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THE 1990 BOHOL EARTHQUAKE: TSUNAMI OBSERVATIONS AND EFFECTS AT BOHOL ISLAND, PHILIPPINES

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ABSTRACT

The earthquake of February 8, 1990 offshore the Island of Bohol in the Central Philippines was a tsunamigenic event caused by crustal displacements along an unknown northeast-southwest trending fault. Isoseismal distribution confirmed such orientation with higher seismic intensities at the southeastern areas of Bohol Island. Subsequent field surveys, interviews with eyewitnesses and measurements of runup heights, support that significant tsunami inundation occurred along the southeastern coast of the island. Based on this investigation and review of historical data, we conclude that the source region of the 1990 tsunami was along an unknown offshore submarine structure.

Keywords: seismic intensity, Alicia Thrust Fault, East Bohol fault, tsunami, runup, tsunami height, Bohol, Philippines, tsunami hazards

INTRODUCTION

The Bohol earthquake of February 8, 1990, had a magnitude M6.0 and occurred at 15:15:35.9 local time (PHIVOLCS, 1990). It was one of the strongest earthquakes to impact the island of Bohol in Central Philippines since the early 1900's. Though moderate in magnitude compared to the known devastating earthquakes in the Philippine archipelago, the 1990 Bohol earthquake nonetheless wrought havoc to at least 16 municipalities on the island - leaving behind numerous casualties, about three hundred injured, several thousand homeless and evacuated from coastal areas. Economic damage to properties was at least Php154 million. A detailed documentation of damages was undertaken by Umbal et al. (1990) two days after the earthquake. Based on damages, felt reports and

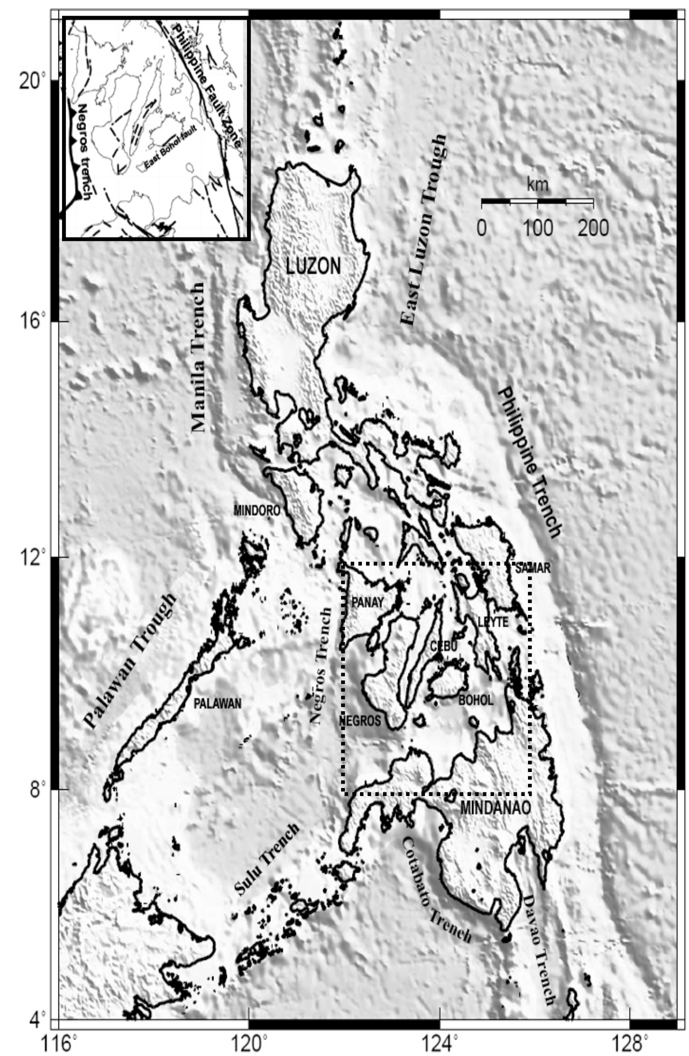

Figure 1: *The Philippine archipelago showing the Bohol Island in south central Philippines. Inset map shows the location of Negros trench, the PFZ and the East Bohol fault.*

experiences of local inhabitants, the maximum earthquake intensity was determined to be VIII on the PEIS or the Philippine Earthquake Intensity Scale (PHIVOLCS, 1996).

Bohol Island is located north of the Island of Mindanao in the southern portion of the Philippine Archipelago (Figure 1). The major structures that influence the tectonics in this region are the Negros Trench located west of Negros Island and the left-lateral strike-slip Philippine Fault Zone (PFZ) transecting the eastern part of Mindanao and Leyte Island. Within Bohol Island, the major structure is the northeast-southwest-striking fault called the East Bohol Fault (PHIVOLCS, 2000) shown in Figure 2, thatis probably related to the Alicia Thrust Fault (BMG, 1981). Bohol Island and adjoining areas had experienced moderate quakes in the past but were mostly lower than magnitude 5 and had no reported major impact on the island.

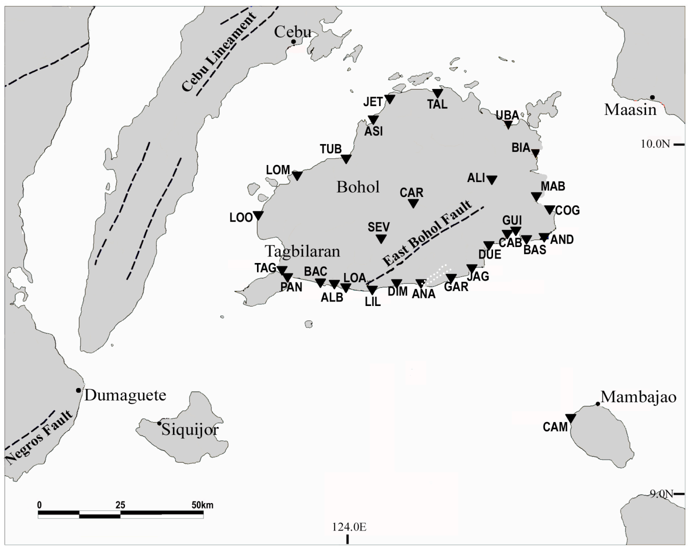

Figure 2: *Areas visited and/or with additional information regarding the 1990 Bohol quake used in this study (inverted triangles). Dashed white line shows the left-lateral ground rupture mapped by Umbal et al. (1990).*

The distribution of earthquakes prior to the 1990 event is rather diffuse and shows no distinct pattern (Figure 3). The preliminary location of the epicenter of the 1990 earthquake was placed 17 km east of Tagbilaran City that was on land and was attributed to the East Bohol fault (Umbal et al, 1990; PHIVOLCS, 2000). However, review of the Global CMT Catalog showed that there were two earthquakes of comparable magnitude on February 8 which occurred only about 30 minutes apart of each other. The second earthquake was also noted in Umbal et. al.'s (1990) report. The origin time, location and focal mechanisms of the two earthquakes are shown in Figure 3B. There was no surface rupture mapped along or associated with the East Bohol fault (EBF). In addition, the southeastern part of Bohol Island experienced a tsunami inundation (Umbal et al, 1990). Considering that the epicenter of the event was initially located inland, the mechanism and nature of the ensuing tsunami was not clear and has remained unexplained. The present study focuses on the seismic intensity and tsunami effects of the 1990 earthquake.

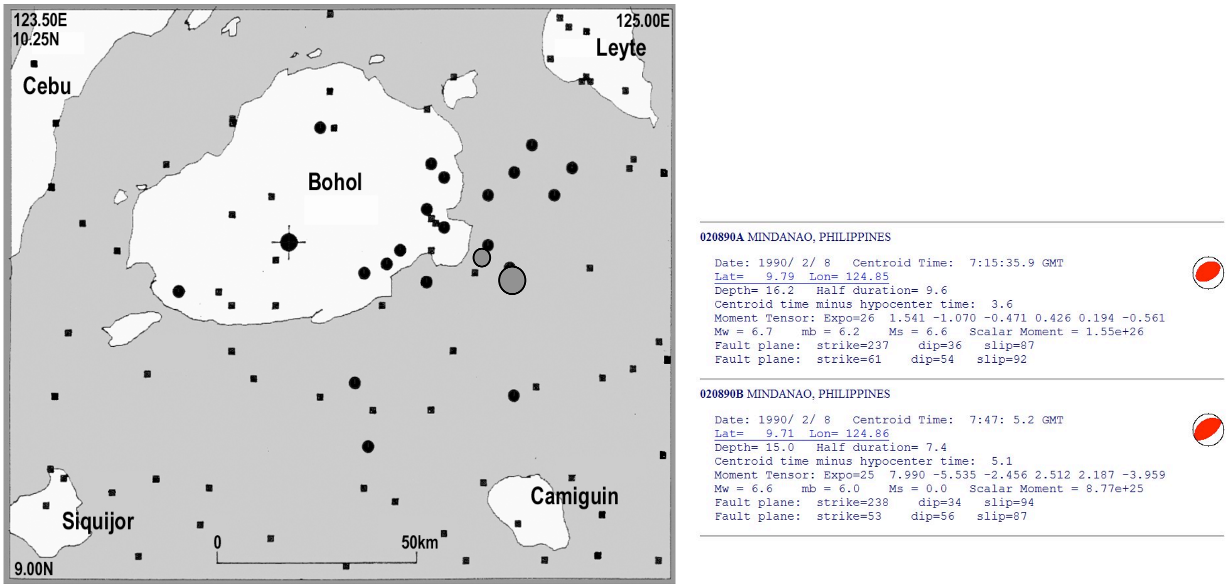

Figure 3: *a. Bohol island and the seismicity plot prior to the M6.2 earthquake in Bohol and vicinity (adapted from Umbal, et. al. 1990). Solid circle with cross indicated the epicenter (PHIVOLCS, 1990) while the solid black squares and circles indicate the seismicity from 1907-1988 and events from Feb. 9-28, 1990, respectively. Relocated epicenters and CMT solutions (b) are from the Global CMT Catalog for the 1515H event (A) and the event about 31min later (B).*

METHODOLOGY

Field surveys conducted in 2002 gathered data in many sites on Bohol island (Figure 2) to investigate and reevaluate the extent of tsunami inundation associated with the 1990 earthquake. Through eyewitnesses' interviews and field measurements, seismic and tsunami data were gathered and analyzed for the purpose of estimating earthquake effects as well as tsunami arrival times, runup heights and tsunami deposition/erosion features along the coast. Local inhabitants were interviewed

about their experiences during the ground shaking and their observations of the tsunami. Whenever possible, the specific sites mentioned during these interviews were further investigated to measure any remaining evidence of tsunami inundation and of maximum runup heights.

The interviews were conducted at regular intervals (ranging from 10 to 20 km) to assure uniform sampling points between communities along the coast. This information was needed to help illustrate the extent of the affected areas and perhaps indicate the most probable location of the tsunamigenic earthquake's source. Results were plotted and correlated with seismic intensity as this was essential in helping clarify tsunami source characteristics for future studies.

OBSERVATIONS AND RESULTS

The 2002 investigations and data collection were done for the eastern, southern and western sides of Bohol Island. Also, interviews were conducted along the north side of the island where damage and intensity had not as high. Additional information and data from Umbal et.al. (1990) were incorporated in the study. The accounts are given in Appendix I.

To protect the privacy of the people interviewed, their names were withheld and each account was labeled with letters W or M (signifying woman or man) with their age at the time of the interview shown in parentheses. From these accounts of ground motions and felt reports, seismic intensities were estimated. Similarly, information on observed tsunami heights were corrected from the predicted height of the Cebu tide gauge station (Mobile Geographics LLC, 2004-2009).

a. Seismic Intensity

Based on eyewitness interviews, it was determined that the quake's shaking lasted for about 3-7 seconds. Along the southeastern shores of the island, strong ground motions, widespread ground fissuring, landslides, subsidence and mud fountaining were responsible for most of the significant damage to the infrastructure of municipalities. Reportedly, a bridge collapsed and roads were closed by rockfalls. Figure 4a shows some of the damage.

Remnants or repairs of century-old churches indicated the extent of severe ground shaking in numerous towns. Based on observations of ground shaking and the associated environmental damage, an isoseismal map was prepared (Figure 4b). High intensities with NE-SW orientation were concentrated along the southeastern part of the island. Mapped ground ruptures (Umbal et al., 1990) were located about 7 km south of the EBF (Figure 2) and west of the highest observed intensities.

b. Tsunami Runup Heights

The coastal topography of Bohol Island is complex, characterized by gentle slopes, steep cliffs, rivers and river inlets, reef areas and mangroves. During the 2002 investigation, a total of 12 maximum tsunami runup heights were determined. Since there was no local tide gauge at Bohol, the nearest tide gauge station in the region was at Cebu Island. Its record of tidal fluctuations during the 1990 event was used to correct the estimates of tsunami runup heights. Since actual record from Cebu station is unavailable at the present time, corrections were applied based on predicted tide level at the Cebu station from the Mobile Geographics LLC (2004-2009) relative to the mean sea level. Table 1 shows the tsunami runup heights for different locations shown in Fig. 5.

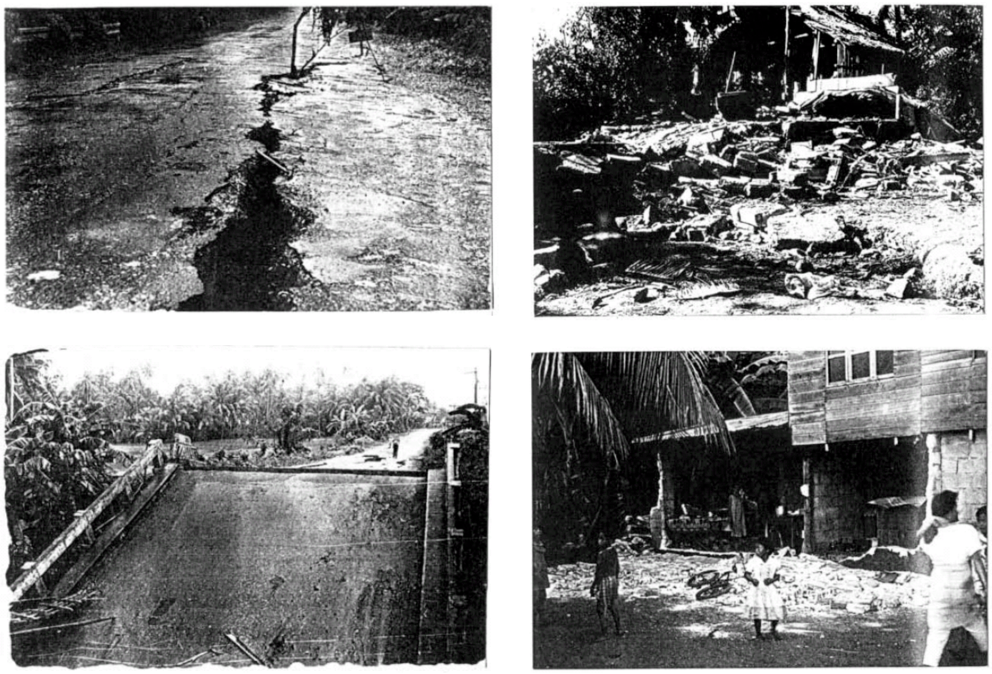

Figure 4a: *Photos adapted from Umbal et al. (1990) showing the damages at Guindulman (A), fault rupture near Anas (B), the collapsed bridge at Alijauan bridge at Jagna (C) and collapsed house in Candabang, Anda (D).*

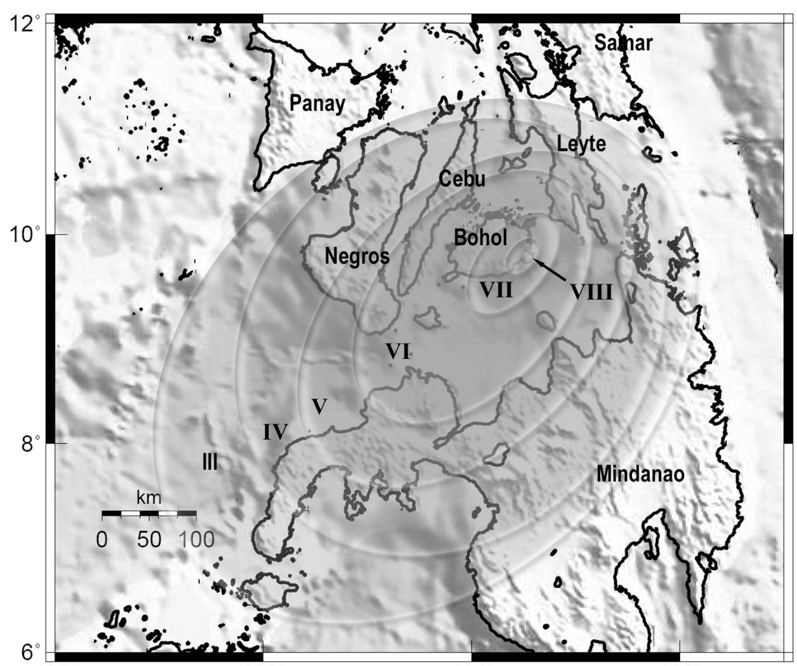

Figure 4b: *The earthquake intensity distribution of the 1990 Bohol earthquake based in this study and Umbal, et. al. (1990). Note the northeast-southwest elongation of the isoseismals.*

Table 1: Measured tsunami runup heights in southeastern Bohol measured after 12years of the tsunami impact.

No.	Place	Date Apr'02	Time (hh:mm)	Location	Measured height (m)	Location Code	PEIS Intensity
1	Ubay	17	15:55	124.461E, 10.058N	0	UBA	VII
2	Biabas	17	14:50	124.537E, 9.980N	0	BIA	VII
3	Mabini	17	11:50	124.522E, 9.867N	0.21	MAB	VII
4	Cogtong	16	15:15	124.524E, 9.842N	0.53	COG	VIII
5	Anda	16	14:20	124.562E, 9.735N	2.11	AND	VIII
6	Basdio	16	13:50	124.515E, 9.726N	1.08	BAS	VIII
7	Guindulman	16	12:30	124.481E, 9.762N	0.98	GUI	VIII
8	Cabantian	16	11:25	124.456E, 9.749N	1.52	CAB	VIII
9	Duero	16	10:15	124.402E, 9.711N	0.5	DUE	VIII
10	Jagna	16	09:45	124.361E, 9.651N	0.47	JAG	VIII
11	G. Hernandez	15	15:50	124.305E, 9.622N	0.32	GAR	VII
12	Anas	15	15:20	124.228E, 9.604N	0.31	ANA	VII
13	Dimlao	15	14:39	124.160E, 9.604N	0.49	DIM	VII
14	Lila	15	11:30	124.092E, 9.588N	0	LIL	VII
15	Loay	15	10:35	124.020E, 9.597N	0	LOA	VII
16	Alburqueque	17	08:30	123.988E, 9.602N	0	ALB	VII
17	Baclayon	15	09:40	123.950E, 9.608N	0	BAC	VI
18	Tagbilaran	18	09:25	123.852E, 9.635N	0.22	TAG	VI
19	Panglao	18	10:05	123.855E, 9.610N	0.31	PAN	VI
20	Camiguin	20	10:30*	124.628E, 9.221N	1.12	CAM	VI
21	Loon	20	15:20	123.780E, 9.806N	0	LOO	VI
22	Lomboy	20	14:30	123.886E, 9.918N	0	LOM	VI
23	Tubigon	20	12:30	124.011E, 9.967N	0	TUB	VI
24	Asinan	20	11:45	124.081E, 10.065N	0	ASI	VI
25	Jetafe	20	11:25	124.133E, 10.138N	0	JET	VI
26	Talibon	20	10:50	124.259E, 10.154N	0	TAL	VI
27	Sevilla	19	09:30	124.094E, 9.695N	0	SEV	VII
28	Carmen	19	11:30	124.219E, 9.835N	0	CAR	VII
29	Alicia	17	13:30	124.433E, 9.902N	0	ALI	VII

*Logged and recorded in the PHIVOLCS' Hibok-Hibok Volcano Observatory, retrieved via telephone interview.

Evidently, the 1990 earthquake generated small to moderate tsunami waves which affected the SE portion of Bohol (Figure 5). The maximum runup height of 2.11m was measured at AND that extends to MAB in the northeast and to TAG in the southwest. Between DIM and PAN, there were only reports of the sea level lowering, but no unusual increase in wave height or tsunami inundation. The reported tsunami at PAN and TAG could probably be due to possible island trapping effect (Yeh et al., 1994; As-Salek, 1998). It is noted that most notable tsunami runup heights were concentrated along the southeastern portion of Bohol Island - including a report from Camiguin island (CAM) of

1.2m based on PHIVOLCS official logs and records at the Hibok-hibok Volcano Observatory. The measured tsunami runup heights had an average height of 1m which was not sufficient enough to cause much destruction. The horizontal tsunami inundation was variable but generally extended to a few tens of meters from the shoreline. Fortunately, the local low tide at the time was low. If the tsunami had occurred at high tide inundation would have been at least 1m higher than what was observed.

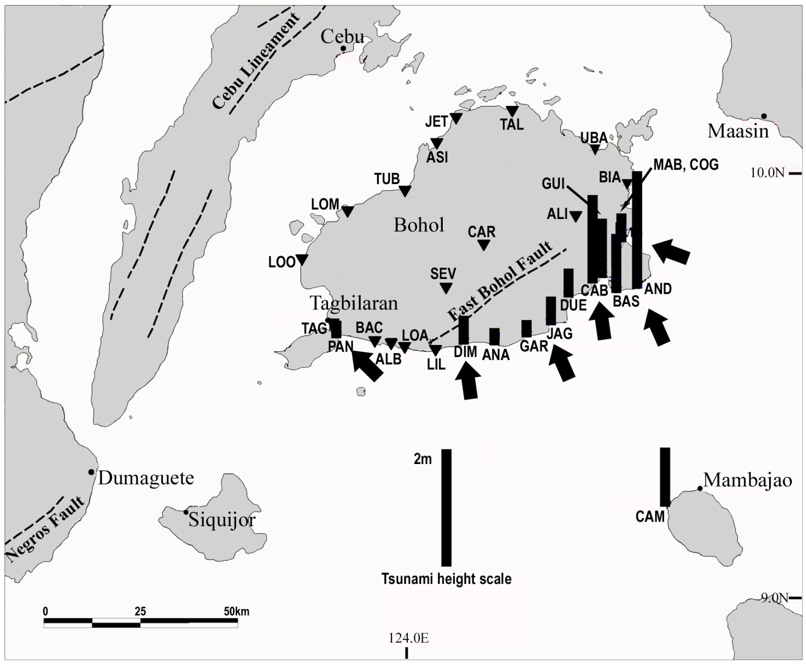

Figure 5: *Tsunami heights measured for the Bohol 1990 quake. Broad arrows indicate the observed direction of the incoming tsunami waves.*

b. Direction of Tsunami Propagation and Other Wave-related Observations

Based on eyewitness accounts, the main direction of the tsunami approach at AND and BAS was toward the north (N), toward NNW at DIM JAG and toward NW at PAN and COG. The direction of propagation indicated that the tsunami had its origin in an area southeast of Bohol. Eyewitnesses reported that the first wave throughout the southern shorelines of Bohol was associated with a depression in sea level. Accordingly, the southeastern shorelines of Bohol experienced a regional sea withdrawal of about 10-200m several minutes after the ground shaking stopped. In areas like BAC, ALB, LOA and LIL, some of the people indicated that the lowering in sea level occurred several minutes after the ground shaking, while others did not note an unusual change. At DIM and ANA, there was a rapid withdrawal of the sea, resembling low-tide, that trapped fish in the reef zone. The sea returned with foamy front and there were at least seven such oscillations. At GAR, however, there was only one wave observed which was 0.32m higher than the normal level. However, an eyewitness in JAG, remembered the trapped fish, cracks on the ground and sandboils when the water retreated three times about 150m away from the shoreline.

At GUI, many witnesses observed a drop in sea level several seconds after the ground shaking, accompanied by a rumbling sound. In this area many houses and boats were washed away by the tsunami when the water reached the town proper with a height of 0.98 m. In AND, the water receded 150-200 m from the shore, came back with a truck-like sound, foamy front and oscillated three times with the first wave being the biggest. In some portion of Anda town, the shoreline was protected by a 2-m high seawall where the tsunami was observed to have splashed over the seawall.

At COG and in MAB, there were observations of the sea receding, then rising about half meter in height several minutes after the ground shaking. Also, there were reports of the water turning muddy. Reportedly, the Alijuan River in DUE flowed inland due to force of the tsunami (Umbal et al., 1990). At TAG and PAN, the sea receded several minutes after the ground shaking then came back murky.

Generally, there was a recession of the sea immediately after ground shaking in the AND, BAS and GUI areas. However, in areas farther to the east and west relative to AND longer time elapsed before the retreat and return of the sea. The witnesses did not note any erosion or deposition of sediments along the shore. Although there were numerous reported landslides in the hills and some of the road were cut, there were no observations of landslides reaching the shore that might have displaced seawater. There were no reported observations of of sea water level changes along the northern part of the island

CONCLUSIONS AND FUTURE WORK

Damages from the 1990 Bohol earthquake were mainly due to intense ground shaking. However, tsunami inundation were observed and experienced at certain areas along the southeastern shores of Bohol Island. The highest seismic intensity was VIII on the X-point scale of PEIS of PHIVOLCS. The observed tsunami heights varied from 0.21-2.11 m and the waves reached also Camiguin Island. The extent of tsunami inundation varied because of the coastal morphology and the presence of barriers, but it was generally a few tens of meters from the shoreline along the southeast coast of Bohol. No notable erosion occurred and no deposition of tsunami sediments was observed.

On the other hand, The documented seismic intensity distribution and tsunami effects determined by this study indicate that the strongest ground shaking effects and devastation occurred in the southeastern portion of Bohol Island. This can be attributed to a possible offshore earthquake source or a submarine landslide induced by the earthquake. The strike of ground rupture correlates well with the elongated form of the earthquake's distribution of isoseismals. The rupture's location is west of both the highest observed intensities and of the observed tsunamis. Moreover, the ground rupture had a strike-slip fault mechanism consistent with thrust kinematics associated with EBF. It is also possible that the rupture extended offshore and that crustal displacements contributed to tsunami generation. However if we consider its location and kinematics, such possibility may be low. Thus, the notable incongruity between the quake's epicenter, the mapped ground rupture, the intensity distribution and the observed distribution of tsunami runup heights highlights the need for further investigation of the 1990 event. Closer scrutiny of aftershock epicenters, together with a source mechanism investigation may provide some clues on how the 1990 Bohol earthquake generated a tsunami.

Another interesting future effort would be a tsunami modeling simulation to verify if an offshore source may be possible. Similarly, an offshore landslide could be modeled to help determine if this was the source of the observed tsunami. Finally, based on the results of this study, we conclude that further investigation should be undertaken on the seismicity of the region and the distribution of earthquakes and aftershocks. Furthermore, a modeling study could help determine the tsunami's mechanism and explain the 1990 tsunami runup heights that were observed at both Bohol and Camiguin islands. Such additional investigations would be very helpful in improving disaster preparedness and mitigation for Bohol Island and would also increase awareness of potential tsunami hazards in the region.

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APPENDIX I

At TAG, W1 (35) was inside her house when the earthquake struck. She felt the sideways ground motion and felt dizzy. She went outside, remembered that it was low tide at the time but about 4 minutes later she noticed that the water was bubbly and subsequently she heard a sound as the level rose to about .20 m. Another witness W2 (68), who was doing laundry when the earthquake occurred, also felt dizzy and held on to a post inside her house to steady herself. She remembered that the ground motion was sideways, sudden and lasted for about 5 seconds. She said that it was the strongest EQ she had experienced. However, nothing inside the house fell on the floor. She did not notice any fissure or mud on the ground. She also remembered that at that time it was low tide. Her house is about 20 m from the shoreline during the mean seal level. She said that the water retreated about 10m and came back "as high as a child" while motioning to the height of her child or up to her chest and noted that the water level increased by about 0.3m based on a banca (local wooden boat) that was floating nearby. After the ground shaking, the water retreated and came back muddy in a flood-like manner. She noted feeling at least 2 minor ground tremors, days after the strong initial quake.

At Baclayon Municipality (BAC), M1 (33) was inside his house (~30m from shore) and felt the sideways shaking during the main shock, followed by feeble shaking. He mentioned that the ground shaking lasted for about 4-5 seconds and that his whole family went outside. The street/road seemed to roll or behave in a wave-like fashion. He mentioned that according to the news, the municipalities of Valencia, Jagna and Guindulman Municipality were heavily affected and suffered more damage than BAC. He said that the waves seem to be stronger than normal. In this vicinity, we noted that the shore area is very flat with ~ 2m-high sea wall extending into the reef area as a ~150m-long groin. On the other hand, at Loay Fishport (LOA), M2 (48) reported that the earthquake shaking he felt was moderate while inside the house, noticed that the cabinets moved, but nothing toppled down. His house was ~ 150m from the seashore thus he did not observed the behavior of the sea. But his neighbors told him about unusual sea behavior. He did not remember seeing any fissures or cracks in their area. In Tocdog, Loay (also at LOA), M3 (30) observed that the sea was normal after the earthquake. There was no extensive damage, nor liquefaction was observed. He recalled that the ground shaking lasted for ~5sec. Their house was located right in front of the sea on the edge of the reef area. There was no panic among family members and neighbors during the ground shaking and nothing fell down inside the house.

In Lila Proper (LIL), M4 (42) was in his house along the shore and he felt sideways shaking motion for about 5s and became dizzy when standing. He said that the household items and furniture did not topple down and that he did not notice any abnormality in sea level. M5 (54), on the other hand, was inside the school about 2km from the shore during the earthquake. He reported that the sudden ground shaking lasted for about 5 seconds. Panicked, all the employees and the school children went outdoors. However, M6 (43) was along the shore when he felt a sudden ground shaking that lasted about 5 seconds and was able to observe about a 60m recession of the sea, approximately 2 minutes after the earthquake. The sea returned into its normal height after several minutes.

At Dimlao Proper (DIM), M7 (37) was near his "kubo", a typical term used for hut, located right in front of the shore and edge of a reef. He was resting inside his house when the earthquake occurred at around 3pm. He felt a sudden jerk that lasted about 7 seconds and was unable to stand. The wall of the house - made of hollow blocks - collapsed. Another motion came after 5-7 seconds later and the sea retreated into a low-tide level, which is about 30m from the shoreline. It returned about 0.5m higher and 20m farther inland than the normal level and had a foamy front and "tunog na parang kumukulo" (boiling-like sound). He remembered that the sea oscillated at least 7 times and that rumbling sound was heard from the sea. The waves deposited fish, mud and seaweeds.

In Anas, Valencia (ANA), W3 (42) was inside her home and she felt the sideways shaking motion and held onto something to prevent herself from falling. She said nothing fell off from the shelf. The felt motion lasted for about 5 seconds and that immediately she went outside. She remembered feeling several ground shaking motions in the preceding days. Right after the first ground shaking, she went out near the shore where she met several neighbors who were also concerned about an impending "tidal wave". They noticed that the sea level lowered to low-tide level and returned into its normal level but about 0.3m higher.

In Garcia Hernandez (GAR) where the flat reef is about 150m offshore, W4 (56) was inside her house that was made mostly of wood. The windows and cabinets shook while some bottles, TV, cabinets fell down from the wall. She got scared and thought that "katapusan na yata ito ng mundo" (it maybe the end of the world). She went out of the house immediately and dropped flat on the road and prayed. She observed that there was one strong shock and many less strong shocks afterwards. The shaking she felt was sideways and she observed the wave-like motion of the road. From the road, she saw that the water retreated about 5m from the former shoreline and left some fish stranded on the ground. Many small fissures (~4m long) and holes (0.2m wide) were observed all over the place. The sea returned back gradually but a little higher than normal (0.3m) and was accompanied with deep rumbling sound and foamy front. There was only one wave was observed at this locality.

In Jagna area (JAG), W5 (27) was at the school grounds near the shore practicing for the upcoming field day celebration. She felt the sideways ground shaking that lasted relatively long but can vaguely recall how many seconds. Some students panicked and jumped from second floor. There were many cracks in the school building and many fissures observed on the ground where water spurted out. The water in the sea retreated by about 150m and came back 0.5m higher than the normal level. She remembered that the sea retreated about 3 times.

In the community called Itum in Duero (DUE), W6 (48) was inside the house when she felt the sideways shaking and saw the fissuring on the ground. "Iba-iba ang dereksyon ng pag-uga" (The shaking directions were varied) and the whole place shook, undulated and moved like a wave. During the first strong shock, she had to hold onto a pole so as not to fall down. The cabinets toppled and plates fell and broke. Five to 10min after the shaking, the water in the sea receded and the neighborhood evacuated to a higher ground. There was no one left in the area, thus nobody was able to observe the return of the water. Some of her neighbors told her about the fissuring of the ground and seeing the ground opening and closing with hissing sounds. Ground shaking was observed and felt for about a week and the community stayed in the evacuation center during that period. She said that prior to this earthquake the BDCC (Barangay Disaster Coordinating Council) was unknown to them.

In Cabantian, Guindulman (CAB) M8 (71) - a community leader - was inside his wooden house when he felt an up and down shaking at first slow, then the vibration became stronger. He can vaguely recall but thought that it lasted about 5 seconds and that he saw ground fissure perpendicular to the road. Reportedly, the sea receded with rumbling sound, then came back at about 1.5 m higher than the normal level. He said the sea level was comparable to the usual low tide level and specifically that the water that came back like a high level tide, receding and returning in a way similar to heavy rains and flooding events.

At Guindulman Proper (GUI) W7 (42) was inside her house located about 15m from the shore when the up and down shaking occurred which lasted for about 10s and frighten her. The refrigerator toppled down. She went out and about 10min later noticed that the water receded about 15 meters from the shore. It came back and inundated the market which was a about 2 meters above sea level. , The water level at the market was about 0.5m high or 1m above the existing seawall. She also remembered many cracks along the highway near the gasoline station where mud came out. Thunder-like rumbling sound was heard during the shaking. Many less strong ground shakings were felt once in a while for about a month. Many houses were washed away and damaged especially those on stilts near the shore, while numerous boats were washed offshore. The bridge collapsed, the church was damaged and the church bell fell down.

At Basdio in Anda (BAS), M9 (48) was among the community leaders who were having a meeting at that time when they felt the ground shake. Everyonr dropped to the ground during the sideways shaking and they heard whooshing and rumbling sounds along with the ground motion. The aftershocks lasted for a week. He vaguely recalled how many seconds the ground shaking lasted but noticed that the water receded by about 100m from shore then came back with rumbling sound. The waves were 1m higher than normal with foamy fronts, retreated several times but subsequent waves were smaller than the first wave. Boats, houses and people were washed away and brought back by the wave activity. There were some cracks and rockfalls reported along shore.

M10 (46) was a member of the PDCC (Provincial Disaster Coordinating Council) residing in Anda poblacion (AND). A day before the quake, he heard an unusual sound. On February 8th he was at the 2nd floor of the Municipal Hall. Everybody panicked when the first strong sideways shaking was felt that lasted about 8 seconds followed by a much stronger shaking. The shaking was accompanied by rumbling sound. Ten minutes after the 2nd shaking, the sea receded by 50-60 m from the shore. The returning water came back carrying mud. In this area, the seawall is about 2m high and the normal high tide level reaches just at the sea-wall. After the earthquake, the wave that came back splashed into the sea wall. Perceptible aftershocks were felt for several days. People became concerned and stayed outside t for fear of "tidal wave". Others evacuated 1/2 km inland. M10 went to his barrio located about 1km from town proper, thus witnessed no other waves. The road was heavily damaged and the Municipal Hall suffered cracks. The water supply from the natural spring decreased to about 50%, probably due to cracks; this condition lasted for about a year.

In Cogtong at Candijay (COG), W8 (45) was inside her house when the earthquake struck. She noted that it was wave-like motion and not sideways. She became very afraid and could not remember how long the shaking lasted. She stayed on the ground. Canned goods in her "sari-sari" store fell down and the TV set was displaced from its original place. She heard neighbors talking about the "tidal wave" and they noticed that the sea was unusually high for that time of the day and the waves became stronger; everybody rushed further inland and was not able to see any other waves. In the same area, M11 (55), an owner of a store located near the bay, remembered that it was low tide at that time. He observed cracks inside his house/store appeared during the sideways shaking. Store goods toppled and fell down. The strong ground shaking was sideways and lasted for at least 4 seconds. After the earthquake, he noticed that the water receded by at least 10m. He noticed that the cemented area of the port suffered a crack and the level of the sea level increased and came back after 5 minutes, muddy and about 0.5m higher than normal. Aftershocks were felt for 3 weeks after the major shock. He remembered a small and generally weak shaking a day before February 8th.

At Mabini (MAB) M12 (47) was at the back of his house making a fish pen at about 100m away from fishponds. When he felt the ground shaking, he had difficulty standing and felt dizzy. He was surprised and stayed sitting down. He said that there were two shakes, several seconds apart. The second shaking was stronger than the first. The church bell rang softly. He went to the plaza after the initial shock. The stronger shaking was accompanied by a rumbling sound and small fissures appeared all over the place. At that time it was low tide but his brother-in-law told him that sea rose higher than normal (sudden high tide) and caused damage on the fish pens, cracking and collapsing some (mud) wall. In the same vicinity, M13 (22) was at school and noted small cracks on the ground after the ground shaking. He went outside and saw that the sea level was higher than normal (higher than the usual low tide level). He cannot recall how many seconds the shaking lasted. However, he remembered that the water at the fishpond became muddy. M14 (39) whose house is about 60m from the fishpond, was fishing at that time and heard rumbling sound thena sudden shaking and subsequent undulating sea motions. He could not recall the time interval between the shaking and the increase in sea water level. He also confirmed that there were two shakings, both accompanied by rumbling sound and that the second shake was stronger. After the shaking, the sea level abruptly increased. He paddled towards the shore, as water increased in height with boiling-like noise. He noticed that some trees were tilted and almost uprooted; the irrigation ditch suffered cracks and opened (not lateral displacement), no mud in cracks, the wave came in once like a flood.

At Alicia Town Hall (ALI), M15 (63) recalled that a rumbling sound preceded the shaking. He was unsure but he thinks that the shaking lasted about 6 seconds. He remembered seeing cracks at the back of the town hall that was located on a hill. At Biabas, Ubay (BIA), M16 (66) was making a "nipa" or palm roof when the earthquake occurred. He first heard a truck-like sound prior to the shaking motion. The glass windows fell down during the sudden and sideways motion. He was unable to stand and kept sitting down. He noted no fissure or cracks or any damage on the fishponds.

No one also observed any abnormality on the water level at the bay. W9 (55), who was a community chairman was inside her store. The shaking and the sound came simultaneously, store goods toppled down but there was no major damage on houses in the neighborhood. At Ubay, Poblacion (UBA) M17 (49) was in his house at the town proper and noted that the ground shaking lasted about 3s, that it was dominantly sideways and was accompanied with truck-like sound. In the same locality, one old house suffered cracks on its wall but there was no crack on the ground or any sign of liquefaction. The sea level was normal, low tide at that time and the public did not panic much. She said that the children went out of school buildings and classrooms and that the teachers guided them and made them drop on the ground. Some of the children were frightened.