Other problems are connected with selection and secondary accumulation of palynomorphs due to their different resistences to the chemical and mechanical (transport) processes. It is difficult to say, whether the accumulation of the individual elements was caused by ecological character of the landscape or by special conditions during the sedimentation. In the caves from the Moravian Karst there are known taphocenoses with prevailing small pollen of Asteroideae, or *Tilia*, and smooth monolete spores of Polypodiaceae.

The supporting profile exactly archeologically and paleontologically dated was studied in the incoming part of the Kůlna Cave (Moravian Karst). The sediments were dated from the ending phase of the Saale Glacial to early Holocene. SVOBODOVÁ (1988, 1992) palynologically elaborated the upper part of this profile. the lower part of the supporting profile was studied by DOLÁKOVÁ (2002). Palynospectra from the Kůlna cave may be used for the comparison with the ones from some other caves.

The Lower Miocene up to Lower Badenian sediments were found in the karstic cavities in the quarries Mokrá (Moravian Karst) and Hranice (Hranice Karst). The typical thermophile elements such as Sapotaceae, *Engelhardia*, *Platycarya* were observed. The pollen and spores were accompanied by amount of the marine Dinoflagellata. Removed Cretaceous palynomorphs were observed – in one case even in pollen conglomerate (Normapolles - Hranice). The existence of the Neogene sediments proved that minimally a part of the Moravian karstic areas is of the pre-Quaternary origin.

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Session h7

NON-POLLEN PALYNOMORPHS FROM FRESH-WATER SEDIMENTS, PEAT DEPOSITS AND ARCHAEOLOGICAL SITES

Exploring the ancient occupation of a site at high altitude (Lake Lauzon, Drôme, France): comparison between pollen and non pollen palynomorphs indications

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Next to Lus-la-Croix-Haute (Drôme, France), Lake Lauzon is located in a small basin 1980 m above sea level, 500 m above the actual timberline, in the middle of typical subalpine grasslands, under cliffs and masses of fallen rocks which overlook the Jarjatte valley to the south. A drilling for samples in the wetland area bordering the lake has made it possible to obtain a core of clayey fine sediments with a high organic matter content, in which pollen as well as many micro-organisms had been particularly well preserved.

The pollen analysis and the non pollen palynomorphs analysis both cover a period from 7145±75 BP to subpresent time. The pollen analysis reveals the presence of a flourishing forest vegetation dominated by *Abies*, and the first signs of human activity near the lake and its nearby basins (Trièves, Jarjatte) in the atlantic period. These signs became more pronounced during the Subboreal period from 4700 BP on, with a clear presence of cereals.

This evolution is totally confirmed by the non pollen microfossils. Every time pollen analysis points to clearings or cultivation, the microfossils indicate that man has often burnt the vegetation to obtain openings (occurrences of type 7) since the Neolithic. Increasing of erosion during the subatlantic period is revealed by the occurrence of *Glomus cf. fasciculatum*. Furthermore, non pollen palynomorphs give information on the eutrophication of the lake which may be explained by more nutrient-rich habitats around due to grazing and agriculture.

Using both of these analysis makes it possible to prove that this elevated site has been occupied and cleared early by man to obtain pasturelands and fields. This led to deforestation, which increased during the subatlantic period and has led to the present grasslands.

Non-pollen microfossils as indicators of change in Everglades ecosystems

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The Florida Everglades is the largest remaining sub-tropical wilderness in the United States. It comprises many kinds of ecosystems, including mangrove swamps in coastal regions, rivers, lakes, open ponds, "sawgrass" (*Cladium*) marshes, sloughs (an aquatic system where *Nymphaea* is important), and tree islands. Tree islands are isolated areas of woody vegetation (trees and shrubs) elevated above the surrounding graminoid-dominated marsh. During the last century over half of the Everglades been lost to agricultural or residential development and hydrological changes have altered the remaining system. Large scale restoration efforts are underway, but there is still much to be learned about recent changes in the Everglades, and how different ecosystems respond to changes in fire and hydrological regimes. In particular, little is known about tree islands or their evolution. Paleoecological studies are being conducted to help increase our knowledge.

Pollen, plant spores and other microfossils have been examined in cores from three different tree islands of the Everglades National Park. Paleoenvironments were differentiated on the basis of pollen and plant spores. Microfossils were then assessed for their value as indicators of Everglades ecosystems. In two cores tree island deposits overlay sediments originating in sawgrass marsh, and slough. Algal forms (primarily *Botryococcus* and Zygnemataceae) occurred in all three ecosystems, thus had limited value. Fungal spores and testate amoebae were generally restricted to tree islands. Some testate amoebae were agglutinate forms with tests comprised of charcoal fragments, thus they withstood the HF used in palynological processing.

The hyaline sheaths of *Gloeotrichia* (a nitrogen-fixing cyanobacteria) were present in lower portions of tree island deposits, but also in other deposits where *Typha* or Poaceae pollen appeared (both taxa are relatively rare in older Everglades deposits). In the Everglades a recent dramatic expansion of *Typha* has been attributed to nutrient enrichment from agricultural run-off. Thus, the co-occurrence of *Gloeotrichia* with *Typha* suggests shifts in nutrient regime prior to European expansion into Florida.

Environmental and paleolimnological evolution since 3500 bp in the Maya lowlands. Multiproxy analysis of the Laguna Tuspan (Peten, Guatemala)

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A 6,5m sedimentary core from the Laguna Tuspan (Peten, Guatemala) provides a 3500 yr BP record of detailed human-environment interactions in Maya Lowlands. Multi-proxies analysis including pollen, non pollen palynomorphs (algae, fungi), charcoal particles, geochemistry and magnetic susceptibility was performed on the same core. Chronology and age-depth relationship based on 8 AMS ^{14}C dating of charcoal and terrestrial material indicate high sedimentation rate and provides a reliable chronology of mayan activities in good agreement with local archaeological data.

The first palynological evidences of Maya disturbances and cultivation (Zea) are registered in the basal part of the core c. 3500 BP. Important human-induced deforestation suggested by the decrease in the pollen of trees and by regular occurrences of disturbance taxa (Asteraceae and *Ambrosia*-type) began around 1000 cal. BC during Pre-Classic period. Several phases of cultivation are identified between this period and the end of Classic period. Sediments, non pollen palynomorphs and magnetic susceptibility show soil erosion during each phases of intensive land-use. The return of forest that follows the disappearance of Zea and disturbance taxa can be related to the Classic Maya Collapse c. 900 cal AD.

Using pollen and palynomorphs to distinguish between four different grassland land use types in the salt marshes and dikelands of the upper Bay of Fundy, Canada

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The Bay of Fundy is a highly sedimentary macrotidal basin extending northeastward from the Gulf of Maine. It is bounded to the northwest by New Brunswick and to the southeast by Nova Scotia. The tidal range in the Cumberland Basin at the head of the Bay of Fundy semi-diurnally fluctuates up to 16 m. Extensive salt marshes border the Cumberland Basin but the majority have been diked for agricultural purposes. Palynomorphs from four different grassland land use types were analysed to determine if the land uses could be distinguished based on their microfossil assemblages. The four land uses were salt marsh, cattle grazed or manured dikeland, unmanured hayed dikeland, and fallow dikeland. Conventional pollen counts from the modern soil samples were sufficient to distinguish between salt marshes, fallow dikelands and farmed dikelands; however, pollen signatures were not sufficiently distinct to differentiate between grazed and hayed agricultural land uses. Salt marsh soils were distinguished from dikeland soils by their proportions of locally produced pollen, such as *Plantago sp.* and *Potamogeton*-type (from *Triglochin*), but more so by arboreal pollen that is largely tidally imported. Fallow dikeland soils were enriched in shrub and Asteraceae Tubuliflorae-type pollen while farmed dikeland soils were enriched in Poaceae, Fabaceae and Asteraceae Liguliflorae-type pollen. In order to differentiate between grazed/manured and hayed/unmanured land uses, several types of coprophilous fungal spores were counted in a subset of samples from each land use type and statistically analysed. The fungal spores identified included *Podospora*-type, *Sordaria*-type, *Tripterospora*-type and *Cercophora*-type. Fungal spore counts in farmed dikeland samples with regular cattle grazing or manure application were significantly higher than those from the hayed dikelands, as well as those from the salt marshes and fallow dikelands. This combined pollen and coprophilous fungal spore approach allows for a more detailed interpretation of land uses and may be very useful for historical land use reconstruction.

Extrafossils as palynological tool for the reconstruction of long-term Alpine vegetation change due to Holocene snow avalanches in Tyrol (Austria)

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Snow and ice avalanches belong to the most destructive natural hazards in the Alps. However, the Holocene history and frequency of large avalanches was unknown up to very recently. Here we present results performed in the Ziller Valley (Tyrol) within an interdisciplinary research programme between palynologists, dendrochronologists, foresters, modellers as well as avalanche experts (HOLA – Evidence and Analysis of Holocene Avalanche Events', **http://fbva.forvie.ac.at/800/hola.html**).

The comparison of palynological changes at our study sites 'Schwarzensteinmoor' and 'Schwarzensteinalpe' with dendrochronologically dated avalanche events allows the reconstruction of 6000 years of avalanche impact on the *Pinus cembra* timberline and on Alpine vegetation in general.

Extrafossils such as algal cysts or fungal spores thereby clearly add to our understanding of (palaeo-)ecological change at high altitude and allow to assess the relative importance of climatic change and of prehistorical human impact in the Eastern Alps. Cysts from snow algae such as *Chlamydomonas* and *Chloromonas* may hereby help to reconstruct the long-term avalanche frequency for the Holocene.

Other algae such as *Botryococcus* are clarifying the role of hydrological change for the long-term development of the Alpine flora and vegetation. The intriguing correlation between *Botryococcus* blooms at 2150 m a.s.l. and the expansion of the Abieti-Fagetum at lower, montane altitudes may therefore point to (summer) precipitation as driving factor for the massive immigration and expansion of *Abies alba* and *Fagus sylvatica* 6500 years ago.

Other extrafossils such as spores from coprophilous fungi (see also the new Innsbruck-Extrafossil-Database at **http://botany.uibk.ac.at/downloads/extrafossils.pdf**) are hereby of special interest, as they also allow to adress the importance of livestock grazing and prehistoric man on tree populations at timberline in the Austrian Alps.

A multi-proxy reconstruction of late Holocene environmental history and human interrelationships in Uganda

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Reconstructing environmental history and human-environment interrelationships in pre-colonial central Africa during the Late-Holocene period has been the focus of recent palaeoenvironmental and archaeological studies. This paper details an attempt to investigate the potential of phytoliths and fungal spores used in combination with other sources of palaeoenvironmental information as proxies of vegetation history in Uganda. The research focuses on the last ca. 1000 years, which is a period of major socio-economic and environmental changes in the region. Phytoliths, pollen and fungal spores were extracted from sediment cores collected from a previously excavated archaeological site located at Munsa and used in conjunction with conventional charcoal, AMS ^{14}C and archaeological information.

Fossil phytoliths provided additional information in reconstructing vegetation, enabling the discrimination of vegetation types and agricultural activities generally invisible in standard pollen and carbon isotope analyses. Phytolith morphotyes discriminated forest and shrub vegetation dominated by C_3 plants from C_3/C_4 grasses that are adapted to various soil environments and climatic conditions. The phytoliths also provided evidence of early banana cultivation in the region. The remains of fungal spores indicate past periods of high densities of herbivores around the site. Phytolith and pollen records indicate significant vegetation change in the region for the last ca 4,000 years. A relatively wet and forested period existed prior to the period ca 1,000 yr. BP. This was followed by a period of human induced forest clearance and burning that caused a significant decline in forest vegetation, increased charcoal and grassland-dominated community in the study area. A phase of forest recovery occurred ca 200yr. BP, correlating with the archaeological evidence of abandonment of the site.

Key words: Munsa archaeological site, phytoliths, vegetation history, Uganda.

Reconstructing Holocene palaeoclimate using pollen, non-pollen palynomorphs and geochemical data from the ombrotrophic peat bog of Pena da Candela, NW Spain

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Pena da Cadela bog is a saddle mire situated in the Xistral Mountains (NW Spain), at an elevation of 970 m a.s.l. and 25 km south of the coast. Present day vegetation is dominated by sedges (*Carex durieui, C. vulgaris, C. panicea, Eleocharis multicaulis*) and grasses (*Agrostis curtisii, A. hesperica, Molina caerulea, Deschampsia flexuosa*); heathers are also present (*Erica mackaiana, E. cinerea*) (FRAGA VILA et al., 2001).

In October 1998 a peat core of 185 cm was taken by direct sampling in a recently opened ditch. The core was sliced into 2 cm sections and the sections analysed for trace elements, pollen and non-pollen palynomorphs. The trace elements were measured using an energy-dispersive miniprobe multi-element analyzer (EMMA) at Key Analytical Inc (Canada) whilst the pollen and palynomorphs were prepared and analysed following routine methods (Barber, 1976). The age of the base of this core is 5,300 calibrated years BP.

Variations in the abundance of non-pollen palynomorphs (NPP) show no correlation with a temperature index (TI) but a few of them showed a remarkable similarity with a humidity index (HI) developed for NW Spain in a previous work (MARTINEZ CORTIZAS et al., 1999). Non-pollen palynomorphs T18 and T44(?) show a direct relationship to HI and also to *Cyperaceae* abundance, while T306 shows an inverse relationship. These results indicate that T18, T44 and *Cyperaceae* increased during wet periods and decreased during dry periods; T306 percentages increased during dry and decreased during wet periods. The changes in NPP abundance suggest the presence of at least four main wet periods during the last 5,300 years (based on the T18 abundance): 1860 BC to 1590 BC, 1015 BC to 260 AD (probably two periods: 1015 BC to 790 BC and 580 BC to 260 BC), 190 AD to 525 AD and 1110 AD to 1470 AD.

The records of chemical elements also show good correlation with the NPP / wetness variations. Lithogenic elements were supplied to the bog by the deposition of atmospheric dust (Ti, Y, Zr) as well as some elements bound to the organic matter (like Se and Br). All have high concentrations in peat sections with low T18 (i.e. during dry phases) and low concentrations coinciding with high T18 abundance (i.e wet phases). During dry periods higher dust deposition may be expected since the amount of atmospheric dust and its residence time is inversely correlated to the amount of rainfall (PROSPERO & LAMB, 2003), explaining the increase in the fluxes of lithogenic elements. The increase in concentration of elements bound to the organic matter (OM) seems to be related to an enhanced peat degradation / decomposition. FREEMAN et al. (2001) have demonstrated that the shortage of oxygen limits peat decomposition by restraining the enzimatic activity of the phenol oxidase, while aeration has the opposing effect. On the other hand, different authors have found that halogens (as Cl and Br) are incorporated to the OM during its degradation (MYNENI, 2002; KEPPLER & BIESTER, 2003). In wet periods the high water table prevents or slows peat decomposition because of the anoxic conditions, while in dry periods the drop of the water table increases aeration in the upper sections of the bog accelerating peat degradation and the incorporation of halogens to the OM. Increased peat mineralization may also affect to the concentration of lithogenic elements since the inorganic material will be relatively enriched due the mass loss of the organic component of the peat. The net effect may be an enrichment of many elements in the peat during dry periods.

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Freshwater algal palynomorph records from the Holocene Lagoonal deposits in the coastal plain of Rio Grande do Sul, Brazil

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The specific features of the present-day environment of the Coastal Plain in the State of Rio Grande do Sul is a result of the Holocene evolution of this region associated with climatic changes and sea-level oscillations. Lagoons, which formed during the last Postglacial marine transgression, are widespread. The reconstruction of the history of these lagoons and surrounding areas are usually based on palynological data from the Holocene lagoonal sediments. Freshwater algal palynomorphs are encountered in the Holocene lagoonal deposits of this region together with pollen and spores of terrestrial and aquatic vascular plants, cysts of dinoflagellates and acritarchs, and fungal spores. These palynomorphs are represented by zygospores and coenobias of Chlorophycean and Zygnematophycean algae. Sometimes, freshwater algal palynomorphs are more frequent in samples than the palynomorphs of other plants.

Due to sporopollenin-like composition of the exterior layer, the freshwater algal palynomorphs are very well preserved in deposits and are not destroyed during the chemical treatment of samples. Van Geel (1976) and Van der Hammen (Van Geel & Hammen, 1978) were the first palynologists who indicated the importance of fresh water algal palynomorphs for palaeoecological reconstructions. The zygospores of *Spirogyra, Zygnema, Mougeotia, Debarya* and coenobias of *Botryococcus* and *Pediastrum* are the most widespread algal palynomorphs in the Holocene deposits. All of them are considered as freshwater algae but differ in tolerance to salinity, depth, and pH.

The algal palynomorphs were studied both superface sediments, and core Holocene sediments. The recent superficial deposits from the lagoon, salt marshes, freshwater marshes, peat and fluvial deposits were collected and analyzed in order to establish the algal palynomorph assemblages for each. type of environment and use the obtained data for palaeoecological reconstruction. As a result, four types of assemlages were recognized: (1) Predominant: *Pediastrum* + *Mougeotia* + *Spirogyra* with subordinate *Debarya, Zygnema,* and rare *Chara* (fluvial deposits); (2) Predominant *Spirogyra* with subordinate *Botryococcus, Debarya, Zygnema, Mougeotia* (freshwater marsh deposits); (3) Predominant *Botryococcus* with subordinate *Spirogyra* and rare *Debarya, Mougeotia,* and *Zygnema* (salt marsh and superface lagoonal deposits); (4) Predominant *Spirogyra* with subordinate *Pseudoschizea,* ocasional *Botryococcus, Zygnema, Coelastrum,* and very rare *Tetraedron* (peat).

The Holocene deposits were collected from cores extracted from 6 boreholes drilled in the dos Patos Lagoon, the Tramandaí Lagoon and adjacent terrestrial areas. A total of 120 samples were studied. A great number of freshwater algal palynomorphs were identified in the Holocene lagoonal deposits. The changes in ratio between marine algal palynomorphs (dinoflagellates and acritarchs), silicoflagellates and freshwater algae palynomorphs related to marine transgression and regression stages comply with diatom analysis data and ^{14}C datings.

The deposits corresponding to the epoch of transgression include less freshwater palynomorps than those in the regressive series. However, *Botryococcus* predominate, and *Spirogyra* constantly present virtually in all Holocene lagoonal sediments. Significant predominance of *Botryococcus* in comparison with the sum of all encountered palynomorphs was determinated from the lagoon deposits corresponded to regressive stage. Other freshwater algal palynomorphs (*Pediastrum, Mougeotia, Debarya, Zygnema, Pseudoschizea*) in lagoonal deposits are sporadic. They were probably allochthonous, carried by freshwater influxes into lagoon during the pluvial periods, which led to freshening of the lagoons. Their proportion in different samples are varying, probably due to oscillations in atmospheric precipitation.

Obtained data indicate that freshwater algal palynomorphs are important for the reconstruction of the environmental evolution of the Coastal Plain during the Holocene. They may serve as sensitive indicators of salinity, pH and depth changes in palaeolagoons influenced by climate and sea level oscillations. Increase in *Botryococcus* content in lagoonal deposits may be related to dry periods, and *Pediastrum* increase, on the contrary, may indicate pluvial periods.

Detailed morphologic studies of freshwater algal oalynomorps and the establishment of their ecology are important for succesful application of these algal palynomorphs in palaeoecological reconstruction.

Non-pollen palynomorphs in alder carrs

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The interpretation of palaeo-ecological data may profit greatly from the inclusion of non-pollen palynomorphs (VAN GEEL 1972, VAN GEEL 1978, VAN GEEL *et al.* 1980/81, PALS *et al.* 1980, etc.). Thus far analysis of bog peat has received most of the attention in this respect. The focus of the Palaeo-Landecology Group Greifswald lies on fen ecosystems, including alder carrs. In these peat deposits, pollen grains and macrofossils are usually in a bad state of conservation (BARTHELMES 2000). Many non-pollen palynomorphs are more resistant to corrosion and thus provide an interesting alternative source of palaeo-information.

To improve the interpretation of non-pollen palynomorph data surface samples were compared with data on vegetation and environmental conditions.

The samples were taken in 11 alder carrs with varying ecological conditions in northeastern Germany. Material was gathered from both hummocks and hollows and varied from moss, to dead wood and bark, to litter. Samples were prepared following the standard protocol for pollen samples (*cf.* FAEGRI & IVERSEN 1989). Vegetation relevees were made, including mosses and fungi, and environmental conditions like pH, nutrient factors, and water level and dynamics were measured.

Besides providing indicators by correlation of palynomorph data with environmental conditions and vegetation, comparison with the present taxa encountered may lead to the identification of the actual producers of the non-pollen palynomorphs.

In order the information more easily accessible, a database that includes data on morphology, habitats, environmental conditions, life strategies, correlations with other species, taxonomy, and (when available) a photograph has been created. Data from literature and from other, unpublished sources has been added where possible. Standardised morphological descriptors allow for easy identification and description. The growing database will be made available as an aid in identifying non-pollen palynomorphs and as a tool for providing information on site conditions indicated by these non-pollen palynomorphs.

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The paleo-environmental indicator value of non-pollen palynomorphs in lake sediments, peat deposits, and archaeological sites

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In pollen preparations, other microfossils of various origin are often also preserved. Over the past 35 years, the palynology of Late Quaternary deposits has been studied at the Paleoecology research group of the

University of Amsterdam. Pollen analyses have been combined with the study of all 'extra' microfossils (non-pollen palynomorphs: NPP) exhibiting a characteristic morphology.

The aim has been to catalogue as yet uncharacterised fossils, and this strategy has resulted in a number of 'new' palaeo-environmental indicators being discovered. Among the NPP were fungal spores, algal remains, cyanobacteria and invertebrates. In a series of papers, the NPP have been described and illustrated and their indicator value discussed. In every case, morphological descriptions have been combined with stratigraphic information, often in the form of pollen and macrofossil diagrams.

Several hundred 'Types' have now been distinguished. In most cases initially there was none, or hardly any taxonomical and ecological knowledge about these Types. The identification of the palynomorphs was attempted with the aid of literature and by consultation with colleagues in the fields of invertebrate zoology, phycology, mycology and plant anatomy. Among the Types there still are many taxa which have not been properly identified, but some of them nevertheless can be used as palaeo-environmental indicators. In such cases, the ecological information is inferred from the co-occurrence (curve matching) with identified taxa (e.g., pollen, seeds).

Most fungal, algal taxa and cyanobacteria have a much longer geological history than angiosperms and gymnosperms, and, therefore, some of the NPP studies are also of interest for palynologists specialised in the analysis of pre-Quaternary deposits. An overview will be given of the most informative NPP from lakes, fens, bogs and archaeological sites. Some hitherto undescribed fossil fungal spores (*Oncopodiella trigonella*, *Bactrodesmium* cf. *abruptum*), indicating nearby stands of trees on An Loch Mór, a presently tree-less island located near the west-coast of Ireland, will also be presented.

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Fungal spores in pollen diagrams as cultural indicators examples from our own work

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Since Bas van Geel (Amsterdam) has made us aware of the interpretative value of extra microfossils encountered in pollen slides, we found that certain easy-to-count fungal spores are of great value in tracing cattle

grazing and other forms of past human activity in the landscape. (1) In Sägistalsee, a lake high in the northern Swiss Alps, spores of the dung fungi *Podospora*, *Cercophora*, and *Sporormiella* supported the interpretation of pollen and spores in terms of early cattle grazing (Neolithic and later; Wick et al., 2003). (2) In Bibersee, a small former lake on the Swiss Plateau north of the Alps, fungal spores of *Ustulina deusta* trace the management of *Fagus* forests (van der Knaap and van Leeuwen, 2001). This fungus thrives preferentially on bark of dead and dying *Fagus* trees. *Ustulina* declined abruptly around 3600 cal BP when grassland pollen and Cerealia increased, but continued high *Fagus* pollen values indicate that the beech forests were little affected. Our explanation for the decline of *Ustulina* is that humans removed the dead *Fagus* wood, possibly for the use as fuel and to facilitate forest grazing. (3) In an unpublished pollen diagram from the Azores, *Podospora* and *Cercophora* spores appear with the first colonization by man in the sixteenth century. (4) In a pollen diagram from peat with near-annual resolution for the last century (Praz Rodet in the Swiss Jura Mountains; van der Knaap et al., 2000), extreme peaks of *Podospora* and *Sporormiella* dung-fungal spores and grassland plant pollen (*Trifolium* and others) are too short in duration (essentially one level analysed for pollen) to allow an interpretation as a change in local vegetation from peat to grassland and back again. It must therefore represent dung on the bog surface left by stray cattle, with grassland pollen in the dung and the fungi growing on it.

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Mid-Holocene environmental change at Black Ridge Brook, Dartmoor, SW England: a new appraisal based on fungal spore analysis

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Black Ridge Brook is an upland peat site in a climatically wet area of SW England. Pollen evidence from the area has shown that it was once wooded, with *Betula* and then *Corylus* dominant, before successive periods of change to more open ground and a gradual spread of mire vegetation types. Previous palaeoecological work inferred a history of burning and grazing based on microscopic charcoal levels and pollen indicators of acid heath and bog vegetation. This led to the development of a qualitative model of vegetation change and blanket bog initiation that implicated Mesolithic human activity, as suggested elsewhere in upland Britain.

In this paper, the assumptions of grazing and burning at the site are tested using fungal spore assemblages. Fungal spores are common in some peat types, and in many pollen preparations, but have often been under-utilised. A re-analysis of the changing vegetation patterns, combining charcoal, pollen and fungal spore data confirms the importance of grazing in certain phases of the vegetation development, although not in all cases. Indicators of burned ground are less conclusive, perhaps suggesting phases when the site itself was burned, rather than receiving microcharcoal fragments only from distal sources. Multivariate statistical analysis of the combined fungi, pollen and charcoal data suggests that there is a clear link between some fungal types and different stages of woodland recession. Fungi associated with *Calluna* suggest that the site itself was only colonised by *Calluna* in the last phase of the diagram, despite relatively high pollen counts in earlier stages.

Overall, conclusions regarding the interpretation of the Black Ridge Brook site and the use of fungal spores in this context may be reached. Firstly, the Black Ridge Brook data are well structured and show both local and regional changes in vegetation and fire history, with fungal evidence able to distinguish between the two in some cases. Secondly, fungi appear to show a local pattern primarily, with many interpretations still limited to palaeoecological inference. Identification of phases of local burning and grazing, however, enhances our understanding of the sequence of events leading eventually to the current open blanket mire landscape.

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Multi-proxy studies in the lake Estanya (pre-Pyrenean region, NE of Iberian Peninsula): 2,000 years of land use and climatic change

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Lake Estanya is a carbonated lake located at 670 m a.s.l. in the Pre-Pyrenean ranges, close to the northern boundary of the Ebro Basin. Climate is characterized by an annual rainfall of 625 mm and a mean annual temperature of 12.2 °C.

Maximum water depht is 22 m. The lake is monomictic, with a thermal stratification extending from March to September. The lake has a negligible catchment area and it is mainly fed by underground springs.

A core of 1,57 m depth was obtained in the shore of the lake using a piston core.

Multi-proxy analyses were carried out. Proxies analyzed were: lithology, sediment structure, mineralogical composition, water and organic carbon content, ostracod content, geochemistry of ostracod valves, microcharcoal particles, pollen and non-pollen microfossils.

Chronological model was built using radiocarbon dates and historical data of land use with a strong correlation with changes of taxa in the pollen record.

Cross comparison between multi-proxies allowed us to isolate between human and climate signals and to determine the causes of the environmental changes.

Seven main episodes of environmental change were established on the basis of multi-proxy data:

Episode I (160±90 to 1075±40 AD): Dominance of saline waters as a consequence of low water levels. Non-pollen microfossils suggest mesothrophic-eutrophic conditions during X-XI th centuries.

The first important human impact on vegetation were due to the frequent fires indicated by the maximum charcoal concentrations during the IX th -XI th centuries. The first phase of large-scale forest clearances and soil erosion occurred at the same time as the lake reached its lowest water level.

Muslim and Christian warlords carried out raids over the border, and the high frequency of fires could have been used as a military strategy to prevent settlements. Pollen record indicates thet griculture during the X th century was mainly dedicated to vineyards, cereals and hemp.

Nitrophilous herbs and the high percentages of *Artemisia* suggest that the clearances could also be attributed to the expansion of pastoral activities in spite that non-pollen microfossils related to grazing are very scarce.

Episode II (1075±40 to 1220±40 AD): This episode is mainly characterized by a rise in the water level probably due to moister conditions. Woodland recovers former deforested areas because of a decline in wars and human activity, although vineyards and cereal crops continue to be present.

Episode III (1220±40 to 1360±50 AD): This episode records a drastic change in water chemistry suggesting shallower conditions and calcium-rich water. Lake level reconstruction indicates a fall to 2m below present day level. Non pollen microfossils indicate shallow-eutrophic waters and high temperature.

Olive groves expanded during the XIII th century at the expense of vineyards induced by the warmer and drier conditions between 1220 and 1360 AD. These climatic conditions could be correlated with the Medieval Warm Period.

Episode IV (1360±50 to 1580±40 AD): A progressive change from shallower to freshwater (mesotrophic) conditions occurred as a consequence of water level rise. Maximum water level occurred at ca. 1550 AD. The rise in water level coincided with the increase in hemp production. The water channels linking the three lakes were probably built during this episode. Nevertheless, little water was added by the channels to the lake compared with the large volume from the underground sources.

This episode records two phases of vegetation change: 1360-1510 AD is characterized by large-scale deforestation due to the expansion of pastoral and arable farming; the phase 1510-1580 AD recorded a forest regeneration as a consequence of the demographic crisis during the Modern Age.

Episode V (1580±40 to 1760±30 AD): Multi-proxy data suggest a fall in the lake water level and mesothropic conditions. The minimum lake level was recorded at ca. 1700 AD. Hemp production reached a peak according to the pollen diagram. The peak of terrigenous sediment input at 40 cm depth could be attributed to the hemp retting process, as stones were placed over the hemp to prevent it from floating away.

This episode started with a clearance of the mixed forest and a maximum land use (cultivation of cereal, olive and hemp).

Episode VI (1760±30 to 1895±40 AD): The lake level reconstruction shows a progressive rise in waterlevel. Demographic expansion led to maximum vegetal degradation, inducing the growth of shrubs and matorral communities. The pollen diagram shows the reduction of hemp production and the expansion of olive crops between 1800 and 1850 AD.

Non pollen microsfossils suggest the development of pastoralism.

Episode VII (1895±40 to 1991 AD): The rogressive decrease in water level led to mesohtopic status. Agricultural activity decreased as a consequence of depopulation after 1870. Non pollen microsfossils indicate large grazing activities.

Session h8

POLLEN CALIBRATION AND QUANTITATIVE RECONSTRUCTION OF PAST VEGETATION COVER

Reconstructing 17 centuries of forest history around Lake Clair, Quebec, Canada

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Lake Clair is located in the Sugar Maple – Yellow Birch Vegetation Domain (Mixed Forest Biome) of southern Quebec, *ca.* 50 km northeast of Québec City, close to the southern limit of the Boreal Forest (Balsam Fir – Yellow Birch Vegetation Domain). The forest stand in the lake's watershed remained untouched, and is now occupied by six tree species: Sugar Maple (*Acer saccharum* : 68%), American Beech (*Fagus grandifolia* : 9%), Balsam Fir (*Abies balsamea* : 9%), Red Spruce (*Picea rubens* : 8%), Yellow Birch (*Betula alleghaniensis* : 6%) and some White Birch (*B. papyrifera*) (% of total basal area).

High resolution pollen analysis of a short core (0-50 cm of surficial lake sediments), spanning the last 1700 years (^{210}Pb and ^{14}C dating), reveals assemblages that closely track the landscape-level vegetational changes that occurred outside the watershed in the neighbouring Saint-Lawrence Lowlands: 1) the early settlement under the French Colony (Seigneurie de Portneuf since 1647 A.D.), 2) the progressive clearing of forests for agriculture in the Lowlands, 3) its maximal extension to the hinterland, towards the Laurentian Highlands and Lake Clair between 1830 and 1870 A.D., and 4) the demise of marginal agriculture since 1920 A.D. Nowadays, the closest agricultural areas are located some 10 km away from the lake. They never got closer in the past. Pollen evidence for those changes include the arboreal pollen decline and recovery, and the changing representation of cereals, weeds, and second-growth tree species like Red Maple (*Acer rubrum*). All are long-distance transported from outside the watershed and totalize 15-20% of the pollen sum. A decline from 10 to 3-4% in the pollen representation of White Pine (*Pinus strobus*) and of Eastern Hemlock (*Tsuga canadensis*) underscores those extra-regional vegetational changes.

Within the regional pollen source-area, that is the Lake Clair catchment itself, the quantitative changes in forest composition through time were assessed by applying a correction factor to the pollen representation of each of the five tree genus represented in the forest canopy. Those correction factors were derived from a

comparison between the pollen percentage of each taxon in the uppermost sediments and its modern abundance in the regional vegetation (% basal area). This allowed the reconstruction of the primeval, late Holocene forest around Lake Clair, and the examination of the changes that occurred during the last two millenia.

The pre-historical forest composition, albeit similar to the modern, experienced marked changes in the abundance of Red Spruce, Balsam Fir, Sugar Maple and American Beech. The former two appear to have responded closely to the Little Ice Age (cooling) by increasing their abundance, but they also show a sustained increase at the scale of the Upper Holocene (Neoglacial). Sugar Maple and American Beech experienced a corresponding decline at both temporal scales, but only the former responded to the end of the Little Ice Age by a spectacular increase of its populations. Sugar Maple thus reacted much as an tolerant species. The intolerant American Beech was a much more important component of the primeval forest (22% compared to 9% in modern times). There are indications for cyclic changes in the mutual abundance of Sugar Maple and American Beech that could relate to competition, or to century-scale climate cycles. Finally, a steady decline of the pollen accumulation rates for the deciduous species is indicative of an overall decline in the density of the tree cover throughout the last 17 centuries, perhaps translating long-term depletion of soil nutrients.

Pollen analysis of Lake Clair's sediments thus exhibit the long-term response of a forest to both climatic and non climatic (competition and soils) environmental changes.

Objective comparison of vegetation composition between sites using pollen assemblages

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A new method to assess the differences in species composition of the surrounding vegetation between pollen sites is proposed and tested. Differences in the regional pollen background can strongly influence the pollen representation of vegetation (Sugita 1994; Sugita et al. 1999; Parshall and Calcote 2001). Even if the vegetation composition is the same within the relevant source area of pollen (as defined in Sugita 1994), the pollen assemblages can differ in other regions or in different time periods with the changes in the background pollen. This makes objective comparison of the vegetation composition among sites using pollen assemblages difficult.

The proposed method, the Qualitative Assessment of Difference method or QAD, neutralizes the impacts of the background on the pollen assemblages and objectively ranks the plant abundances of individual taxa between sites. Based on the pollen assemblage data, the differences in vegetation proportion of the constituent taxa are assessed at a pair of sites at the same time horizon using an inverse form of the Extended R-value model (Prentice and Parsons 1983), and are expressed as positive, negative, or no difference between the sites. Although the results are qualitative, this method is free from the artefacts of percentage calculation of pollen assemblages and is unconstrained by the changes in background pollen abundance. We demonstrate the validity of the method using a hypothetical example, and an empirical data set of the surface pollen from forest hollows and the surrounding vegetation from northern Michigan and northwestern Wisconsin in the United States. The QAD method is appropriate for sites closely located to each other, satisfying the assumptions that the background pollen loading and pollen productivity for individual taxa considered are consistent among sites. Reconstruction of the vegetation composition using the fossil pollen records from four forest hollows at the Sylvania Wilderness in northern Michigan shows the advantages of the method over the stand-type reconstruction based on the multivariate numerical techniques.

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