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FAULTING, STRUCTURAL DAMAGE, LIQUEFACTION, AND LANDSLIDES FROM THE LUZON, PHILIPPINES EARTHQUAKE OF JULY 16, 1990: SLIDE SET AND BIBLIOGRAPHY

by

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SUMMARY

A magnitude (M_s) 7.8 earthquake occurred in north-central Luzon at 4:26 P.M. local time on July 16, 1990. The Philippine and Digdig faults ruptured over a distance of at least 110 km, and displacements at the surface were as great as 6.2 m, left-lateral horizontally, and less than 1 m vertically. At least 1,283 people died, mostly in the collapse of multi-story buildings at considerable distance from the epicenter. Ground shaking in the epicentral area caused relatively little damage; much greater structural damage occurred in Baguio City and along the coast of Lingayen Gulf. Numerous roadways and bridges were damaged by ground shaking or earthquake-induced ground failure (landslides and liquefaction). The abundant landslides throughout mountainous central and northern Luzon were predominantly shallow (less than 1m-deep) disaggregated slides of tropical soils incorporating minor weathered bedrock. The landslides blocked major transportation routes to northern Luzon, which delayed rescue and relief efforts. Fluvial, deltaic, and beach sand deposits liquefied and caused bearing-capacity failures, subsidence, and lateral spread landslides, which damaged structures, bridges, and highways, chiefly along the western coast of Luzon. The most dramatic liquefaction effects were in the 0.5 km^2 central part of Dagupan, where buildings severely tilted and subsided as much as 2 m.

The majority of this collection of 64 slides were taken by members of a U.S. Geological Survey team investigating the earthquake from July 26 to August 8, 1990. Several additional slides were contributed by others. Trevor Matuschka of Engineering Geology Ltd. of Auckland, New Zealand, visited the area at about the same time and photographed some areas we were unable to visit. The staff of the Philippine Institute of Volcanology and Seismology (PHIVOLCS) and John Nakata of Tohoku University contributed additional slides. The slides and captions are divided into four sections dealing with the principal topics of our post-earthquake investigations: faulting (F), damage to structures (S), effects of liquefaction (L), and mass movement (M) or landslides. The single letter abbreviations are used to designate the topic on the slides and captions.

A list of published reports is included at the end of this report as a bibliographic aid for those seeking more information on this earthquake and its effects.

FIGURE CAPTIONS

FAULTING

F-O: Map of central Luzon showing large cities, epicenter of July 16, 1990 earthquake (circle) and approximate location of surface rupture along the Philippine Fault Zone (PFZ) and Digdig Fault (DF).

F-1: Digdig fault surface break in 7/16/90 earthquake just north of Digdig. Fault trace has about 4 m of left-lateral offset. Road offset near center and at bottom of photo. View from the north. Photo by C. Newhall

F-2: Philippine fault surface break of 7/16/90 near Bato Ferry, about 21 km southeast of Rizal with 4.85 m of left-lateral offset and 1.6 m vertical displacement of pilapil (rice-paddy dike). Person stands on fault trace extending left to right across photograph with down-dropped flooded field in background on northeast side of fault. Photo by C. Newhall

F-3: Philippine fault surface break of 7/16/90 in Rizal, where two stands of the fault ruptured. Photo shows the northern fault strand, which has the smaller offset of the two; the fault shows left-lateral offset of the street in the foreground and a vertical scarp trending northwest toward the corner of the school in the background. Photo by C. Newhall

F-4: Northwest of Rizal, the 7/16/90 surface break of the Philippine fault trended northwest beneath this collapsed bridge and failed irrigation canal. Photo by G. Wieczorek

F-5: Team from the U.S. Geological Survey and Philippine Institute of Volcanology and Seismology team establishing a set of quadrilateral posts across the surface break of the Philippine fault in Rizal, to be periodically measured to detect afterslip along the fault. Photo by C. Newhall

F-6: Southern trace of Philippine fault surface break of 7/16/90 through Rizal. Destroyed houses shown here directly over surface break. Horizontal offset here was at least 2.4 m. Photo by C. Newhall

F-7: Small hill in background showing geomorphic expression of Philippine fault scarp southeast of Rizal. The 7/16/90 rupture followed this preexisting scarp. Photo by C. Newhall

F-8: Westward view of Digdig fault surface break of 7/16/90 near Lombay Bukid, about 10 km northeast of San Jose. Person is standing on fault trace, extending from left to right; fault scarp on west side of trace (behind person) showed about 3.6 m left lateral and 0.6 m vertical displacement. Photo by G. Wieczorek

F-9: Digdig fault surface break south of Digdig, showing left lateral offset of roadway. Photo by G. Wieczorek

F-10: Digdig fault surface break of 7/16/90 north of Digdig, viewed from the south. Left-lateral displacement took place obliquely across road. (Same area appears in center of F-1). Photo by C. Newhall

F-11: Digdig fault surface break near Imugan, about 3 km west of Santa Fe. Fault is in central part of area. Left lateral displacement of several meters shown by displaced pilapils. Large light-colored patches are probably deposits of liquefied sand ejected from beneath the surface during the earthquake. Photo by PHIVOLCS staff and John Nakata

STRUCTURES

S-1: Eastward view of Hyatt Terraces Hotel, Baguio, damaged in 7/16/90 earthquake and aftershocks. About 80 people were believed buried in the hotel. Local miners set up search-and-rescue operations in the yard adjacent to the hotel. Photo by G. Wieczorek

S-2: Northeastward view of the Hyatt Terrace Hotel, Baguio, damaged in the 7/16/90 earthquake and aftershocks. Southern condominium section (to the right in the photo) reportedly collapsed in main shock, whereas center section collapsed in an aftershock later that evening. Photo by C. Newhall

S-3: Collapsed southern condominium section of Hyatt Terraces Hotel, Baguio, destroyed in main shock of 7/16/90 earthquake. Inaccessibility of Baguio due to landslides along major highways, prevented large equipment from being used in the search and rescue operations. Local miners (center of photo) tunneled into wreckage for survivors. Photo by G. Wieczorek

S-4: Closeup of search-and-rescue operations within southern condominium section of Hyatt Terraces Hotel, Baguio. Three survivors were rescued as late as 11 and 12 days after the earthquake. Photo by G. Wieczorek

S-5: Damage to southwestern wing of Hyatt Terraces Hotel, Baguio. Photo by G. Wieczorek

S-6: Closeup view of local ground failure beneath foundation of northwestern corner of Nevada Hotel, Baguio. The scarp of this slump showed about 0.4 m combined horizontal and vertical displacement (towards the right in this photograph). Photo by G. Wieczorek

S-7: Strong-motion instrumentation for aftershock monitoring in basement of the Hyatt Hotel, Baguio. Photo by L. Wennerberg

S-8: Basement of the collapsed Hyatt Hotel, Baguio. Photo by L. Wennerberg

S-9: Southwestward view of Hotel Nevada, Baguio, the first two stories of which collapsed in the 7/16/90 earthquake. Uncollapsed portion in the rear was added after the original construction. Photo by C. Newhall

S-10: Three-story factory in Export Processing Zone, Baguio, which collapsed in the 7/16/90 earthquake and burned one day later as a result of a propane leak. Identical building in rear of photo, on excavated ground rather than fill, responded differently to earthquake shaking and was damaged but did not collapse.

S-11: Detail of collapsed structure in the Export Processing Zone, Baguio. (same area as S-10 above) Photo by L. Wennerberg

S-12: Collapsed structure in the Export Processing Zone, Baguio. Building in background with identical design suffered damage to columns, but did not collapse. (same area as S-10 and S-11 above) Photo by L. Wennerberg

S-13: A GEOS (Generalized Earthquake Observing System) instrument used for aftershock studies of the 7/16/90 Luzon, Philippines earthquake. Photo by C. Newhall

S-14: Deployment of a GEOS at the site of a collapsed factory in the Export Processing Zone, Baguio. Same site as in S-8. Photo by C. Newhall

S-15: Strong shaking caused collapse of building in Baguio. Photo by L. Wennerberg

S-16: Concrete bus waiting-stand in Agoo toppled by strong shaking in 7/16/90 earthquake. Photo by G. Wieczorek

S-17: Strong shaking damage to unreinforced masonry church in Naguilian, about 12 km southeast of San Fernando. Photo by G. Wieczorek

S-18: Collapse of first story of a multi-story residence from strong shaking in Umingan. Photo by C. Newhall

S-19: Recovery of rebar steel from Philippine Christian Colleges building in Cabanatuan. This was the only major structure to collapse in this major town closest to the epicenter of the 7/16/90 earthquake. Photo by C. Newhall

S-20: Because of apparently weak shaking, it was difficult to find any damage in San Jose, although the surface trace of the fault rupture was less than 10 km away. Photo by L. Wennerberg

S-21: Structural collapse of buildings in La Trinidad, a city in the mountains approximately 6 km north of Baguio and 40 km NE from the nearest observed surface rupture. Photo by L. Wennerberg

S-22: Front wall of building that collapsed in San Fernando on the west coast, approximately 60 km from observed surface fault rupture. Photo by L. Wennerberg

LIQUEFACTION

L-1: Southwestward aerial view of central Dagupan, where extensive liquefaction of saturated sandy sediments during earthquake resulted in subsidence and tilting of buildings in a 0.5-0.6 km^2 area. Collapsed Perez Blvd. bridge (in foreground) resulted from lateral spread of river banks toward center of San Pablo River channel. Photo by G. Wieczorek

L-2: Northwestward aerial view of Dagupan, with buildings tilted by differential settlement into liquefied soils. Gray patches on streets are sand-boil deposits from liquefaction in the 7/16/90 earthquake. (Closeup from a slightly different view of top portion of L-1). Photo by C. Newhall

L-3: Buildings along Perez Blvd. in central Dagupan, one of which has tilted 18 degrees and is now supported by adjacent building. Gray patches in front of buildings is sand expelled during liquefaction. Photo by C. Newhall

L-4: Subsidence and tilting of buildings along Perez Blvd. in Dagupan. Gasoline tanks at service station in background floated to ground surface in the liquefaction area during earthquake. Photo by C. Newhall

L-5: Subsidence of 1 - 2 m and tilting of building due to liquefaction at corner of Perez Blvd. and Galvan St. in Dagupan. Photo by G. Wieczorek

L-6: Perez Blvd. Bridge over the San Pablo River, Dagupan, collapsed due to a liquefaction-induced lateral spread of the river banks toward the center of the channel. (same bridge appears in center of L-1). Photo by G. Wieczorek

L-7: Differential settlement due to liquefaction damaged this service station along Perez Blvd. in Dagupan. Gasoline tanks in background floated to the ground surface during the earthquake. Photo by C. Newhall

L-8: First story of radio tower building in Dagupan, originally level with the sidewalk at left has subsided approximately 2 m. Ground fractures and expelled sand indicated liquefaction had occurred beneath building. (radio tower building appears in center of L-1). Photo by G. Wieczorek

L-9: Drilling a water well in Dagupan. Liquefaction-induced ground failure and subsidence was extensive through parts of the city and damaged the water distribution system. Photo by L. Wennerberg

L-10: Large sand boils up to 5 m in diameter near Aringay caused by liquefaction during the earthquake of 7/16/90. Patches of expelled sand from large sand boils were abundant in fields and along coast of Lingayen Gulf between Aringay and Dagupan. Photo by G. Wieczorek

L-11: Multi-section Carmen bridge at Rosales collapsed during 7/16/90 earthquake. Sections of decking and superstructure fell off bridge supports after liquefaction-induced tilting of foundation piers. Bridge originally crossed the broad floodplain about 3 m above ground level. Photo by G. Wieczorek

L-12: Foundation piers of bridge at Rosales, tilted up to 30 degrees from vertical due to liquefaction during the 7/16/90 earthquake. Sand boils and fissures were abundant around bridge. Photo by G. Wieczorek

MASS MOVEMENT

M-1: Massive landsliding triggered by the 7/16/90 earthquake on slopes above village of Digdig. Shallow soil and rock slides brought down large volumes of loose debris from hillsides into ravines, onto alluvial fans, and into rivers; recently deposited sediment can be observed near bridge. Photo by G. Wieczorek

M-2: Abundant shallow soil and rock slides triggered by the 7/16/90 earthquake in mountains near the surface fault rupture of the Digdig fault. Thin soil and shallow rock slides occurred preferentially on steep slopes at ridge crests and noses. Photo by G. Wieczorek

M-3: Reactivated rock block slide along mountainous highway southeast of Baguio. Throughout the area affected by landsliding in the 7/16/90 earthquake only a few block slides and slumps of soil and rock were observed. Photo by G. Wieczorek

M-4: View across body of large complex slump-soil lateral spread at Bateria, triggered by 7/16/90 earthquake. Landslide moved toward the left in this photo; disrupted remnants of roadway surface are visible on body of slide. Road originally extended straight toward bus in the background, beyond the northwest flank of slide. Photo by G. Wieczorek

M-5: Disruption of the Dalton Pass highway from San Jose to Santa Fe caused by landslides severely limited access to northern Luzon in the weeks following the 7/16/90 earthquake. Soil and rock shaken lose by the earthquake was mobilized from hillside ravines by subsequent storms into debris flows that periodically blocked roads. Photo by G. Wieczorek

M-6: Near San Nicolas, large quantities of sediment and trees have been deposited by debris flows and flood waters in the channels and along the banks of rivers below mountainous areas severely affected by landslides in the 7/16/90 earthquake. Some post-earthquake debris flows originated as earthquake-generated landslide debris on hillsides and in ravines; others formed in major channels in response to overtopping of earthquake-induced landslide dams that had briefly blocked the rivers. Photo by G. Wieczorek

M-7: Bridge at Puncan has been blocked by logs and sediment. Increased sediment and organic load in the river has been generated by landslides triggered by the 7/16/90 earthquake. A small lake has backed up behind the bridge and is draining across the Dalton Pass highway. Photo by C. Newhall

M-8: Logs backed up behind bridge near Umingan. Flooding during monsoon season was accentuated by increased sediment and organic load in rivers from landslides triggered by the 7/16/90 earthquake. Here, accumulation of logs during a high-flow period threatens to destabilize bridge supports. Photo by C. Newhall

M-9: Ground fissures of a lateral spread oriented parallel to the river, near Aringay, indicated downslope extensional movement towards river. Sand was expelled from some fissures, providing evidence that liquefaction occurred in association with this lateral spread. Photo by G. Wieczorek

M-10: Lateral spread in embankment fill damaging highway north of Rizal. Water level in adjacent fields generally close to ground surface. Photo by Trevor Matuschka

M-11: Scarp of slump on upstream shoulder of Masiway Dam embankment located approximately 20 km northeast of Rizal. Photo by Trevor Matuschka

M-12: Rock and debris slides north of Baguio on route to Ambuklao Dam. Photo by Trevor Matuschka

M-13: Settlement of rock fill adjacent to spillway of Ambuklao Dam about 15 km northeast of Baguio. Photo by Trevor Matuschka

M-14: Rock slides behind switchyard at Ambuklao Dam about 15 km northeast of Baguio. Note large boulder in yard. Photo by Trevor Matuschka

M-15: Pile foundations of transmission tower were partially undermined by debris slide near Ambuklao Dam about 15 km northeast of Baguio. Photo by Trevor Matuschka

M-16: Transmission tower suspended by wires following landslide near Ambuklao Dam about 15 km northeast of Baguio. Photo by Trevor Matuschka

M-17: Extensive landslides caused by the earthquake in steep terrain of northern Luzon. Photo by PHIVOLCS staff and John Nagata

M-18: Extensive landslides caused by the earthquake, and heavy production of sediment caused by the monsoonal rains. Photo by PHIVOLCS staff and John Nagata

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