Geologic Hazards Photos Volume 2
Earthquake Events

Cape Mendocino Earthquakes: An Illustration of the Effects of a Moderately Large Earthquake in a Sparsely Settled Area

Statistics:
On April 25, 1992, at 11:06 A.M. a magnitude 7.1 mainshock near Petrolia, California, initiated a series of shocks in the Cape Mendocino area. Two additional shocks of magnitudes 6.6 and 6.7 occurred the next morning. The first shock was located six miles north of Petrolia in a sparsely populated part of southwestern Humbolt County. The second and third earthquakes were located offshore, about sixteen miles west of the first earthquake. The three quakes were felt over an approximate area of 86,000 km2. The region of strongest earth shaking is bonded by the Eel and Mattole River valleys. Five small communities are located within a 50 mile radius of the three earthquake: Honeydew, Petrolia, Rio Dell, Scotia, and Ferndale.

The main shock came immediately after a Saturday morning parade at Ferndale, the only population center in the epicentral area. Horses were reportedly spooked during the parade, but riders attributed it to the flags fluttering in the wind along the parade route.

Seismicity and Geology:
The Cape Mendocino region of California's north coast is one of the most seismically active regions in the conterminous United States. This seismic zone accounts for twenty-five percent of the seismic energy release in California in the last 50 years. It coincides with the Mendocino Triple Junction, a tectonically unstable area where three tectonic plates that make up the earth's outer shell join together. Paleoseismicity studies of two major zones of faulting in the southern Cascadia subduction zone fold-and-thrust belt near Eureka have produced a record of at least five large earthquakes during the past 1,700 years.

The mainshock on April 25 is exceptional for several reasons: It generated a tsunami, which was well recorded along the West Coast and measurable in the Hawaiian Islands. It also produced distinct uplift (maximum uplift = 1m) along a 25-km- long section of the coastline. Ground shaking during the quake reached at least intensity VIII on the Modified Mercalli scale. The April 25 mainshock is the largest historic earthquake in this region with an epicenter clearly located on land and the only damaging event that may have resulted from thrust faulting along the Cascadia subduction zone.

Damage:
Collectively these shocks caused significant damage to older structures in the sparsely populated, mountainous, epicentral region. The earthquake caused 98 injuries and moderate damage in Humboldt County. Losses could top $66 million. Single- and double-story, wood-frame houses and commercial buildings were the most common type of structures in the epicentral region, where lumbering is the principal industry. Many foundations were the pier and post type which provide little resistance to lateral ground shaking. The earthquakes jarred many older homes with this type of underpinning off their foundations.

Earth Effects:
A broad zone of ground fractures, coastal uplift, and elevation changes are the only surface changes to indicate the location and tilt of the fault plane. Strong ground shaking during the earthquakes triggered numerous landslides in steep mountainous areas. A landslide at Scotia Bluffs (south of Scotia) temporarily interrupted traffic on the North Coast Railroad. Tension cracks, due to soil compaction and downhill slumping, restricted traffic on the Mattole Road between Honey-dew, Petrolia, and Ferndale.

Liquefaction took place in scattered localities in modern deposits of the Mattole River between Petrolia and Honeydew and in the flood-plain deposits of the Eel and Salt Rivers. Soils liquefy when ground water near the surface is forced between the grains of sand during an earthquake. The sandy soil behaves like a very thick liquid. Structures then settle or tip in the liquefied soil or are ripped apart as the ground spreads laterally or

flows. Sand blows result from the eruption of liquefied sediment from the subsurface onto the ground. The eruption of liquefied sediment is facilitated by fissures in the ground, which are also produced by strong shaking during an earthquake. Many geologists and seismologists believe that the main shock in this sequence may be a forerunner of a much more powerful earthquake in the Pacific Northwest.

Slide Set Images

Garage slid down hill due to earth shaking This garage slid down hill due to the earth shaking in Rio Dell, a town of 2,900. The garage extended out over the north bank of the Eel River. The garage was supported by a framework of wooden stilts. The stilts collapsed and the garage fell backwards from street level. Other buildings in the neighborhood had similar damage, but the damage was not as severe or as impressive. This neighborhood was an older residential area which lay just south of the business district of Rio Dell and followed the Eel River bank. At total of twelve homes were destroyed, and 57 sustained major damage in Rio Dell. On Main Street fifteen out of twenty of the older one and two-story buildings incurred damage including broken glass, fallen bricks, and cracked plaster. Buildings shifted as much as two feet from their pre-earthquake positions. The earthquake caused contamination of water supply systems, broke water mains and sewer pipes, and interrupted telephone, gas and electricity services. The total earthquake damage was estimated at $8 million. Photograph credit: Lindie Brewer, U.S. Geological Survey.

View of mall at Scotia that was destroyed by earthquake-caused fire The view shows the area destroyed by the fire in Scotia. It is believed that the fire early Sunday, April 26th, resulted from an electrical short caused by the earthquake. Before the fire, the mall consisted of five one-to two-story, wood-frame, commercial buildings including a lumber yard, a pharmacy, a coffee shop, a grocery store and a Ben Franklin Variety Store. While local firemen were attempting to save the mall, the second major shock occurred which snapped the town's water main. Firemen drew water from a nearby log pond, in order to continue fighting the fire. Scotia, a 123-year-old town lies north of Rio Dell across the Eel River. The two towns are joined by bridges across the Eel River. Fifty homes were damaged and a shopping center consisting of five stores burned to the ground. As in Rio Dell, water mains and sewer pipes were broken and water supply systems contaminated. Telephone, gas and electricity services were interrupted. Total damage was estimated at between $10 and $15 million. Photograph credit: Lindie Brewer, U.S. Geological Survey.

Second view of Scotia mall A second view of the mall in Scotia that was destroyed by a fire. It is believed that the fire early Sunday, April 26th, resulted from an electrical short caused by the earthquake. Before the fire, the mall consisted of five one-to two-story, wood-frame, commercial buildings including a lumber yard, a pharmacy, a coffee shop, a grocery store and a Ben Franklin Variety Store. While local firemen were attempting to save the mall, the second major shock occurred which snapped the town's water main. Firemen drew water from a nearby log pond, in order to continue fighting the fire. Scotia, a 123-year-old town lies north of Rio Dell across the Eel River. The two towns are joined by bridges across the Eel River. Fifty homes were damaged and a shopping center consisting of five stores burned to the ground. As in Rio Dell, water mains and sewer pipes were broken and water supply systems contaminated. Telephone, gas and electricity services were interrupted. Total damage was estimated at between $10 and $15 million. Photograph credit: Lindie Brewer. U.S. Geological Survey.

Support pillar on Scotia's Lumber Museum A redwood support pillar at the top of the portico that covered the front entrance to the Lumber Museum in Scotia shifted during the earthquake. The Lumber Museum is located on Scotia's Main Street, just across the street from the burned out mall. Although the museum was closed, other exterior damage was to windows which were either cracked or broken out. After the quake sheets of plywood covered the damaged windows. Photograph credit: Lindie Brewer, U.S. Geological Survey.

Damage to 70-year old house and chimney in Honeydew This 2-story, wood-frame, stucco-veneer house in Honeydew was severely cracked when the chimney pulled away from the house. The east-west sway of the 70-year old structure during the earthquake caused the separation between the chimney and the house. The house was vacant at the time. In this town, close to the epicenter, houses were shifted on foundations; cupboards were emptied; and brick chimneys fell. The single-story, wood-frame building where the post office and general story were located showed no signs of movement on its foundation. Photograph credit: Lindie Brewer, U.S. Geological Survey.

Remains of Petrolia's business district after earthquake and fire This slide shows the remains of the business district in Petrolia after the earthquake-related fire burned the Post Office and the 100-year-old general store. Downtown Petrolia consisted of a post office, a 100-year old general store, a gas station, and a volunteer fire station. The post office, gas station, and the general store burned to the ground in an earthquake-related fire. The door of the fire station was jammed by the first large shock. Several firemen were required to raise the door before the fire equipment could be removed. The fire station was later condemned. Buildings that had been recently constructed performed well during the earthquakes with little or no damage. However, damage was severe to poorly-built or poorly-designed structures. One and two story, wood frame houses and commercial buildings were the most common type of construction. A total of five homes were destroyed, 28 sustained major damage, and 25 required minor repairs. Total damage was estimated at $1 million. As in other towns in Humboldt County, services including water, sewer, telephone, gas and electricity were interrupted. Photograph credit: Lindie Brewer, U.S. Geological Survey.

Chimney damage in Petrolia This brick chimney, typical of many others in Petrolia, was toppled due to the severe earth shaking. Other chimneys (even those with steel rods) were broken, or cracked. The inside fireplace in this house was also shattered. Photograph credit: Lindie Brewer, U.S. Geological Survey.

Earthquake bounced this front-end loader one foot into the air This large front-end loader, located in a residential neighborhood of Petrolia about three blocks east of the burned business district, reportedly was bounced one foot into the air. On this same street, new homes of good construction were not damaged; nearby an older, wood-frame home was severely damaged when it was partially shirred off its foundation. Photograph credit: Lindie Brewer, U.S. Geological Survey.

Petrolia residence shifted on foundation This Petrolia residence shifted on its foundation causing the porch to separate from the house. Wooden skirting along the bottom of the house shows the direction of movement of the house on the foundation. Photograph credit: Lindie Brewer, U.S. Geological Survey.

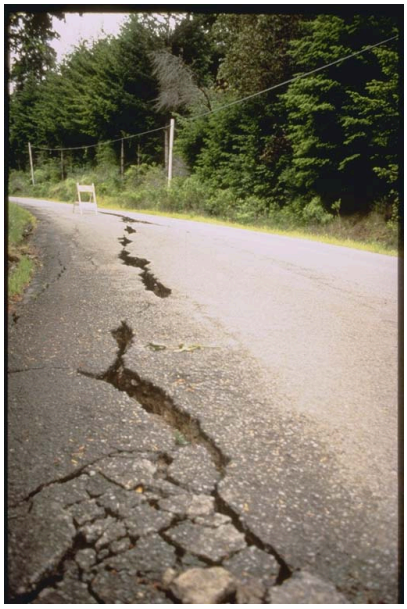
Residence south of Petrolia that shifted off foundation The Christian residence south of Petrolia shifted off its foundation because the house was not anchored to the foundation. The structure, which was declared a total loss by insurance standards, shifted toward the northwest. A primitive post and pier foundation was common in the Petrolia area. This view shows separation of the porch from the rest of the structure. The house damage was more severe where additions were attached to the original structure. Photograph credit: Lindie Brewer, U.S. Geological Survey.

Damage Due to Inadequate Cross-Bracing, Iran BUILDING DAMAGE, STEEL STRUCTURES
Damaged four-story steel structure with inadequate bracing on one side. The cross-bracing on the back side of the building prevented serious structural damage. The inadequate bracing did, however, fail at their connections during the shaking. The braces were later repaired and the building was restored. Photograph Credit: M. Mehrain, Dames and Moore.

Tilt of 8-story Steel Structure, Iran BUILDING DAMAGE, STEEL STRUCTURES Tilt from the perpendicular of an 8-story steel structure that was under construction at the time of the earthquake. There were insufficient moment frames in the direction in which the tilt occurred. The damage to the building resulted from inadequate design and detailing and deficiency in workmanship. Photograph Credit: M. Mehrain, Dames and Moore.

Damage to Building with Rod Bracing, Iran BUILDING DAMAGE, STEEL STRUCTURES Although the rod bracing ruptured in this light steel industrial building in Ganjeh, thirty kilometers from the epicenter, there was no structural damage. Only two per cent of the buildings in the area were fabricated with steel frames or reinforced concrete. Had these types of construction been extensively used, the damage and death toll would have been lowered considerably. Photograph Credit: M. Mehrain, Dames and Moore.

Concrete Frame Construction, Iran BUILDING DAMAGE, CONCRETE BUILDINGS
Typical Iranian concrete frame construction with brick infill. As in past earthquakes, nonductile concrete-frame buildings performed poorly, and unreinforced masonry infill construction was most vulnerable to earthquake damage. Photograph Credit: M. Mehrain, Dames and Moore.

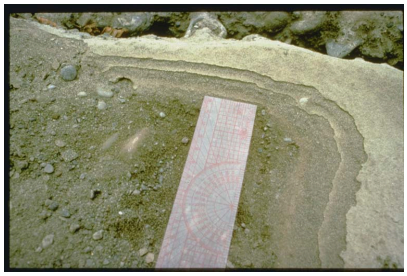


Collapse of Mid-Rise Concrete Building, Iran BUILDING DAMAGE, CONCRETE BUILDINGS
Collapse of a mid-rise concrete building and damage to the adjacent building. The two adjacent 5-story concrete-frame buildings were both under construction at the time of the earthquake. The structure on the right collapsed completely damaging the corner column of the structure to the left. Photograph Credit: M. Mehrain, Dames and Moore.

Total Failure of Mid-Rise Concrete Building, Iran BUILDING DAMAGE, CONCRETE BUILDINGS
Total failure of a mid-rise concrete building in Rasht. The building had plain (undeformed) bars for reinforcement. In the City of Rasht, far field, long-period ground motion appeared to cause the partial or total collapse of many such mid-rise buildings. Photograph Credit: M. Mehrain, Dames and Moore.

Damage to Elevated Concrete Water Tank, Iran OTHER STRUCTURAL DAMAGE
Concrete elevated water tank-empty at the time of the earthquake-shows only tension cracks at the base of its shaft. Elevated water tanks sway like inverted pendulums during earthquake shaking. When the tanks are filled with sloshing water, the shafts supporting the tanks generally fails. In general such elevated concrete water tanks sustained damage in this earthquake. Photograph Credit: M. Mehrain, Dames and Moore.

Collapse of Concrete Water Tank, Iran OTHER STRUCTURAL DAMAGE
This elevated concrete water tank, two-thirds full at the time of the earthquake, collapsed. The tank was forty-six meters high and had a volume of one thousand five hundred m3. The structure had a reinforced concrete shaft and a prestressed concrete tank and had served the City of Rasht for twenty years. Fortunately the tank collapsed away from an adjacent building. Photograph Credit: M. Mehrain, Dames and Moore.



Pier Displacement of Concrete Bridge, Iran OTHER STRUCTURAL DAMAGE
Large lateral pier displacement of undamaged concrete bridge. Although the lateral displacement at the ground level was about 25.4 cm there was no observable damage either to the columns or girders of this bridge. In general bridges performed relatively well in the 1990 Iranian earthquake. Photograph Credit: M. Mehrain, Dames and Moore.

Sefidrud Dam, Iran OTHER STRUCTURAL DAMAGE
Relatively undamaged Sefidrud Dam located within one km of the fault. The buttress dam has a height of 106 meters, a length of 425 meters and a base width of 100 meters. The dam was reportedly designed for a static lateral force coefficient of 0.25. The reservoir was almost full at the time of the earthquake and experienced very intense ground motion (0.60g). Horizontal and diagonal cracks occurred at the top of some buttresses, but the dam remained stable. However, a massive rockfall near the dam caused the collapse of the guard house and the death of the guard. Photograph Credit: M. Mehrain, Dames and Moore.

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