Ann. Naturhist. Mus. Wien, Serie A	122	45–67	Wien, 31 Jan. 2022

Gravettian Sites in Moravia (Czech Republic) from a Natural Science Perspective

Rudolf Musil[1]

(with 9 figures)

Manuscript submitted on June 17th 2019,
the revised manuscript on August 25th 2019.

Abstract

Moravia is the central part of the region between the Danube and Southern Poland, which was settled by the people of the Gravettian Culture in the years 35–24/25 ka cal. BP. The Gravettian was a society of people with a high culture level based on successful animal hunting. This allowed to set aside some of the population from animal hunting and gave time for other activities. There existed a primitive division of labour. The basis for this was undoubtedly a well organized life for the entire society. A certain differentiation of their settlements also came about in Moravia. One can find there not only central settlements with a high living standard and culture but also long-term hunting settlements and short-term hunting stations. The end of the Gravettian Culture was linked with the great climatic change (LGM), which lead to the end of the existing ecosystem and consequently also to the loss of the economic basis. From my point of view, this culture disappeared fairly quickly.

Keywords: Moravia, Gravettian, sources of raw material, environment, requirements of herbivores, economics, terminal Gravettian.

Introduction

Gravettian sites in Moravia differ greatly from the surrounding areas in terms of their numbers within a fairly small territory. Major differences can also be found in the level of culture of its inhabitants. Significant attention was, therefore, paid to it from varying scientific perspectives, be they archaeological or natural science. Increased attention was focused, first and foremost, on the most important sites of Dolní Věstonice-Pavlov and Předmostí about which dozens of articles have been published with various specialised focuses. Systematic research on them began at the end of the 19th century and is continuing to the present. This article attempts to analyse the issues of these sites from a different perspective than has usually been the case with monothematic focused works.

[1] Masaryk University, Faculty of Natural Sciences, Institute of Geological Sciences, Kotlářská 2, 61137 Brno, Czech Republic; e-mail: rudolf@sci.muni.cz

Methods

The article makes use not only of a number of already presented conclusions from my previous publications but also of publications by other authors from various scientific disciplines which concern the time period of Gravettian sites in Moravia (Czech Republic). Their concrete, at time even descriptive, level was used for theoretical considerations concerning the life and culture of the Gravettian people and the organization of their activities.

Abbreviations and explanatory notes

The maps of each site are unscaled. Strong lines (arrows) mean the great influx of raw materials, the weak the opposite one.

GCM – Global Climatic Model

RCM – Regional Climatic Model

LCM – Local Climatic Model

LGM – Last Glacial Maximum

MNI – Minimum number of individuals

Geographical distribution of the Gravettian sites

There is no more telling evidence of the large amount of animals in Moravia at the time of Gravettian Culture than the remarkably vast number of Gravettian settlements (Oliva 2007). These were, on the one hand, the settlements under the Pavlov Hills (Dolní Věstonice, Pavlov, Milovice), and, on the other hand, a huge settlement in Central Moravia, Předmostí. These sites are completely different from the usual settlements known from this time period. We also know from this territory a large number of small settlements or hunting camps. If we include also sites where terrain research was not yet carried out and localities which only experienced collection work, there are 68 sites in total at present (Oliva 2007). This large number on such a small surface makes Moravia truly unique. Moravia had the greatest concentration of Gravettian sites in Central Europe.

Gravettian localities differ from one another significantly in terms of the extent, number, and importance of findings. The localities can be divided based on their importance into three types.

1. Central settlements with a great and organized development of the way of life and related cultural activities. They consisted of highly organized communities, in all probability with division of work. They differ from the other sites above all in long-term settlements, a high degree of specialisation in mammoth hunting (Musil 1968, 1997, 2005), a high degree of organisation of work, the transport of raw matrial from distant areas for the production of artefacts (Přichystal 2002; Verpoorte 2005; Bartošíková 2005), ceramic animals and human figurines (Klíma 1997; García Diez 1997, 2005a),

Fig. 1. Gravettian settlement under and around Pavlov Hills (Pavlov, Dolní Věstonice, and Milovice). The arrows point to the raw material source visited by people of the respective site. They mainly used glacial sediments (moraines) of southern Poland (flint) and silicates from the Krakow-Czenstochova Jurassic (two regions). In smaller quantities or rarely, raw materials from northern Moravia (glacial sediments), southern Moravia, Czech-Moravian Highlands, Cretaceous flints from Boskovická brázda, eastern Slovakia or from northern Hungary (ten regions) were found. Rocks from extremely distant areas (eastern Slovakia, Hungary) are only occasionally represented. The largest distance from Poland is 530 km, from eastern Slovakia or from northern Hungary 660 km. This reflects the multiple contacts of the settlement. Drawing by Andreas Kroh, using "Location map of Czechia and Slovakia" by NordNordWest (Wikimedia Commons, CC BY-SA 3.0 de) as base map.

textile products (canvas) (Soffer & Vandiver 2005; Adovasio *et al.* 2005), and artistic decorative objects (García Diez 2005b).

A group of long-term settlements under the Pavlov Hills are part of this category in Moravia (Dolní Věstonice, Pavlov, Milovice) and in Central Moravia (Předmostí).

2. At long-term hunting sites with signs of stone tool production and the remains of hunted game, there are only few remains of the above-mentioned activities. They never achieve the level of the central settlements. Examples are Ostrava-Petřkovice (Landek), Napajedla I, Jarošov II (Podvršťa), and Boršice I (Chrástka).

3. Short-term hunting stations where the main activity was only hunting of animals and the production of tools.

Fig. 2. Předmostí and the areas of raw material supply. The situation is very similar to Dolní Věstonice and Pavlov, but not in every respect. A large amount of raw materials for the production of artefacts comes, similar to Dolní Věstonice and Pavlov, from glacial sediments of southern Poland (flint) and unlike Pavlov's from the Krakow-Czestochova (Jurassic silicates). A large amount of radiolarian rock from the White Carpathians (the nearest suitable raw material) (two regions). In smaller quantities or rarely, raw materials from Czech-Moravian Highlands, Krumlov, eastern Slovakia, and eastern Hungary (seven regions) occur. The largest distance from Poland is 430 km, from eastern Slovakia or from northern Hungary 490 km. All other Gravettian sites of Moravia have not reached the significance of Dolní Věstonice-Pavlov and Předmostí. Drawing by Andreas Kroh, using "Location map of Czechia and Slovakia" by NordNordWest (Wikimedia Commons, CC BY-SA 3.0 de) as base map.

An examination of the regional distribution of the Gravettian localities serves to indicate that their dispersion was not uniform, but that they were concentrated only around larger watercourses, first and foremost, along both banks of the Morava and Dyje rivers. This is not a random aspect of course.

The above-mentioned distinctions are mainly based on the number of artefacts and faunal remains as well as the diversity of documented activities. Another approach is based on the subsistence strategies of hunter-gatherer groups using central settlements or basecamps for a longer period of the year complemented by different sorts of satellite camps like hunting stations, places for raw material procurement or collecting special fruits or plants. They differ essentially in settlement structures, variety of tools and variety of fauna, as well as the existence of waste disposals or desposits of different kinds (Pichler

Fig. 3. Spytihněv and Landek: As far as the Spytihněv site is concerned, the raw material comes to a large extent from glacial sediments of southern Poland (flint) (one region), only; a small amount from the White Carpathians (radiolarite rock) (one region). The small amount of raw material, from the site Landek was transported from southern Poland (glacial sediments, flint) and the White Carpathians (radiolarite rock) (two regions). The greatest distance to the Polish raw material sources from Spytihněv is 440 km, from Landek 290 km. Drawing by Andreas Kroh, using "Location map of Czechia and Slovakia" by NordNordWest (Wikimedia Commons, CC BY-SA 3.0 de) as base map.

1996; BINFORD 1980). Reconsidering the complete inventory of Moravian sites under this aspect would go beyond the scope of this work.

Raw material sources and transport routes

The seasonal migration of animals along paths between the north and south in the river valleys or between hilly country and lowlands around rivers also served as transport paths for human groups and for the import of raw material for the production of artefacts (MUSIL 2010a). According to SVOBODA (2001), between 60 % and 90 % of the raw material from the Gravettian sites in southern Moravia derived from Silesia. The collections of Absolon and Klíma from the Dolní Věstonice site contain about 84 % flint from moraine sediments (OLIVA 2007). The dominant rocks represented most frequently include flints from glacial sediments and silicates from the Krakow-Czestochova Jurassic (OLIVA 2007). These areas – located in southern Poland today – were the main source

Fig. 4. Napajedla: The raw material comes in large quantities from southern Poland (glacial sediments, flint) and from the Carpathians (radiolarian rock) (two regions). A small amount originates from Czech-Moravian Highlands, eastern Slovakia, and eastern Hungary (six regions). The raw material supply is very similar to Předmostí. The greatest distance of Napajedla site from Poland is 390 km and from Hungary 450 km. Drawing by Andreas Kroh, using "Location map of Czechia and Slovakia" by NordNordWest (Wikimedia Commons, CC BY-SA 3.0 de) as base map.

of raw materials used to produce artefacts. The largest raw material import from there was recorded in the following sites: Pavlov, Dolní Věstonice, Milovice, Předmostí, Spytihněv, Napajedla, Jarošov, Boršice, Mladeč, and Lechotice.

As far as northern silicates are concerned, glacial sediments from northern Moravia (Silesia) are made up of clayey-dusty sand with an insignificant share of psephitic fractions. The main source was the local rock from the vicinity of Opava, Hlučín and the Jeseníky Mountains. Glacial faceted pebbles of a northern origin come in a great variety of sizes and can be found at various localities in varying numbers. Their representation is always, however, extremely low in terms of domestic rocks and consists of only around 0.3–3 % (Gába 1972, 1977, 1980). This means that the glacial silicates (flint) in Gravettian localities do not come from the territory of northern Moravia, as is sometimes stated, but from Polish Silesia. In the case of the Krakow-Czestochova Jurassic, we are concerned with a primary source. Both source areas lie, however, far from the northern borders of Moravia.

Fig. 5. Jarošov: The main raw material were silicates from the Krakow-Czestochova Jurassic (silicate, one region). A small amount originates from southern Poland (glacial sediments, flint), the Czech-Moravian Highlands, eastern Slovakia and eastern Hungary (four regions). The greatest distance is similar for both Poland and Hungary (*ca*. 450–460 km). Drawing by Andreas Kroh, using "Location map of Czechia and Slovakia" by NordNordWest (Wikimedia Commons, CC BY-SA 3.0 de) as base map.

Rocks from local Moravian sources were also used but to a lesser extent. They come from primary localities (hornstones of the Krumlov, hornstones from Stránská Skála, hornstones from Litenčická pahorkatina, spiculites from the Cretaceous of Boskovická brázda, rock crystals from the Bohemian-Moravian Highlands, porcellanites from the vicinity of Uherské Hradiště, Zdislavice-Troubky hornstones, Olomučany hornstones, radiolarian rocks from the White Carpathians (Předmostí, Landek, Spytihněv, Napajedla, Boršice, Lechotice, Pohořelice) or from secondary deposits like gravels in river courses. Rocks from extremely distant areas (eastern Slovakia, northern Hungary: Dolní Věstonice-Pavlov, Předmostí, Napajedla, Jarošov) are also occasionally found in differing numbers, but primarily in smaller numbers (Oliva 2007).

The majority of raw material sources are in a distance of 430–440 km (Poland) from some Gravettian sites. However, the distance is even bigger from Eastern Slovakia or Hungary: 530–660 km.

Fig. 6. Boršice: Most of the raw materials were from southern Poland (glacial sediments, flint) (one region), and a smaller quantity from the White Carpathians (radiolarite rock) and the Czech-Moravian Highlands (two regions). The greatest distance from Poland is 460 km. Kůlna Cave: Only a small amount of material from southern Poland (glacial sediments, flint), the Czech-Moravian Highlands, and the near surroundings. Kůlna Cave is of minor importance during the Gravettian. Distance from Poland: 360–370 km. Drawing by Andreas Kroh, using "Location map of Czechia and Slovakia" by NordNordWest (Wikimedia Commons, CC BY-SA 3.0 de) as base map.

Views vary as to how the rocks found their way to the settlements for the production of artefacts. It is difficult to imagine that the hunters of the time would have repeatedly dragged these rocks from their source areas to their sites. In addition, the large settlements existed over the course of the entire year. Therefore, I do not believe that the entire group of Moravian localities was mobile as was the case with the locality Sowin in south-west Poland (Wisniewski *et al.* 2012). The intake of raw materials must have been well-organized and perhaps carried out by selected members of the group .

The topography of Moravia and its environment

The topography of Moravia is extremely varied with an alternation of lowlands, highlands, and relatively high mountains over short distances. The highlands run west-east and, therefore, form a kind of filter, making north-south or south-north migration of the

Fig. 7. Mladeč Cave: The main input of raw material comes from southern Poland (glacial sediments, flint) (one region). A small amount originates from the Czech-Moravian Highlands, from the White Carpathians (radiolarite rock), and from the surrounding regions (four regions). The greatest distance to raw material sources (southern Poland) is 310 km. Ostrožská Nová Ves: The small amount of raw material comes from southern Poland (glacial sediments, flint) and from the Krakow-Czestochova Jurassic (silicates) (two regions). The greatest distance from Ostrožská Nová Ves to the raw material sources is 400 km. Drawing by Andreas Kroh, using "Location map of Czechia and Slovakia" by NordNordWest (Wikimedia Commons, CC BY-SA 3.0 de) as base map.

fauna more difficult. Only the Moravian Gate enables the link of the southern Danubian and Polish regions. Moravia also provided a climatic transition between the always warmer and more arid Pannonian Basin and the Danube Region including southern Moravia and the colder and more humid lowlands of southern Poland.

The environment may be defined on the basis of several criteria. Two principal interconnected groups of factors can be recognized. There are above all physical factors such as landscape topography, the existence of watercourses, the amount of precipitation, processes of accumulation and denudation, thickness of snow cover, temperature conditions, and others. These physical factors are followed by biotic factors, including the vegetation and faunal communities. The perspective of only one discipline cannot explain, however, the complexity of the environment (MUSIL 2010a).

Fig. 8. Lechotice: Most of the raw material is from southern Poland (glacial sediments, flint) (one region) and a small amount from the White Carpathians (radiolarian rock) (one region). The greatest distance is 380 km. Drawing by Andreas Kroh, using "Location map of Czechia and Slovakia" by NordNordWest (Wikimedia Commons, CC BY-SA 3.0 de) as base map.

The climate of the studied region has always been influenced by two major gradients: the north-south gradient and the west-east gradient. The north-south gradient is interrupted by mountain barriers which divide this central part of Europe climatically (above all thermally) into two fractions, the north and the south. The west-east gradient also divides this area into two parts from a climatic point of view (predominantly precipitation). The increasing continentality of the climate from west to east alters the temperate and wet winters and cool summers in Western Europe into harsh winters and hot summers in the east. This is complemented by significant regional contrasts in height zoning (Musil 2011a).

There are several possible approaches to environmental analysis: the Global Climatic Model (GCM: 1st order changes), the Regional Climatic Model (RCM: 2nd order changes), and the Local Climatic Model (LCM: 3rd order changes) (Musil 2010a).

The mesoclimate (LCM) played the principal role in the study of the environment of sites. The extremely variable relief of Central Europe leads to considerable local differences. There are highlands and mountains of various sizes, as well as lowlands, which have a big influence on the special local situation.

Fig. 9. Pohořelice: The main input of raw material comes from the White Carpathians (radiolarite rock) (one region), a small amount from the Krakow-Czestochova Jurassic (silicates) and from nearby surrounding (two regions). The greatest distance from Pohořelice site to the raw material sources is 380 km. Pohořelice is the only site where the largest amount of raw material comes from the White Carpathians (radiolarite rock). Drawing by Andreas Kroh, using "Location map of Czechia and Slovakia" by NordNordWest (Wikimedia Commons, CC BY-SA 3.0 de) as base map.

The middle Pleniglacial had a relatively mild climate (VAN ANDEL 1998). The area of Moravia was not climatically uniform during the Gravettian, between 35 ka cal. BP up to 24/25 ka cal. BP. There was a cold and humid climate in the northern part, which is especially typical not only for northern Moravia but primarily for southern Poland. There was a warmer and more arid climate in southern Moravia. Southern Moravia, therefore, formed a single province along with the Danubian Region, while the northern part of Moravia was more similar to the southern part of Poland. This is also reflected in the different preservation of bones. The surface of the bones from northern Moravia with more abundant precipitation were covered or filled with calcium carbonate. The $CaCO_3$ crusts were up to 2 cm thick (MUSIL 2005). Several bones were often heavily weathered (Petřkovice). As far as teeth are concerned, only the enamel remains. This preservation indicates significant amounts of rainfall (VAN ANDEL & DAVIES 2003).

There were thus two climatic units, one comprising southern Moravia and northern Austria (Middle Danube Province, Province A) and another unit made up of northern

Moravia and southern Poland (Province B). Central Moravia consequently represented an intermediate unit (Musil 2008, 2010a).

The landscape of Moravia was highly differentiated in terms of its vegetation cover. There were coniferous forests with sporadic deciduous trees and marshy places in the valleys of the large watercourses (the Morava, Dyje, Svratka, and Bečva rivers) (Rybníčková & Rybníček 1991). There was open landscape with shrubs and isolated trees, sometimes with smaller woods and additionally a typical steppe, further from the river. The highest altitudes were barren and were the origin of the loess which occurs everywhere at lower altitude zones. A similar development of the landscape was described from other areas as well (Markova *et al*. 1995; Putshkov 1997; Lang 1994).

The Předmostí site was chosen as a model in Moravia. Předmostí was a particularly important place with regard to the migration of the fauna, being located in a distinct strategic position with two major south-north-running migration routes running from the Danube Region and continuing through the Moravian Gate as a single route to the broad lowlands of northern Europe. The length of the migration route connecting the Danube region and the Polish lowlands is more than 300 km.

Temperatures at Předmostí based on modelling indicate that there was a much larger difference between winter and summer temperatures than today. Then, winter temperatures were between −17.8 and −23.4 °C, the summer ones between 13.7 and 19.2 °C (Aiello & Wheeler 2003).

As far as altitude is concerned, three distinctly different environments can be distinguished. The fluvial plains of the Bečva River Valley, which is about 5 km wide and flanked by lowland and hilly relief, and the broad (about 10 km) fluvial plain of the Morava River are in close proximity to the Předmostí site. The floodplains along the rivers Bečva and Morava were covered by coniferous woodland. The vegetation changed from river valleys towards the highlands (with an altitude of about 300−500 m a.s.l.), initially probably into a landscape of a park character, then into steppe with sparse trees and shrubs. This zone, immediately adjacent to the gallery woodlands, was the main hunting ground for the people. The highest mountains were basically of no value for large animals and thus for human hunting (Musil 2008).

Ecological analysis of game indicates a high diversity of animal species. The animals lived both in the forest and in the open countryside. Hunting was, therefore, possible in two areas with differing plant cover. It was only of seasonal importance at intermediate altitudes of the highlands during the humid period, *i. e.*, in spring and to a lesser extent in the summer. From the viewpoint of human hunting only the river valleys were important all year around, but particularly so in the winter, when the animal herds from higher altitudes migrated into the forests around the rivers.

Hunting of animals was thus focused on animals occurring in low hilly uplands of a steppe character and also on those which gathered in the gallery forests in higher valleys all over the winter (Stewart *et al*. 2003).

The animals hunted at Předmostí can be divided according to their numbers into the following groups (Musil 2008):

1. Mammoths (MNI on the basis of most abundant bones, 72.05 %). Mammoths clearly predominated among the hunted species. The unusual quantity of mammoths was evoked by the occurrence of warm springs.

2. Wolves (MNI 7.42 %), foxes (MNI 6.92 %), and hares (MNI 6.20 %) were the second largest group of game animals. The preservation of wolf bones is quite different from that of the other animals. The bones are not broken open and parts of the skeletons or often the entire skeletons have been recovered in an anatomical order. They primarily provided fur and served as food only as an exception.

3. Reindeer (MNI 2.59 %) and bear (MNI 0.72 %): A conspicuously low number of hunted animals.

4. All the other species were hunted only occasionally: *Gulo gulo*, *Equus germanicus*, *Ursus arctos*, *Coelodonta antiquitatis*, *Megaloceros giganteus*, *Alces alces*, *Castor fiber*, *Crocuta crocuta spelaea*, *Panthera spelae* (*leo*?), *Panthera pardus*, *Bison priscus*, *Bos primigenius*, *Meles meles*, *Capreolus capreolus*, *Capra ibex*, and *Ovibos moschatus*. Microfauna: *Lemmus lemmus*, *Dicrostonyx torquatus*, and *Talpa europaea*.

Hunted species, based on my knowledge, can be divided into three groups. The first group of faunal remains were the main food base for the existence of people of that time. The individual sites were located in different environments and were not identical in time and, therefore, population density associated with the success of hunting was different. The second group includes species that normally did not serve as food apart from extraordinary periods of food shortage. In the third group there are species that have never served as food.

The environment and faunistic community of Dolní Věstonice, Pavlov, and Milovice by the Dyje River was very similar, if not identical to Předmostí.

Comparing recent biomes to those from the end of the Last Glacial, no exact analogy exists today and an approximation would need to consider a combination of several recent biomes. Out of these, one has to exclude tundra completely from the alluvial valleys. Regarding other biomes, the largest part of these would match the conditions of recent taiga and steppe landscapes.

The Last Glacial biome was thus completely different from recent ones, in all probability resembling the southern limit of the taiga with a transition through a sparse presence of deciduous trees to a landscape of a parkland character and consequently to steppe, the details being dependent upon the regional climate and the altitudinal zonality.

The same opinion is shared by Ložek (2002), having studied Pleistocene molluscs in detail. Based on this knowledge he writes that *"there is no recent analogy for the conditions in the Pleniglacial. The development of soils and the composition of the vegetation and fauna are extremely different from those under recent conditions in sub-polar regions, with which the environment of Central European glacial periods is frequently* *compared. The fossil gastropod fauna includes, for example, sub-arctic and arcto-alpic species, as well as several steppe species found at present in warm and dry zones of the temperate region. This indicates that conditions were much more favourable than those in the far north at present. For this reason, the use of terms such as 'loess steppe' and in particular 'tundra' in the description of the glacial environment describe ecosystems which are in fact only superficially similar to the recent steppe of Eurasia or the subpolar tundra."*

Food requirements of herbivores

The majority of the publications which deal with this period are concerned with the diversity of community. They calculate the findings of particular species, the number of bones found, and the number of individuals, but do not deal with the issue of their food requirements. I consequently attempt in this chapter to present the conditions under which species of herbivores could permanently live in the landscape. I present mammoths here as an example.

In order to obtain some idea of their food requirements, one has to first focus on elephants of today. The assumption, of course, is that their food requirements would be quite similar to mammoths.

The basic question of the existence of mammoths in a certain area is sufficient plant food, its composition, and most importantly the amount of energy which an elephant gains from it. An analysis of the stomach content of 700 elephants in Uganda has demonstrated that the food comes from 41 plant species (Krause 1998; Musil 1999). This means that elephants eat all the plant food which they come across, from grass to the branches of bushes and trees. The same was also demonstrated in an analysis of undigested food in the stomachs of Siberian mammoth cadavers where only the kind of plants was different, consisting primarily of herbs (Musil 1999).

Elephants do not, however, digest all the food they eat and surprisingly not even half of it. They are equipped with a less effective digestive system than other herbivores. Adult individuals daily consume approximately 46 kg of plant matter (calculated as dry vegetable matter). One has to realize however, that the amount of food is not of the most importance, but its energy value. This, of course, differs significantly for various plants and primarily as its preservation is concerned.

Grass, which provides the primary food for mammoths outside the winter season, will serve as an example. The amount of protein in grass fluctuates over the course of the year from 3 % to 12 %, while the branches of bushes contain between 12 % and 18 %. These are consequently more important for the nourishment of animals.

The energy value of the main food (grass), differs over the course of a year. It is highest when the grass is green (*ca*. 12 %). If one leaves out the existing smaller areas in proximity to water, one has to assume there was only green grass in the spring months on the surface of the large steppe land. This would gradually dry out over the course of the following months without rainfall (continental climate) and the content of the protein would decrease by around half (6–7 %), wherein it would contain up to 31 % of indigestible fibre. During the summer, when it only consists of straw, it only has 2–3 % of protein and 32 % of indigestible fibre (Krause 1998). If mammoths had to subsist on only this kind of dry grass, it would be far below the level needed for a food minimum. Even with a full stomach the animal would be hungry. Therefore, the main factor for the stay of mammoths in the landscape would not merely be the amount of plant food and its seasonal production, but first and foremost its energy value. In addition, older female animals and their offspring, that is the herd, were affected most by these factors. They are less mobile than the solitary living male animals.

This means that the animals could graze on grassy steppe land, especially in the spring months. During the dry period they would consequently have to migrate to areas where the grass was always green or where bushes and trees grew, which is primarily in river valleys. On the basis of this knowledge, it has to be assumed that the river valleys with their food richness must have attracted an entire herd of mammoths during the dry season and in the winter months. The Gravettian localities were consequently usually located on the banks of river valleys.

So far, the focus has been exclusively on the food of animals. However, water is equally important for mammoths as food. They could only live in a certain area for a longer period if there was sufficient water. As fas as their daily demand is concerned, it varied based on the age of the animals and according to what food the animals lived on. It also depended on the temperature of the air. On average, however, one adult animal consumed 70–90 litres of water daily with green food. However, animals subsiding on dry food need much more. This would, of course, also be the case in the winter months. For this reason, there is a large number of hunted mammoths in the Gravettian settlement of Předmostí, where nearby warm water springs have occured until today. This was the easiest accessible source of water in the winter months.

Economic prosperity, an analysis and description

Knowledge of the environment is one of the basic foundation stones for reaching an understanding on the life of past communities based on the economic conditions, which is hunting, the number of individuals, and their function within the groups, on the possible organization of labour and in the level of their cultural life. Only after achieving this understanding, one can focus on the life of these people.

Economics is a science concerning the use of all possible resources and the intensity of husbandry. The economy of the Gravettian society is primarily based on hunting and on the use of everything which the hunted animal provides, further on sources of raw materials for production of tools and on plant growth. The task of economic behaviour is the attainment of maximum advantages for the life of the entire band of people with the minimum expense of resources. The more this is achieved, the more people can live in a group and the more it can be distributed. This essentially determines the level of living standard of the people. This involved not only the quantitative perspective, but first and foremost the qualitative perspective.

What are the prerequisites for an analysis of the living standard? One primarily proceeds from the assumption that economic behaviour in primitive cultures is strongly influenced by traditions. Only then the economic analysis can be devided into several sectors. The primary and basic economic sector is hunting. Of primary importance is the amount of living animals in the area which were suitable for hunting and its success. All previous studies indicate that the diversity of the fauna and the number of individuals was high at the time of the Gravettian Culture and numerous remains of bones demonstrate that hunting also must have been successful (Musil 1968, 1997, 2003, 2010b). This is the first, most important, and basic assumption for all further analysis. The measure of the "richness" of the hunting group is consequently the number of hunted animals over a short time.

The second economic sector is the quality of the exploitation of the prey. The hunted animal did not, of course, only serve as mere food. The preserved bones demonstrate that the people apparently utilised everything from the hunted animals which was possible at the time.

The third economic sector is consequently that which could be labelled as a superstructure where all remaining activities of the group could be arranged. I would in this case only proceed from the central localities of the Dolní Věstonice-Pavlov and Předmostí type as opposed to the smaller Gravettian sites.

At this point, in accordance with the above-mentioned criteria, I would like to perform an analysis of the living standard of the people of the Gravettian central settlements based on their labour activities.

1. Hunting of animals was so successful that it did not have to be the only activity for all people at the time. Consequently, not everyone had to participate in the hunt, but only a part of the population. The remaining part could dedicate themselves to other activities (Musil 1997). This could be considered the most important finding from these localities.

2. Both the basic activity as well as all other activities necessarily assumed a fairly high level of organization in the division of labour. Each individual or smaller group of people could not in any case do anything which they felt like.

3. Production of stone tools. If one leaves aside the number of smaller raw materials from local sources and the unique distant raw materials, not only the largest settlements have high consumption of raw materials for production of artefacts which come from distant sources (moraine of southern Poland, the Krakow-Czestochova, Jurassic). This does not consist of tens of kilograms, but actually of hundreds of kilograms which were transported over major distances. Research from the Pavlov I site in 1957 demonstrated that 2,000 pieces of silicates came from an area of 4 m^2 and 38,823 chipped artefacts

from an overall excavation surface of 120 m^2 (KLÍMA 1959). It is impossible that such a large amount could find its way to this locality only by diffusion amongst people. It also cannot be assumed that the entire hunting group would leave for the field where the raw materials were located and consequently returned back with them to their original place. The sites were actually inhabited year-round. Therefore, certain members of the hunting group must have been chosen for the systematic transport of raw materials and the eventual seeking out of new fields.

4. A large number of various products from bone, primarily from mammoths as well as from other hunted animals, were found in the cultural layer. 88 products from bone, 26 from antlers, and 68 from mammoth tusk are listed by KLÍMA (1997) from the research of Pavlov I in the year 1957 alone. 40 decorative and artistic objects were found in total, along with 36 pendants from perforated teeth of foxes, wolves and horses. There were 35 uses of snails and bivalves in total. A number of similar findings was also published by GARCIA DIEZ (2005a, 2005b) and HLADILOVÁ (2005). This brief list indicates that a large number of art objects were discovered in the cultural layer.

It is improbable that all members of the settlement would have contributed to the production, but only those who were able to produce these objects. In the light of the solid provision of food from hunting, it can be assumed that these members could have been excluded from other work responsibilies.

5. The found ceramic, actually the first in the Palaeolithic cultures, is of course not utilitarian. The typological study of the collection from Dolní Věstonice and Pavlov (3,113 objects) demonstrated that it can be divided into groups of non-figurative (98 %) and figurative (anthropomorphic, zoomorphic and anthropomorphic or zoomorphic objects) (SOFFER & VANDIVER 1997). The same conclusion as with the previous number can be applied to this group.

6. Negative prints (91 objects) on baked clayey fragments reminiscent of textile are described by ADOVASIO *et al*. (1997) from Pavlov I. In their view, one can distinguish between two different technological methods. Some of them are referred to as textile prints and the second are more reminiscent of ropes. If this is the case, these consist of the oldest findings of this kind in the world. The conclusion is the same as with the previous two groups.

One could continue further with the list of additional working activities. Only one thing arises, however, from the above-mentioned. The solid economic situation linked with the larger number of members of the settlement, allowed choosing certain members depending on their abilities from hunting and assigning them to different tasks. This meant that a division of labour came about, wherein not everyone did the same thing. All of this required a fairly high organization of the life of the group, without which this division of labour could not exist. At the same time, specialisation in a particular work not only meant increased productivity but also the possibility of new discoveries.

There is a huge difference between the economic prosperity of large Gravettian settlements in Moravia in comparison with the previous and even the following Palaeolithic cultures. None of them can compare with what can be determined in Gravettian Culture. The division of labour led to a specialisation of subjects based on various branches of activity. Any kind of specialisation leads, however, to an emphasis and to an increase in the overall level of life and culture.

The Gravettian period lasted in Moravia *ca*. 9,000 years and was marked not only by a high living standard but also by a relatively high level of culture, which never existed before or after this period. Around 30 ka cal. BP the Pavlovian way of life came to an end, which some authors interpret by a shift of big base camps further to the East and changes in settlement structures due to climatic changes (Otte 1993; Escutenaire *et al.* 1999).

Substantial climate change – LGM. The demise of Gravettian sites in Moravia

The LGM (24.6–19 ka BP, 28.6–22.5 ka cal. BP, GS 4-2.1) led to significant changes, to cooling and initially to increased aridity, which was then replaced by greater precipitation. The first period with high precipitation occurred during the final stage of the existence of Gravettian sites (Dolní Věstonice). The period between 25–23 ka cal. BP represents the coldest time of the Last Glacial (van Andel 2003; van Andel & Davies 2003; Barron *et al*. 2003).

As early as the beginning of the LGM, during this period, and primarily after it, essential changes in the environment occured, which not only led to a reduction of faunal species diversity, but also to essentially decreased numbers of representatives of particular species. Environmental changes did not by any means consist of a mere decrease in average temperatures, since these temperature changes were not essential for the lives of an entire range of animals (mammoths, reindeer, and other animals used to an Arctic climate), but it mainly consisted of changes in distribution and composition of plant species.

The majority of the hunted animals were herbivores. The decrease in temperature could not in any way manifest itself on the grass cover of the steppe as it always remained the same. The only thing that could actually have changed would have been the forests along the watercourses, which were important for herbivores not only during the summer but mostly in the winter months. In Moravia its essential restriction must have come about with the reduction of this food base during the unfavourable months. In my opinion the coniferous forests around the watercourses ceased to exist or were so decreased in size that it necessarily led to the migration of certain species, primarily mammoths, into more favourable areas. All these factors caused a major reduction in the number of herbivores and thus a decline in the number of animals available for hunting.

The hunting society would only have prospered if the number of animals available for hunting and living in the vicinity of the settlements was large. The economic foundation of the Gravettian people was primarily provided by mammoths, together with a number of other animals of medium size. The declining number of mammoths specifically provided far less food. This indicates a relatively narrow subsistence base. The reduction of animals had an impact on the economic base and was possibly one of the factors responsible for the abandonment of the settlements. The Kostenki-Willendorf phase of the Gravettian ended around 24–25 ka cal. BP (Nerudová & Neruda 2015).

The Austrian locality of Grubgraben (Epigravettien), which is located relatively close to the Moravian border, provides the most complete information concerning the sudden change in the environment after the demise of Gravettian Culture. In terms of time, the site of Grubgraben belongs to the period prior to 18,400 ±330 uncal. BP and 18,960±290 uncal. BP (Haesaerts 1990). Four figures from Brandtner (1996) also confirmed this time period: 18,380 ± 130 uncal. BP to 19,380 ± 90 uncal. BP. Palaeobotanical conclusions indicate that there existed an open steppe landscape where *Pinus cembra* prevailed. Haesaerts (1990) assumes a cold and pronouncedly arid climate. This is also demonstrated by the composition of the hunted animals. The composition of the Grubgraben fauna is completely different from that at the Gravettian sites (Musil 2002). Of most interest, however, is that there is a complete lack of typically northern species (see Musil 2018) which would not have been affected by the cooling down. Certain additional causes apparently existed, of which we still know nothing about.

The following species were found (Haesaerts 1990; Logan 1990; Musil 2002): the main hunted animals were reindeer (MNI *ca.* 73 %) and horses (MNI *ca.* 22 %). Another highly represented species was the ibex (MNI 2.4 %). All of the other species were only occasionally present: aurochs (several teeth), artic fox (lower jaw and several canine teeth), in all probability wolverine (one bone), mammoth (a small fragment of tusk from a young animal, apparently from a carcass), brown bear, hare, and birds.

Concerning composition, it actually corresponded more to the hunted animals of the Moravian Magdalenian sites. The differences in the spectrum of game between the Epigravettian and the Magdalenian groups is clearly visible in the inventories of Brno-Štýřice (Epigravettian) with mainly mammoth and Balcarka Cave (Magdalenian) with mainly reindeer. The time span between the two sites is only 300 years. This shows that Epigravettian and Magdalenian groups existed in rapid succession, each of them using different resources and territories (Nerudová & Neruda 2015).

Discussion and conclusion

Based on my studies (Musil 1999, 2000, 2008, 2010a, 2011a, 2011b), I conclude that a high differentiation of temperatures and in terms of the amount of rain existed in Central Europe at the time of the Gravettian Culture (35–24/25 ka cal. BP). The climate was fairly oceanic at this time in the European west, but generally arid in the east. In Moravia the amount of precipitation decreased from north to south.

The landscape of Moravia was highly differentiated in terms of vegetation cover. There were only coniferous forests with sporadic deciduous trees in the river valleys and an open steppe landscape with shrubs and isolated trees further from the river. The highest places were without vegetation cover.

River valleys were important for herbivorous animals throughout the year, particularly in winter. The majority of the Gravettian settlements are consequently located on slopes around rivers.

Moravia consisted of a unified Gravettian area along with the Danube Region and southern Poland. Moravia was at the same time a central region. This fact deserves a comprehensive analysis from the perspective of all Gravettian sites from the entire territory.

In the same way that we currently distinguish between various sizes and various cultural levels of settlement (capitals, cities, towns, and villages), we can also see the beginning of something similar at the time of the Gravettian (central settlements, more long-term hunting settlements, and short-term hunting stations).

There is clear evidence for permanent transport of rock in the majority of settlements from the glacial sediments of southern Poland and from the Krakow-Czestochova Jurassic. The quantity of imported rocks at the localities did not actually depend on the distance. There does not exist a one-time transfer of these raw materials but a continuous transfer throughout the entire period of the existence of the sites. The transfers had to have been well-organized and were performed in all probability by groups of people who were selected only for this activity.

The central settlements (the settlements under Pavlov Hills, Předmostí) attained an unprecedented cultural height as can be seen from the entire range of completely new and first-time appearing objects (ceramics, weaving). It was in this respect essentially distinct from the previous Palaeolithic culture and to a certain extent also from the following Palaeolithic culture. This way of life is also linked with the need for a certain organization and with the greatest probability this is manifested in the beginning of the division of labour.

References

Adovasio, J.M., Hyland, D.C. & Soffer, O. (1997): Textiles and cordage: A preliminary assessment. Pavlov I – Northwest. – The Dolní Věstonice Studies, **4**: 403–442.

Aiello, L.C. & Wheeler, P. (2003): Neanderthals thermoregulation and the glacial climate. – In: van Andel, T.H. & Davies, W. (eds): Neanderthals and modern humans in the European landscape during the last glaciation: Archaeological results of the Stage 3 Project. – pp. 147–166, Cambridge (McDonald Institute).

Barron, E., van Andel, T.H. & Pollard, H. (2003): Glacial Environments II. Reconstructing the Climate of Europe in the Last Glaciation. – In: van Andel, T.H. & Davies, W. (eds): Neanderthals and modern humans in the European landscape during the last glaciation: Archaeological results of the Stage 3 Project. – pp. 57–78, Cambridge (McDonald Institute).

Bartošíková, Z. (2005): Lithic assemblage of the southeastern periphery (1957, 1970, 1971). – The Dolní Věstonice Studies, **14**: 112–133.

BINFORD, L.R. (1980): Willow smoke and dog's tails: Hunter-gatherer settlement systems and archaeological site formation. – American Antiquity, **45**: 4–20.

BRANDTNER, F. (1996): Zur geostratigraphischen und kulturellen Zuordnung der Paläolithstation Grubgraben bei Kammern, NO. – Spisy Archeologického Ústavu AV ČR Brno, **5**: 121–145.

ESCUTENAIRE, C., KOZLOWSKI, J., SITLIVY V. & SOBCZYK K. (1999): Les Chasseurs de Mammouths de la Vallée de la Vistule. Krakow-Spadzista B, un Site Gravettien à amass d´Ossements de Mammouths. (Monographie de Préhistoire Générale, 4). – 100 pp., Brussels (Musées Royaux d'Art et d'Histoire et Université).

GÁBA, M. (1972): Příspěvek k poznání ledovcem transportovaných pazourků. – Zprávy Vlastivědného ústavu v Olomouci, **157**: 16–17.

GÁBA, M. (1977): Petrografie ledovcových soukvů jesenické oblasti ve Slezsku. – Práce odboru přír, věd Vlastivědného ústavu v Olomouci, **30**: 1–38.

GÁBA, M. (1980): Nové poznatky o rýhování souvků pevninského zalednění v kvartéru ČSSR. – Geologický průzkum, **22**/4: 118–119.

GARCÍA DIEZ, M. (2005a): Decorative patterns on the organic objects. – The Dolní Věstonice Studies, **14**: 309–373.

GARCÍA DIEZ, M (2005b): Catalogue of worked ceramic pieces. – The Dolní Věstonice Studies, **14**: 399–431.

HAESAERTS, P. (1990): Stratigraphy of the Grubgraben loess sequence. – In: MONTET-WHITE, A. & HAESAERTS, P. (eds): Epigravettian Site of Grubgraben, Lower Austria. The 1986–1987 Excavations. – Études et Recherches Archéologiques de l'Université de Liège, **40**: 15–36.

HLADILOVÁ, Š. (2005): Tertiary fossils, especially molluscs. – The Dolní Věstonice Studies, **14**: 374–390.

KLÍMA, B. (1959): Objev paleolitického pohřbu v Pavlově. – Archeologické rozhledy, **11**: 305–316.

KLÍMA, B. (1997): Die Knochenindustrie, Zier- und Kunstgegenstände (Bone industry, decorative objects, and art). – In: SCOVODA, J.P. (ed.): Pavlov I – Northwest. The Upper Paleolithic burial and its settlement context. – The Dolní Věstonice Studies, **4**: 227–286.

KRAUSE, H. (1998): The Mammoth and the Food. – 739 pp., New Delhi (Indira Printers).

LANG, G. (1994): Quartäre Vegetationsgeschichte Europas, Methoden und Ergebnisse. – 461 pp., Stuttgart (G. Fischer Verlag).

LOGAN, B. (1990): Analysis of the faunal Material. – In: MONTET-WHITE, A. & HAESAERTS, P. (eds): Epigravettian Site of Grubgraben, Lower Austria. The 1986–1987 Excavations. – Études et Recherches Archéologiques de l'Université de Liège, **40**: 65–92.

LOŽEK, V. (2002): Vývoj přírody a podnebí. – In: SVOBODA, J., HAVLIČEK, P., LOŽEK, V., MACOUN, J. MUSIL, R., PŘICHYSTAL, A., SVOBODOVÁ H. & VLČEK, E. (eds): Palaeolit Moravy a Slezska (Paleolithic of Moravia and Silesia). – The Dolní Věstonice Studies, **8**: 38–47.

MARKOVA, A.K., SMIRNOV, N.G., KOZHARINOV, A.V., KAZANTSEVA, N.E., SIMAKOVA, N. & KITAEV, L.M. (1995): Late Pleistocene distribution and diversity of mammals in northern Eurasia. – Paleontologia i Evolucio, **28–29**: 5–134.

MUSIL, R. (1968): Die Mammutmolaren von Předmostí (ČSSR). – Paläontologische Abhandlungen, Abt. A., Paläozoologie, **3**/1: 1–191.

Musil, R. (1997): Hunting Game Analysis. – In: Scovoda, J.P. (ed.): Pavlov I – Northwest. The Upper Paleolithic burial and its settlement context. – The Dolní Věstonice Studies, **4**: 443–468.

Musil, R. (1999): Životní prostředí v posledním glaciálu na území Moravy. (The environment in the Last Glacial on the territory of Moravia). – Acta Musei Moraviae, Scientiae geologicae, **84**: 161–186.

Musil, R. (2000): The environment in Moravia during the stage OIS 3. – In: Orschiedt, J. & Weniger, G.C. (eds): Neanderthals and Modern Humans – Discussing the Tradition: Central and Eastern Europe from 50.000–30.000 B.P. – Wissenschaftliche Schriften des Neanderthal Museums, **2**: 68–75.

Musil, R. (2002): Das Studium der Pferde aus der Lokalität Grubgraben. – Acta Musei Motaviae, Scientiae geologicae, **87**: 165–219.

Musil, R. (2003): The Middle and Upper Palaeolithic Game Suite in Central and Southeastern Europe. – In: van Andel, T.H. & Davies, W. (eds): Neanderthals and modern humans in the European landscape during the last glaciation: Archaeological results of the Stage 3 Project. – pp. 167–190, Cambridge (McDonald Institute).

Musil, R. (2005): Jarošov-Podvršťa. A faunal Anomaly among Gravettian sites. Osteological Material Analysis. – In: Škrdla, P. (ed.): The Upper Palaeolithic on the Middle Course of the Moravia River. – The Dolní Věstonice Studies, **13**: 203–216.

Musil, R. (2008): The Paleoclimatic and Paleoenvironmental Conditions at Předmostí. – In: Velemínská, J. & Brůžek, J. (eds): Early Modern Humans from Předmostí. A new reading of old documentation. – pp. 15–20, Praha (Academia).

Musil, R. (2010a): Palaeoenvironment at Gravettian Sites in Central Europe with emphasis on Moravia (Czech Republic). (Die Paläoumwelt mitteleuropäischer Gravettien-Fundstellen mit Schwerpunkt auf Mähren, Tschechische Republik). – Quartär, **57**: 95–123.

Musil, R. (2010b): Animal Prey. – The Dolní Věstonice Studies, **14**: 190–228.

Musil, R. (2011a): Gravettian Environmental Changes in N-S Transect of Central Europe. – Central European Journal of Geosciences, **3**/2: 147–154.

Musil, R. (2011b): The Environment of Pavlov and its surrounding area during the Pavlovian. – In: Svoboda, J. (ed.): Pavlov Excavations 2007–2011. – The Dolní Věstonice Studies, **18**: 76–114.

Musil, R. (2018): Phenological analysis of the Last Glacial vertebrates from the territory of Moravia (the Czech Republic) – Continuity and change in faunistic communities. – Fossil Imprint, **74**/3–4: 199–236.

Nerudová, Z. & Neruda, P. (2015): Moravia between Gravettian and Magdalenian. – Forgotten times and spaces. – pp. 378–394, Brno (Institute of Archaeology of the Czech Academy Brno and Masaryk University Brno).

Oliva, M. (2007): Gravettien na Moravě. (Dissertationes archaeologicae Brunenses/Pragensesque, 1). – 257 pp., Brno (Masarykova univerzita, Filozofická fakulta).

Otte, M. (1993): Upper Palaeolithic Relations between Central and Eastern Europe. – In: Chapman, J.C. & Dolukhanov, P. (eds): Cultural Transformations and Interactions in Eastern Europe. (Worldwide Archaeology Series, 6). – pp. 56–64, Newcastle (Avebury).

Pichler, S. (1996): Paläoökologie des östlichen Gravettien. Quellen und Ansätze ökologischer Rekonstruktionen der jungpleistozänen Umwelt. (Universitätsforschungen zur Prähistorischen Archäologie, 35). – 213 pp., Freiburg (Habelt).

PŘICHYSTAL, A. (2002): Zdroje kamenných surovin. – In: SVOBODA, J., HAVLÍČEK, P., LOŽEK, V., MACOUN, J. MUSIL, R., PŘICHYSTAL, A., SVOBODOVÁ, H. & VLČEK, E. (eds): Paleolit Moravy a Slezska. – The Dolní Věstonice Studies, **8**: 43–49.

PUTSHKOV, P.V. (1997): Were the mammoths killed by the warming? (Testing of the climatic versions of Würm extinctions). – Vestnik Zoologii, Supplement **4**: 3–81.

RYBNÍČKOVÁ, E. & RYBNÍČEK, K. (1991): The environment of the Pavlovian – paleoecological results from Bulhary, South Moravia. – In: KOVAR-EDER, J. (ed.): Palaeovegetational development in Europe and regions relevant to its palaeofloristic evolution: proceedings of the Pan-European Palaeobotanical Conference, Vienna, 19–23 September 1991, PEPC 1991. – pp. 73–79, Vienna (Naturhistorisches Museum Wien).

SOFFER, O. & VANDIVER, P. (1997): The Ceramics from Pavlov Excavation. Pavlov I – Northwest. – The Dolní Věstonice Studies, **4**: 383–401.

SOFFER, O. & VANDIVER, P. (2005): Ceramic fragments. – The Dolní Věstonice Studies, **14**: 415–431.

STEWART, J.R., KOLFSCHOTEN, T.H., MARKOVA, A. & MUSIL, R. (2003): The Mammalian Faunas of Europe during Oxygen Isotope Stage Three. – In: VAN ANDEL, T.H. & DAVIES, W. (eds): Neanderthals and modern humans in the European landscape during the last glaciation: Archaeological results of the Stage 3 Project. – pp. 221–231, Cambridge (McDonald Institute).

SVOBODA, J. (2001): The Pavlov site and the Pavlovian: A large hunter's settlement in a context. – Praehistoria, **2**: 97–115.

VAN ANDEL, T.H. (1998): Middle and Upper Palaeolithic environment and the calibration of ^{14}C dates beyond 10.000 BP. – Antiquity, **742**/275: 26–33.

VAN ANDEL, T.H. (2003): Glacial Environments I: The Weichselian Climate in Europe between the End of the OIS-5 Interglacial and the Last Glacial Maximum. – In: VAN ANDEL, T.H. & DAVIES, W. (eds): Neanderthals and modern humans in the European landscape during the last glaciation: Archaeological results of the Stage 3 Project. – pp. 9–20, Cambridge (McDonald Institute).

VERPOORTE, A. (2005): The lithic assemblage of Pavlov I (1954, 1956, 1963, 1964). – The Dolní Věstonice Studies, **14**: 75–111.

WISNIEWSKI, A., FURMANEK, M., BOROWSKI, M., KADZIOLKA, K., RAPINSKI, A. & WINNICKA, K. (2012): Lithic raw material and late Palaeolithic strategies of mobility: A case study from Sowin 7, SW Poland. – Anthropologie, **1**/4: 391–409.