Investigating glacial/interglacial cyclicity from downhole logging data and mineralogical composition: an example from the ICDP drilling project Lake Junín, Peru.

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Poster-EGU2020-3891

THE IDEA

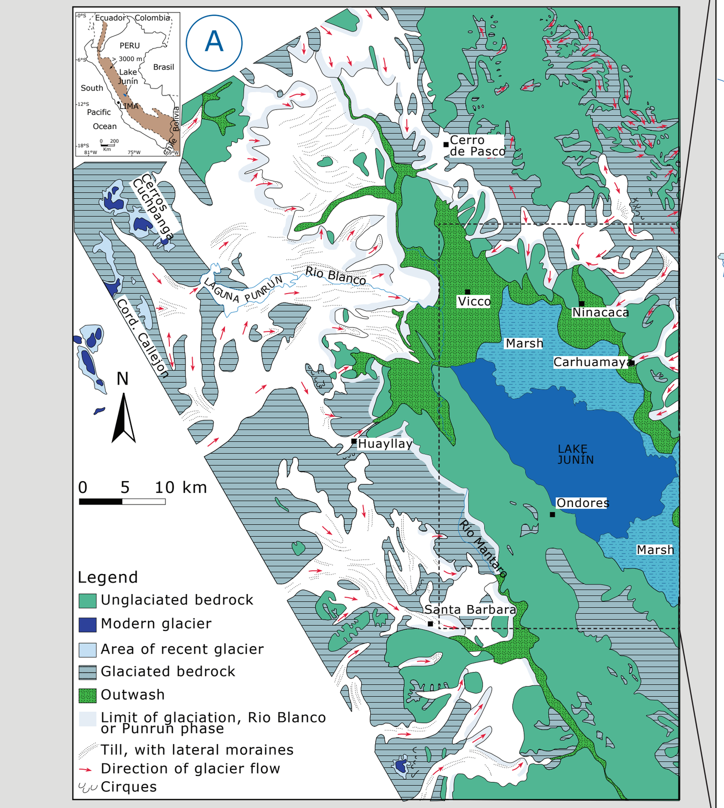
Can the history of lake records covering the glacial-interglacial cycles be reconstructed from downhole logging data without the high-resolution data derived from core analysis?

The response of depositional environments to the climatic variations is periodic in time and these climatic variations are embedded on sediments and recognized as variation in their physical properties (e.g. grain size, mineral type, mineral abundance especially for clay, organic matter), which are also detected by downhole logging measurements. The sedimentary record is a function of depth, so that in case the long-term rate of sediment accumulation is rather constant, then the variation of its physical properties with depth (expressed as cycles/meter) will approximate their variation with time (expressed as cycles/million years). The spectral analysis method can greatly enhanced the understanding of possible relationships between sedimentation rate, and climate patterns of the past with the present.

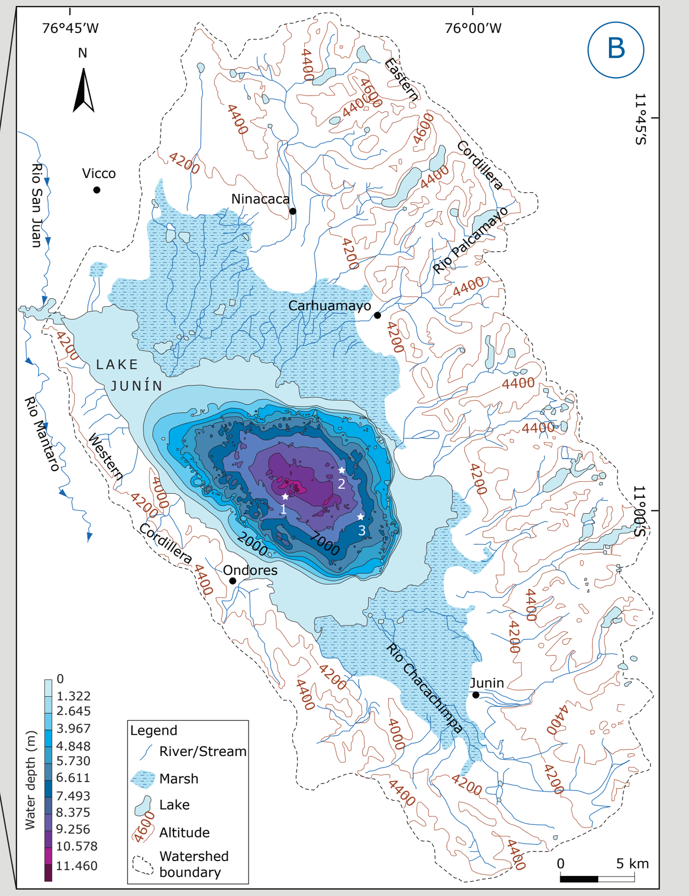
Can the presence or absence of clay minerals help to recognise glacial/interglacial climate cyclicity?

Selected sixty-eight samples were taken in order to compare and characterize the minerals in the lake sediments at different depths. The mineralogical analyses performed by X-ray diffraction (XRD) show the composition of each sample. Linking the abundance and the lack of clay minerals in core samples with the downhole logging data, a relationship between geological history of the lake and climate change processes can be recognized. Consequently, the different mineralogical composition of the sediments, especially the presence or absence of smectite in the clay bulk, reflects a glacial/interglacial climate cyclicity.

LOCATION



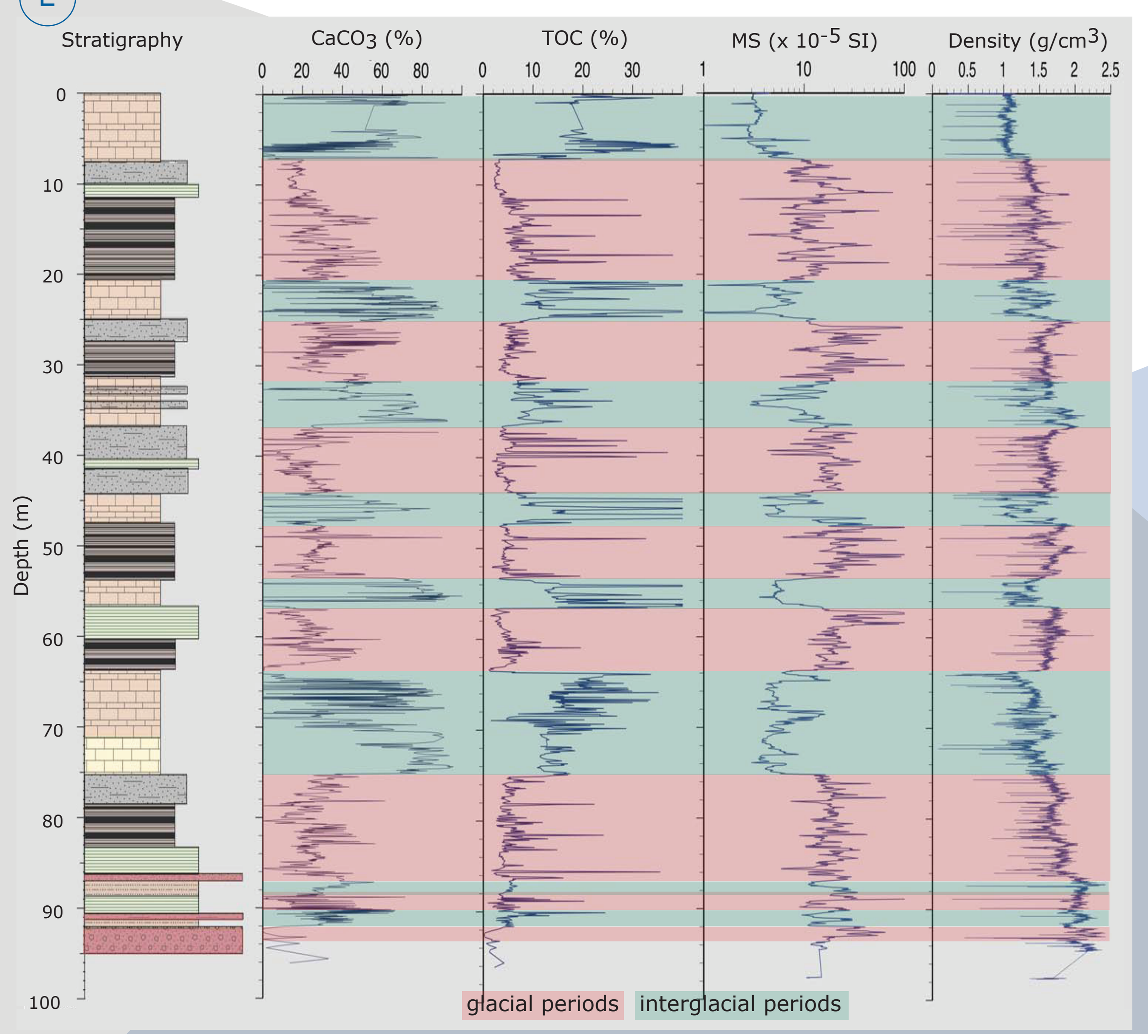
A) Map of Junín Plain and adjacent mountains, showing distribution of glacial features. Limits of the older (Rio Blanco) and younger (Punrun) phases are on the west side of the plain (modified by Wright, 1983; Smith et al., 2005a,b)).



B) Lake Junín and its drainage basin. Dashed line is the watershed boundary. The white stars indicate the three drill sites (modified by Rodbell et al., 2012). The water depth of the Lake Junín is shown.

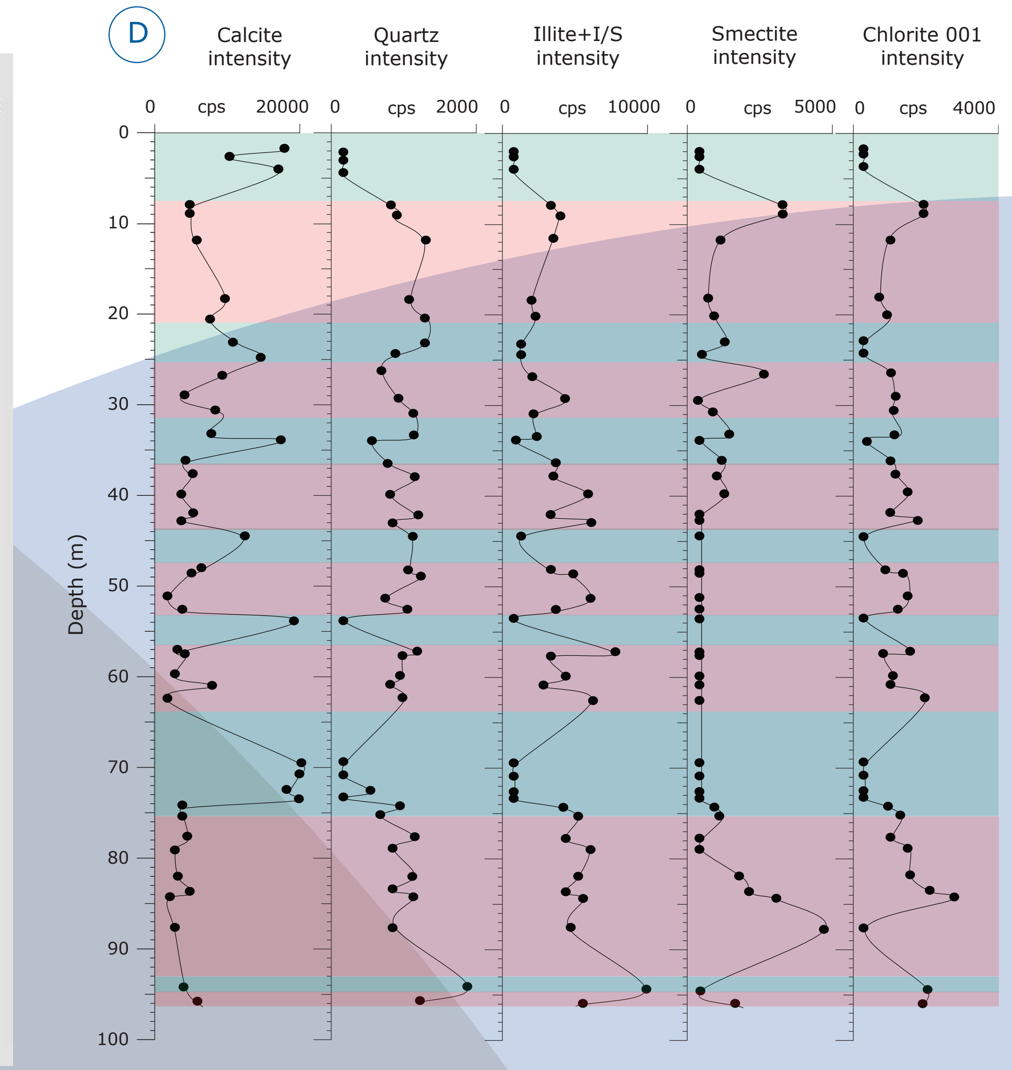
Lake Junín is located at 4082 m above sea level in the Andes and is the largest lake (300 km2) entirely within Peruvian territory. Lake Junín is controlled by a thick sediment package (>125 m) dominated by alternating packages of carbonate and glaciogenic silts with thin peat and organic-rich mud layers. The lake predates the maximum extent of glaciation, and is in a geomorphic position to record the waxing and waning of glaciers in the nearby Cordillera. Bedrock consists primarily of Paleozoic-Mesozoic marine carbonates, with some exposure of pre-Cambrian crystalline silicate rocks along the eastern cordillera. The lake owes its origin to >250-ka-aged coalescing glacial outwash fans that dam the northern and southern ends of the lake, respectively.

MINERALOGICAL COMPOSITION



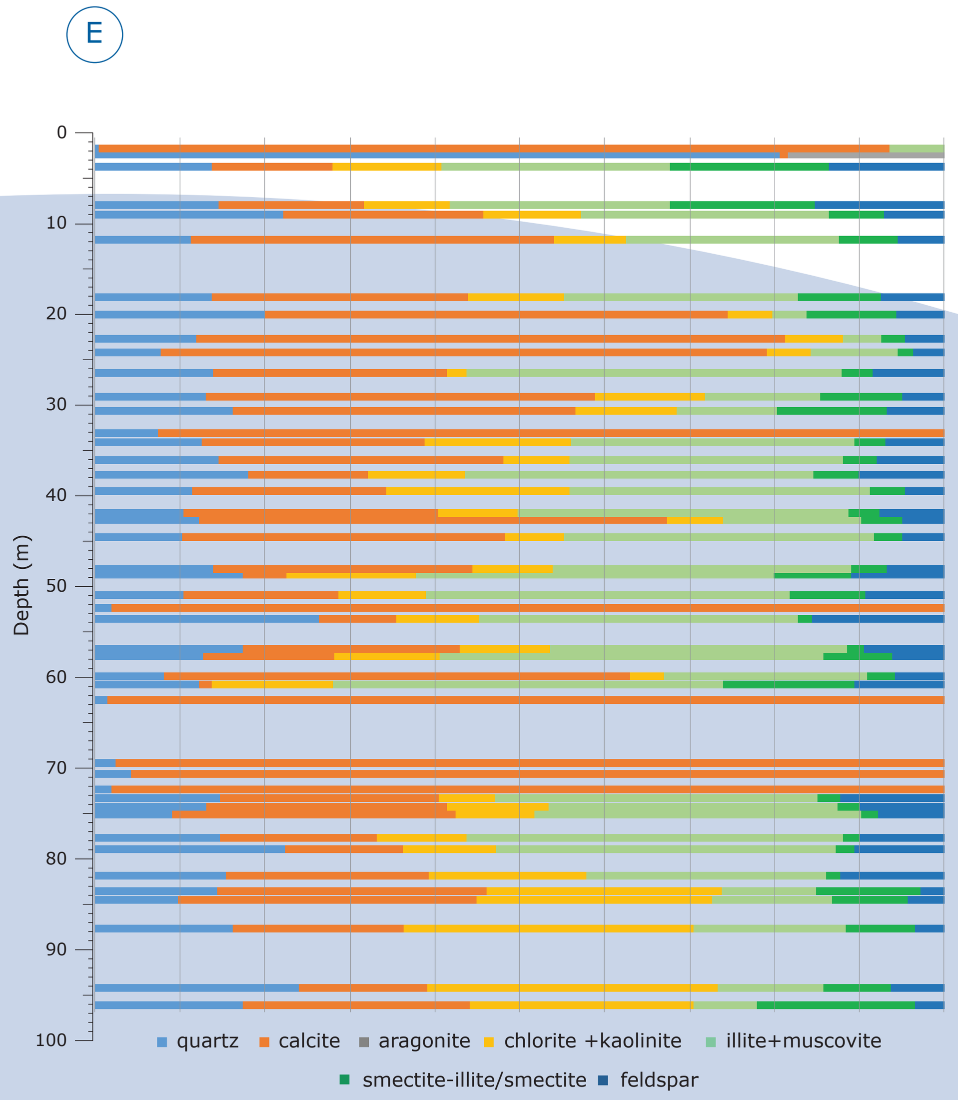
C) Stratigraphic profile at Lake Junín drill site 1. Pink and green colours show the glacial and interglacial periods. the glacial period is marked by low calcite and TOC but high MS and density. interglacial periods are marked by high calcite and TOC but low MS and density values (Sherpa, 2018 and Rodbell et al., 2018). TOC: total organic content; MS: magnetic susceptibility; CaCO3: calcite. The measurement have been carried out on drill core.

CORE CLAY-MINERALOGY



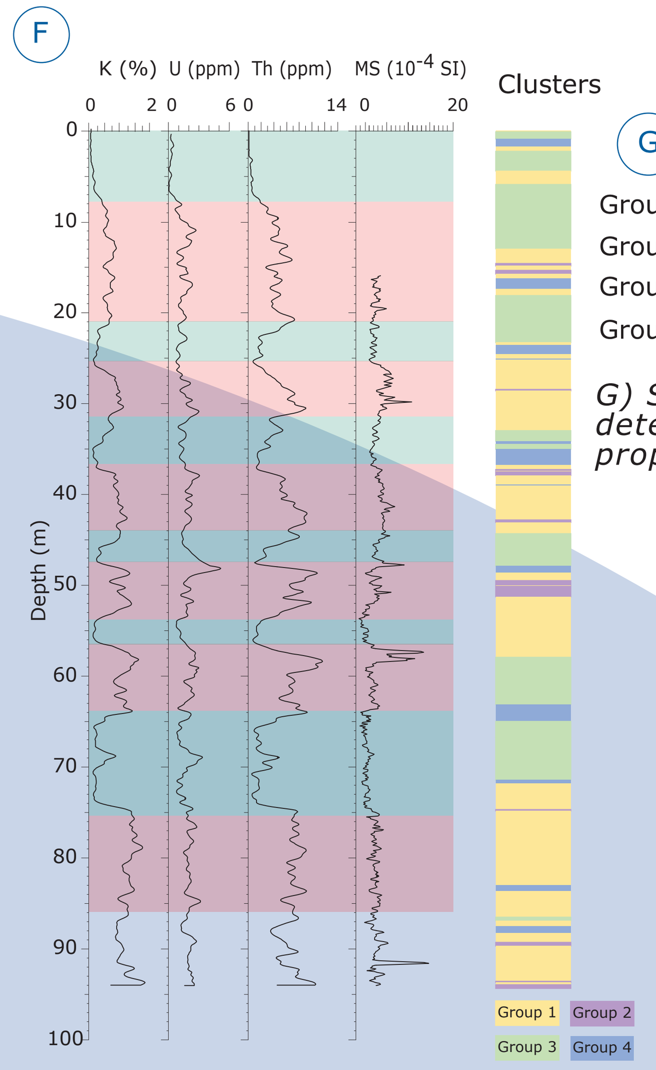
D) Comparison of semiquantitative analyses of specific clay minerals in selected core samples of hole 1D. A good correlation can be detected, reflecting glacial and interglacial periods. Interglacial periods are marked by high calcite intensity, and low quartz, and clay minerals. Glacial periods are marked by low calcite intensity and an increase of clay minerals, chlorite and quartz.

BULK-ROCK-MINERALOGY



E) Quantitative XRD analysis of the bulk rock mineralogy in hole 1D

CLUSTER ANALYSIS



F) Four downhole logging measurements have been taken into account for the cluster analysis: potassium (K), uranium (U), thorium (Th) and magnetic susceptibility (MS).

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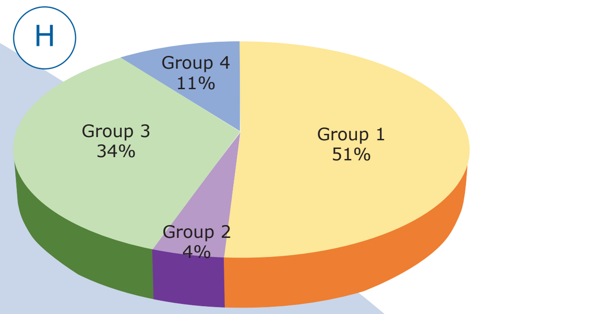
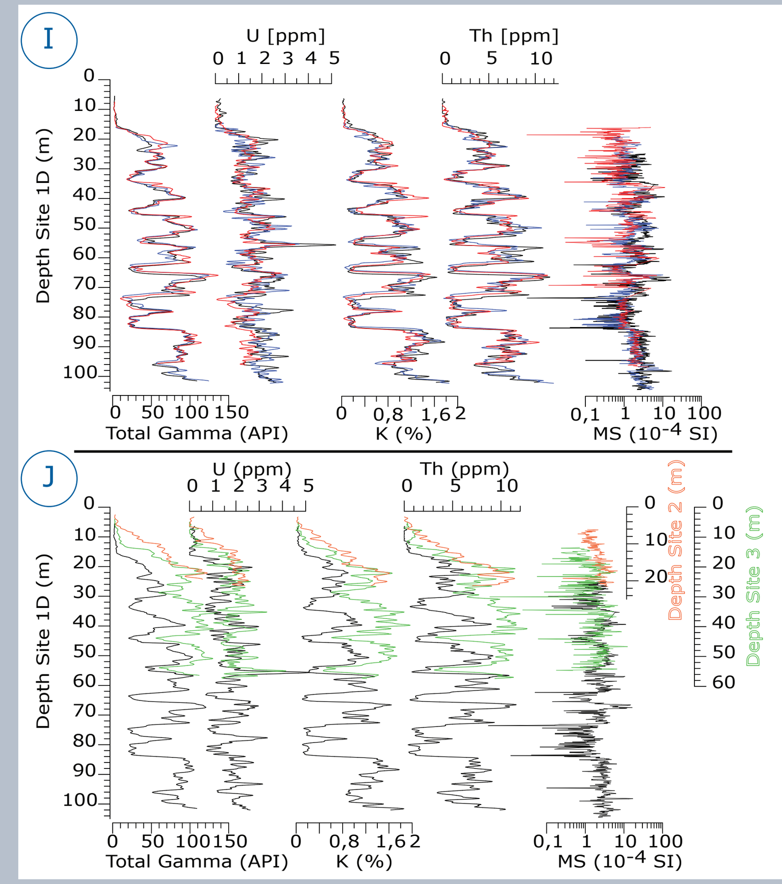
	Potassium	Uranium	Thorium	Mag Sus
Group 1	1.1209	1.8903	6.9216	2.9980
Group 2	1.3629	2.2312	9.5946	9.1646
Group 3	0.3254	1.2501	2.2493	1.2292
Group 4	0.6472	2.8503	3.7914	2.0840

G) Statistical analysis was carried out to detect goups with different physical properties.

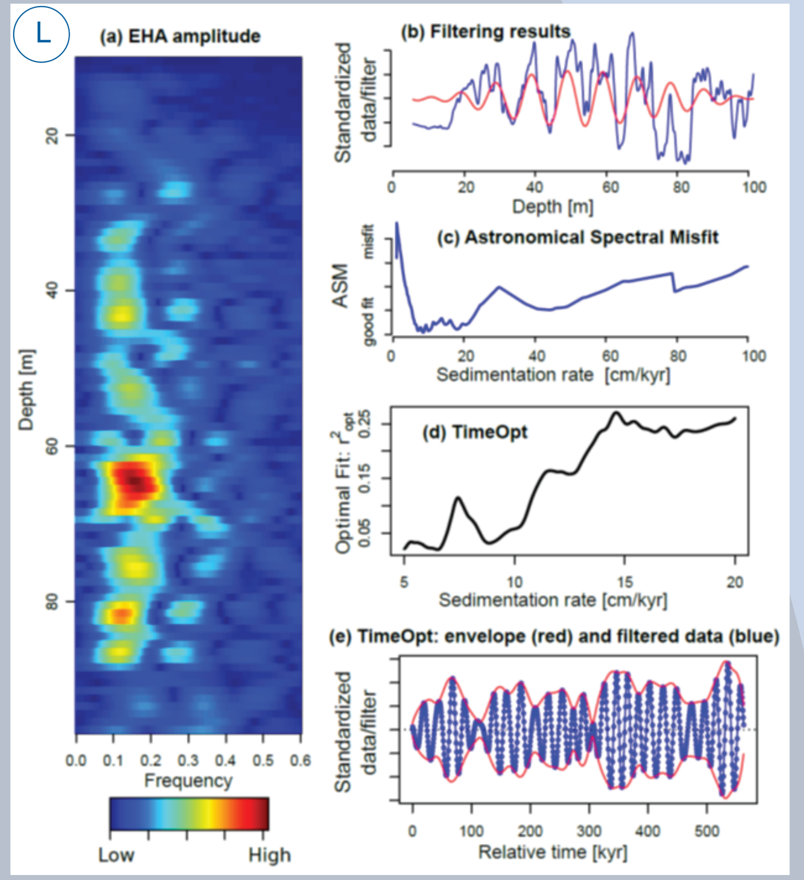


H) the pie shows the contribution of each cluster. The groups 1 and 3 are dominant with 51% and 34%, respectively. Group 2 is the less representative with only a 4%.

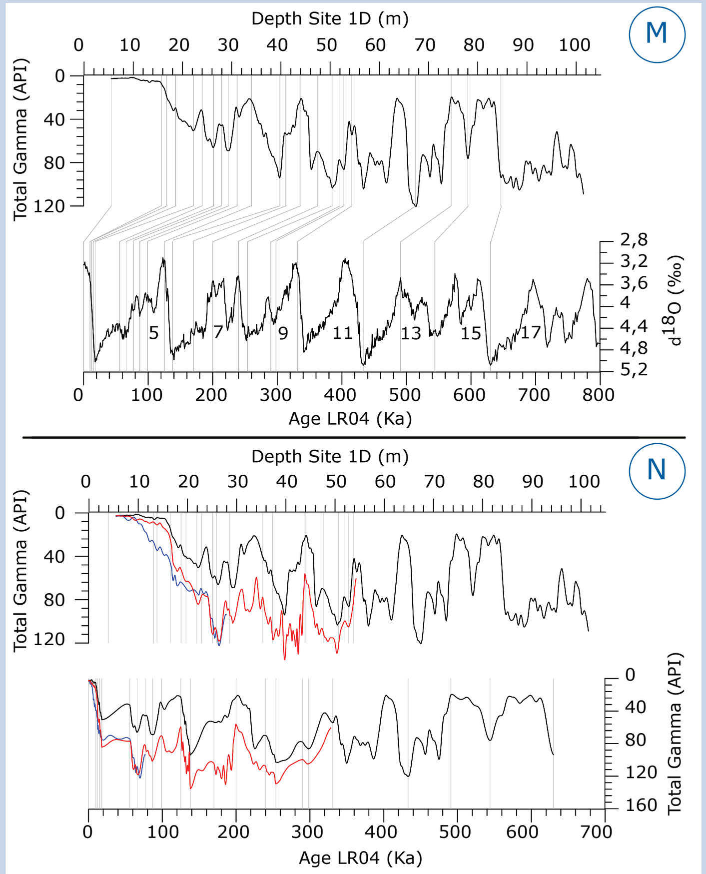
CYCLOSTRATIGRAPHIC ANALYSIS



I) Plot of the downhole logging datasets for Site 1 Holes A, C, D. From left to right: Total Gamma Ray, the Uranium (U), Potassium (K) and Thorium (Th) contents and the magnetic susceptibility (MS). Note general similarity of the datasets.
J) Comparison of Site 1 Hole D (black), Site 2 Hole A (orange) and Site 3 Hole B (green). Note general similarity of the data. Also note that the depth axes were stretched to give a visual match.



L) (a) Evolutive harmonic analysis suggests no major shift in sedimentation rate in the interval from ~30-90m.
(b) Filtering of the ~10 m component (frequency range: 0.08-0.12, roll-off rate 103) suggests 6 prominent cycles and less clear cyclicity at the top and base of the dataset.
(c) Results from the Average Spectral Misfit suggest sedimentation rates between 5 and 20 cm/kyr.
(d) Time Opt results for the dataset excluding the upper 20 m; a best fit is achieved for a sedimentation rate of ~15 cm/kyr.
(e) Relative time scale for the dataset excluding the upper 20 m based on the comparison of precession amplitude and eccentricity (TimeOpt).
For these analyses the Meyers´software (2014) and approach (2015, 2019) have been used.



M) Correlation of the Total Gamma data of Lake Junin (top) to the LR04 stack (bottom), grey lines indicate correlation tie points. Numbers in the d18O record represent Marine Isotope Stages.
N) Aligning of the Total Gamma data of all 3 Sites to the Site 1D depth scale (top; black: Hole 1D, red: 3B, blue: 2A), and application of the correlative age model (bottom), which exports the age model from (a) to all 3 Lake Junin sites.

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ACKNOWLEDGMENTS

This research is funded by DFG SPP 1006, project number 339093449.
The Lake Junín Drilling Project has been partially funded by International Continental Scientific Drilling Program (ICDP - http://www.icdp-online.org).
The cluster analysis was carried out with the INCA software.