University of South Bohemia, České Budějovice;
Faculty of Biological Sciences, Department of Botany
(Jihočeská univerzita v Českých Budějovicích,
Biologická fakulta, Katedra botaniky)

Petr Pokorný:

PALAEOECOLOGY OF A FORMER LAKE ŠVARCENBERK AND THE DEVELOPMENT OF THE SURROUNDING LANDSCAPE DURING THE LATE-GLACIAL AND THE HOLOCENE.

University of South Bohemia, České Budějovice;
Faculty of Biological Sciences, Department of Botany
(Jihočeská univerzita v Českých Budějovicích,
Biologická fakulta, Katedra botaniky)

Petr Pokorný:

PALAEOECOLOGY OF A FORMER LAKE ŠVARCENBERK AND THE DEVELOPMENT OF THE SURROUNDING LANDSCAPE DURING THE LATE-GLACIAL AND THE HOLOCENE.

(PALEOEKOLOGIE BÝVALÉHO JEZERA ŠVARCENBERK A VÝVOJ OKOLNÍ KRAJINY V POZDNÍM GLACIÁLU A HOLOCÉNU.)

(Abstract to the dissertation)
(Abstrakt doktorské dizertační práce)

Třeboň, 2000

Supervisor (školitel):
RNDr. *Vlasta Jankovská*, CSc.; Institute of Botany, Academy of Sciences of the Czech Republic, Brno

Letecký snímek s vyznačením plošného rozsahu původního jezera Švarcenberk a místa nálezu pazourkových artefaktů datovaných do střední doby kamenné (označeno křížkem), v popředí obec Ponědrážka

ÚVOD.

Jezerní sedimenty jsou vyhledávaným studijním objektem paleoekologického výzkumu. Oproti organickým sedimentům rašelinišť mají několik významných předností, které zvyšují jejich výpovědní hodnotu pro rekonstrukci přírodních poměrů minulosti. Především je to jejich komplexnost, tedy schopnost poskytnout mimořádně různorodý studijní materiál. Tímto materiálem mohou být pylová zrna rostlin, rostlinné makrozbytky, různé zbytky vodních organismů - planktonních řas, rozsivek, zooplanktonu (především Cladocera), vodního hmyzu (především Chironomidae), atd. Také chemické, izotopové a strukturní složení jezerních sedimentů vypovídá mnoho o vývoji jezerní pánve a jejího povodí. Protože se jezerní sedimenty mimořádně dobře hodí k vzájemné korelaci tak různorodého paleoekologického záznamu, jsou hlavním zdrojem informace o vývoji klimatu. Další výhodou jezerních sedimentů jakožto studijního objektu je možnost postavit jejich studium na velmi detailní chronologii. Jemná stratigrafie jezerních sedimentů často dovoluje vysoké časové rozlišení (u laminovaných sedimentů až na úroveň jednotlivých roků). Oproti telmatickým sedimentům (rašelinám) mají ovšem jezerní usazeniny některé nesporné nevýhody, z nichž nejzávažnější jsou obtíže s absolutním datováním pomocí 14C (blíže viz. např. OLSON 1986) a principiální problém nízkého prostorového rozlišení (zvláště velké jezerní pánve integrují množství informací z velmi širokého okolí).

Naprostá většina území České republiky, stejně jako velká část ostatní střední Evropy, leží v oblasti, která nebyla během kvartéru nikdy přímo postižena zaledněním, tedy v tzv. periglaciální zóně. Důsledkem toho je fakt, že přirozené vodní nádrže větších rozměrů jsou v této oblasti výjimečným jevem. Proto bylo na našem území nalezeno dosud jen velmi málo jezerních sedimentů. Nesporně největší původní jezero na našem území bylo tzv. Komořanské jezero v Mostecké pánvi. Skrývka dolu Československé armády však nedávno zničila i poslední zbytky jeho sedimentů. Nejcennější partie byly odtěženy ještě dávno předtím, než mohly být spolehlivě odebrány a archivovány. Byl tak natrvalo zničen jeden z nejvýznamnějších přírodních archivů ve střední Evropě, který mohl být pouze z části využit paleoekology (RUDOLPH 1926, LOSERT 1940, JANKOVSKÁ 1983, NEUSTUPNÝ 1985). V novější době se poměrně kvalitního paleobotanického zpracování dočkaly sedimenty původního jezera na lokalitě Vracov na jižní Moravě (RYBNÍČEK 1983, RYBNÍČKOVÁ & RYBNÍČEK 1972) a jezerní sedimenty na Třeboňsku (lokality Velanská cesta a Švarcenberk; JANKOVSKÁ 1970, JANKOVSKÁ 1980).

Vývoj metod paleoekologického výzkumu v posledních desetiletích značně pokročil a do popředí zámu se dostaly komplexní přístupy. Právě na základě studia jezerních sedimentů byla v poslední době dosažena řada významných výsledků (např. AMMANN & LOTTER 1989, DEARING 1991, GOSLAR ET AL. 1993, LOTTER ET AL.1992). Proto nastala potřeba nalézt plně srovnatelný studijní materiál také na území České republiky a komplexně ho zpracovat tak, aby mohlo být provedeno srovnání výsledků s výsledky dosaženými v západnějších částech Evropy. Za tímto účelem byla jako nejvhodnější vytypována lokalita Švarcenberk v Třeboňské pánvi. (V roce 1969, při odběru sedimentů z ručně kopané sondy, zde narazila Vlasta Jankovská na zbytky jezerních sedimentů pohřbené pod několika metry rašeliny.) Na počátku nové etapy výzkumu bylo nejprve třeba určit rozsah a hloubku jezerní pánve, rámcově stanovit stáří její výplně a na základě těchto poznatků rozhodnout, které profily by byly vhodné ke komplexnímu paleoekologickému zpracování. Výsledkem pilotní studie tak byl objev jezerní pánve ledvinovitého tvaru a nečekaných rozměrů (cca 450 X 700 m), navíc se značnou hloubkou (v centrální části až 11 m). První pylové analýzy záhy prokázaly značné stáří bazální výplně. Šťastnou shodou okolností tak byl pro plánovaný multidisciplinární výzkum nalezen v mnoha směrech ideální studijní materiál a jeho zpracování se stalo tématem této doktorské dizertační práce.

SUMMARY OF THE MAIN RESULTS
(SHRNUTÍ HLAVNÍCH VÝSLEDKŮ)

Lake basin, its origin and stratigraphy.

The extend of lake deposits within the basin was mapped in detail by approximately 120 hand borings. The altitude of individual stratigraphic transitions was obtained by relative leveling. The former lake was found to have a maximum surface 0.51 km^2,and the ratio of the surface to drainage basin to be about 1:8. Correlation of the individual cores across the basin was achieved by visual stratigraphy, which reflects well the environmental conditions during the time of sedimentation. The borders distinguished between several litostratigraphic units can therefore be assumed to be roughly time-parallel. In two littoral sampling points (one of which was performed and studied in SW part of the basin by JANKOVSKÁ 1980), pollen analyses and radiocarbon dating confirmed this assumption. In the littoral parts of the former lake basin, only a thin layer of Late-glacial sediments is present, completely lacking deposits older than Younger Dryas. This can be explained by intensive reworking of the shores during Late-glacial rather being the result of lower lake levels during this period. As the lake was fed almost exclusively by artesian water, water-level remained constant over the entire period of its existence, and water-level reconstructions can't be used as a climatic indicator, unfortunately.

The striking features of the basin morphometry is its kidney-shaped form, surprising depth and declivity (the presence of unusually steep slopes), and relatively great age of its infilling. Unfortunately, no radiocarbon date exists from the basal sediments, but their age is estimated around 16 000 BP from the pollen-analytical results. On the basis of these finds, the origin of such structure can be best explained as the remnant of a huge Pleniglacial ground-ice lens - an open-system pingo (WASHBURN 1980).

Development of the lake basin and its catchment: correlation of biostratigraphic and sedimentological data.

In the section below, the basic facts about the development of the lake basin and the surrounding landscape are discussed. Pollen, macrofossil and sediment composition analyses together with the analyses of subfossil algae form the main source of our knowledge. To be captured in its chronology as well as in its spatial scale, the development of the basin has been studied in three different radiocarbon-dated and inter-correlated profiles, situated in the center and the margins of the former lake.

Initial warming after the last Glacial maximum.

The lowermost sediments in the center of lake basin consist of fine silt with some coarser sand particles. They are dark-colored as they contain FeS. This suggest anoxic conditions as iron sulphide deposition usually occur under prolonged or permanent stratification of the lake (ENGSTROM & WRIGHT 1984). The formation of these sediments antedate the period of rapid Late-glacial climatic warming at about 13 000 BP. Their pollen spectra are characterized by high non-arboreal pollen (NAP) values, suggesting an open herbaceous vegetation. Grasses, *Cyperaceae, Chenopodiaceae, Betula nana, Alnus viridids, Salix* (most likely some dwarf willow species), *Thalictrum* and *Artemisia* were important components of the vegetation. The occurrence of *Ranunculus* subgen. *Batrachium* can be used as climatic indicator for minimum July temperatures, suggesting those to be at least 10 °C, while *Hippophaë rhamnoides* presence (found exclusively as pollen) suggest at least 11 °C (HUIZER & IZARIN 1997).

Very low sedimentary organic carbon content (values not exceeding 3%) suggest low productivity in the lake as well as in its catchment (see also very low N and P values during that time). Low nutrient status together with small productivity was primarily caused by low energy input into the ecosystem. High content of Na, K and reworked Tertiary pollen suggest high erosion rate in lake catchment during this period. This can be ascribed to sever, highly continental and unstable climatic conditions implicating intensive surface cryogenic processes, slope outwash and riling. Furthermore, the absence of stable soils in the catchment caused good availability of sediment for erosion. Slightly lower values of all erosion indicators in the lowermost approx. two decimeters of sediment core is apparently the result of high relative proportion of coarse sediment fraction (consisting mostly of quartzite grains), rather than lower allogenic sediment fraction input to the lake basin.

Relatively high *Helianthemum* percentages (up to 3%) point to the presence of bare, calcareous substratum (HOEK 1997). This accord well with the results of sediment chemical analyses, showing high *Ca* content. This find is in sharp contrast with present-day conditions in the area under study, where most soils are leached, highly acidic, almost completely lacking calcium carbonate.

The rise in *Pinus* pollen percentages up to values higher than 60% between 870 and 910 cm indicates the period of local pine expansion. Individual pine trees must have been scattered more or less sporadically in the landscape of steppe and tundra-like character. Pine expansion suggest some temporal climatic amelioration. At about that time (cca.15 000 BP), weak traces of initial pedogenesis are described from lowlands of Central Europe. The same period is characteristic in European loess plateaus by a short break in eolic deposition suggesting slightly warmer and wetter climate (TYRÁČEK 1995). In our sediment chemistry record, no evidence for intensive pedogenetic processes has been found for the critical period.

A warm oscillation of Late-glacial Interstadial.

An abrupt climatic amelioration is recorded in many areas of the World at around 13 000 BP (e.g. LOWE ET AL. 1994). Reforestation by birch and later by pine is recorded over the most of NW and Central Europe during this time. The lower limit of mean July temperatures needed for tree birch colonization is usually taken as 10 °C, but 12 °C is the optimum for the development of *Betula pubescens* woodland (BIRKS 1993). Similar development can be traced also in the area under study: Reforestation by birch and pine resulted in decline of most of pioneer heliophyllous herbs, that were characteristic for the preceding period. In aquatic environment, abrupt climatic amelioration caused the expansion of submerged macrophytes including *Ceratophyllum demersum*, which appears for the first time in the lake. *Nymphaea, Nuphar, Filipendula* and *Typha latifolia* occurrence also point to minimum July temperatures at least 12 °C (HUIZER & IZARIN 1997).

Late-glacial Interstadial appears to be a period with significantly increased organic production, as reflected in sharp transition from minerogenic to organic sedimentation: Organic-rich gyttja („sapropel") with organic carbon content exceeding 15% started to accumulate ($C_{org.}$ content reaches 25% during the later - Alleröd phase of the Interstadial). Sedimentary organic carbon curve is synchronous with the curve of sedimentary N. Also phosphorus content in the sediments seems to be a good indicator of past nutrient status of the lake (for discussion of problems associated with phosphorus uptake and postdepositional changes see ENGSTROM & WRIGHT 1984).

The onset of warm, less continental climate (connected with the decline of cryogenic and slope processes) has lead to significantly decreasing erosion rates in lake catchment obvious from the progressive decline in sedimentary Mg, K and sharp decline in reworked Tertiary pollen. Intensive soil development under forested conditions has probably been the major factor affecting the transport of above mentioned cations into the lake. During episodes of relatively stable soils, deep weathering of mature soil profiles and formation of clay minerals should diminish the base content of mineral material prior to its erosive removal and sedimentation in lake basin (ENGSTROM & WRIGHT 1984). Decalcification of the developing soils continued up to the maximum extent during this period as seen from the decline in sedimentary *Ca* to values comparable with those characteristic for the Holocene. The decalcification of soil horizons together with competitive pressure of expanding forest were probably two most important factors responsible for complete decline of *Helianthemum* and *Plantago maritima*-type from regional vegetation (as seen from the pollen record). The period of first intensive soil development is also recorded for the Late-glacial Interstadial in lowland loess plateaus of the Czech Republic: Loess formation, which was characteristic of Late Pleniglacial, terminates during Bölling phase (the first half of the Late-glacial Interstadial) and initial pedogenesis takes place during that time (LOŽEK & CÍLEK 1995).

Younger Dryas climatic reversal.

The Younger Dryas as a biozone has been widely recognized over the most of Europe. Concerning the duration and the amplitude, this climatic oscillation was the most important during the whole Late-glacial period (LOTTER ET AL. 1992). Younger Dryas climatic deterioration, dated roughly between 11 and 10 ka BP, is correlated with a readvance of polar waters into the North Atlantic. Although the problems of absolute dating accompany the recognition of Younger Dryas event (the „^{14}C plateau" occurrence; AMMANN & LOTTER 1989), it has been described from many sites in the world and today is believed to be a global event (PETEET 1995). At site under present study, clear evidence of climatic deterioration is also dated to Younger Dryas chronozone. However, this climatic oscillation did not resulted in complete deforestation. The pine-birch woodland became only somewhat more open, whereas the importance of heliophyllous herbs and dwarf shrubs - *Alnus viridis, Salix, Betula nana, Chenopodiaceae* and *Artemisia* newly increased. Proxy-evidence suggest, that climatic deterioration was rather increase in continentality than decrease in summer temperatures (see also AMMANN 1989): Reconstructed minimum July temperatures are still at least 12 °C, e.i. the same value as reconstructed for western Poland (WALKER 1995).

During the Younger Dryas episode, sedimentation character in the lake basin changes to more minerogenic again. Organic carbon content decreases to about 10%, accompanied by fall in N and P, suggesting period of lower productivity. Slight increase in erosion indicators (Mg, K, reworked Tertiary pollen) is observed during the same time. This increase is only indistinctive, suggesting that soil development was not interrupted completely during Younger Dryas and the destruction of yet-formed soils has not been significant.

Early Holocene climatic amelioration (Preboreal and Boreal periods).

There is abundant evidence throughout Europe for a rapid rise in temperature at around 10 000 BP, although precise dating of this event is difficult as another „radiocarbon plateau" occurs at about that time. Over many areas of central and north-west Europe, Younger Dryas open communities were replaced within less than 500 years by *Betula/Pinus/Corylus* woodland (WALKER 1995). The preservation of *Pinus*-dominated forest in the area under study during the whole Early Holocene and relatively late development of deciduous forest, was connected with the persistence of continental climate during that time and generally low nutrient status together with the sandy character of soils. *Pinus* forest persisted in the area until the increase in humidity during the onset of Boreal period (for evidence see later), although deciduous forests started to develop in favourable locations somewhat earlier. The rapid temperature rise during Preboreal is indicated in lake environment by early occurrence of *Najas marina, Najas minor* and *Trapa natans* macrofossils. *Najas marina* suggest a mean July temperature not below 15 °C (LOTTER 1988), *Trapa natans* even more. According to GAMS (1926) and JORGA ET AL. (1982), water chestnut requires mean July water temperature not below 20 °C and in May, when it starts flowering, at least 12 °C. The rapid change to warmer climatic conditions is also evidenced (according to VAN GEEL ET AL. 1989) through appearance of macroscopic colonies of thermophillous blue-green algae *Gloeotrichia pisum*. This proxy-evidence suggest that the present-day temperature values were reached as early as about 9 800 BP.

Organic sediment (gyttja), rich in macrofossils, started to accumulate in the basin again. The short decrease in organic production at 480 cm is problematic to attribute to some climatic oscillation without exact time control available. Sedimentary phosphorus content fluctuate but is generally low during Early Holocene. It suddenly fall to very small values during Boreal period. The exact explanation of this phenomenon is not still possible without more data available (the study of phosphorus forms would be necessary).

The Early Holocene sediment record from Švarcenberk lake comprises a prominent Fe peak, dated to around 8 600 BP. It may be best explained as the reflection of intensive leaching caused by sudden humification of climate (ENGSTROM & WRIGHT 1984, STARKEL 1991). In the pollen record, the same period is characterized by *Picea abies* expansion. There is probably some connection between these two phenomena, as spruce grows preferably on waterlogged soils and is able to produce highly acidic, raw humus, promoting intensive leaching. The gradual development of nutrient-poor, acid soils was an important factor in the Holocene vegetation development, as emphasized by IVERSEN (1958, 1964). The building-up of raw humus on the soil surface and resulting reducing conditions may have released Fe from the soil and it traveled to the lake in solution or bound in organic complexes. Resembling ferrugineous peak has been described from lowland areas of the Czech Republic, where Early Holocene debris are cemented by limonite and goethite (LOŽEK & CÍLEK 1995). Also in Poland, the beginning of Holocene is characterized by inwashing of dissolved iron into the lakes and this is interpreted as the first stage of intensive soil leaching (PAWLIKOWSKI ET AL. 1982). In southern Sweden, the Fe content of several Early Holocene lake sediments is very high. DIGGERFELD (1972, 1975) attributes this ferrugineous peak to early leaching from Late-glacial soils in the catchment and subsequent transport by groundwater to the lake.

Holocene climatic optimum (Atlantic).

The climatic optimum sediment record is strongly affected by local environmental change - the final terrestrialization of the lake basin. After terestrialization of the lake, the center of the basin has developed into a eutrophic march - reed swamp surrounded by alder carr. Accumulation of peat began that time. As the peat surface started doming over the surrounding terrain, the wetland has successively developed into oligotrophic Sphagnum peat-bog, isolated from direct influence form former lake catchment. This process is well-reflected in sediment chemical record: Nutrient status of the peat is very low and C/N ratio sharply increase if compared with underlying lake sediments.

Evidence for early human impact on vegetation from the sediments of the Lake Švarcenberk.

Today, palaeoecologists diverge in their ideas concerning earliest history of human impact on natural environment. The deepest roots of modern, anthropogenic landscape of central Europe are traditionally viewed in the Neolithic period. Pre-Neolithic, central European landscape is sometimes considered to be the „virgin" one (RYBNÍČKOVÁ & RYBNÍČEK 1985) and the potential of palynological indication of human impact is generally believed to be very limited (KLOSS 1987, BERGLUND 1988). However, new evidence shows, that Mesolithic populations of hunter-gatherers exploated their natural environment more intensively than previously assumed. E.g. the utilization of several plant species (hazel - *Corylus avellana*, water-chessnut - *Trapa natans* and other water species) could even have the character of intentional management (ZVELEBIL 1994).

Recent discovery of thick, buried lake sediments in the Třeboň Basin represents an exceptional opportunity for the study of early human impact on vegetation, since Mesolithic settlement has been found in the nearest vicinity of the former lake. High concentration of charcoal particles in lake sediments of Early Holocene age may indicate intentional forest burning. Pollen curves of several secondary anthropogenic indicators (*Thalictrum*, *Calluna vulgaris*, *Rumex acetosella*, *Plantago major*-type, *Plantago lanceolata*, *Gramineae*) seem to be correlated with the occurrence of sedimentary charcoal particles, as well as the presence of *Pteridium* spores (this fern usually grows in burned forest soils). The early occurrence of *Trapa natans* nuts (dated close to 10 000 BP) in the lake sediments evoke the suspicion of its intentional introduction by hunter-gatherer populations. Interesting are also the early finds of cereal-type pollen (*Triticum*-type), which can be interpreted either as long-distance transport or the result of the domestication of autochtonous grasses (ZVELEBIL 1994, REGNELL ET AL. 1995).

The indirect evidence of human presence in the lake ends up in the Middle Holocene (around 6 000 BP), when the terrestrialization process of the lake reached its final stage.

Appendix: Long-term vegetation dynamics of aldercarr communities and its palaeoecological significance.

After the terrestrialization of the lake Švarcenberk, alder carr (*Alnus glutinosa* fen) communities developed in its place. During the investigation, significant stratigraphic hiatuses has been observed in connection with alder-peat occurrence. Inspired by these finds, comparative study of local vegetation development has been performed in alder carr "Na Bahně" (eastern Bohemia). The Late Holocene sedimentary sequence has been studied by means of pollen and macrofossil analyses and combined with present vegetation analysis. Local successional changes started with an oxbow lake (160 cal BC) which has later terrestrialized (630 cal AD). Then it changed from a typical alluvial fen into a *Sphagnum*-dominated spring mire (950 cal AD) supplied by water arising from river terrace surrounding the locality from three sites. In the center of this wetland a small patch of alder carr developed (1000 cal. AD), showing a tendency towards cyclic succession. The alder carr alternated several times with an open *Carex* fen (1 100 cal AD to recent). The last fen-to-alder carr transition has been documented by direct observations performed by several investigators during this century.

Proposed model of autogenic cyclic succession corresponds well with direct field observations and can be used to interpret alder carr structure, its dynamics, as well as the occurrence of stratigraphic hiatuses developing under alder carr communities: Long-term persistence of alder-dominated stands require continuous alder regeneration. Alder carrs require nearly full light conditions for their establishment. Most alder-dominated stands with a canopy cover of 30 - 50 % are not suitable for surviving of alder seedlings (KORPEĽ 1995, TUCKER & FITTER 1981). The light regime in a closed alder carr is insufficient even for regeneration from the bases of dead mother trunk, so daughter trees have a low vitality and die soon. Seedlings and basal shoots can develop and contribute to the canopy only in a swamp carr on a floating mat where trees are short (2 to 3 m tall, with little foliage) and sparse (MC VEAN 1956b). Another factor adversely affecting the establishment of alder seedlings in alder-dominated stands is often too high a soil moisture (MCVEAN 1956a). In an alder carr, mineralization of the peat results in increased soil moisture and waterlogging. The age structure of most alder stands also raises doubts about their long-term persistence. Even-aged alder populations, indicating a short single period of alder establishment, are usually found (PIGOTT & WILSON 1978, TUCKER & FITTER, 1981). Therefore, the through regeneration of alder in an alder carr seems to be unlikely. As alder cannot regenerate in closed-canopy stands, a massive dieback of even-aged alder trees can be expected at an age of 100-150 years, depending on their vitality. Increased light availability may stimulate the development of an open mire covered with light-demanding plants and intensively accumulating the peat. The more substrate has been mineralized during previous alder phase, the longer is the stage of open vegetation, because the mineralization resulted in an increased soil moisture. Thereto, the evapotranspiration rate decreases as the result of tree layer dieback, also contributing to general waterlogging of the site. Only when the newly formed peat layer starts doming over the groundwater table again (as a whole or by forming the tussocks), alder seedlings may establish on the site and the cycle is completed. Newly established alder stand is even-aged because the establishment took place during a short time. If the peat layer is repeatedly mineralized during alder carr phase, the cycle can hardly be inferred from palaeoecological data._In the central part of the "Na bahně" site, where the sediment core has been taken, peat mineralization is a slow process due to the high and stable water level resulting from the local springs. Thus the exceptional hydrological conditions resulted in a well-preserved palaeoecological record.

REFERENCES (LITERATURA)

AMMANN B. & LOTTER A.F. (1989): Late-glacial radiocarbon and palynostratigraphy of the Swiss Plateau. *Boreas*, 18: 109-126.

AMMANN B. (1989): Response times in bio- and isotope-stratigraphies to Late-glacial climatic shifts - an example from lake deposits. *Ecologae Geol. Helv.*, 82/1: 183-190.

BIRKS H.H. (1993): Ihe importance of plant macrofossils in Late-glacial climatic reconstructions: an example from western Norway. *Quaternary Science Reviews*, 12, 719-726.

DEARING J.A. (1991): Lake sediment record of erosional processes. *Hydrobiologia*, 214: 99-106.

DIGGERFELD G. (1972): The post-glacial development of Lake Trummen. *Folia Limnologica Scandinavica*, 16, 1-104.

DIGGERFELD H. (1975): The post-glacial development of Ranvinken bay in Lake Immeln. III. Palaeolimnology. *Geologiska Föreningens i Stockholm Förhandingar*, 97, 13-28.

ENGSTROM D.R. & WRIGHT H.E. JR. (1984): Chemical stratigraphy of lake sediments as record of environmental change. In: HAWORTH E.Y. & LUND J.G.W. (eds), *Lake sediments and environmental history.* Leicester University Press, U.K., pp. 11-67.

GAMS H. (1926): Hydrocaryaceae. In: HEGGI (ed.), *Flora von Mitteleuropa*. Band V/2. München, pp. 882-894.

HOEK W. (1997): Palaeogeography of Lateglacial Vegetations. Aspects of Lateglacial and Early Holocene vegetation, abiotic landscape, and climate in The Netherlands. *Netherlandse Geografische Studies*, 230: 1-147.

HUIZER A.S. & IZARIN R.F.B. (1997): The reconstruction of past climates using multi-proxy evidence: An example of the Wichselian Pleniglacial in northwest and central Europe. *Quaternary Sci. Rev.*, 16: 513-533.

IVERSEN J. (1958): The bearing of glacial and interglacial epochs on the formation and extinction of plant taxa. *Uppsala Universiteit Arssk*, 6, 210-215

IVERSEN J. (1964): Retrogressive vegetational succession in the post-glacial. *Journal of Ecology*, 52: 59-70.

JANKOVSKÁ V. (1970): Ergebnisse der Pollen- und Grosrestanalyse des Moors „Velanská cesta" in Südböhmen. *Folia Geobot. Phytotax.*, 5: 43-60.

JANKOVSKÁ V. (1980): *Paläogeobotanische Rekonstruktion der Vegetationsentwicklung im Becken Třeboňská pánev während des Spätglazials und Holozäns.* Vegetace ČSSR A11, Academia, Praha.

JANKOVSKÁ V. (1983): Palynologische Forschung am ehemaligen Komořany-See (Spätglazial bis Subatlanticum). *Věstník Ústředního ústavu geologického*, 58(2): 99-107.

JORGA W., PIETSCH W. & WEISE G. (1982): Beiträge zur Ökologie und Bioindication von *Trapa natans* L.. *Limnologica*, 14(2): 385-394.

KLOSS K. (1987): Pollenanalysen zur Vegetationsgeshichte, Moorenentwicklung und mesolilisch-neolitischen Besiedlung in Unteren Rhinluch bei Friesack, Bezirk Potsdam. *Ver. Mus. Früh. Potsdam* 21: 101-120.

KORPEĽ, Š. (1995): *Die Urwälder der Westkarpaten*. Gustav Fischer Verlag, Stuttgart.

LOSERT H. (1940): Beiträge zur spät- und nacheiszeitlichen Vegetationsgeschichte Innerböhmens. I. Der „Kommerner See". *Beih. Bot. Cbl.*, Dresden, 60: 346-393.

LOTTER A.F. (1988): Paläeoökologische und paläolimnologische Studie des Rotsees bei Luzern. Pollen-, grossrest-, diatomen- und sedimentanalytische Untersuchungen. *Diss. bot.*, 124: 1-187.

LOWE J.J., AMMANN B., BIRKS H.H., BJÖRCK S., COOPE G.R., CWYNAR L., DE BEAULIEU J.-L., MOTT J.R., PETEET D.M. & WALKER M.J.C. (1994): Climatic changes in areas adjacent to the North Atlantic during the last glacial-interglacial transition (14-9 ka BP): a contribution to IGCP-253. *Journal of Quaternary Science*, 9, 185-198.

LOŽEK V. & CÍLEK V. (1995): Late Weichselian-Holocene sediments and soils in mid-European calcareous areas. *Anthropozoikum*, 22, 87-112.

MCVEAN D. N. (1956a): Ecology of *Alnus glutinosa* (L.) Gaertn. III. Seedling establishment. *J. Ecol.* 44: 195-218.

MCVEAN D. N. (1956b): Ecology of *Alnus glutinosa* (L.) Gaertn. V. Notes on some British Alder populations. *J. Ecol.* 44: 321-330.

NEUSTUPNÝ E. (1985): K holocénu Komořanského jezera. *Pam. Archeol.*, Praha, 76: 9-70.

OLSON I.U. (1986): Radiometric dating. In: BERGLUND B.E. (ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology*. J. Wiley & Sons.

PAWLIKOWSKI M., RALSKA-JASIEWICZOWA M., SCHÖNBORN W., STUPNICKA E. & SZEROCZYŃSKA K. (1982): Woryty near Gietrzwald, Olsztyn Lake District, northeast Poland - vegetational history and lake development during the last 12 00 years. *Acta Plalaeobotanica*, 22, 1-120.

PETEET D. (1995): Global Younger Dryas? *Quaternary International*, 28, 93-104.

PIGOTT C.D. & WILSON J.F. (1978): The vegetation of North Fen at Esthwaite in 1967-9. *Proc. Roy. Soc. Lond.* B200: 331-351.

REGNELL M., GAILLARD M.J., BARTHOLIN T.S. & KARSTEN P. (1995): Reconstruction of environment and history of plant use during the late Mesolithic (Ertebole culture) at the inland settlement of Bökegerg III, southern Sweden. *Veget. Hist. Archaeobot.* 4: 67-91

RUDOLPH K. (1926): Pollenanalytische Untersuchungen im thermophilen Florengebiet Böhmens: Der Kommerner See. *Ber. Deutsch. Bot. Ges.*, Jena, 44: 239-248.

RYBNÍČEK K. (1983): The environmental evolution and infilling process of a former lake near Vracov (Czechoslovakia). *Hydrobiologia* 103: 247-250.

RYBNÍČKOVÁ E. & RYBNÍČEK K. (1972): Erste Ergebnisse paläogeobotanischer Untersuchungen des Moores bei Vracov, Südmähren. *Folia Geobotanica et Phytotaxonomica*, 7, 285-308.

RYBNÍČKOVÁ E. & RYBNÍČEK K. (1985): Palaeogeobotanical evaluation of the Holocene profile from the Řežabinec Fish-pond. *Folia Geobot. Phytotax. 20*: 419-439.

STARKEL L. (1990): Environmental changes at the Younger Dryas-Preboreal transition and during the early Holocene: some distinctive aspects in Central Europe. *The Holocene*, 1, 234-242.

TUCKER J.J. & FITTER A.H. (1981): Ecological studies at Askham Bog Nature Reserve 2. The tree population of Far Wood. *Naturalist* 106: 3-14.

TYRÁČEK J. (1995): Depositonal chnges in non-glaciated regions of central Europe. *Quaternary International*, 28, 77-81.

WALKER M.J.C. (1995): Climatic changes in Europe during the last glacial/interglacial transition. *Quaternary Int.*, 28: 63-76.

WASHBURN A.L. (1980): *Geocryology. A survey of periglacial processes and environments.* John Wiley and Sons, New York.

ZVELEBIL M. (1994): Plant use in the Mesolitic and its role in the transition to farming. *Proceedings of the Prehistoric Society* 60: 35-74.