SELECTED
PHILIPPINE SEISMICITY REFERENCES

Edited by David J. Leeds

January 1977

Note: These 44 pages of annotated references have been extracted from a longer, comprehensive documentation of Philippine seismicity in order to supplement the EERI Reconnaissance Report on the 1976 Mindanao Earthquake. For details on availability of the complete reference list, contact the Editor.
The Philippines alone has a dozen or so of these active volcanoes to her name. These volcanoes, starting from the north, are: Batan, Caballo, Smith Volcano, Camiguin, Bohol, Leyte, Samar, Guimaras, Negros, and a few others. By reason of geography, therefore, it is not surprising that the Archipelago has so many volcanoes.

Curiously, when one next considers the distribution in space of destructive tectonic earthquakes, he finds that such quakes have also shown a tendency to be centered either along the borders of the Pacific or along the Mediterranean-Himalayan region. The two major volcanic belts of the world and its two main seismic regions are, therefore, coincident or the same. Thus one speaks of the "Circum-Pacific belt of fire" as the "Circum-Pacific seismic belt," and the "Mediterranean volcanic belt" as the "Mediterranean seismic belt." This close parallelism of the world's main volcanic and seismic regions further shows that volcanicity and seismicity are inter-related to crustal deformation, and their ratings in point of time, a measure of crustal unrest.

From a consideration of the major seismic belts of the world, one finds that again by reason of geography the Philippines is also earthquake prone. She has been visited by destructive earthquakes in the past, very recently, and will no doubt be so visited in the years to come. The second major seismic belt cuts through the Mediterranean and the Black Sea, thence along the Himalayas and into China, and then merges with the Pacific Basin belt in the area between the Philippines and New Guinea. We, therefore, find the Philippines in that unfortunate position of being at or close to the juncture of two major seismic belts. By the law of averages then, more earthquakes should occur near or within our Islands than in those regions far from this juncture, and statistics bear this point out.

According to one investigator, the ten places most visited by earthquakes during the 19th century were:

- Philippines
- China
- Java
- Japan
- Mexico
- Greece
- India
- United States
- Brazil
- Australia

The above list shows the Philippines at the head with a relative seismicity rating of 71. 29 points more than Japan — very well known for her earthquakes.

Available data on Philippine seismicity shows that the Archipelago feels on the average country are equally vulnerable to destructive earthquakes. This is so because, while the Philippines is cross-cut by large fractures along which any dislocation would produce a tectonic earthquake, the fractures or structural surfaces of weakness are not so the same stability. Displacements take place more often in some than in others.

Studies show that tectonic earthquakes and volcanic eruptions, though seemingly unrelated solid earth, are indeed ultimately traceable to build-up of strain within the crust and, therefore, serve as indicators of crustal unrest; that the Philippines, because of its geographic position has had volcanic eruptions and destructive earthquakes in the past, and will doubt have more of the same in the immediate future; and that destructive earthquakes tend to be centered along active major structural lines of the Archipelago. If we plot the distribution time of volcanic eruptions and destructive earthquakes that
The last decade of the nineteenth century was quite a typically restless period for the Philippines, a period that lasted four years into the twentieth century. During this period the Philippine archipelago was subjected to some of the most destructive earthquakes and volcanic eruptions in its history. The last of these events was the eruption of Mayon Volcano in 1943, which destroyed the town of Legazpi and killed over 2000 people.

The next active period covered seven years from 1911 to 1918, during which the eruptive activity of Taal Volcano on January 30, 1911, and the eruption of Mayon Volcano in 1934, and the eruption of Pinatubo in 1932, were the most significant events. Taal Volcano erupted on January 30, 1911, and the eruption of Mayon Volcano in 1934, and the eruption of Pinatubo in 1932, were the most significant events. Taal Volcano erupted on January 30, 1911, and Mayon Volcano erupted on August 19, 1934, and Pinatubo Volcano erupted on May 15, 1932.

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Circum-Pacific Faulting in the Philippines-Taiwan Region

CLARENCE R. ALLEN
Division of Geological Sciences
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Abstract. Conflicting views of circum-Pacific tectonics have focused on the Philippines-Taiwan region, where there has been neither convincing documentation nor general agreement on the importance of transcurrent (strike-slip) faulting or the possible sense of regional horizontal displacement. Structural and physiographic features of the 1200-km-long Philippine fault zone are fully as spectacular as those of the better-known San Andreas and Alpine faults, and current activity is indicated by many localities in which scarps cut Recent gravels. Predominance of horizontal over vertical displacements is indicated by linearity of the fault trace, failure of one side to be consistently higher than the other, disregard for gross physiography, and scissoring of individual scarps within the zone. Consistent stream offsets on Luzon, Masbate, and Leyte demonstrate unequivocally that the sense of Recent displacement has been uniformly sinistral (left-handed). The Philippine fault has no obvious geologic relationship to active volcanoes, but the parallelism and proximity of the fault to the Mindanao trench suggest a close causal relationship. The remarkable Longitudinal Valley of eastern Taiwan represents another great transcurrent fault parallel to the western Pacific rim, and ground displacements during historic earthquakes indicate a sinistral sense of displacement here as well as in the adjacent Philippines. This study does not support the hypothesis of counterclockwise rotation of the Pacific basin, but more important is the further documentation of the predominance of transcurrent faulting in active circum-Pacific orogenic areas. These results reinforce earlier field studies in Alaska, California, Chile, and New Zealand, as well as emphasizing the geological reality of the results of seismic fault-plane solutions indicating the world-wide predominance of transcurrent movements.

Fig. 9. Maps at same scale of Philippine, San Andreas, Atacama, and Alpine faults.
TSUNAMIS AND SEISMIC SEICHS OF SOUTHEAST ASIA

By Wm. H. Berninghausen

ABSTRACT

This paper lists 93 entries, describing tsunamis and seiches which have been reported from southeast Asia during the period extending from 1946 through 1965. Most of these tsunamis were reported from the western portions of Indonesia and the southern Philippines. Lesser numbers were reported from the northern Philippines, southern China and Formosa. No tsunamis are listed from the coasts of the relatively aseismic regions surrounding the southern three-fourths of the South China Sea. About half of the tsunamis in Indonesia were generated by volcanic activity, while most of the waves reported from other portions of the area were generated by earthquakes.

Southern Philippines

1965 March 14, Philippines. Earthquake felt on Luzon and Mindoro (12°05′N., 121°05′E.). Near Pola (13°00′N., 121°26′E.) on Mindoro the sea “looked an extensive and very fertile plain rendering it unfit for planting and dwelling.” (Repeiti 1946). (This may be a case of subsidence rather than a tsunami.

1960 Aug. 16, Philippines. Destructive shock reported from southeastern Luzon and eastern Visayan Islands (10°30′N., 123°00′E.). The sea was disturbed. (Repeiti 1946).


1961 Sept. 21, Philippines, Mindanao, Sulu Archipelago (06°00′N., 121°00′E.) and southern Visayan Islands. Destructive earthquake generated what has been described as the greatest sea wave ever recorded in the Philippines. At the Basin Island (06°31′N., 120°39′E.) waves 6 meters (20 feet) above normal swept the market, causing extensive damage and killing a number of persons. At Jolo (06°00′N., 121°00′E.) Sulu Archipelago the waves had 15 minute intervals. Waves reported at Zamboanga (06°51′N., 122°01′E.). Dapitan (08°30′N., 123°25′E.) the sea rose 12 meters (40 feet) at the mouth of the bay. At Negros (00°00′N., 127°00′E.) waves almost swamped a boat in the bay. (Nature 1947; Masso 1947; Milne 1947; Repeiti 1948).

1962 Feb. 27, Philippines. Epicenter 10°12′N., 121°07′E.; broke submarine cables between Cuba and Mashatu and Biris Island. (Repeiti 1947).

1962 Sept. 1, Philippines, Epicenter 09°30′N., 121°16′E. Waves noted along the south coast of Negros. (Repeiti 1931).

1962 Nov. 11, Philippines. Epicenter off Canthino, Chile at 28°30′S., 70°00′W. Waves reported in the Philippines from Zamboanga to Mindanao, and Basiuin. Waves were also reported from Samoa, Fiji, Solomon, New Guinea, the Carolines, Australia and New Zealand, (Gutenbein and Richter 1941, Hart 1931, Heck 1947, Keys 1947, Lanzon 1931, and Selga 1925).


1967 July 18, Philippines. Epicenter 09°20′N., 125°00′E. Waves reported from Mambajao (09°15′N., 124°35′E.) and Canaguijo Island (09°11′N., 124°12′E.). The disturbance of the sea lasting about an hour. (Repeiti 1947).

1967 May 25, Philippines. Epicenter 12°12′N., 122°00′E. Waves observed on the eastern side of Tablas Island (12°25′N., 123°02′E.), (Repeiti 1931).

1968 Dec. 28, Philippines. Destructive earthquake and wave reported from Calabato (07°15′N., 121°15′E.) the capital of Mindanao Province. Wave probably struck the coast near Calabato, which is inland, (Georgetown Univ. 1926).

1968 Jan. 21, Philippines. A destructive earthquake with its epicenter at 11°00′N., 122°00′E. generated a seismic sea wave which killed 2 persons in Bodo Strait (06°35′N., 122°30′E.), (Murphy and Ulrich 1947a, Seismol. Soc. America 1948).
See also: Lake Taal

Lake Taal

D. W. K. R. C. 59 1 5

EARTHQUAKE CATALOG

DAVID LEEDS AND ASSOCIATES

WHERE, WHEN, AND HOW

UPHILL

Catastrophic shaking and destruction occurred in the Philippines during the earthquake of 1906. The shock was felt throughout the region, causing widespread damage, especially in Manila, where the majority of the deaths occurred. The death toll was estimated to be over 2,000, with many more injured. The earthquake caused extensive damage to buildings, infrastructure, and transportation networks, leading to a significant disruption of daily life. The aftermath of the earthquake led to a period of rebuilding and recovery, with much of the focus on improving seismic codes and building regulations to prevent future disasters.

For more information, please refer to the Earthquake Catalog by David Leeds and Associates.
TSUNAMIS AND SEISMIC SEICHES OF SOUTHEAST ASIA

BY WM. H. BERNINGHAUSEN

ABSTRACT

This paper lists 93 entries, describing tsunamis and seiches which have been reported from southeast Asia during the period extending from 416 through 1965. Most of these tsunamis were reported from the western portions of Indonesia and the southern Philippines. Lesser numbers were reported from the northern Philippines, southern China and Formosa. No tsunamis are listed from the coasts of the relatively aseismic regions surrounding the southern three-fourths of the South China Sea. About half of the tsunamis in Indonesia were generated by volcanic activity, while most of the waves reported from other portions of the area were generated by earthquakes.

Lake Seiches

1776 Sept. 24. Philippines, Luzon. An eruption of Mount Tala (14°00'N., 121°30'E.) a volcano located on an island in Lake Tala (13°56'N., 121°00'E.), caused a wave that reached a strip of shore more than 16.7 meters (55 feet) wide. (Masé 1911, Worcester 1912).

1781 Nov. 20. Philippines, Luzon. An eruption of Mount Tala caused waves on Lake Tala which together with the volcanic ejecta destroyed the nearby towns of Tala, Lupa, Tanuan and Sama. These waves also washed out the road to Bañyon on the west side of the lake. (Masé 1911, Worcester 1912).

1811 Jan. 30. Philippines, Luzon. An eruption of Mount Tala caused waves on Lake Tala. Waves 2.3 to 3 meters (8 to 10 feet) high carried away houses and caused loss of life in some of the barrios. (Masé 1911, Pratt 1911, Worcester 1912).

1826 June 28. Indonesia, Western Sumatra. Destructive shocks in the Padang Highlands caused waves on Lake (Danau) Singkarak (09°57'N., 100°37'E.). (Visser 1930).

1835 April 10. Philippines, Epicenter 08°00'N., 123°00'E. Destructive earthquake rocked the southern Philippines. Seiches on Lake Lutan (07°53'N., 121°15'E.) in northwestern Mindanao destroyed an entire village on the west shore; (Murphy and Choud 1957, Seismol. Soc. America 1955).

1915 Sept. 30. Philippines, Luzon. Waves caused by the explosive eruption of Mount Tala in Lake Tala caused waves which reached 3.7 meters (12.1 feet) above the lake level and swept inshore as much as 80 meters (260 feet). Undoubtedly much larger waves swept the coast earlier. (Moore et al 1965).

* Cannot be located in available gazetteers.
Positions of epicenters were calculated from the observations of 10 or more stations, and were reported in the following publications:
Seismological Bulletin January 1, 1962 to December 31, 1966
Preliminary Determination of Epicenters January 1, 1967 to December 31, 1969
The seismicity of southern Asia

G. A. Eiby,
Seismological Observatory, Wellington,
New Zealand Department of
Scientific and Industrial Research

INTRODUCTION

The concept of 'Monsoon Asia', which is the basis of most studies in this volume, has little relevance to seismology. Nevertheless, Monsoon Asia contains densely populated areas of high seismic risk, parts of the world's two major seismic belts traverse it and their meeting-point lies within the region. It is, therefore, highly interesting to the seismologist, and a region in which a knowledge of seismic risks is of great social and economic importance. Because of the difficulty of discussing systems of seismicity that lie partly inside and partly outside the region, this paper will concentrate upon those seismic systems that lie wholly between the parallels 45° N. and 15° S, and between longitudes 65° and 155° E.

SOURCES

Instrumental coverage of southern Asia, comprising about one-sixth of the earth's surface, is very uneven, and in most places totally inadequate. This is in some measure a recent problem. The earliest seismograph station to be established in Asia was Osaka (1882). It was followed by Zi-ka-wei (1906), Manila (1908), and Batavia (Djakarta) and Mizusawa (1909). By the late 1920s, sufficient stations were operating to detect large shocks (above about magnitude 7), but the distribution of the recording stations in azimuth and distance was poor, and the positions of many earthquakes in this period are uncertain by as much as 100 km. As world standards improved, only a few of the Asian stations were able to modernize their equipment, and their number remained totally inadequate. The two world wars caused serious interruptions to recording at the important stations of Hong Kong, Manila, Amboina and Medan.

For the instrumental period from about 1905 up to 1954, Gutenberg and Richter's (1954) study of world
The seismcity of southern Asia

THE PHILIPPINE ARC

There is a long historical record of earthquakes in the Philippines (Repetti, 1946) but instrumental coverage has been less adequate, and interrupted by war. Recent shocks are discussed by Minoza et al. (1960). Neuman van Padang (1963) has reviewed the volcanism, and Allen (1962) described the important sinistral transcurrent Master Fault that runs the whole length of the group.

Large shallow earthquakes are common throughout the Philippines, except in the outlying westerly island of Palawan. Palawan is separated from the main island group by the stable Sulu Sea, which is possibly oceanic in character, and experiences only a relatively small number of shallow shocks. The broad pattern is that of an asymmetrical arc, with the deep and narrow Mindanao Trench facing the oceanic Philippine Basin to the east, vigorously active volcanoes and a belt of deeper earthquakes to the west. The details, however, are more complex, the two ends of the arc differing in character and being more active than the central part.

In central and southern Luzon, the largest earthquakes have been those of 18 April 1907 (M = 7.6), 20 August 1937 (M = 7.5), and 8 April 1942 (M = 7.7). They are significantly smaller than a similar group in Mindanao, on 15 August 1918 (M = 8.4), 14 April 1924 (M = 8.3) and 25 May 1913 (M = 7.9).

The volcanism is similarly divided. The group of active volcanoes just south of Manila includes Taal, twice active in the last few years, and extends along the southern part of the island to Mayon. Mindanao has a second active group, whose northernmost member is Hibok-Hibok, on Camiguin Island. This group of active volcanoes is confined to the western part of Mindanao. In the central islands of the Philippines, only Canlaon on Negros Island has been reported active in recent times (1866-1906), all other volcanism being in a solfataric stage.

At its northern end, the Mindanao Trench shallows to the general level of the Philippine Basin, and it cannot be traced east of Luzon. The seismcity of the Philippine Arc, however, continues along the structure of the southern part of the island, with the large shallow shocks concentrated on the basin side, and intermediate earthquakes, mostly between 150 and 200 km deep, lying close to the volcanoes and extending into Mindoro. Transition to the oppositely oriented margin of northern Luzon occurs near the Master Fault. The trench is well marked in the central section of the arc, but most of the seismic activity north of Mindanao is shallow. The Mindanao volcanoes are associated not with intermediate seismicity, but with true deep shocks, many deeper than 600 km. A few intermediate foreshocks occur quite close to the trench, and the epicentre assigned to the shallow magnitude 7.9 shock on 25 May 1913 in even on the oceanic side of it. Since close stations with good timing have only recently begun operating, it seems highly likely that there is some systematic error in the epicentre and depth determinations for this region.

It is probable that the earthquakes of southern Mindanao do not belong tectonically to the Philippine Arc, but to one of three other systems that meet in the island. The first extends from the western peninsula through the Sulu Archipelago to Sabah, the second from the southernmost point through the Sangihe Islands to the Minahassa Peninsula of Sulawesi (Celebes). These systems embrace the basin of the Celebes Sea; and the third, which is marked by a sudden change in the strike of the trench and the loss of its curvature, is interrupted before it reaches Halmahera.
EARTHQUAKE MECHANISMS AND ISLAND ARC TECTONICS IN THE
INDONESIAN-PHILIPPINE REGION

BY THOMAS J. FITCH

ABSTRACT

Forty-four new focal mechanisms from shallow-focus earthquakes in the Indonesian-Philippine region have been determined from P and S waves recorded on long-period instruments. The dominant modes of deformation are thrust and normal faulting rather than strike-slip faulting. Along the Sunda and Philippine arcs the most active zone of shallow focus activity occurs between the ocean trench and the line of active volcanoes. Mechanism solutions from earthquakes in this zone are all of the thrust type with the sense of motion on the shallower dipping of the two nodal planes consistent with underthrusting beneath the island arc. Seismic slip vectors strike in a northeasterly direction along the convex side of the western Sunda arc and strike in a westerly direction along the Philippine arc and its extension along the eastern margin of the Celebes Sea. Normal faulting mechanisms from one earthquake under the Java Trench and another under the Philippine Trench may result from extension in the upper surface of the lithosphere as it bends beneath the island arc. The curvature of the Sunda arc may have caused the inclined seismic zone beneath the arc to shoal toward the northwest. There is a correlation between negative isostatic gravity anomalies, maximum water depth in the trench and the length and shape of the seismic zone beneath the Sunda arc. Shoaling of the inclined seismic zone beneath the nearly linear Philippine arc can be explained by a decrease in the slip rates from south to north along the arc. Complex regions such as western New Guinea, the Sulu Spur and lesser Philippine islands may include a number of small plates of lithosphere.

SEISMICITY

The spatial distribution of shallow focus epicenters in the area of this study (Gutenberg and Richter, 1954; Barazangi and Dorman, 1969) (Figure 3) shows that nearly all the activity is confined to long zones rarely wider than 200 km. Intermediate and deep focus earthquakes (Figure 4), although not as numerous as the shallow events, are clearly distributed in long-narrow zones that parallel adjacent zones of shallow focus activity (Gutenberg and Richter, 1954; Barazangi and Dorman, 1969).

These active seismic zones, in general associated with other forms of tectonic activity, e.g., volcanism (Gutenberg and Richter, 1954), divide the Indonesian-Philippine region into four large relatively inactive regions or plates (Le Pichon, 1968; Barazangi and Dorman, 1969); the Asian, the Indian Ocean-Australian, the Philippine Sea and the Pacific Ocean plates (Figure 1). In this region the boundary between the Philippine Sea and Pacific Ocean plates is defined by a series of oceanic trenches associated with only minor seismicity; however, the remaining border of the Philippine Sea plate is defined by seismic activity (Katsumata and Sykes, 1969). In detail, the plate boundaries are open to considerable interpretation in southern Luzon, between Mindanao and Celebes and between Celebes and western New Guinea. The seismicity in these complex regions is discussed in the following subsection.
FROILAN C. GERVASIO

Substantially enriched geological data have accumulated since the Geology and Oil Possibilities of the Philippines by Corby, et al., 1951 was published. Most of them are the results of intensive regional mapping done by the Geological Survey and Petroleum Divisions of the Philippine Bureau of Mines; some basin areas were worked out by private oil companies. This paper is an attempt to fill the need to modify some of the earlier geologic interpretations and existing views regarding the tectonic evolution of the Archipelago in view of the fact that since the early part of 1960 numerous intrusive and sedimentary rocks considered as pre-Tertiary basement have turned out to be either Paleogene or Miocene in age.

Corby distinguished four tectonic provinces in the Philippines, namely: (1) Palawan and Mindoro — as a possible extension of Malangatna’s Sunda-land; (2) to the east, and south extending north along western Luzon — a belt of disconnected basins which accordingly subsided without interruption during the Tertiary until the close of Pliocene when they were folded; (3) farther east — an orogenically active zone characterized by active volcanoes, maximum negative anomalies, angular unconformities during the Miocene, and considerable seismic activity; and (4) covering Samar and eastern Luzon — a bordering belt in which the Tertiary has been practically undisturbed. Irving (1950) considered the western part of the Philippines as the outer edge of pre-Tertiary and early Tertiary Sunda-land and the eastern part excluding northern Luzon, as an arc of late Tertiary development. He believed that the principal sigmoidal ridges and major sea basins are original and primary features Hess (1955) interpreted the Philippines as made up of convex arcs which have progressively developed from west to east by periodic tectonism, Wilson (1959) distinguished the Philippines as a broken arc and while referring to the evolution of island arcs but not in particular to the Philippines, he remarked that the first stage, the single island arc, apparently starts to grow as soon as a conical fracture zone forms in the crust and upper mantle and allows lava to rise.

Meanwhile, it is significant to note that Gutenberg and Richter (1954), on the basis of wave velocities survey, regarded the area east of the Philippines under the Philippine Sea as a continental structure and drew the boundary line of the Pacific basin from New Zea-land and round by way of Halmahera and Yap to Guam. It is further of interest
SEISMICITY OF THE EARTH

By B. GUTENBERG and C. F. RICHTER
SEISMOLOGICAL LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY

(Facsimile of the Edition of 1954)

Figure 19. Formosa-Philippines.
EARTHQUAKE RESISTANT REGULATIONS

A WORLD LIST

1973

Compiled by the
INTERNATIONAL ASSOCIATION
FOR EARTHQUAKE ENGINEERING
April 1973

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OH-OKEYAMA, MEGUROKU, TOKYO 152

PHILIPPINES

REPUBLIC OF THE PHILIPPINES
NATIONAL STRUCTURAL CODE
FOR BUILDINGS
"LATERAL FORCES"
APPROVED JUNE 23, 1972

Note: An updated set is in press (11-76) however we think there is no change.
THE LANAO EARTHQUAKE, PHILIPPINES
1 APRIL 1955

by

R. L. Kintanar\(^1\), J. C. Quema\(^2\), and A. Alcaraz\(^3\)

I. SUMMARY AND CONCLUSIONS

About sixteen minutes after two o'clock, Manila time, on the early morning of April 1, 1955 or sixteen minutes past eighteen hours of the 31st of March, Greenwich Time, central western Mindanao, Philippines experienced a very strong earthquake which caused extensive destruction and loss of lives in Misamis Occidental and especially in Lanao Province. This earthquake ranks among the most severe to have hit this portion of the Archipelago within the present century.

The epicenter of the earthquake as determined by distribution of intensities, effects, destruction, and by seismographic records was at a point between Lake Lanao and Panguil Bay or more specifically at latitude 7° 55' North and longitude 124° 05' East. The tremor was apparently of normal focus and had a maximum intensity of Rossi-Forel VIII (Adapted). The maximum acceleration during the main tremor may have reached 0.5 g.
Visayas & Mindanao Areas
Isoseismal Map

Quake of April 1, 1955
Time 2:18 A.M. (Local)
**Extension and seismicity**

The Philippines Archipelago is a large and complex region, which accounts for over 3.2% of the world's seismic activity. It consists of several arcs with associated rifts and areas of block tectonics.

**TABLE 15.2**

Earthquakes of the Philippines (Region 22)

<table>
<thead>
<tr>
<th>Date</th>
<th>Epicenter</th>
<th>M</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1599 June 21</td>
<td>Manila</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1619 Nov. 20</td>
<td>N. Luzon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1645 Nov. 30</td>
<td>Manila</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1658 Aug. 20</td>
<td>Manila</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1675 Mar.</td>
<td>Mindoro</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1743 Jan. 12</td>
<td>Tayabas, Luzon</td>
<td></td>
<td>several hundred dead</td>
</tr>
<tr>
<td>1787 May 13</td>
<td>Panay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1796 Nov. 5</td>
<td>Manila</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1824 Oct. 26</td>
<td>Manila</td>
<td></td>
<td></td>
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<tr>
<td>1830 Jan. 18</td>
<td>Luzon</td>
<td></td>
<td></td>
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<tr>
<td>1852 Sep. 16</td>
<td>SW. Luzon</td>
<td></td>
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</tr>
<tr>
<td>1863 Jan. 3</td>
<td>Manila</td>
<td></td>
<td></td>
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<tr>
<td>1869 Aug. 16</td>
<td>S. Masbate</td>
<td></td>
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<tr>
<td>1871 Dec. 8</td>
<td>S. Mindanao</td>
<td></td>
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<tr>
<td>1876 Jul. 26</td>
<td>N. Mindanao</td>
<td></td>
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<tr>
<td>1878 Sep. 16</td>
<td>Mindanao</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1879 Jul. 1</td>
<td>Surigao, Mindanao</td>
<td></td>
<td>300 dead</td>
</tr>
<tr>
<td>1880 Jul. 18</td>
<td>Luzon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1889 May 26</td>
<td>Batangas, Luzon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1892 Mar. 16</td>
<td>Luzon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1897 Sep. 20</td>
<td>Batasan, W. Mindanao</td>
<td>8.6</td>
<td>tsunami</td>
</tr>
<tr>
<td>1897 Oct. 20</td>
<td>Samar</td>
<td>8.1</td>
<td>7.9</td>
</tr>
<tr>
<td>1901 Dec. 14</td>
<td>Batangas, Luzon</td>
<td>7.8</td>
<td>7.8</td>
</tr>
<tr>
<td>1903 Dec. 20</td>
<td>off E. Mindanao</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>1907 Apr. 18</td>
<td>S. Luzon</td>
<td>7.2</td>
<td></td>
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<tr>
<td>1911 Jul. 12</td>
<td>N. Mindanao</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>1918 Aug. 15</td>
<td>off S. Mindanao</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>1924 Apr. 14</td>
<td>off SE. Mindanao</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>1934 Feb. 14</td>
<td>off N. Luzon</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>1937 Aug. 20</td>
<td>central Luzon</td>
<td>7.5</td>
<td>20 dead</td>
</tr>
<tr>
<td>1942 Apr. 8</td>
<td>N. Mindoro</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>1943 May 25</td>
<td>off Mindanao</td>
<td>8.1</td>
<td>400 dead</td>
</tr>
<tr>
<td>1948 Jan. 24</td>
<td>S. Panay</td>
<td>8.3</td>
<td>270 dead</td>
</tr>
<tr>
<td>1949 Dec. 29</td>
<td>NW. Luzon</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>1952 Mar. 19</td>
<td>off N. Mindanao</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>1955 Mar. 31</td>
<td>Lanao, Mindanao</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>1968 Aug. 1</td>
<td>Casiguran, Luzon</td>
<td>7.3</td>
<td></td>
</tr>
</tbody>
</table>

Map 18. Seismicity of the Philippines, Region 22. (Seismicity contours are numbered in $10^4$ ergs km$^{-3}$ year$^{-1}$.)

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EARTHQUAKE CATALOG
DAVID J. LEEDS AND ASSOCIATES
Census of the Philippines.
Bull. No. 3 1904 81pp.
SEISMOLOGY REFERENCE SHEET

PHILIPPINE ISLANDS
DIRECTOR
GEN. J. P. SANGER, U. S. A.
ASSISTANT DIRECTORS
HENRY GANNETT, VICTOR H. OLMSTED

BULLETIN 3

VOLCANOES AND SEISMIC CENTERS
OF THE PHILIPPINE ARCHIPELAGO

BY
REV. M. SADERRA MASÓ, S. J.
Assistant Director of the Philippine Weather Bureau

DEPARTMENT OF COMMERCE AND LABOR
BUREAU OF THE CENSUS: 1904
THE SEISMIC CENTERS OF SAMAR, LEYTE, AND EASTERN MINDANAO.

By Rev. Miguel Sadera Masó, S. J.,
Assistant Director of the Weather Bureau.

(Reprint from the Bulletin of the Weather Bureau for August, 1910.)

The least stable region of the Philippine Islands is, beyond doubt, represented by the strip of the Archipelago which contains the Islands of Samar and Leyte and the eastern portion of Mindanao. The distribution of the districts which have been shaken most violently by the various earthquakes of which we have any knowledge seems to indicate two seismotectonic lines, whose general directions are nearly parallel. One of these follows the eastern coasts of Mindanao and Samar; the other commences in Davao Gulf and, extending in a northerly and north-northwesterly direction, passes along the valley of the Agusan River, through the eastern part of Butuan Bay and the southwesternmost part of Leyte, thence to the northern coast of Leyte and to Biliran Island, and finally terminates in the neighborhood of Masbate Island. Each of these lines possesses peculiar characteristics as to topographic relief and seismicity, of which we will try to give an idea in these brief notes.

The coastal seismotectonic line.—The cause of the great instability observed on the eastern coasts of Mindanao and Samar became clear when in January and February, 1907, there was discovered a submarine trough of extreme depth adjacent to them. This discovery was made by the German gunboat Planet, then engaged in a voyage of hydrographic exploration around the world, the results of which have been published in the “Annalen der Hydrographie und Maritimen Meteorologie.” The following data as well as the map shown on Plate VIII are taken from the number corresponding to the month of May, 1907; some additions having, however, been made to the map, in order to render it more useful for our purpose.

This line, or rather the axis of the depths ranging from 8,000 to 9,000 meters, begins near parallel 6° north and meridian 128° east of Greenwich and, running northwestward, approaches the meridian 127°, from which it never departs far until it reaches 8° north. From the latter parallel it continues in a north-northwesterly direction as far as parallel 13°5′, beyond which the bottom, after having reached the maximum depth of 9,000 meters, commences to rise by an easy gradient toward northwest. Between parallels 7° and 13° the trough lies always within 90 to 45 kilometers from the coast, which fact represents an extraordinary slope. From Mayo Bay in Mindanao to the northeast of Samar, the latter varies between 1:10 and 1:5. In several places the slope is not continuous and uniform from the coast to the bottom of the trough, but shows a bench or terrace at depths between 4,000 and 6,000 meters. The escarpment from the coast to the bench is as steep as 1:6 near the coast of Mayo Bay and 1:3 to the northeast of Samar, while that of the section from the said bench to the bottom of the depression is somewhat less pronounced. On the other hand, the eastern bank of the latter has a rise of only 4 kilometers in 180 (1:45); hence, this Philippine trough may be considered as monoclinal.

The eastern coasts of Japan are universally considered as highly unstable, owing to their steep declivity toward the trough of Tuscaraola, which runs along the coast of Japan and the Kurile Islands. But if we compare the conditions of instability found on the eastern coasts of Mindanao and Samar, as deduced from their declivity, with those of the region mentioned, we will readily see that our coasts must be much more unstable than those of the said empire. After all, according to Professor Milne, the Japanese slope, measured from the high central mountains to the bottom of the Tuscaraola trough, is only 1:30 to 1:20, being thus about the same as found
DEPARTMENT OF THE INTERIOR
WEATHER BUREAU
MANILA CENTRAL OBSERVATORY

CATALOGUE

OF

VIOLENT AND DESTRUCTIVE
EARTHQUAKES IN THE
PHILIPPINES

WITH AN APPENDIX
EARTHQUAKES IN THE MARIANAS ISLANDS

1599–1909

BY

REV. MIGUEL SADERRA MASÓ, S. J.
ASSISTANT DIRECTOR OF THE WEATHER BUREAU

MANILA
BUREAU OF PRINTING
1910
HISTORIA
DEL
Observatorio de Manila

FUNDADO Y DIRIGIDO POR LOS PADRES
DE LA MISIÓN DE LA COMPANÍA
DE JESÚS DE FILIPINAS

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1.—Resúmense los acontecimientos de aquellos

CAPÍTULO XII.—EL DEPARTAMENTO SÍSMICO, Y
CAMBIOS Y SUCESOS DE 1890 A 1894.

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sísmicos del Observatorio en 1890. 2.—Reconocimiento
oficial de esta Sección; primeros Directores. 3.—
Publicaciones: “La Sismología en Filipinas.” 4.—Marcha
del Observatorio y sucesos ocurridos de 1890 a 1894;
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TICO Y SÍSMICO DESPUÉS DE 1901.

1.—Expedición Magnética a Mindanao. 2.—Cierra
se el Observatorio Magnético en Manila a causa de
los tranvías eléctricos. 3.—Edifícase uno nuevo en Antí-
polo. 4.—Publicación de las observaciones Magnéticas.
5.—Departamento de temblores de tierra: nuevos sismó-
grafos. 6.—Observatorio de Baguio: estación vulcan-
sísmica de Ambulong. 7.—Estado actual del Servicio
Sismológico. 8.—Montanon un sismógrafo en la isla de
Guam y otro en Butúan. 9.—Observaciones y publi-
caciones sísmicas de este último período...
EARTHQUAKE PROBLEMS IN THE PHILIPPINES

I. Present Status of Seismic Observation Networks

The official government agency in charge of seismic work in the Philippines is the Geophysical Division of the Philippine Weather Bureau. This division has under it one main seismological observatory located in Quezon City a few miles northeast of Manila, four seismic sub-stations located in Bagino City, Ambulong, Batangas, Cebu and Davao Cities.

The main observatory was established in 1941 under the American Rehabilitation Program. The previous observatory, which was located in Manila, was burned during the war together with all the scientific papers and data gathered and compiled for more than 100 years. Choice of location was made in Quezon City where traffic and other disturbing influence which may affect the recordings were at a minimum. During the first year of operation, American as well as Filipino personnel handled the work. Later, when the Rehabilitation Program ended, the work was done solely by Filipinos.

II. Seismicity of the Philippines

As we all know the earth is divided into two great seismic belts and the Philippine Archipelago is located in the so-called "Circum-Pacific Belt of Fire". This belt borders the Pacific Ocean, ranging from the Pacific Coasts of South to North America, then to Alaska, Kamchatka, Japan, Philippines, and to Indonesia. According to Gutenberg it is in this belt where most of the world's active volcanoes are located and about 80% of the world's earthquakes occur.

The Philippines has a long and tragic history of destructive earthquakes. The first comprehensive reports of earthquakes were made during the Spanish Regime in the Philippines. Numerous and detailed reports of damages caused by these earthquakes in various parts of the Archipelago were compiled by Spanish historians. Unfortunately, all these valuable records were burned during the War.

An average of two earthquakes every three days occur in the Philippines. Luckily, most of these tremors are very small and are detected only by seismographs. The most active region is the eastern half of Mindanao and the islands of Samar and Leyte. About 16 felt earthquakes (Intensity III or over; Rossi-Forel Scale, Adapted) occur in this area every year. A well-known fault line which passes thru the Mindanao Dup runs almost parallel to this region. The Northern part of Luzon, including the Batanes and Babuyan Islands, ranks second, having a yearly average of 13 felt earthquakes. The most recent destructive earthquake in this part occurred on December 29, 1949. Central Visayas ranks third in seismicity having a yearly average of 11 felt earthquakes.
Philippines

Luzon Earthquake of 2 August 1968

19-31 August 1968

by S. Omote
  Y. Osawa
  I. Skinner
  Y. Yoshimi

Fig. 3.2. Annual average of felt shocks in the period 1862-1918, as determined by the Philippines Weather Bureau.
Seismicity of the Philippines

by

Olimpio D. Peña, for the Course of Seismology in 1962-1963

INTRODUCTION

I would like to state at the very beginning that, being connected with the Philippine Commission on Volcanology under the National Research Council, my work is primarily in the study of Philippine volcanoes and not seismology. However, since it is a well known fact that earthquakes usually occur before, during, and even after most volcanic eruptions, studies have been made along this line in order to utilize this phenomenon in the prediction of such volcanic activities. It is due to this reason that our office has engaged in the study of earthquakes and also due to this consideration that I was sent here in Japan to study Seismology with the end in view of utilizing this knowledge in our volcanological works.

EARLY SEISMOLOGICAL STUDIES

Early accounts of Philippine earthquakes were made by Spanish friars, Governors, Corps of Military Engineers, Chroniclers and travellers - the earliest one being that written by Gov. Santiago de Vera in his report to the King of Spain about a fort then under construction, which was destroyed by an earthquake on July 13, 1599. It was not until January 1, 1865, when the Manila Observatory was founded that study on earthquake began. Its main function at first was mainly meteorological observations and later, Astronomy, Terrestrial Magnetism and Seismology were added.

A simple pendulum seismoscope and a spiral vertical seismoscope were put into service between 1865 and 1868. Between 1868 - 1889 new instruments were added: a Bertillon seismograph, a Cecchi seismograph, a Rossi seismoscope, an improved simple pendulum, two geophones and a Gray-Milne three-component seismograph. These instruments were very crude compared to modern standards and could scarcely record an earthquake which was not perceptible to human beings. In 1901 better instruments were acquired and the list of earthquakes were classified as instrumental and non-instrumental.

There were three persons chiefly responsible for the seismic work of the Manila Observatory: Father Federico Faura, S.J., 1879-1890; Father Saderra Naso, S.J., 1890-1896 and 1902-1926; and Father William Repetti, S.J., 1923-1942. Father Repetti made a very invaluable contribution in this field of study by preparing a Catalogue of Philippine Earthquakes which covered the years 1569-1899 and was published in the Bulletin of the Seismological Society of America in July, 1946, and from which the writer drew freely much information.

After the end of World War II, seismological works were made by both American and Filipino seismologists. Modern seismographs were installed and determination of epicenters were made instrumentally. From 1949, after the end of the rehabilitation program, up to the present, most of the works are being done by Filipinos - except for the Baguio Observatory which is being run by the Jesuit Fathers.

Others who made great contribution in this field were Centeno and Abella, Spanish geologist and mine engineer, Becker, the first American geologist to make investigation in the island, B. Koto, a Japanese geologist and Montesinos de Bulloque, a French seismologist; have also made contribution to the subject, though neither has ever visited the country.

PHILIPPINE SEISMICITY AND ITS RELATION TO TECTONIC LINES

Although the Philippines has many active volcanoes, most of its earthquakes are not volcanic in origin but tectonic - that is, due to the sudden slipping of the earth's crust along a plane of weakness. Many seismologists who have studied the seismicity of the country believed that, like all seismic regions, earthquakes here originate along

* On leave from the Commission on Volcanology, Philippine
Bulletin of the
Seismological Society of America

Vol. 36 JULY, 1946 No. 3

CATALOGUE OF PHILIPPINE EARTHQUAKES, 1589–1899*

BY WILLIAM C. REPETTI, S.J.

INTRODUCTION

Catalogues of Philippine earthquakes have appeared from time to time, the two most nearly complete probably being that by Alexis Perrey, *Documents sur les tremblements de terre ... des Philippines*, and that of Father Saderra Masó, S.J., in his *La seismologia en Filipinas*. During the present writer’s incumbency of the office of seismologist of the Manila Observatory it seemed desirable to have a complete and accurate catalogue of Philippine earthquakes. Putting this desire into execution resulted in the present catalogue covering 310 years, 1589–1899. It can be stated with reasonable certainty that there is very little material which has not been seen in the compilation of this catalogue. If it were to be absolutely complete, it would have to be extended to the present time, but there are reasons for ending it with the year 1899. There is the historical reason—which we admit is not very weighty in such a subject—that the year 1899 ended the Spanish regime in the Philippines. Secondly, the instruments in operation in the last years of this period were very crude by modern standards and could scarcely record an earthquake which was not perceptible to human beings; the catalogue, then, is mainly a list of non-instrumental shocks. With the reorganization of the Manila Observatory in 1901 as the Weather Bureau of the Philippines, new and better instruments were acquired. Records have since been divided into lists of instrumental and noninstrumental reports, and these have been more widely circulated than the reports in the Spanish regime. A third and very potent reason for not extending the catalogue is the fact that the outbreak of war in 1941 put an end to the work of the Jesuits in the Manila Observatory.

The war has added a new value to this catalogue, because no small amount of the source material was lost in the battle of Manila in February, 1945. The destruction makes it desirable to put a few words on record concerning the Observatory. The Manila Observatory began its work on January 1, 1865, with a series of meteorological observations, which were continued without interruption until January, 1942. In the course of years, Sections of Terrestrial Mag-

* Manuscript received for publication February 8, 1946.
The seismicity of the earth 1953-1965

J. P. Rothé
Director/Directeur
Bureau central internation de séismologie

unesco 1
Earth sciences 1969
Evolving Seismic and Tectonic Patterns Along the Western Margin of the Philippine Sea Plate

Hugh Rowlett and John Kelleher

Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964

Epicenters of large shallow earthquakes ($M \geq 6.9$) of the past 55 yr and their aftershocks were recomputed for the western boundary of the Philippine Sea plate. These large shocks were not evenly distributed along the plate margin but clustered, particularly near Taiwan and near the islands of the central and southern Philippines. The concentration of large earthquakes near Taiwan is approximately confined to the area where continental lithosphere of the Asian plate appears to be colliding with remnants of the Luzon arc. Large shocks were infrequent near the central Ryukyu and west of Luzon along a segment of the Manila Trench. In both of these locations, major bathymetric features near the trenches may be interacting with the subduction margin. Thus the variations in size and frequency of large events correspond spatially to changes in the tectonic conditions of plate convergence along the margin. The uneven distribution of large shocks therefore may represent a long-term pattern of occurrence. Segments of the plate boundary near the southwestern Ryuku arc and near the Philippine Trench are suggested here as areas of seismic potential in that these regions have a past record of large shocks and have tectonic similarities to other seismic zones where long intervals of quiescence culminated in large earthquakes. The techniques used previously to identify areas of seismic potential do not appear applicable, however, to much of this plate margin, particularly to those segments which consist of broad irregular zones of deformation. Recomputation of epicentral data prior to 1964 moves several large shocks closer to the trace of the Philippine Fault from both the east and the west. These relocated epicenters, combined with both recent data and historic descriptions, suggest that much of the fault may have been active during the past century.

Fig. 1. (a) Major tectonic features of the western Philippine Sea plate. Longitudinal Fault (L.F.) of Taiwan and Philippine Fault (solid lines), active volcanoes (triangles) from Newman Van Padden [1953] and Kuro [1962], and trenches (saw teeth on upper plate) are shown. The 100-fm (183 m) contour represents the approximate boundary of the continental margin. (b) Epicenters (circles) of large shallow earthquakes ($M \geq 6.9$) near the plate boundary since 1918. Three large earthquakes occurring during 1915, 1916, and 1917 along the southwestern portion of the Ryukyu arc are also plotted. Note the clustering of epicenters near Taiwan and the islands of the central and southern Philippines and the absence of epicenters in the Luzon Strait and along part of the Ryukyu arc.
SEISMICITY OF THE PHILIPPINES
(1907 - 1964)

Submitted by: F.O. R.G. S.
SEVILLA, VALENZUELA, BELLOSILLO Jr.
Training Class 1963 - 1964

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To Drs. S. Omote and T. Santo of the International Institute of Seismology and Earthquake Engineering - for their gracefulness in allowing the authors the use of the facilities of the Institute; and also to the members of the Staff for their assistance;

Grateful acknowledgements, likewise go to Drs. T. Hirono and his staff of the Japan Meteorological Agency, and T. Hagiwara and his personnel of the Earthquake Research Institute, Tokyo University - for making the sources of the materials available.

INTRODUCTION

The purpose of this paper is to discuss the seismicity of the Philippines.

In the book of B. Gutenberg and C.F. Richter, "Seismicity of the Earth and Associated Phenomena" - seismicity of the Philippines has been discussed. The discussion was used purposely in incorporating the data in evaluating the relative seismicity of the various parts of the earth.

In the present paper, using the work of Gutenberg and Richter as a fundamental basis, the authors aim in evaluating the seismicity of the different regions of the Philippines. Intended also is the discussion of the geological nature of the regions where seismic activities are frequently occurring.

Since volcanic eruptions are preceded, accompanied and even followed by earth tremors, correlations of the alignments of volcanoes in active stage shall be attempted. Other aspects, such as mountain structures, depths of ocean in or near the Archipelago and other phenomena related in one way or another to seismic activities shall also be included.
Handbuch der Geophysik
herausgegeben von
Professor Dr. B. Gutenberg

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Fig. 452. Die Erdbebentätigkeit der Philippinen
philippines

Eastern Luzon Earthquake of 7 April 1970

by I. Skinner
M. Watabe

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GEOLOGY AND MINERAL RESOURCES OF THE PHILIPPINE ISLANDS

* The chapter on Seismology was written in collaboration with Migo Saderra Masó, S. J., assistant director of the Philippine Weather Bureau.

BY

WARREN D. SMITH

THE GOVERNMENT OF THE PHILIPPINE ISLANDS
DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES
BUREAU OF SCIENCE
MANILA
Publication No. 19

(Actual date of publication, April 20, 1925.)

119 pp 270-290
Global patterns of earthquake activity are depicted by dots which represent epicenters of shocks occurring between 1 July 1963 and 31 December 1972, having associated body-wave magnitude 4.5 or greater, and whose location was determined from the observations of 10 or more stations. Circles represent epicenters of very large shocks having surface-wave magnitude 8.0 or greater, and occurring in the interval 1897 through 1972. Date and magnitude of each are shown. Three colors distinguish the principal depth-of-focus classes of earthquakes in ricated seismic zones.
PHILIPPINE EARTHQUAKES AND STRUCTURE

By Bailey Willis

ABSTRACT

The accompanying two maps (in pocket) show the distribution of earthquake epicenters in the Philippine Archipelago as plotted by the Rev. William C. Repetti, S.J., Chief of the Section of Seismology and Terrestrial Magnetism of the Manila Observatory, for the years 1920 to 1936, inclusive. The text presents their relations to active structures of several types observed by the writer in a geological reconnaissance in the spring of 1937. The dynamics of the Archipelago and the mechanisms of the stresses are sketched in accordance with the hypothesis that the Philippine block is an eroded mass rising along the contact between the crustal elements that respectively underlie the China Sea and the adjacent Pacific Basin.

The Agusan River Valley and the region to the east of it as far as the coast of the Pacific Ocean, constitute that part of the Philippine Archipelago which at present shows the greatest seismic activity, both as to number and intensity of disturbances. In June, 1893, and again in the same month of 1894, the Agusan district experienced the severest seismic upheaval recorded in the annals of the valley. During the seventeen years which have passed since then, no fewer than 16 earthquakes have occurred in the same territory whose intensities lay between degrees VI and IX of the scale. On the eastern coast of Mindanao the most recent earthquake of force VIII took place in March, 1909. The greater number of these earthquakes of the Agusan make themselves felt chiefly, and possibly even have their origin, near the central part of the valley, which is characterized by a broad expanse of level, marshy ground, partly occupied by three principal lakes of permanent character which, however, in times of e...linearly heavy rainfall coalesce into one having a length of about 50 kilometers and a maximum width of some 20 kilometers. This entire region subsided considerably on the occasion of the earthquakes of 1893 and 1894, whereby large tracts of wooded and partly cultivated land were converted into swamps, though formerly the water reached them only during the highest floods. This region is undoubtedly the most unstable portion of the line of fracture which runs along the Agusan Valley and extends beyond it in the direction of the Davao Gulf in the south, and Leyte Island in the north. In this same region of the lakes a second, less important fault-line seems to meet the one mentioned, or to cross it. This secondary line of fracture runs from the valley across the eastern range of elevations and, following a W-E direction, extends toward the Great Trough of the Pacific of more than 8,000 meters' depth, which lies about 90 kilometers off the coast. The existence of such secondary fault seems to be established by the earthquake of March, 1909, and many others which could be traced to the same origin. But as we have only recently described these two fault-lines in a paper under the title "The Seismic Centers of Samar, Leyte, and Eastern Mindanao," we refer the reader to the latter, and proceed to describe the most recent earthquake which took place in that region.

Time.—At Manila the earthquake of July 12 was registered at 12:9:41 Insular time (one hundred and twentieth meridian east of Greenwich); hence, on the Agusan, or along the epicentral line whose middle portion is at a distance of some 900 kilometers from Manila, it must have occurred at 12:8:6, or thereabout. It is impossible to ascertain the instant of its occurrence even approximately from the reports received at the Observatory, since this part of Mindanao has no telegraphic connection with the rest of the Archipelago, nor any other adequate means for keeping correct time.

Intensity.—A fair idea of the intensity of the earthquake may be gained from the reports sent to the Central Observatory from a number of places; some of them situated within the valley itself, like Talacogon, La Paz, Bunawan, Veruela, and Butuan; others at some distance from it, as Humatauan, Boston, Baganga, Caraga, and Davao to the east and south, Cagayan to the northwest, Nasipit and Cabarbonan to the north-northwest and north.

Talacogon.—The Rev. Salvator Giralt, S. J., writes: "While we were dining (after 12 o'clock noon), there took place a very violent earthquake which wrought great havoc in the convento and church. The creaking of the beams was something awe-inspiring; doors and windows were wrenched from their hinges. Both, in the church and in the house, not only light objects, but also quite heavy pieces of furniture were rolling about..."
Eastern Visayas and Mindanao

Map showing the isoseismals of the Earthquake of July 12, 1911

Soundings in meters

Approximate Scale

Plate VII.
NOTES CONCERNING THE RAGANG VOLCANO AND A GREAT EARTHQUAKE IN SOUTH MINDANAO

By Miguel Saderra Masó

The following notes, by Rev. Father Masó, were transmitted to the Bulletin through Professor Warren D. Smith of the University of Oregon.—Editor.

RAGANG VOLCANO, MINDANAO.—In the month of July, 1916, during a Constabulary patrol through the region situated between Lake Lanao and Cotabato, Lieut. W. F. Donnelly, P. C., came in sight of an active volcano which from all indications had recently erupted a discharge of volcanic ash and vapors capable of partially destroying the vegetation for 3.5 kilometers around.

Later, in September, Col. P. E. Trab, U. S. Cav., Chief of the District, greatly interested in the discovery of Lieut. Donnelly, undertook a second expedition in company with Capt. G. O. Fort, P. C., and the said lieutenant to locate the crater and examine its actual state of activity. Arriving in the region, the party met with some difficulty in discovering the volcano, on account of the fog. When the fog lifted they saw a group of three peaks or cones with a deep hollow in the center between them. From the hollow or crater, apparently extinct at present, there radiates toward the southeast an old current of broken and jagged lava extending about three kilometers. In some places the lava, not so broken, presents the slaty and cobbled type characteristic of some recent Vesuvian flows. All around the cones and crater the products of former eruptions are scattered in the order of their size, boulders and bombs, pedregal, sand and ashes, to a great distance. The actual activity is shown by numerous jets of surphurous vapor issuing from vents distributed in the interior faces of the cones, forming the broken crater, and in the current of lava. At present the most active center is a great fissure, about thirty meters long and five wide and deep, opened across one of the cones. This crater seems to have been the origin of the last and very recent outburst; it is steaming energetically but filling up with loose material carried down its walls by the rains. There are all around the principal cones, other extinct vents, some in the shape of small cones and some of cracks and crevasses.

Capt. Fort, in his interesting report, for the perusal of which, to extract all the given details, we are greatly indebted to the courtesy of Gen. H. Hall, advances the opinion that formerly there existed four peaks around the crater, but the one in the southeast was blown up by violent explosions, the open breach giving an outlet to the molten lava.

The position of the new volcano is approximately 124° 29' E., and 7° 40' N.; it occupies the north end of a line of extinct but relatively modern volcanic cones, which, in a E.N.E.-W.S.W. direction, extends to the old Makaturing. This volcano, according to the last map of the Bureau of Constabulary, is situated at about 124° 19' E. and 7° 36' N.

This volcanic line seems recent compared with other cones of the country and specially with the powerful currents and layers of basalt found in the Lanao section. All this zone occupies the heart of the part of Mindanao occupied and exclusively controlled until quite recently by the Moros. For this reason it remained for centuries unexplored by outsiders. That the Ragang volcano has been constantly
more or less active is evident from the meaning of the name “Palao Ragang,” “the mountain where smoke or fire rises,” by which it is known among the Moros. There exist, moreover, some historic but vague reports which indicate the occurrence of recent volcanic eruptions in this section. Such reports refer to occasional falls of ashes in different towns of the coasts north and south of Mindanao. The last fall was reported from the District of Dapitan, where in April, 1873, appeared a big black cloud with a consequent rain of ashes coming from the interior—south or south.

The present state of the slagggy flow from the Ragang volcano and of the ashes, lapilli and volcanic blocks, scattered all along the coast of the Ilana Bay, seems to suggest the occurrence of tremendous and relatively recent eruptions, may be shortly before and perhaps even after the discovery of the Islands. Undoubtedly the whole narrow neck or isthmus lying between the Iligan and Ilana bays and which unites the Zamboanga Peninsula to the main body of Mindanao Island, has been in preceding epochs the field of great volcanic activity, owing to volcanic action its present relief and perhaps its upbuilding.

**Great Earthquake in South Mindanao.**—A great earthquake occurred on the 31st of January at 8th 02° 42′ (G. T.) 11th 37° 42′ (L. T.) and shook the whole island of Mindanao and the eastern part of the Jolo Archipelago. The epicenter was probably at some distance south of the Saragani Bay, in the Celebes Sea, where from time to time originate similar extensive earthquakes. The last one reached destructive intensity VIII-IX in the region of Glan, southeast and east of Saragani Bay.

In the following extracts, due to the courtesy of Chief of the Philippine Constabulary Col. H. Hall, are described some particulars of the earthquake and of the damage done by the same. This earthquake was really a great tectonic disturbance registered in all the observatories.

Extract from narrative report of the Senior Inspector of Cotobato for the month of January, 1917:

“A severe earthquake occurred in Glan and vicinity at 11:35 a. m., January 31, 1917, which lasted about one minute. Eighteen (18) houses were wrecked in Glan and Glan Padiliu and seven (7) people killed in the barrio of Tuyan by a great landslide caused by the earthquake. All the Constabulary buildings at Glan were wrecked, except the new addition to the barracks, and one soldier, Private Paris, and one prisoner, Mamaya Gas, were slightly injured by falling timbers. The government dock at Glan was so badly damaged that it can scarcely be used for anything until extensive repairs have been made. The new storeroom of the Colony Store that was just recently built was completely destroyed and the other colony buildings so badly damaged that they will not be worth repairing. The school house in Glan was wrecked and has been abandoned, school being held in the public dispensary until another place can be arranged. The surface of the ground cracked open in some places a width of from two to three feet and in several places water and mud were thrown several meters into the air. A tidal wave of about four feet came in a few minutes after the earthquake. The damage to all government buildings, property and supplies is estimated at $4,510.69. There have been many light earthquakes at irregular intervals during the day and night ever since the severe shock of the 31st of January.”

Narrative report of Cotabato for the month of February, 1917:

There were eight heavy earthquake shocks recorded in the Glan section during the month, and many light shocks. On February 14th there was quite a severe shock which shook down several houses that had been practically wrecked by the earthquake of January 31st.”

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GREAT EARTHQUAKE AND TIDAL WAVE IN SOUTHERN MINDANAO, P. I.

By Miguel Sabella Masó

On August 15, 1918, at 12h 20m 28s (G. M. T.), a great seismic disturbance was recorded at Manila, the origin of it being at a distance of about a thousand kilometers. Subsequent telegraphic reports showed that the whole island of Mindanao had been violently shaken by an earthquake of very long duration. The epicenter, as far as it could be inferred from later reports, was in the Celebes Sea between the 124th and 125th meridians east, and the parallels 5° and 6° north.

The number of aftershocks during the successive days was so great that the Observatory at Manila, a thousand kilometers distant, recorded fifty-one of them to the end of August. At the station of Butuan, situated in Mindanao at about 450 kilometers north northeast from the center a Wiechert seismograph recorded 509 during the same period, about 250 of which occurred on the 15th and 16th.

In September, word came from the Philippine constabulary officers stationed at Lebak and Glen, stating that the earthquake had caused great damage in the southern country, facing Celebes Sea, between Cotabato and the Davao Gulf; and that it had been followed by a tremendous sea wave which swept the whole coast between Lebak and Glen, completing the destruction caused by the shocks. All the devastated country is inhabited by Moros and wild tribes, so the real amount of damage and number of casualties is not yet, and probably never will be, known. The following reports published by the local press refer only to the Sarangani Bay and to the vicinity of Port Lebak, where constabulary posts exist and some white men live. The town of Glen is situated at the entrance of Sarangani Bay, while Port Lebak lies about a hundred miles to the northwest.

Captain Malone of the Philippine constabulary stationed at Glen, Cotabato, reports that the earthquake which occurred on the night of August 15th, last, destroyed all houses in Sarangani Bay and so far as known killed forty-six people. He reports that the earthquake lasted for three minutes and ten seconds and was later followed by a tidal wave reaching as high as twenty-four feet at some points and at the constabulary station at Glen to the height of eighteen feet, thereby destroying all of the houses that had been shaken down by the shock and drowning a number of people, cattle, horses and other domestic animals and destroying all of the food supply of those living near the beach and all of the crops on the low lands. All native vintas were either destroyed or taken out to sea. Large rivers were completely obliterated and new ones created. He further reports that a slide occurred on one of the large mountains adjacent to Sarangani Bay and it is his opinion that a number of wild people living at the foot of the mountain were buried, but as yet no definite reports have come in.

L. B. Kidwell, who has a saw-mill at Port Lebak, reports that the tidal wave at his place was between six and eight feet, killing six people and carrying a number of logs quite a distance inland. Light earthquakes have been almost continuous since August 15th both at Sarangani, Lebak and Cotabato, but no further damage has been done.

Another report says:

To the south of Port Lebak for some forty miles (I know nothing farther south) there was a tidal wave variously estimated at from twenty to twenty-five feet by Moro loggers who know what these measures are. Several Moros were drowned.
THE LANAO EARTHQUAKE OF APRIL 1, 1955

The most catastrophic earthquake to occur in the Philippines after World War II happened at 2:17 A.M., (local time) in the early morning of April 1, 1955. This earthquake was centered between Lake Lanao and Pangnib Bay in the province of Lanao at latitude 01° 55’ north and at longitude 124° 05 east.

A Maximum intensity of between VII-VIII was felt in the western half of Lanao and the eastern third of Misamis Occidental. The area affected by Intensity VI and higher included the rest of Lanao, Misamis Occidental, Zoni boanga del Norte, Zamboanga del Sur, Misamis Oriental, Bukidnon, and even the southern tip of Negros Oriental. Included within the intensity isoseismals are all the rest of the provinces of Mindanao and Visayas, thus giving the earthquake a Macroseismic area of approximately 1,400,000 square kilometers.

As in the case of most destructive earthquakes, the salient geologic feature of this earthquake was the control of damage by the difference in the type of ground conditions. The greatest destruction was wrought to structures built on alluvial deposits along unstable slopes. Structures relatively closer to the epicenter but built on firm ground were only slightly damaged while those of the same type of construction further away but on poorly consolidated deposits were severely damaged.

The total number of casualties for the tremor as compiled by the authorities and relief agencies were about 400 all told. Compared to earthquakes of like magnitude (Paganida 7.0) occurring in other countries, the number of casualties was small. This, in a large measure, was due to the resiliency of wooden constructions which characterize the preponderance of Filipino homes. In the municipal district of Tugya beside Lake Lanov, there was high loss of lives (174 out of about 2,000) and this was brought about because of the rather unfortunate geologic situation of the settlement. The deaths were due to drowning when the portion of the town bordering the lake slipped (as much as 40 feet) into the water.

No true surface expression of the movement that caused the tremor was observed but evidences observed from the apparent change of the lake water level and from the distribution of slides and sand boils, complemented by observed fissures, strongly suggest the possibility of a major fracture oriented approximately N 75° W starting a little east of Masui in the eastern side of lake Lanao and extending towards and beyond Molave in Misamis Occidental.

Perhaps the absence of any surface trace of faulting is not altogether unusual considering the depth (40 - 60 kilometers) at which major displacement must have occurred. The vertical development could very well have been taken up by the overlying formations. However, around lake Lanao, there are indications that changes in elevations of land surface points may have occurred.
THE LANAO EARTHQUAKE
(April 1, 1955)
MAP OF ISOSEISMALS

- Epicenter
- Intensity VII-VII
- Intensity VI
- Intensity V
- Intensity IV
- Intensity III
**Severe Earthquake and Tsunami Hit the Philippines, August 16, 1976**

Mindanao, the southernmost and largest of the Philippine Islands, was rocked by an earthquake of magnitude 8.0 on the Richter scale, during the early morning hours of August 17, local time (1610 UTC Aug. 16). This earthquake generated a devastating tsunami in the Celebes Sea that caused havoc and destruction along coastal communities of the Moro Gulf in Mindanao and neighboring Sulu Islands. More than 8,000 people were killed or are missing, making this the worst earthquake and tsunami disaster in the history of the Philippines.

Early reports estimated the earthquake epicenter to be somewhere in the Celebes Sea between the islands of Mindanao and Borneo. These reports listed that thousands of persons were either killed or missing and that many more were made homeless by the earthquake and subsequent tsunami waves. The earthquake occurred at night, when offices and schools in Cotabato, Zamboanga, and other cities were unoccupied and this reduced loss of life in the major centers. However, in the coastal fishing communities where most of the houses are built on posts on tidal beaches and even in bays, the tsunami waves swept through the villages in near darkness, only minutes after the people had been roused by the tremor. No tradition existed to move to higher ground in the event of a severe earthquake and people were caught and washed out to sea.

Damage to boats and fishing gear was heavy and the livelihood and the economy of many coastal communities have been disrupted. Relief operations began almost immediately by local civil and military agencies, and the government of the Philippines acted promptly to begin rehabilitation and reconstruction.

Honolulu Observatory posted a tsunami watch following the earthquake and queried tide stations of the Tsunami Warning System in Okinawa, Yap, and Malakal. Based on negative wave reports from these stations, Honolulu Observatory determined there would be no Pacific-wide tsunami and cancelled the watch. Apparently, most of the tsunami energy was trapped in the Celebes Sea which is bounded by numerous islands and shoals.

According to reports received from the Indonesian Hydrographic Office, no unusual wave activity affected the Sulawesi (Celebes) and Kalimantan (Borneo) Coasts of Indonesia.