SEISMIC STATION DEPLOYMENT , KINGDOM OF TONGA, JUNE TO OCTOBER 2006
REPORT TO THE DEPARTMENT OF LANDS AND SURVEY

In response to the May 3, 2006 (magnitude 7.9) earthquake in the Ha'apai group, a consortium of governments and universities deployed 7 seismic stations and 6 GPS stations in the Kingdom of Tonga . These organizations were the Tongan Department of Lands, Survey and Natural Resources, Geoscience Australia, Ohio State University, the Institute for Geophysics at The University of Texas, Austin and Washington University in St. Louis. These stations were deployed in June of 2006 and removed in October, after it was estimated that most of the aftershocks had occurred. The purpose of the deployment was to try to determine the sense of movement of the main (May 3) event from aftershocks recorded by this seismic array. The sense of motion has implications for the generation of tsunami. Based on the information available at the time of the main event, two possibilities existed for the fault motion which led to this earthquake.

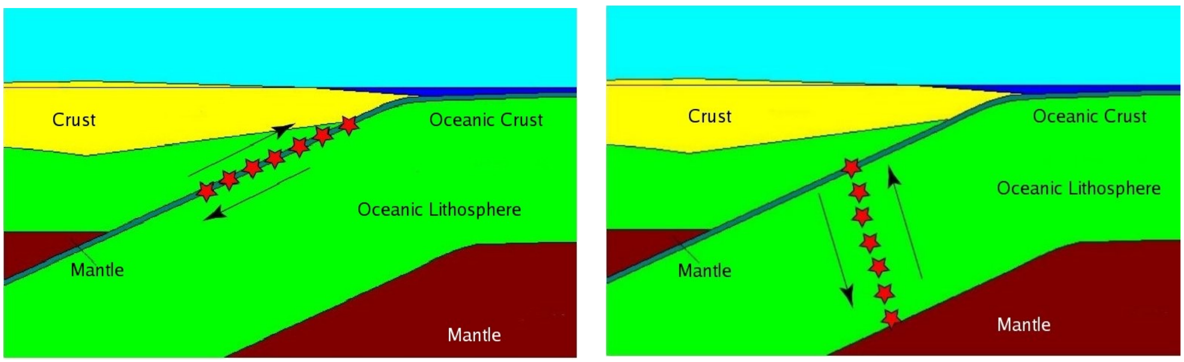


Figure 1. (a) Shallow thrust event (b) Slab tear event.

One possibility (fig. 1a) is a shallow thrust event, while the other is a rupture within the slab (fig. 1b). It is the thrust event which can result in the development of a tsunami. While there are world wide array stations in existence to record major seismic events and there are three permanent seismic stations in Tonga, we wanted to install a temporary seismic array in the Kingdom to record as many aftershocks as possible, even the smaller ones. It was hoped that enough aftershocks would be recorded by the temporary array to allow us to determine the sense of movement for the aftershocks and possibly relate this to the sense of movement for the main shock. Seven seismic stations were installed during the first two weeks of June 2006 (fig. 2). These were deployed with the help of personnel from the Department of Lands and Survey, Tonga along with the following people:

Tavita Fatai	Department of Lands and Survey, Tonga
Jim Whatman	Geoscience Australia
Anna-Liisa Lahtiner	Geoscience Australia
David Heeszel	Washington University in St. Louis
Patrick Shore	Washington University in St. Louis

The stations were located at the following locations.

Station		Sensor	Latitude	Longitude	Start time
NUIA	Tongatapu	Guralp-40T	S21.0641	W175.3237	2006:154:04:01
EUAS	'Eua	Guralp-40T	S21.4427	W174.9123	2006:157:20:54
NMKA	Nomuka	Guralp-40T	S20.2567	W174.8007	2006:160:22:46
TVKA	Tellekivavau	Guralp-40T	S20.3150	W174.5222	2006:161:23:36
FOAM	Foa, Ha'apai	Guralp-ESP	S19.7357	W174.2918	2006:163:22:57
TOFA	Tofua	Guralp-40T	S19.7141	W175.0600	2006:165:03:44
ATA	Ata	Guralp-40T	S21.0568	W175.0044	2006:170:00:10
and three SPANET stations:					
TPU	Tongatapu	Guralp-3T	S21.1500	W175.1830	
HAP	Ha'Apai	short period	S19.8250	W174.3500	
VAV	Va'Vau	Guralp-3T	S18.6640	W173.9770	

The locations are shown in the map (figure 2)

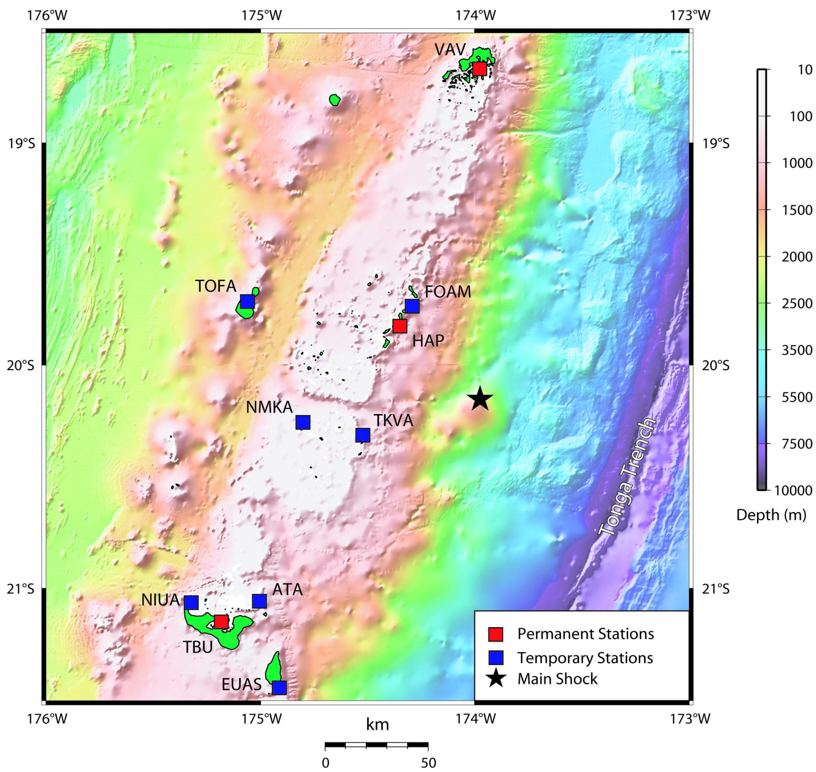
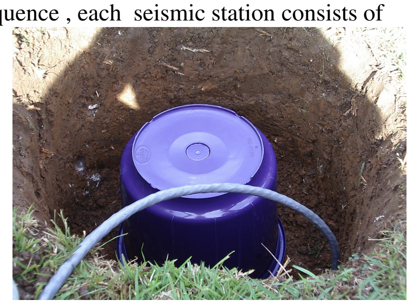


Figure 2. Location of seismic stations.

The 7 seismic stations were not designed to be serviced, but rather to be demobilized approximately four months after the deployment. As shown in the following sequence , each seismic station consists of

i) a seismic sensor placed on a concrete pad approximately 0.5 m below ground surface



ii) the sensor covered for insulation and to protect from flooding

iii) an outer covering for the sensor

iv) electronics, data logger and power source protected in a plastic bin

v) solar panels and fence with the sensor and equipment buried for insulation

The stations were visited in October 2006. At that time data was collected and the equipment removed. Over the next few months David Heeszel and Anna-Liisa Lahtiner scanned the data looking for seismic signals which could be used to determine as accurately as possible, the location and sense of motion of the aftershock. An example of an event recorded across the array on Julian day 184 is in figure 4.

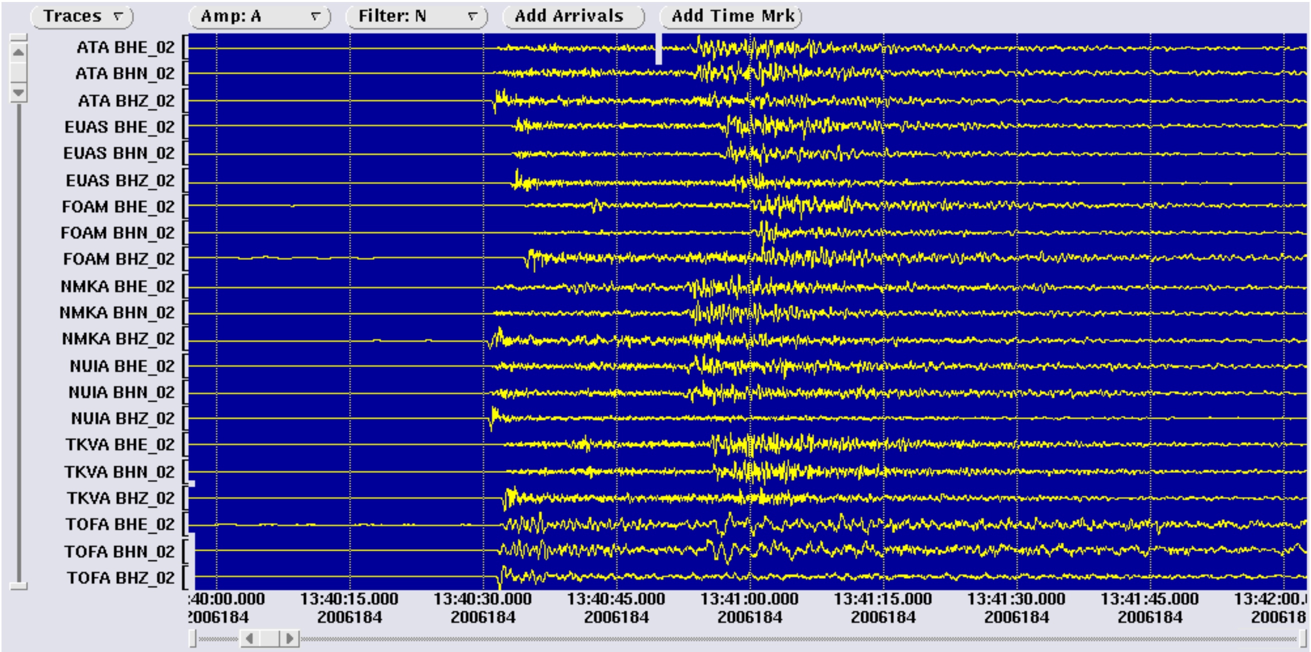


Figure 4 Example of traces for all seven seismic stations. There are three traces for each station - vertical(BHZ), north-south (BHN) and east-west (BHE)

During this analysis more than 300 aftershocks were identified and the locations of the rupture was determined. These were combined with data from previous deployments in Tonga (SPASE Deployment 1993-1995) and with the locations of ruptures determined from world wide seismic network recordings. These locations are shown in figure 5.

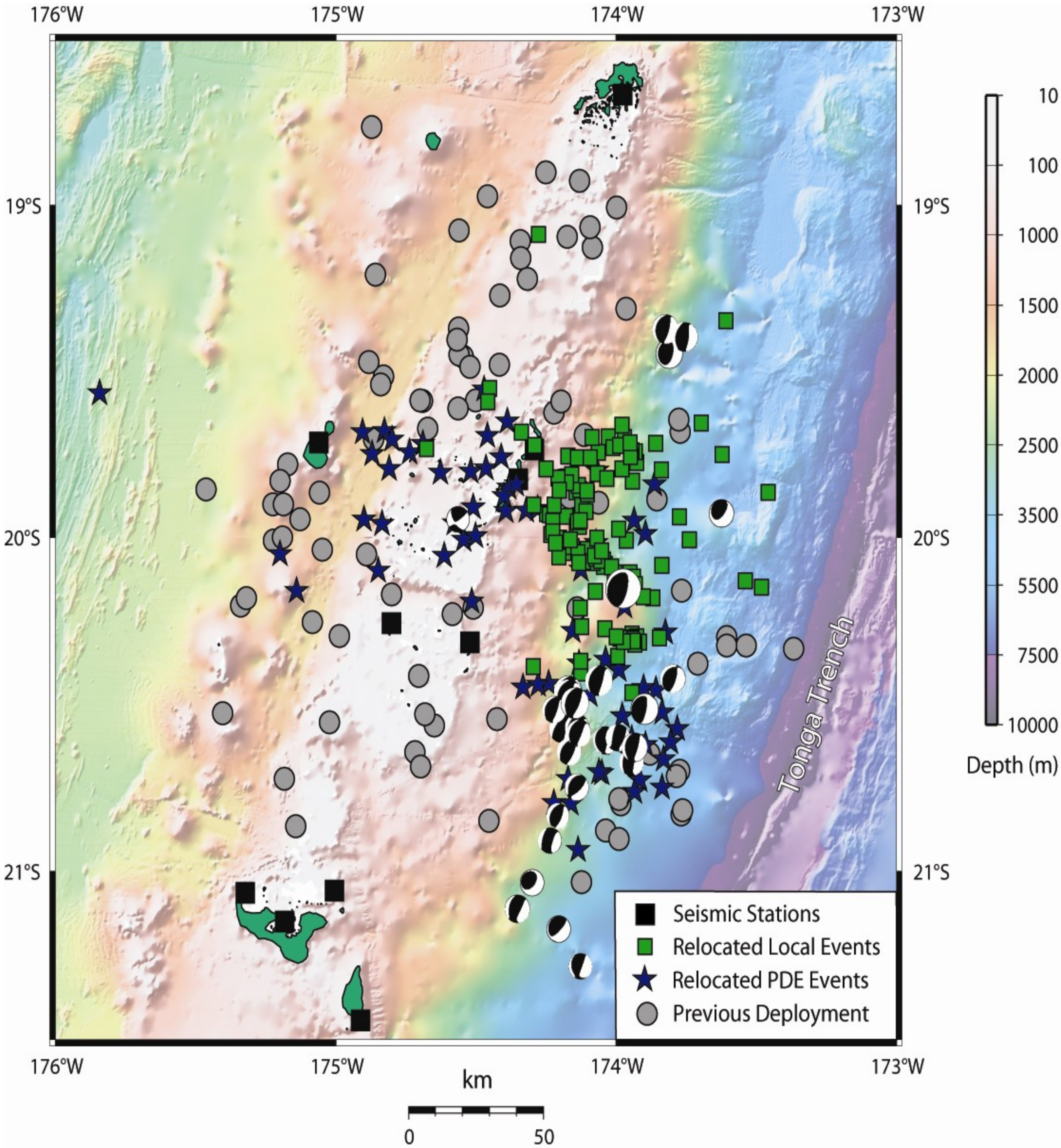


Figure 5: Map of historical and recent seismic activity. The black squares represent seismic stations. The main shock event of May 3, 2006 is the largest focal mechanism (black compression, white extension), while the rest of the focal mechanisms represent historical seismically associated with the Tonga Trench.

The Tongan region is highly active seismically. More than 80 to 90 teleseismically detected earthquakes (over a magnitude 4.0) are recorded each year. Figure 4 shows the distribution of recent seismic activity. Black squares make the locations of this deployment's seismic stations. Grey circles are earthquakes detected during the SPASE (1993-1995) deployment. Blue stars are events recorded by world wide seismic stations (large enough events to be recorded world-wide) and by the permanent stations located in Tonga. Green squares represent the set of seismic events recorded during his deployment. These will include many more smaller events which could not be recorded by world wide stations.

All events have been relocated using a local velocity model in a manner that will reduce source to station path biases. The location of the main shock and the subsequent aftershocks is consistent with a slab tearing event and not a tsunami generating shallow thrust. It is our initial assessment that the main shock is located too deep and too far west of the shallow thrust zone as defined by the focal mechanism locations to have been a shallow thrust events. We believe that the aftershock locations represent reactivation of shallow faults and fractures within the upper portion of the subducting slab.

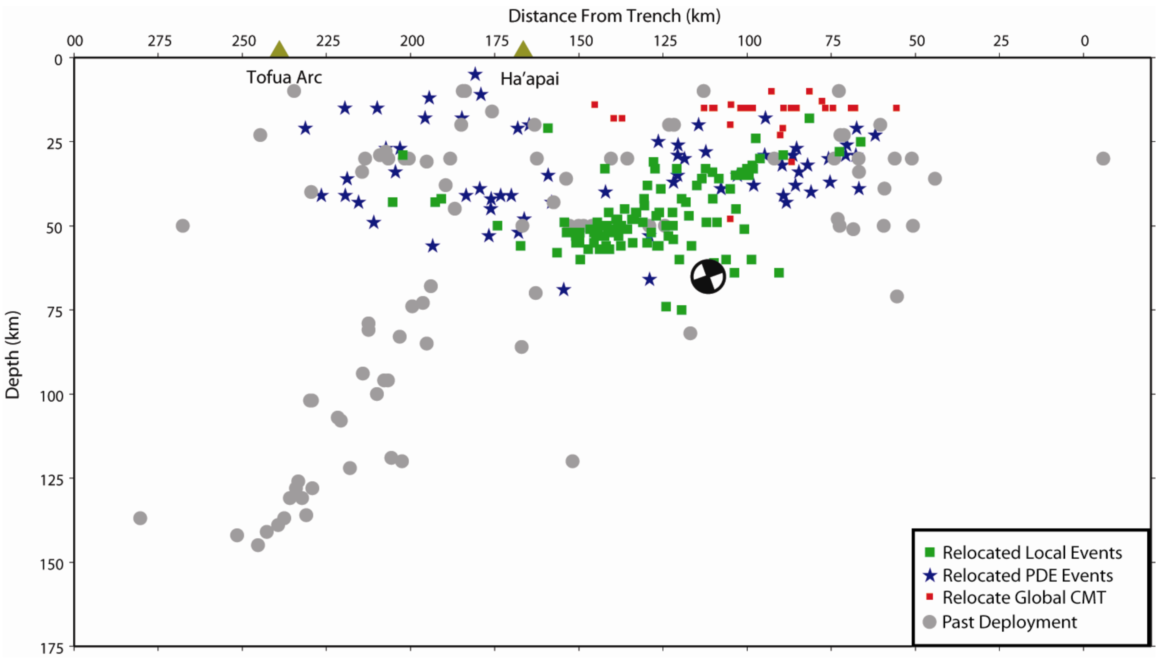


Figure 6: Earthquake locations viewed in a cross-section perpendicular to the trench. All symbols are the same as in figure 1 except that in this case the focal mechanisms are plotted as red squares. Additionally the main shock has been rotated to view in profile.

The main concept is that the main shock lies below the region outlined by the aftershocks. We think that the aftershocks are thrust events - which were re-activated by the main event. They do however outline the region of the subducting slab for which we would expect a thrust event to originate. The main shock does not lie within this region - it lies well below.

Phil Cummings of Geoscience Austrailia carried out an estimation of the expected slip from both possible fault plane solutions, rupture on a shallowly dipping plane and on a steeply dipping (slab tear) plane. These are shown in figure. 7. These estimates were then compared to vertical displacements measured at a GPS station in Ha'Apai. This comparison is shown in figure 8. The shallowly dipping fault plane shows very little displacement while the steeply dipping fault plane matches the observed displacement quite well. This supports the seismic evidence that the main shock was a slab tear.

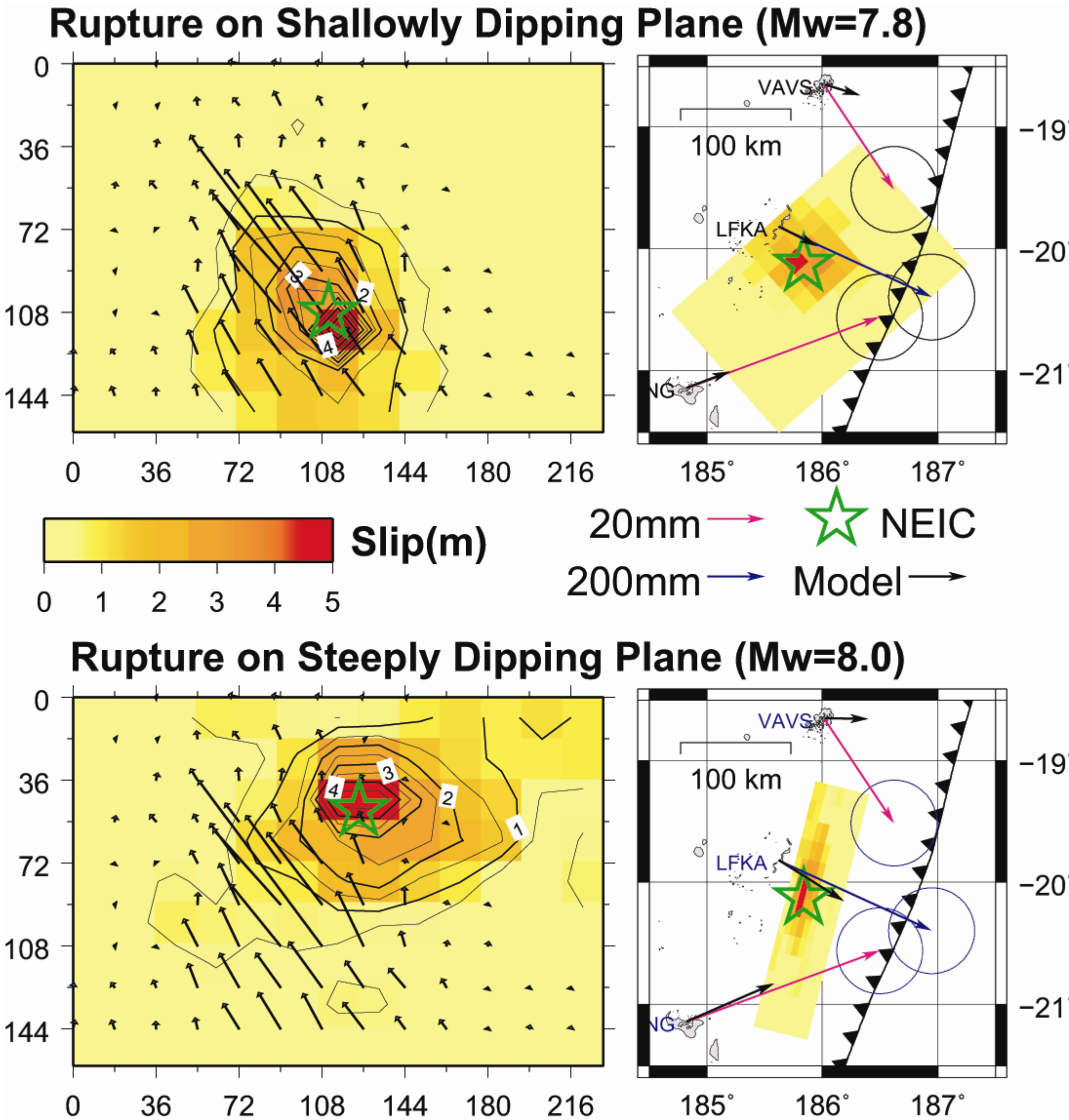


Figure 7: Estimation of slip from both fault plane solutions from the focal mechanism. The images on the left are a plot of both the estimated slip magnitude on the fault plane in question and relative motion of the upper plate to the subducting slab. The contours and colors here represent the magnitude of the slip on each fault plane while the vectors represent the motion of the Tonga Islands with respect to the down going slab. The scales are in km. The figures on the right are a map view of the slip area with the Tonga Islands superposed. The black vectors are the motions of the permanent GPS stations in Tonga during the earthquake while the colored vectors are the measured motion of the stations. The green star represents the NEIC location of the earthquake in both plots.

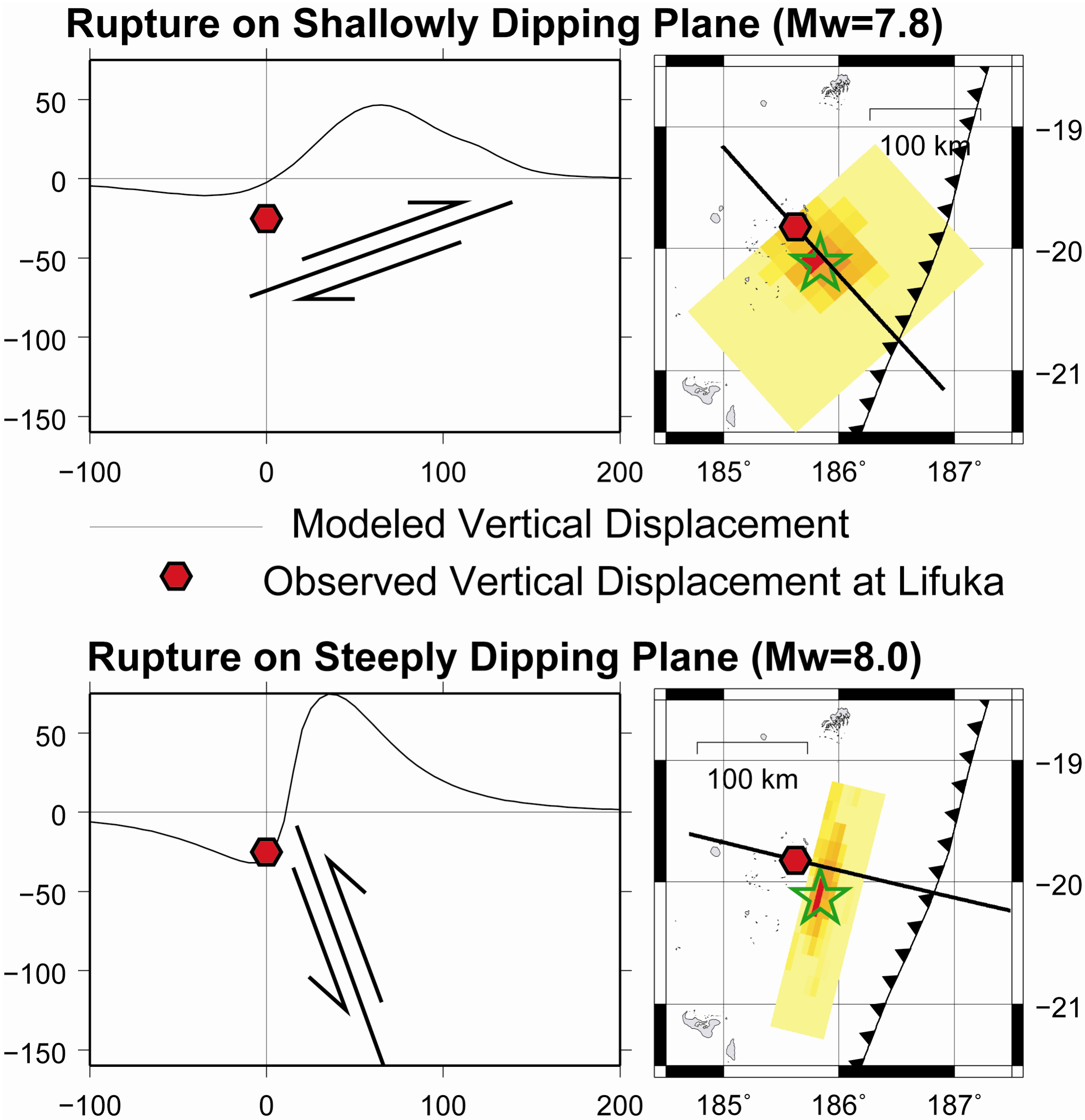


Figure 7: Plot of vertical displacement measured at Ha'Apai GPS station relative to what is predicted by the shallowly dipping and steeply dipping fault plane respectively. The shallowly dipping fault plane shows very little displacement while the steeply dipping fault plane matches the observed displacement quite well. This supports the seismic evidence that the main shock was a slab tear.

CONCLUSION

It is our preliminary conclusion that the M_w 8.0 earthquake in Tonga on May 3, 2006 was a slab tearing event rather than a shallow thrust typical of a tsunami generating earthquake. Therefore, we conclude that the tsunami risk to the Tonga Islands is not greater than it has been previously understood to be. This is supported by both the relocation of aftershocks and by an modeling of the slip on the main shock.