The ICDP Dead Sea Deep Drilling Project

Achieving the longest Paleo-Environmental, Tectonic, and Seismological Archive of the late Quaternary Levant

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1. Overview

The Dead Sea, located in the Dead Sea Basin (DSB) at the lowest continental elevation on Earth (426 m bsl), has alternately expanded during ice ages and contracted during interglacials. At its maximum extent during the last ice age as glacial Lake Lisan, it filled the DSB from its present location northward to the Sea of Galilee (Neev and Emery, 1967; Stein, 2001). Its changing size and composition through time reflects the climatic-hydrologic history and the tectonic architecture of its location, in the mid-latitudes, on the continent, and on the boundary between the Saharan desert and Mediterranean climate zones. These changes are recorded and preserved in the lake sediments, giving them unique potential for investigating the expansion and contraction of these climatic zones, as well as the linkages between high latitude and tropical climate. Moreover, the DSB located along the Dead Sea Transform Fault, is an active tectonic region where sediments preserve the history of earthquakes. The DSB is also the locus of humankind’s migration out of Africa, and the home of peoples from Paleolithic to modern times. Studies of the sedimentary sections exposed on the Dead Sea margins have been applied to issues with global and regional implications associated with paleoclimate, tectonics, paleoseismology, paleomagnetism and human history.

The subaerial lake deposits, however, show critical limitations:

- Even in the best-preserved subaerial sections of the Lisan Formation along the Dead Sea margin, time intervals are missing due to lake level fluctuations and erosion. The deposits from these time missing intervals, however, should lie at the bottom of the Dead Sea.
- Deposits from interglacial times are completely inaccessible due to low lake levels. The deposits representing the history of warm climate intervals are only accessible at the bottom of the Dead Sea.

In order to overcome these critical limitations, a group of PIs from Israel, USA, Germany, Switzerland, Japan and Norway have sought support for more than a decade from the International Continental Scientific Drilling Program (ICDP) for a deep drill core in the Dead Sea. The purpose of the drilling was to recover a long term and continuous paleo-seismic and
climatic archive, going back several glacial-interglacial cycles. The seismic information will be integrated with the basin development and rift tectonics, and the paleo-hydrological and climate information will be integrated and evaluated in a framework of global climate modeling.

The location of the drilling sites was decided according to the seismic data. Seismic lines and drilling sites are marked in Figure 1.

![Fig. 1: Bathymetric chart of the northern deep basin of the Dead Sea (after Neev and Hall, 1979) with N-S (left-right) and E-W (up-down) seismic lines. The figure shows (Red dots) the selected sites for the Dead Sea Deep Drilling Project (DSDDP). The drilled site DSEg1 is located in a flat basin at an elevation of 720 m bmsl and 300 m below the Dead Sea surface (which is currently at 425 m bmsl). Its co-ordinates are: 35.4650°E, 31.5082°N. The alternative site DSEg2 was not drilled. Instead we moved to the shore of Ein Gedi Spa and drilled there at water depth of 2.4m (DSEg3).](image-url)
2. Drilling operations

During the drilling operation (November 2010 to March 2011) we drilled two sets of nearly continuous sedimentary cores (Figures 1, 2):

(1) **Deep site (Figures 1, 2a):** at water depth of ~300 m close to the deepest area of today’s Dead Sea. In this site we drilled to the maximum depth of 459 m beneath the lake floor and then drilled several shallower holes down to ~100 m beneath the lake floor.

(2) **Shallow site (Figures 1, 2b):** at ~2.4m depth near Ein Gedi spa shore. We drilled here down to 350 m beneath the lake floor.

**Figure 2c** illustrates the chronology and achievements of the drilling operation.

![Fig. 2a: The drilling barge at the deep site on a stormy Dead Sea](image)
Fig. 2b: The shallow drilling site at Ein Gedi spa (water depth of 2.4 m and drilling depth of 350 m).

Fig. 2c: DSDDP Holes and Their Depths

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Fig. 3: Pebbly layer at ~ 235m overlying a 45 m salt sequence possibly mark a significant lake retreat (dry down?)
The sedimentary cores fill in known (and estimated) gaps in the outcrop sediments and provide a nearly continuous and undisturbed record covering at least the past two glacial-interglacial cycles judging from changes in dominant lithology.

The sedimentary record recovered from the drilling operation can be divided into two dominant lithologies: salt layers interbedded with laminated mud (Figure 4), and massive and laminated marl interbedded with thin salt layers. Silt and sand and gravel indicate intervals of extremely low lake level. The salts are more abundant in the deep-water site while shallow laminated marls dominate the shallow-water site (beneath the Holocene section).

**Fig.4:** Interglacials intervals in the cores generally comprise salt and marl, salt often laminated, aragonite often present. In the lower left side: Prof. Emi Ito holds a core on the barge
3. Logging operation

In the end of each phase of drilling the ICDP logging group performed logging operation within the boreholes. First logging was done within the casing and then in the naked borehole. In the deep site we were able to perform naked-borehole logging to the maximum depth of 460 m and in a second borehole to ~100 m beneath the lake floor.

4. Operations at the Ein Gedi field laboratory

The drilled cores were transported to the field laboratory at Kibbutz Ein Gedi. In this laboratory we performed the following:

(1) Initial description of the lithology of the sediments while still in the liners.

(2) Low resolution magnetic susceptibility analysis

(3) Sampling for biomarkers (performed by members of the Swiss group)

The cores were then stored in a cooling container that in the end of the project was shipped to Germany and transported to GFZ-Potsdam.
5. Core opening and sampling campaigns at GFZ-Potsdam

In June and October 2011, and July 2012 the PIs and other scientists that are involved in the scientific part of the project and students gathered in GFZ-Potsdam for core opening, cutting and description and sampling of the core material. The cores were cut into two halves. One halve was saved for storage (Fig. 5) and on the other halve the following operations were performed:

1. High – resolution photography of the core.
2. Detailed description of the lithology of the core as observed by eye or in cases under the binocular- microscope and in smear slides.
3. High –resolution magnetic susceptibility scanning.
4. Low-resolution XRF analyses by XRF scanner (Fig. 6). This analysis is time consuming and has been accomplished so far for the cores from the deep site. We will accomplish the low resolution XRF analysis of the cores from the shallow-water site (off the shore of Ein Gedi spa), and then carry out high-resolution XRF analysis of selected intervals in the cores. An illustration of the scientific potential in the XRF analysis is given in Fig. 7 that shows the Ti/Cl and S/Ti ratios along core A. While Ti is a measure for detritus material deposited at the bottom of the lakes, Cl is an indicator for salt and S for gypsum. We recovered long intervals of salt deposition, which will be explored during the following scientific phase of our research program. We use the Ti/Cl ratios to establish a preliminary chronology of the interval of the thick salt and pebbly layer (Fig. 3) that were related to a significant retreat of the lake. The chronology is established by correlation to the δ¹⁸O record of the Soreq Cave speleothem that was dated in high resolution by U-Th method (Bar-Matthews et al., 2003). The correlation is shown in Fig. 8, indicating last interglacial time. In July 2012 we sampled core A in high-resolution getting material for the various scientific projects. Aragonite samples are currently analyzed for U and Th and oxygen isotopes for the establishment of the chronology. The isotope data will be combined with the chemical XRF data.
Fig. 5: Cores stored at the GFZ repository

Fig. 6: Core emplaced in the XRF machine at GFZ-Potsdam
Fig. 7: Cl/Ti, S/Ti and magnetic susceptibility in core A samples
Fig. 8: The Cl/Ti ratio that reflects a regional climatic signal can be used for chronological correlation with $\delta^{18}O$ in the Soreq cave speleothem that was dated in high resolution by U-Th.
6. Publications and public relation

The Dead Sea ICDP drilling project has received extensive publicity and media attention. Articles in newspapers and TV programs from Japan to Abu-Dhabi covered the drilling operations. The project was reported in the EGU meetings in Vienna (April, 2011, 2012) and in a press conference in the AGU meeting in San Francisco (December 2011). The latter was followed by reports in scientific journals (e.g. Nature and Science online) and newspapers worldwide and in EOS article.

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