Tsunami heights and limits in 1945 along the Makran coast estimated from testimony gathered seven decades later in Gwadar, Pasni and Ormara

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Abstract.
The towns of Pasni and Ormara were the most severely affected by the 1945 Makran tsunami. The water inundated almost a ~~kilometer~~kilometre at Pasni, engulfing 80% huts of the town while at Ormara tsunami inundated two and a half ~~kilometers~~kilometres washing away 60% of the huts. The plate boundary between the Arabian plate and Eurasian plate is marked by Makran Subduction Zone (MSZ). This Makran subduction zone in November 1945 was the source of a great earthquake (8.1 Mw) and ~~of~~ an associated tsunami. Estimated death tolls, waves arrival times, the extent of inundation and runup remained vague. We summarize observations of tsunami through newspaper items, eye witness accounts and archival documents. The information gathered is reviewed and quantized where possible to get the inundation parameters in specific and impact in general along the Makran coast. The quantization of runup and inundation extents is based on a field survey or ~~on~~ old maps.

1 Introduction

The recent tsunami events of 2004 Indian Ocean (Sumatra) tsunami, 2010 (Chile) and 2011 (Tohoku) Pacific Ocean tsunami have highlighted the vulnerability of coastal areas and coastal communities to such events. Credible vulnerability assessment of a coast depends upon reliable geoscientific data on past tsunami events. The data from past events is crucial as it forms the basis for numerical models that simulate tsunami and tsunami hazard assessment (Hoffmann et al., 2013) which in turn can be used for planning and mitigation and most importantly it can serve as an input for the development of tsunami early warning systems (TEWS).

The tsunami hazard of a coast is dependent upon the tsunami sources among many other parameters. The coast of Pakistan lies in close proximity of the Makran subduction zone. The historical tsunami events known in the region are sparse but have been reported by several studies (Dominey-Howes et al., 2006; Heidarzadeh et al., 2008) with the oldest one being in 325

BC (Pararas-Carayannis, 2006). The evidences of Paleo-tsunami by MSZ isare debatable (Dominey-Howes et al., 2006) as the only instrumentally recorded tsunamigenic earthquake from MSZ was in November 1945, an 8.1 Mw thrust event that occurred almost 8 km southeast of Pasni (Quittmeyer and Jacob, 1979). AnOother probable source of the tsunami can be landslides such as the one triggered by the 24th September 2013 inland earthquake (Hoffmann et al., 2014; Baptista et al., 2020) or potentially from the landslide on Owen ridge (Rodriguez et al., 2013).

The 1945 event being the only recorded event serves as the basis for modelling of the tsunami in the region (Rajendran et al., 2008; Heidarzadeh et al., 2008; Neetu et al., 2011) but the event itself is poorly recorded because of the aftermath of world war II and political situation of then India. We have summarized the historical accounts, eyewitness accounts and newspaper items to come up with the impact of the 1945 tsunami along the coastal cities (then towns) of Pakistan while quantizing the data where ever possible. A field survey is carried out along the three coastal cities of Gwadar, Pasni and Ormara during which inundation parameters along the three cities are identified using the landmarks reported in eyewitness accounts and newspaper items. Similar efforts have been carried out in different areas of the world over many years going back to at least the 1960 Chile tsunami. More recent ones include post tsunami field surveys of 1992 Nicaragua tsunami (Satake et al., 1993), Srilankan field survey of 2004 tsunami (Goff et al., 2006), 2010 Chile tsunami (Tsuji et al., 2010) and 2018 Sulawesi tsunami (Widiyanto et al., 2019; Mikami et al., 2019). All these surveys were carried out immediately after the tsunami event but the study presented here connects a field survey carried out recently with the tsunami event that took place approximately 70 years ago. A similar study tThat assesses the inundation parameters several years after the event has been conducted in Chile for the 1960 tsunami by (Atwater et al., 2013). However, this technique was pioneered by (Okal et al., (2002) and was applied first for the Auletian tsunami.

An effort was made by Hoffmann et al. 2013 to review and summarize historical accounts, eyewitness accounts, newspaper items and previously published work for the four countries connected by the Arabian Sea; Oman, Iran, India and Pakistan. According to the study inundation and losses were greatest along what is now the coast of Pakistan. However, the study of Hoffmann et al. 2013 did not report the runups and inundation extents or depths. A study by (Okal et al., (2015), also based on field survey and eyewitness accounts quantizes the runup data along a 280 km long segment of Iranian shore. The study reports runup between 2.3–13.7 m and a time delay in the arrival of tsunami, indicating a secondary mechanism such as a landslide. Here, we report runups and inundation extentsthese parameters for the first time, for Gwadar, Pasni and Ormara. The findings are based on the information provided in the eyewitness accounts and newspaper items, a ground survey is conducted to locate the landmarks and come up with the runups and inundation extents along the coast of Gwadar, Pasni and Ormara.

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2 Makran Earthquake of 1945 and Tsunami

The 1945 tsunami was a result of a thrusting event of 8.1 Mw at MSZ (Daniele E. Byrne and Dan M. Davis 1992) (Byrne et al., 1992). The earthquake was felt at Muscat, along the entire coast of Makran and many other places of now Pakistan which

were far inland, e.g., Montgomery, Dadu, Dera Ismail Khan. ~~The earthquake~~It ~~-~~was widely recorded at different stations around the world (Hoffmann et al., 2013). The earthquake was followed by five recorded aftershocks ~~(Daniele E.Byrne and Dan M. Davis 1992)~~ (Byrne et al., 1992). The event generated a tsunami that hit the countries in the north-western Indian Ocean. Fig. 1 shows the relative position of Gwadar, Pasni and Ormara relative to the epicentre location of the 1945 earthquake as reported by different studies.

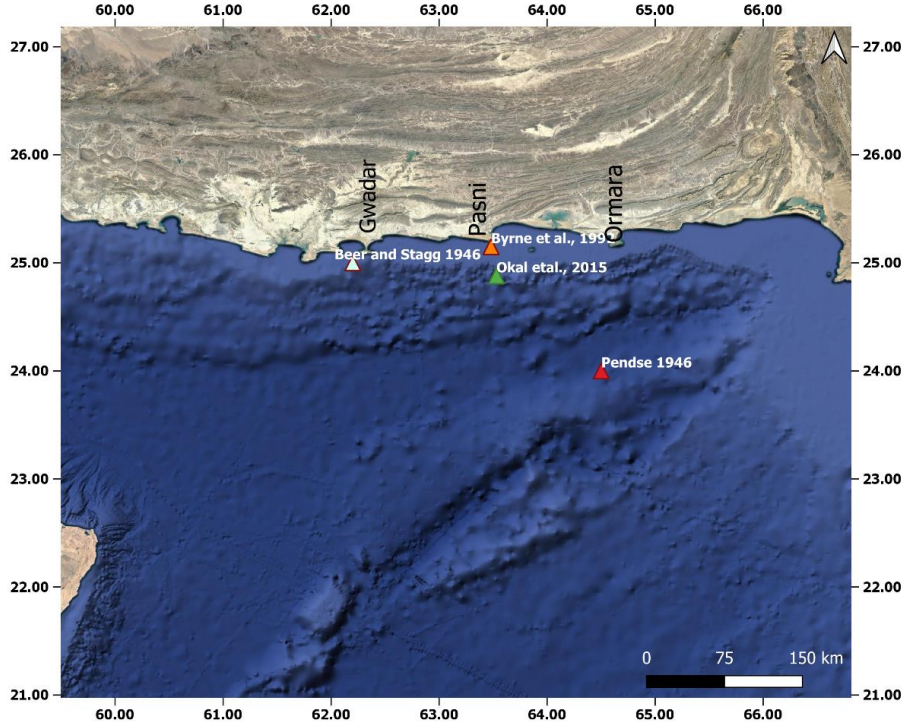

Fig. 1 An index map showing the towns of Gwadar, Pasni and Ormara relative to Makran subduction Zone. The triangles show the epicenter for the 1945 event after different prior studies (Data plotted on © Google Satellite image).

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3 Impact of the 1945 Makran Tsunami

The aftermath of the 1945 Makran tsunami is not very well recorded due to the political situation of the region. The study reports the impact of the tsunami in general and inundation parameters in specific along three coastal cities Gwadar, Pasni and Ormara. For assessing the inundation parameters, ~~that is~~the runup and the inundation extent, a ground survey was conducted to locate the landmarks reported in various newspaper items and eyewitness accounts published in a UNESCO booklet by Kakar et al. 2015. The coordinates~~lat/long~~ of these landmarks were used to extract the inundation parameters using Google Earth.

3.1 Gwadar

The city of Gwadar is one of the major coastal cities along the coast of Pakistan. The ~~R~~recently built deep-water port has added to the importance of the city. Gwadar is also the hub of Gwadar district today that in itself consists of four sub-districts; Gwadar, Pasni, Ormara and Jiwani.

In 1945 Gwadar district consisted of only Peshkan, Sur, Nigor and Pleri along with Gwadar city (see **Fig. 2**~~**Fig. 1**~~ (b)). According to the 1931 census report of India (Vol. I, Part I), chapter 1, page 13, Gwadar had been excluded from the census of India because of being in possession of the Sultan of Muscat. Gwadar was in possession of the Sultanate of Oman from 1734 to 1958. In 1945, the population of Gwadar town was 5875 according to Records of Oman 1867 – 1947 (see **Fig. 2**~~**Fig. 1**~~ (a)). For the same reason, no information on the damages was found in Government reports of Baluchistan nor much was reported in Indian newspapers regarding Gwadar. According to a hand-written letter by the Sultan of Oman (Sa'eed Bin Taimoor), Gwadar suffered estimated financial damages of approximately 70,000 rupees and four lives were lost (**Fig. 2**~~**Fig. 1**~~ (c)). The letter has previously been translated as "Five nights ago, an earthquake occurred before dawn time, though no damages happened here as the earthquake was subtle, but the sea rose higher than usual to the point that it entered in the wadi that is behind Masjid Al-Khor mosque at the wadi and news have been received about this earthquake from Al-Hind (India) and Makran, and that Gwadar had been greatly affected and the losses have reached approximately 70,000 Rubbiyya and four have been killed, and it is all in the hands of God." by (Hoffmann et al., 2013).

The main source of information at Gwadar is eyewitness accounts ~~(~~**Table 1**~~)~~ ~~Table 0.1)~~ because of the absence of written history. The eyewitnesses along the coast were interviewed at the beginning of this decade and are compiled and published in the form of a UNESCO booklet by Kakar et al. 2015. These eyewitness accounts form the basis of assessing the approximate runup and inundation extents at Gwadar town. From eyewitness accounts, the places and landmarks that were reported as the inundation extent or being inundated are mapped and shown in **Fig. 3** ~~Fig. 0.2~~. Mulla Band and Shadu band, the two dams are the highest landmarks that were identified to be inundated by eyewitness accounts. The maximum runup elevation is found at ~~Mulla Band, approximately 56 m at a distance of 1 km from the eastern shore~~ Jamat Khana (11 m). A~~part from the two dams, a~~ll the points indicate a runup elevation of 5 to 11 m

approximately and inundation extent to be in between 200 to 9075~~5~~0 m from the eastern bay (**Fig. 3~~Fig. 2~~**) whereas none of the eyewitness accounts reports inundation along the western bay other than Master Abdul Rasheed stating, "Water came from the east and crossed to the other side." ~~this might be partly because the western bay might not be populous at that time.~~ The wave was reported to be as high as minaret or to be 3—3.6 m by the eyewitnesses.

a

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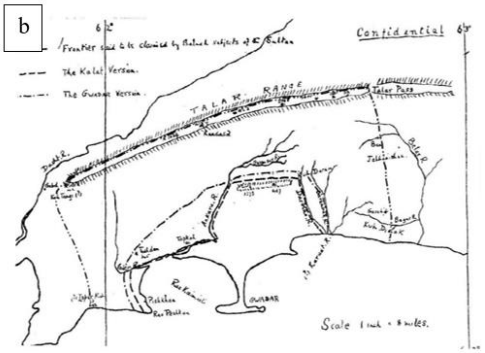
APPENDIX "A"

POPULATION.

	British Subjects			Omani Subjects	
	Aghakhani Khojas.	Hindus.	Miscellaneous	Arabs	Baluchis.
Gwadur Town	400	120	305	50	5,000.
Peshkan.	-	-	20	2	500.
Sur.	-	-	30	-	300.
Nigor.	-	-	15	-	1,000.
Pleri.	-	-	1.(Haji Charib Shah a Baluch Pir or Saint)	-	30.
Total	400	120	371	52	6,830

b



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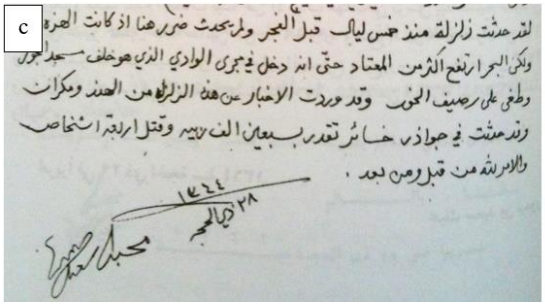
لقد حدثت زلزلة منذ خمس ليال قبل الفجر ولم يحدث ضرر هنا اذ كانت الهزة
ولكن البحر ارتفع الزمن المعتاد حتى انه دخل في مجرى الوادي الذي هو خلف مسجد بور
وطغى على رصيف الجوب وقد وردت الاخبار عن هذه الزلزلة من الهند ومكران
وقد حدثت في جوادر خسائر تقدر بسبعين الف روبيه وقتل اربعة اشخاص
والامر لله من قبل ومن بعد .
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APPENDIX "A"

P O P U L A T I O N.

	British Subjects			Muscat Subjects	
	Aghakhani Khojas.	Hindus.	Miscellaneous	Arabs	Baluchis.
Gwadur Town	400	120	305	50	5,000.
Peshkan.	-	-	20	2	500.
Sur.	-	-	30	-	300-
Nigor.	-	-	15	-	1,000.
Pleri.	-	-	1.(Haji Charib Shah a Baluch Pir or Saint)	-	30.
Total	400	120	371	52	6,830

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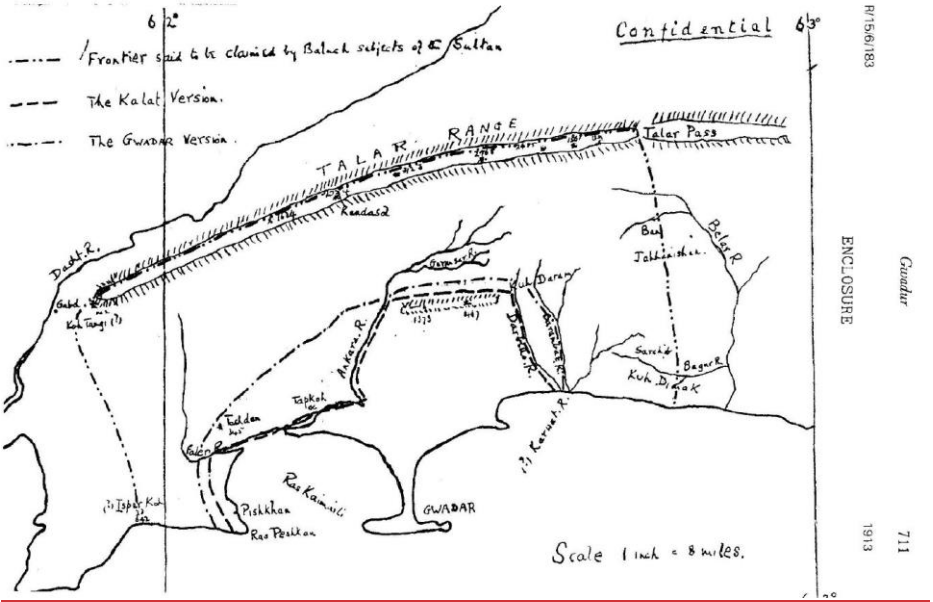
b



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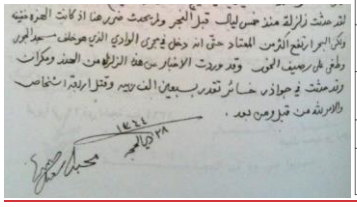

There has been an earthquake five nights ago before dawn	لقد حدثت زلزلة منذ خمس ليال قبل الفجر
And by then, damages happened here as if the shaking was light	ولمر يحدث ضرر هنا اذ كانت الهزه خفيفه
But the sea rose more than usual	ولكن البحر ارتفع اكثر من المعتاد
Until that it entered the sea of the valley which is behind Al-Jor Mosque	حتى انه دخل في بحري الوادي الذي هو خلف مسجد الجور
And it overwhelmed the creek wharf	وطغى على رصيف الخور
And the news about this earthquake was received from India and Makran	وقد وردت الاخبار عن هذه الزلزله من الهند و مكران
And losses took place in Gwadar estimated at seventy thousand rupees	وقد حدثت في جوادر خانر تقدر بسبعين الف ربيه
And killed four people	و قتل أربعة أشخاص
And the command belongs to Allah before and after.	والامر لله من قبل و من بعد

Fig. 21 (a) Population of Gwadar in 1945 from Records of Oman 1867 – 1947. (b) Old map of Gwadar from a letter written by Lieut. Col. J. Rasmay, agent to the Governor General and Chief Commissioner in Balochistan to mark the boundary of Gwadar

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and Kalat in 1913, printed in Records of Oman 1867-1947. (c) An excerpt of a letter by Sultan of Oman, Sa'eed bin Taimoor along with transliteration of the excerpt. ~~(Hoffmann et al., 2013)~~

Table 1 Summary of eyewitness accounts. Here EQ stands for earthquake. Wave heights are not from some datum but are personal interpretation of the interviewee.

Name	Age in 1945 (yrs)	No. of waves	Largest wave	Reported wave heights	Reported arrival times of waves		Inundation extent/depth
Eyewitnesses at Gwadar							
Amina	20	–	–	High as minaret	–	–	Mulla Band, Shadu band, ashkoki, Chanali were completely inundated. Waja Khizer, area infront of Koh e Batil was also inundated.
Mulla Murad Mohammad*	–	–	–	~~10-12 feet~~3–3.6 m	–	–	–
Hassan Ali* Souhail	–	–	–	–	–	–	Water Jammat Khana (15 feet deep), WAPDA house was inundated and area where Agha khani community lived was also inundated.
Master Abdul Majeed	7-8	–	–	–	–	–	Water came from east and crossed to the other side. The water also went southward to graveyard near Koh-e-Batil.
Hasan Ali*	–	–	–	–	–	–	Water came from east and went towards Mulla Band. Jammat Khana was used as shelter as the building was strong.
Eyewitnesses at Pasni							
Shamsi Mai	16-17	–	–	~~20-25 feet~~6–7.6 m	–	–	2-3 km inland
Master Abdul Rasheed	12	–	2nd	–	Before 6:00 am	Around 6:00 am	Few km inland
Sakhi Dad	10-12	3	3rd	6–7.6 m~~20-25 feet~~	6:00 am	–	–
Qadir Buksh* Kushesh	5	–	–	~~14-15 feet~~~ 4.5 m	–	–	–
Ajyani Guli	11	3	–	–	–	–	–
Khudi Dost	10-15	–	–	–	30 min after EQ	–	Part of Wadsar drowned.
Karim Buksh	13	7 or 8	–	–	6:00	–	Father's boat was placed by tsunami on the top of mosque.
Haroon*	~1.4	3	–	~~60,40,30 feet~~18, 12, 9 m for 3 waves	–	–	–
Rabuk (Rabia)	5-6	–	–	–	–	–	Water damaged many houses and a mosque.

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Ganj Buksh	14-15	_	_	_	_	_	destroyed houses, boats, and debris nearly as far inland as Paraag. Many houses and boats were stranded beside Jaddi Hill
Eyewitnesses at Ormara							
Dildar Sahab	12	3	_	_	_	_	Naik Noor Mohammad Dargah inundated with 4 feet deep water.
Qadir Buksh	15-16	_	_	_	1-1.5 hrs after EQ	_	Water went about as far as the present high school and reached the Naik Noor Mohammad Dragah.
Madni	10-11	_	_	~~14 feet~~4 m	30 min after EQ	_	_
Shamsudin	6	_	_	_	30 min after EQ	_	_
Master Fateh Mohammad Baloch	15	3	3rd	_	5 a.m	_	Water reached Naik Noor Mohammad Dargah. *Gaali*, an Indian cargo boats wreckage was carried to Soorani Stream.
Guli	8	_	_	_	_	_	Water reached Naik Noor Mohammad dargah (knee deep). Family took refuge where now is Teshil Municipal Office.
Lari	11	_	1st	_	_	_	Water reached Naik Noor Mohammad Dargah. Water reached the area where present Fisheries Office is.
Sualeh	12-14	_	_	_	30 min after EQ	_	~~A~~ A lot of big fish like sharks and whales were brought on shore near the Customs House. There were dead bodies where the Fisheries Office is now.

*learnt about the event through their elders.

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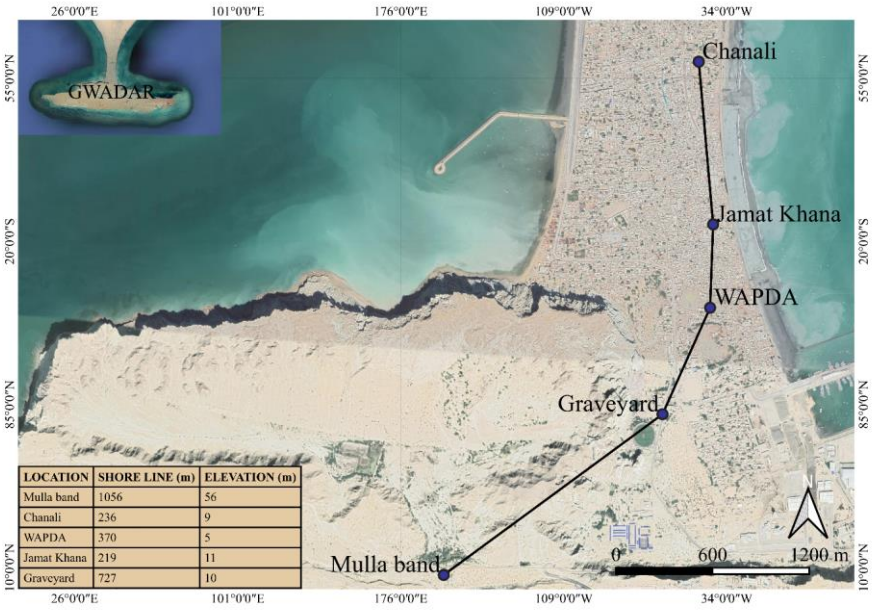

LOCATION	SHORE LINE (m)	ELEVATION (m)
Mulla band	1056	56
Chanali	236	9
WAPDA	370	5
Jamat Khana	219	11
Graveyard	727	10

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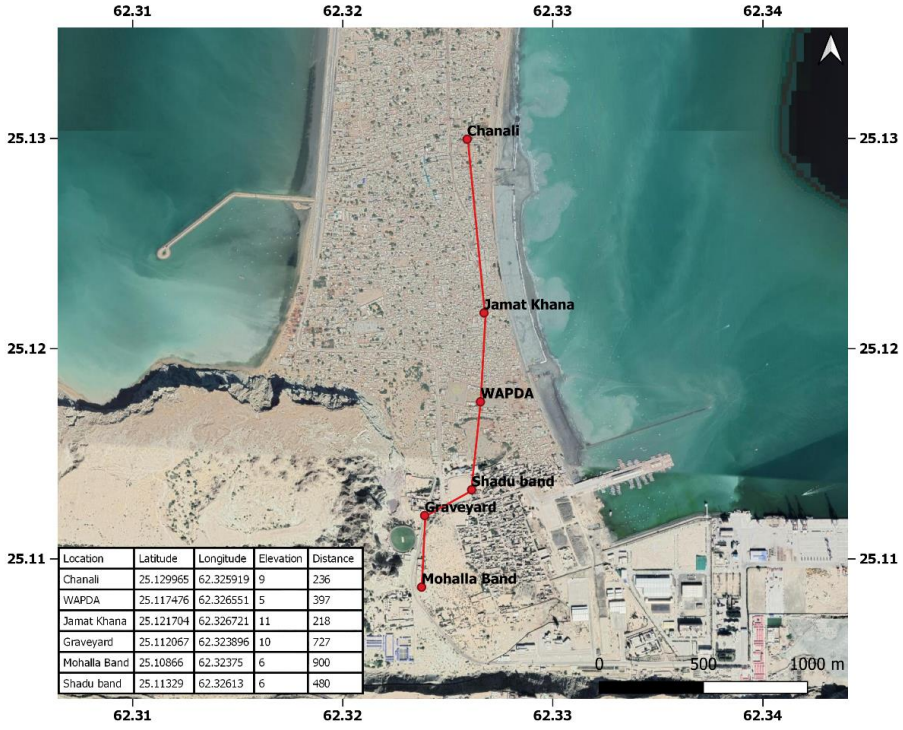

Location	Latitude	Longitude	Elevation	Distance
Chanali	25.129965	62.325919	9	236
WAPDA	25.117476	62.326551	5	397
Jamat Khana	25.121704	62.326721	11	218
Graveyard	25.112067	62.323896	10	727
Mohalla Band	25.10866	62.32375	6	900
Shadu band	25.11329	62.32613	6	480

Fig. 3~~2~~ Locations as identified by eyewitness accounts to have been inundated by the 1945 tsunami, plotted on © Google Satellite image. The line shows a crude estimate of inundation extents.

3.2 Pasni

The City of Pasni still remains small even today. It lies on the Makran Coast o~~f~~ the Arabian Sea about 450 km from Karachi. Administratively, Pasni is the headquarter of the Pasni sub-division of Gwadar district that includes Pasni and Ormara Tehsils (tehsil - county) as well as Astola Island which lies 40 km ESE of Pasni, in the Arabian Sea. According to the census of India, Volume IV, Baluchistan (pp. 12) in 1931 total population of Pasni was 1989 (Male: 1090 and Female:

899) which grew to3616 (Male: 1852 and Female: 1764) in 1941 (Census of India, Volume XIV, Baluchistan, pp. 14). Therefore, it is estimated that the population of Pasni in 1945 would have been in the 4000s.

The Baluchistan Agency Administration Report 1945-46 in many of its sections described the devastation caused by a tidal wave that was preceded by an earthquake. Part I of Baluchistan Agency Administration Report 1945-46, reports of a severe earthquake on the coast of Makran and Lasbela on 28th November~~,~~ 1945 at 3:30 am. It further reports that Ormara and Pasni suffered substantial damages. According to the report around 7:00 am, 30 feet high tidal wave struck Pasni, submerging the entire town while claiming 47 lives (Fig. 4~~Fig. 3~~).

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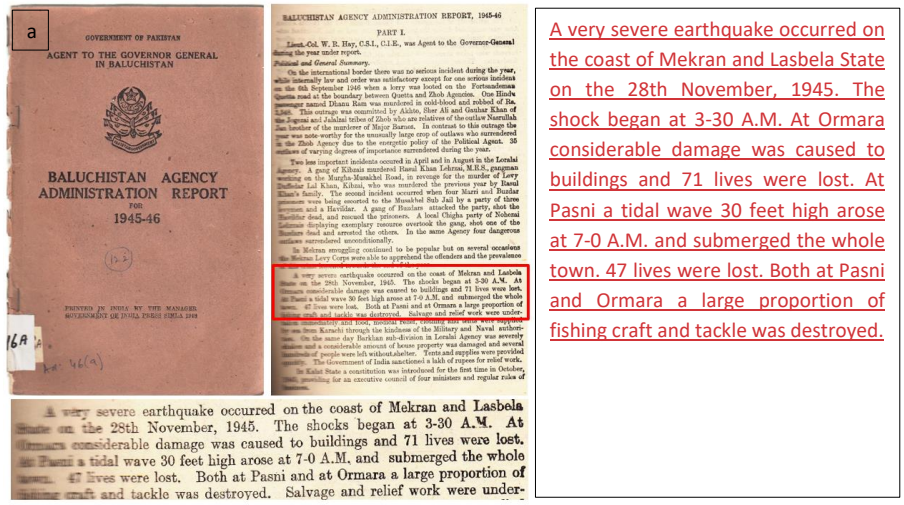

A very severe earthquake occurred on the coast of Mekran and Lasbela State on the 28th November, 1945. The shocks began at 3-30 A.M. At Ormara considerable damage was caused to buildings and 71 lives were lost. At Pasni a tidal wave 30 feet high arose at 7-0 A.M. and submerged the whole town. 47 lives were lost. Both at Pasni and at Ormara a large proportion of fishing craft and tackle was destroyed.

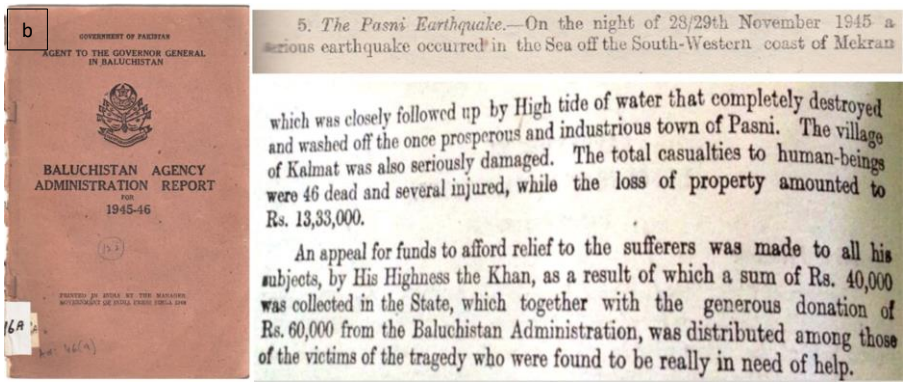

Fig. 43 (a) Excerpts of Baluchistan Agency Administration Report, 1945 – 1946, Part I. (b) Excerpts of Baluchistan Agency Administration Report, 1945 – 1946, Appendix XI, pp. 59 and 60.

Appendix XI Kalat State, of the same, reports, "A serious earthquake occurred in the Sea off the South-Western coast of Makran which was closely followed up by a High Tide of water that completely destroyed and washed off the once prosperous and industrious town of Pasni." The financial damages and relief efforts at Pasni are also mentioned. It further

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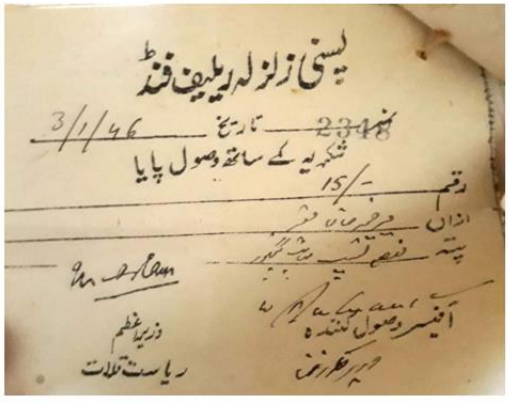
states that the Khan of Kalat~~,~~ made an appeal for funds to provide relief to the sufferers which resulted in a substantial amount that was afterwards distributed among the people at Pasni (Fig. 5~~Fig. 4~~).

This unfortunate event was widely reported by many newspapers around the world but it was most extensively covered by "Times of India." Times of India on Friday, 30th November 1945 reported sea~~-~~water rushed into the town of Pasni and washed away a good number of people. Government buildings including Post and Telegraph office and rest house were washed away. Times of India on Saturday, 1st December 1945 reported, "the town of Pasni is a vast sheet of water with only housetops being visible….Custom House is reported to have been damaged". Times of India on 6th December 1945 reported that Mr. J. L. Jerath, Director Posts and Telegraphs, Sind and Baluchistan, who had been on H.I.M.S. Hindustan, a naval ship sent to Pasni and Ormara for relief work, upon his return from Pasni and Ormara said that ~~the~~ 80% of the huts at Pasni and 60% of the huts at Ormara are estimated to be washed away by the tidal wave (Fig. 5~~Fig. 4~~). Sind Observer on 6th December 1945 reported for Pasni, "The whole village has been totally razed to the ground…..Customs goods and other properties including furniture were carried away by the tidal wave to the other extreme of the village. About 7,000 people here are homeless."



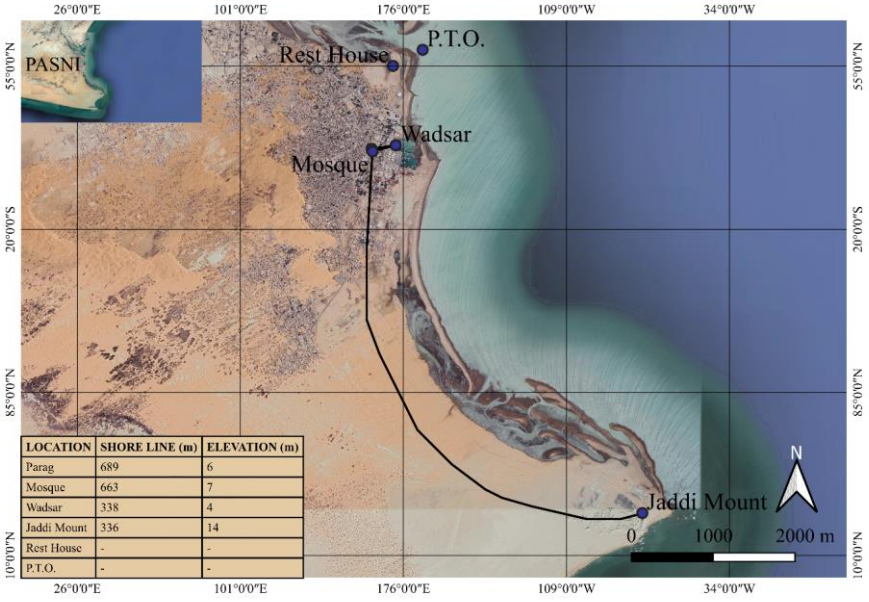
Mr. Jerath, who left Karachi on Saturday by H.M.I.S. HINDUSTAN, said that at Ormara, most of the huts had been washed away by the tidal wave. At Pasni the destruction was even more widespread. It is estimated that about 60 per cent of the huts have been washed away at Ormara and 80 per cent at Pasni. About 100 persons have probably been killed at either place. There were a number of injured and doctors on board the H. M. I. S. KARACHI, which was sent on Thursday, and H. M. I. S. HINDUSTAN, which left Karachi on Saturday, treated them. Five serious cases, needing hospital treatment, have been brought to Karachi by the HINDUSTAN.

Fig. 54 Relief efforts at Pasni and Ormara. Slip for an amount of 15 PKR of Pasni Relief Fund received by a survivor of 1945 tsunami (on the right). Times of India clipping showing that Director Post and Telegraph went on the H.M.I.S. Hindustan to Pasni and Ormara (on the left).

The inundation extents and runups were not reported in any of the government reports and newspaper items. The places, Rest House and Post and Telegraph office reported by Times of India as being washed off by the tsunami; were located through an old map of the Pasni city, from 1943 (a quarter-inch sheet of by the Survey of India. G41-P Turbat, interim edition 1941, reprinted April 1943, scale 1:253,440), (Fig. 7~~Fig. 6~~). PTO was found to be approximately 460 m and Rest House at 570 m from the shoreline at that time. The shoreline of Pasni has changed since 1945, not only as a result of erosion

and deposition of sediments but also because of the event itself as it is reported by many eyewitnesses that part of Pasni slid underwater.

The extents of inundation based on field survey following the eyewitness accounts and reported landmarks therein, are approximately 300 to 700 m from the shoreline whereas the runup elevations are between 4 – 14 m (Fig. 6~~Fig. 5~~). Among these points, Wadsar is the one closest to shore and also has minimum runup elevations but as this area was reported by several eyewitnesses to have been drowned or slid under-water because of the event therefore we expect that location of Wadsar is not the actual inundation extent but it is rather an area which was inundated (see Fig. 6~~Fig. 5~~). Moreover, the number of waves as per the eyewitness accounts were three.



LOCATION	SHORE LINE (m)	ELEVATION (m)
Parag	689	6
Mosque	663	7
Wadsar	338	4
Jaddi Mount	336	14
Rest House	-	-
P.T.O.	-	-

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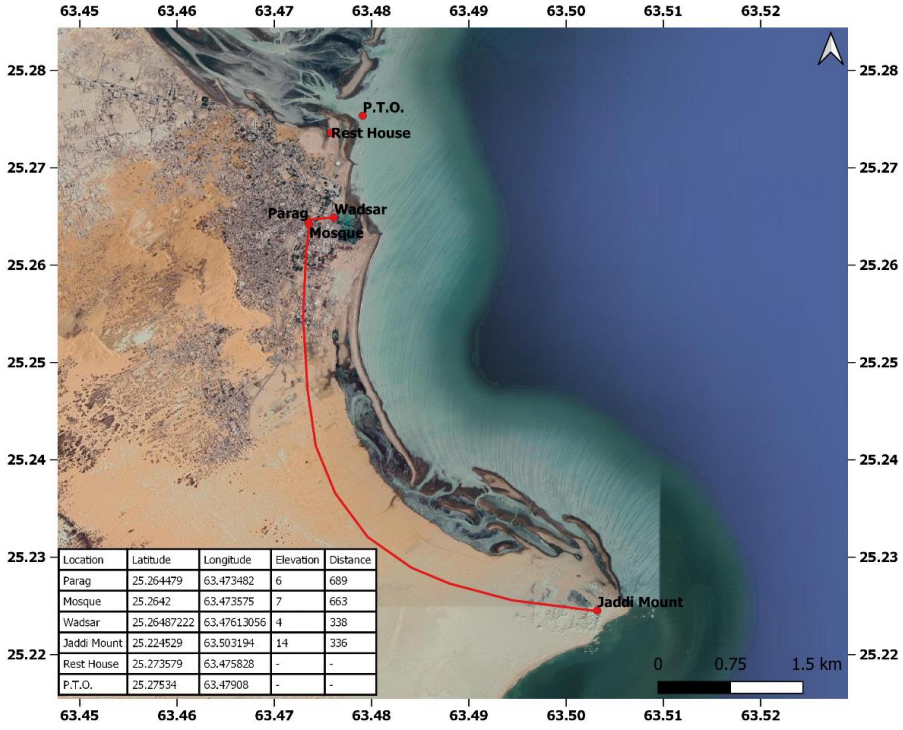


Location	Latitude	Longitude	Elevation	Distance
Parag	25.264479	63.473482	6	689
Mosque	25.2642	63.473575	7	663
Wadsar	25.26487222	63.47613056	4	338
Jaddi Mount	25.224529	63.503194	14	336
Rest House	25.273579	63.475828	-	-
P.T.O.	25.27534	63.47908	-	-

Fig. 65 Locations as identified by eyewitness accounts to have been inundated by the 1945 tsunami, plotted on © Google Satellite image. The line shows a crude estimate of inundation extents. The points which have not been joined through the line were identified from newspaper accounts.

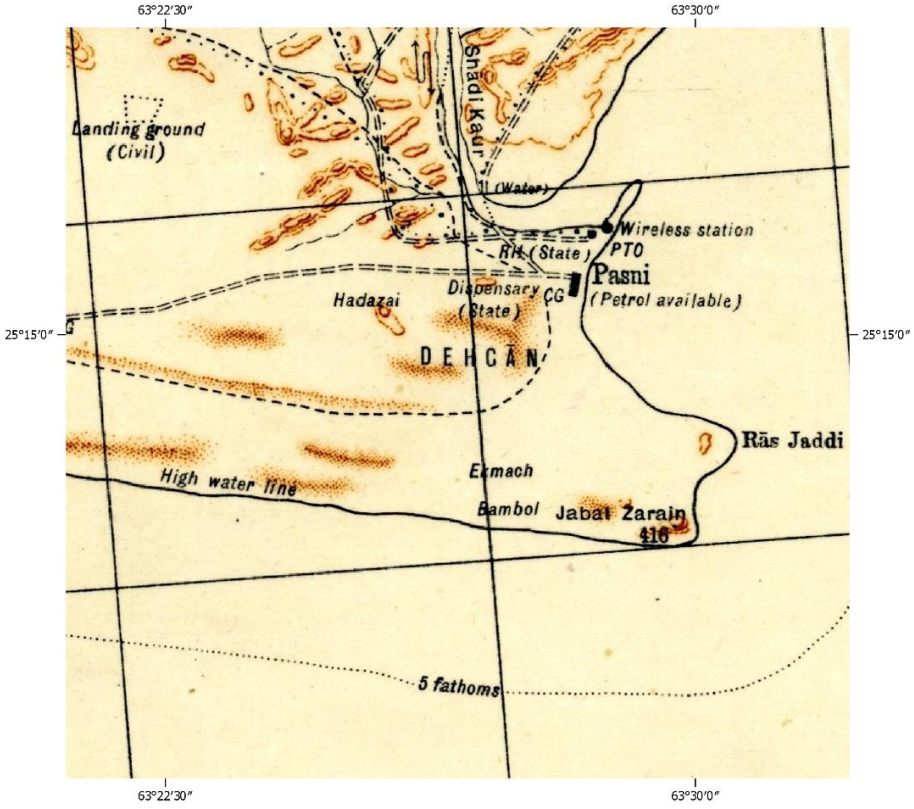


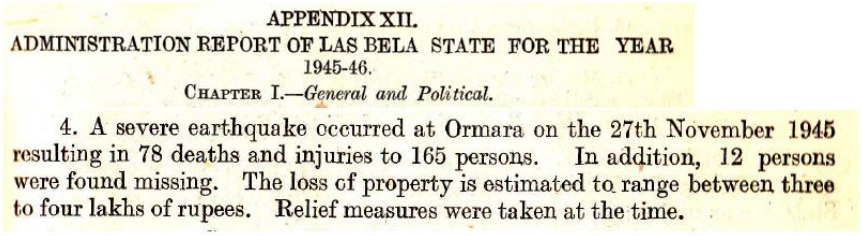
Fig. 76 Old map of Pasni. An excerpt from a quarter-inch sheet by the Survey of India. G41-P Turbat, interim edition 1941, reprinted April 1943, scale 1:253,440.

3.3 Ormara

Ormara, still is not very populous but it is an important city of Gwadar district along the Makran coast. Ormara in 1945 came under the Las Bela state and was part of British Balochistan. The first year for which the population for the city of Ormara could be found during the study is 1981. According to a report of Pakistan bureau of statistics in 1981 total population of Ormara was 8265. Therefore, it can be speculated that the city of Ormara had a population ofin only 1,000s in 1945.

In the Baluchistan Agency Administrative Report Appendix XII, the damages by the 1945 event are reported stating that it resulted in 78 deaths and 165 people were injured though it is unclear whether the tsunami caused the fatalities or the earthquake itself caused the deaths (Fig. 8~~Fig. 7~~).

Devastation at Ormara~~,~~ was not much less than the devastation at Pasni. As reported in Times of India, 6th ~~Decemeber~~December, Mr. Jerath, Director Posts and Telegraph estimated 60% of huts to have been washed away by tsunami at Ormara. Dawn reported on 2nd December 1945 that the town of Pasni was completely flat and the condition at Ormara is no different from Pasni.



APPENDIX XII.

ADMINISTRATION REPORT OF LAS BELA STATE FOR THE YEAR 1945-46.

CHAPTER I.—*General and Political.*

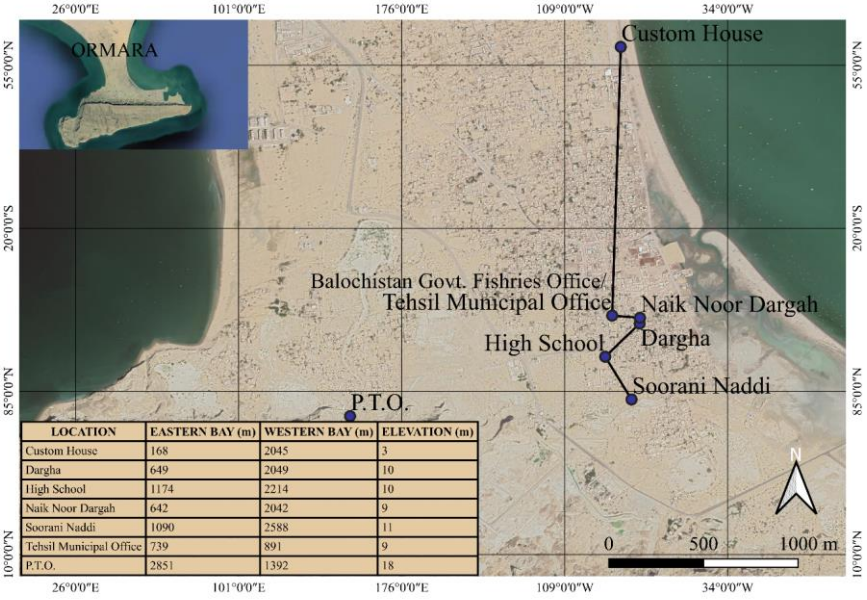
4. A severe earthquake occurred at Ormara on the 27th November 1945 resulting in 78 deaths and injuries to 165 persons. In addition, 12 persons were found missing. The loss of property is estimated to range between three to four lakhs of rupees. Relief measures were taken at the time.

Fig. ~~8~~7 Excerpts of Baluchistan Agency Administration Report, 1945 – 1946, Appendix XII

Eyewitnesses remembered the arrival of three waves after the earthquake and destruction of an Indian cargo boat, *Gaali* and the wreckage being carried to Sorani stream. The waves arrived either an hour or an hour and a half after the earthquake. The accounts have been quantified to get inundation extent and runup at Ormara, through a ground survey. It is found that the maximum runup elevation is approximately 11 m and the maximum inundation extent is almost 2.5 km (Fig. 9~~Fig. 8~~).

The Post and Telegraph Office (PTO) ~~that~~ was reported by the Times of India to have been inundated during the 1945 event. The PTO was located through an old map of the city (a quarter-inch sheet ~~of~~ by the Survey of India. ~~Metadata in Kakar et al. 2015, p. XVII:~~ G41-Q Ormara, second edition 1937, scale 1:253,440) and was found to be approximately 1 km from the shoreline.

Interviews of local fishermen at Ormara in the 1970s, reported in (Page et al., 1979) provided evidence of uplift at Ormara due to the 1945 earthquake which is interpreted by the author to be around 2 m. The same is evident by the interview of Qadir Buksh, “The shoreline shifted. Before the event the shore was inland of where it is today.” (Kakar et al., 2015a).



LOCATION	EASTERN BAY (m)	WESTERN BAY (m)	ELEVATION (m)
Custom House	168	2045	3
Dargha	649	2049	10
High School	1174	2214	10
Naik Noor Dargah	642	2042	9
Soorani Naddi	1090	2588	11
Tehsil Municipal Office	739	891	9
P.T.O.	2851	1392	18

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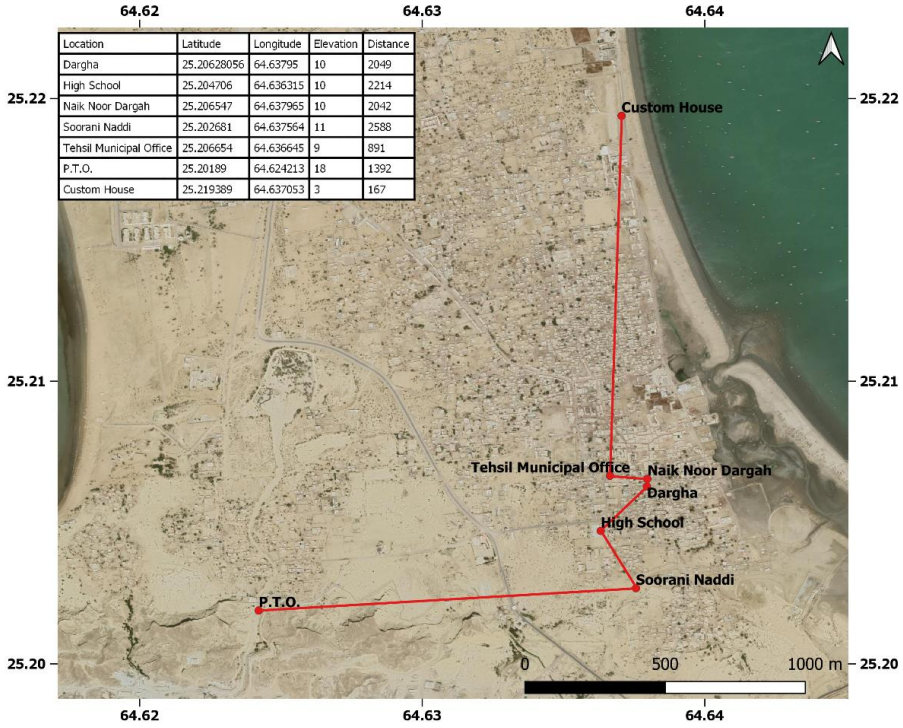

Fig. 98 Locations as identified by eyewitness accounts to have been inundated by the 1945 tsunami, plotted on © Google Satellite image. The line shows a crude estimate of inundation extents. The point which has not been joined through the line was identified from newspaper accounts.

4. Results and Discussion

The historical accounts for large earthquakes along the Makran Subduction zone are sparse and disputable. Nevertheless, the possibility of large earthquakes cannot be ruled out. With Mega-cities such as Karachi (Pakistan) and Mumbai (India) and many other growing coastal cities such as Gwadar (Pakistan), Chabahar (Iran) and Batinah (Oman), the seismic hazard from Makran Subduction Zone and risk of ensuing tsunamis cannot be over-looked. The growing population and large investments

in infrastructure along the coasts bordering the Arabian Sea demands ~~of~~ reliable risk assessment for tsunami in the region but not enough data is available for the same.

In many cases, historical accounts are a valuable source of information for the reconstruction of past tsunami events (Atwater et al., 2013; Dominey-Howes et al., 2006) where scientific data is not present. We first summarize the description of the 1945 event in newspaper items, historical reports and eyewitness accounts and then use eyewitness accounts and newspaper items combined with a field survey to extract the runups and inundation extents for coastal cities of Pakistan through the reported tsunami observations there-in.

At Gwadar, although there wasere not much damages but the maximum runup is found to be 1156 m and the maximum inundation extent is around 9700 m. These extents have been derived from the landmarks identified by the eyewitnesses but one of the eyewitnesses (Master Abdul Majeed) also reported, "Water came from the east and crossed to the other side" which is indicative of tsunami engulfing the entire landmass along the east to west stretch. None of the other eyewitnesses reported such inundation, The study does not use this account to conclude that the water might have swept across the entire tombolo as many other survivors had reported water reaching up to certain landmarks only. Another survivor of the event, Amina reported that the "huge wave" did not enter the city. She further reported the water reached the mosque; water was everywhere with no place to go but the water wentgo further than the mosque. She also named some places that were inundated by the tsunami, such as the Mulla band and Shadu band (Kakar et al., 2015b). ~~If these two dams (Mulla band and Shadu band) were inundated, it can be expected that the water might have swept across the entire tombolo.~~ The water reaching the Mulla Band, reported by Amina and Hasan Ali might be that they were reporting "Mohalla Band" rather than "Mulla Band" or "Mohalla Band" is the new name of the neighbourhood just beside the Gwadar Miniport which was previously called as "Mulla Band", an area that is very likely to be inundated during the 1945 event. Shadu Band is another neighbourhood beside the new football stadium of Gwadar. In order to be sure if the interpretation of the locations was right, interviewers of the Amina were interviewed as Amina had passed away.

The maximum runup and inundation extent at Pasni as measured are approximately 14 m and ~~0.~~7006 ~~k~~m, respectively. The inundation extents are not the actual extents for every point marked on **Fig. 3**~~**Fig. 2**~~ but in some cases mark the landmarks that were identified as inundated. Moreover, the shoreline at Pasni has changed drastically since 1945 and the inundation extents for most of the points have been extracted using the recent imagery from Google Earth. Therefore, these two factors can contribute to the fact that the actual inundation extent in 1945 could have been greater than reported here.

At Ormara the maximum runup and inundation extents are approximately 11 m and 2.5 km (from Western Bay after the epicenter from ~~(Daniele E. Byrne and Dan M.Davis, 1992))~~(Byrne et al., 1992) (see **Table 2**~~**Table 2**~~). The inundation extent at Ormara~~,~~ is the greatest among all the townscities considered in the study although Pasni was much closer to the epicentreer. This might be contributed by the fact that Pasni had sand dunes near the town which according to many eyewitnesses saved their lives as it was a place of refuge whereas at Ormara no such natural defencse was present beside the town.

Table 2 Impact of 1945 Makran tsunami along the coastal cities of Pakistan.

City	Maximum runup (m)	Maximum Inundation extent (m)	Number of Waves	Maximum Wave Height (m)	Casualties	Financial Damages (Rs.)	Present day equivalent (US $)
Gwadar	56	700	–	3–6	3–4	70,000	~453
Pasni	7.6	1000	3	9.1	47	1,3,33,000	~8630
Ormara	11	2500*	3	–	76	300,000-400,000	~1945–2589

*from Western Bay

If we take the same population as 1941 (1939) and find the percentage of people who lost their lives to the 1945 tsunami event at Pasni, it is found to be approximately 1.3% (considering the population of 1941 as the nearest estimate of population in 1945). The town of Ormara had an estimated population of nearly 1000 and sustained 76 casualties that gives approximately 8% of the population wiped off by the event.

~~(Ambraseys and Melville, 1982)~~

5 Conclusions

This paper draws on the eyewitness accounts and newspaper items to estimate the runup and inundation extent at Gwadar, Pasni, Ormara and Karachi. Pasni and Omara were the most severely affected cities. The inundation extent at Ormara, is the greatest among all the cities considered in the study although Pasni was much closer to the epicentre. The uncertainty is inherent to the parameters derived here due to reasons such as, personal interpretation of the event of the survivors and survey being conducted after 70 years of the event. Therefore, the inundation parameters presented here may be a crude approximation of the actual parameters but it still paints a picture of the wreck-havoc caused by the 1945 Makran tsunami.

The data collected in the form of eyewitness accounts, archival reports and newspaper accounts from countries bordering the Arabian Sea should be used to draw reliable limits on the source of the earthquake and ensuing tsunami. Similar studies in the neighbouring countries can further facilitate the cause and contribute to reliable risk assessment of the coasts along the Arabian Sea.

The time of arrival of waves at Pasni as reported by multiple survivors was around 6 a.m. whereas only Khudi Dost reports the waves to have arrived almost half an hour after the earthquake (**Table 1**). It is reported in Baluchistan Agency Administration Report (**Fig. 4**), *"At Pasni a tidal wave 30 feet high arose at 7-0 A.M. and submerged the whole town."* Therefore, it is evident that there is a time difference of 2–3 hours between the earthquake and the arrival of the largest wave. This finding is in concordance with the eyewitness accounts from Iran and the finding is reported in (Okal et al., 2015) and with the observation of (Beer and Stagg, 1946). This time delay in the arrival of tsunami is suggestive of some secondary

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mechanism such as landslide, associated with the earthquake. This can also be the reason why most of the witnesses reported that the 2nd or the 3rd wave as being the highest of the waves that attacked the coast.

The majority of the eyewitnesses along the Makran coast of Pakistan had reported the time of arrival of the tsunami as half an hour after the earthquake. (Beer and Stagg, 1946) reported, "The first tidal observation was made at 9 hr. 47 min. local time, but it was then noted that the tidal-levels were well above their normal value, suggesting that an earlier wave may indeed have arrived by that time." Therefore, the time reported here by the eyewitnesses as thirty minutes after the earthquake might be the time of arrival of the first wave associated with the earthquake whereas the larger wave generated by an ancillary phenomenon arrived 2–3 hours after the earthquake.

The total number of estimated fatalities associated with the Makran earthquake and ensuing tsunami vary between 300 (Ambraseys and Melville, 1982) to 4000 (https://www.ngdc.noaa.gov/hazards/tsu_db.shtml). The more widely reported number of fatalities is 4000 (e.g., Heck, 1947; Heidarzadeh et al., 2008; Rajendran et al., 2008)~~(Heidarzadeh et al., 2008)~~ but this figure is associated with only the region of Karachi and Indus Delta rather than the Makran coast of Pakistan. According to Times of India, 5th December 1945, the reports of 4000 casualties came from a party of nine congressmen. It was reported only for the 100 miles coast from Karachi to Keti-bunder (a region in Indus Delta). These reports, according to an express letter written by the Chief Secretary to the Government of Sind, to the Secretary to the Government of India were "greatly exaggerated."

Moreover, according to the comment of the Chief Secretary to the Government of Sind on estimates of the loss of lives by congressmen, published in Times of India, 6th December 1945, "They were highly exaggerated. The coastline is sparsely populated. The sub-divisional officials have asked for only small grants for relief, indicating that the damage caused is not as heavy as reported."

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Author Contribution

Hira Ashfaq Lodhi prepared the manuscript, identified the landmarks from eyewitness accounts and newspaper items for the field survey. Shoaib Ahmed conducted the field survey. Haider Hasan searched for archival documents.

Competing Interests

The authors declare that they have no conflict of interest.

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