Joint research on the Lake Atnsjøen ecosystem changes – *assumptions and methodology*

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- Project: FSS/2013/IIC/W/0022, *“Reconstruction of the Environmental Changes and Monitoring - Tools for Planning the Sustainable Development of the Lake Ecosystem”*
- Project duration: 01.03.2014 – 29.02.2016
- Project team members IGiPZ, PAN: **dr I. Zawiska, dr M. Słowiński**
- Project team members NINA: **dr T. Jensen, dr A.K. Schartau, dr B. Walseng**
- Project experts: **dr M. Obremska** (ING, PAN), **dr M. Woszczyk** (UAM), **prof. dr hab. W. Tylmann** (UG)
- External cooperation: **dr L. Nevalainen, dr T. Luoto, M. Oksman**

The **main aim** of the project is to exchange knowledge between the partners on the possibilities of using results of the research on lakes' history (**paleolimnology**) and contemporary **environmental monitoring**. Our study site is **Lake Atnsjøen** located in eastern part of Southern Norway, near Rondane National Park.

Paleolimnology is a scientific subdiscipline which deals with reconstructing the paleoenvironments of inland waters and especially changes associated with climatic fluctuations, human impacts (e.g., eutrophication, or acidification).

Paleolimnological studies are based on analyses of **lake sediment cores**, including the physical, chemical and mineralogical properties of sediments, and diverse biological records (e.g., fossil diatoms, Cladocera, ostracodes, molluscs, pollen, pigments, or chironomids).

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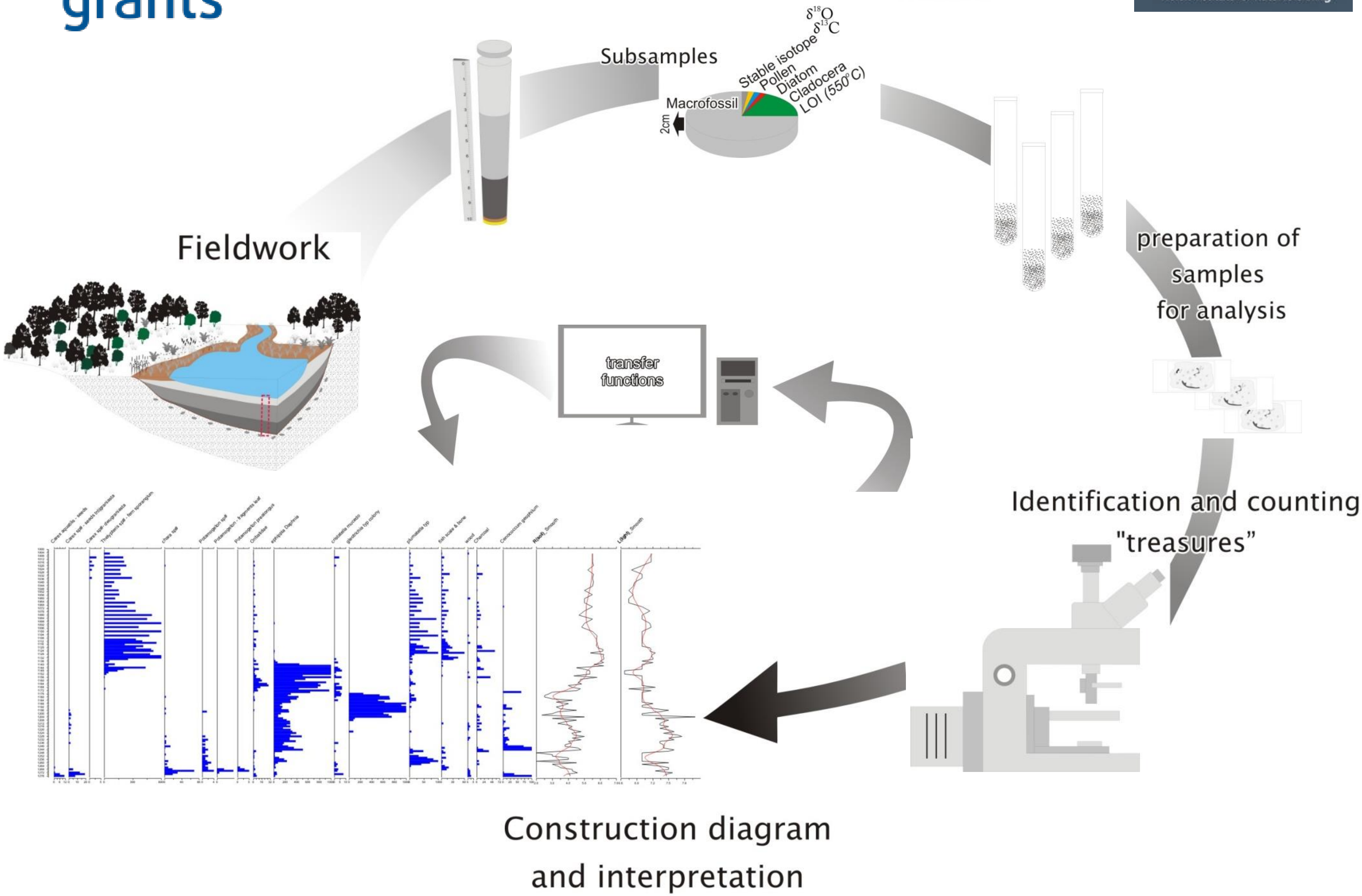

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The age of Lake Atna sediments was detrmined using standard dating methods: ^{210}**Pb** and ^{14}**C.** The results of dating allowed to build depth scale into age scale.

The history of the lake environment and catchment changes were revealed with the use of various paleolimnological methods:

- Subfossil Cladocera and ephippia analysis
- Palinology
- Macrofossil analysis
- Chironomid analysis
- Diatom analysis
- Chemical composition of the sediment

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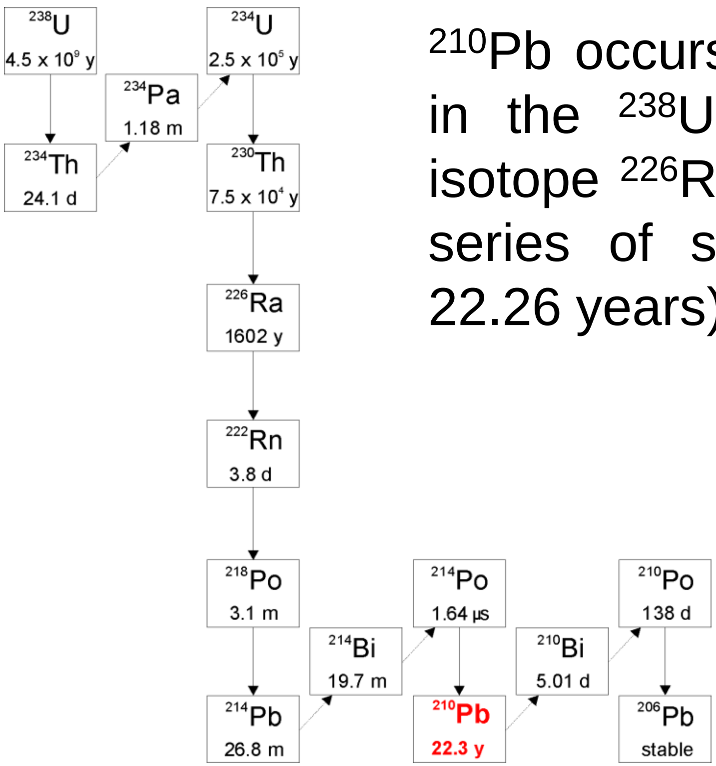
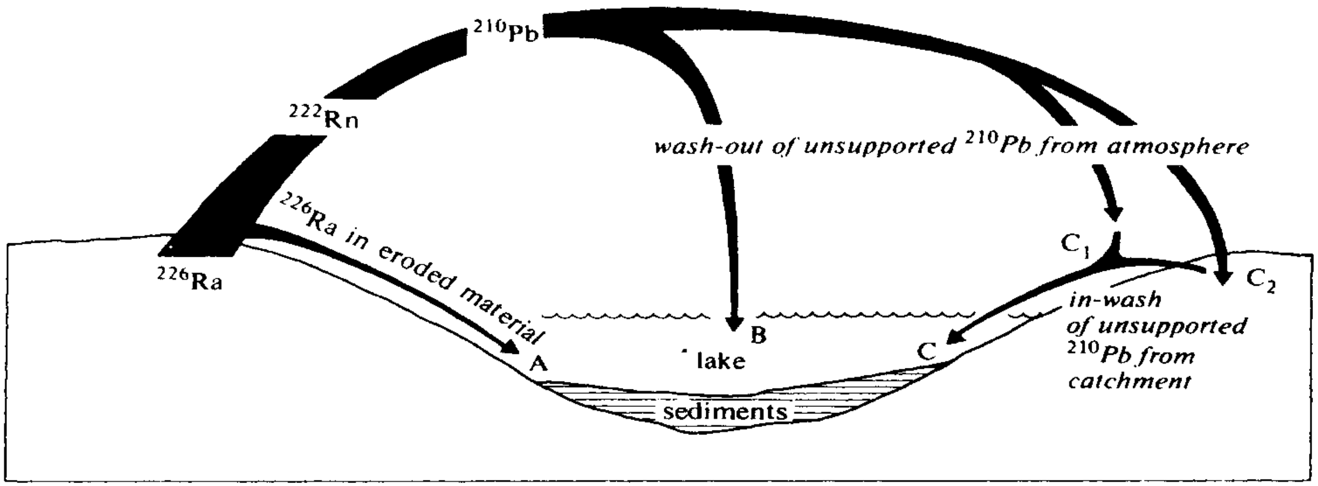
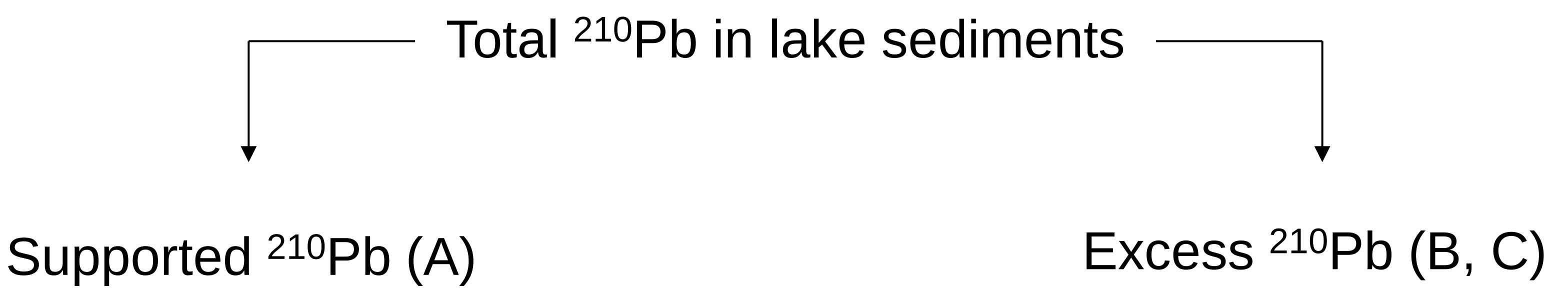
^{210}Pb dating

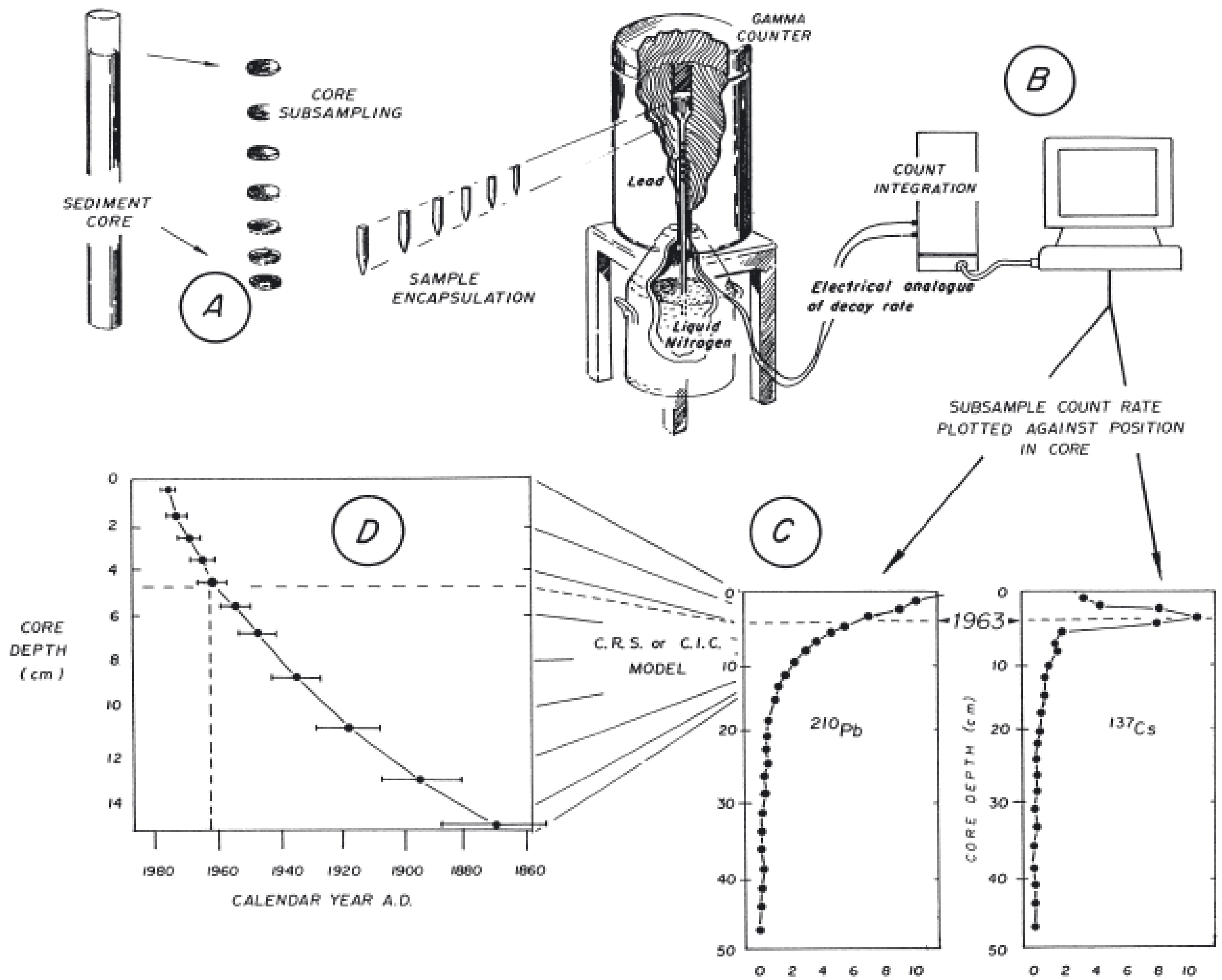


^{210}Pb occurs naturally as one of the radionuclides in the ^{238}U decay series. Disintegration of the isotope ^{226}Ra yields ^{222}Rn which decays through a series of short-lived isotopes to ^{210}Pb (half-life 22.26 years).



Håkanson and Jansson (2002)





Smol (2008)

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What can be dated with ^{210}Pb?

1. Glacier ice
2. Lake sediments
3. Marine sediments
4. Peat
5. Alluvial sediments

Analytical techniques:

1. Alpha spectrometry
2. Gamma spectrometry

Limitations:

1. Only undisturbed sediments
2. Time range 120-150 years
3. Uncertainty increases with age
4. Dates >100 years risky!!!
5. Different calculation models can produce different results
6. Need for independent validation!

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Laboratory techniques

Alpha spectrometry

Prons:

1. Small mass of dry sediment required
2. Low detection limits
3. High measurement precision
4. Reasonable counting time

Cons:

1. Wet digestion necessary
2. Destructive technique
3. Only ^{210}Pb measured
4. Isotope equilibrium in almost 2 years

Gamma spectrometry

Prons:

1. No chemical treatment
2. Non-destructive measurements
3. Other isotopes measured simultanously
4. Isotope equilibrium in 3 weeks

Cons:

1. More sediment necessary
2. Longer measurement time
3. Higher detection limits
4. Lower precision

Combination of both methods possible

Cladocera analysis

The Cladocera (water fleas) are major component of the microcrustacean fauna of freshwater lakes. They live close to the shore, among the plants in littoral zone and also offshore in pelagic zone. Some species are herbivores (plant eaters) while some are carnivores (animal eaters). During most of the growing season, Cladocera reproducee via unfertilized female-bearing eggs. If the environmental conditions deteriorate (e.g., overcrowding, limited food availability, temperature exceeds limits, oxygen depletion), males are produced parthenogenetically and efippia are generated sexually (gamogenesis).

Cladocera

- 620 species discovered so far, ~90 live in Europe
- 0,2 – 18mm size
- Live in pelagic, litoral, benthic zones
- Reproduce by parthenogenesis and sexually
- Cladocera produce dispousal eggs (efipia) that preserve in the sediments
- Remains of ≈70 species preserve in the sediments
- Efipia- dispousal eggs

Subfossil Cladocera analysis allows to reconstruct:

- Trophy changes
- Acidification changes
- Climate – temperature is an important factor controlling Cladocera distribution
- Lake level fluctuations

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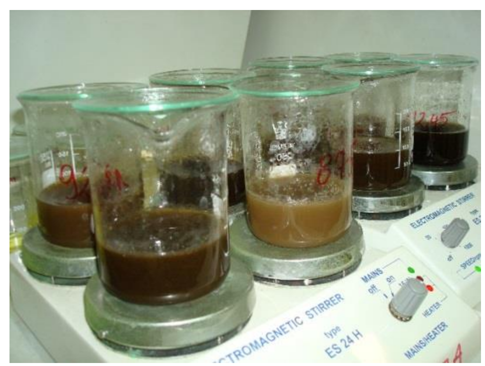
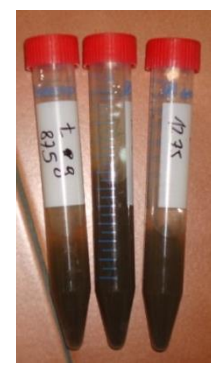
Subfossil Cladocera analysis – laboratory method

Material for subfossil Cladocera analysis is always prepared according to standard procedure described in Frey (1986). Samples (1 cm^3 of fresh sediment each) are treated with hot 10% KOH for 20 min using a magnetic stirrer in order to deflocculate the material, sieved through 33-µm mesh and diluted in 10 cm^3 distilled water. Slides are prepared from 0.1ml of each sample and examined with a microscope (Olympus BX41).

1cm^3





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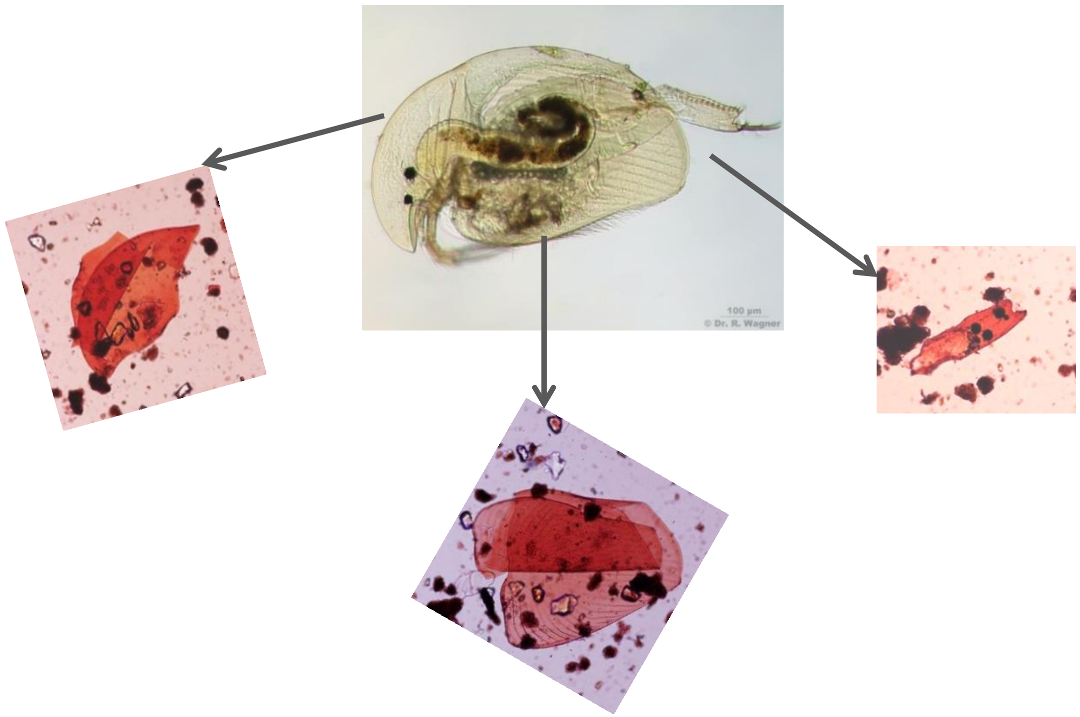
Picture of living Cladcocera specimen (*Acroperus harpae*)



Pictures of subfossil remains of *Acroperus harpae* that preserve in the lake sediments

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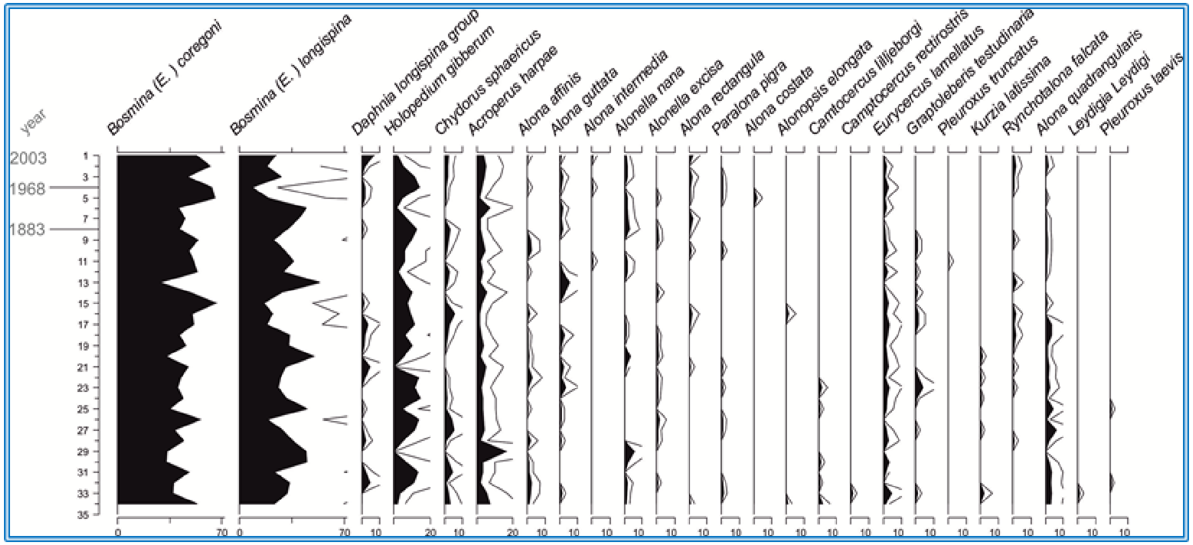
Subfossil Cladocera analysis - results

Results are presented on the stratigraphic diagrams of percantage share of species, absolute abundances and species fluxes, created by means of specialised software. One of the most popular is C2 by Juggins:

(https://www.staff.ncl.ac.uk/stephen.juggins/software/C2Home.htm)



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Pollen analysis – Palynology

Palynology studies composition of pollen grains and spores that accumulated in lake sediments. The analysis allows to reconstruct past vegetation changes in the area, which are often due to climate changes or human activity. Pollen grains and spores are extremely resistant to decay.

Pollen analysis

Material for pollen analysis is always prepared according to standard procedure, described in Berglund and Ralska-Jasiewiczowa (1986). All sporomorphs are identified and counted until a minimum of 500 pollen grains of trees and shrubs (arboreal pollen, AP). Pollen grains of all herbaceous species (except the local aquatic and telmatic plants) are counted as non-arborescent pollen (NAP), and the sum of AP and NAP is considered as 100%. The pollen distribution diagrams are drawn by the means of specialised software, for example Tilia2 and Tilia-Graph (Grimm,1992). Basing on the changes in the share of AP and NAP local pollen assemblage zones are divided.

Classical pollen diagram prepared by Ulf Hafsten (1957) with modification

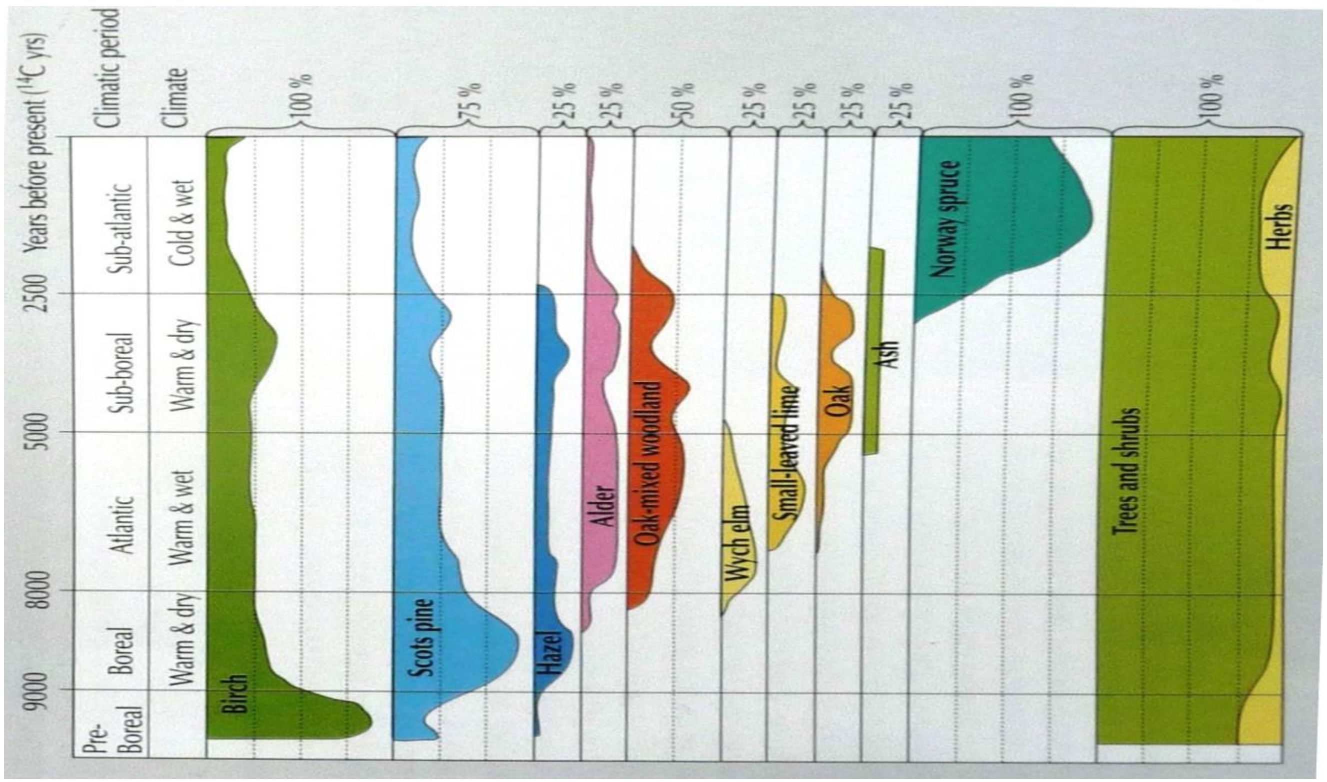

Figure from „National Atlas of Norway. Vegetation" Asbjørn MOEN. 1999

Example of pollen grains from Lake Atnsjøen

Carex t..

Juniperus communis

Isoëtes lacustris, Poaceae, Pinus

Picea abies

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Macrofossils analysis

Macrofossil are plant and animal parts visible with a bare eye or under the binocular. In the lake sediments preserve well:

- Plant remains such as: seeds + fruits (orchids to coconuts), cones, Sporangia, leaves + buds, needles, wood
- Remains of different animals such as: fish, oribatida, Cladocera ephippia etc.

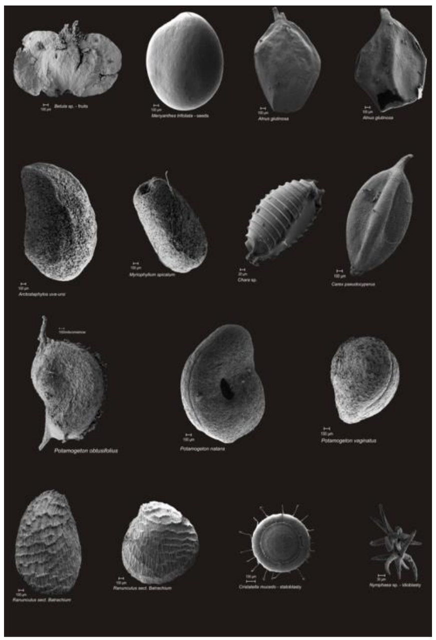
Macrofossil analysis provides record of local vegetation and helps to reconstruct:

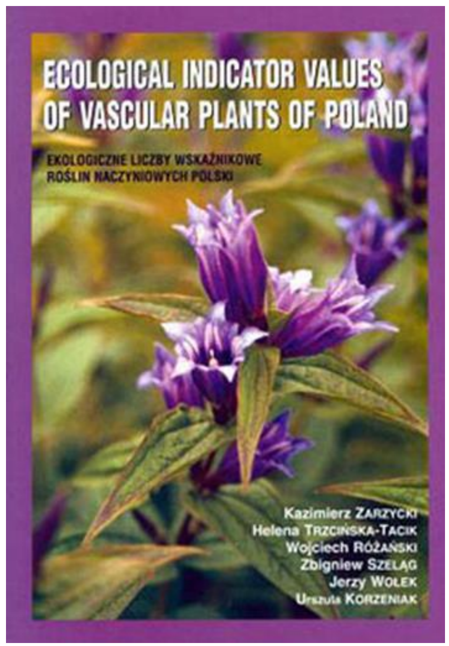
- Water level fluctuations (paleohydrology)
- Lake trophy changes
- Climate changes

Macrofossil analysis

The samples for the plant macrofossil analysis are rinsed in warm water on 0.125 mm mesh size sieves. Macrofossils are diagnosed with the use of a stereoscopic microscope and a light microscope. Species determination of individual fossils is performed with the help of the appropriate keys (Berggren 1968, 1981; Tobolski 2000; Velichkevich and Zastawniak 2006, 2009). The results are usually presented in the form of stratigraphic diagrams with the use of a program - C2 (Juggins, 2003). The generative parts are summarized in the diagrams in absolute numbers (seeds, fruits), while the vegetative fragments of vascular plants as well as *Sphganum* mosses were visually determined in percentages of the total volume of the sediment samples.

Main books used in interpretation of macrofossils data:





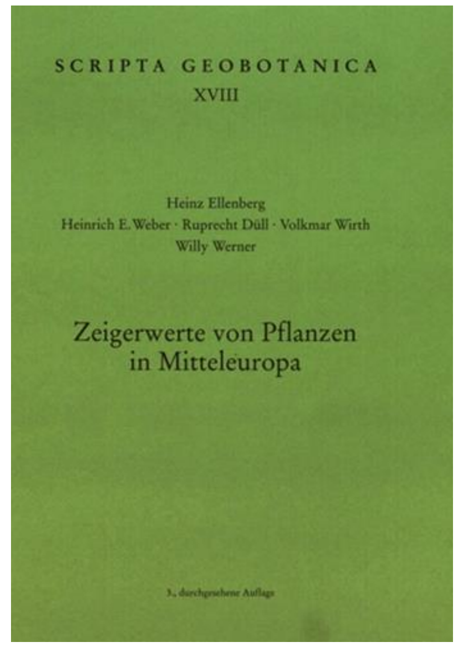


Table 2 Climate indicator plant taxa, their minimum mean July temperature and reference

Plant taxon	Minimum mean July temperature °C	Reference
Arctostaphylos alpinus	≤15	Hoffmann *et al.*, 1998
Betula nana	7	Brinkemper *et al*, 1987; Ran, 1990
Calluna vulgaris	7	Kolstrup, 1979, 1980
Caltha palustris	8	Kolstrup, 1980
Carex rostrata	8	Brinkkemper *et al.*, 1987
Ceratophyllum demersum	15	Litt, 1994
Cornus suecica	8	Kolstrup, 1980
Crytogramma crispa	9.9	Vorren, 1978
Eleocharispalustris	10	Kolstrup, 1979, 1980
Empetrum	7.7	Vorren, 1978
Epilobium angustifolium	7	Brinkemper *et al.*, 1987
Eriophorum vaginatum	7	Brinkkemper *et al.*, 1987
Juniperus communis	8	Kolstrup, 1980
Lobelia dortmanna	>10	Kolstrup and Wjjmstra, 1977
Myriophyllum spicatum	10	Kolstrup, 1980
Nuphar lutea	12	Kolstrup, 1980
Nymphaea alba	12	Kolstrup, 1980
Nymphaea candida	12	Kolstrup, 1980
Pinus sylvestris	>12	Iversen, 1954
Polygonum viviparum	5	Kolstrup, 1980
Potamogeton filiformis	8	Kolstrup, 1979, 1980
Potamogeton mucronatus	13	Brinkkemper *et al.*, 1987
Ranunculus flammula	8–9	Kolstrup, 1979, 1980
Ranunculus Subgenus *Batrachium*	10	Brinkkemper *et al.*, 1987
Sanguisorba minor	12	Isarin and Bohncke, 1998
Sanguisorba officinalis	9–10	Kolstrup, 1979, 1980
Selaginella selaginoides	7	Kolstrup, 1979, 1980
Thalictrum alpinum	7.7	Vorren, 1978
Trollius europaeus	6–7	Kolstrup, 1980
Typha angustifolia	14	Kolstrup, 1979, 1980
Typha latifolia	13	Isarin and Bohncke, 1998

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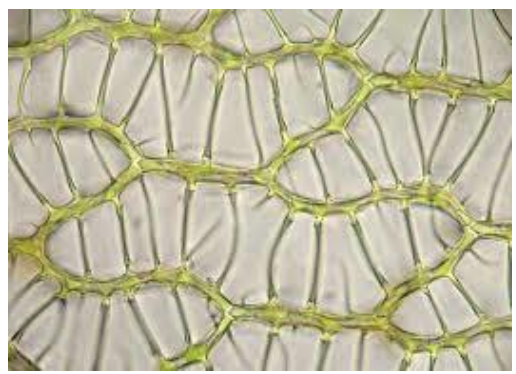
Macrofossils from Lake Atna

http://www.butbn.cas.cz/en/ecology/staff/martina-ctvrtlikova

Isoëtes lacustris



Sphagnum sp.

Betula nana

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Chemical composition of the sediments helps to reconstruct:

1) Rate of denudation (SiO_{2ter}, Ti, Al, AM, AEM)
2) Intensity of bioproductivity (OM, SiO_{2biog}, P, carbonates)
3) Red-ox/oxygenation (Fe/Mn, Cu/Zn, S, pristane/phytane)
4) Salinity (Mg/Ca, Sr/Ca, Na/K, B, TOC/S)
5) Anthropopressure (heavy metals, FAP, BC, PAH)

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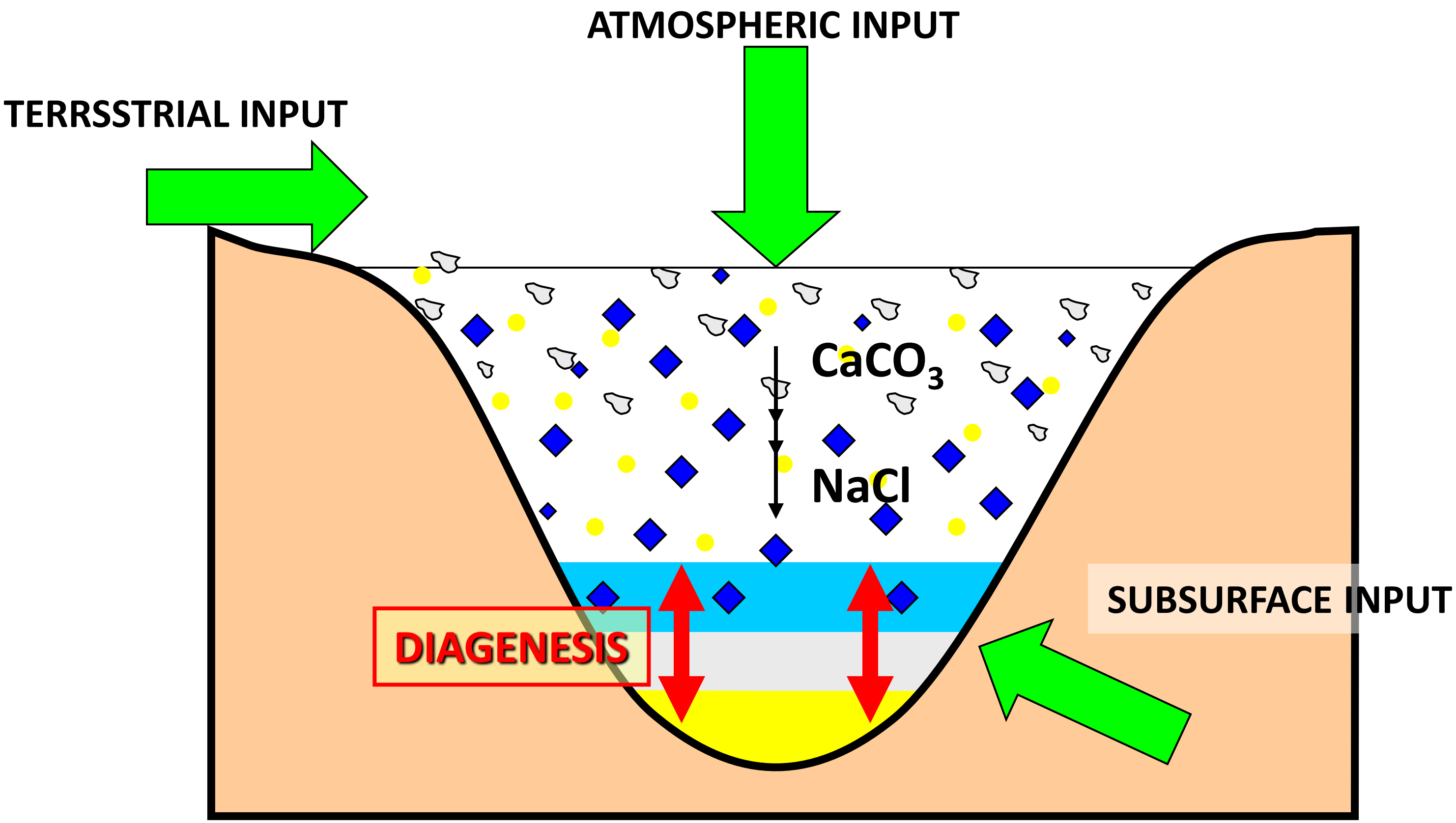
BASIC ASSUMPTION OF CHEMICAL ANALYSIS OF LAKE SEDIMENTS:

EQUILIBRIUM BETWEEN THE COMPOSITION OF WATER AND SEDIMENTS



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Lake sediments – geochemical perspective

- **Endogenic** – formed in lake water column

INDICATE PHYSICAL AND CHEMICAL CONDITIONS IN THE LAKE

- **Allogenic** – delivered from the catchment

INDICATE PHYSICAL PROCESSES IN THE CATCHMENT

- **Diagenetic** – formed within the sediment

NOISE

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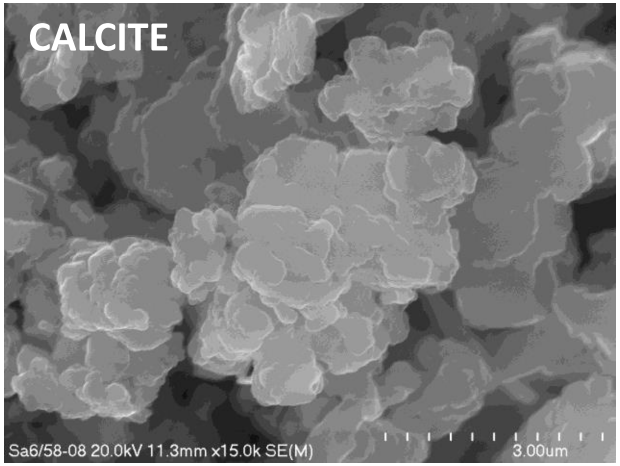
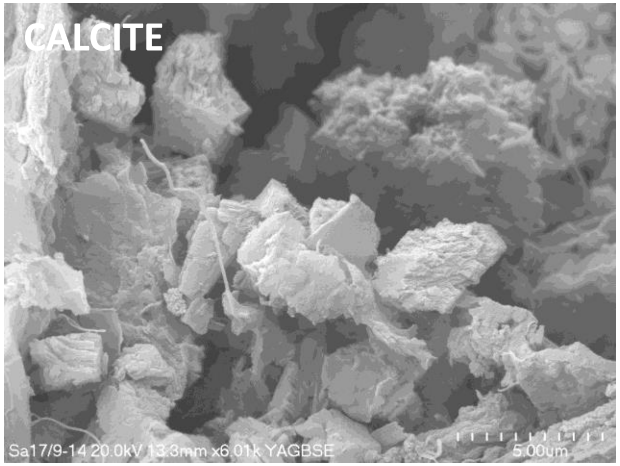
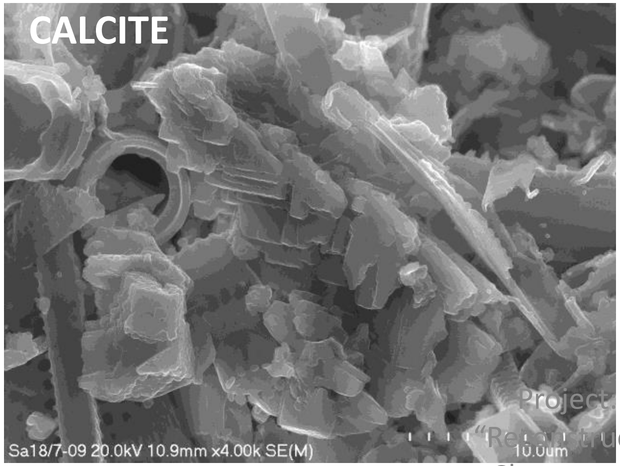
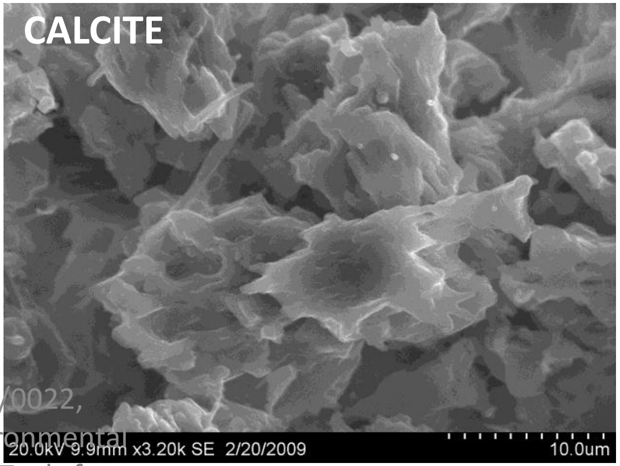
Endogenic components: Carbonates









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Genesis of carbonates

1) Leaching of soils
2) Carbonate sceletons
3) Incrustations (e.g. charophyts)
4) Evaporation
5) Mixing precipitation
6) Microbial activity

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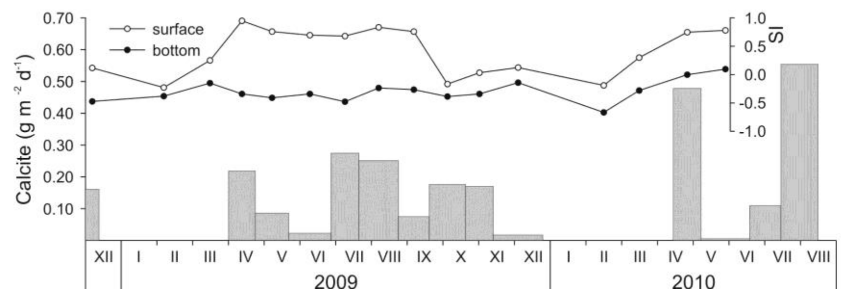
Genesis of carbonates: activity of phytoplankton

Lake Lucieńskie (central Poland)

Lake Suminko (northern Poland)



Tylmann in. (2012)

$$SI = \log \frac{IAP}{K_{sp}}$$

SI>0 – precipitation
SI<0 – dissolution

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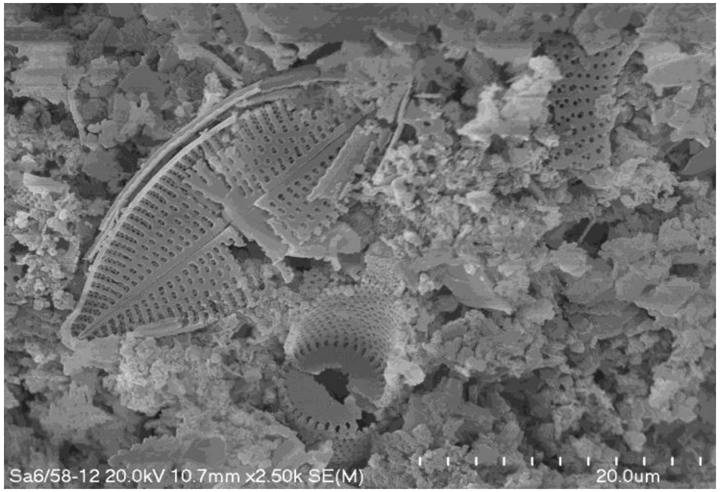
Endogenic components: biogenic silica

- Sponge spicules
- Phytoliths
- *Chrysophycae* cysts
- Diatom frustules



(phot. M. Woszczyk)

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Endogenic components: organic matter

Genesis of organic matter:

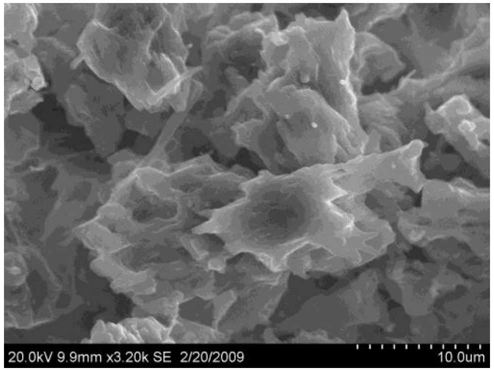
- **Biomass production**
- **Oxygen deficiency in water**
- **Great water depth**

Allogenic components

Terrigenous silica

Fot. M. Woszczyk

Detrital calcite



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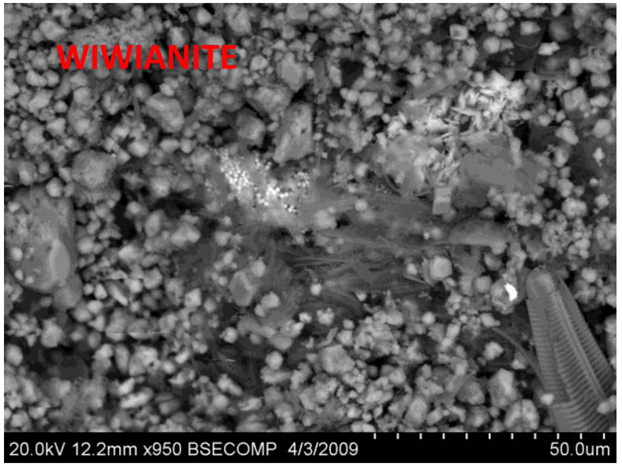
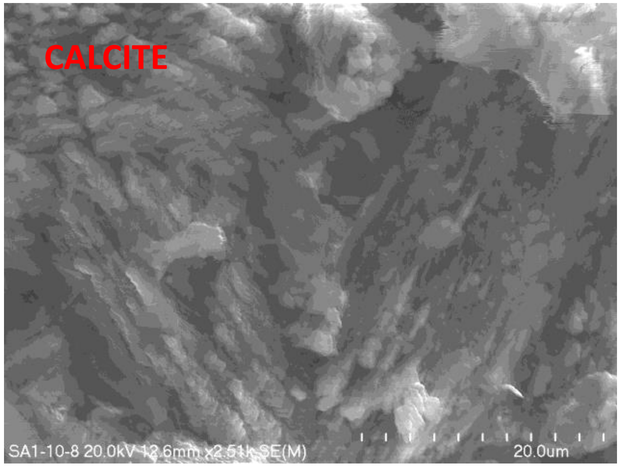
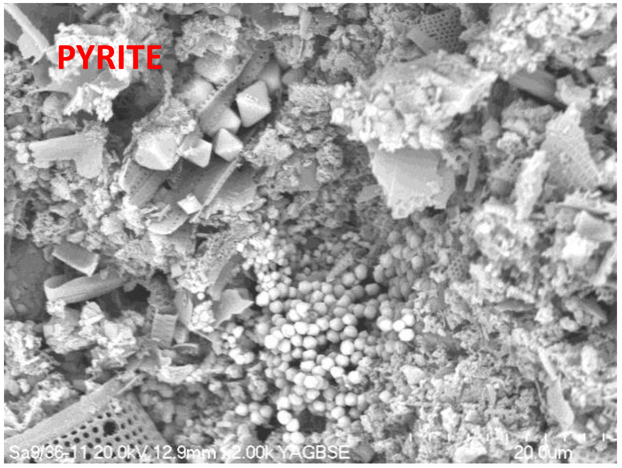
Diagenetic components







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