1. EPICENTERS OF EARTHQUAKES
EARTHQUAKES THAT HAVE FOCAL DEPTHS LESS THAN 70km.
EARTHQUAKES THAT HAVE FOCAL DEPTHS 70km AND OVER
2. CRUSTAL MOVEMENT
HORIZONTAL DEFORMATION.
HORIZONTAL STRAIN.
VERTICAL MOVEMENT (I).
VERTICAL MOVEMENT (II)

## 1. Epicenters of Earthquakes (Earthquakes That Have Focal Depths Less Than 70 km). (Earthquakes That Have Focal Depths 70 km and Over)

Situated in the Circum-Pacific Seismic Zone, Japan is known as a country which is subject to frequent earthquakes. The earthquake energy discharged in Japan and its peripheries is said to account for about 15% of that of the entire world.

The majority of the earthquakes with focal depths of less than 70 km are concentrated in the seabed extending on the continental side from the trenches, but their occurrence in the inland areas is sporadic. The density of epicenters in the Kuril-Kamchatka Trench and also in the periphery of the Japan Trench is particularly high. Practically every destructive earthquake occurs in depths less than 70 km.

Earthquakes with focal depths of 70 km and over occur on the continental side from the trenches. The shallower the hypocenter is in depth, the closer the earthquake is to a trench, and the deeper the hypocenter, the closer the earthquake is to the Asian Continent. This feature is particularly evident in the peripheries of Northeast Japan.

**Salient Points of the Legend and Map Compilation**

The distribution of the epicenters of the earthquakes recorded by the earthquake observation network of the Japan Meteorological Agency were classified into earthquakes with focal depths of less than 70 km and earthquakes with focal depths of 70 km and over for use in the map. The reason is that no data are available on the magnitudes of the latter. As the occurrence of the former group of earthquakes is extremely great, the map represents only those which exceeded 5.0 in magnitude.

The map was prepared for the earthquakes which have occurred since 1926. This is because the redevelopment of the earthquake observation network was stepped up with the Kantō Earthquake which occurred in 1923 as a turning point, thus making it possible to publish highly accurate observation findings.

The magnitude is one of the measures to express the scale of an earthquake, and the Japan Meteorological Agency determines the magnitudes of earthquakes with focal depths of less than 70 km according to the equation,

$M = \log A + 1.73 \log \Delta - 0.83$, (TSUBOI, 1954).

Where M is the magnitude, A the maximum ground amplitude ($\mu$), and $\Delta$ the epicentral distance (km). When the magnitude increases by one, it is said that the seismic energy rises by about 32 times. In the peripheries of Japan, earthquakes with a magnitude of 5-6 take place at a rate of about 100 times a year, earthquakes with a magnitude of 6-7 occur at a rate of about 10 times a year, earthquakes with a magnitude of 7-8 occur at a rate of about once a year, and earthquakes with a magnitude of more than 8 take place once every 10 years.

**Source**

1. Japan Meteorological Agency, The Seismological Bulletin, 1926–1970.

## 2. Crustal Movement (Horizontal Deformation). (Horizontal Strain). (Vertical Movement I. II)

These maps illustrate the geographical distribution of the horizontal deformation, horizontal strain and vertical movement which have been computed with geodetic methods. All of them are closely correlated to the tectonics and the occurence of earthquakes.

**Salient Points of the Legend and Map Compilation**

Horizontal Deformation: In Japan, first-order triangulations were conducted twice in the past—i.e., 1882–1913 and 1949–1966. For this map, the computation was made on the basis of the findings of these two first-order triangulations. In the computation, the first-order triangulation points where practically no horizontal deformation is believed to have taken place in the past half century were picked as fixed points and net adjustments were conducted with the whole nation regarded as a single net.

The methodology in which a movement of the crust is indicated with the use of the direction and volume of the deformation (deformation vectors) makes it easy to visually grasp the dislocation, but its defects lie in the facts that this method is strongly influenced by accumulated errors as it parts from a fixed point, and that when a different fixed point is picked, it looks as though the deformation vectors changed all of a sudden, even though the relative position of each point remains unchanged. For this map, many fixed points were picked to minimize these defects.

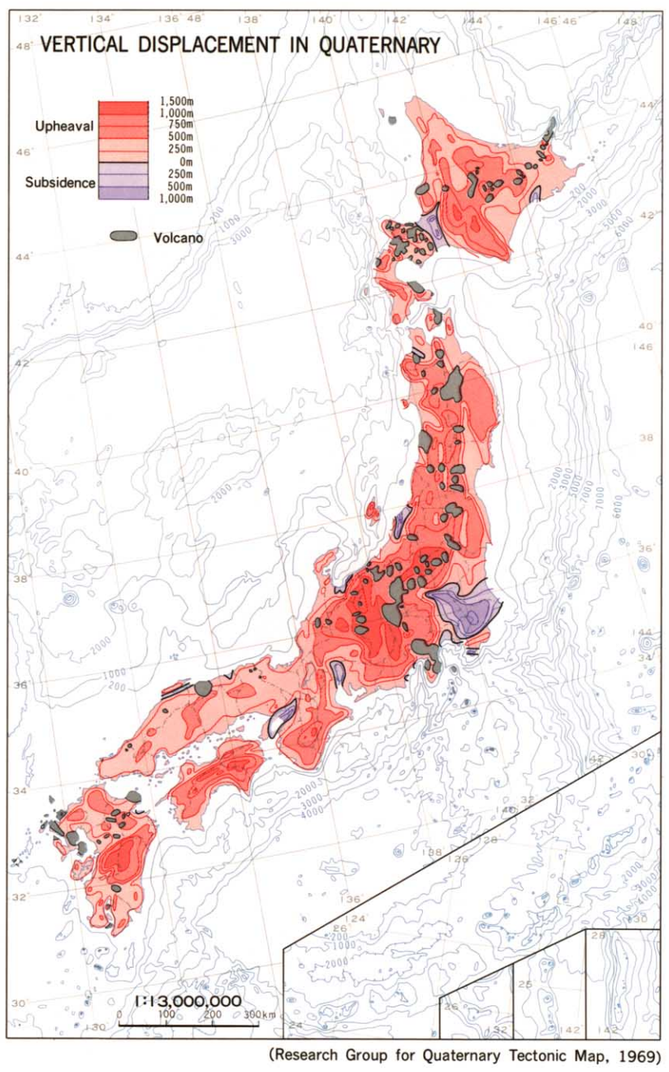
Horizontal Strain: If it is hypothesized that the crust deforms with the linear function of the coordinates, the circle drawn on the ground surface at the old surveying time progressively deforms and turns into an ellipse at the new surveying time. This ellipse is called a strain ellipse. Before and after a deformation, there exist a pair of directly intersecting axes with the intersecting angle remaining unchanged. The pair represents the long and short principal axes of the strain ellipse.

On the basis of the same first-order triangulation findings as in the case of the horizontal deformation, this map illustrates the directions of both principal axes of the strain ellipse computed for each triangle, and also their elasticity rate (principal strain).

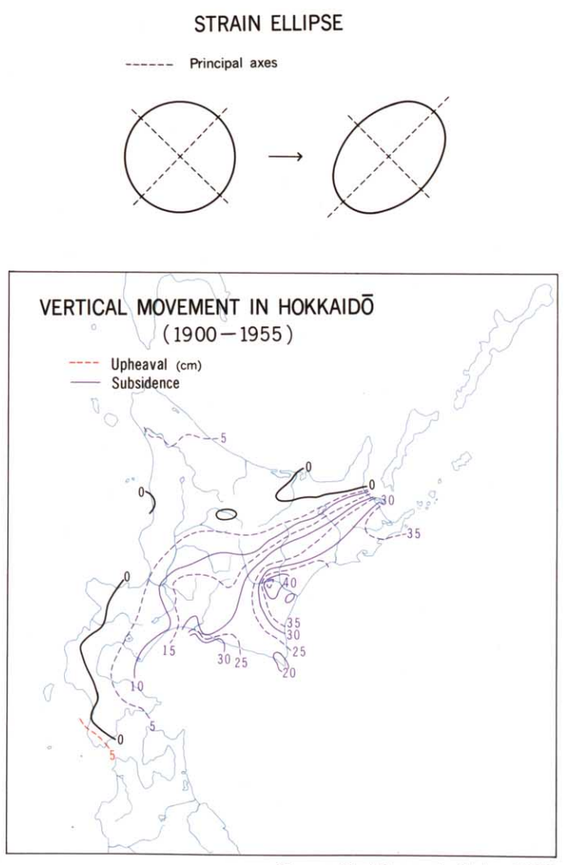
Vertical Movement: For these maps, the findings of the first-order leveling conducted in 1884–1913, 1923–1945 and 1946–1962 were put into order in the standard years of 1898, 1930 and 1950, and the vertical movement of the crust in the meantime was indicated with an isopleth. Here, it is to be noted that the change in the elevation of the datum station and the mean sea level of tidal stations were incorporated in the net adjustment.

**Sources**

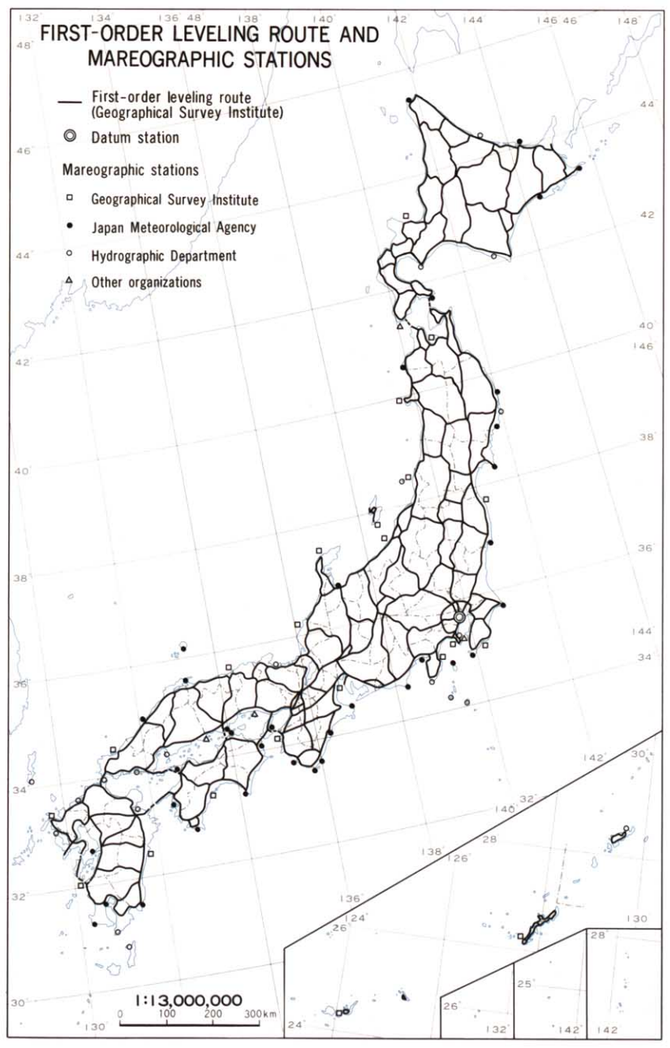
1. Takehisa HARADA and Nobuo ISAWA, Horizontal Deformation of the Crust in Japan—Result obtained by multiple fixed stations—, Jour. Geod. Soc. Japan, Vol. 14 Nos. 2 · 3, 1969.
2. Takehisa HARADA and Atuo KASSAI, Horizontal Strain of the Crust in Japan for the Last 60 Years, Jour. Geod. Soc. Japan, Vol. 17, Nos. 1 · 2, 1971.
3. Tetsuro HAYASHI, A Study on the Vertical Movements of the Earth's Crust by Means of the Precise Leveling, Bull. G.S.I., Vol. XV, Pt. 1, 1969
4. Geographical Survey Institute, Vertical Movement in Hokkaidō, Report of the Coordinating Committee for Earthquake Prediction, Vol. 4, 1970.
5. Research Group for Quaternary Tectonic Map, 1:2,000,000 scale Quaternary Tectonic Map of Japan, 1969.

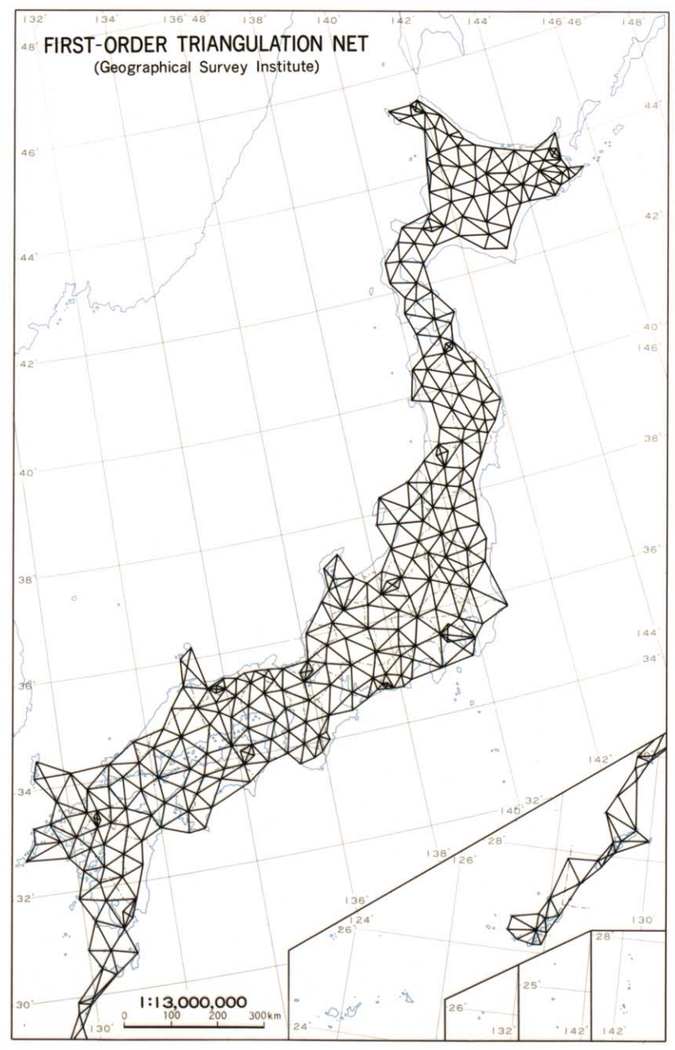



(Research Group for Quaternary Tectonic Map, 1969)



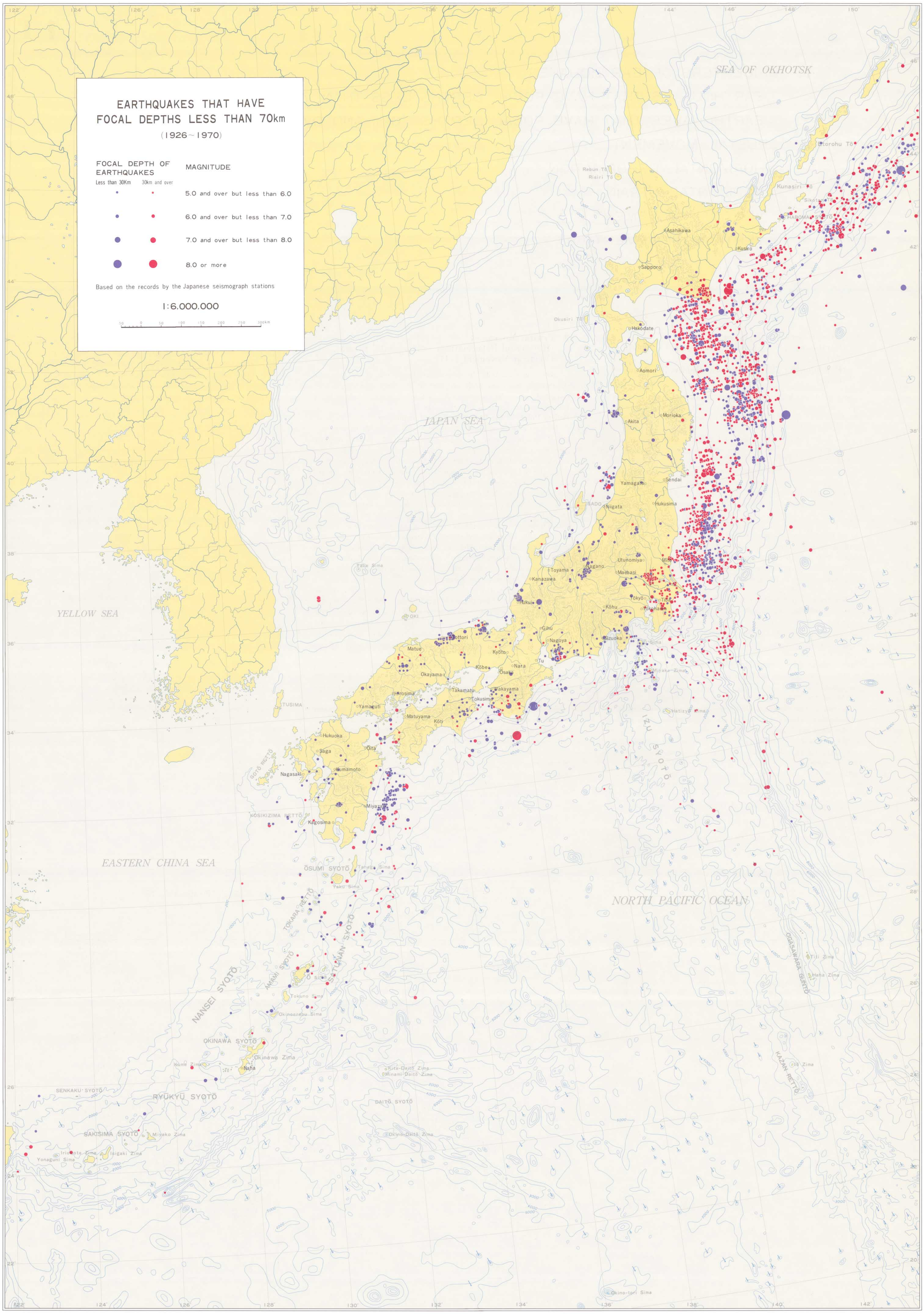

(Geographical Survey Institute, 1970)



# EPICENTERS OF EARTHQUAKES

11.1



# EARTHQUAKES THAT HAVE FOCAL DEPTHS 70km AND OVER

(1926~1970)

FOCAL DEPTH OF EARTHQUAKES

- 70km and over but less than 120km
- 120km and over but less than 200km
- 200km and over but less than 300km
- 300km and over but less than 400km
- 400km and over but less than 500km
- 500km or more

Based on the records by the Japanese seismograph stations

1:6,000,000

50 0 50 100 150 200 250 300km

SEA OF OKHOTSK
JAPAN SEA
YELLOW SEA
EASTERN CHINA SEA
NORTH PACIFIC OCEAN
Etorohu Tō
Rebun Tō
Risiri Tō
Kunasiri Tō
Sikotan Tō
HABOMAI GUNTŌ
Asahikawa
Kusiro
Sapporo
Okusiri Tō
Hakodate
Aomori
Akita
Morioka
Yamagata
Sendai
SADO
Niigata
Hukusima
Utunomiya
Nagano
Toyama
Kanazawa
Hukui
Kōhu
Gihu
Nagoya
Sizuoka
Tottori
Matue
Kyōto
Kōbe
Nara
Osaka
Okayama
Takamatu
Wakayama
Hirosima
Tokusima
Yamaguti
Matuyama
Kōti
Hukuoka
Saga
Ōita
Kumamoto
Nagasaki
Miyazaki
Kagosima
GOTŌ RETTŌ
KOSIKIZIMA RETTŌ
ŌSUMI SYOTŌ
Tanega Sima
Yaku Sima
TOKARA RETTŌ
AMAMI SYOTŌ
Ō sima
Tokuno Sima
Okinoerabu Sima
SATUNAN SYOTŌ
NANSEI SYOTŌ
OKINAWA SYOTŌ
Okinawa Zima
Kume Zima
Naha
SENKAKU SYOTŌ
RYUKYU SYOTŌ
SAKISIMA SYOTŌ
Miyako Zima
Iriomote Zima
Ishigaki Zima
Yonaguni Sima
Kita-Daitō Zima
Minami-Daitō Zima
DAITŌ SYOTŌ
Okino-Daitō Zima
Okino-tori Sima
IZU SYOTŌ
Hatizyō Zima
OGASAWARA GUNTŌ
Titi Zima
Haha Zima
KAZAN RETTŌ
Iō Zima
OKI
TUSIMA
Take Sima

# 11.2

## HORIZONTAL DEFORMATION

Fixed stations

Deformation vectors
2m

Vectors assuming multiple fixed stations calculated by the results of the old (1882–1913) and the new (1949–1966) first order triangulations

1 : 8,000,000

100 0 100 200km


## HORIZONTAL STRAIN

Directions of the principal axes of the strain ellipse

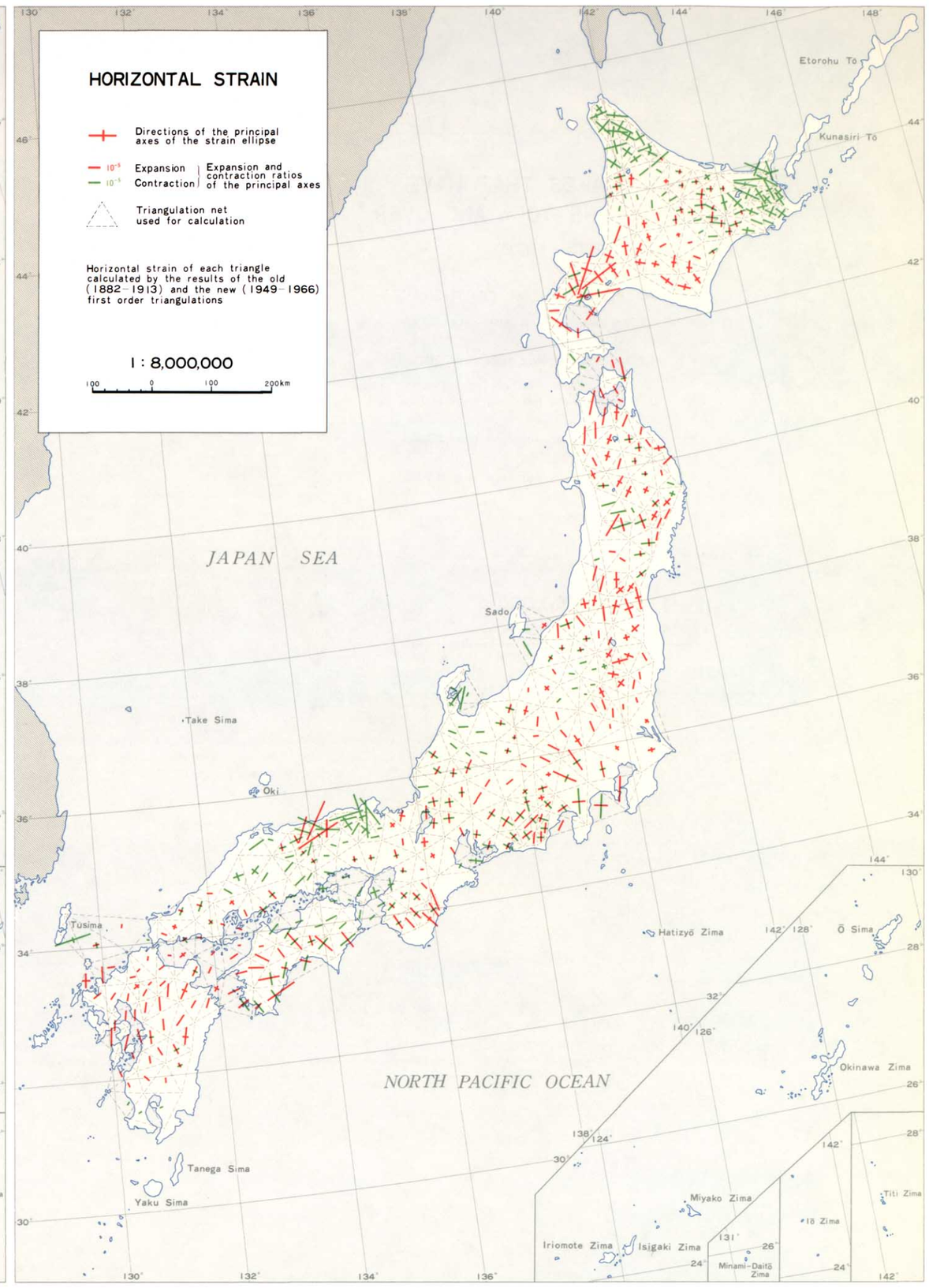
$10^{-5}$ Expansion
$10^{-5}$ Contraction
} Expansion and contraction ratios of the principal axes

Triangulation net used for calculation

Horizontal strain of each triangle calculated by the results of the old (1882–1913) and the new (1949–1966) first order triangulations

1 : 8,000,000

100 0 100 200km




## VERTICAL MOVEMENT (I)

(1898～1930)

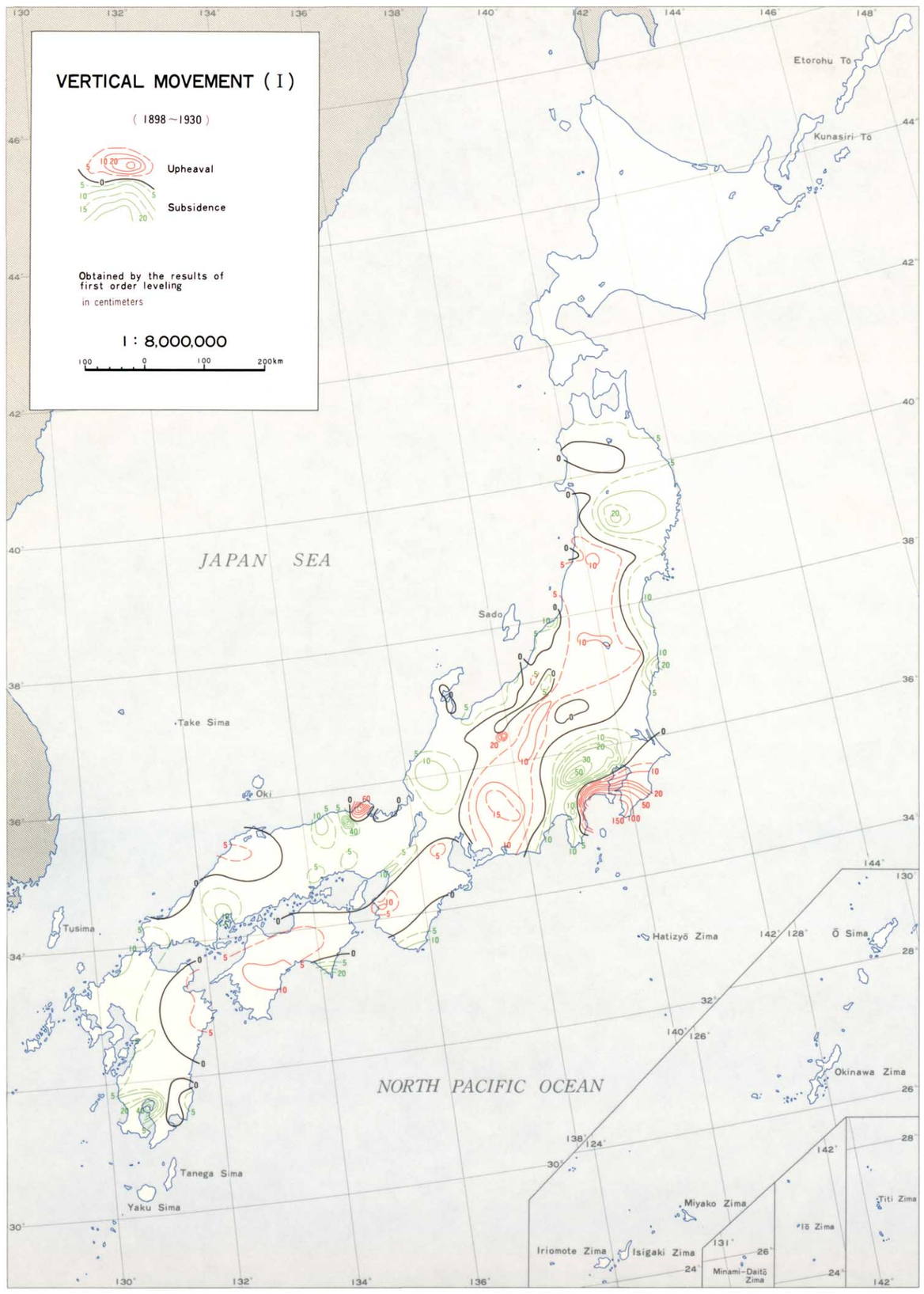
Upheaval

Subsidence

Obtained by the results of first order leveling
in centimeters

1 : 8,000,000

100 0 100 200km




## VERTICAL MOVEMENT (II)

(1930～1950)

Upheaval

Subsidence

Obtained by the results of first order leveling
in centimeters

1 : 8,000,000

100 0 100 200km