in western Slovakia and Moravia. Different approaches, new questions. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.08.004.
Posth, C., Renaud, G., Mittnik, A., Drucker, D.G., Rougier, H., Cupillard, C., Valentin, F., Thevenet, C., Furtwängler, A., Wißing, C., Francken, M., Malina, M., Bolus, M., Lari, M., Gigli, E., Capecchi, G., Crevecoeur, I., Beauval, C., Flas, D., Germonpré, M., van der Plicht, J., Cottiaux, R., Gély, B., Ronchitelli, A., Wehrberger, K., Grigorescu, D., Svoboda, J., Semal, P., Caramelli, D., Bocherens, H., Harvati, K., Conard, N.J., Haak, W., Powell, A., Krause, J., 2016. Pleistocene mitochondrial genomes suggest a single major dispersal of non-africans and a late glacial population turnover in Europe. Curr. Biol. 26, 827–833.
Renssen, H., Kasse, E., Vandenberghe, J., Lorenz, S.J., 2007. Weichselian late pleniglacial surface winds over northwest and central Europe: a model-data comparison. J. Quat. Sci. 22, 281–293.
Reynolds, N., Riede, F., 2019. House of cards: cultural taxonomy and the study of the European Upper Palaeolithic. Antiquity, 371 and Related Papers, pp. 1350–1358.
Roebroeks, W., Mussi, M., Svoboda, J., Fennema, K. (Eds.), 2000. Hunters of the Golden Age: the Mid Upper Palaeolithic of Eurasia 30,000–20,000 BP. University of Leiden, Leiden, pp. 271–280.
Schneider von Deimling, T., Ganopolski, A., Held, H., Rahmstorf, S., 2006. How cold was the last glacial maximum? Geophys. Res. Lett. 33.
Sejrup, H.P., Nygård, A., Hall, A.M., Haflidason, H., 2009. Middle and late weichselian (devensian) glaciation history of south-western Norway, North Sea and eastern UK. Quat. Sci. Rev. 28, 370–380.
Škrdla, P., Vlach, M., Nejman, L., Bartík, J., Demidenko, J.E., Rychtaříková, T., 2021. Settlement strategies in eastern central Europe during the maximum extent of the last glacial ice sheet. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.09.047.
Sommer, R., Nadachowski, A., 2006. Glacial refugia of mammals in Europe: evidence from fossil records. Mamm Rev. 36, 251–265.
Sommer, R.S., Kalbe, J., Ekström, J., Benecke, N., Liljegren, R., 2014. Range dynamics of the reindeer in Europe during the last 25,000 years. J. Biogeogr. 41, 298–306.
Stewart, J.R., Lister, A.M., 2001. Cryptic northern refugia and the origins of the modern biota. Trends Ecol. Evol. 16, 608–613.
Strandberg, G., Brandefelt, J., Kjellström, E., Smith, B., 2011. High-resolution regional simulation of last glacial maximum climate in Europe. Tellus 63A, 107–125.
Stojakowits, P., Mayr, C., Ivy-Ochs, S., Preusser, F., Reitnerf, J.M., Spötl, C., 2021. Environments at the MIS3/2 transition in the northern Alps and their foreland. Quat. Int. 581–582. https://doi.org/10.1016/j.quaint.2020.08.003.
Svenning, J.C., Normand, S., Kageyama, M., 2008. Glacial refugia of temperate trees in Europe: insights from species distribution modelling. J. Ecol. 96, 1117–1127.
Svensson, A., Andersen, K.K., Bigler, M., Clausen, H.B., Dahl-Jensen, D., Davies, S.M., Johnsen, S.J., Muscheler, R., Rasmussen, S.O., Röthlisberger, R., Steffensen, J.P., Vinther, B.M., 2006. The Greenland ice core chronology 2005, 15-42 ka. Part 2: comparison to other records. Quat. Sci. Rev. 25, 3258–3267.
Taberlet, P., Cheddadi, R., 2002. Quaternary refugia and persistence of biodiversity. Science 297, 2009–2010.
Terberger, T., Street, M., 2002. Hiatus or continuity? New results for the question of pleniglacial settlement in central Europe. Antiquity 76 (291), 691–698.
Toucanne, S., Zaragosi, S., Bourillet, J.-F., Marieu, V., Cremer, M., Kageyama, M., Van Vliet-Lanoë, B., Eynaud, F., Turon, J.L., Gibbard, P.L., 2010. The first estimation of Fleuve Manche palaeoriver discharge during the last deglaciation: evidence for Fennoscandian ice sheet meltwater flow in the English Channel ca 20–18 ka ago. Earth Planet Sci. Lett. 290, 459–473.
Tzedakis, P.C., Emerson, B.C., Hewitt, G.M., 2013. Cryptic or mystic? Glacial tree refugia in northern Europe. Trends Ecol. Evol. 28, 696–704.
Willett, H.C., 1950. The general circulation at the last (würm) glacial maximum. Geogr. Ann. 32 (3–4), 179–187.
Willis, K.J., Rudner, E., Sümegi, P., 2000. The full-glacial forests of central and south-eastern Europe. Quat. Res. 53, 203–213.
Willis, K.J., Van Andel, T.H., 2004. Trees or no trees? The environments of central and eastern Europe during the last glaciation. Quat. Sci. Rev. 23, 2369–2387.
Yokoyama, Y., Esat, T.M., Thompson, W.G., Thomas, A.L., Webster, J.M., Miyairi, Y., Sawada, C., Aze, T., Matsuzaki, H., Okuno, J., Fallon, S., Braga, J.C., Humblet, M., Iryu, Y., Potts, D.C., Fujita, K., Suzuki, A., Kan, H., 2018. Rapid glaciation and a two-step sea level plunge into the Last Glacial Maximum. Nature 559, 603–607.

Andreas Maier*
Institute of Prehistoric Archaeology, University of Cologne, Cologne, Germany

Christoph Mayr
Institute of Geography, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Marco Peresani
Department of Human Studies, University of Ferrara, Ferrara, Italy

* Corresponding author.
E-mail address: a.maier@uni-koeln.de (A. Maier).