Beryllium isotopes as tracers of Dead Sea hydrology and the Laschmap geomagnetic excursion

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The content of the cosmogenic isotope 10Be (t1/2= 1.39 Ma) in lacustrine sediments that deposit in lakes with a large watershed is susceptible to both climate and cosmogenic production rate variations. In order to distinguish between these two controls, we measured 10Be and major elements in several sections of the annually laminated sediments of the last glacial Lake Lisan that are composed of detrital sediments and primary (evaporitic) aragonite. The sections were selected to represent different lake configurations (level rise, drop and high-stands) that reflect the regional hydrology and climate and rapid change in the 10Be production rate during the Laschamp geomagnetic excursion. The recycled 10Be was evaluated by measuring the short-lived cosmogenic isotope 7Be (t1/2=53.3d) in modern flood suspended matter, dust and mud cracks. During periods of moderate 10Be production rate variations the 10Be content in the Lisan detrital sediments correlates with lake level and Al+Fe content. During periods of rapid increase in the 10Be production rate, (e.g. the Laschamp excursion) 10Be showed a ~2 fold increase, beyond the above-mentioned correlations (lake levels and Al+Fe contents). This observation suggests that Lake Lisan can serve as a potential high-resolution archive of 10Be production rate variations during periods of geomagnetic excursions. A comparison between 14C and 10Be data in the Lisan Formation shows that the D14C deviation lags the Laschamp induced 10Be peak by ~1000 y.

Integrating seismic stratigraphy and well logging data in defining Dead Sea palaeoclimate changes since the Pleistocene

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Variability of stratigraphic sequences since the Pleistocene in the Dead Sea basin were investigate using interpretation of new 2D high-resolution seismic reflection profiles and downhole logging results. Four sequences (labeled 1-4) were tied to age dated sediment from the ICDP (International Continental Drilling Project) core. These provided chronological information on fluctuations in environmental conditions in the Dead Sea basin as well as on their geological context. Petrophysical data point to major base-level changes since the last 250 kyrs validating significant environmental changes. Long duration wet periods are marked by positive values of natural γ-radiation and continuous deposition of deep lacustrine sediment facies are recognized in the core. Major erosional surfaces and lagunal to evaporites facies were interpreted as dry events following lake level fall. Evaporite-rich stages and erosional unconformities were used as indicator of past lake levels in the Dead Sea basin and suggest a reduction in water inflow with complete desiccation. Lake level falls appears to correlate with major climatic events over the Levant region.

Tripling of Lisan Formation thickness at depocenter by turbidites from seismically-triggered subaqueous landslides

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Ubiquitous turbidites in the 115 meter thick Lisan Formation section of the drill core from the Dead Sea depocenter are recognized by a coarse base (sand-size grains) of a few millimeters to a few centimeters, below a quasi-homogeneous layer of up to more than a meter, usually capped by a thin, dark, fine layer. This archive of turbidites and deformed structures provides a paleoseismic record representing the entire Dead Sea Basin.
Altogether the Lisan deep basin section (LDB) is ~3 times thicker than the Lisan Fm. margin outcrops. Huge (>1 m) folds and breccias are more common in the middle part of the section. A remarkable ~70% of the LDB comprises these deformed and/or allochtonous sediments; an enormous quantity of sediment is added to this deep-lake section due to these events. Previous turbidity measurements during flash floods show flood plumes barely extend a few kilometers off-shore, making it a very unlikely source of thick sediment events in the deep basin.
The abundant scars on the Dead Sea slopes were recently interpreted as subsea landsliding (Lensky et al. 2014, this meeting). Subsea landslides and turbidity currents can also explain the flat abyssal plains, which may have developed due to re-deposition at low angles. The turbidites of the LDB archive are attributed to such landsliding. We present a rough "cut and fill" calculation; the volume of the eroded material from the scarred slopes is analogically compared to the volume of turbidites in the archive. The allochtonous sediments of the LDB archive is more than twice the volume "cut" by landslides from the Dead Sea slope scars. This implies that the Lisan period experienced more than twice the landsliding volume than calculated here for the current Dead Sea modern scars.
The triggering mechanism proposed for these deformations and mass movement events is earthquakes due to the sites' location at the seismically active Dead Sea transform, the on-shore association of deformations associated with faulting, and the well-known correlation of subsea landslides with earthquakes. There is up to an order of magnitude more deformed and mass wasting layers in the LDB than during the same time period in the lake margin sections. This can be explained by: 1. slumps, slides, brecciation, and turbulent flow from any part of the lake reaching the depocenter, 2. lack of hiatuses in the LDB, 3. perhaps lower intensity needed for subsea slides than near shore brecciation and deformation. Recurrence time of mass movement events (large and small) based on this data is ~50-100 years, much closer to the recurrence known from historical and Holocene paleoseismology for M≥6 earthquakes, than what was previously reconstructed from the marginal Lisan.

Halite sedimentology and petrography in the Dead Sea basin as an indicator for paleoenvironment and paleoclimate

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Halite precipitated in the Dead Sea basin during the last three interglacials and represents extremely arid periods when the lake level dropped, possibly below 400m bmsl. The halite is divided into two main types: Large transparent preferential oriented crystals that formed on the lake-bed and small non-oriented crystals that formed on the lake–atmosphere boundary and accumulated on the lake floor. Small crystals tend to form due to relatively high evaporation rate, while large crystals form in lower rates of evaporation and may indicate a limnological structure of a mixed water column. These two types of halite occur at different frequencies and time intervals varying in thickness from a few mm up to tens of centimeters. The mud in between the halite layers or crystals is usually associated with the large-crystal salt type where also mud is found between the halite crystals. Nevertheless, at some specific locations alternations between small-crystal halite and mud is observed.

The thick large crystal layers probably represent the slowest rate of lake level drop (assuming a relatively deep lake) and the crystals are often transparent and contain almost no fluid inclusions, suggesting a very slow growth of the crystals. Assuming that large crystals can grow on the lake floor only when the water column is mixed and the absence of small crystals during these periods may suggest that the temperatures during summer weren't relatively warm, keeping the water column mixed. Alternatively, the degree of saturation of halite may have decreases to below saturation under the higher temperatures of the summer.

The most extreme climatic conditions are represented by the thick small-crystal halite layers that usually include rafts that are associated with high supersaturation of halite and evaporation. These layers do not contain any detrital material beside a few faint layers of some detritus with slightly larger crystals of halite. Frequent alternations (~0.5-1cm of each layer) between the two halite types may represent milder conditions and seem to be seasonal.

An unusual occurrence of halite is alternations between very fine crystals of halite (up to 2 cm thickness) and detritus (~1 mm thick) representing sharp transitions between wet and very dry conditions. These alternations occur at a few places only during MIS 5e and mainly around the pebbles layer that was deposited towards the end of MIS5e. The most frequent and thickest sections of the small-crystal halite with less large-crystal halite mark the beginning of the precipitation of halite at the current and last interglacials.

The structure of the halite and relationship with the mud layers, together with the absence of evidence of halite dissolution, suggests a relatively deep-water body where floods did not mix the whole water column and reduce the degree of saturation of halite. However, the thick sections of halite suggest significant lake level drops, with the most extensive one of at least 300m occurring during MIS 5e.

The Scarred Slopes of the Dead Sea – Evidence for Intensive Subsea Landsliding

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With the fast declining Dead Sea level in recent years, its western coastline present a large sinuosity increase characterized with numerous narrowly curved bays and pointed and narrow small peninsulas. The high-resolution bathymetry of the Dead Sea (grid size = 5 m; Sade et al. 2014) indicates that these new and common features are the exhumation of the topmost parts of distinct underwater ridges that characterize the Dead Sea western slope. These topmost ridges and valleys have common upper altitude of ~-415 m and extend down slope, eastward and perpendicular to the shore, some of them extend all the way to the Dead Sea deep. This distinct morphology characterizes the western slopes of the Dead Sea, whereas in the eastern slopes of the lake these features are much less extensive. The western slope is covered by relatively thick late Pleistocene and Holocene sediments. Characterizing these features and identifying their origin are the goals of this study. The Western slope of the Dead Sea slope has the following features, from top to bottom: (a) an upper exposed coastal plain (altitude ~-400 m) with minor coastline sinuosity (~1.3), (b) steep slope, ~10 degrees, between altitudes of -410 m to -580 m with highest sinuosity (>2), and spacing between ridges is a few hundreds of meters, (c) the lower part of the slope from altitudes of -580 m to -710 m with slope angle ~3 degrees and spacing between ridges is ~1 km, and (d) the practically flat abyssal plains at ~-720 m. Hypotheses for the origin of this morphology include (a) incision by streams during past low sea levels, (b) deposition, (c) tectonic activity, and (d) submarine landslides. Incision by streams is ruled out as most of the underwater valleys have no stream mouth or drainage basin on land. This also rules out deposition. Underwater landslides can explain most of the observed bathymetric morphology: (a) the landslides develop at the steep parts of the slopes, below the coastal plains, (b) the slides generate turbidity currents that propagate downslope while developing wide valleys at the lower part of the slope, (c) the turbidity gravity current reach the bottom of the lake while spreading laterally, and turbidites at low angles while flattening the Dead Sea bottom. We propose that the high slope angles of the basin fill sediments, together with the seismically active environment, the high density of the Dead Sea brine, which reduces the effective weight of the sediments, all contribute to the landsliding. Rapid lake level drops in the past could have enhanced landslides by increasing the effective pore pressure as a result of over-consolidation. Turbidites are documented in the archive of the Lisan formation depocenter (Kagan et al., 2014, this meeting).

Paleo-limnological conditions in the Dead Sea Basin from porewater in the ICDP deep core

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The major ions composition of porewater extracted from core catchers collected along the ~450 m of the ICDP Dead Sea Deep core represent the chemical composition of the hypolimnion (lower water mass) of the terminal-hypersaline lakes that occupied the basin during the last 220 ka, i.e. the Dead Sea, Lisan, Samra and Amora. The salinity depth profile reflects the secular variations in the water balance of these terminal lakes, whereas the depth profiles of some individual ions may be assigned to minerals that precipitated or dissolved (e.g., aragonite, gypsum and halite) from these water bodies due to evaporation/dilution and/or common ion effects.

The profile of Na/Cl ratio reveals three alternations between periods of halite precipitation, as identified by the drop in Na/Cl values to minimum of 0.19, and halite dissolution, during which Na/Cl values rose to over 0.60. These changes are best explained by net evaporation and lake level drops, and net water input with possible lake level rise, respectively. The depth profile of the most conservative major ions, Br- and K+, reveal a ~50% drop in concentration during the Lisan period (between 190-90 m in the core, representing time interval of ~70-14 Ky BP). We attribute this “freshening” to extensive input of runoff water and a general rise in lake level, which is also associated with increasing Na/Cl ratio. The overall salinity of the lake at this period dropped to just ~70% compared to the pre-Lisan period or present day salinity, as indicated by the Na+ and Cl- depth profiles. The difference between these two ion pairs suggests that continuous dissolution of halite during that period “buffered” the lake’s salinity and it did not drop to the dilution levels of Br- and K+. An attempt to reconstruct the paleo-limnology of the lake sequences based on mass balance calculations on the different major ions will be presented at the conference.

Annual cycles of detritus in halite and presence of highly-soluble salts during extremely low stage of the last interglacial Dead Sea

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Exposed last interglacial (e.g. MIS 5, Lake Samra) sediments in the Dead Sea basin are scarce and discontinuous. The ICDP Dead Sea core offers undisturbed sampling of this climatic interval and adds crucial information on interglacial conditions in the Levant and eastern Mediterranean region. This interval in the core is characterized by thick authigenic halite sequences with occasional intercalations of clastics associated with evaporitic gypsum and minor amounts of aragonite. The halite sequences, probably indicating a low lake level that are indirectly represented in exposures as possible hiatus, are primarily comprised of altering laminae of (a) white pure halite with thickness range between 0.5 and 3cm, (b) brown mixed gypsum aragonite and clay with thickness range of ~0.25 to 0.4mm and (c) black layers of clay settling in between halite cumulates with a common thickness of 0.5mm.

We focused our efforts on high resolution characterization and analyses of these laminated sequences by using µXRF, polarized light microscope, and SEM. We propose that the laminations represent annual deposition and possibly seasonal cycles; the white and brown layers formed in summers and winters, respectively. The black laminae represent dust storms. The thickness of a series of white laminas reveal annual cycles of 7-8 years. Recent SEM findings show some K and Mg rich salts associated with the brown layer. Some of them with dissolution texture which suggests extreme low lake level just before a fresher water input.

Sources and Transport of Desert Dust to the Levant During the Last Glacial-Interglacial Cycle

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The Dead Sea is a terminal hypersaline lake receiving water and fine-grain sediments from a large drainage basin in the Levant that extends from the edge of the Sahara to the Mediterranean climate zones. The Dead Sea and its precursors; last glacial Lake Lisan and last interglacial Lake Samra, continuously accumulated desert dust that had settled in the watershed during the mid-late Pleistocene and Holocene periods (Haliva-Cohen et al., 2012). A sediment core retrieved from the lake's center and covering the last ~220 kais comprised of primary halite, aragonite and gypsums and allochtonous silts and clays. The fine particles are used for identifying sources and routes of transport of the dust during the last glacial-interglacial cycle.

We compared the high-stand Lake Lisan and low-stand Lake Samra sediments grain sizes and their chemical and Nd-Sr isotopic compositions. Grain size distributions >1 μm of Lake Lisan have modes of 8-10 μm, whereas Lake Samra samples present smaller modes of 3-4 μm. Similar grain size distribution was observed in the fine-grained sediments of the currently exposed late Quaternary deposits along the Dead Sea (Haliva-Cohen et al., 2012). The Fe and Al oxides concentrations divide the fine grained sediments in the core to three sub-groups probably reflecting degrees of weathering. Least weathered sediments are from glacial Lake Lisan, the moderately weathered sediments are from the last interglacial Lake Samra. The most weathered are those from post-glacial ~11ka. The isotopic compositions of the fine-grained particles present a narrow ranges of εNd, between -6.7 to -5.7 and -5.7 to -4.5 for the Lisan and Samra, respectively. Sr isotopic ratios extend from 0.7081 to 0.7095. The samples lie on the "regional dust array" between Nile and Saharan derived fine dust (Revel et al., 2010, Palchan et al., 2013). The data suggests that during the last glacial the Dead Sea watershed (e.g. the central Levant) received more of the Saharan dust in association with Mediterranean winter rains and strong winds (Enzel et al., 2010). Where during the last interglacial it received recycled loess by floods with increased Nile type isotopic signature reached the lake.

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Aridity cycles in the Levant and Dead Sea lake level collapse during the last interglacial period

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The last interglacial peak represents an analog for conditions in a warmer future climate. Sediments recovered from the Dead Sea and dated to the last Interglacial indicate a complex interplay between Northern Hemisphere (NH) -driven climate in the Levant, which imposes hyperarid conditions during interglacials, and selective incursions of tropical climate systems from the south. A relatively wet phase during the peak of the last interglacial is associated with a threshold crossing of African monsoon intensity that briefly dampened the hyperarid conditions. As conditions shifted to below threshold values, the Dead Sea experienced one the strongest arid spells in its studied history and approached full desiccation. These results place new time constraints on possible windows of human migration and habitation in the Levant corridor, and are considered in the context of climate models predicting a more hyper-arid Levant with increased global mean temperatures, a scenario that will lead to increased fresh water scarcity at a time that the surrounding populations are fully using the regional fresh water runoff.

Source-to-sink processes in an active tectonic hypersaline basin: the anatomy of mass transport deposits in the Dead Sea

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Continental archives such as interplate endorheic lacustrine sedimentary basins provide an excellent source of data for studying regional climate, seismicity and environmental changes through time. Such is the case for the sediments that were deposited in the Dead Sea basin, a tectonically active pull-apart structure along the Dead Sea fault (DSF). This elongated basin is characterized by steep slopes and a deep and flat basin-floor, which are constantly shaped by seismicity and climate.

In this study, we present initial results on the sedimentology and internal structure of mass transport deposits in the Pleistocene Dead Sea. The database used for this study consists of a long core retrieved at ~300 m water depth in the deepest part of the Dead Sea as part of an international scientific effort under the auspice of the ICDP. Micro-facies analysis coupled by elemental scanning (µXRF), granulometry and petrophysical measurements (magnetic susceptibility) have been carried out on selected intervals in order to decipher and identify the source-to-sink processes and controlling mechanisms behind the formation of mass transport deposits.

The findings of this study allowed defining and characterizing the mass transport deposits into separate sedimentary facies according to the lake level and limnological conditions. Investigating sediments from the deep Dead Sea basin allowed better understanding and deciphering the depositional processes in relation with the tectonic forces shaping this basin.