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Paleoenvironmental Changes In Lake Van During the Late Glacial-Holocene

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Lake Van is the fourth largest terminal lake and the largest soda lake in the world (volume 607 km^3, area 3,570 km^2, and maximum depth 461 m). The pH of its waters is 9.81 and salinity is about ‰ 22. It is located in the Eastern Anatolian High Plateau in Turkey, with the present lake level located at 1649 m. This region has a continental climate influenced by the Siberian High Pressure, North Atlantic and Mid-Latitude Subtropical systems. Its varved sediments with high sedimentation rate (0.5-0.7 m/ka) provide a continuous record of climatic conditions for Quaternary period.

Multi-proxy analyses, including inorganic XRF Core Scanner elemental, total organic (TOC) and inorganic carbon (TIC), stable carbon and oxygen isotopes of bulk carbonate, and XRD mineralogical analysis, were carried out in the upper part of the 144 m-long composite stratigraphic section recovered by the ICDP-PaleoVan Project in the Northern Basin. The age model was constructed using AMS C-14 analysis and tephra ages from previous studies. The main purpose was to study the paleo-environmental changes during the last glacial-interglacial cycle covering the last 25 ka in the Lake Van region.

The studied composite stratigraphic section consists of five lithological types: a) banded and/or laminated clayey silt, b) homogeneous clayey silt, c) tephra, d) graded sand-silt (turbidite-homogenite), and e) deformed lacustrine sediments and tephra layers (i.e., slide and slump deposits). The time interval between 12.5 and 6.5 ka calBP (Younger Dryas, YD - early Holocene) consists mainly of banded and laminated sediments with tephra intercalations, whereas the interval between 25 and -14.5 ka cal BP sediments are predominatly of graded sand-silt (mass transport deposits) with tephra and homogeneous clayey silt interbeds. The multi-proxy analyses were mainly conducted on the banded and laminated clayey silt and homogeneous clayey silt layers that are authoctonous lake sediments. There is a strong covariance between δ^{18}O and δ^{13}C values of the bulk carbonates (r>0.88), which demonstrates that the lake remained as a closed basin in general. The TOC and TIC values are higher during the Holocene and Younger Dryas (TOC>2.5 wt% and TIC>3 wt%) than those during the late glacial (TOC <2 wt%) and TIC <3 wt%). There is a weak positive correlation between TOC and TIC for the Holocene (r=0.37), and a weak negative correlation for the late glacial and YD sediments (r=-0.22). The highest TOC values (>4 wt%) are observed during 9-6.5, 5.7 and 5-4 ka calBP. Significant positive correlations between TOC, TIC, δ^{18}O and δ^{13}C values during these periods suggest high TOC and TIC values are related to high organic productivity, probably associated with low water levels in the lake. High amplitude oscillations (7 ‰) in δ^{18}O, and δ^{13}C values during 14-13 ka calBP and late Holocene (5 ka BP-present) suggest lake level oscillations and associated changes in the lake's organic productivity. The lowest δ^{18}O values (< ‰ -4) are observed at 4-2, 17-14, 21.3 and 27-26 ka calBP, which probably correspond to relatively high lake levels.

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Sediments of Lake Van – a high-resolution archive of changing climate, volcanic events and seismic activity in Eastern Anatolia for the last 500'000 yrs

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Varved sedimentary records have shown their high potential to reconstruct abrupt and global climate change within the marine realm (e.g. Cariaco Basin, Santa Barbara Basin). Continental counterparts, consisting of long and varved lacustrine records can be found in the subsurface of some deep lakes, such as Lake Van. Lake Van is a 440 m deep closed soda lake situated in a climatically sensitive semiarid and tectonically active region in Eastern Anatolia, Turkey. The ICDP project Paleovan aims to reconstruct the climatic, tectonic and volcanic history of Lake Van. Driven by an international and interdisciplinary scientific team, two sites, Ahlat Ridge (AR) and Northern Basin (NB) were drilled in summer 2010 recovering sedimentary records of 220 and 140 m, respectively. A total of 800 m of sediment-cores were opened, described and photographed in spring 2011 at the IODP core repository in Bremen. Lithologies of up to five parallel cores (multiple coring) were correlated and a composite profile was defined giving priority to core quality and continuity. Preliminary Ar/Ar dates of the core catcher yielded a basal ages of $\sim$500′000 years. Using this rough age model, geochemical measurements (every 20 cm) indicate that TOC is high in warmer periods (interglacials) and low in colder periods (glacials). These TOC fluctuations match marine isotope stages and extrapolated Holocene sedimentation rates. The 219 m long AR composite profile consists of $\sim$80 % lacustrine sediments, $\sim$10 % of volcaniclastic deposits and 10 % gaps interpreted to be coarse-grained volcaniclastic that are difficult to be recovered. The lacustrine mud, i.e. clayey silt composed of mainly clay minerals and carbonate. Based on major macroscopic sediment features eight major lacustrine sediment types ($\sim$900 layer) were differentiated and separated from the volcaniclastic deposits (300 layer). Impressive color transitions and a repetitive pattern of similar lithological successions occur throughout the record. The sub-mm thin laminated intervals as recovered from different interglacials/interstadials stand out prominently against the more banded lithologies of the remaining sections. From 168 to 189 meters below the lake floor a unit of major irregularities and accumulation of deformations were identified as a large-scale mega-event deposit. It overlies a unit of carbonate-poor diatomaceous mud and a gravel-rich unit containing fresh-water gastropods (Bithynia) and mussels. The gravel is interpreted to have been deposited under beach-like conditions and reflects the early transgressive state of the lake′s history.
The distinct and great variability of sediment types is indicative of highly and rapidly changing depositional conditions forced by lake level and other climate-driven changes and by tectonic events over the past 500'000 years. The annual laminated intervals reflect strong seasonal fluctuations in particle fluxes to the lake bottom and bottom water anoxia. The onset/cessation of theses episodically occurring laminations represent threshold crossings indicative for abrupt changes of climate (e.g. Dansgaard-Oeschger cycles) and tectonic activities. The partly varved lacustrine record enables, for the first time, to reconstruct the environmental and climate conditions captured during several glacial/interglacial cycles at a mid-latitudinal continental realm.

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Noble gases in the sediment pore water as proxies for physical transport processes and past environmental conditions in Lake Van (Turkey)

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Since many decades unconsolidated sediments have been proposed as a potential archive for noble-gas records to reconstruct past environmental conditions in lakes and oceans. In addition, the accumulation of non-atmospheric noble-gas isotopes allows tracing the geochemical origin and transport processes of the pore fluids [7]. For instance, the abundance of terrigenic He isotopes reflects the residence time and transport dynamics of the dissolved species in the pore space. The $^3\mathrm{He}/^4\mathrm{He}$ ratio of terrigenic He can be used to constrain the geochemical origin of the pore fluids [3, 7]. However, methods for reliable and robust noble-gas analysis in pore water of unconsolidated sediments have been developed only recently [1, 6].

Lake Van (Turkey) is one of the largest terminal lakes and the largest soda lake on Earth. The physical conditions of the lake are known to react sensitively to changes in the hydrological cycle and to the environment of the lake catchment [2]. Therefore, the noble-gas record in the sediments of Lake Van have a great potential as an archive to reconstruct past climate evolution in eastern Anatolia where the atmospheric south-western jet stream intersects the northern branch of the subtropical high pressure belt [4]. Also, the basin of Lake Van is situated in a tectonically active region characterized by the presence of major faults and volcanos and is known to accumulate mantle fluids [3, 7]. Noble-gas isotopes are therefore expected to yield insights into the origin and transport processes of terrigenic fluids in the sediment pore space and their release into the water body [7].

In this study we present noble-gas and salinity data measured in the pore water of sediment samples collected in Lake Van. Noble-gas data from short cores (~ 2 m) taken at different sites throughout the lake basin are discussed from the point of view of the fluid transport in the pore space. In this context, we interpret the latest results from the noble-gas samples acquired in 2010 during the ICDP PaleoVan drilling operations from 220 m long cores [4, 5]. Noble-gas measurements are further linked to salinity measurements in terms of past lake level fluctuations and physical conditions of the water body of Lake Van.

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Paleogeophysical characterization of a climate archive based on downhole logging in the ICDP project PALEOVAN

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Lake Van (eastern Anatolia, Turkey) is the 4th largest terminal lake worldwide and is located at a key climatic position. Past climate changes have been recorded in the sensitive hydrological system of Lake Van, which is evident from terraces around the lake. The lake sediments archives approximately 500,000 years of climate history. The ICDP project PALEOVAN aims to enhance the understanding of the paleoclimatic and paleoenvironmental conditions of the Middle East.
Investigations (shallow coring, surface geophysics) have been started in 1970's and a deep drilling campaign has been executed in summer 2010. Two boreholes with total depth of 140 m (Northern Basin) and 220 m (Ahlat Ridge) were drilled; the core recovery was about 91 % (Ahlat Ridge) and 71 % (Northern Basin). The Ahlat Ridge site is located in a deep basin of Lake Van (water depth: 375 m). Results from a geophysical survey indicate, that an undisturbed sedimentary sequence is preserved. The lithology consists mainly of clayey silt and tephra deposits, which originates from several volcanoes in the surrounding of Lake Van.
A continuous dataset of downhole data (spectral gamma ray, magnetic susceptibility, dipmeter, and resistivity) as well as partly sonic data have been achieved at both sites.
Spectral gamma ray, resistivity, and susceptibility data have been interpreted by applying multivariate statistics (cluster analysis). The logs have been subdivided into cluster units based on similarities in their physical properties. The lithological information from the visual core description has been taken into account and associated lithological units have been derived.
The tephra deposits at the Ahlat Ride drillsite are characterized by strong differences in their physical properties. The tephra differ mainly in their natural radioactivity and susceptibility values. In cooperation with other PALEOVAN working groups, not only differentiation but also linking with different volcanic sources and eruption phases is possible.

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Structural and stratigraphic analysis of the Lake Van, Eastern Turkey: An integration of high resolution seismic and drilling data

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Lake Van in Eastern Anatolia (Turkey) is the fourth largest terminal lake in the world with a surface area of 3,574 km^2, a volume of 607 km^3, a maximum depth of 450 m, and a maximal length of 130 km WSW-ENE. In summer 2010, Lake Van was chosen for scientific drilling in the framework of the International Continental Drilling Program (ICDP) aiming to recover long paleoclimate and paleoseismic archives. Two sites (Ahlat ridge and Northern basin) were successfully drilled based on seismic data collected during a pre-site survey in 2004. Here we present a joint interpretation of the seismic and drilling data.

Seismic data reveals the main structural features inside the lake, including the Northern basin, Tatvan basin, Ahlat sub-basin, and Deveboynu basin. These basins are separated by basement ridges such as Northern and Ahlat ridges. Seventeen seismic sequence boundaries including the top of the acoustic basement were interpreted and mapped in the Tatvan basin. The time-structure maps were converted into depth using the time-depth relationship constructed from seismic-to-well tie at the Ahlat ridge well. The structure maps of the sequence boundaries exhibit tilting to west, suggesting that the sequences were deposited with greater subsidence in the west. NE-trending normal faults are dominant; E-W oriented thrust faults are seen locally.

The seismic sequences in basins are dominated by an alternation of well-stratified and chaotic reflecting layers. The chaotic seismic facies are interpreted as mass-flow deposits (up to $\sim$50 m thick), most probably triggered by earthquakes and/or rapid lake level fluctuations. The absence of mass flows in Ahlat sub-basin indicate that most mass flows originate close to the southern shore of Lake Van and that Ahlat ridge is likely to have acted as a structural barrier for these mass flows. The moderate-to-high-amplitude, well-stratified facies seen in the deeper parts of the basins are interpreted as lacustrine deposits and tephra layers. Core-to-seismic correlation supports this interpretation; strong high-amplitude reflections on seismic data correlate well with thick ($\sim$2 m) tephra layers.

Seismic data suggest a minimum age of 500 ka for Lake Van, consistent with the preliminary results of core dating. Since then, lake level fluctuations reaches an amplitude of more than 500 m (up to 450 m deeper and 80 m higher than the present lake level) but the deep basins were permanently filled with water.

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Temporal framework of Lake Van sediments provided by single crystal 40Ar/39Ar dating of tephra layers

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The timing and evolution of Lake Van is closely connected to that of the two major active stratovolcanoes Nemrut and Süphan bordering the lake in the west and north. Here we focus on dating the tephrostratigraphy of the sediments of Lake Van drilled at 2 sites in the ICDP Paleovan project (Site 1: Northern Basin, 142 m; Site 2: Ahlat Ridge, 214 m) to provide a high resolution temporal framework of climate evolution. More than 90 vol.% of the volcanic particles in the cores have probably been supplied by Nemrut volcano; lesser amounts of tephra of subduction-related composition derived from Süphan volcano are interspersed between Nemrut tephra layers. Compositionally fingerprinted and texturally prominent tephra layers in the cores were correlated to some of the ca. 40 fallout tephra layers recognized by us on land during the pre-site survey, many of them also dated. Macroscopically recognizable layers in the cored sediments are mostly in the mm-to cm scale but some are up to 20 m thick as documented basically by intervals of nonrecovery. The tephrostratigraphy and dating of the sediments cored depends fundamentally on the stratigraphic and temporal framework of the land tephrostratigraphy documented during the pre-site survey.
Ages determined by single crystal 40Ar/39Ar dating of anorthoclase phenocrysts from onland tephra show major explosive activity of Nemrut Volcano throughout at least the past 400 000 years. Dating of alkali feldspars in cc samples from the lowermost 60 m of Site 2 cores has yielded preliminary ages ranging up to ca. 570 ka, some of the ages showing high standard deviations.
Here we present new dates determined on both onland tephra and tephra througout the cores which will be available by April. The new data will help to determine the oldest Nemrut tephra found sofar on land and provide a more detailed temporal framework throughout both the land tephrostratigraphy and that of the cores allowing to interpret the sediments and their various parameters (TOC etc) to the MIS scale. The rounded polymict clasts of the basal epiclastic fresh water sediments drilled at Site 2 petrographically resemble the continental red beds forming the basement of the town of Ahlat. Feldspar crystals from these basal sands yield ages from ca 2 to 16 Ma, slightly extending the age of Miocene volcanics erupted over wide areas in eastern Anatolia north of Lake Van.

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Lake Level Changes of Lake Van over the Last 400 ka: Evidence from Deltas in Seismic Reflection Data and ICDP Drilling

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Lake Van is located on the East Anatolian Plateau of Turkey, which is a key area to obtain long-term regional paleoclimate records. This study is based on the correlation of seismic reflection data acquired by IFM-GEOMAR in 2004 and the borehole stratigraphic information obtained from two sites drilled by International Continental Scientific Drilling Program (ICDP) Paleovan Project in 2010. The drilled sites (Northern Basin and Ahlat Ridge) are located at the water depths of 245 m and 357 m, where drill holes reached to depths of 145.5 m and 220 m below the lake floor, respectively. Physical core properties were measured by the Geotek Multi Sensor Core Logging (MSCL) equipment at the onshore lab of the drilling campaign. Correlation between the seismic and MSCL data was based mainly on matching the two data sets of the tephra layers that were characterized by high reflection amplitudes and the high magnetic susceptibility values. Stratigraphic correlation between the two sites was done using the magnetic susceptibility profiles. Seismic reflections representing the different tephra layers were then traced over the basin. A tentative age model was constructed based on AMS ^{14}C dates, tephra correlation and varve counting. It was then tuned with the isotope stages using the δ^{18}O and δ^{13}C isotope data, and used to date the seismic reflections.

The seismic lines extending from the north towards the 460 m deep Tatvan Basin in the south reveal a stack of at least five deltas that developed over the past 400 ka cal BP. According to the age model these deltas developed during the cold periods. The minimum lake level occurred at about 350 ka cal BP (MIS-10) when the lake level was about 550 m below the present lake level. Considering possible crustal subsidence due to sediment and water loading and sediment compaction, the water level at the time would have been 400-350 m below the present level. Another delta formed at 200 m below the present lake level during the Last Glacial Maximum. The other deltas at 160 m 235 m, 300 m and 490 m below the present lake level (without the subsidence correction) are dated 125-95, 166-142, 195-169 and 270-234 ka cal BP, respectively. Estimated dates have an error approximately 10 ka due to uncertainties in estimating the ages of seismic reflectors and isotope stage boundaries. From the seismic stratigraphic analysis, it can be concluded that interglacial epochs have lower sedimentation rate than the glacial epochs. This was mainly due to the high rate of physical weathering, low lake levels and abundant mass-flow events during glacial epochs. During high lake levels, mainly laminated and banded sediments were deposited, whereas glacial epochs with low lake levels are characterized by grey homogenous muds and turbidite sedimentation. The turbidites commonly range in thickness from a few cm to a few meters, and are characterized by a sharp basal boundary, overlain by a sandy bed that passes upward into graded and laminated clayey silt and a homogeneous mud layer.

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Late Holocene High Resolution Multi-Proxy Climate and Environmental Records From Lake Van, Eastern Turkey

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Lake Van is the world's largest soda Lake with a surface area of 3522 km2, a water volume of 576 km3 and a maximum water depth of 451m. It is situated in the East Anatolian Highlands of Turkey at (43°E and 38.5°N) at an altitude of 1650m. The lake is characterized by a high pH ($\sim$9.8) and annually varved sediments.
Four interface cores with lengths of up to 1.4 m and undisturbed top were collected from Lake Van. All cores were analyzed for physical properties using Geotek Multi Sensor Core Logger (MSCL), inorganic elemental analysis using an Itrax XRF core scanner, and total organic carbon (TOC) and inorganic carbon (TIC) analysis using TOC analyzer. Radionuclide (210Pb and 137Cs) analysis and varv-counting were used to establish the chronology, with the two methods providing very conformable results. The varves were counted using 60 μm resolution digital X-ray radiograpic images. An increase in the activity of 137Cs radioisotope in comparison with 210Pb age data gives support for the presence of the record of 1986 Chernobyl nuclear accident. The sedimentation rate varies from 0.4 to 0.7 mm/year at different core sites.
Our sedimentary records extend back to about 3600 a BP and are correlatable between the different core sites. Elemental (Ti, Fe, K) and magnetic susceptibility profiles suggest relatively large detrital input occurred over the last 750 a BP, during 1700-1150 a BP, 2150-1700 a BP, 2150-1800 a BP, 2450-2350 a BP, and 3150-2600 a BP, which are interpereted to correspond to wet periods. The intervening periods during 1150-750 a BP, 1800-1700 a BP, and 2350-2150 a BP, 2600-2450 a BP are characterized by low detrital input and high carbonate contents, correponding to relatively dry periods. There also short dry periods at 150 a, BP, 1450-1400 a BP and 2950 a BP within the long wet periods listed above. High organic productivity correponding to >5% TOC in the sediments occurs during 110 a BP, 210 a BP, 460 a BP, 530 a BP, 790 a BP, 1460 a BP, and 1940 a BP. In general, there is negative correlation between the TOC and TIC contents.

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Glacial/interglacial and MIS3 climate variability recorded in Lake Van, eastern Anatolia

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The 220 m long sediment profile of Lake Van (eastern Anatolia, Turkey), covering its entire ca. 500 ka long history displays an extraordinary textural variety; laminated-, banded-, and graded-clay sections are intercalated with numerous tephra layers. Here, we present X-ray fluorescence (XRF) profiles, which help not only to delineate compositional differences between the lithotypes, but also to identify intervals of abrupt changes, most likely related to glacial/interglacial transitions. Terrigenous elements (K, Al, Ti, Fe) are more abundant in banded/graded clays than in finely laminated sections. This systematic variation suggests higher detrital supply during colder periods (glacials) and lower during warmer periods (interglacials). Within the topmost 40 m of the profile the terrigenous elements pattern tend to show Dansgaard/Oeschger-type variability and a clear Younger Dryas signal. Comparing our XRF profiles with other available data (e.g.: Lake Van macro- and micro-facial analysis, porewater salinity profile, dating of the terraces) and paleoclimate records from the Levant region we aim to identify the mechanisms transmitting high-latitude climate signal into the mid-latitude continental interior.

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Sulfate reduction and microbial abundance in saline, alkaline Lake Van (Eastern Anatolia, Turkey) – ICDP Expedition 5034

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Lake Van is the fourth lagest terminal lake in the world. It is located on the Eastern Anatolian High Plateau (Turkey) and surrounded by two semi-active vulcanos (Nemruth Dagi and Syphan Dagi). Evaporation processes, chemical weathering of vulcanic rocks and hydrothermal activity have created an environment of extreme alkalinity (155 m eql-1, pH 9.81) and salinity (21.4 ‰ (Kempe et al., 1991). Sediments of saline and highly alkaline soda lakes, such as Lake Van, represent one of the most extreme environments on Earth (Stam et al., 2010). These sediments host extremophilic microorganisms (alkaliphiles and halophiles) that have adapted their metabolism to these peculiar environmental conditions (Oren et al., 2002)
In summer 2010 the ICDP Expedition 5034 (ICDP project PALEOVAN) retrieved long sediment cores at two sites at Lake Van, Northern Basin (5 km offshore, 245 meters below lake level, mbll) and Ahlat Ridge (12 km offshore, 357 mbll) [2]. At both sites, samples from optically undisturbed core catcher material were collected on site to investigate microbial abundance and activity. Close to both drill sites two short gravity cores (ca. 70 cm long) were retrieved to sample the sediment/water interface.
We here report the first results from microbiological investigations (porewater chemistry, cell abundance and sulfate reduction rates, SRR) in samples from the two sites at Lake Van. Although the two sites are relatively close to each other, SRR differ significantly. The sedimentary microbial ecosystem in Lake Van is apparently more sensitive to environmental conditions like water depth and sedimentation rate than marine systems. The shallower Northern Basin site exhibits significantly higher SRR than Ahlat Ridge, which is located 7 km further offshore and ∼100 m deeper. Microbial sedimentary abundance is similar at both sites, but cell abundance decreases linearly with depth, as compared to a logarithmic decrease with depth in marine sites. Due to the lack of other long lacustrine sedimentary cell abundance records, it is not clear whether these findings are unique or a common feature of lacustrine sediments.

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Long continental pollen record of the last ca. 500 ka in eastern Anatolia – First palynological results from Lake Van cores obtained in 2010

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Lake Van is located in a climatically sensitive semiarid and tectonically active region in Eastern Anatolia, Turkey. It is a key site to reconstruct terrestrial paleoecology and paleoclimate in the Near East during the Quaternary. Lake Van is the largest soda lake (surface area 3.570 km^2) and the fourth largest terminal lake in the world (volume 607 km3). The maximum water depth is 460 m and the maximum length is 130 km WSW-ENE. The present lake level is at an elevation of 1,646 m above mean sea level. The northern and eastern part of Lake Van is mainly characterized by steppe vegetation related to the so-called Irano-Turanian plant geographical territory. In contrast, some remnants of deciduous oak forests can be observed mainly in the Bitlis Massive, SW of the lake. We present preliminary palynological results of a long continental sedimentary record obtained during a coring campaign supported by the International Continental Scientific Drilling Program (ICDP) in summer 2010. The composite profile from the Ahlat Ridge, the most important site for paleoclimatological studies (total length of ca. 218 m), yields a continuous paleoclimate archive encompassing ca. 500.000 years. The record is partly characterized by annually laminated sediments. By using pollen analysis, several glacial and interglacial/ interstadial periods can be observed. The warm stages can be identified based on higher amounts of pollen from thermophilous trees such as deciduous oak. In addition to the current interglacial stage (MIS 1), pronounced warm phases coincide with past interglacials probably correlative to MIS 5, 7, 9 and 11 or 13. Cold stages are characterized by pollen types related to steppe plants such as Artemisia, chenopods and grasses. The glacial-interglacial cycles as reflected in the palynological data are in broad agreement with those of stable oxygen isotope analyses based on autigenic carbonate of the lacustrine sediments (bulk). Caused by the state of the art, more detailed information will be given to the last 130,000 years.

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Biomarker analysis in 500 kyrs sediment record of Lake Van - potential implications for paleoclimate in eastern Anatolia

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Biomarkers are organic molecules indicative of specific organisms and/or specific conditions such as salinity, oxygen or temperature. Preserved in the sediment, these molecules represent unique tools for investigating paleoenvironments. The biomarker study presented here is part of the ICDP PALEOVAN project. The main objectives are to distinguish between allochtonous and autochtonous organic fractions and to reconstruct paleotemperatures in eastern Anatolia over glacial-interglacial timescales.

Allochtonous and autochtonous organic fractions can be differentiated on the molecular level using lipids typical for land plants and algae. Concentration of fatty acids, sterols and n-alkanes are determined on 60 samples distributed over the entire 219 meters sediment profile. The results are interpreted with the help of the lithostratigraphy and two other proxies measured with a relatively high depth resolution. Total organic carbon (TOC) is indicative of productivity and/or preservation whereas potassium (K) XRF intensity is indicative of detrital input.

Temperature reconstructions are widely performed in marine system using a lipid produced by haptophyte algae, so-called alkenones. Alkenones are found in most of the analyzed samples. In order to find an appropriate calibration curve, equations from the literature are tested on sediment trap material. Obtained temperatures are compared with actual measurements from the water column over the years 2008-2011.

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A 500,000-Year-Long Sediment Archive of Lake Van in Eastern Anatolia

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Lake Van, a large terminal lake in eastern Anatolia (Turkey), holds a key position within a sensitive climate region between the Black Sea, Caspian Sea and Mediterranean Sea. Lake Van extends over 130 kilometers on a high plateau; lake level at present is 1665 meters above sea level. The lake water, up to 450 meters deep, is alkaline (pH ∼9.8) and saline (∼21.4‰. Its long and partly annually laminated sedimentary record provides an excellent paleoclimate archive because it yields a long and continuous continental sequence that covers several glacial-interglacial cycles spanning more than 500,000 years. Lake Van is therefore a key site to reconstruct Quaternary climate evolution in the near east. Moreover, being located in a tectonically active area bordered by two historically active volcanoes, it holds a unique paleoseismic and volcanic archive. As a closed and saline lake, Lake Van reacts very sensitively to lake level changes caused by any alterations in the hydrological regime in response to climate change. Because the lake is the deepest lake in Anatolia, which, in contrast to other more shallow lakes, likely never dried out in its history, it was identified as the most promising candidate to contain a long and continuous sediment archive. The drilling campaign, supported by the International Continental Scientific Drilling Program (ICDP), operated by the U.S.-based company Drilling, Observation and Sampling of the Earths Continental Crust (DOSECC), was carried on in July and August 2010. DOSECC developed and assembled a new Deep Lake Drilling System (DLDS) that was specifically designed for coring sediments from deep lakes and that was first operated in Lake Van. The DLDS worked at water depths of up to 360 meters. Cores from 140 meters (Northern Basin site) and 220 meters (AhlatRridge site) below the lake bed depth were retrieved. To obtain a complete sedimentary section, the two sites were cored multiple times. Total length of all parallel cores recovered at the two sites is over 800 meters, allowing a consistent look back in time at the scale of several glacial-interglacial cycles. The cores are stored at an Integrated Ocean Drilling Program's core repository located at the University of Bremen's Center for Marine Environmental Sciences (MARUM) in Germany. This repository's ideal sampling and preparation facilities have been used for splitting, photographic and X-ray fluorescence (XRF) scanning of the core halves, and writing core descriptions and taking samples during spring 2011. Samples have been taken to analyze a variety of characteristics, including paleomagnetics, sedimentology, inorganic geochemistry, black carbon concentrations, pollen species and abundances, isotopes and biomarkers, general composition, and tephra layers. Preliminary single-crystal argon dating of anorthoclase in the tephra, XRF scanning results, as well as pollen analyses, suggest that the Ahlat Ridge record encompasses more than 500,000 years of paleoenvironmental and volcanic/geodynamic history. In addition to the current interglacial stage (marine isotope stage 1), three to four interglacial stages can be identified on the basis of annually laminated lithologies and higher amounts of pollen from trees such as deciduous oak, which favor warmer environments. These submillimeter-scale annual laminations reflect strong seasonal fluctuations in particle supply resulting in alternations of aquatic biomass, authigenic carbonates, and detrital constituents. These warm phases must have coincided with bottom water anoxia and probably coincide with marine isotope stages 5, 7, 9, and 11 or 13. Cold stages are characterized by non-laminated, banded lithologies and predominance of pollen types related to steppe plants. The pore water chemistry as well as the occurrence of freshwater mollusks in sediments from the very bottom at the AR site suggest the initiation of Lake Van as an open freshwater body having an outlet at that time. The recovery of several meter thick tephra layers allows correlation to major dated and compositionally fingerprinted fallout tephra deposits studied on land. Numerous small-scale sediment deformations and seismoturbidites were identified that record earthquake history of this seismically active area. The area's susceptibility for seismic hazards has been once more documented by the magnitude 7.1 earthquake affecting the eastern shore of the lake on October 23, 2011.