Supplement of Nat. Hazards Earth Syst. Sci., 24, 3279–3290, 2024
https://doi.org/10.5194/nhess-24-3279-2024-supplement

Natural Hazards and Earth System Sciences
Open Access

Supplement of

Tsunami inundation and vulnerability analysis on the Makran coast, Pakistan

Rashid Haider et al.

Correspondence to: Rashid Haider (r.haider@nug.rwth-aachen.de)

Table S1: The compilation of tsunamites discovered at different coasts along the Arabian Sea (sorted age-wise) (Haider et al., 2023)

No.	Event Year (radiometric)	Event Assigned	Location	Brief detail	Reference
1	1948 ± 9 to 1969 ± 10 (Back as of 2022)	1945	Pindara to Okha, India	The documented sand-sheet in the paleo mud flats shows physical, geochemical and biological characteristics such as basal erosional/sharp contact with the underlying unit and lack of sorting along with the presence of mud-clasts. The sedimentary layer also shows an abnormal inland extent of >570 m from the present high-water line.	(Prizomwala et al., 2022)
2	1945[a] Tsunamigenic earthquake event	1945	Sur Lagoon, Oman	In this study, particle size, stable isotopic and foraminiferal (taxa and taphonomy) analyses were conducted on surface sediment samples from Sur Lagoon to determine modern spatial trends in the lagoon for future comparison with over-wash sediments deeper in the geologic record	(Pilarczyk and Reinhardt, 2012)
3	Older than 1958 [b]	1945		5-25cm thick bed of bivalve shell taphonomy	(Donato et al., 2008)
4	C^{14} 722-905 cal BP	1000		They reinterpreted the age of 25-cm-thick tsunamigenic layer based on the new discovery of parallel-oriented woody axes in the sedimentological context of the tsunami shell layer in the Sur lagoon. The woody axes were analysed anatomically and identified as pertaining to the grey mangrove Avicennia.	(Decker et al., 2022)
6	1508–1681 CE	1524	Kelshi, India	This laterally extending 30–40-cm-thick tsunamites zone, coinciding with a habitation level, displays varied sedimentary structures including scour-fill features, and is inter-layered with shells, at a height of 3 m from the high-tide level.	(Rajendran et al., 2020)
7	C^{14} - ~ 872 BP OSL – (Ka) (1130 ± 170) (1110 ± 160)	1000	Fins to Tiwi, Oman	Sedimentological and archaeological evidence for past tsunamis and describe new data on the impact of the 1945 Makran tsunami in Oman.	(Hoffmann et al., 2020)
8	C^{14} - (BP) (1565 ± 35)(1930 ± 30)(950 ± 30) (1445 ± 30) OSL – (Ka) (1.11 ± 0.11) (1.18 ± 0.11)(1.29 ± 0.22)	1000	Panjor to Luni, India	Sedimentology and geochemistry reveal an offshore origin of this sand sheet, from where it was eroded by a high energy wave and deposited in a supratidal environment	(Prizomwala et al., 2018)
9	OSL – (1.3 ± 0.3) (6.6 ± 0.7) (35.4 ± 4.3)	1052	Mundra-Bhadreshwar, Madhavpur-Chorwad, Ratiya, India	GPR studies and trenching the subsurface sand layers shows features that identify and locate features that might have formed during a reported extreme event and its effects. a wave height of ~4–5 m along Saurashtra coast. Southern Owen Ridge is considered as tsunami source.	(Bhatt et al., 2016)
10	4522 ± 200 BP	4522	Ras ul Hadd, Oman	Archaeologically rich evidence of past extreme wave events is preserved in the onshore stratigraphic record. Comprehensive mapping and analysis of extreme wave deposits suggests an Early Bronze Age.	(Hoffmann et al., 2015)
11	5840 ± 30 BP	5840	Fins, Oman	Investigated coarse- to fine- grained, marine tsunami deposits using GPR. Wedging out of sediments and fining inland features, as well as several erosion features at the base of the deposit. Minimum calculated runup height of >17m.	(Koster et al., 2014)
12			Ramin, Iran	The boulders, weighing up to 18 t, are found up to 6 m above present mean sea level and up to 40 m from the present shoreline.	(Shah-Hosseini et al., 2011)
13			Dive Agar, India	Sediment signatures at the two nearby beach sites on the west Two sedimentary deposits are inferred as indicative of two palaeo tsunami events relating to the Sunda Arc in the south and the Makran tectonic zone in the north. The occurrence of sporadic boulders, wedge- shaped heavy mineral sand layers and capping of the deposit by a pedogenic surface at Guhagarh depicts an older tsunami of larger magnitude compared to Dive Agar.	(Sangode and Meshram, 2013)
14			Guhagar, India		
15			Fins to Sur, Oman	The blocks occur as individual rocks of up to 120 tons, as imbricated sets and as ‘‘boulder trains	(Hoffmann et al., 2013)

[a] Age based on foraminiferal provenance and taphonomy

[b] Age Based on Pb^{210} (n=1). Sample immediately above the tsunamites

Table S2: Timeline for chain of events and issuance of warning alerts during three (03) tsunami cases in the Indian Ocean.

17 September 2013 Makran tsunami (near-field case)		
Sequence of events	Timeline	Time lapsed (Minutes)
EQ occurrence	16:59 IST	0
Gwadar+		~10
1st warning (alert/watch advisory)	17:10 IST	11
2nd warning (no tsunami confirmation) *	17:15	16
Tsunami generated just around or after issuance of 2nd warning alert		
No further tsunami warning or bulletin issued		
1st tsunami detection (Qurayat tide station)	17:38	39
2nd tsunami detection (Oman tide station)	17:42	43
3rd tsunami detection (Sur tide station)	17:46	47
4th tsunami detection (Chahbahar tide station)	18:02	65
BPR detected tsunami	18:09	72
5th tsunami detection (Khawr Wudam tide station)	18:42	102
6th tsunami detection (Jask tide station)	18:47	107
7th tsunami detection (Dibba tide station)	18:52	112

17 July 2006 Java tsunami (far-field case)		
Sequence of events	Timeline	Time lapsed (Minutes)
EQ occurrence	15:19	0
Tsunami arrival at java coast, Indonesia (nearest one)	15:34	15
1st warning (alert/watch advisory) by United States Pacific Tsunami Warning Centre *	15:38	19
The tsunami reached at Makran coast after approx. 9 hours		~550

25 October 2010, Mw 7.7, Mentawai, Indonesia (far-field case)		
Sequence of events	Timeline	Time lapsed (Minutes)
EQ occurrence	21:42	0
1st warning (alert/watch advisory) by Indonesia Meteorological, Climatological and Geophysical Agency*	21:47	5
Tsunami arrival at Pagai coast, Indonesia (nearest one)	21:47	5
Japan Meteorological Agencies issued local tsunami watches 7 and 19 minutes after the earthquake. The tsunami warning announced at international early warning system.		
The tsunami reached at Makran coast after 9 hours		540

*Confirmation on bases of the epicentre being on the land part. Based on historical earthquake and tsunami data, Tsunami Threat does not exist for India.

+ Due to closeness of source, it should had arrived at the Gwadar earlier and had gone unnoticed due to its low hight and low tide level. The tide gauge record of event is not available at UNESCO’s Sea level Monitoring Facility