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Signals of two earthquakes at Lake Altaussee (Salzkammergut, Austria)

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Assessing strong earthquake recurrence in a low seismicity region such as the Salzkammergut (North-Eastern European Alps) is difficult, due to the relatively short time span covered by instrumental and historical data. Lacustrine sedimentary records enable to investigate the various geohazards typically occurring in an inner-Alpine setting. Lake Altaussee is studied in the frame of the Walter-Munk-Project "Lake Altaussee". It is mainly fed by subaqueous karst springs and has no major subaerial river inlet and therefore it contains rather slowly-accumulating (~0.6 mm/yr) organic-rich sediments. Analysis of multibeam bathymetry, subbottom profiles and sediment cores shows two striking sedimentary event deposits which are hypothesized to be induced by earthquake shaking. (1) Around 1767-2127 yr cal BP (modelled 95% probability range) a change from organic-rich sediments to numerous intercalated clastic carbonate layers is observed at the subaqueous karst spring site. At this transition, an in-situ soft sediment deformation structure (SSDS) can be distinguished by computer tomography analysis. The identified SSDS present at ~50m water depth and unrelated to mass movement processes is a indicator for seismic shaking. Moreover, seismic shaking might have influenced the hydrogeological system, increasing upward water velocity of the karst spring or increasing the sediment load, leading to the build up of inclined sediments forming a crater rim. (2) The second event deposit occurred between 957-1196 yr cal BP (modelled 95% probability range). Subbottom profiling data and sediment cores show a megaturbidite (> 0.5--2m thick), which can be traced across the basin lake floor and a bit thinner onto large blocks which are present in the eastern part of the Lake. The blocks are up to 70 m large. The estimated impact volume of the large blocks is ~400,000 m^3 causing widespread deformation of basin-plain deposits, as well as developing into mass flow and turbidity currents. Specifically, the basin long core with hole A and B (~10 m apart) show a strikingly different sequence with fold structures and inclined laminations below the mass flow deposits. Moreover, radiocarbon ages in this sequence are out of order and show ages between ~8000 and ~11000 yr cal BP. The megaturbidite can be divided into a lower 'graded unit' with stacked medium and fine sand beds with varying thicknesses within the sediment cores. The upper 'homogenous unit' of the megaturbidite contains silty deposits and are interpreted to have formed under influence of seiche bottom currents, followed by suspension fallout. Numerical modeling results of a wave generated by a mass movement impacting the lake show flooding at the western shoreline with a flow depth and flow speed of 4-8 m and 6 m/s respectively. The distribution pattern of the large blocks and the internal structure of the megaturbidite likely indicate multiple large gravitational mass movements that occurred quasi-simultaneous. The Megaturbidite shows multiple sand layers ('pulses') which could be formed by turbidite amalgamation but this needs further investigation. This study provides an important step for improving the seismic hazard assessment of the North-Eastern Alps and as well as characterizing cascading effects of the two formerly-unknown earthquakes.

Session: *Pangeo workshop: Earth Surface Dynamics*
Keywords*: Lacustrine Sediments, Earthquake, Rock fall, Lake Altaussee, subaqueous spring*