

## **Indonesia - Java - June 2, 1994**

On June 3, 1994 (local date), a large, shallow thrust earthquake (with moment magnitude of 7.8) occurred off the southeastern coast of Java - near the east end of the Java Trench in the Indian Ocean. A devastating tsunami was generated which was much larger than expected for the size of the earthquake. Twenty to thirty minutes after the main shock, tsunami waves arrived at the nearest coasts. The most severe tsunami damage occurred along the southern coast of East Java where waves ranging in height from 1-14m killed more than 200 East Java coastal residents. Along the southwestern coast of the Island of Bali the waves ranged from 1-5 meters. In total, 223 persons lost their lives, approximately 400 were injured, and over 1000 houses were destroyed.

This event had several unusual characteristics and was consistent with other so-called "tsunami earthquakes". As with the Nicaragua earthquake of September 2, 1992., residents along the southeastern East Java coast did not experience strong ground motions, thus they were not concerned that a major tsunami would strike.



*Tsunami Damage in East Java*

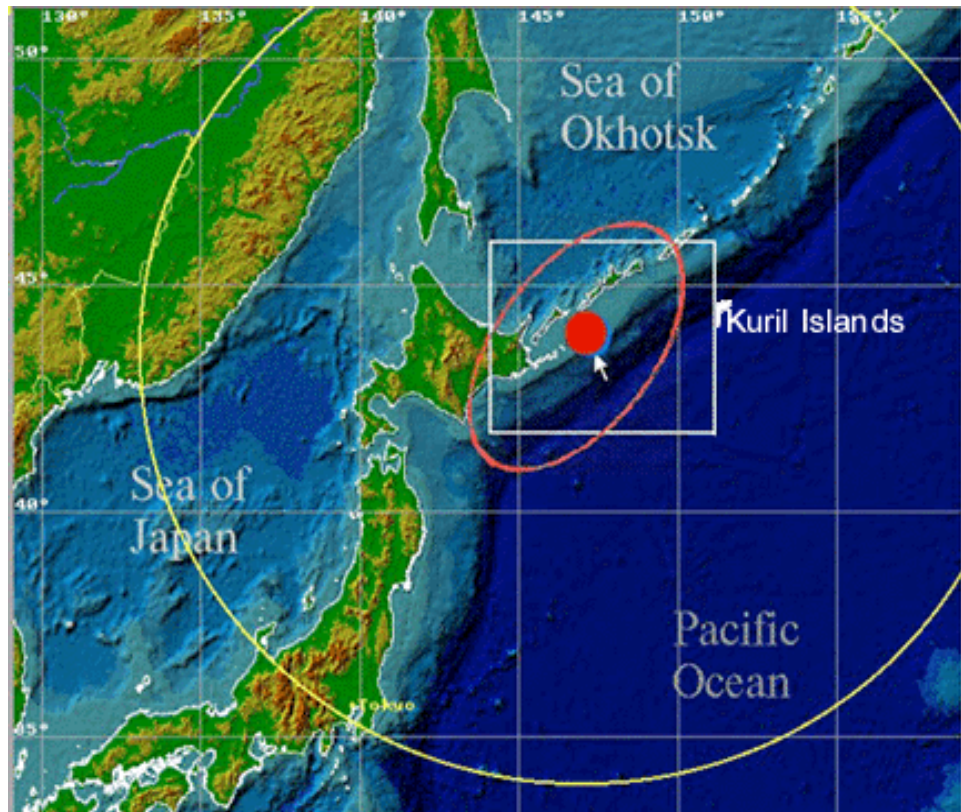
## Russia - Kuril Islands, Shikotan - 4 October 1994

A large, magnitude 8.1 earthquake near Shikotan, one of the South Kuril Islands in Russia, killed 11 people and injured 242.

The quake was associated with very strong ground motions and generated a tsunami.

Regional and Pacific wide warnings were issued for the Kuril Islands, Japan, the Hawaiian Islands and the west coast of Canada and the United States.

The area most affected by local damaging tsunami waves were primarily Shikotan, Kunashir, Iturup, of the South Kuril Island Group, and Hokkaido, Japan. There was approximately 50 cm of subsidence at Shikotan Island.



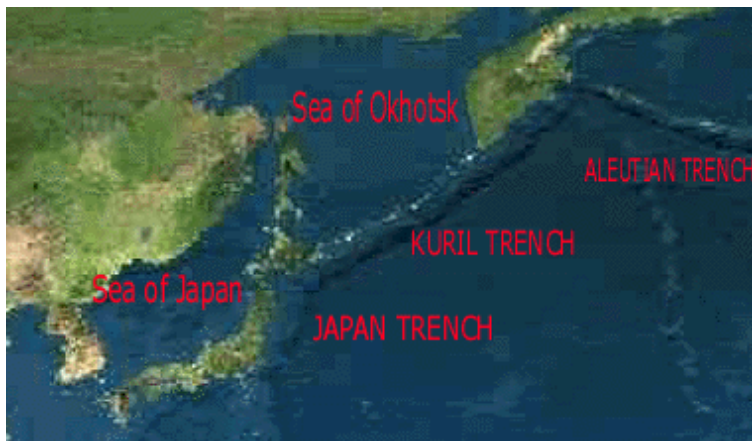
Tsunami runup height measurements were made in Shikotan, Iturup, Kunashir, and small islands between Shikotan and Hokkaido by a team of international scientists. Maximum runup on Shikotan Island was determined to be approximately 10 m high. However none of the reported casualties was attributed to the direct effects of the tsunami.

At Kuzhno-Kurilsk, Kunsashir Island, tsunami heights ranged from 2.5-3.0 m. In the older part of town (fronted by a gentle beach) all houses were damaged by the wave that penetrated 200-500 m inland.

In Japan, the areas most affected were Kushiro, Hachinohe, Chichijima and Hanasaki, in Hokkaido. One person was killed and 140 more were injured. Many more runup measurements along the Hokkaido coast were carried out by a team of scientists from Tohoku University in Japan. An approximately 1.8 m tsunami runup was reported in Nemuro.

The tsunami waves were not damaging in Hawaii but were readily recorded. The highest recorded wave at Midway I. was 0.54 meters(peak to trough) and in Kahului, Maui, 0.8 meters (peak to trough).

Based on the earthquake aftershock distribution the tsunami generating area was estimated to be only 120 on 100 km. Many things were learned from this particular earthquake, the plate tectonics of the region and the potential of tsunami generation in the Southern Kuril islands-Northern Hokkaido region. There were many similarities in magnitude, and epicenter location of this event with two other quakes which had occurred on 13 and 19 October 1963. In spite of their great magnitude, neither the 1994 quake not these past quakes generated a destructive tsunami outside the source region.



Specifically, the October 4, 1994 earthquake (and the 1963 earthquake) occurred at the Pacific side boundary of a smaller tectonic subplate which includes the Sea of Okhotsk and perhaps a portion of the northern part of the Sea of Japan. This subplate is characterized with large earthquakes such as the 1963 and 1994 events but with lesser vertical subduction and rotational movement, as the North Pacific Plate grinds against it. The whole area appears to be highly fractured in an

east-west direction and the crustal displacements appear to be occurring along the boundaries of subplates that may not be longer than 200-250 miles. It appears that the fractured smaller plates along the northern part of the Japanese Trench limit the extent of crustal displacements and therefore the size of the resulting tsunami. The historical record supports this as well. This is the reason why very large magnitude earthquakes from that region produce only locally catastrophic tsunamis.

## Philippines - Mindoro - November 15, 1994

An earthquake with magnitude of 7.1-centered 11 km N22°W of Baco, Mindoro, near Verde Island - generated a local destructive tsunami. In oriental Mindoro, the combined effects of the earthquake and the tsunami killed a total of 78 people, injured 430, damaged or destroyed 7566 houses in 13 out of 15 municipalities, damaged roads, destroyed or damaged 24 bridges, and sunk numerous fishing boats. There was no time to issue a warning. Approximately five minutes after the tremor, tsunami waves struck along a 40 km stretch of the northern and eastern shoreline of Mindoro island, from Puerto Galera up to Pinamalayan. Also affected were Verde and Baco Islands, north of Mindoro. Waves with a maximum runup of 8.5 meters occurred at Pulong Malaki (Baco Island). Minor waves were also reported at Batangas Bay.



Areas hardest hit by the tsunami were in Barangays Malaylay, Old Baco, Wawa, and Baco Islands. Waves with maximum runup of 6 meters caused the greatest destruction, leaving at least 41 persons dead and destroying fishing boats and 1530 houses.

Fortunately, being well prepared by the Philippine Civil Defense authorities, most of the inhabitants in the area reacted quickly to the earthquake's natural warnings. After being awakened from their sleep by the strong ground motions of the

earthquake, they heard a strong jet like sound of water, first receding then coming back. Knowing that a tsunami was coming, they evacuated quickly to higher ground and were thus able to save themselves from the incoming waves. What also helped was the fact that the tide was at its lowest level at that time of the night.

Unfortunately, most of the people that died in this area were children and old people that could not move fast enough to higher ground. Almost half of the casualties who drowned were children below 10 years old. The lesson learned was the importance of educational programs and preparedness, particularly for the young. Apparently, such programs are now in place in the Philippines where, in recent years, several tsunami disasters have killed thousands of people. Without such preparedness the death toll for this Mindoro tsunami would have been much greater. Nonetheless, this disaster also indicated the need for these educational programs to be continuous and intensive, particularly in areas known to be vulnerable to the tsunami disaster.