

Initial Report on 23 June 2001 Arequipa, Peru Earthquake

On June 23, 2001, at 8:33PM UTC, 3:33 PM local time, a $M_w=8.3$ (USGS) earthquake occurred near the coast of south-central Peru along the subduction zone between the Nazca and South American tectonic plates. The districts of Arequipa, Moquegua, Tacna, and Ayacucho sustained losses (Figures 1 and 2). This initial reconnaissance report has been prepared by Eduardo Fierro of Wiss, Janney, Elstner Associates Inc. based on his field observations from June 28th to July 3rd.



Figure 1. Map of Peru showing the epicenter location. (Source: modified from United Nations)

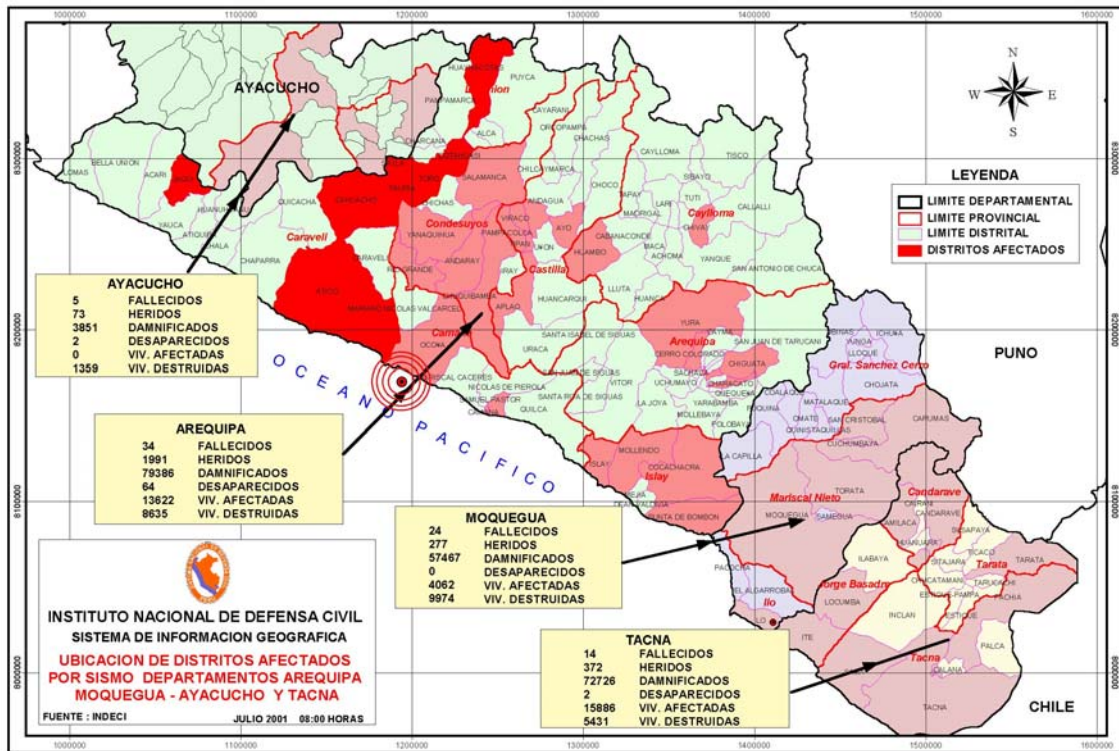


Figure 2. Distribution of losses. Translation: fallecidos = dead; heridos = wounded; damnificados = people affected; desaparecidos = missing; afectadas = damaged; destruidas = destroyed. (Source: National Institute for Civil Defense, Peru)

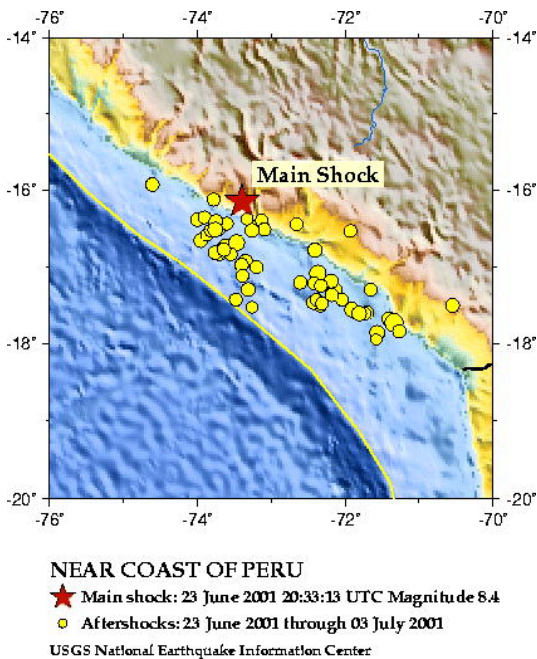


Figure 3. Main event and aftershock locations through 3 July 2001. (Source: USGS)

The National Institute for Civil Defense of Peru reports 77 dead, 68 missing, 2,713 wounded, 213,430 people affected, 33,570 houses damaged, and 25,399 houses destroyed. A geographic breakdown of the losses is given above in Figure 2.

There have been dozens of strong aftershocks in the region (Figure 3).

To date, only one strong motion record of the main event has been recovered from a station in Moquegua. Two other instruments in the epicentral area apparently malfunctioned. Field surveys and local reports indicate that the duration of ground motion was relatively long (45-60 seconds) with peak ground accelerations ranging from approximately 0.10g near Arequipa to 0.30g near Moquegua. The southern coastline was affected by a tsunami following the main event; the coastal towns of Ocoña and Camana were particularly hard hit.

Observations from Locations Reporting Most of the Damage

AREQUIPA

The ground accelerations were apparently not very high in Arequipa, a city located about 120 miles inland from the epicenter of the main event. There are no ground motion records from Arequipa, apparently due to instrument malfunction. However, local people reported that the duration of motion was approximately one minute. Primarily historical buildings and older stone masonry structures sustained damage. An estimate of 0.10g appears reasonable for the peak ground acceleration in Arequipa based on observed damage patterns.

The city's historic Cathedral of Arequipa sustained heavy damage, mainly due to the collapse of one of its towers. The cathedral is situated on the Plaza de Armas in Arequipa's historic center, a UNESCO World Heritage site. The cathedral, founded in 1612, was damaged by previous earthquakes and fire and was substantially rebuilt in the 19th century. Both towers of the cathedral were apparently damaged in previous earthquakes and rebuilt most recently in about 1940. This cathedral is the symbol of Arequipa and an important part of the architectural heritage of Peru.



Figure 4. Cathedral of Arequipa, pre-earthquake file photo. (Source: personales.com)



Figure 5. Cathedral of Arequipa as it appeared on June 28, 2001. (Photo by E. Fierro)

A set of still photos extracted from a video recording taken during the earthquake shows part of the collapse sequence of the towers at the Cathedral of Arequipa (Figures 6 and 7, photos purchased by E. Fierro). Figures 8 to 13 show details of the damage, especially to the towers.



Figure 6. Cathedral of Arequipa, first still photo from sequence taken during main event on 23 June 2001.



Figure 7. Cathedral of Arequipa, subsequent still photo showing impending collapse of left tower shown in Figure 6.



Figures 8, 9, 10, 11. Cathedral of Arequipa. [Clockwise starting above] View from the main square (Plaza de Armas); view from the roof; bent rails used to support the upper tower; collapsed tower punctured the vaulted dome above the main altar. (Photos by E. Fierro)



Figures 12 and 13. The precarious tower is supported by four 35 cm by 35 cm concrete columns and four steel rails. One of the steel rails buckled. Arches attached to the main structure were also damaged. (Photos by E. Fierro)



Figures 14 and 15. Church of Santa Marta; towers pulled away from the main structure. Buttresses supporting the main structure show signs of distress. (Photos by E. Fierro)

Many cathedrals and religious monuments sustained damage. The Convent of Santa Catalina, founded in 1579, was heavily damaged. Many traditional domed and vaulted structures were extensively damaged. One example of a lightly damaged vaulted ceiling in an historic home is shown in Figure 16. Many of the damaged older dwellings have roofs made with heavy blocks of low strength “sillar” (consolidated volcanic ash) supported by steel rails (Figure 17).



Figure 16. Typical historic dwellings with vaulted roof. (Photo by E. Fierro)

Figure 17. Rail supported “sillar” roofs suffered widespread damage. (Photo by E. Fierro)

COASTLINE NEAR CAMANÁ AND OCOÑA

At least 50 landslides or rock falls were reported along the Pan-American Highway south of Camaná in La Bajada del Diablo (Figure 18). No warning signs were observed anywhere along the roadway. The major damage to the south of Camaná was caused by the tsunami induced by the main shock (Figures 19 to 23). Residents reported that within 20 minutes after the ground shaking, three waves around 4 meters high hit the coastline near Camaná (source: Reuters). However, this area is primarily used as a summer resort and since it is currently winter in Peru, most of the beachfront properties were unoccupied. The tsunami caused extensive property damage along 30 kilometers of the coastline and reportedly resulted in the loss of 15 to 20 lives.



Figure 18. The Pan-American Highway south of Camaná sustained damage; no warning signs posted. (Photo by E. Fierro)



Figure 19. Tsunami swept away wooden summer houses over a 10 Km stretch of coastline between Camaná and Ocoña. Note the barren streets remaining. (Photo by E. Fierro)



Figure 20. Tsunami damage near Camaná; wreckage remaining from masonry house damaged by tsunami. (Photo by E. Fierro)



Figure 21. Tsunami damage near Camaná; about 30 Km of the coastline was heavily affected by the tsunami. (Photo by E. Fierro)



Figure 22. Tsunami damage near Camaná; collapse of beachfront property due to foundation failure. (Photo by E. Fierro)



Figure 23. Tsunami damage near Camaná; foundation failure. Note the undamaged wall at top story indicating relatively weak ground shaking. (Photo by E. Fierro)

CAMANÁ

Downtown Camaná suffered minor damage. Primarily adobe houses and some school buildings sustained structural damage. Most of the damage could be attributed to configuration problems such as soft stories or short-column effects. Figures 24 to 27 show typical damage to old school buildings. Both new and older schools with short column problems performed poorly. Schools designed using the most recent Peruvian code had isolation details between infill masonry walls and the concrete framing and avoided the short column failures. Figures 28 and 29 show an example of the most recent school construction; the school shown in these photos performed well.



Figure 24. An old school in Camaná. Three columns failed in shear. (Photo by E. Fierro)



Figure 25. One of the failed columns at school shown in Figure 24. No special reinforcement in the short-column area; wide spacing of transverse reinforcement. (Photo by E. Fierro)



Figure 26. Short column at another school in Camaná. Even #3 at 4 in. o.c. transverse reinforcement did not prevent heavy damage. (Photo by E. Fierro)



Figure 27. Another short column condition at school shown in Figure 26. Damage to both masonry infill and to short column. (Photo by E. Fierro)



Figure 28. This school in Camaná built using the new Peruvian code did not suffer any damage. (Photo by E. Fierro)



Figure 29. The walls were separated from the reinforced concrete frames by an elastomeric material to avoid short-column configuration. (Photo by E. Fierro)

OCOÑA

In Ocoña, a small city near the coast to the northwest of Camaná, mainly adobe houses sustained damage. Field observations indicate that the city experienced relatively low ground shaking.



Figures 30 and 31. Church in Ocoña built using very poor construction materials; both the mortar and brick were weak. Previously damaged and patched following earthquake 4 years ago. (Photos by E. Fierro)



SUMMARY

Initial surveys indicate that most damage occurred in areas to the east and southeast of the epicenter of the main event and that historic structures and old houses sustained the most severe damage. The coastline south of the epicenter was extensively damaged by the tsunami that followed the main shock. The intensity of ground shaking varied with a maximum peak ground acceleration of approximately 0.30g, and all reports indicate that the shaking continued for a long duration. Strong aftershocks are still occurring on a daily basis.

The Peruvian National Institute for Civil Defense reports that distribution of immediate relief material is ongoing as of July 5, 2001. The Peruvians may need long-term international financial and technical support for repair and rehabilitation of the damaged historic structures, which are an important part of our international cultural heritage.

ACKNOWLEDGEMENTS

All the photos and field observations in this report are by Eduardo Fierro from the San Francisco/Emeryville branch office of Wiss, Janney, Elstner Associates, Inc.(WJE). Mr. Fierro is originally from Callao, Peru. This report was assembled and edited by Ayhan Irfanoglu and Cynthia Perry, also of WJE, based on photos and text emailed from Peru by Eduardo Fierro. Mr. Fierro can be contacted at <mailto:efa@wje.com>.

Mr. Fierro would like to gratefully acknowledge the assistance of local officials and members of the engineering community in Peru in providing access, accommodations, and information. In particular, he would like to thank Jorge Ojeda, Executive Director of Autodemas; José Tong, Dean of the Colegio de Ingenieros de Lima; Daniel Torrealva, Universidad Catolica del Peru; Alejandro Muñoz, Universidad Catolica del Peru; Javier Pique, Universidad Nacional de Ingenieria; and Adolpho Gonzalez, Colegio de Ingenieros de Tacna. Names of other individuals who provided assistance will be included in the final version of this reconnaissance report.