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INFORMAL REPORT

EARTHQUAKES, TSUNAMIS, AND
VOLCANOES OF SOUTHEAST ASIA

NOVEMBER 1968

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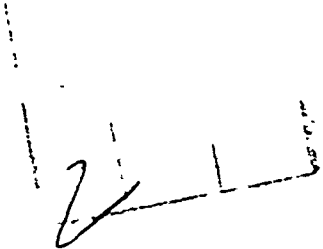
INFORMAL REPORT

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ABSTRACT

Earthquakes in this area are concentrated along the Indonesian island arc and the portion of the Circum-Pacific seismic belt which extends from New Guinea through Taiwan.

Most of the tsunamis which have been reported from this area have occurred in the Banda, Molucca, and Celebes Seas of eastern Indonesia. A few tsunamis have been reported from the Sulu Sea, the northeastern quarter of the South China Sea, the Java-Makassar Strait region, and the Indian Ocean side of Indonesia.

Volcanic activity in this area is concentrated into three regions. The first extends along the Indonesian island arc from Sumatra through Ceram. The second borders the Pacific Ocean from New Guinea through the Philippine Islands and Taiwan. The third, a region of submarine volcanism, lies in the South China Sea off South Vietnam.

This Informal Report was prepared by the Geological Section, Environment Branch, Oceanographic Analysis Division.

This manuscript has been reviewed and is approved for release as an UNCLASSIFIED Informal Report.



H. W. DUBACH
Acting Division Director

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A. Earthquakes.

Seismic activity in this area is concentrated along the Indonesian island arc and the portion of the Circum-Pacific seismic belt which extends from New Guinea through Taiwan.

A representative distribution of earthquake epicenters is shown in Figure 1. The epicenters of all Class A and B shocks are shown; however, in regions of highest activity only enough Class C and D epicenters are shown to emphasize the concentration of earthquakes. Seismic activity in this area is much greater than the world average. For example, about 5% of all Class A, B, and C earthquakes each year occur in and near the Philippine Islands, although the Philippine region is only about 0.1% of the world area. This is a relative seismicity of about 50 to 1.

Shallow shocks are fairly evenly distributed through the seismic zones, but intermediate and deep shocks tend to cluster along the deeper parts of a fault zone that approaches the surface of the earth's crust in the deep trenches (Java Trench, Sunda Trough, Timor Trough). The fault zone dips downward to the north or to the west beneath the islands, and the deep end lies beneath the Java, Flores, Banda, Molucca, and Celebes Seas, where the intermediate and deep shocks are concentrated.

All shocks reported in 1955 by the U.S. Coast and Geodetic Survey are shown on Figure 1 and are indicative of the annual number of earthquakes. Australia, Borneo, the Sunda Shelf, most of the South China Sea, and the continent of Asia in this area are aseismic (few or no earthquakes).

The geographic distribution of earthquake effects is shown on Figure 2. Destruction and damage from earthquakes have occurred throughout the seismic zones. Earthquake damage and destruction have also occurred in several regions on the coast of China, where the epicenter of the earthquake was not shown.

The amount of earthquake damage is related to the type of building construction, as well as to the severity of shocks. Damage may be greater in a region of infrequent shocks where poorly constructed buildings are the rule, than in highly seismic regions where shock resistant structures are built.

B. Tsunamis

Seventy-eight tsunamis have been recorded in this area between the years 416 and 1965. The coastal regions that have been affected by these waves and therefore those which are also regions of potential damage are shown on Figure 2. It is probable that many unrecorded tsunamis have occurred, most of which probably were unreported because they caused little or no damage.

All tsunamis reported in this area have originated within the area. However, waves caused by the explosive eruption of Krakatau in the Sunda Strait in 1883 were reported from tide stations as far away as England. These waves were 3 to 9 feet (0.9 to 2.7 meters) high along the south coast of Sumatra, 11 feet (3.4 meters) high 23 nautical miles west of Djakarta, 6 feet (1.8 meters) high at Djakarta, about 8 inches (20 centimeters) high in Selat Surabaya, and over 100 feet (30.5 meters) high in Sunda Strait. Waves caused by this explosion probably struck most of the southern coastal

regions of Indonesia and northern Australia.

Most of the tsunamis in the area probably affect larger regions than reports indicate. Probably nearly all tsunamis reported from northern Sumbawa or Flores also are felt on the south coast of Celebes. Waves recorded at Pulau-pulau Banda, Ceram, or Amboina probably affect most of the other shores bordering the Banda Sea.

Date of occurrence and brief descriptions of 20 tsunamis which have been reported between 1900 and 1965 follow:

1907 Jan. 4 Sumatra. Wave and earthquake on south coast.

1908 Feb. 6 Sumatra. Epicenter 05°00'S., 100°00'E. Wave along south coast.

1908 Mar. 24 Timor. Damaging shock and wave at Atapupu.

1913 Mar. 14 Epicenter 04°48'N., 126°36'E. Shock felt in Philippines.

Destruction reported from Kepulauan Sangihe and Pulau-pulau Talaud (04°20'N., 126°50'E.).

1918 Aug. 15-16 Violent earthquake in southern Mindanao. Epicenter 05°06'S., 125°30'E. Waves 6 to 24 feet high swept Mindanao between Lebak and Glan, destroying villages and drowning a number of people. Waves 3 feet or higher reported from northern peninsula of Celebes.

1921 May 14 Makassar Strait. Epicenter 00°42'N., 117°54'E. Earthquake damage at Songkulirang. Sekurah severely damaged by waves.

1922 Sept. 1 Waves noted along south coast of Negros.

1923 Feb. 23 Mindanao. Waves entered river at Cotabato.

1924 May 6 Luzon. Shock in South China Sea. No damage from wave noted at Agno.

- 1927 Aug. 7 Flores and Pulau Paloe. Tsunami and earthquake accompanied volcanic eruption.
- 1928 March 26 Sunda Strait. High waves accompanied eruption of Krakatau.
- 1928 Aug. 4-5 Flores and Pulau Paloe. Three waves 15 to 30 feet high accompanied eruption on Pulau Paloe. Twenty boats destroyed, and many natives killed or injured.
- 1928 Dec. 29 Mindanao. Destructive earthquake and wave reported from Cotabato.
- 1934 Feb. 14 Luzon. Epicenter at $18^{\circ}00'N.$, $118^{\circ}00'E.$ Some people narrowly escaped drowning by wave at San Esteban. Surges were noted at sea south of Vigan.
- 1938 Feb. 2 Eastern Banda Sea. Epicenter $05^{\circ}00'S.$, $131^{\circ}30'E.$ Shock noted and wave damage reported from Pulau-pulau Banda and Pulau-pulau Ewab.
- 1938 May 19 Epicenter $01^{\circ}00'N.$, $119^{\circ}00'E.$ Two waves 6 to 9 feet high damage property and killed several persons in Makassar Strait.
- 1948 Jan. 24 Panay. Destructive earthquake. Epicenter at $11^{\circ}00'N.$, $122^{\circ}00'E.$ Wave killed 2 persons in Iloilo Strait.
- 1949 Dec. 29 Northwestern Luzon. Destructive shock. Epicenter $17^{\circ}30'N.$, $121^{\circ}30'E.$ Mag. 7.2. Wave killed 1 person.
- 1965 Jan. 24 Western Ceram Sea. Destructive earthquakes. Epicenter $02^{\circ}24'S.$, $126^{\circ}00'E.$ Earthquake killed 71 people and did heavy damage on Pulau Sanana. Tsunami destroyed 90% of city of Sanana. Wave also hit Nemlea on Buru.

C. Volcanism

The area probably contains more active volcanoes than any other region of comparable size on the earth. Most volcanic activity is concentrated in three regions. The first lies along the part of the Indonesian island arc which extends from Sumatra through Ceram. The second region borders the Pacific Ocean from New Guinea through the Philippine Islands and Taiwan and has structural links with the first region in Celebes. The third, a region of submarine volcanism, lies in the South China Sea off South Vietnam. Most of the volcanoes are on islands. Figure 3 shows these features.

Submarine volcanic activity reported in Karimata Strait and between the Paracel Islands and South Vietnam have not been fully verified. As the Karimata Strait is not structurally related to the present centers of seismic or volcanic activity, the validity of the report of an eruption in 1925 is suspect.

Much of the volcanic activity in this area is characterized by explosions and extensive ash falls which have accompanied many of the eruptions. Two eruptions in this area rank high among the world's worst natural disasters. The 1815 eruption of Gunung Tambora killed 92,000 people, more than one-fourth of the total killed in all historic eruptions. Approximately 30 cubic miles of material were ejected by the explosion, and the ash fall blacked out the sun and caused three days of total darkness for a maximum distance of 300 nautical miles from the volcano. Prior to this eruption Gunung Tambora had been considered inactive. The explosive eruption of the volcanic island of Krakatau in 1883 is believed to have been caused by sea water coming in contact with molten lava beneath the volcano

when the cone collapsed following a relatively minor eruption. The noise of the explosion was heard 3,000 nautical miles away, and the ash cloud which rose an estimated 50 miles high circled the earth and caused red sunsets at many places. Most of the 5 cubic miles of ejected material fell within 8 or 9 nautical miles of the crater. The ash fall caused 24 hours of total darkness 130 nautical miles away, and ships 1,600 nautical miles away reported significant ash falls on their decks. The major destruction was caused not by the ash fall but by the tsunami generated by the explosion. The waves destroyed 295 populated places and killed 36,000 people on Sumatra and Java.

Many of the fatalities close to the volcanoes are caused by mud flows, clouds of incandescent ash and gas, floods, and lava flows, whereas ash falls and tsunamis may take their toll at greater distances.

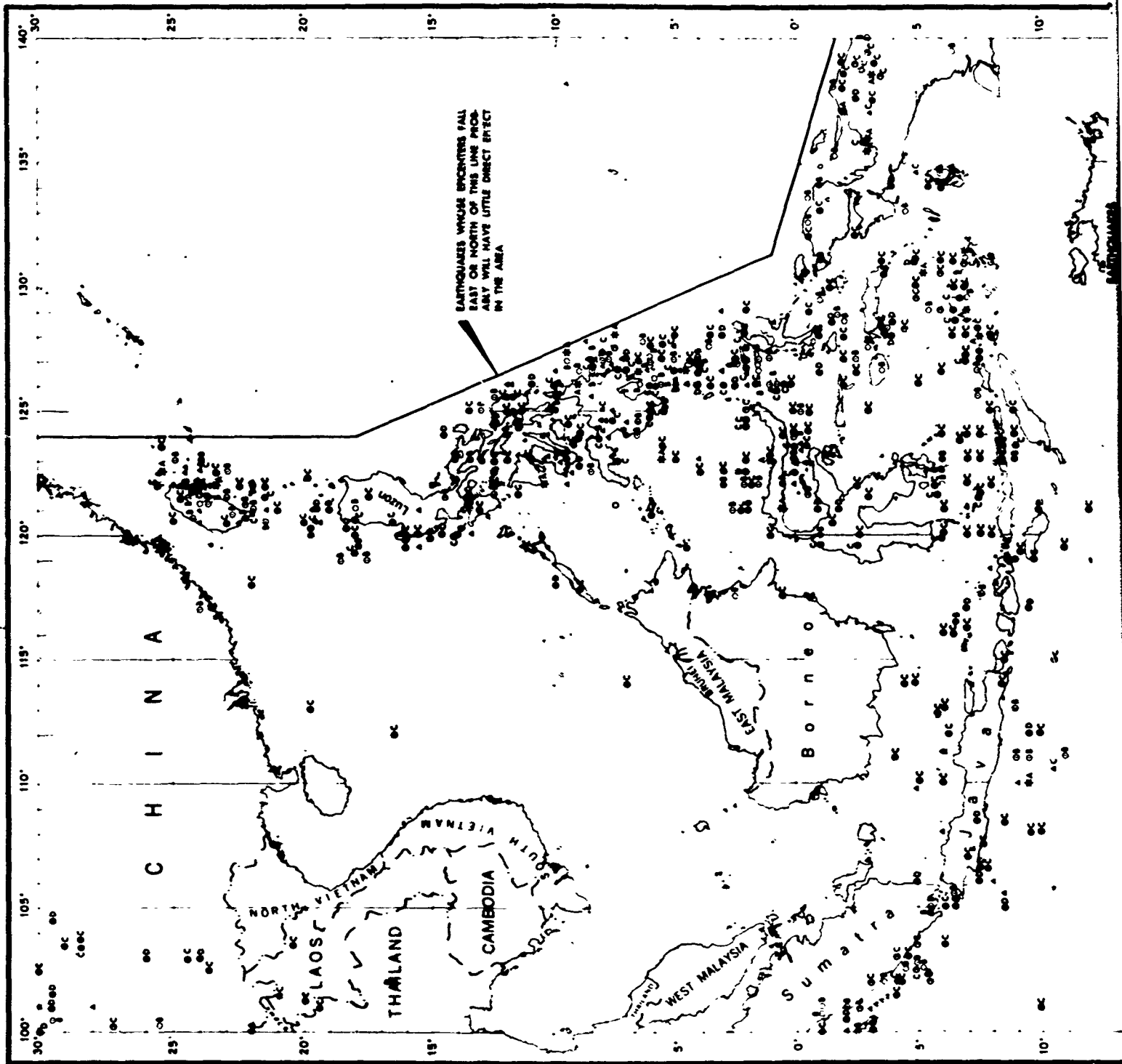
Although other eruptions in the area have not been as spectacular, they have taken their toll of lives over the years. For example, the hot clouds of ash which were thrown out by eruptions of Gunung Merapi on Sumatra in 1930-31 killed 1,350 people in the immediate vicinity of the volcano. Ten thousand people were reported killed by the mud flows, floods, and ash falls which resulted from the 1587 eruption of Gunung Kelud in central Java. A similar eruption in 1919 killed 5,110 people and destroyed about 100 villages. Winds, at different elevations above the cone, blowing in opposite directions caused an elliptical distribution of the 40 million cubic yards of ash which settled east and west of the volcano at different times. Similar wind patterns may account for the irregularities in

the distribution of ash from the 1815 eruption of Gunung Tambora. An eruption of Mount Taal on Luzon in 1912 killed about 1,400 persons. The 1965 eruption of Mount Taal destroyed only crops and livestock.

Many volcanoes in the area are dormant and exhibit only solfatara and fumarole activity. Mud volcanoes have been reported in Pulau-pulau Ewab, Timor, and Brunei Bay. The mud volcanoes in Timor and Brunei Bay are thought to be caused by rising gas escaping from petroleum accumulations, whereas those in Pulau-pulau Ewab are believed to be mud lumps.

REFERENCES

1. EVANS, F. J. and WHARTON, W. L. "On the Seismic Sea Waves Caused by the Eruption of Krakatoa." In: Royal Society of London, The Eruption of Krakatoa, and Subsequent Phenomena. Report of the Krakatoa Committee, pt. 3., p. 89-150. G. J. Symons, ed. London: Trubner and Co. 1888.
2. KUNO, HISASHI. "Submarine Volcanoes East and North of Taiwan," "Volcanoes of Ryukyu Islands and Kyusyu," pt. 11, Japan, Taiwan and Marianas." In: International Volcanological Association, Catalogue of the Active Volcanoes of the World. . Rome 1962. p. 1-8.
3. MURPHY, LEONARD M. and CLOUD, WILLIAM K. United States Earthquakes, 1955. Washington: U. S. Govt. Print. Off. 1957. 83p.
4. NEUMAN VAN PADANG, M. "Pt. 1, Indonesia" and "Pt. 2, Philippine Islands and Cochin China." In: International Volcanological Association. Catalogue of the Active Volcanoes of the World. . . Naples, Italy. Pt. 1, 1951, 271 p./ pt. 2, 1953, 49p.
5. SIEBERG, A. "Erdbebengeographie" (Earthquake geography). In: Gutenberg, beno ed., Handbuch der Geophysik, bd. 4, lief. 3, fig. 405, p. 702; fig. 406, p. 705; fig. 407, p. 710; fig. 408, p. 713; fig. 409, p. 719; fig. 410, p. 721; fig. 415, p. 738. Berlin: Borntraeger. 1932.
6. U. S. NAVAL OCEANOGRAPHIC OFFICE. "Earthquake data and bibliography file." Washington. Unpublished.
7. ----- "Tsunami data and bibliography file." Washington. Unpublished.



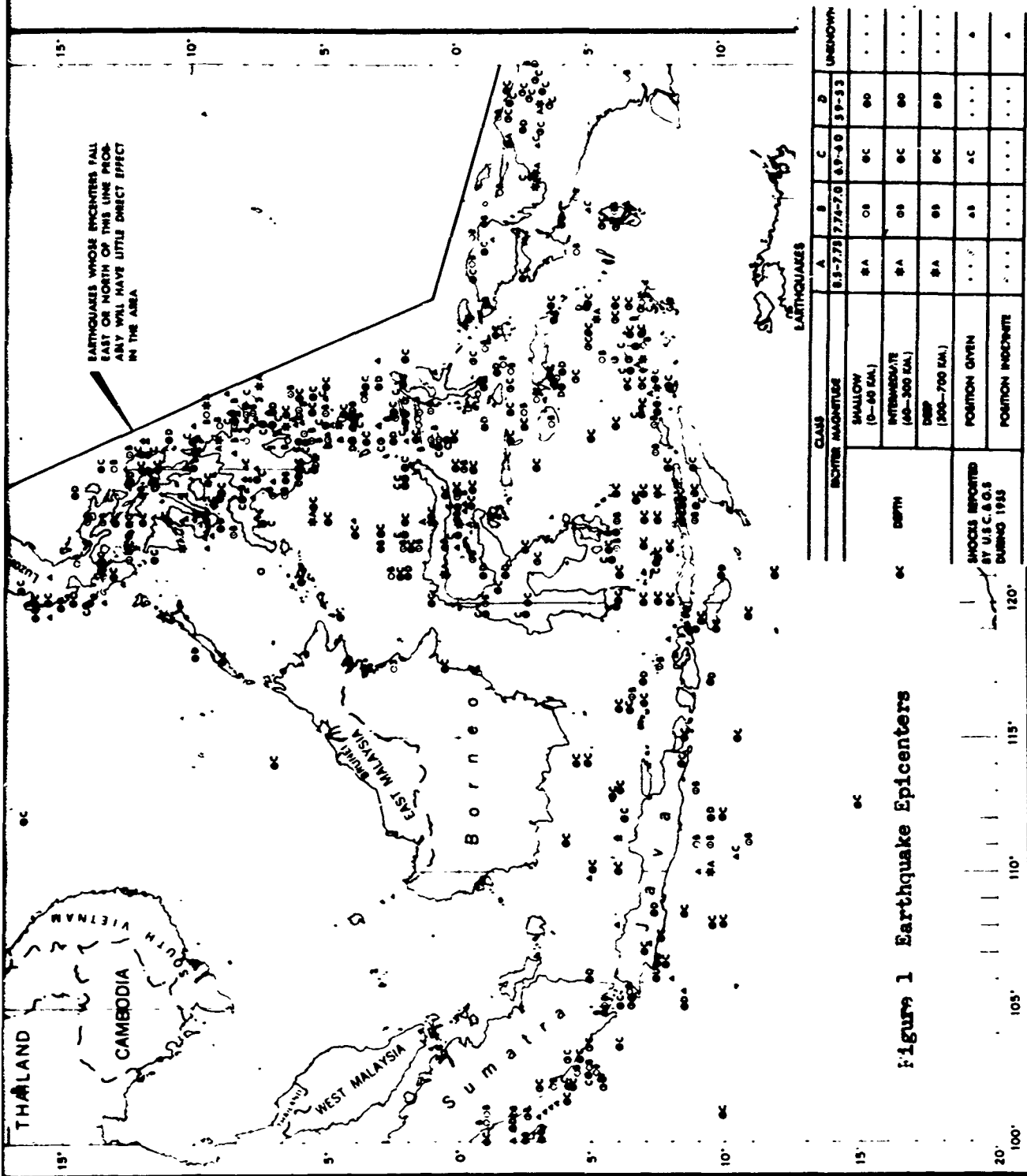
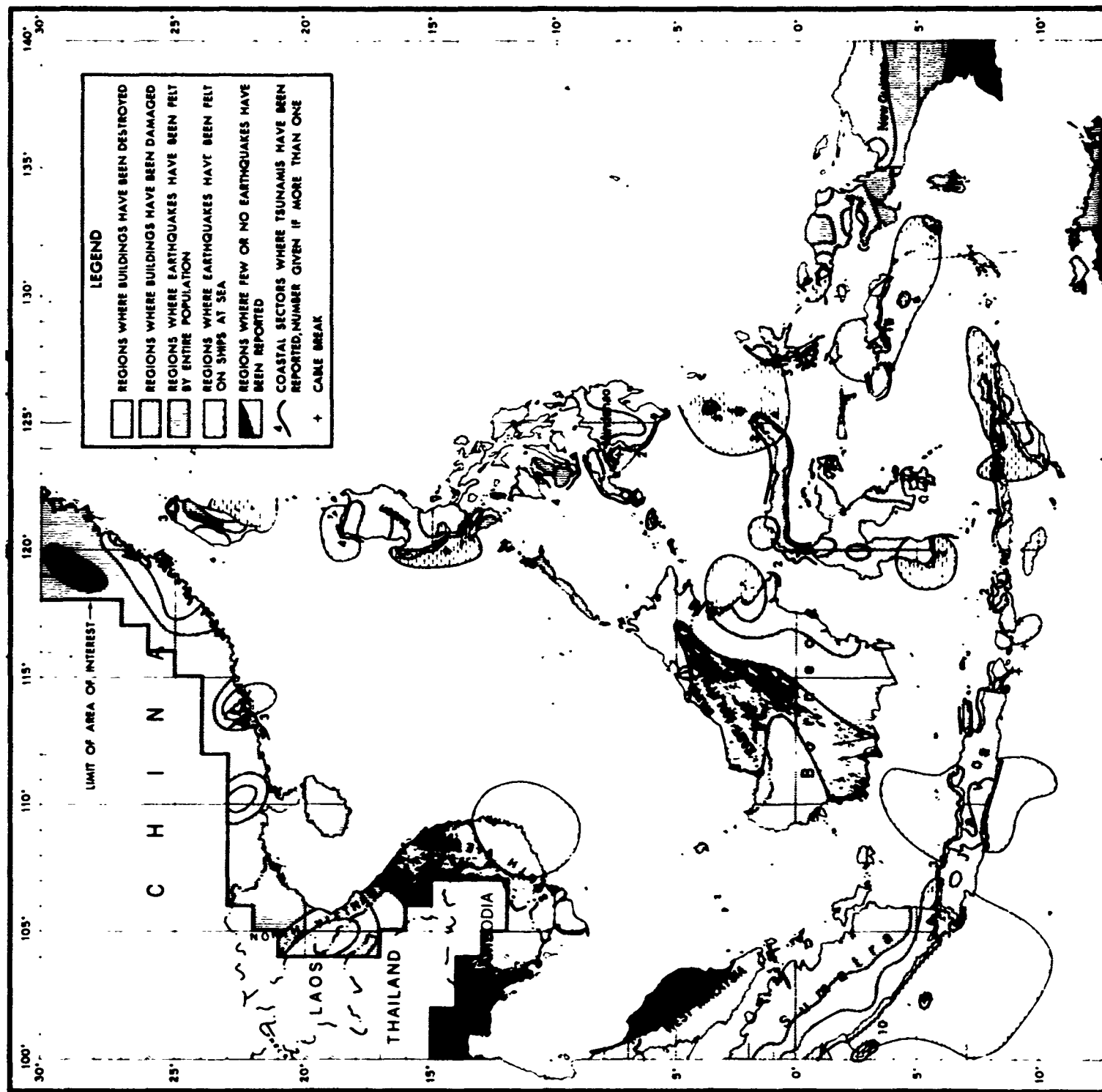


Figure 1 Earthquake Epicenters

WHERE MORE THAN ONE SHOCK HAS BEEN REPORTED FROM AN EPICENTER ONLY ONE IS SHOWN.



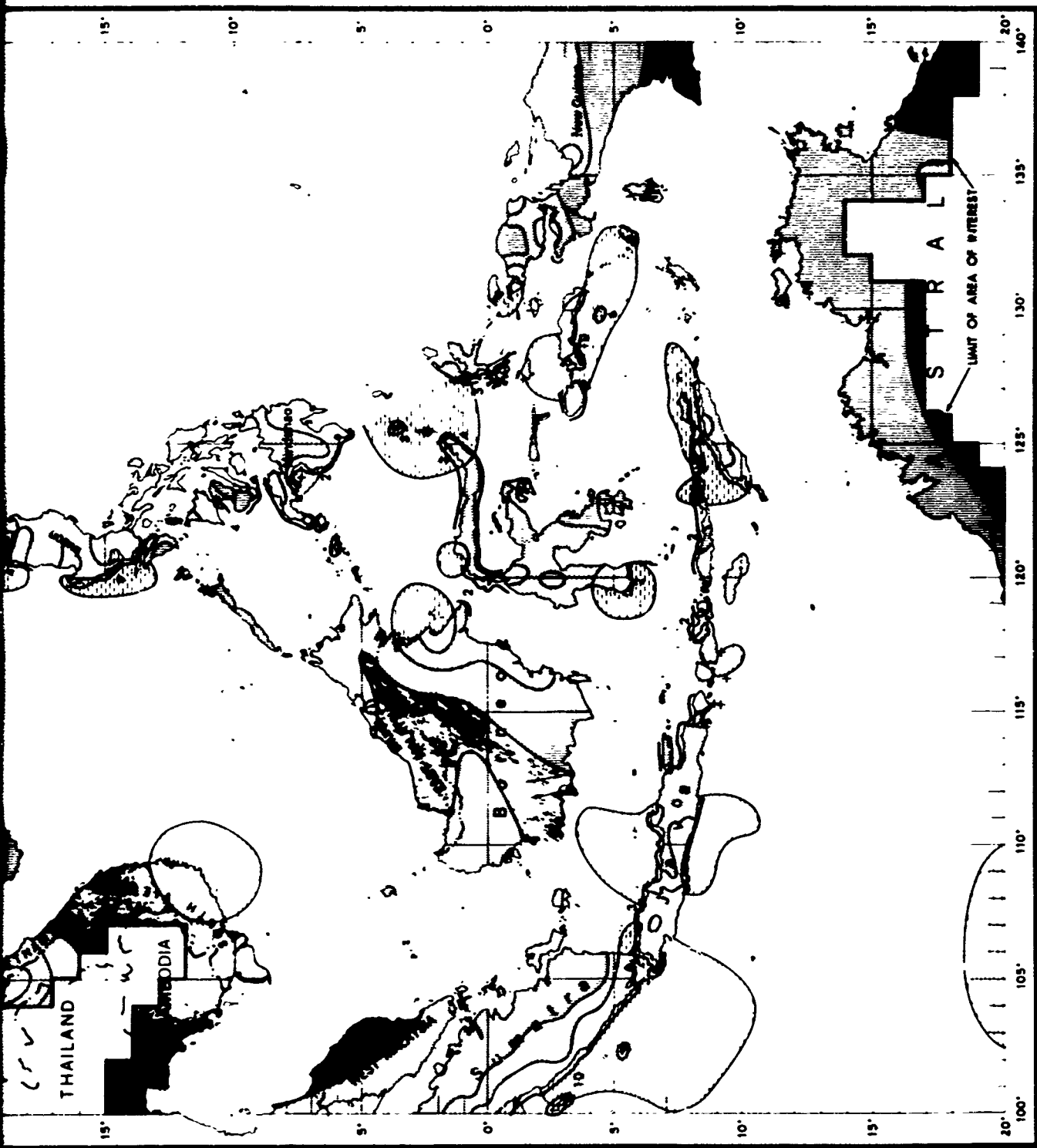
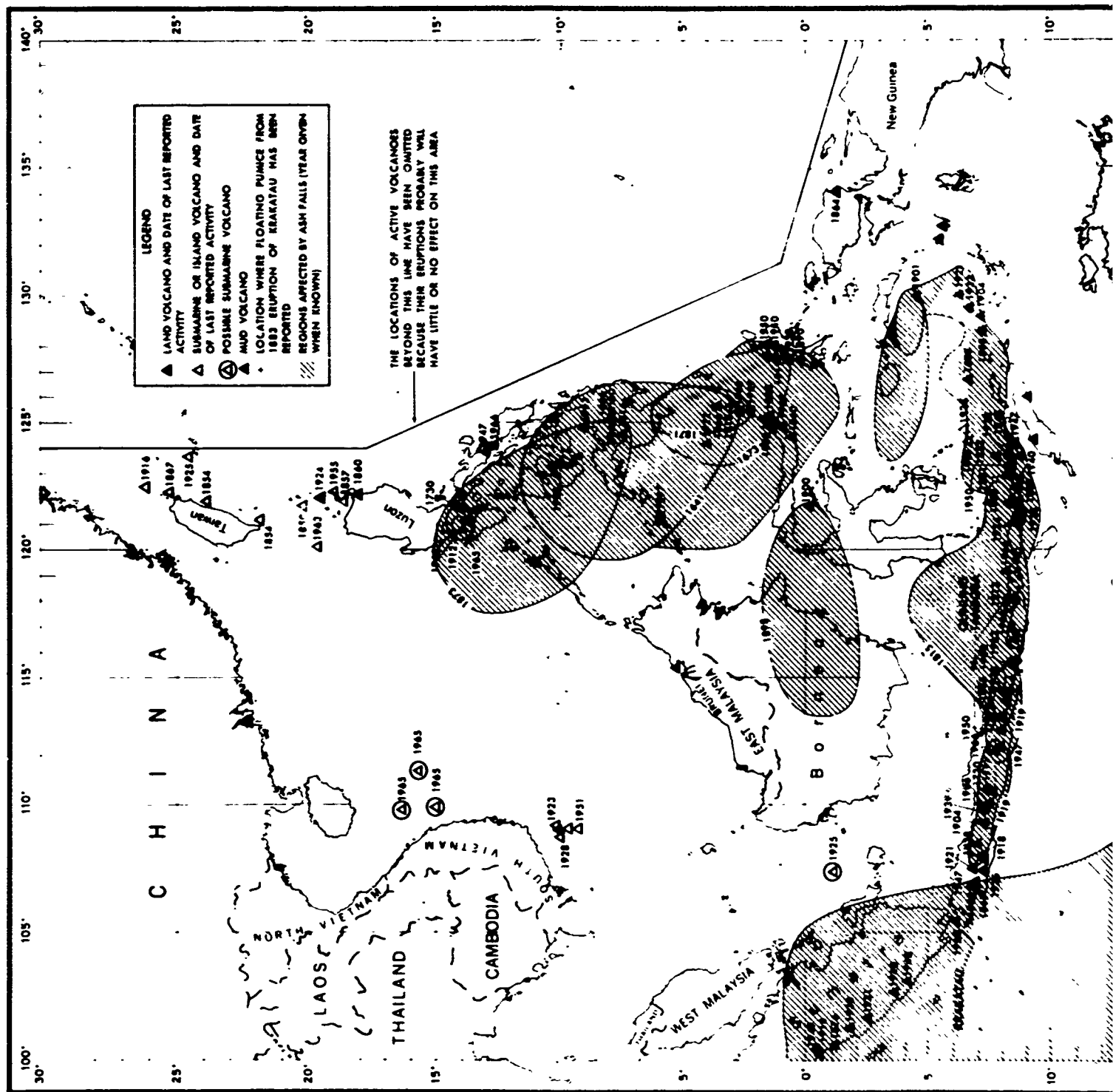


Figure 2 Regions Affected by Seismic Activity



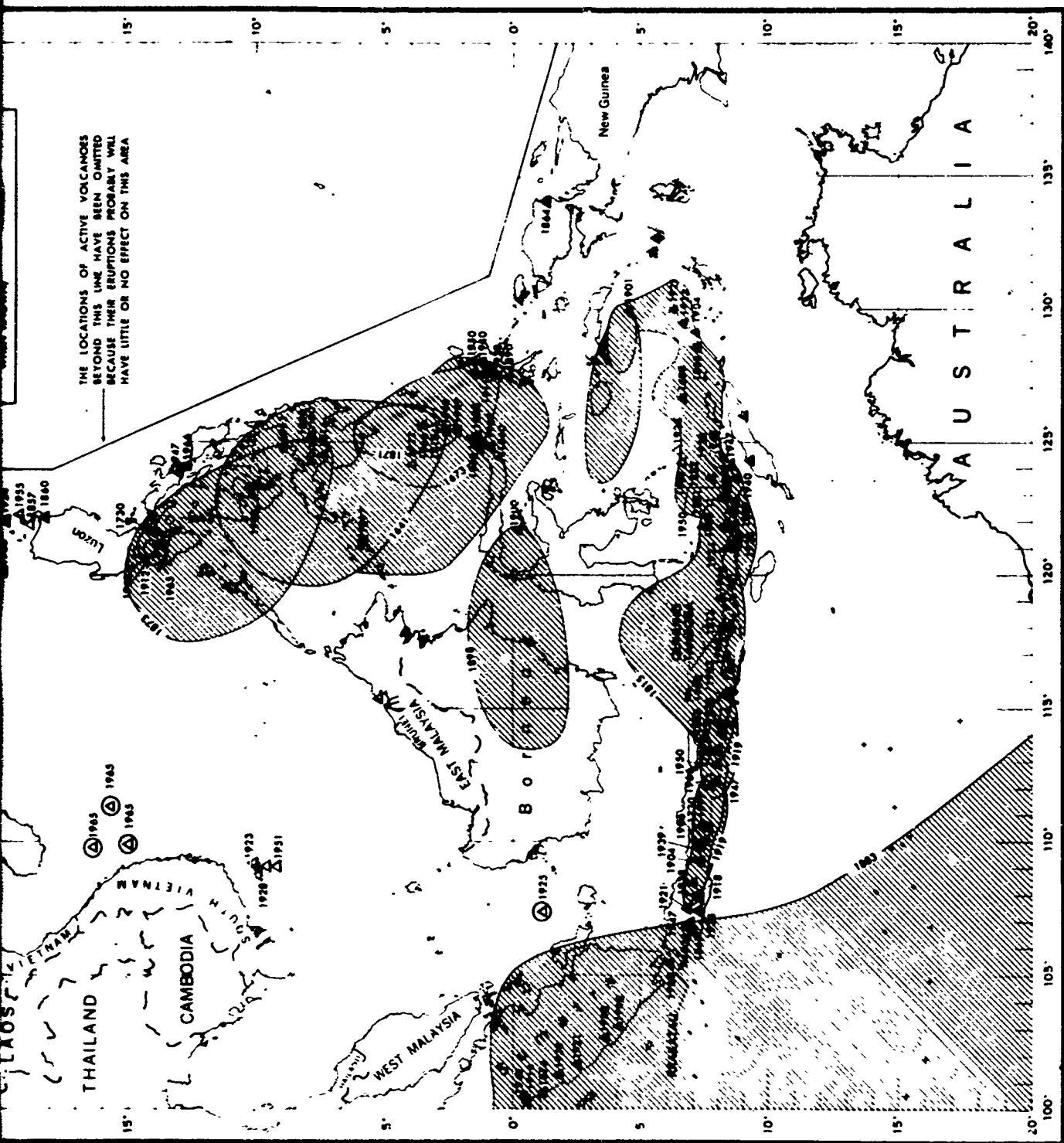


Figure 3 Volcanoes

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