

PROCEEDINGS
OF
THE SECOND WORLD CONFERENCE
ON
EARTHQUAKE ENGINEERING

Tokyo and Kyoto, Japan

July 11—18, 1960

Volume III



Conference Organized by the

SCIENCE COUNCIL OF JAPAN

in cooperation with the

JAPAN SOCIETY OF CIVIL ENGINEERS
ARCHITECTURAL INSTITUTE OF JAPAN
SEISMOLOGICAL SOCIETY OF JAPAN

Copyright ©, 1960
by
Science Council of Japan
2nd Edition, 1965

*The Organizing Committee is not responsible either for the
statements made or for the opinions expressed in this volume.*

Printed by
GAKUJUTSU BUNKEN FUKYU-KAI
(Association for Science Documents Information)
OH-OKAYAMA, MEGURO-KU, TOKYO

CONTENTS

Volume I

	PAGE
PREFACE	I
PICTURE	XIII
AUTHORS' PICTURES.	LI
Members of the Organizing Committee	1
Association supporting the Conference	4
List of Donors	5
List of Participants.	10
Program	68
Registration and Pre-Conference Get-together.	78
Exhibition, Exhibitors and Movie Show.	79
Publications	85
Visits to Research Institutes	87
Social Events.	88
Tours	90
Program for Ladies.	92
Addresses delivered at the Conference	95
Opening Session <i>K. Muto</i>	95
. . . . <i>M. Yamagata</i>	96
. . . . <i>S. Ogata</i>	97
. . . . <i>T. Sato</i>	98
. . . . <i>H. Kano</i>	99
. . . . <i>J. E. Rinne</i>	100
Receptions <i>K. Muto</i>	102
. . . . <i>H. Kano</i>	102
Closing Session <i>I. Konishi</i>	103
. . . . <i>K. Muto</i>	104
Business Meetings	106
Minutes of Business Meetings	106
Recommendations for the Formation of an International Organization on Earthquake Engineering	114
Conference Summary. . . . <i>K. Muto</i>	118
Special Lectures	
<i>Y. Tanaka</i> On the Oldest Aseismic Iron Bridge in Japan.	123
<i>T. Naito</i> Fifty Years of Earthquake Engineering Practice.	127

Contents

<i>G. W. Housner</i> . . . Design of Nuclear Power Reactors Against Earthquakes	133
<i>R. Tanabashi</i> . . . Earthquake Resistance of Traditional Japanese Wooden Structures	151
Soil and Foundation Conditions Relative to Earthquake Problems (Session I)	
<i>H. Matsuo</i> and <i>S. Ōhara</i> . . . Lateral Earth Pressure and Stability of Quay Walls During Earthquakes	165
<i>H. B. Seed</i> Soil Strength During Earthquakes	183
<i>Y. Tahara</i> , <i>T. Takata</i> and <i>M. Fukuoku</i> . . . Some Experimental Studies on the Earthquake Proof Design of the Foundation of Bridge Pier in Soft Ground	197
<i>Y. Ishii</i> , <i>H. Arai</i> and <i>H. Tsuchida</i> . . . Lateral Earthpressure in an Earthquake	211
<i>V. A. Murphy</i> . . . The Effect of Ground Characteristics on the Aseismic Design of Structures	231
<i>S. Shiraiishi</i> Resistance of Foundation Ground Against Overturning Forces	249
<i>T. Shinohara</i> , <i>T. Tateishi</i> and <i>K. Kubo</i> . . . Bearing Capacity of Sandy Soil for Eccentric and Inclined Load and Lateral Resistance of Single Piles Embedded in Sandy Soil	265
<i>S. Niwa</i> An Experimental Study of Oscillating Earth Pressures Acting on a Quay Wall	281
<i>S. Murayama</i> and <i>T. Shibata</i> . . . On the Dynamic Properties of Clay	297
<i>Subsoil Research Team of the Earthquake Research Institute</i> . . . Earthquake Damage and Subsoil Conditions as Observed in Certain Districts of Japan	311
<i>T. Mogami</i> . . . Session Summary	327
Recent Strong Motion Earthquakes and Resulting Damage (Session V)	
<i>N. N. Ambraseys</i> . . . On the Seismic Behaviour of Earth Dams	331
<i>E. Rosenblueth</i> . . . The Earthquake of 28 July 1957 in Mexico City	359
<i>K. V. Steinbrugge</i> and <i>V. R. Bush</i> . . . Earthquake Experience in North America 1950-1959	381
<i>K. C. Cheng</i> Report on the 1951 Earthquake in Taiwan	397
<i>R. Flores</i> , <i>S. Arias</i> , <i>V. Jenschke</i> and <i>L. A. Rosenberg</i> . . . Engineering Aspects of the Earthquakes in the Maipo Valley, Chile, in 1958.	409
<i>C. M. Duke</i> Foundations and Earth Structures in Earthquakes	435
<i>J. A. R. Johnston</i> . . . A Brief History of Damaging Earthquakes in Wellington City and Developments in Multi-storied Building Construction in New Zealand	457
<i>R. Diaz de Cossio</i> . . . Foundation Failures During the Coatzacoalcos (Mexico) Earthquake of 26 August 1959.	473
<i>J. Krishna</i> , <i>R. S. Mittal</i> , <i>A. R. Chandrasekaran</i> and <i>S. K. Manglik</i> Kapkote Earthquake of Dec. 28, 1958.	487
<i>C. Lomnitz</i> A Study of the Maipo Valley Earthquakes of September 4, 1958.	501

Contents

<i>J. Despeyroux</i> . . . The Agadir Earthquake of February 29th 1960, Behaviour of Modern Buildings During the Earthquake	521
<i>Y. Sakabe</i> On the Damage of Fukui Earthquake and the Destructive Power of Earthquake of Such a Kind	543
<i>D. Tocher</i> Movement on Faults.	551
<i>R. Vignola</i> and <i>E. Arze</i> . . . Behavior of a Steel Plant under Major Earthquakes.	565
<i>H. Kawasumi</i> . . . Session Summary	581
Special Reports on the Recent Earthquake Damage	
<i>J. Despeyroux</i> . . . The Agadir Earthquake of February 29th 1960, Behaviour of Modern Buildings During the Earthquake.	589
<i>H. K. Afshar</i> . . . Report on the Lar Earthquake of 24th April 1960.	591
<i>R. Flores</i> Engineering Aspects of Chilean Earthquakes of May 21 and 22, 1960	609
<i>K. V. Steinbrugge</i> and <i>R. W. Clough</i> . . . Chilean Earthquakes of May, 1960: A Brief Trip Report	629
<i>R. Takahashi</i> . . . Report on the Chilean Tsunami of 1960	639
Index of Authors and Contributors to the Discussion	

Volume II

Analysis of Structural Response and Instruments (Session II)

<i>Response Analyzer Committee</i> . . . Non-linear Response Analyzers and Application to Earthquake Resistant Design	649
<i>G. N. Bycroft</i> . . . Analogue Computer Techniques in Aseismic Design.	669
<i>G. V. Berg</i> and <i>S. S. Thomaidis</i> . . . Energy Consumption by Structures in Strong-Motion Earthquakes	681
<i>R. L. Jennings</i> and <i>N. M. Newmark</i> . . . Elastic Response of Multi-Story Shear Beam Type Structures Subjected to Strong Ground Motion	699
<i>R. I. Skinner</i> , <i>K. M. Adams</i> and <i>K. J. Brown</i> . . . Earthquake Response of Bending Structures Derived from a Mixed Mechanical-Electrical Analogue.	719
<i>J. Penzien</i> . . . Elasto-Plastic Response of Idealized Multi-Story Structures Subjected to a Strong Motion Earthquake	739
<i>E. Shima</i> , <i>T. Tanaka</i> and <i>N. Den</i> . . . Some New Instruments Used in Earthquake Engineering in Japan.	761
<i>H. Tajimi</i> . . . A Statistical Method of Determining the Maximum Response of a Building Structure During an Earthquake	781
<i>S. Kotsubo</i> . . . Daynamic Water Pressure on Dams During Earthquakes.	799
<i>R. W. Clough</i> . . . Effects of Earthquakes on Under-water Structures	815
<i>W. T. Thomson</i> . . . A Survey of the Coupled Ground-Building Vibrations	833
<i>F. Neumann</i> . . . A Broad Formula for Estimating Earthquake Forces on Oscillators	849

Contents

<i>I. Konishi and Y. Yamada.</i> . . . Earthquake Responses of a Long Span Suspension Bridge	863
<i>J. I. Bustamante and E. Rosenblueth.</i> . . Building Code Provisions on Torsional Oscillations.	879
<i>A. S. Veletsos and N. M. Newmark.</i> . . Effect of Inelastic Behavior on the Response of Simple Systems to Earthquake Motions	895
<i>K. Kubo.</i> . . Aseismicity of Suspension Bridges Forced to Vibrate Longitudinally	913
<i>A. Hirai, T. Okumura, M. Ito and N. Narita.</i> . . Lateral Stability of a Suspension Bridge Subjected to Foundation-Motion	931
<i>G. Oberti and E. Lauletta.</i> . . Dynamic Tests on Models of Structures.	947
<i>M. Takeuchi and K. Nakagawa.</i> . . Vibrational Characteristics of Buildings.	961
<i>L. Zeevaert.</i> . . Base Shear in Tall Buildings During Earthquake July 28, 1957 in Mexico City	983
<i>G. W. Housner.</i> . . The Plastic Failure of Frames During Earthquakes	997
<i>T. Taniguchi.</i> . . Seismic Wall Effect in Framed Structure in Relation to the Period of Tall Buildings.	1013
<i>L. S. Jacobsen.</i> . . Damping in Composite Structures.	1029
<i>N. Ando.</i> . . Nonlinear Vibrations of Building Structures	1045
<i>J. A. Blume.</i> . . A Reserve Energy Technique for the Earthquake Design and Rating of Structures in the Inelastic Range	1061
<i>T. Kobori and R. Minai.</i> . . Study on Unstationary Vibration of Building Structure with Plastic Deformation of Substructure	1085
<i>D. E. Hudson.</i> . . A Comparison of Theoretical and Experimental Determinations of Building Response to Earthquakes	1105
<i>H. Kobayashi.</i> . . Dynamic Properties of Building Decided by Measurement of Vibration During Earthquake	1121
<i>T. K. Caughey, D. E. Hudson and R. V. Powell.</i> . . The C. I. T. Mark II Response Spectrum Analyzer for Earthquake Engineering Studies	1137
<i>S. Gershanik and G. Dedeant.</i> . . A Solution of the Basic Differential Equation of Seismic Loads and its Relation with the Expansion on Series of Eigenfunctions	1149
<i>R. I. Skinner, K. M. Adams and K. J. Brown.</i> . . Handbook for Determination of Response of Shear Buildings to an Earthquake	1161
<i>K. M. Adams, R. A. Morris and R. I. Skinner.</i> . . An Analogue Computer for the Determination of the Earthquake Response of Buildings in Bending and Shear Modes	1181
<i>J. A. Blume and R. W. Binder.</i> . . Periods of a Modern Multi-Story Office Building During Construction.	1195
<i>T. Tajime.</i> . . Theoretical Research on the Transient Vibration of Structures Subjected to Earthquake	1207
<i>R. Tanabashi.</i> . . Nonlinear Transient Vibration of Structures.	1223
<i>K. Muto, H. Unemura and Y. Sonobe.</i> . . Study of the Overturning Vibration of Slender Structures	1239
<i>H. Ishizaki and N. Hatakeyama.</i> . . Experimental and Numerical Studies on Vibrations of Buildings	1263

Contents

<i>A. G. Nazarov, B. K. Karapetian and S. A. Shahinian.</i> . . . The Method of Direct Determination of Reduced Spectra of Seismic Accelerations	1285
<i>J. A. Blume and J. F. Meehan.</i> . . . A Structural-Dynamic Research Program on Actual School Buildings.	1297
<i>H. Sandi.</i> . . . A Theoretical Investigation of the Interaction between Ground and Structure During Earthquakes	1327
<i>N. N. Ambraseys.</i> . . . The Seismic Stability of Earth Dams.	1345
<i>V. V. Bolotin.</i> . . . Statistical Theory of the Aseismic Design of Structures.	1365
<i>A. Z. Kats.</i> . . . Measurements of Dynamic Strains in Grounds and Constructions	1375
<i>S. Hayashi and N. Miyajima.</i> . . . Experimental Studies of the Vibration Characteristics of Quay Walls	1383
<i>S. Okamoto and T. Takahashi.</i> . . . On Behaviors of an Arch Dam During Earthquakes	1401
<i>I. Toriumi, Y. Satō and R. Yamaguchi.</i> . . . Vibrations in Foundation, Structure and in its Vicinity on the Elastic Ground	1413
<i>M. Derleres.</i> . . . Earthquake as Dynamic Phenomenon and Earthquake Resistant Structures	1431
<i>H. Goto and K. Kaneta.</i> . . . Analysis with an Application to Aseismic Design of Bridge Piers.	1449
<i>M. F. Barstein.</i> . . . Application of Probability Methods for Design the Effect of Seismic Forces on Engineering Structures	1467
<i>M. Ifrim.</i> . . . Dynamic Analysis of Tall Structures Subjected to Earthquake Motion.	1483
<i>S. Okamoto and Y. Tsuboi.</i> . . . Session Summary.	1507

Index of Authors and Contributors to the Discussion

Volume III

Seismicity and Earthquake Ground Motion (Session III)

<i>T. Hirono.</i> . . . Seismicity of Japan.	1511
<i>M. P. White.</i> . . . The Meaning of Spectra of Earthquake Records Obtained in or near Structures	1523
<i>E. Gajardo and C. Lomnitz.</i> . . . Seismic Provinces of Chile.	1529
<i>K. Kanai.</i> . . . An Empirical Formula for the Spectrum of Strong Earthquake Motion	1541
<i>J. J. Figueroa A.</i> . . . Some Consideration about the Effect of Mexican Earthquakes	1553
<i>N. Nasu.</i> . . . Investigation of the Ground in the Northern Part of the City of Yokkaichi in the North Ise Industrial District	1563
<i>J. L. Alford.</i> . . . Damage Produced by Small Ground Motions	1583
<i>I. Muramatsu and T. Yabashi.</i> . . . The Seismic Intensity at a Certain Dam Site	1593
<i>W. K. Cloud and D. S. Carder.</i> . . . Ground Motions Generated by Underground Nuclear Explosions	1609

Contents

<i>K. C. Chakravorty and D. P. Ghosh.</i> . . . Seismological Study of the Crustal Layers in Indian Region From the Data of Near Earthquakes	1633
<i>S. A. Fedotov.</i> . . . Seismicity of the South of the Kuril Islands	1643
<i>F. Kishinouye.</i> . . . Microseisms and Subsoil Conditions	1649
<i>P. Kumar.</i> . . . Geotectonic Movements and Their Influence on the Hydrography of Indo-Gangetic Plains.	1655
<i>P. G. Buffinton.</i> . . . Earthquake Insurance in the United States—A Reappraisal.	1669
<i>H. Kawasumi.</i> . . . Session Summary.	1687
Earthquake Resistant Design, Construction and Regulations (Session IV)	
<i>Y. Tsuboi and M. Kawaguchi.</i> . . . On Earthquake Resistant Design of Flat Slabs and Concrete Shell Structures.	1693
<i>J. E. Rinne.</i> . . . Design Criteria for Shear and Overturning Moment	1709
<i>D. Vergun and D. V. Whitmore.</i> . . . Aseismic Design of Two Long-Span Multi-Story Buildings.	1725
<i>V. A. Bikhovsky, J. I. Goldenblat and J. L. Korchynski.</i> . . . Design of Earthquake-Proof Building Structures in the USSR.	1743
<i>J. G. Bouwkamp and J. F. Meehan.</i> . . . Drift Limitations Imposed by Glass.	1763
<i>K. S. Zavriev.</i> . . . Guaranteeing Antiseismicity of Buildings on the Basis of Investigations Carried out in the USSR	1779
<i>J. M. Raphael.</i> . . . The Effect of Lateral Earthquake on a High Buttress Dam.	1791
<i>J. Krishna.</i> . . . Seismic Data for the Design of Structures	1803
<i>T. Naka, M. Wakabayashi and S. Takada.</i> . . . Quake Resisting Design of Composite Structures in Japan.	1811
<i>A. Zeevaert.</i> . . . Construction Practices for Multistory Buildings Subjected to Earthquakes.	1827
<i>R. W. Binder and W. T. Wheeler.</i> . . . Building Code Provisions for Aseismic Design.	1843
<i>J. F. Borges.</i> . . . Portuguese Studies on Earthquake Resistant Structures.	1877
<i>S. V. Medvedev.</i> . . . The Forecast of Seismic Effects on Constructions.	1889
<i>H. J. Degenkolb.</i> . . . Earthquake Resistant Design of Small Buildings.	1901
<i>M. Numata.</i> . . . Earthquake-Resistant Design for Civil Engineering Structures, Earth-Structures and Foundations in Japan.	1917
<i>Y. Otsuki.</i> . . . Design Seismic Forces for Reinforced Concrete Buildings	1947
<i>T. Hatano and H. Tsutsumi.</i> . . . Dynamical Compressive Deformation and Failure of Concrete under Earthquake Load	1963
<i>S. Ban and H. Muguruma.</i> . . . Behaviour of Plain Concrete under Dynamic Loading with Straining Rate Comparable to Earthquake Loading	1979
<i>S. Menayas.</i> . . . Accuracy and Simplification of the Seismic Design	1995
<i>E. Rosenblueth.</i> . . . Aseismic Provisions for the Federal District, Mexico.	2009
<i>R. Hicks and I. A. B. Gaunt.</i> . . . The Seismic Design of a Nuclear Power Station for Japan.	2027
<i>M. Hatanaka.</i> . . . Study on the Earthquake Resistant Design of Gravity Type Dams	2041

Contents

<i>I. Minami.</i> . . . A Consideration on Earthquakeproof Design Methods of Earth Dam.	2061
<i>S. Tani.</i> . . . Study on Arrangements of Aseismatic Elements	2075
<i>K. Takeyama, T. Hisada and Y. Ohsaki.</i> . . . Behavior and Design of Wooden Buildings Subjected to Earthquake.	2093
<i>A. Brenier.</i> . . . French Regulations for Civil Engineering in Regions Broken by Seismism.	2113
<i>S. Sachanski.</i> . . . Analysis of the Earthquake Resistance of Frame Buildings Taking into Consideration the Carrying Capacity of the Filling Masonry.	2127
<i>R. N. Joshi.</i> . . . Striking Behaviour of Structures in Assam Earthquakes.	2143
<i>A. A. Beles and M. Ifrim.</i> . . . Engineering Aspects of Earthquakes in Rumania in the Light of Modern Investigations	2159
<i>E. Titaru and A. Cismigiu.</i> . . . On the Rumanian General Design Specifications for Civil and Industrial Buildings in Seismic Areas; Examples	2177
<i>E. Titaru and A. Cismigiu.</i> . . . Aseismic Design of an Oil Refinery in the State of Assam India.	2203
<i>N. Korcinski.</i> . . . On Aseismic Resistance of Structures Taking into Account the Different Behavior of Materials to Shock Loads	2217
<i>T. Hisada.</i> . . . Session Summary.	2225

Index of Authors and Contributors to the Discussion

SEISMICITY AND EARTHQUAKE
GROUND MOTION
(SESSION III)

*The questions not answered in a written form by the
author do not appear on the pages of discussion.*

Seismicity of Japan

Takuzo Hirono*

Japan belongs to the Circum-Pacific Seismic Zone and its seismic activity is more vigorous than any other place of the same zone. Japan experiences earthquakes which are perceptible somewhere on Japan about 1497 times in average year from 1923 to 1959 but they vary considerably from year to year (See Fig.1) and become numerous after any big earthquake or by occasional earthquake swarms. The maximum number for the last 37 years occurred in 1930 amounting to 5770 while the minimum in 1958 was 850. The former was caused by the earthquake swarms which occurred near Hakone..[1].

The geographical distribution of the number of earthquakes which were felt by persons is shown in Fig.2 which is made on the basis of the data of the last 38 years. It indicates that the most frequently felt region is that along the Pacific coast of east and north Japan, while other regions are not so frequent, and the most quiet region is north Hokkaido. Fig.3 is a similar chart made by the late Prof. Omori [2] showing the total number for 6 years from 1885 to 1890 and it shows also that the Pacific coast of east Japan is most frequent. This fact indicates that the trend of the recent seismic activity has not changed very much since that time.

In Fig.2, the largest number of perceptible earthquakes was observed at Tsukuba to the east and Wakayama to the west both of which amount to 137 times per year as the mean value of from 1921 to 1958. [3] This value means that about 18% of the total felt earthquakes in Japan are occurring in these two localities. The former is situated within the most frequently felt region of the Pacific coast, but the latter is isolated outside of that region. The earthquakes of Tsukuba occur mostly at depths of between 30 to 60 Km, while those of Wakayama occur, shallower than 30 Km. Though these two places are habitually occurring regions, sometimes there are temporarily local swarms of earthquakes especially at volcanic regions.

That the most frequently felt region lies along the Pacific coast of north and east Japan suggests that there is a zone of seismic activity off these coasts. Fig.4 which shows the distribution of the epicenters of earthquakes during 1926-1956 assures this suggestion. All these earthquakes have the magnitudes such that the diameters of their perceptible areas are larger than 200 Km, that is, about 4.0 in M scale (the magnitude scale of Gutenberg and Richter) and let us call them A group. Fig. 4 shows that the seismic activity concentrates off the coast of the Kanto District. It extends northwards under the Pacific Ocean along the coast of east and north Japan, while in west Japan it disperses evenly over the land and less active under the sea far off that coast. [4].

The number of earthquakes mentioned above is about 1/2 in the average year as seen in Fig.5 and it is about 10% of the average number of all perceptible earthquakes. Let us call the latter group as F: it involves A in it. Secular variations of these two groups are very different from each other. While F group has been diminishing recently, A group has been increasing. The yearly number of earthquakes with a perceptible area

* Japan Meteorological Agency

of larger than 600 Km in diameter is also shown in Fig.5 as B group. Their magnitudes are larger than $5\frac{3}{4}$ in M scale. They occur about 23 times in the average year, and, hence, it is 16% of A group.

The earthquake which could cause casualties has a magnitude larger than 6. The distribution of such dangerous shocks which occurred during recent 31 years is shown in Fig.6. It also shows that the largest activity is under the Pacific Ocean similar to Fig.4. But as they originated far off the coast, the majority of these shocks ended in harmlessness. Even the earthquakes of the order of 7 in M scale which could kill few thousand persons if it occurs under a crowded city remained in causing a weak tsunami at the worst.

The data of 31 years above mentioned shows that the earthquakes of magnitude larger than 6 occur 16 times in average year, of which 4 are deeper and 12 shallower than 60 Km, and among shallower ones, 10 occur under the sea and 2 on land of which only one causing damage. Those larger than 7.0 in M scale occur twice in average year of which one is deep and once every 3 years on land.

It is true that earthquakes of the order of 7 in M scale occurred occasionally on land, but the earthquakes of the order of 8 did not happen on land during 31 years now under consideration. They occurred under the Pacific Ocean, and they were only 4 times. The last earthquake of the order of 8 which occurred on land is the Mino-Owari Earthquake of 1891 (M: 8.4) which is famous for a fault traced to a distance of about 100 Km. It demolished or badly damaged 142,177 houses and killed 7273 people.

Some of the earthquakes of the order of 8 which occurred under the ocean brought large tsunamis destroying harbours and fishing villages. As a matter of fact, when the submarine origin is under the shallow sea near the land the direct damage of shock is comparatively more severe than the damage due to tsunami as in the case of the Nankaido Earthquake of 1946, while when the origin locates far off the coast under the deep sea bottom, it causes big tsunami devastating the coasts nearest to the origin. This devastation is far greater than the direct damage of shock as in the case of the Sanriku Earthquake of 1933.

As stated above the sea bottom off the coast of the Pacific Ocean of north and east Japan is most vigorous in seismic activity but big earthquakes of the order of 8 in M scale occur also under the Pacific Ocean off the coast of west Japan, and though Fig.6 indicates their epicenters as points, the regions of crustal deformation due to them are thought to occupy considerably large areas. Fig.7 which was made by Mr. Musha[5] shows the epicentral regions of destructive earthquakes during the past two thousand years. It shows the largest areas correspond to the earthquakes of the order of 8 in M scale. When large epicentral areas are also taken as active places, the zone of seismic activity of the Pacific coast is thought to be continuous throughout north, east and west Japan and this is called the Outer Seismic Zone. On the other hand, several earthquakes of the order of 7 in M scale have occurred along the coast of the Japan Sea forming another seismic zone which is called the Inner Seismic Zone. Besides these, several minor ones seem to exist

and earthquakes occurring there do not always cause less casualties than those of the two major zones.

Now, it must be noted that in Fig.4 and 6, only the epicenters shallower than 60 Km in depth are shown. As far as seismicity is concerned it would be inadequate to omit deep earthquakes, but there is no record of damage by any earthquake which originated at a depth deeper than 80 Km. Therefore it is not so significant from the point of view of earthquake engineering that we confine ourselves to show the geographical distribution of deep earthquakes during 1926-1956 (Fig.8). Earthquakes deeper than 200 Km form themselves into seismic zones other than those for shallow earthquakes.

The earthquakes by which damage was caused in Japan since 1900 have amounted to 70 in number [6], among these those bringing the death roll of more than 10 were 24, that is, Japan has about one of these per year. The earthquake which caused greatest number of casualties in Japan was the Kanto Earthquake of 1923 by which 576,000 houses were destroyed or burnt down and 143,000 persons were killed or missing. The next is the Fukui Earthquake of 1948 in which 99,000 houses were burnt down and 3,579 persons were killed.

One of the most remarkable features of the epicentral region of large earthquakes is its habit of repetition of earthquake's occurrence. For instance, in the Pacific Ocean off west Japan large earthquakes have occurred 7 times or more in almost the same place in the past two thousand years. This is a very important fact as it suggests that the place where people have experienced severe earthquakes will probably be visited some day by another earthquake of a similar intensity. Therefore, the intensity distribution of large earthquakes is very interesting. Fig.9 is an example showing the intensity distribution in the case of the Nankaido Earthquake of 1946.

The scale of earthquake intensity which is now used in Japan consists of 7 grades excluding no feeling (See Table 1). Though determined by the feeling of human body, observed intensity was found to have a considerably close relation with the maximum acceleration of ground motion and it is given by Prof. Kawasumi [7] as

$$a_n = 0.8 \left(10^{\frac{n-1}{2}} - 10^{\frac{n}{2}} \right) \text{ gal} \quad \text{for } 1 \leq n < 7$$

$$a_0 < 0.8 \text{ gal.}$$

$$a_7 > 250 \text{ gal.}$$

where a_n is the acceleration corresponding to the intensity n , and the 7th grade of the intensity scale was created after the Fukui Earthquake of 1948.

Damage to houses begins to appear when the intensity attains to 5 grade and houses fall down when it becomes 6 grade. Fig.10 shows the distribution of the number of occurrences of intensities larger than 4 for the last 38 years. It shows that earthquakes with 5, 6 and 7 intensity grades occur most frequently in the Kanto District which is Tokyo and its surrounding area, and actually the place where earthquakes of these intensities occur more frequently than any other places is an

isolated point, Kofu. The observed number at Kofu is 13 for the same period, but all of them occurred in 1923, the year of the great Kanto Earthquake.

Besides the 108 weather stations of J.M.A. (Japan Meteorological Agency) there are about 1,100 weather sub-stations where seismic intensity is observed without instruments, and all of these stations send in reports on the observations they have made to the J.M.A. This data, especially data regarding the maximum earthquake intensity in a certain place, is made available to construction engineers before they begin to erect constructions of any kind, i.e. buildings, embankments, bridges etc.

As it is impossible for one station to determine the exact origin of earthquake the above mentioned 108 stations, each being equipped with seismographs of one and 100 in magnification, form a network and work together in order to ascertain an earthquake's origin, and the location and the intensity distribution of the earthquake felt by persons are generally announced officially about 50 minutes after the occurrence of the earthquake and when there is a fear of tsunami by a submarine earthquake, a tsunami warning is to be issued from some of 8 tsunami warning centers within 20 minutes after the earthquake's occurrence. Then, of course, the network of communication needs to work at its highest speed so that the warning is in time for the arrival of tsunami.

Casualties by earthquakes are tending to increase because city populations are growing larger and larger and large industrial constructions such as factories etc. are becoming more and more. In order to prevent such casualties not only earthquake proof engineering but also earthquake prediction is important. Consequently, seismologists in Japan who have the facilities to do so are concentrating their efforts on this problem of earthquake prediction. This has been one of the major problem facing seismologists in Japan since the days of Prof. Omori and Inamura.

References

- 1 Seismological Section, J.M.A. (1959): Number of Felt Earthquakes classified according to the Districts and Classes (1923 - 1958)
- 2 F. Omori (1907): Jishingaku-Kowa (Lectures on Seismology)
- 3 J.M.A. Seismological Bulletin, December Issues of 1955 -
- 4 J.M.A. (1958): Catalogue of Major Earthquakes which occurred in and near Japan (1926 - 1956)
- 5 J.M.A. (1952): Manual of Seismological Observation.
- 6 Compiled by Tokyo Astronomical Observatory (1960): Rika-Nenpyo (Scientific Annals)
- 7 H. Kawasumi (1943): Seismic Intensity and Seismic Intensity Scale (in Japanese), Zisin Vol.15, p.187

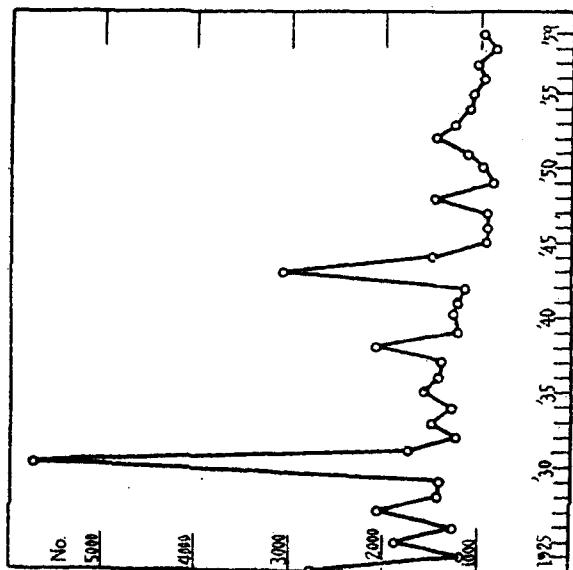


Fig. 1 The secular change of the number of earthquakes felt in Japan in each year.

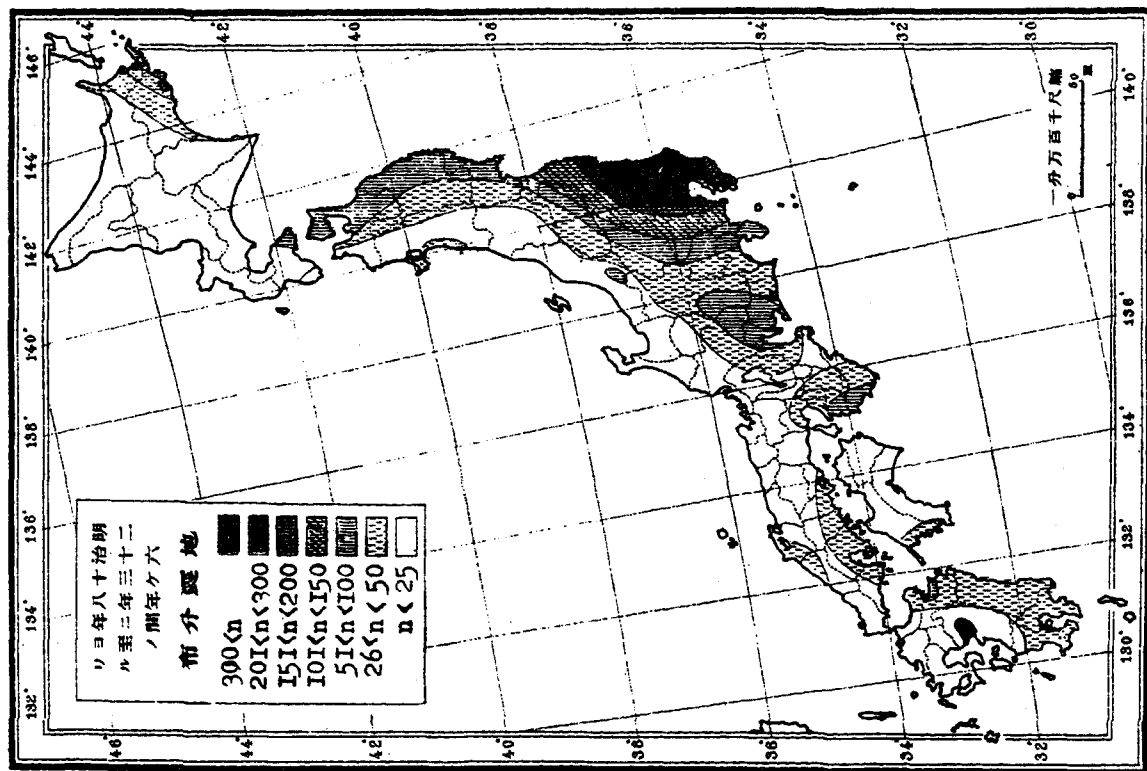


Fig. 3 The distribution of the number of felt earthquakes during 6 years from 1885 to 1890 (Taken from Prof. Omori's Jishingaku-kowa)

Fig. 2
The distribution
of the number of
felt earthquakes
in the average
year from 1921
to 1958.

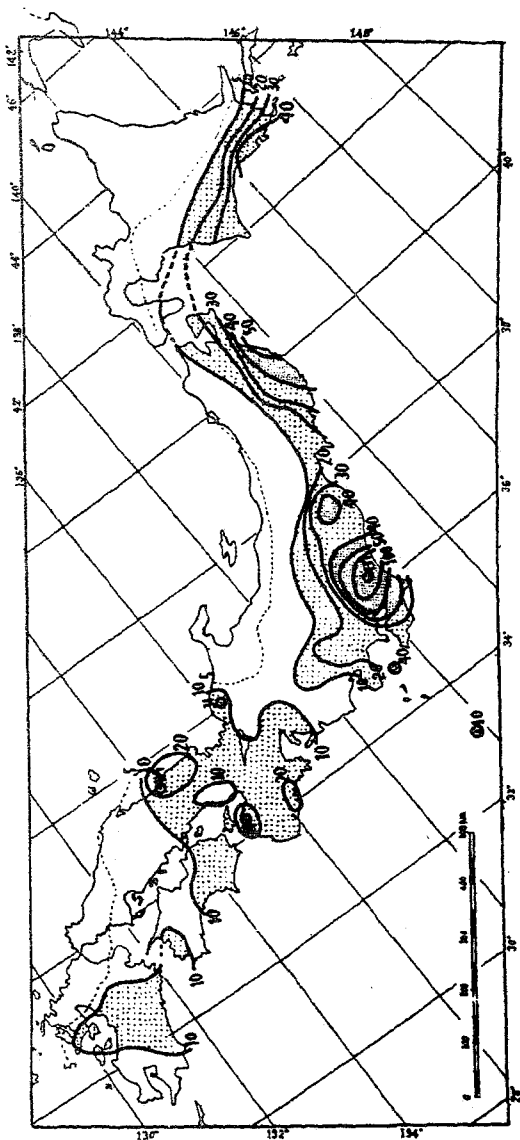
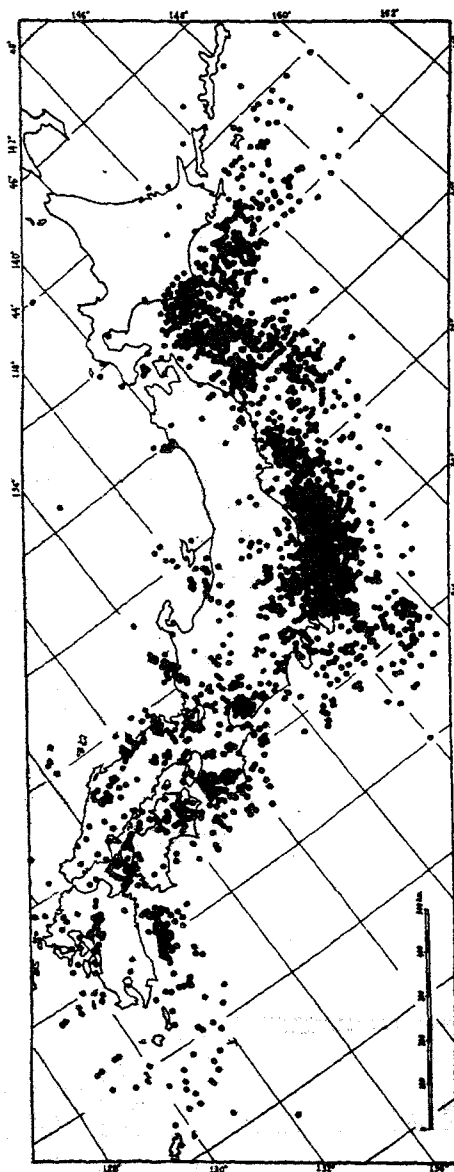


Fig. 4
The distribution
of the centers of
earthquakes larger
than that with
the felt area of
the diameter of
200 km (1926-1956).



Seismicity of Japan

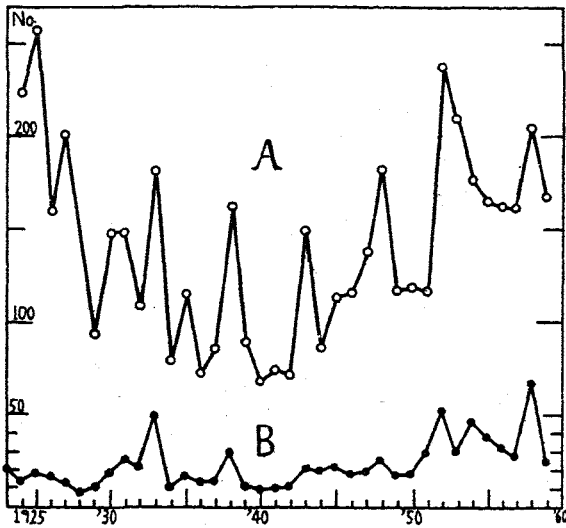


Fig. 5

The secular changes of the number of earthquakes which occurred in Japan in each year: A group—the diameter of the felt area is larger than 200 km. B group—the diameter larger than 600 km.

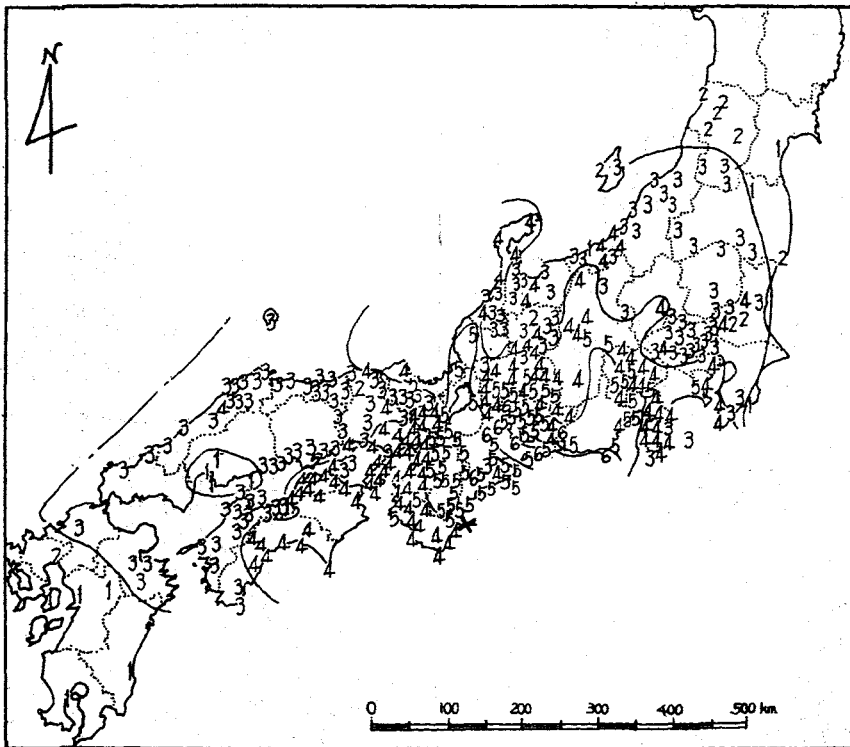


Fig. 9 The intensity distribution due to the Tonankai Earthquake of 1944.

Fig. 6
The distribution of the centers of earthquakes larger than that of magnitude 6 which occurred during 1926-1956.

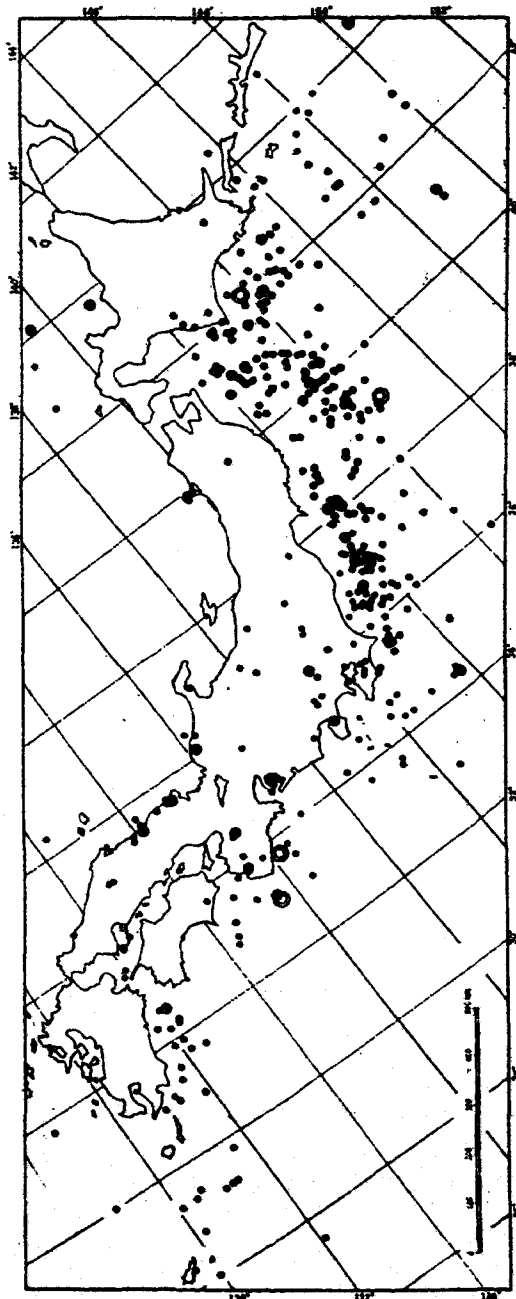
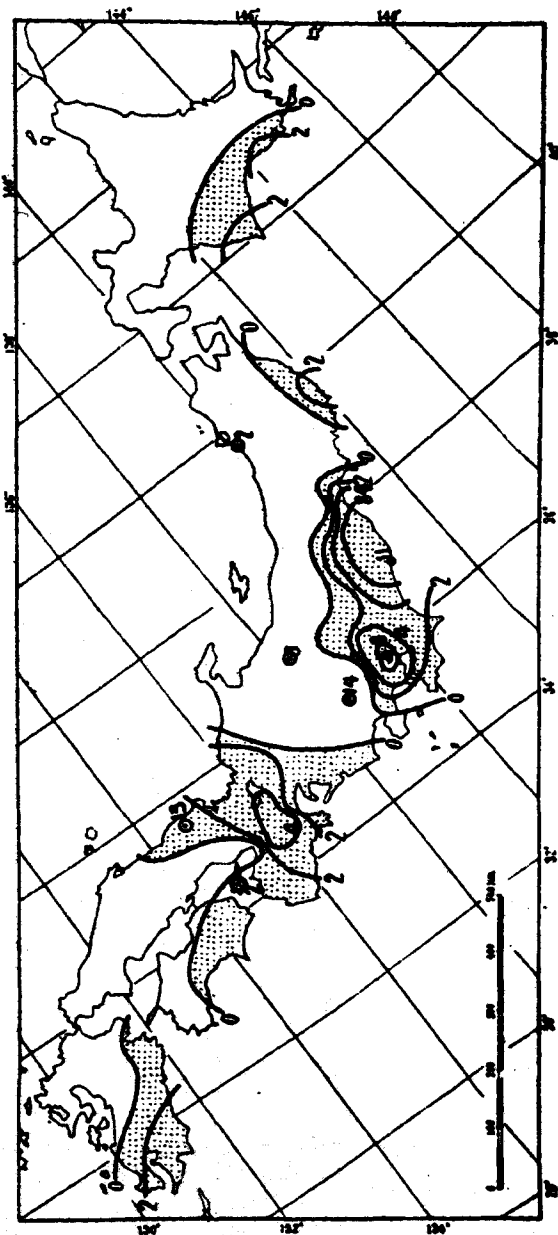


Fig. 10
The distribution of the observed number of intensities larger than the 4th grade during the years from 1921 to 1958.



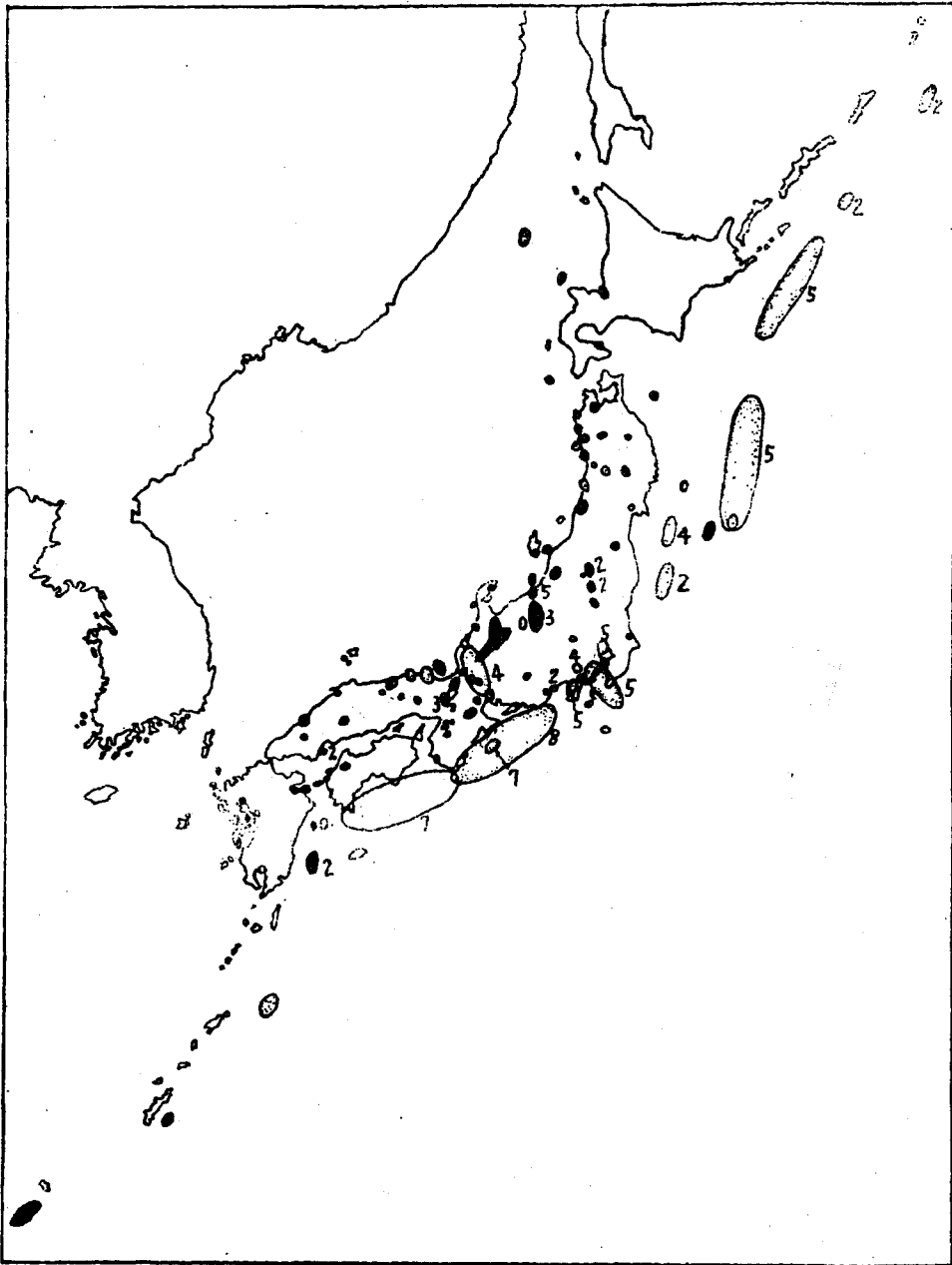


Fig. 7 The distribution of the epicentral areas of the destructive earthquakes which occurred during Christian era. The black area occurred before 1890. Numerals mean the number of occurrences at the same place.

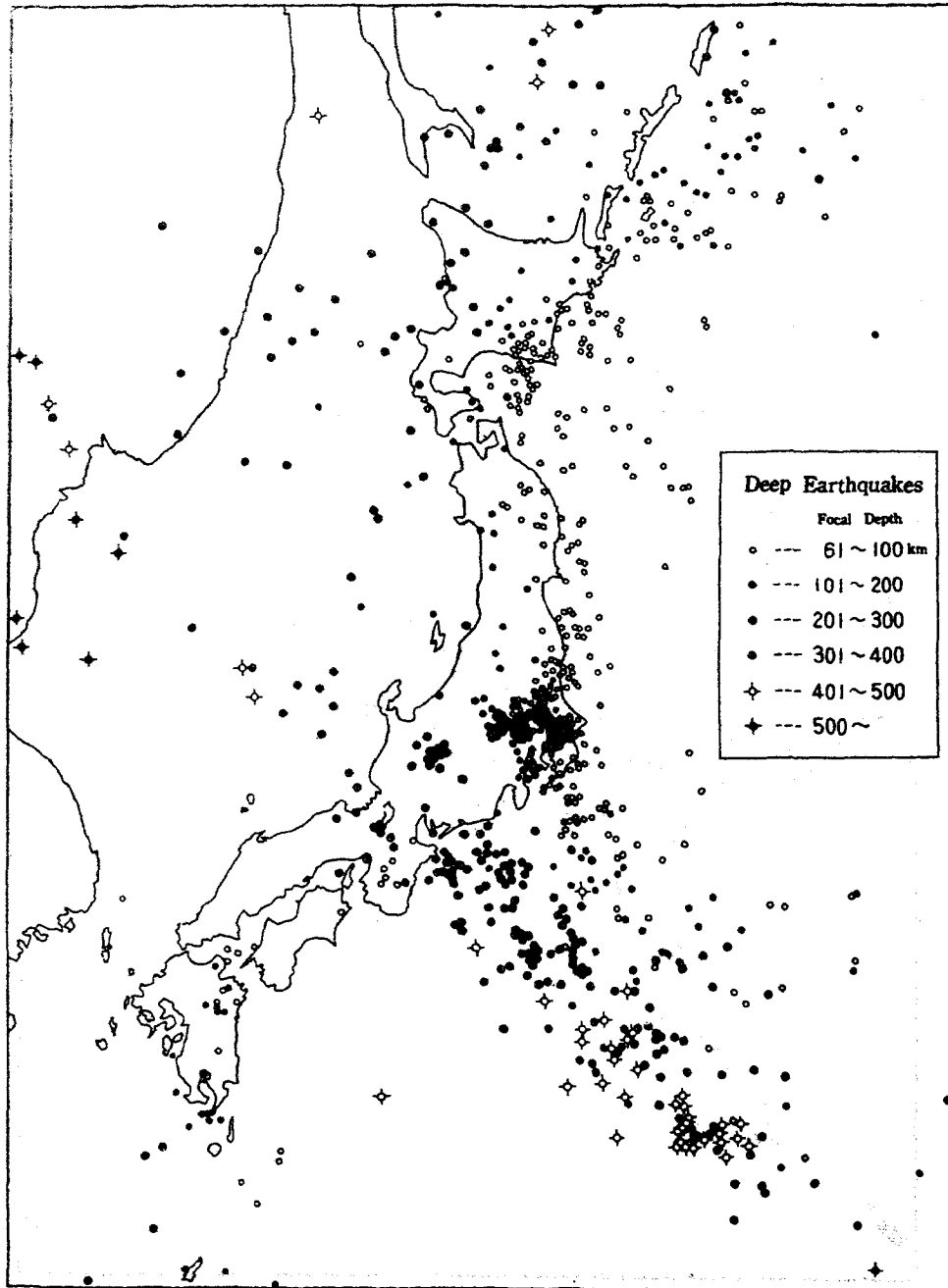


Fig. 8 The distribution of the earthquakes whose focal depths are deeper than 60 km (1926 - 1956).

Seismicity of Japan

Table 1 Scales of seismic intensity

The intensity of the shock is estimated according to the scales 0 - VII as follows :-

Scale	0	I	II	III	IV	V	VI	VII
	No Feeling	Slight	Weak	Rather Strong	Strong	Very Strong	Disastrous	Very Disastrous

- 0; No Feeling: Shocks too weak to cause human feelings, registered only by a seismograph.
- I; Slight: Extremely feeble shocks only felt by persons at rest or by those who are observant to an earthquake.
- II; Weak: Shocks felt by most persons, slight shaking of doors and Japanese latticed sliding doors (Shoji).
- III; Rather Strong: Slight shaking of houses and buildings, rattings of doors and Japanese latticed sliding doors (Shoji), swinging of hanging objects like the electric lamps, moving of liquids in vessels.
- IV; Strong: Strong shaking of houses and buildings, overturning of unstable objects, spilling of liquids out of vessels.
- V; Very Strong: Cracks in the walls, overturning of gravestones, stone lanterns etc., damaging of chimneys and mud-and-plaster warehouses.
- VI; Disastrous: Demolition of houses less than 30%, landslips, fissures on the roads, the ground etc.
- VII; Very Disastrous: Demolition of houses more than 30%, intense landslips, large fissures in ground, the faults.