Human-driven and natural vegetation changes of the last glacial and early Holocene

Ph.D. Thesis

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Contents

Motto

Buďme vděčni našim předchůdcům, zvláště těm, kteří už mezi námi nejsou. Nepsali na počítačích, nepoužívali statistiku a neměli k dispozici C-14 data. Obtížně se propracovávali k determinaci jednotlivých pylů a spór i ke správné interpretaci získaných dat. Díky nim však můžeme my dnes rychleji pokračovat a objevovat neobjevené pro generace následné.

Vlasta Jankovská

I declare that this thesis or any part of it was never submitted to obtain any other academic degree.

Acknowledgements

This thesis took a long way to finish, and this would not be achieved without all scientific and mental support of all my colleagues, friends and family.

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Studying the Mesolithic would not be possible without cooperation with archaeologists. The one who had great influence is Petr Šída. I appreciate we could start cooperation on environmental topics concerning the hunter-gatherer populations. Another person I would like to thank is Dagmar Dreslerová, who supported me with fruitful discussions upon archaeological and palaeoclimatological topics, and who encouraged me when I was down.

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Tímto bych chtěl poděkovat svým rodičům, kteří mě podporovali po celou dobu mého studia, ač jim musela připadat neúměrně dlouhá.

Introduction

Dramatic changes occurred in global climates during the period of the last glacial and at the beginning of the Holocene. The major part of the time is evidenced for general climatic instability, which largely affected vegetation as well as human populations. Considering the fact that hunter-gatherers were an inseparable part of natural ecosystems at that time, we may better uncover their living strategies, resources and dynamics with detailed understanding of the vegetation distribution and development.

The aim of the present thesis is to reconstruct the vegetation as the main factor of an environment of Upper Palaeolithic and Mesolithic hunter-gatherers in central Europe. Chronologically, the period of interest starts with the oxygen isotopic stage 2 (OIS 2; 30 ka B.P., according to Bond *et al.*, 1997) and ends after the last cooling event 8200 cal. B.P. with the beginning of the Holocene climatic optimum. Culturally, this is the period of late Palaeolithic and Mesolithic hunter-gatherers, who finally vanished with on-coming neolitisation (Fig. 1).

The late Pleistocene period, which had a huge significance for humans (Finlayson & Carrion, 2007), was traditionally depicted as harsh glacial maximum climate. But this, paradoxically, apply to a small fraction around 18 ka B.P. (21–21.5 ka cal. B.P.) only. Glacial climate before the last glacial maximum (LGM) and late-glacial climate after it was far less severe (van Andel & Tzedakis, 1996). The question remains how responded the vegetation to these changes. Modelling vegetation patterns during the glacial period is an issue since Frenzel (1968) proposed his concept. Even he suggests some forest vegetation in central-eastern Europe in the LGM. Recent simulations for the Interpleniglacial (OIS 3) place taiga vegetation to central Europe (Huntley *et al.*, 2003). Even models for vegetation distribution in the LGM show boreal-forest or forest-tundra (Harrison & Prentice, 2003), however, pollen data from central Europe were missing for calibration of these models. Studying vegetation and climate changes has possible implications for understanding patterns of migration of human population during the OIS 2 as their adaptive responses (Svoboda, 2007).

The afforestation process started due to warming and relatively stable climate at the beginning of the Holocene. New set of species immigrated and established climax broadleaf forests. The afforestation in central Europe was probably at the highest level that time. However, there are different views whether it was complete or there still existed a lot of open spaces (see Ložek, 2004; Sádlo *et al.*, 2005; Vera, 2000). This is especially important considering this period as the time of last hunter-gatherers. Human populations started to be less mobile and probably affected local environments more intensively.

Although ecosystems are still considered as naturally evolved, humans could play very significant role in supporting survival of some steppic species in generally forested landscape. They also could act supporting intentional or unintentional migration of some

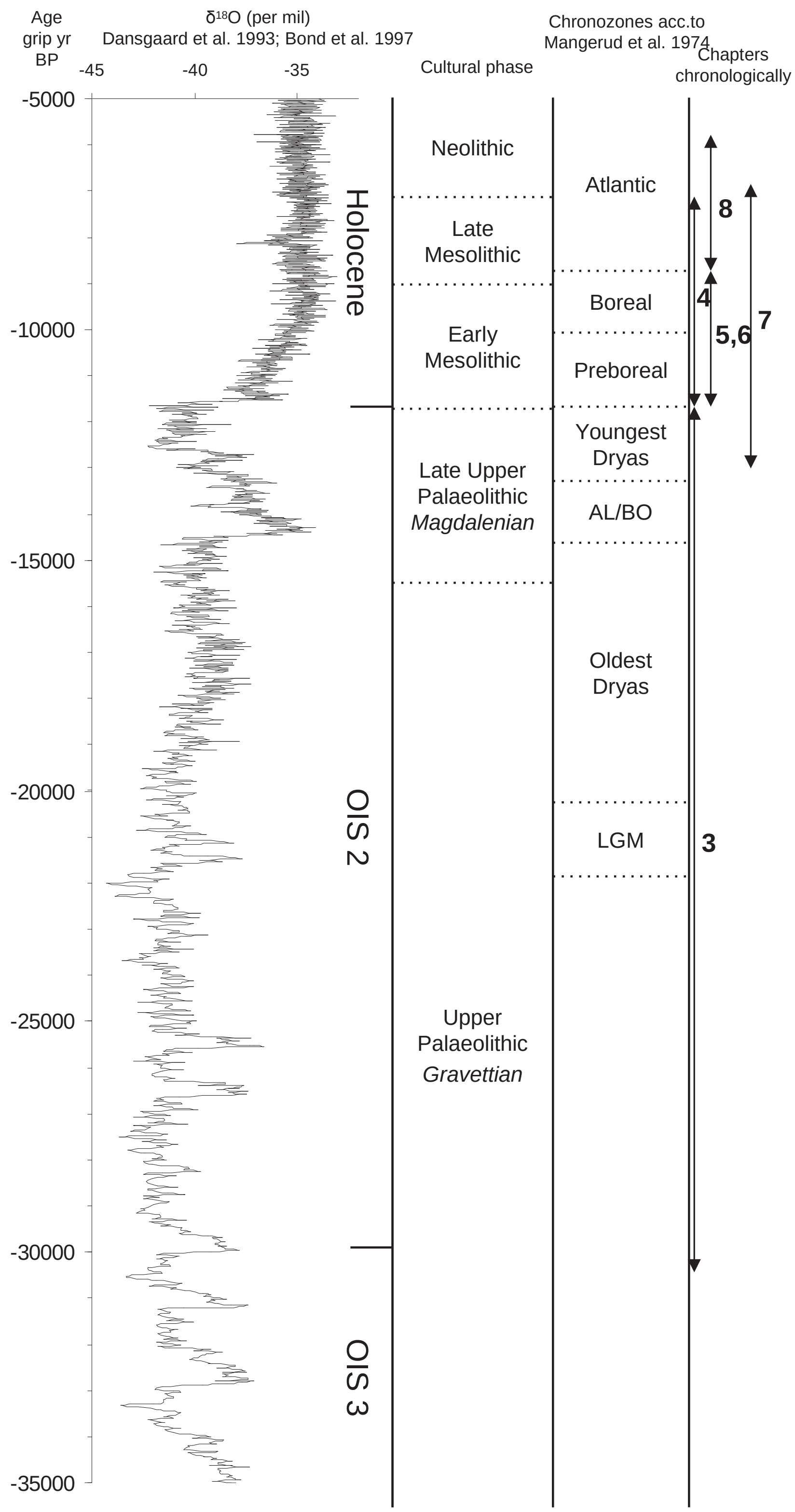

Fig. 1: Chronological framework and periodization used in the text. Boundaries of particular zones must be taken as referential, since exact dating is problematic. Numbers and arrows show chapters of the thesis referring to particular period.

species. On the other hand, humans probably contributed to final extinction of megafauna in central Europe, namely mammoth, rhinoceros or European bison (Burney & Flannery, 2005; Wroe *et al.*, 2006). All of them were big herbivores and their dismissing could play very important role in vegetation development. Since, it is very difficult to find any significant traces of hunter-gatherers in central-European ecosystems by mean of palaeoecological methods, we find very useful, and this is a specific aim of the present thesis, to search for traces of human impact.

Reconstruction and interpretation of various stages of glacial and early postglacial vegetation, climatically induced development of no-analog communities and evolution of human impact, which finally led to evolution of cultural landscape, are very important questions in palaeoecology.

Vegetation during of the last glacial and early Holocene in central Europe

Traditional views depicted vegetation development in central Europe since the pleniglacial to the Holocene as a final dominance of forest over treeless steppe or tundra vegetation. Cold glacial period was determined as treeless landscape, while warming up forced immigration of trees from the south at the end of the glacial. However, recently we have more sophisticated information about the glacial climate, which led to numerous suggestions and models, that central European landscape and vegetation did not suffer that much from such severe conditions during the whole glacial. Most recent views about the last glacial and early postglacial vegetation in central Europe are briefly described below.

Vegetation and climate during the OIS 3 (Fig. 1) was widely studied by the OIS Three Project (Cambridge, 2003). It suggested that during the warmer interstadial phases central Europe could harbour parkland vegetation with coniferous trees, even with some admixture of broadleaf trees. These models were so far hardly supported by very few palaeobotanical data. Some records come from Western Europe and southern Poland. Palaeobotanical finds from Moravia and Hungary are discussed in Chapter 3. What we find crucial is correct interpretation of these finds.

Even during the coldest stages of the pleniglacial there could still exist isolated populations of tree species in periglacial landscape (Lang, 1994). Their habitats could be most probably situated along rivers (already proposed by Frenzel (1968)) or in protected intermontane valleys (see Chapter 3). This also supports new theories about no-existent/discontinuous permafrost during warm/cold stages of the pleniglacial (Alfano *et al.*, 2003).

Although we have only modelled data for the LGM in central Europe, there exist records from southern and eastern Europe interpreting vegetation as glacial steppe (Elenga *et al.*, 2000; Tarasov *et al.*, 2000). Question is whether trees survived the LGM in central Europe? One positive answer can bring comparison of climate, which did not differ that much between warm and cold periods, and BIOME model of vegetation during the LGM (Harrison & Prentice, 2003). Another answer can bring new palaeobotanical finds presented in Chapter 3, showing that trees massively occurred in early late-glacial pollen records. Generally we may assume that climate during the OIS 3 and 2 most probably had large local or regional discrepancies, which influenced vegetation distribution and possible existence of local refugia.

During the last interstadials in late Pleistocene, taiga vegetation developed. It retreated during cool stadial phases and spread again at the beginning of the Holocene. This is well documented by several pollen assemblages in central and central-eastern Europe (see

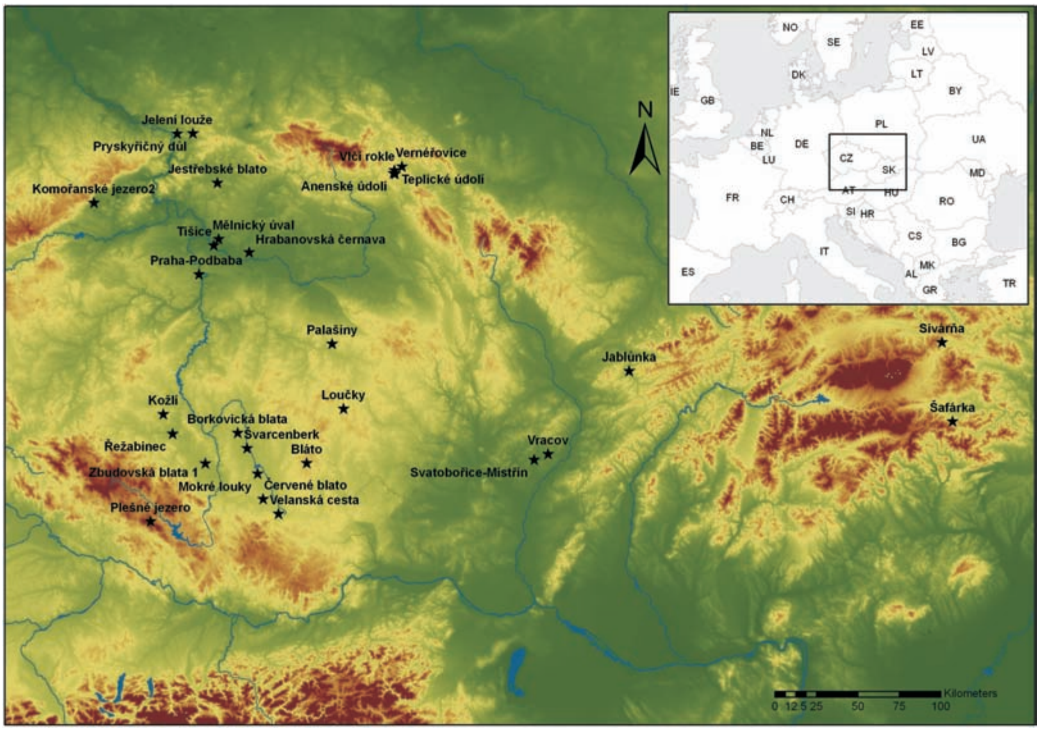

Fig. 2: Fossil pollen sites used in the thesis, projected on a hypsometric map of eastern-central Europe. Alphabetical list of localities (numbers in the brackets indicate chapters where locality is used): Anenské údolí (8), Bláto (4), Borkovická blata (4), Červené blato (4), Hrabanovská černava (3, 4), Jablůnka (3), Jelení louže (8), Jestřebské blato (4), Komořanské jezero (4), Kožlí (4), Loučky (4), Mělnický úval (4), Mokré louky (4), Palašiny (4), Plešné jezero (3, 4), Praha-Podbaba (3), Pryskyřičný důl (7), Řežabinec (4), Sivárňa (3), Svatobořice-Mistřín (4), Šafárka (3), Švarcenberk (3, 4, 5, 6), Teplické údolí (7), Tišice (8), Velanská cesta (4), Vernéřovice (4), Vlčí rokle (7), Vracov (4), Zbudovská blata (4).

Chapter 3 and 4). Special attention must be given especially to *Picea abies, Pinus cembra* and *Larix decidua*. They occurred in eastern part of central Europe (Carpathian region) during the late glacial and at the beginning of the Holocene. However, their extent towards the west is unclear. Broadleaf trees started to occur at the beginning of the Holocene. Some appeared very early like *Corylus, Ulmus*. Together with others (*Tilia, Acer* and *Fraxinus*) they finally formed so-called mixed-oak forests or woodland (Pokorný, 2005). This kind of vegetation, with admixture of *Picea*, persisted in the region of central-eastern Europe until middle Holocene.

Today, there exist suggestions for analogue communities of the last glacial vegetation. Walker et al. (2001) studied calcium-rich tundra in Alaska, which they suggest as hypothesized "Mammoth Steppe" analogue. This kind of vegetation had probably significant importance in supporting various Pleistocene mammals as nutritious forage. Following climatologic predictions (Frenzel *et al.*, 1992) there were suggested also analogous woodland and steppic vegetation in southern Siberia (Chytrý *et al.*, 2007; Chytrý *et al.*, 2008; for more information see Chapter 3). The analogical inference, comparison of fossil pollen assemblages and modern assemblages, is highly demanding approach in palaeoecology (Jackson & Williams, 2004). However, in most cases we deal with no-analog communities

(Williams & Jackson, 2007), compositionally unlike of any found today, and with no-analog climate conditions (lowered CO2, seasonality insulation or persistent ice-sheet). These assumptions can also influence possible convergence or divergence in relationship between vegetation and assemblages. Errors can arise from such sources in analog analysis.

Scheme and main questions of the work

Chapter 1 brings the general assumptions and introduction to the problem, which is being resolved in particular studies. They are sorted in this work chronologically.

Chapter 2 *'The relationship of modern pollen spectra, vegetation and climate along a steppe-forest-tundra transition in the Western Sayan Mts., southern Siberia, explored by decision trees'* comes with a very important assumption in palaeoecology, that understanding relationship between vegetation and pollen deposition is crucial for reliable reconstructions of the past landscapes. This problem becomes more serious, if we could do this kind of research in the closest modern analogy of the past vegetation and landscape of central Europe. According to recent vegetation surveys and biogeographical attributes, this kind of analogous vegetation can be found in the southern Siberian mountain ranges. We ask the questions to what degree of precision is it possible to predict studied vegetation on the basis of surface pollen spectra and which taxa contribute to this most significantly. Results enhanced 'Interpretation of the last-glacial vegetation of eastern-central Europe using modern analogues from southern Siberia' in **Chapter 3**.

Question about vegetation cover in the last glacial in central Europe is recently an important topic in palaeoecology. We examine together different fossil pollen records of the full- and late-glacial from the region of central-eastern Europe and interpret them in the light of recent palaeoclimatic knowledge. We reconstructed and interpreted late-pleistocene vegetation during the time of rapid ecological turnover. It was an important living factor for changing cultural groups of modern human populations (Finlayson & Carrion, 2007), in the area of central-eastern Europe known as Gravettian, Epigravettian and Magdalenian (Svoboda, 1999). Distribution of forest, steppe and tundra vegetation could markedly affect their technological innovations (Finlayson & Carrion, 2007).

Chapter 4 *'Detection of the impact of early Holocene hunter-gatherers on vegetation in the Czech Republic, using multivariate analysis of pollen data'* brings new data and analyses of the evidence of human activity at the start of the Holocene. During this period dramatic environmental changes occurred. Finally more stable and favourable climate resulted in natural afforestation, while the last hunters adopted more specialized strategies of subsistence. Although pre-Neolithic agriculture still brings a lot of opposed views (Behre, 2007; Tinner *et al.*, 2007), an intentional management could play an important role even in spreading species of anthropogenic use (e.g. Mesolithic diet). For the research into early Holocene human impact a detailed network of both palaeobotanical as well as archaeological evidence is needed. From this reason a close collaboration with archaeology may be very fruitful. The main questions of this study ask what whether there are patterns and specific anthropogenic indicators in pollen data that can be attributed to Mesolithic human influence.

Chapter 5 and 6 represent the case studies at recently discovered extensive Mesolithic settlement around the extinct lake Švarcenberk in southern Bohemia. In *'Mesolithic settlement of the former Lake Švarcenberk (south Bohemia) in its environmental context'* we combine both natural-scientific and archaeological methods to investigate the impact of hunter-gatherers on upland vegetation and lake ecosystems. Noticeable signs of human presence around the lake in the Mesolithic were found already in the pollen record from the central profile of the lake. Further, we focused on study of littoral pollen assemblages in the closest vicinity to Mesolithic archaeological sites. The important objects of the study are plant macrofossils that have significance for our knowledge of plant use in the Mesolithic.

Chapter 6 *'Early Holocene wooden artefacts from the Lake Švarcenberk'* focuses on archaeological finds around the above-described lake. In the year 2005 during an extensive surface artefact survey, we finally discovered nine Mesolithic sites. During the excavation of littoral part of the lake, we focused not only on botanical finds but also on possible organic artefacts preserved in the sediment. We expected the shallow littoral part to be important in benefiting as an access point to the lake. We focused on possible finds of artefacts (fresh or chaired wood) in the same exploratory sondage as used for palaeoecological methods. In this chapter we describe rare finds of Mesolithic wooden artefacts and we give an interpretation using pollen and plant macrofossils that were found together.

Chapter 7 summarizes information about *'Post-glacial vegetation development in sandstone areas of the Czech Republic'*. Herewith it brings case studies from sandstone regions, which is quite extraordinary landscape described by its typical sandstone geomorphology (network of narrow valleys and top plateaus). Sandstone regions in the Czech Republic offer great amount of favourable places, which could harbour Mesolithic hunter-gatherers. Several archaeological surveys have been made in the western part of the Bohemian Createaceous Basin (Svoboda, 2003; Šída & Prostředník, 2007). They found out that occupation of the region during Mesolithic times was quite intense. However our palaeoecological results show the landscape with predominantly natural vegetation development. This can be due to several reasons. One is that profiles recording the Early Holocene period are concentrated in the north-eastern part of the region which has predominantly montane character (i.e. wet and favourable for the development of forest vegetation). Another reason is that profiles themselves were collected in the core parts of sandstone complexes, which could be very hardly accessible and used by humans. Some implications for Mesolithic human impact in sandstones were discussed already in Chapter 4. During the period of Late Mesolithic, the Boreal and early Atlantic according to Mangerud *et al.* (1974), climax broadleaf forests with prevalent *Quercus, Tilia, Ulmus, Acer* and *Fraxinus* had developed. This forest persisted even in the sandstone areas thanks to high content of the bases (including Ca2+) in the soils – this feature being generally characteristic for the Early Holocene.

In **Chapter 8** we describe process of the degradation of these broadleaf climax forests as the result of accelerated Middle Holocene acidification. We can generally assume that acidification of central-European ecosystems had its start already in early Atlantic - the time that is widely recognized as a transition from Mesolithic hunter-gatherer societies to Neolithic farming societies. We use an example of two pollen profiles located in sandstone areas and one in extensive river-terrace environment (Labe, Central Bohemia). Acidification can be very well observed in these regions as soils developed on acidic substrata, and thus are more sensitive to loss of nutrients. We ask the following question: In which cases this happened naturally and where it happened due to anthropogenic pressure?

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Conclusions

The main conclusions, specific to each research topic, have been mentioned in appropriate chapter. To summarize, the thesis brings new original data and reinterprets existing pollen assemblages of the last glacial and early Holocene in central Europe. It also deals with analysis of the analogues and with vegetation-pollen relationship when interpreting past vegetation.

The study of analogue environment brought several important conclusions. A considerably tight relationship was found between the composition of pollen spectra and climate characteristics in southern Siberian analogue landscape. This means that past climatic conditions can be reasonably predicted by the fossil pollen spectra. There were found the best pollen predictors (such as *Pinus sylvestris, P.cembra, Betula alba, Artemisia, Graminae*) and 300 m distance around the sampling point as the best factors explaining vegetation type.

Vegetation was interpreted for the last glacial and the beginning of the Holocene in the light of new palaeobotanical finds and according to modern approaches. Occurrence of some tree species during various stages of the last glacial were confirmed, however, local discrepancies in vegetation and climate were also highly important. This supports strong gradient in increasing treeless vegetation from the eastern-central Europe towards the west.

Vegetation continued being naturally evolved with the start of the Holocene. However, studies at certain archaeological localities confirmed assumption that humans could in some cases even intentionally contribute to spreading of several plant species.

Finally, the acidification process was recognized as an important turnover leading to evolution of cultural landscape in central Europe. In some cases it happened continuously (several thousands years), in other under very strong anthropogenic pressure. The main characteristics of this process are decline of mixed-oak forests established during early Holocene and immigration of *Fagus sylvatica* and coniferous trees into ecosystems.

Curriculum vitae of Petr Kuneš

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- 1998 - 2001: Master degree, Department of Botany, Charles University, Prague, in: Ecological Botany (Geobotany) (Thesis: Holocene Vegetation Development and Pollen Deposition in the Adrspassko-teplicke skaly Mts. NE Bohemia)
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- March - July 2001: Albrecht-von-Haller-Institut für Pflanzenwissenschaften, Universität Göttingen, Germany

Field experience [outside Europe]:
1997: Turkey (1 month); 1999: Iran, Pakistan, India (W Himalaya) (2,5 months); 2000: Thailand, Laos, SW China (Yunnan, Sichuan), E Tibet (2 months); 2001: Nepal (E Himalaya), India (Sikkim, W Bengal) (2 months); 2002: Tibet (1,5 month); 2003: Siberia - Western Sayan Mts. (1 month); 2005: Galapagos (1 month); 2005: Tibet (1,5 month); 2006: Kyrgyzstan (1 month)

Grant projects:

Project leader:

- 2003-2005: Reconstruction of the natural vegetation of sandstone rocks in the National Park České Švýcarsko and the surrounding sandstone area by the mean of pollen analysis of profiles (Ministry of the Environment CR, SE/620/7/03)
- 2003-2005: Vegetation and landscape during the Early Postglacial as an environment for hunter-gatherer populations (GA AV CR, KJB6111305)

Joint applicant:

- 2007-2011: Long-term development of cultural landscape of Central Bohemia as a co-evolution of human impacts and natural processes (GA AV CR, IAAX00020701) - project leader Petr Pokorný

Researcher:

- 2007-2009: Pollen Database of the Czech Republic (GA UK, 29407) - project leader Vojtěch Abraham
- 2006-2008: Dynamics of spreading of woody species in central European landscape (GA CR, GA526/06/0818) - project leader Tomáš Herben
- 1999-2001: Small-scale diversity in Late Glacial and Holocene vegetation history in a landscape with strong geomorphological gradients (GA AV CR, IAA6005904) - project leader Vlasta Jankovská
- 1998-2000: Palaeoecology of small peat-deposits in the area of block sandstones (GA UK) - project leader Tomáš Herben

Papers in SCI journals:

Kuneš, P., Pokorný, P. & Šída, P. (2008) Detection of impact of Early Holocene hunter-gatherers on vegetation in the Czech Republic, using multivariate analysis of pollen data. *Vegetation History and Archaeobotany*. (published online)

Jankovská, V., Kuneš, P. & Van Der Knaap, W.O. (2007) 1. Fláje-Kiefern (Krušné Hory Mountains): Late Glacial and Holocene vegetation development. *Grana*, **46**, 214–216.

Pokorný, P., Boenke, N., Chytráček, M., Nováková, K., Sádlo, J., Veselý, J., Kuneš, P. & Jankovská, V. (2006) Insight into the environment of a pre-Roman Iron Age hillfort at Vladař, Czech Republic, using a multi-proxy approach. *Vegetation History and Archaeobotany*, **15**, 419–433.

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Šída, P., Pokorný, P. & Kuneš, P. (2007) Dřevěné artefakty raně holocenního stáří z litorálu zaniklého jezera Švarcenberk [Early Holocene wooden artifacts from the Lake Švarcenberk]. *Přehled výzkumů*, **48.** (in press)

Pokorný, P. & Kuneš, P. (2005) Holocene acidification process recorded in three pollen profiles from Czech sandstone and river terrace environments. *Ferrantia*, **44**, 101–107.

Kuneš, P. & Jankovská, V. (2000) Outline of Late Glacial and Holocene Vegetation in a Landscape with Strong Geomorphological Gradients. *Geolines*, **11**, 112–114.

Chapters in monographs:

Pokorný, P., Šída, P., Kuneš, P. & Chvojka, O. (2007) Mezolitické osídlení bývalého jezera Švarcenberk (jižní Čechy) v kontextu vývoje přírodního prostředí [Mesolithic settlement of the former Lake Švarcenberk (south Bohemia) in its environmental context.]. *Bioarcheologie v České Republice – Bioarchaeology in the Czech Republic* (ed. by J. Beneš and P. Pokorný), Praha. (in press)

Kuneš, P., Pokorný, P. & Jankovská, V. (2007) Post-glacial vegetation development in sandstone areas of the Czech Republic. *Sandstone Landscapes* (ed. by H. Härtel, V. Cílek, T. Herben, A. Jackson and R. Williams), pp. 244–257. Academia, Praha.

Popular articles:

Hédl, R. & Kuneš, P. (2002) Minja Konka, nejvýchodnější tibetská velehora. *Živa*, **50** 262–264.

Kuneš, P. (2001) Pod střechou světa - Západní Himálaj. *Živa*, **49**, 261–264.

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Kuneš, P. (2001) Vývoj holocénní vegetace a spad pylu v Adršpašsko-teplických skalách. Depon in: Knihovna katedry botaniky PřF UK, Praha, 97 pp. [MSc. thesis in Czech]

Kuneš, P. (1998) Studium vývoje vegetace za pomoci pylových pastí. Depon in: Knihovna katedry botaniky PřF UK, Praha, 22 pp. [BSc. thesis in Czech]

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