Introduction

It is commonly assumed that the lower-crust is essentially aseismic in rift zones. In relation to a more recent trend of research, the presence of a significant micro-seismicity has been observed in the Dead Sea region.

Geological setting

The Dead Sea Transform (Figure 1) is an intracratonic plate boundary resulting from the late-Cenozoic breakup of the Arabo-African continent. This boundary extends over 1,000 km from the zone of sea floor spreading at the southern tip of the Sinai Peninsula to the Taurus-Zagros zone of convergence in Turkey (Freund, 1965).

The Dead Sea basin is an active pull-apart located along the Dead Sea Transform. The amount of left-lateral motion along the Transform in the Dead Sea region is estimated at 105 km (Quennell, 1958; Freund et al., 1970).

The Dead Sea basin is a morphotectonic depression over 130 km long and 7-18 km wide. It is a seismically active region (van Eck and Hofstetter, 1989) along the Dead Sea Transform, for which some 4,000 years of combined archaeological, historical and instrumental seismological investigations are documented (Ben-Menahem et al., 2019). For the northern half of the Dead Sea basin (main lake and salt pans), earthquakes of M ≥ 5.8 ≤ 6.2 have a recurrence interval of approximately 160 years (Shapira, 1997). The last such event was a magnitude 6.2-ocurred in the main lake (Shapira et al., 1993) in 1927 at an unknown depth.

1984-1997 Seismicity

Out of 2,283 routinely recorded earthquakes in the Dead Sea region, 410 earthquakes have well-constrained locations, including depth (Figure 2). First P arrivals from 42 well-constrained earthquakes that nucleated in the Dead Sea basin were carefully rejected manually, and weighted according to the quality of their onsets.

Lower crustal seismicity in the Dead Sea region

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Two independent evaluations of the uncertainty on depths derived from model Israel have been made. First, we applied perturbations to model Israel (Figure 4a) and relocated the 42 well-constrained earthquakes with resulting models. This method evaluates the sensitivity of the depths to departures from model Israel, and it provides individual error bars (Figure 4b).

As a second approach to depth uncertainties, we determined true depth errors for a series of blasts from quarry Oceana. Oceana is a Dead Sea salt quarry located on the western salt pan south of the main lake, and only 5 km away from the main cluster of deepest earthquakes (Figures 3a and 4c). We only considered shallow blasts with at least 3 P readings, and an azimuthal gap not greater than 150 degrees. In addition, we required the distance of the closest station to be 3-4 km and we rejected events not explicitly attributed to Oceana by the analyst. Figure 4d reveals that Oceana blasts located with model Israel do not display true depth errors greater than 2 km, with the exception of two outliers.

An upper bound uncertainty of ± 5 km is estimated under 20 km but depth errors should not exceed ± 2 km for most earthquakes.

These 42 well-constrained earthquakes were relocated with the Velest program and the 1-D velocity model Israel (Figure 3b). The resulting distribution of depths in the Dead Sea basin is plotted in Figure 3c: 60 percent of well-constrained microearthquakes (0.3 < ML ≤ 3.2) nucleated at depths of 20-32 km and more than 40 percent occurred below the peak seismicity situated near 20 km. With the Moho at 32 km, the upper mantle appeared to be aseismic during the 14-year data period.

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Conclusions

In the Dead Sea region, well-constrained microearthquakes (0.3 ≤ ML ≤ 3.2) display continuous focal depths down to the Moho found around 32 km depth. A relatively cool and brittle lower crust is consistent with the surface heat flow of 40 mWm-2. The upper mantle should also be in a seismogenic state but appeared to be aseismic during the 14-year data period. The absence of micro-seismicity in the upper mantle remains an open question.

References


Further information

Publications and Software: http://www.faldersons.net