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Seismicity of the Earth 1900–2012

Philippine Sea Plate and Vicinity

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TECTONIC SUMMARY

The Philippine Sea plate is bordered by the larger Pacific and Eurasia plates, and by the smaller Sunda plate. The Philippine Sea plate is unusual in that its borders are nearly all zones of plate convergence. The Pacific plate is subducted into the mantle, south of Japan, beneath the Izu-Bonin and Mariana Island arcs, which extend more than 3,000 km along the eastern margin of the Philippine Sea plate. This subduction zone is characterized by rapid plate convergence and high-level seismicity extending to depths of over 600 km. In spite of this extensive zone of plate convergence, the plate interface has been associated with few great (M > 8.0) "megathrust" earthquakes. This low seismic energy release is thought to result from weak coupling along the plate interface (Scholz and Campos, 1995). This convergent plate margin is also associated with unusual zones of back-arc extension (along with resulting seismic activity) that decouple the volcanic island arcs from the remainder of the Philippine Sea plate (Karig and others, 1978; Klaus and others, 1992).

South of the Mariana arc, the Pacific plate is subducted beneath the Yap Islands along the Yap trench. Similarly, the northwestern margin of the Philippine Sea plate is subducting beneath the Eurasia plate along a convergent zone, extending from southern Honshu (north of the map area) to the northeastern coast of Taiwan, manifested by the Ryukyu Islands and the Nansei-Shoto extension; the Okinawa Trough. At Taiwan, the plate boundary is characterized by a zone of arc-continent collision; whereby the northern end of the Luzon island arc is colliding with the buoyant crust of the Eurasia continental margin offshore China.

Along its western margin, the Philippine Sea plate is associated with a zone of oblique convergence with the Sunda plate. This highly active convergent plate boundary extends along both sides the Philippine Islands, from Luzon in the north to Sulawesi in the south. The tectonic setting of the Philippines is unusual in several respects: it is characterized by opposite-facing subduction systems on its east and west sides; the archipelago is cut by a major transform fault, the Philippine Fault; and the arc complex itself is marked by volcanism, faulting, and high seismic activity. Subduction of the Philippine Sea plate occurs at the eastern margin of the archipelago along the Philippine Trench and its northern extension, the East Luzon Trough. The East Luzon Trough is thought to be an unusual example of a subduction zone in the process of formation, as the Philippine Trench system gradually extends northward (Hamburger and others, 1983). On the west side of Luzon, the Sunda plate subducts eastward along a series of trenches, including the Manila Trench in the north, the smaller and less well-developed Negros Trench in the central Philippines, and the Sulu and Cotabato trenches in the south (Cardwell and others, 1980). At its northern and southern terminations, subduction at the Manila Trench is interrupted by arc-continent collision between the northern Philippine Island arc and the Eurasian continental margin between the Sulu-Borneo Block (Sunda plate) and Luzon at the island of Mindoro. The Philippine Fault, which extends over 1,200 km within the Philippine arc, is seismically active. The fault has been associated with major historical earthquakes, including the destructive M7.6 Luzon earthquake of 1990 (Yoshida and Abe, 1992). Several other active intra-arc fault systems are associated with moderate-to-high seismic activity, including the Cotabato Fault and the Verde Passage-Sibuyan Sea Fault (Galgana and others, 2007).

Relative plate motion near the Philippines (about 80 mm/yr) is oblique to the plate boundary along the two plate margins of central Luzon, where it is partitioned into orthogonal plate convergence in the subduction zones and nearly pure translational motion along the Philippine Fault (Barrier and others, 1991). Profiles B and C reveal evidence of opposing inclined seismic zones at intermediate depths (roughly 70–300 km), and complex tectonics at the surface along the Philippine Fault.

Several relevant tectonic elements, plate boundaries, and active volcanoes, provide a context for the seismicity presented on the main map. The plate boundaries are well constrained along the axis of the trenches and more diffuse or speculative in the South China Sea and Lesser Sunda Islands. The active volcanic arcs (Siebert and Simkin, 2002) follow the Izu, Volcano, Mariana, and Ryukyu island chains, and the main Philippine Islands parallel to the Manila, Negros, Cotabato, and Philippine trenches.

Seismic activity related to the motions of the Philippine Sea plate (Allen and others, 2009) has produced seven great (M>8.0) earthquakes and 250 large (M>7) events. Among the most destructive events were the 1923 Kanto earthquake, the 1948 Fukui and the 1995 Kobe (Japan) earthquakes (99,000, 5,100, and 6,400 casualties, respectively), the 1935 and the 1999 Chi-Chi (Taiwan) earthquakes (3,300 and 2,500 casualties, respectively), and the 1976 M7.6 Moro Gulf and 1990 M7.6 Luzon (Philippines) earthquakes (7,100 and 2,400 casualties, respectively). Some events are too small to show on the map. There have also been several tsunami-generating events in the region, including the Moro Gulf earthquake, whose tsunami resulted in more than 5,000 deaths.

DATA SOURCES

The earthquake locations shown on the main map (left) and on the depth profiles (lower left) are taken from the global 1900–2007 Centennial catalog (Engdahl and Villaseñor, 2002), a catalog of high-quality depth determinations for the period 1964–2002 (Engdahl, personal commun., 2003), and U.S. Geological Survey (USGS) National Earthquake Information Center (NEIC) for the period 2008–2010. Major earthquakes (7.5–8.2) are labeled with the year of occurrence, whereas earthquakes (8.0–8.2) are labeled with the year of occurrence and also denoted by a white outline (Tarr and others, 2010).

The Seismic Hazard and Relative Plate Motion panel displays the generalized seismic hazard of the region (Giardini and others, 1999) and representative relative plate motion vectors using the MORVEL model (DeMets and others, 2010).

Pre-instrumental seismicity for the Philippine Sea was obtained from the NOAA National Geophysical Data Center (2010) database of significant earthquakes; locations are Geophysical Data Center (2010) database of significant earthquakes. Locations are approximate, based on macro-seismic reports and field investigations. We selected earthquakes with associated reports of moderate to major damage, 10 or more deaths, and estimated magnitude of 7.5 or greater (if known), Modified Mercalli Intensity at least X, or tsunami generation.

Base map data sources include GEBCO (2008), Volcanoes of the World dataset (Siebert and Simkin, 2002), plate boundaries (Bird, 2003), and geographic information from Digital Chart of the World (1992), and ESRI (2002). Slab contours are from Hayes and others (2012). Additional information on plate boundaries in the Philippine region was derived from Galgana and others (2007) and Galgana (2008).

Seismic Hazard and Relative Plate Motion

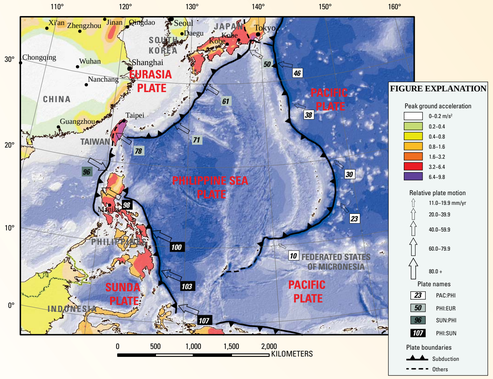

FIGURE EXPLANATION

Peak ground acceleration
- 0–0.2 m/s²
- 0.2–0.4
- 0.4–0.8
- 0.8–1.6
- 1.6–3.2
- 3.2–6.4
- 6.4–9.8

Relative plate motion
- 11.0–19.9 mm/yr
- 20.0–39.9
- 40.0–59.9
- 60.0–79.9
- 80.0 +

Plate names: 23 PAC-PHI; 50 PHI-EUR; 46 SUN-PHI; 107 PHI-SUN

Plate boundaries: Subduction; Others

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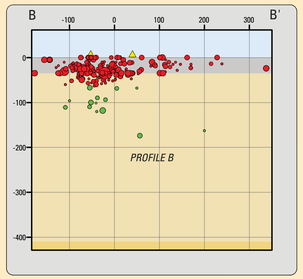
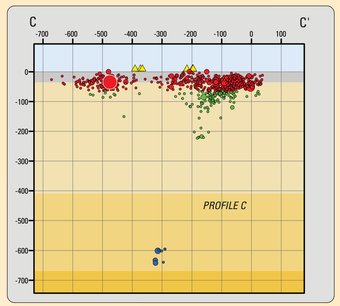
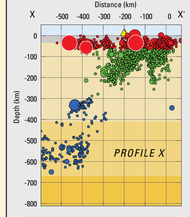




DEPTH PROFILE EXPLANATION

Profiles of earthquake and volcano locations are constructed from the mapped data. Locations of the profile intersection with the surface are drawn on the map and labeled to coincide with the profile label. Box defines extent of earthquakes included in the profile. Length of the profile graphic is the same as in the map. Distance in kilometers from the trench axis is indicated in the X direction, depth in kilometers is indicated in the Y direction. There is no vertical exaggeration. See Explanation for color key. Not all earth layers, earthquake depths or magnitude, are visible on every profile.

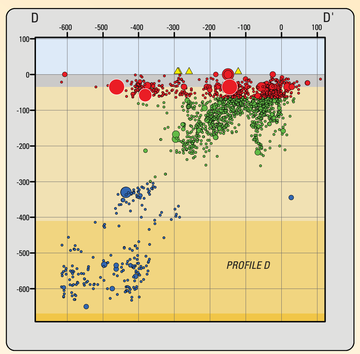


Magnitude Classes
- 4 - 5.9
- 6 - 6.4
- 6.5 - 6.9
- 7 - 7.4
- 7.5
- 7.6
- 7.7
- 7.8
- 7.9
- 8.0
- 8.1
- 8.2

Depth of Focus
- 0 - 69 km
- 70 - 299 km
- 300 - 700 km

Quaternary Volcanoes

Earth Structure
- Air
- Crust
- Upper Mantle
- Transition Zone
- Lower Mantle



MAP EXPLANATION

Magnitude classes
- 6.5-7.0
- 7.0-7.5
- 7.5-7.6
- 7.6-7.7
- 7.7-7.8
- 7.8-7.9
- 7.9-8.0
- 8.0-8.1
- 8.1-8.2

Active volcanoes

Mean slab depth: 60 km; 100; 200; 300; 400; 500; 600

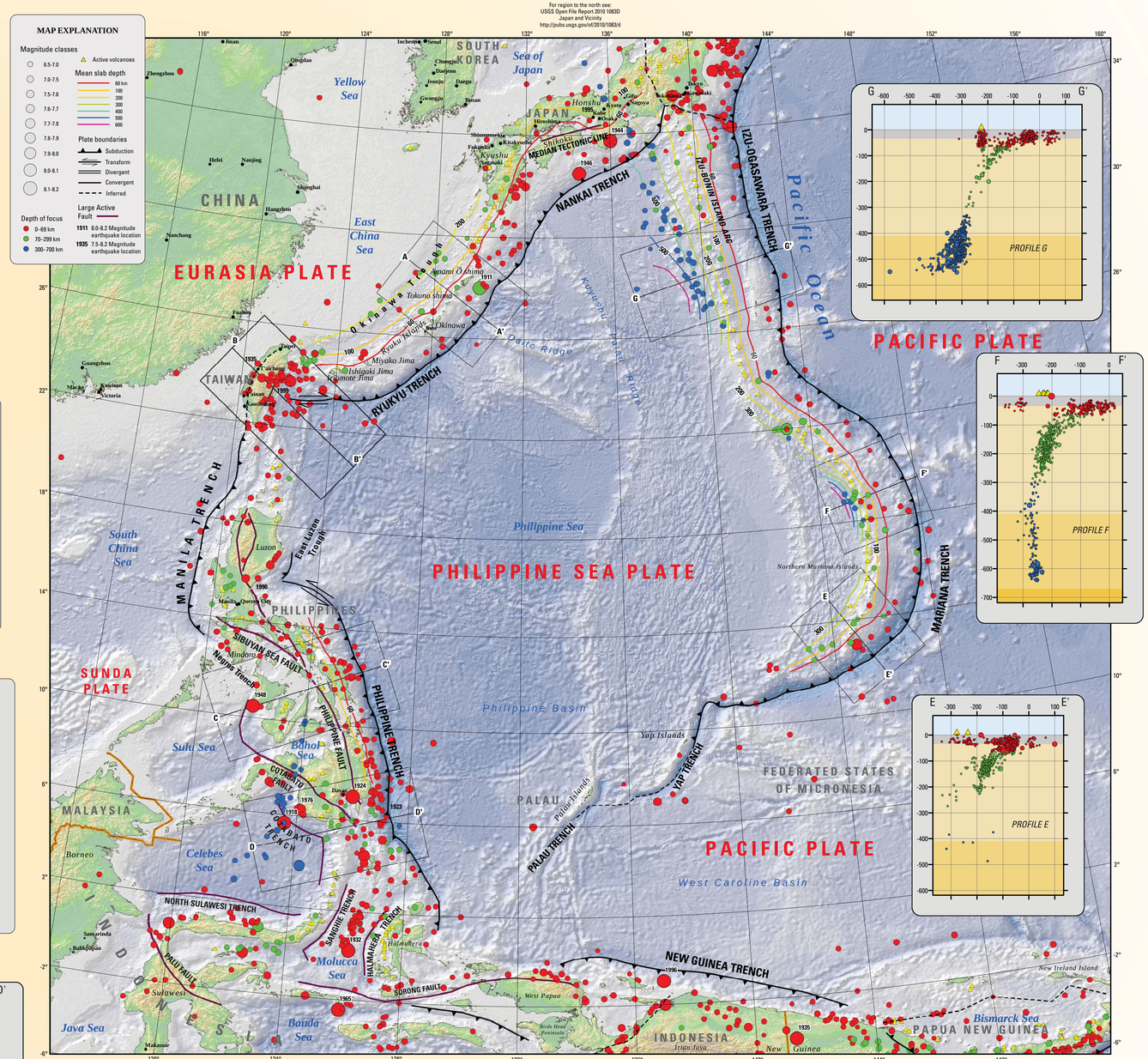
Plate boundaries: Subduction; Transform; Divergent; Convergent; Inferred

Large Active Fault

1911 8.0-8.2 Magnitude earthquake location

1935 7.5-8.2 Magnitude earthquake location

Depth of focus
- 0-69 km
- 70–299 km
- 300–700 km



Albers Equal Area Conic Projection
Digital map database and cartography by Greg Smoczyk
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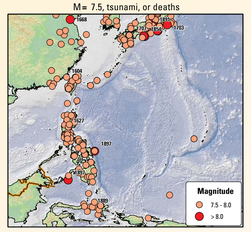
SCALE 1:10,000,000
0 200 400 600 800 1,000 KILOMETERS

For region to the south see: USGS Open File Report 2010 1083H New Guinea and Vicinity http://pubs.usgs.gov/of/2010/1083/h

PRE-INSTRUMENTAL SEISMICITY 1500–1899

M= 7.5, tsunami, or deaths



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