Environmental and human impact from prehistoric to modern times: The Lake Lucerne event stratigraphy

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For perialpine regions, lake sediments are outstanding archives to reconstruct an event stratigraphy from the Late Glacial period to modern times. Such a stratigraphy is composed of a chronologic succession of various climatic, environmental and anthropogenic impacts, with many of them representing natural hazards occurring in and around the lake. Lacustrine sediments record sensitively, continuously and with high temporal resolution these impacts. The key is to recognize the various events along the geologic timeline and to date these with the best possible chronostratigraphic methods.

Dating techniques in lacustrine sediments comprise a variety of methods, that recently became more and more sophisticated. AMS-radiocarbon analysis of terrestrial organic matter provides the backbone for dating the prehistoric sedimentologic succession. Volcanic tephras, as the Late Glacial Laacher See Tephra or the Boreal Vasset Killian Tephra, can generally be tied to distinct, well-dated volcanic eruptions and allow independent, precise dating and correlation between different archives. Calibration of historically-recorded events identified in the sedimentary record, such as rockfall-, subaquatic slide- and flood-deposits, provide the means to establish a chronostratigraphic framework for the younger section, partially with a temporal resolution of a few minutes. A series of human environmental impacts of known ages can further be used to date the most recent sediments. Onset of steamship traffic in the 19th century, for instance, produced combustion products, that can be detected in the lake sediments using automated image analysis techniques and SEM observations (Thevenon & Anselmetti, subm.). Morphological analysis of these pyrogenic particles allows distinction of the used burning agent (wood, coal, diesel oil) that mark the period, at which the steam engine types were switched to match the upcoming new technologies. Global radiogenic markers, such as elevated 137-Cesium contents originating from nuclear bomb testing and from the Chernobyl accident, further date the sedimentologic column with annual accuracy. In Lake Lucerne, glacial varves and anthropogenically-induced biogeochemical varves with seasonal resolution occur in Late Glacial sediments and in the sediments deposited during the last ~60 years, respectively. Once selected cores are dated with all those methods, high-resolution seismic stratigraphy, with a vertical resolution of ~10 cm, together with petrophysical core properties, can carry these ages through the entire basin establishing thus a quasi-3D age model for the complete basin fill.

When the entire succession of sedimentary layers can be assigned with ages, the time series of detected events can be interpreted and put into a geologic and historic context. Number and thickness of flood turbidites, for instance, shed light on recurrence rates and intensities of flood events, contributing to the ongoing discussion of elevated flood activities due to recent climate change. In a similar fashion, paleoearthquakes leave their characteristic traces in the sediments through synchronous triggering of basinwide subaquatic slides and associated megaturbidites and tsunami wave deposits. Calibrated by the historic Mw=6.2 AD 1601 earthquake (Siegenthaler et al, 1987), traces of five large prehistoric earthquakes could be found within the last 15'000 years in Lake Lucerne sediments (Schnellmann et al, in press). Three of these events were even significantly stronger (Mw>6.5) and also caused basinwide slope failures in Lake Zurich (Strasser et al. in press). The event occurring around ~2300 cal yrs. BP, did not only affect the lakes but also led to major rock slides in the entire Central Swiss area (B. Keller, pers. communication). Anthropogenic impact can be seen in the varying content of pyrogenic products embedded in lake sediments. A first peak in large charcoal particles occurs in Lake Lucerne around 5500 cal. yrs. BP, coinciding with a recently found extensive neolithic lake settlement at the shores of Kehrsiten. Further variations in pyrogenic products could reflect the climate-driven human migration patterns and also socioeconomic progress, such as the opening of the Gotthard pass in the 13th century. The opening of this N-S traffic axis led to an increased biomass-burning activity reflecting the rising significance of the Lake Lucerne area not only on a Helvetic (AD 1291!), but also on a European scale (Trümpy, 1998). The last and major human impact recorded is the manmade eutrophication, marked by deposition of varved organic-rich sediments. Deposition and preservation of these 'black shales' resulted from anoxic bottom waters caused by increased environmental pressure from growing populations and agriculture in the middle of the 20th century.

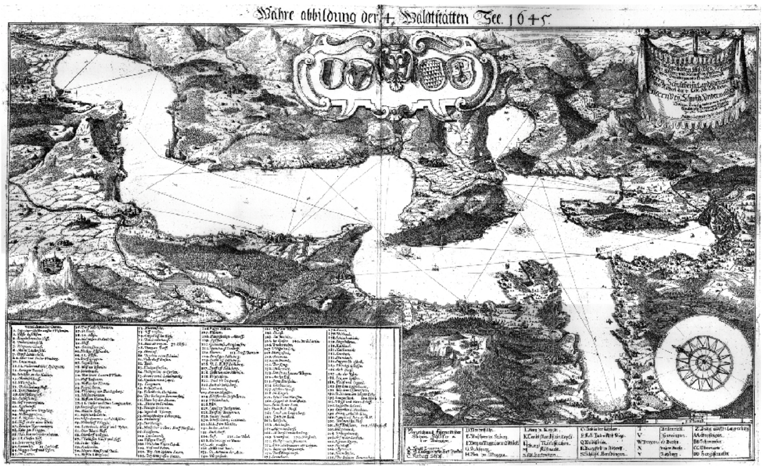

Figure 1. Lake Lucerne seen from the North by Johan Leopold Cysat in AD 1645.

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