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Editorial

Holocene Environments, Human Subsistence and Adaptation in Northern and Eastern Eurasia

1. Background

From 11th to 15th February 2020 the Beijing Branch Office of the Eurasia Department, German Archaeological Institute (DAI), and the Institute of Geological Sciences, Freie Universität Berlin jointly hosted an international workshop in Berlin headlined 'Archaeology in Eurasia – Bridge Building to Natural Sciences'. The impetus for this was the launch of the DAI research program 'GROUNDCHECK – Cultural Heritage and Climate Change' which was designed to study past climate and societal dynamics in a global comparative perspective to provide applicable knowledge on long-term processes to understand current climate change and its manifold consequences and to support the safekeeping of cultural heritage (https://www.dainst.blog/groundcheck/about-groundcheck/). The Eurasia Department's project 'Food in a Changing World: Humans • Climate • Landscape in Northeast Asia' is part of this program. The workshop was its kick-off event and at the same time another brainstorming meeting of the now decade-long 'Bridging Eurasia' research initiative. Brought to life in 2010 this initiative informally unites and promotes a large number of young scholars from different disciplines striving for comparison of archaeological and environmental data on local to trans-regional scale to understand the deep linkages between human behaviour, natural resources, and climates. Already, two special issues of the journal Quaternary International and one volume in the journal The Holocene have originated from it (Spengler et al., 2016b; Wagner et al., 2014; Tarasov et al., 2013).

Against the backdrop of this broader programme, this particular workshop focused specifically on the Holocene period in northern and eastern Eurasia. In particular, the collection of speakers sought to explore the origins and impact of the East Asian crop repertoire, rice in the subtropical eastern Chinese floodplain and millet in the temperate zone further north. In both cases the exact areas and timing of domestication have not yet been determined with certainty (Fig. 1B). Several thresholds of anthropogenic impacts on Earth systems have been debated by different authors in Eurasia in the Holocene (Fig. 1B): enhanced human impact on natural environments in the form of agriculture since 11,700 cal yr BP (Ellis et al., 2021), a transition towards increased disturbance around 6000 cal yr BP, full transformation of the global environment by 3000 cal yr BP (Stephens et al., 2019), and the timeframe of the 'early anthropogenic hypothesis' with the start of enhanced emissions of CO_2 by 7000 cal yr BP and CH_4 by 5000 cal yr BP (Ruddiman, 2003; Ruddiman et al., 2020). The disagreement about the rate and timing of pre-industrial anthropogenic carbon emissions and whether they had an influence on Holocene climate trends (Ruddiman et al., 2020) stems from different assumptions for per-capita land use, degrees of land clearance, and/or population growth in early agricultural societies. With a long history of agriculture including the greenhouse gas emission intensive wet rice farming, eastern Eurasia plays a key role in providing more robust data.

Agricultural societies in the middle/lower Yellow River valley based mainly on the rainfed grain crops foxtail (*Setaria italica*) and broomcorn (*Panicum miliaceum*) millet spread across large parts of eastern Eurasia leading to a quasi-exponential population growth between 8000 and 4000 cal yr BP (Leipe et al., 2019). By contrast, it has been recently hypothesised that farmers in the lower Yangtze valley focused mainly on wet rice (*Oryza sativa*) cultivation were weakly expansive (Qin and Fuller, 2019), which challenges long-held views about the southward expansion of rice cultivation (Bellwood, 2005), but needs to be tested by further research. The merging of rice and millet cultivation, however, seems to have been key to a number of fundamental changes in eastern Eurasia: the formation of densely populated settlement clusters and ultimately state foundation, which caused major landscape transformations in the Yellow River catchment between 5000 and 4000 cal yr BP (Hosner et al., 2016); the spread of low-intensity mixed rice-millet farming to southern China and Southeast Asia by around 5000 cal yr BP (Deng et al., 2018; Fuller, 2020); and the emergence of the temperate phenotype of *japonica* rice, which likely evolved in the lower Yellow River basin around 4000 cal yr BP through natural genetic mutation or human-induced selection (Fuller et al., 2016). This genetic change promoted the spread of rice to other temperate regions such as the Korean peninsula around 3500 cal yr BP and parts of the Japanese archipelago around 3000 cal yr BP (Leipe et al., 2020). Until then the islands were inhabited by hunter-fisher-gatherer societies that at times had high settlement densities (e.g. Abe et al., 2016), and the question is to what extent they contributed to the transformation of the environment. The same applies to the northern boreal forest zone with cold continental climate where hunter-fisher-gatherer economies persisted into historic times.

These latter two areas are regions with a great research potential concerning the development of high-resolution reconstructions of climate parameters, assessment of vegetation and animal communities available to human societies and their ramifications for human-environment interactions, exploration of the temporal and spatial nature of the adoption of farming and herding, and the study of the formation and maintenance of trans-zonal Eurasian exchange networks. Our workshop gathered 30 junior and experienced senior scholars from Berlin, Hakodate, Irkutsk, Nagoya, Ningbo, Novosibirsk, Potsdam, Sankt Petersburg, Sapporo, Taipei, Ulan-Ude, Vladivostok, and Zürich specialised in the fields of archaeology and palaeoenvironmental sciences. The current special issue was launched as proceedings of the meeting and aims (1) to present current palaeoenvironmental and archaeological

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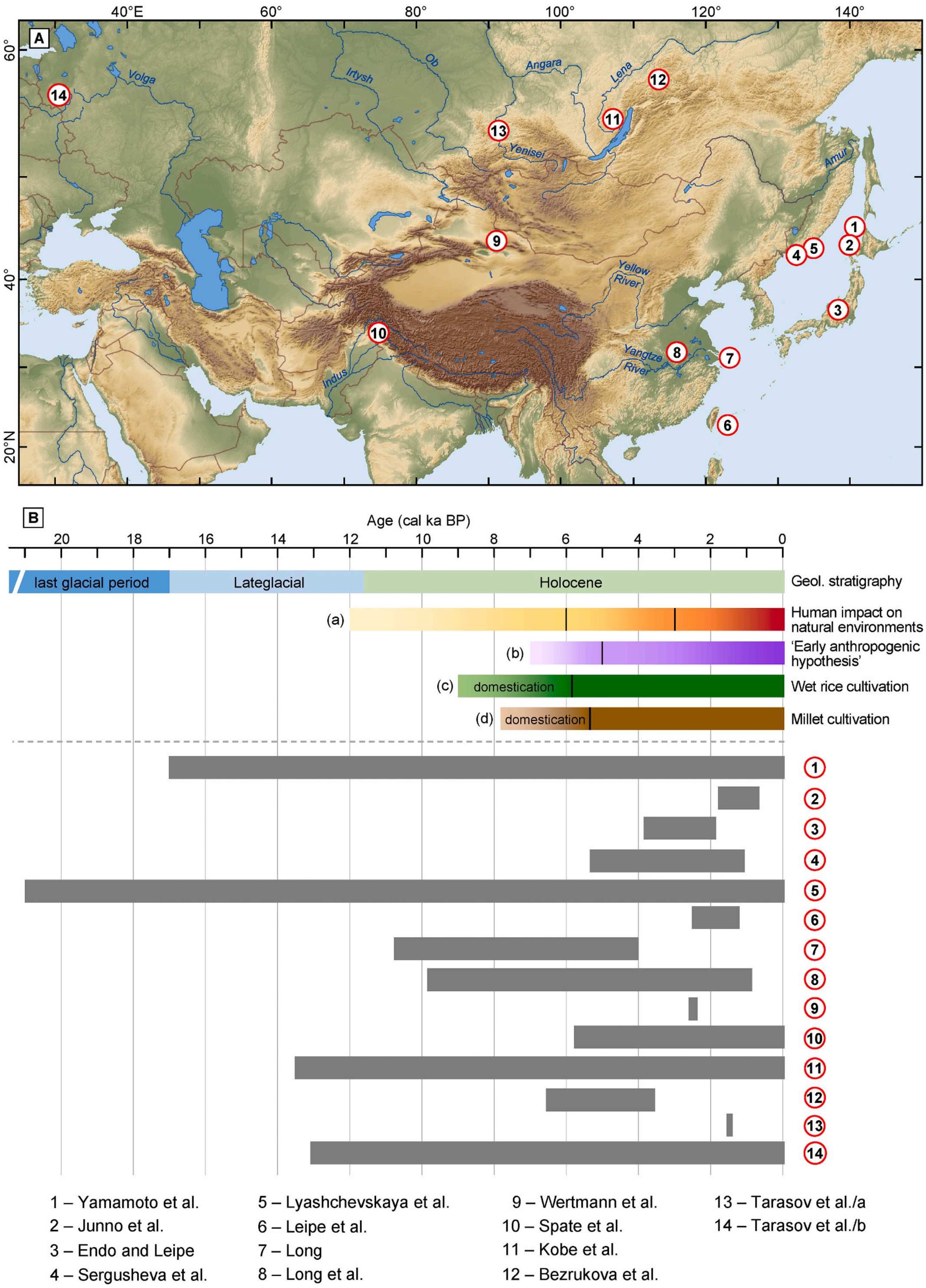

Fig. 1. (A) Topographic map showing the study site locations of the 14 papers contained in the special issue and (B) summary chart illustrating the chronologies of the 14 studies along with the geological stratigraphy; (a) enhanced human impact on natural environments since 12,000 cal yr BP (after Ellis et al., 2021) with two main transitions (black lines) towards increased disturbances around 6000 and 3000 cal yr BP (after Stephens et al., 2019); (b) the timeframe of the 'early anthropogenic hypothesis' with the start of enhanced CO_2 (7000 cal yr BP) and CH_4 (5000 cal yr BP) emissions (after Ruddiman, 2003; Ruddiman et al., 2020); and the chronologies of (c) wet rice and (d) millet cultivation in Eurasia with the suggested main domestication phases after Fuller (2020) for rice and Stevens et al. (2021) for millet.

case studies as well as regional data syntheses from different regions of Eurasia, with a particular focus on eastern Asian and the northern boreal zone, (2) to compare environmental and archaeological records in order to assess the changing nature of potential human-environment relationships across space and time, (3) to identify unresolved questions and gaps in the current knowledge about cultural and climate/environment histories, and (4) to stimulate new international cross-disciplinary collaborations to address these future research tasks. The 14 case studies or reviews are organised by study region. Their locations and chronologies, along with the associated geological stratigraphy and major cultural developments, are illustrated in Fig. 1.

2. Overview of reviews and case studies

2.1. Eastern Eurasia and adjacent southern region

The first five studies of the special issue focus on human-environment histories in different areas of the Sea of Japan region. The opening article by Yamamoto et al. (2022, this volume) presents records of biomarkers and pyrogenic compound in sediments from Lake Kushu on Rebun Island, northern Japan (Fig. 1, site 1). The data enabled the reconstruction of changes in limnology, the local environment, and local to regional fire activity during the last 17,000 years. The pyrogenic compound concentrations suggest phases or events of increased fire activities around the lake at about 6600–6000 cal yr BP and during the late 19th and early 20th century CE. While the latter is likely related to the activities of recent settlers who colonised the island, it remains unclear whether the Middle Holocene fires occurred naturally or were related to Jomon hunter-fisher-gatherer activities. The biomarkers suggest changes in limnological conditions and vegetation distribution, which are in line with palynological, sedimentary, and diatom records from the same lake. However, whether these changes were human-induced or natural remains a topic for future archaeological and paleoenvironmental studies. The investigation demonstrates the potential of the applied geochemical compounds, including polycyclic aromatic hydrocarbons (PAHs), pentacyclic triterpene methyl ethers (PTMEs), *n*-fatty acids, and glycerol dialkyl glycerol tetraethers (GDGTs), as proxies for reconstructing past environmental change, human activities, and their interrelation in future studies.

Junno et al. (2022, this volume) investigate the economy of the local populations at Kafukai Bay during a 1000-year sequence of Rebun's long hunter-fisher-gatherer history (Fig. 1, site 2). The authors conducted lipid residue analysis on sherds from 35 ceramic vessels recovered from pit houses at the Kafukai archaeological sites 1 and 2 representing the Susuya (ca. 1st–5th century CE), Okhotsk, and Satsumon (ca. 12th–13 century CE) occupation phases. The results show that vessel use of all cultural groups was focused on processing aquatic resources, reflecting the local maritime environment. However, lipid signatures also suggest differences in subsistence strategies. During the Okhotsk period, marine animal resources (fish and mammals) were of greater importance, as evidenced by contemporaneous zooarchaeological assemblages. By the Middle Okhotsk period (ca. 600–800 CE), the function of the vessels had diversified and the resources processed in the analysed pots comprised marine, anadromous, and terrestrial non-ruminant animal and terrestrial plants. These findings are in line with palaeoenvironmental records from Lake Kushu, which show a phase of enhanced deforestation at 640–715 CE, and the intensification of Okhotsk exchange activities during the 6th and 8th centuries CE, indicating increasing anthropogenic pressure on terrestrial and marine environments. The study underlines the great potential of lipid residue analyses for reconstructing subsistence economies of pottery-using prehistoric cultures.

Endo and Leipe (2022, this volume) present a review of early agriculture in Japan for which they collated the results of 225 studies on seed impressions in pot sherd assemblages from 182 archaeological sites across the islands Kyushu, Shikoku, and Honshu covering the Late/Final Jomon–Middle Yayoi period (ca. 2000–1 BCE) (Fig. 1, site 3). The aim was to study the spatio-temporal spread of cereal-based agriculture and crop preferences. The results show that rice, foxtail millet, and broomcorn millet were introduced to Japan as a package and first appeared in northern Kyushu during the Initial Yayoi period (ca. 800/700–500/400 BCE according to the existing pottery typology). However, a few seed impressions in Final Jomon (Tottaimon phase 1) pottery suggests that there was cultural influence or small-scale immigration from the Korean peninsula before the Initial Yayoi period, which is in agreement with ambiguous evidence for the existence of rice in the Central Highlands (central Honshu) in the 11th century BCE during the Final Jomon period (Leipe et al., 2020). Another key result is that the crops spread across the study region discontinuously, which corroborates the finding of a previous study on the spread of rice cultivation using Bayesian chronological modelling applied to a set of radiocarbon dates obtained from carbonised rice grains (Leipe et al., 2020). This discontinuous spread of agriculture, which has been also documented for other regions such as Europe (Bocquet-Appel et al., 2012), seems to be determined by a combination of cultural traits related to the heterogeneity of indigenous Jomon populations as well as environmental factors. A combination of cultural and environmental factors also seems to be responsible for the diverse pattern of crop preferences. One example is the preference for rainfed millet cultivation in the Central Highlands where Jomon populations were already familiar with plant cultivation (azuki and soy bean) and management (chestnut and acorn). This and the mountainous environment less suitable for wet rice cultivation are the most likely reasons for the millet preference by early local farmers. By contrast, rice-focused agriculture spread relatively quickly across western Japan, where Jomon population density was low and natural resources less rich, compared to eastern Japan. Another important finding is the absence of barley and wheat impressions, which challenges narratives based on ambiguous evidence about the use of these cereals during the Yayoi period.

The article by Sergusheva et al. (2022, this volume) is the first of two studies concerned with the human and environmental histories of the Primorye region in the southern Russian Far East (Fig. 1, site 4). The authors investigate the history of broomcorn and foxtail millet cultivation using a set of 27 radiocarbon dates of millet remains representing different cultural periods and a review of archaeological records (with particular focus on agricultural tools) from the archaeological sites/cultural layers from which the dated millet originate. The calibrated ages of the dated millet and the toolkit records provide robust evidence that the crops arrived in the study region in the early 3rd millennium BCE. Although there is ambiguous evidence for an earlier appearance of the crop in Primorye, i.e. during the second half of the 4th millennium BCE, the authors note that this needs to be verified by future archaeobotanical studies and direct dating. The available archaeological records indicate that millet was part of a cultural package introduced to Primorye by immigrating populations. Where these newcomers came from and what triggered their migration are important questions in the context of cultural dynamics during the Late Neolithic/Early Bronze Age period in East Asia. By examining population estimates based on archaeological site data for prehistoric China (Wagner et al., 2013; Hosner et al., 2016) as well as archaeological and palaeoenvironmental records from the wider study region, the authors lay out different scenarios for the spread of millet farmers to Primorye, involving a combination of intertwined climate (long-term drying in northern China and the eastern Eurasian steppe) and anthropogenic (population growth in Neolithic societies in northern China, advancing agropastoralists from the Eurasian steppes to northern China) factors. Important to note is that millet cultivation did not lead to a shift to full-scale agriculture in the study region, but remained part of a complex subsistence economy until the 1st millennium CE.

Lyashchevskaya et al. (2022, this volume) review and compare available palaeoenvironmental and archaeological records from the southern part of Primorye covering the last 21,000 years in order to identify possible relationships (Fig. 1, site 5). The authors find evidence that many of the reconstructed climate and environmental changes were accompanied by cultural transformations, for example in subsistence economies, migratory movements, population distribution and numbers. The onset of Middle Holocene maximum temperature and moisture conditions around 8500 cal yr BP was accompanied by the emergence and flourishing of the highly adaptive Neolithic Rudnaya, Vetka, and Boisman cultures. The latter was specialised in marine foraging, benefitting from rising sea temperatures, the formation of numerous warm shallow bays and lagoons, and the development of abundant marine food resources. From around 6400 cal yr BP, the study region experienced climate cooling and a decrease in sea level, resulting in the filling of shallow-water lagoons with sediments and peat accumulation in the coastal lowlands. This was accompanied by a fundamental change in the fishing strategy (shift from fishing in lagoons to fishing in the open sea) of the coastal Neolithic Boisman population. This change in the coastal environments likely led to documented conflicts that developed over competition for dwindling traditional marine food resources towards the end of this culture (ca. 6200 cal yr BP). Another connection may exist between the immigration of Zaisanovskaya cultural populations and the onset of cooler climate conditions from around 6000 cal yr BP. These newcomers probably originated from regions further west, where climate conditions were colder than in the maritime parts of the study region. Agriculture, which was introduced by the cultivation of broomcorn and foxtail millet during the Zaisanovskaya period (ca. 6000–3600 cal yr BP), diversified (growing number of cultivated crops, animal husbandry) and intensified from the beginning of the Late Holocene (ca. 4000 cal yr BP), which could also have been a response to progressive climate cooling. Although southern Primorye with its diverse maritime and continental landscapes and rich archaeological record is one of the best-studied regions in the Russian Far East, this study highlights the importance of additional research based on robustly dated and high-resolution environmental records and well-dated archaeological material to draw more definitive conclusions about the indicated causal relationships between climatic and environmental changes and prehistoric cultural dynamics.

Moving to Taiwan, the study composed by Leipe et al. (2022, this volume) is based on charred macrobotanical assemblages recovered from prehistoric cultural layers at the Sanbaopi 5 archaeological site in the south-west of the island (Fig. 1, site 6). The investigation, which is part of an island-wide first systematic case study of archaeological macrobotanical remains from an archaeological site, revealed that *Vigna angularis* var. *nipponensis*, a wild bean (Fabaceae) that was cultivated and domesticated (*V. angularis* var. *angularis*, commonly known as azuki or red bean) likely independently in prehistoric Japan, Korea, and China, was used in the study area between the first half of the 1st millennium BCE (Wushantou phase) and 6th century CE (Niaosong phase). Morphological analysis of the pulse records from Sanbaopi 5 suggests that they may have been selected for size increase and underwent domestication during this period. Regardless of whether the large-size *Vigna* present large wild forms, local domestication or introduced azuki, the records emphasise that local farmers did not solely rely on mixed millet-rice cultivation, but were engaged in a broad-spectrum food economy that also incorporated low-cost management/cultivation of pulses as well as hunting, fishing, and gathering. This suggests a prolonged history of less intensive crop cultivation at the study site with rice either grown in natural freshwater wetlands or rainfed, which corroborates the hypothesis that the spread of agriculture south of the Yangtze valley was mainly propelled by populations that practiced low-intensity non-irrigated farming.

Long (2022, this volume) addresses the Early–Middle Holocene cultural evolution in the lower Yangtze region (Fig. 1, site 7), which is the birthplace of *japonica*-type rice and was home to some of the oldest sedentary and full-scale agricultural societies in East Asia. In his paper, Long reviews the development of rice cultivation from the Shangshan (ca. 10,800–8600 cal yr BP), the first sedentary culture in this part of the world with the earliest evidence of rice exploitation, to the middle or late period of the Liangzhu culture (around 4600–4300 cal yr BP), which was characterised by full-scale agriculture based on the cultivation of wet rice with key domestication traits fixed. By synthesising sedimentary evidence, the author illustrates the different effects of global sea level rise on the development of the Hangzhou and Yangtze bay environments during the Early and Middle Holocene and concludes that this global climate-controlled process had a substantial impact on cultural trajectories in the study region. On the Ningshao Plain south of Hangzhou Bay, which was the homeland of early regional Neolithic societies, rising sea levels created unstable hydrological conditions as a consequence of higher exposure to marine influence. By contrast, after the sea level had become more stable around 7500–7000 cal yr BP, the Taihu Plain north of Hangzhou Bay became increasingly protected from marine influence by the progradation of the Yangtze Delta, which infilled and replaced the ancient Yangtze bay, providing an extensive wetland environment favourable for the development of the Majiabang, Songze, and Liangzhu cultures (ca. 7200–4000 cal yr BP) and the prolonged development of rice domestication/cultivation. Demonstrating the vulnerability of coastal zones to rising sea levels and its consequences to societies in the past, the study contributes to the identification of potential risks of current global warming and the urgent need for adaptation strategies.

Further elaborating on the topic of Asian rice, Long et al. (2022, this volume) focus on the chronology of the crop's origin and spread (Fig. 1, site 8). The authors compiled a database of published rice-related radiocarbon dates from Asia and Africa and assembled these dates through a Bayesian chronological model in order to provide a quantitative timeframe for early evidence of rice use from across the study region. The model estimates the beginning of rice exploitation in the lower Yangtze region at ca. 7430 BCE. Roughly one millennium later, rice exploitation started in the middle Yangtze and southern Huai River and Shandong (ca. 6680–6200 BCE). These regions may be regarded as early places of rice cultivation from which the plant spread as a mature crop (after the key domestication traits had been fixed) to south-eastern (ca. 3050 BCE) and south-western (ca. 2650 BCE) China and Southeast Asia (ca. 2190 BCE). The results corroborate genetic evidence that the southwestward spread of *japonica*-type rice led to its interbreeding with proto-*indica*-type rice on the Indian subcontinent, which had been exploited there since ca. 6460 BCE, resulting in the emergence of the *indica*-type and its enhanced use after ca. 2290 BCE. Drawing on archaeological site data from prehistoric China, the authors suggest that the spread of *japonica*-type rice from its homelands (lower and middle Yangtze, southern Huai River, and Shandong) was possibly driven by migrants who adopted a mixed rainfed millet-rice farming system, which was likely more extensive and expansive than wet rice-focused agriculture. This finding supports the hypothesis by Qin and Fuller (2019) that the early spread of rice cultivation was mainly driven by farmers practicing low-intensity rainfed farming. However, Long et al. plausibly note that more well-dated archaeobotanical data are needed to test this and competing scenarios.

Wertmann et al. (2022, this volume) examined a leather scale armour recovered from the Yanghai cemetery archaeological site located 43 km southeast of the present-day city Turfan in the north-eastern part of the Tarim basin in north-western China (Fig. 1, site 9). Thanks to the dry climate conditions, the ancient armour is excellently preserved and allows for detailed analyses of design, manufacture, and direct dating. Radiocarbon dating result places the armour into the first half of the 1st millennium BCE (786–543 cal yr BCE, 95% probability range). This chronology together with other records of military equipment used in prehistoric Eurasia suggest that the artefact originates in the Neo-Assyrian Empire. In this case, the exceptional armour find represents rare actual proof of West–East technological transfer across Eurasia during the 1st millennium BCE, a period since which long-distant exchange activities, socio-economic transformations, and human impact on the natural environment increased substantially (Stephens et al., 2019). In Eurasia, the main driving force for this new phase of Bronze Age globalisation was the expansion of agropastoralists with their livestock and diverse crop packages (e.g. Wagner et al., 2011; Spengler et al., 2016a; Tarasov et al., 2019) and horseback riding (Kelekna, 2009), which started to accelerate in the 2nd millennium BCE. The use of horses not only increased mobility and the radius of action, it also led to the development of chariotry and cavalry, which provoked a new era of warfare and the expansion of early states and empires. The Yanghai leather scale armour symbolises the dispersal of military technologies and is thus an impressive testimony of cross-Eurasian cultural connections during the early 1st millennium BCE.

The study by Spate et al. (2022, this volume) aims to better understand the cultural trajectories and changes in subsistence strategies in the Kashmir valley during ca. 5000–2000 cal yr BP (Fig. 1, site 10). To evaluate these developments from an environmental perspective, the authors present new palynological and sedimentological records from three different study sites in the Kashmir valley, which represent a substantial contribution to the still fragmentary regional palaeoenvironmental record. The results show that the study region was characterised by dry climate conditions between 4500 and 1500 cal yr BP, which was mainly driven by decreased winter precipitation due to weakened winter westerly disturbances. The authors propose that the documented diverse subsistence economy practiced by local groups since 4500 cal yr BP, including a suite of summer (broomcorn millet) and winter (barley, wheat) crops, enabled the maintenance of an agricultural lifestyle despite the long-term drying and cooling trend. During 3000–2000 cal yr BP, the economy was further broadened by pastoral adaptations. This diverse subsistence economy also shows that the Kashmir valley was integrated in a far-reaching exchange network with connections to East Asia, Central Asia, and the Indus valley region since the onset of agricultural practices around 4500 cal yr BP.

2.2. Northern Eurasia

The next three papers deal with climate variability, human activities and/or human-environment interactions in different parts of southern Siberia (Fig. 1, sites 11–13). Kobe et al. (2022, this volume) present an important contribution to the understanding of Holocene vegetation and climate dynamics in the Lake Baikal region of Eastern Siberia and address longstanding questions about spatial variations between Cis- and Trans-Baikal. The robustly dated high-resolution palynological record from Lake Ochaul in Cis-Baikal (Fig. 1, site 11) covering the last 13, 500 years shows that both long-term (millennial-scale) and short-term (centennial-scale) climate trends were mainly linked to North Atlantic climate forcing and that the regional vegetation reacted sensitively to these climate oscillations. Together with directly dated zooarchaeological remains from a camp site at the lakeshore, the environmental reconstructions shed new light on the so-called Middle Neolithic cultural hiatus proposed for Cis-Baikal during the Middle Neolithic (ca. 6660–6060 cal yr BP) and its causality (Tarasov et al., 2007; Weber, 2020). The archaeological data demonstrate that the cultural hiatus does not apply to all of Cis-Baikal and that humans continued living at least in some areas, such as the study region, which apparently offered favourable environmental conditions for large herbivores, and thus attractive prey for hunter-gatherers, as suggested by the pollen-based vegetation reconstructions. The study highlights the Lake Ochaul environmental archive and the adjacent archaeological site as an excellent place to study human-environment interactions over the past 30,000 years.

Bezrukova et al. (2022, this volume) present the first radiocarbon-dated palynological record spanning the last ca. 6600 years from a peat section in the lower Vitim River region on the Patom Plateau (Fig. 1, site 12). While the region is especially famous for its Upper Palaeolithic (ca. 50,000–14,000/10,000 cal yr BP) archaeological sites with rich cultural assemblages, it was also attractive for Mesolithic–Neolithic–Bronze Age (ca. 14,000/10,000–3000 cal yr BP) hunter-fisher-gatherers. However, we still know very little about the region's Late Pleistocene–Holocene climate and environmental history. The pollen record presented here not only demonstrates in detail the vegetation and climate developments during this period, but also provides evidence that they may have influenced cultural change in the study region. Archaeological records show that, unlike Cis-Baikal, there was no Middle Neolithic cultural hiatus (ca. 6660–6060 cal yr BP) in the lower Vitim River region, which may be related to the spread of Scots pine, which begun 600 years later than in the Lake Baikal region. The study represents an important stepping stone for further investigation of the role of climate and environmental changes on hunter-fisher-gatherer activities during the Holocene.

Tarasov et al. (2022a, this volume) examine the way of life of the Tashtyk culture, which flourished in the Minusinsk Basin in the upper reaches of the Yenisei (Fig. 1, site 13) between the 1st and 7th century CE, in relation to environmental conditions. Their study is based on assemblages of plant and animal remains from a spectacular, well-preserved grave of the Oglakhty burial ground. A dating approach based on 15 radiocarbon dates on different materials associated with the grave narrowed the probabilistic age range of its period of construction and use to ca. 250–300 CE. The archaeological record illustrates the connections of the local populations with other parts of Eurasia during the early 1st millennium CE. Besides goats, cattle, and horses, the most important component of the local Tashtyk people's economy were sheep, kept for their skin and wool, which reflects the sustained influence of the spread of woolly sheep from their region of origin in Mesopotamia (Breniquet and Michel, 2014) into Central Asia during the 2nd millennium BCE (Shishlina et al., 2020) and the suitability of the southern Siberian steppes for livestock farming. By keeping domesticated horses, the local Tashtyk people were able to maintain long-distant exchange relations with silk production centres in eastern China via either oases-states in the Tarim and Turfan basins or via the Mongolian steppes, as documented by polychrome *jin* silks from the studied grave. The authors find evidence that the thriving of the Tashtyk culture was paralleled by a weak trend towards wetter and warmer climate. However, the review of regional palaeoenvironmental records indicates that further research in this direction is needed to gain a better understanding of the Holocene climate and environmental evolution in southern Siberia.

The special issue concludes with the multidisciplinary study composed by Tarasov et al. (2022b, this volume) focusing on Central European Russia, the westernmost study region of the special issue (Fig. 1, site 14). It uses fossil pollen records and archaeological data to examine Lateglacial and Holocene changes in vegetation and human activities in the lowlands and hilly plains of the western part of Central European Russia. The outlined pollen data and pollen-based biome reconstructions from Lake Zhizhitskoye represent one of the best-dated continuous palaeoenvironmental record in the study region showing the thermal and moisture evolution for the last 13,000 years. The taiga-like patchy forests under humid conditions that dominated the Lateglacial between 13,000 and 11,650 cal yr BP were replaced by cool-temperate deciduous broad-leaved trees and shrubs, which prevailed until 8000 cal yr BP. Warmest conditions were recorded during the Middle Holocene (ca. 8000–4000 cal yr BP), which were followed by a cooler and wetter climate during the Late Holocene. The pollen data and biome scores also provide a record of regional deforestation activities, which intensified stepwise. After moderate disturbances during the Neolithic (ca. 5000–3000 cal yr BP) deforestation strengthened from ca. 2800 cal yr BP, indicating increasing demands for pasture and arable land as well as timber and firewood during the Iron Age. Further surges in deforestation activities are recorded at the 2nd half of the Iron Age (5th century BCE–5th century CE) and again from ca. 1200 cal yr BP after the onset of the Middle Ages. In addition, the timing of the decline of the Neolithic pile dwelling settlement at the lake around 3800 cal yr BP suggests that Neolithic populations, which lived in the region during the Middle Holocene, were affected by deteriorating climate conditions after ca. 4000 cal yr BP.

3. Conclusions

All 14 articles combine palaeoenvironmental with archaeological data to create new knowledge and thought-provoking conclusions. Six teams concentrated on the reconstruction of past climate and environmental changes; three articles focus on early grain crop dispersal, one on the use of beans, one on the use of aquatic resources, and one on the role of sheep and horse as well as wild plant and animal species in subsistence economies; one author relates long-term coastal changes to cultural development; and one team found proof of intense west-east

Eurasian exchange in goods and knowledge in the form of a scale armour made of animal hide, about the time when the globe's surface was already largely transformed by human impact. The studies employ a wide range of methods, including palynological, malacological and ostracod analyses, sedimentology and geomorphology, sediment geochemical, biomarker and pyrogenic compound analyses, analysis of lipid residues and seed impressions on pottery, archaeobotanical and zooarchaeological analyses, and radiocarbon dating as well as systematic synthesis of palaeoenvironmental and archaeological records and Bayesian chronological modelling. Through their work in different parts of northern and eastern Eurasia and the adjacent region to the south, the authors fostered long-standing research cooperation, but also initiated new interdisciplinary and multinational research activities. While the study results advance understanding about the evolution of human and environmental systems and their interrelation and thus contribute to current debates about the Anthropocene, they also set out vast knowledge gaps that remain to be addressed in future research. The historian William James Durant said in 1945 "It is a mistake to think that the past is dead. Nothing that has ever happened is quite without influence at this moment." (https://www.will-durant.com/invitation.htm, retrieved 5th February 2022). We hope that this special issue will encourage further interdisciplinary research to unravel the deep history of human-environment relations in Eurasia.

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The guest editors dedicate this special issue to Pavel E. Tarasov (Institute of Geological Sciences, Freie Universität Berlin), most reliable and always fair colleague, demanding mentor, and witty motivator, on the occasion of his forthcoming round birthday. With research ideas far ahead of his time, he urged and trusted us to bring the meeting and this volume to life. Thank you.

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