Sharp changes in lake-levels preconditioning seismogenic mass failures in the Dead Sea*

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1. INTRODUCTION

Under a changing climate, it is crucial to understand the relationship between mass failures and climate-driven factors such as changes in water-level (*Owen et al., 2007*). Despite extensive investigations on this topic, the relationship between changes in water-level and mass failures is still highly disputed.

Some researchers propose that lowering of sea-level leads to mass failures (*McHugh et al., 2002; Huhn et al., 2019*), while, others suggest that raising of sea-level induces mass failures (*Nisbet and Piper, 1998; Trincardi et al., 2003; Georgiopoulou et al., 2010; Brothers et al., 2013; Neves et al., 2016*).

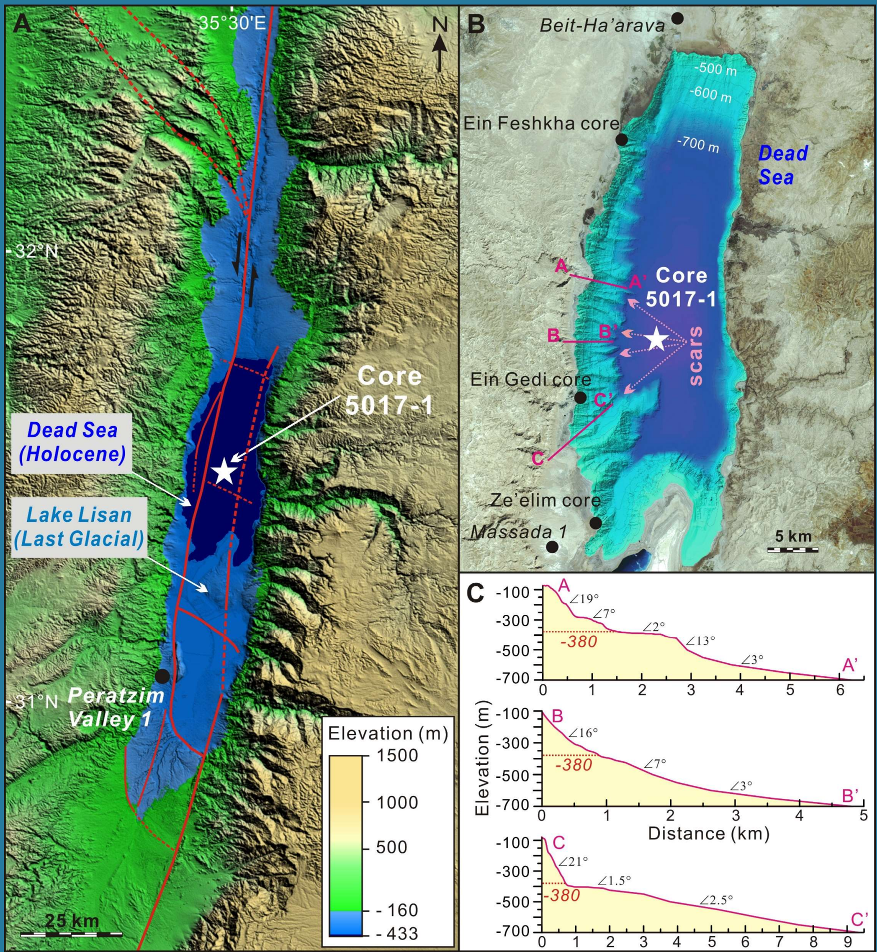
In contrast, other researchers conclude that no clear correlation exists between mass failures and sea-level change as the ages of failure events are random (*Urlaub et al., 2013; Pope et al., 2015*).

In order to test the above arguments regarding climatic impact on mass failures, we present a record comprises 471 layers of seismogenic mass failure deposits from the Dead Sea center over the last 220 kyr.

We have specifically chosen the Dead Sea as our case study as it provides a unique opportunity to distinguish and separate trigger and preconditioning factor(s).

Earthquake acts as the trigger for the 471 events. In addition, the sedimentary sequence is well-dated, with dating uncertainties less than ±1 kyr for the focused time interval (50-0 ka) (Torfstein et al., 2015; Kitagawa et al., 2017). Moreover, the lake-level history, the morphology of basin slopes, sedimentation rates and sedimentary processes in the lake center are also well-understood.

2. GEOLOGICAL SETTING & MATERIALS



ICDP Core 5017-1: a 457 m-thick sedimentary sequence from the Dead Sea center

Fig. 1. Tectonic setting of the Dead Sea Basin. (A) Active faults in the basin (*Bartov et al., 2006; Ben-Avraham et al., 2008*). (B) Bathymetric map showing the morphologic characters of basin slopes (*Sade et al., 2014*). (C) Path profiles showing the present-day morphologic characters of basin slopes which are used as an analog for the past 220 kyrs. The black points mark locations referred to in this study.

3. CHRONOLOGY

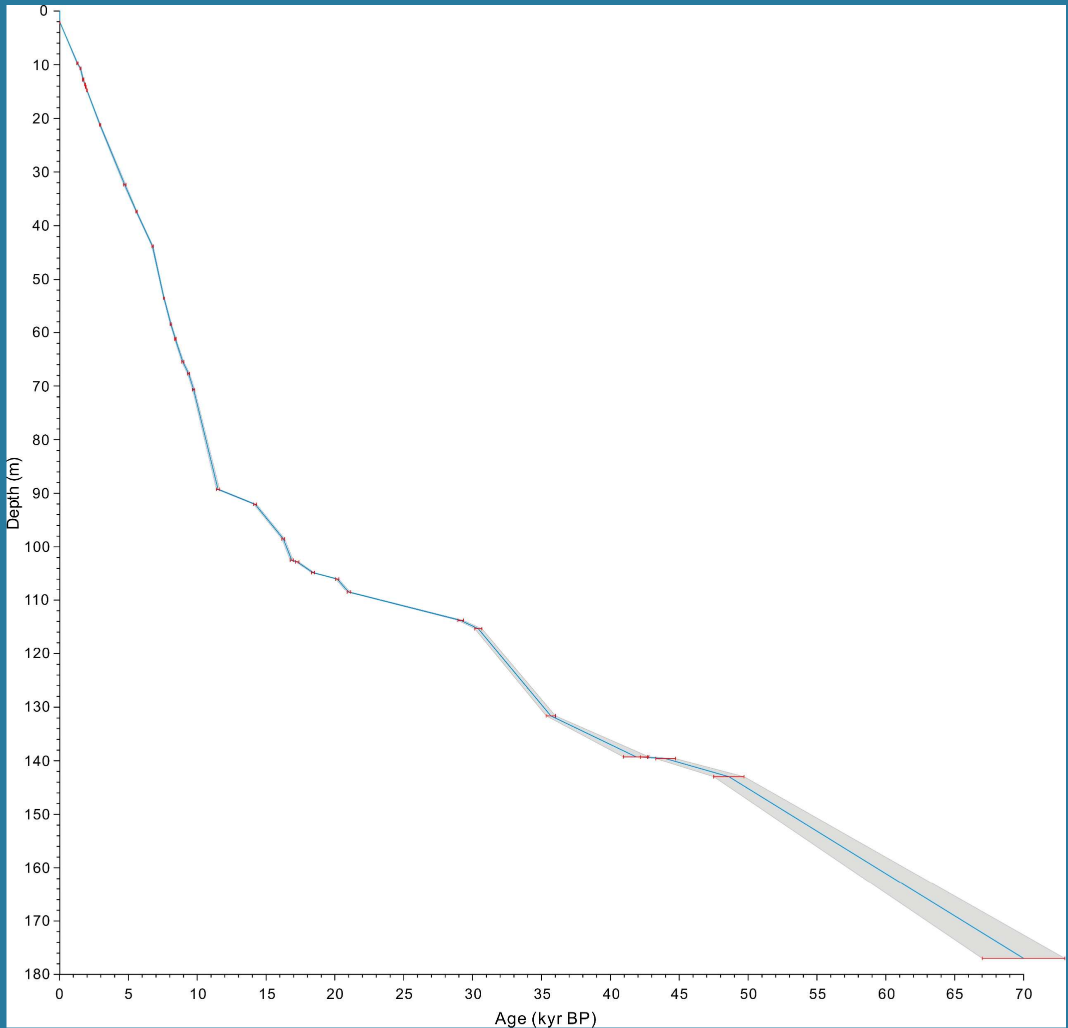


Fig. 2. Age model of Core 5017-1.

Thirty-four 14C ages with 1σ error (*Kitagawa et al., 2017*), five U-Th ages with 2σ error, and three integrated (between U-Th ages and δ18O stratigraphy) ages (*Torfstein et al., 2015*) are used to plot the figure (Table DR1).

4. RESULTS AND DISCUSSION

Seismogenic mass failure deposits in the Dead Sea Center

Type I:
Seismogenic sandy turbidites
(Lu et al., to be submitted)

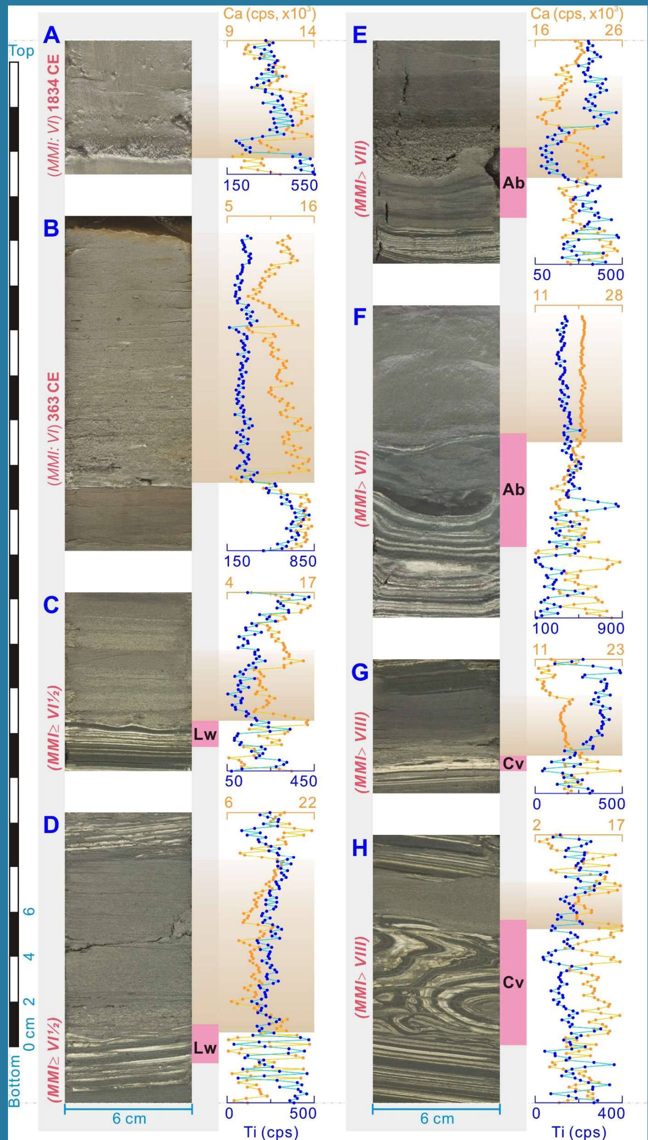
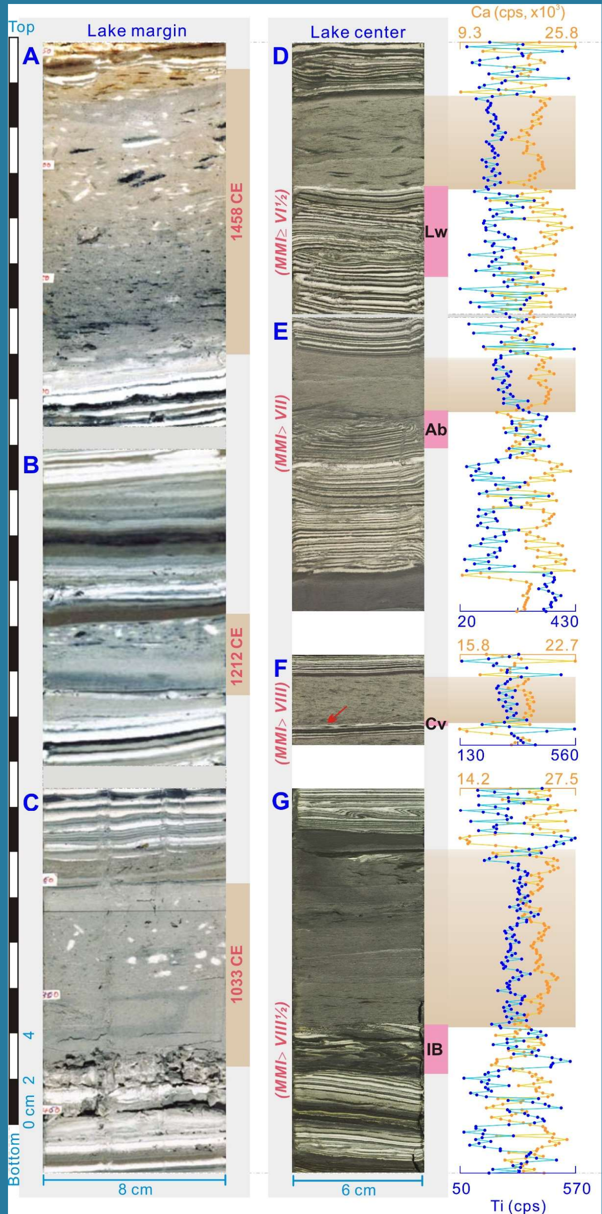


Fig. 3. Seismogenic turbidites from the Dead Sea center. (A, B) Turbidites (brown color) that correlate to historic earthquakes. (C-I) Turbidites are overlying in situ folded layers (pink color). (J-L) Turbidites are overlying intraclast breccia layers (IB). (M-R) Turbidites are overlying micro-faults (MF).

Type II: Laminae fragments-imbedded detritus layers

(Lu et al., to be submitted)

Fig. 4. Type II layers from the Dead Sea margin (Ein Gedi core) and center (Core 5017-1). (A-C) The layers from the lake margin that correlate to historic earthquakes (Migowski et al., 2004; Agnon et al., 2006). The layers from the lake center (brown color) are overlying in situ folded layers (D-F), intraclast breccia layer (G) and micro-fault (H). (I-M) The layers from the lake center without underlying in situ seismites. (N-Q) Event clusters.



Type III: Slumps

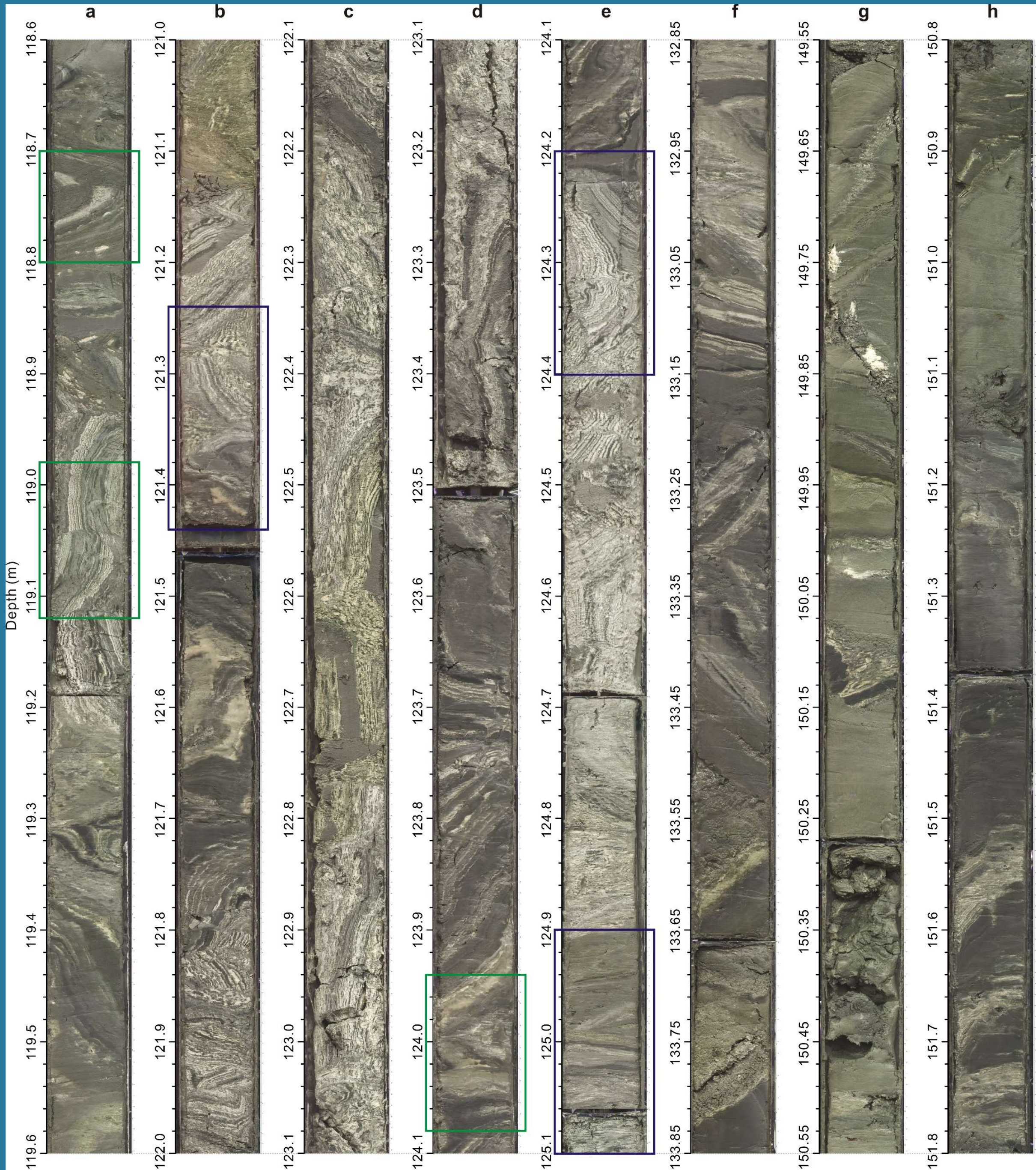
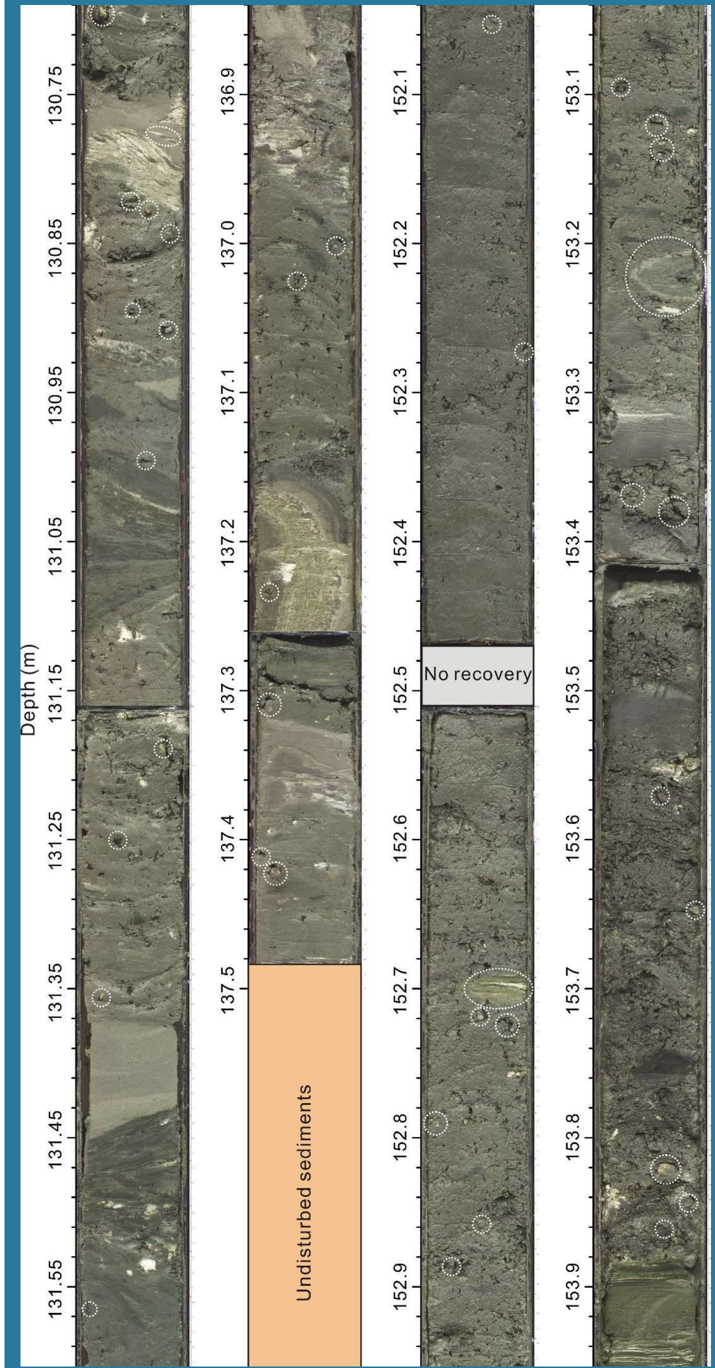


Fig. 5. Slumps from the Dead Sea center (Core 5017-1).
(*Lu et al., 2017, JGR*)

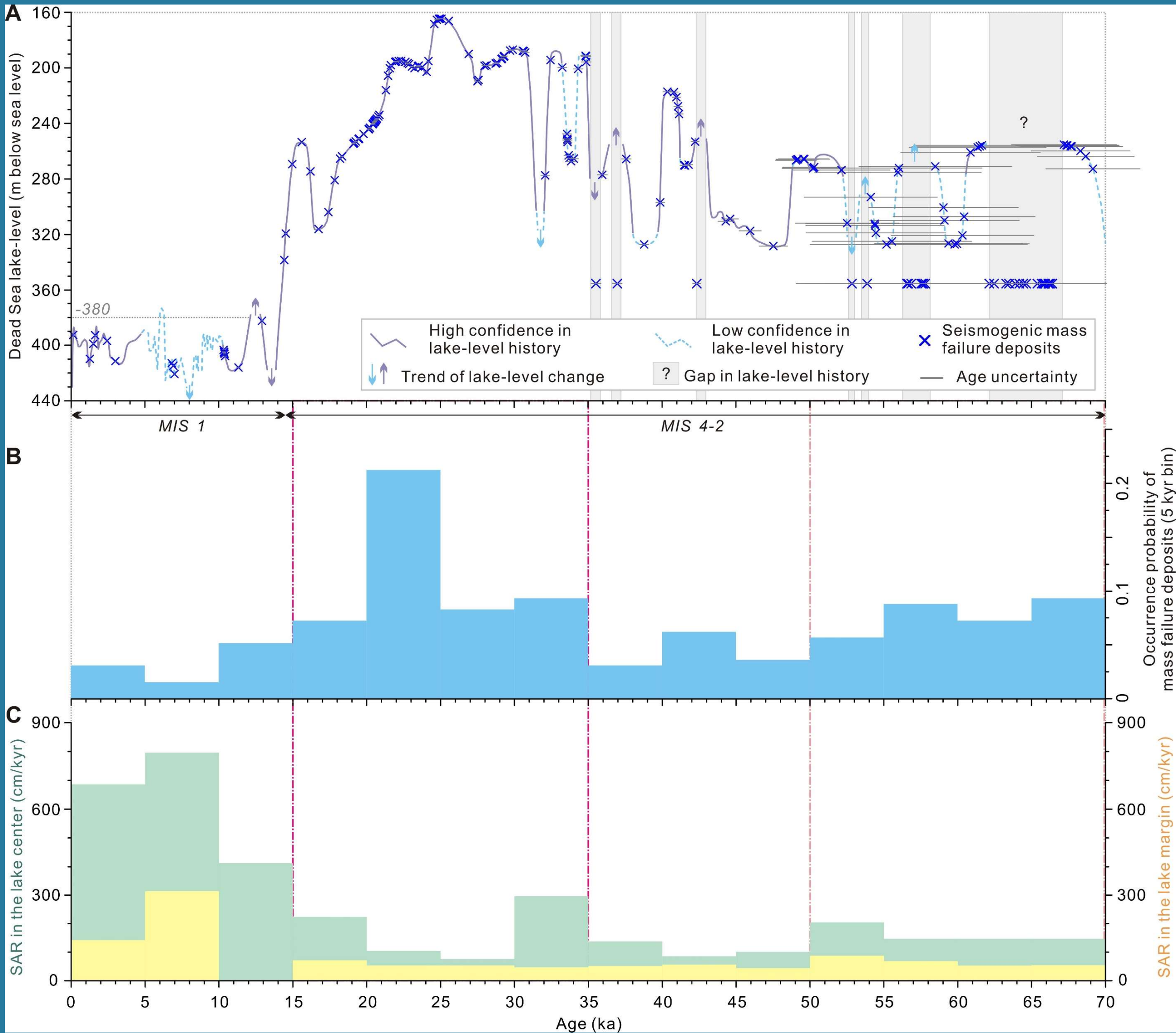


Type IV: Chaotic deposits

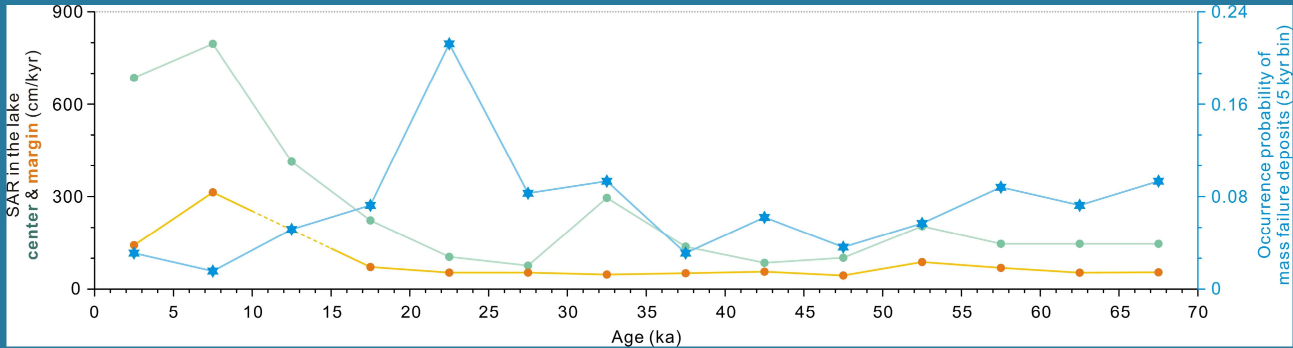
- **Fig. 6. Chaotic deposits from the Dead Sea center (Core 5017-1).**
- The white circles indicate gravels, coarse sands, and intraclasts.
- (*Lu et al., 2017, JGR*)

Distribution of Events along with Lake-levels and SARs over the last 70 kyr

Fig. 7. Distribution of seismogenic mass failure deposits (events) in the Dead Sea center over the last 70 kyr. (A) Distribution of events along with time and lake-level (Bookman et al., 2006; Torfstein et al., 2013; Morin et al., 2018). (B) Occurrence probability of the events. (C) Calculated SAR (5 kyr bin) in the lake center (Core 5017-1) and margins (Fig. 1B, C) are based on previously published ages (Migowski et al., 2006; Torfstein et al., 2013; Torfstein et al., 2015; Kitagawa et al., 2017).



Decoupling between SARs and mass failure occurrence probability



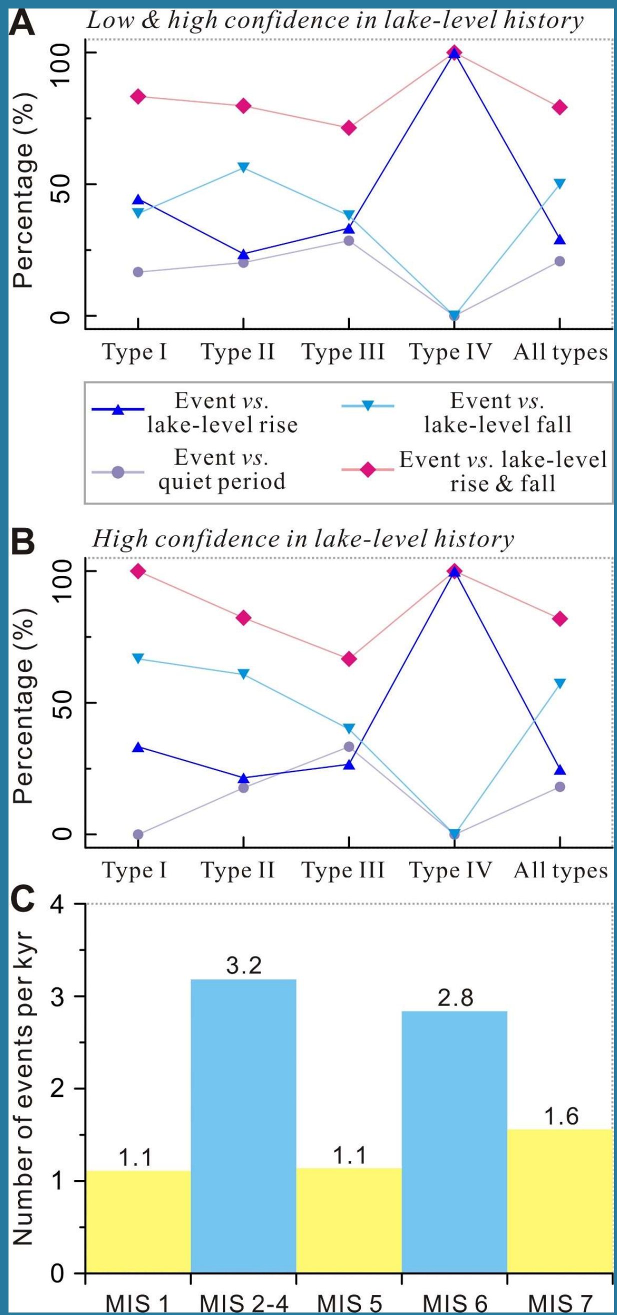
- **Fig. 8. Comparison occurrence probability of mass failure deposits (Fig. 7B) with SAR in the Dead Sea center and Margin (Fig. 7C).** The correlation factor between lake margin and lake center SARs and mass failure events occurrence probability are -0.43 and -0.46, respectively.

Lake-Level Change as a Facilitator of Seismogenic Mass Failures

Fig. 9. The occurrence of seismogenic mass failure deposits (events) in different lake-level statuses. (A) The percentage of events in different lake-level statues (both low & high confidence in lake-level history) over the past 50 kyr. (B) The percentage of events in different lake-level statues (high confidence in lake-level history) over the past 50 kyr.

Occurrence of Seismogenic Failures in the Past Few Glacial-interglacial Cycles

Fig. 9. (C) Occurrence of events in different glacial (low-stands) – interglacial (high-stands) conditions over the last 220 kyr (MIS 7-1).



5. CONCLUSIONS

- **In the Dead Sea Basin, seismogenic mass failures are more likely to occur during rises or falls in lake-level rather than in the quiescent intervals between.**
- **Seismogenic mass failures occurred more frequently during glacials (highstand with high-amplitude lake-level change) than in the interglacials.**