ROYAL OBSERVATORY, HONG KONG

TECHNICAL NOTE NO. 33

SEISMICITY OF HONG KONG

BY

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CONTENT

SEISMICITY OF HONG KONG

INTRODUCTION

The Agadir earthquake of 1960 and the Alaskan earthquake of 1964, with the accompanying loss of lives and damage to buildings have spurred renewed interest in the study of regional seismicity. Until 1957, the seismicity of these places was underestimated, and the damage in the next decade, traceable to the underestimation, was a painful lesson. The seismicity of various regions should be re-evaluated from time to time in the light of ever-accumulating data. In particular, the impression has been formed that the seismicity of Hong Kong and of Kwangtung Province in China is low. A survey of worldwide seismicity for the year 1960 (8) showed Hong Kong as a region of no seismicity; that particular study however was carried out over a short period of time. A survey spanning a longer period is attempted in this note in order to arrive at an estimate of the rate of seismic energy release in the area.

In discussing the seismic activity of a region, the first topic that comes to mind is that of destructive earthquakes. This in turn resolves into two parts: The possibility of a major destructive earthquake occurring in that region, and the probability of a major earthquake occurring during a given period. The first question can easily be settle if, from historical data, it can be definitely shown that at least one major earthquake has occurred in that region. Once the possibility of the occurrence of a major earthquake is established, the estimate of probability of major earthquakes in that area can be inferred from the occurrence frequency of small earthquakes there.

POSSIBILITY OF LARGE EARTHQUAKE IN HONG KONG

Tremors from the Swatow earthquake of 1918, a major destructive earthquake, were felt in Hong Kong on February 13, 1918. The destruction and other effects of that earthquake were amply reported in newspapers and journals at that time (7). Seismic instruments had not yet been introduced to Hong Kong, and hence there were no instrumental records. Despite this handicap, teleseismic data allowed the epicentre of this earthquake to be determined as 24°N 116½°E, some 80 km to the north-northwest of Swatow and about 300 km east-northeast of Hong Kong. In Swatow and the neighbouring villages great damage was done, every house suffered and most were demolished. The death toll was over one thousand. In Hong Kong, comparatively little damage was done, one house on the Peak area had to be vacated and cracks appeared on the walls of several other houses including the Hong Kong Club (1).

INTENSITY DISTRIBUTION FOR THE SWATOW EARTHQUAKE OF 1918

Reports from various parts of Kwangtung in 1918 are listed in the Chronological Tabulation of Chinese Earthquakes (3). These comprise descriptions of such effects as rumbling noises, rattling windows, displacement of objects, falling plaster, structural damage and so on from which intensities were deduced. In Chiu Chow, close to the epicentre, reported structural damage ranged from frame structures destroyed with their foundations to the collapse of well built stone structures and bridges. There were also landslides and damage to embankments. The intensity distribution for this earthquake is summarised in Table 1 and presented in Figure 1. In Table 1, the epicentral distances are estimates based on the approximate epicentral location of 24°N, $116\frac{1}{2}^{\circ}$E. The meaning of the intensity scale used is given in Appendix III.

TABLE 1

INTENSITY DISTRIBUTION FOR THE SWATOW EARTHQUAKE 1918

Geographical location	Epicentral distance (km)	Modified Mercalli Scale
Hoi Ping	500	4
Canton	350	6
Hong Kong	300	7
Wai Chow	200	7
Ho Yuen	200	8
Wai Loy	100	9
Loon Chuen	100	8
Tai Po	90	8
Mui Yuan	80	9
Swatow	60	10
Chiu Chow	40	10
Epicentre	0-30	10

DISTRIBUTION OF INTENSITY IN KWANGTUNG PROVINCE
FOR THE SWATOW EARTHQUAKE 1918 (MODIFIED MERCALLI SCALE)

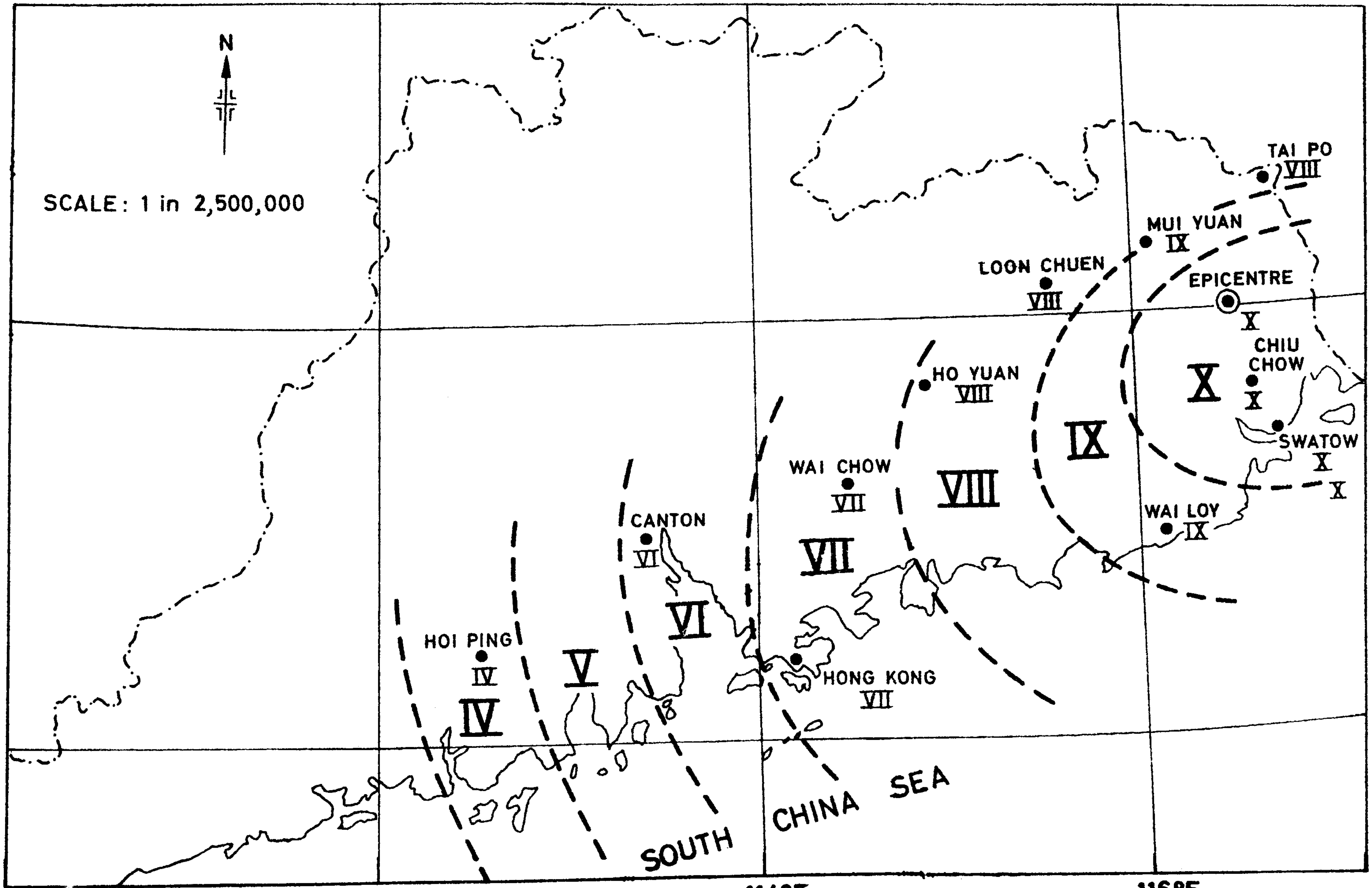


Fig 1

MAGNITUDE OF THE SWATOW EARTHQUAKE

The magnitude of a given earthquake is a rating given to it which is independent of place of observation. It is calculated from measurements on seismograms and was originally defined by Richter as the logarithm of the maximum amplitude on a seismogram written by an instrument of a standard type at a distance of 10 km from the epicentre.

Although magnitude has been specifically defined in terms of instrumental observations, several methods have been proposed for estimating the magnitude of an earthquake from a knowledge of the geographical distribution of intensity. Karnik (13) correlated between magnitude and the maximum intensity, I_{max}, for shallow shocks. The empirical relationship below was used.

$$M = 0.67\ I_{max} + 1.7\ \log_{10} h - 1.4 \qquad (1)$$

where h is the depth of the focus in kilometres and I_{max} is in the Modified Mercalli Scale.

For an I_{max} of 10 and a generally accepted focal depth for shallow earthquakes of 10 kilometres, a magnitude of 7.0 can be assigned to the Swatow earthquake.

Adams and others (15) gave another relationship between epicentral intensity in the Modified Mercalli Scale, I_o, the magnitude M and focal depth h in kilometres.

$$I_o = 1.5\ M - 3.5\ \log_{10} h + 3.0 \qquad (2)$$

Applying this relationship, a value of 7.0 is again obtained for the magnitude of the Swatow Earthquake of 1918.

From teleseismic analyses, Gutenberg-Richter and Duda (2) arrived at a magnitude of 7.3 for the 1918 Swatow Earthquake. This slightly higher value, obtained from analyses of seismograms recorded at Uppsala, Sweden is compatible with the other estimates and confirms the relatively large magnitude of the Swatow earthquake.

A magnitude of about 7.0 can therefore be assigned to the Swatow earthquake of 1918. The occurrence of a tremor of magnitude of this order is further substantiated by fault movements and fissures reported near the epicentral area. (3) Hence the possibility of a major destructive earthquake near Hong Kong is established; an estimate of the probability of a major earthquake in the area can be inferred from the occurrence frequency of small earthquakes recorded near Hong Kong.

THE PROBABILITY OF EARTHQUAKES

In the study of recurrence periods of earthquakes, it has been shown empirically that the number, n , of earthquakes during an arbitrary interval of time in a given seismic region is related to the magnitude M (Richter 1958) by:

$$\log_{10} n = a - bM \quad \ldots\ldots\ldots\ldots \quad (3)$$

where a and b are coefficients that can be determined from the records.

Sykes and others (14) have derived a similar but different empirical equation

$$\log_{10} N = A - bM \quad \ldots\ldots\ldots\ldots \quad (4)$$

where N is the number of earthquakes equal to or exceeding magnitude M and where A and b are coefficients that can be arrived at from the records.

In equations (3) and (4), the value of a and A are functionally related and generally depend upon the length of the record and the particular seismic region. After examining worldwide data, Gutenberg and Richter (2) found that b varies from region to region and gave the following values of b:

Shallow Shocks	$b = 0.90 \pm 0.02$
Intermediate shocks	$b = 1.20 \pm 0.20$
Deep Shocks	$b = 1.20 \pm 0.20$

Isacks and Oliver (9) tabulated 45 determinations that have been made by various authors of the value of b. All the determinations gave values between 0.8 and 1.4; of the 45 cases, 33 gave values between 0.9 and 1.2

THE PROBABILITY OF "LOCAL" EARTHQUAKES IN HONG KONG

Earthquakes with epicentral distance less than 320 km from Hong Kong are considered to be "local" earthquakes. This classification was made so as to exclude all earthquakes with origins in the circum-Pacific Belt.

The data used for the present study cover two periods, September 1931 to July 1940 and December 1951 to June 1968, a total of 26 years. The listed "local" earthquakes (Appendix I) are fitted to the equation $\log_{10} N = A - bM$. Only earthquakes with magnitudes equal to or larger than 3.0 were considered. There were 223 earthquakes in this category.

Table 2 lists the cumulative frequency N of "local" earthquakes in various magnitude classes over the period of 26 years under consideration. Fitting these data into equation (4) gives

$$\log_{10} N = 6.33 - 1.25\,M$$

which is shown graphically in Figure 2.

TABLE 2

CUMULATIVE FREQUENCY OF "LOCAL" EARTHQUAKES IN VARIOUS MAGNITUDES

Magnitude M	Frequency N
3.0	223
3.1	216
3.2	204
3.3	182
3.4	146
3.5	78
3.6	71
3.7	52
3.8	42
3.9	31
4.0	24
4.1	19
4.2	15
4.3	11
4.4	7
4.5	6
4.6	4
4.7	2
4.8	1

NUMBER OF "LOCAL" EARTHQUAKES N

FOR MAGNITUDE M OR ABOVE

OVER A PERIOD OF 26 YEARS

$$\log_{10} N = A - bM$$

$b = 1.25$

$A = 6.33$

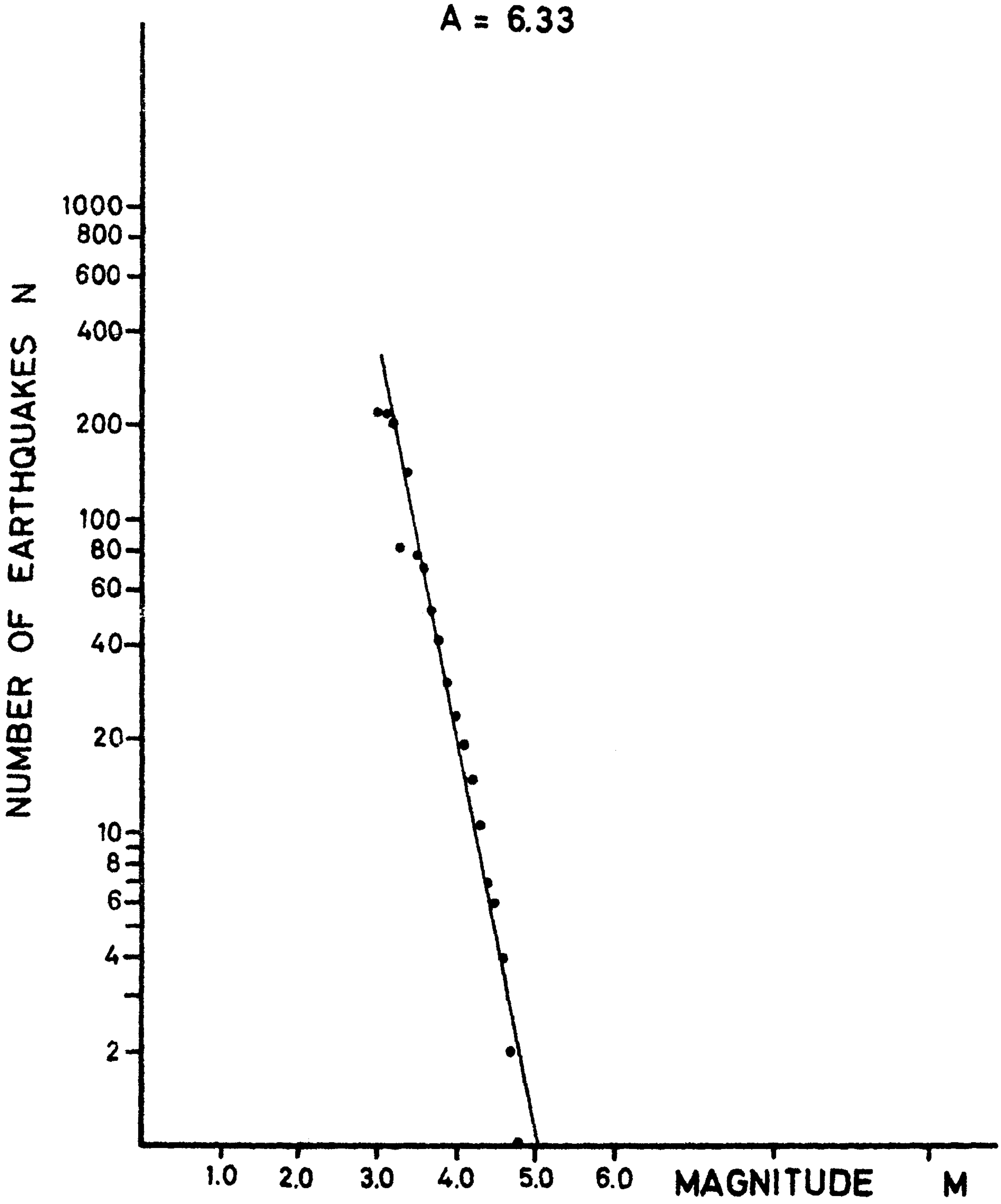


Fig. 2

Extrapolation was attempted to find the probable frequency of occurrence of large "local" earthquakes. Earthquakes equal to or greater than magnitude 6.0 were considered capable of causing damage. From equation (5), $N = 0.0676$ when $M = 6.0$.

Thus the probable number of earthquakes with magnitude 6.0 and above near Hong Kong in the time span of 26 years (1931 to 1940 and 1951 to 1968) is 0.0676. That is, "local" earthquakes with magnitude 6.0 or above can be expected to occur, on average, once in about 384 years, say 400 years. The values of N and recurrence periods for different magnitude are given in Table 3 below.

TABLE 3

RECURRENCE PERIOD OF "LOCAL" EARTHQUAKES OF VARIOUS MAGNITUDES

Magnitude M	Frequency in 26 years N	Recurrence Period 26/N
6.0 and above	0.0676	384 years
6.5 and above	0.0160	1622 years
7.0 and above	0.0038	6839 years

From the data in the Chronological Tabulation of Chinese Earthquake Records for Kwangtung which are presented in Figure 3, it will be seen that 30 destructive earthquakes were reported out of a total of 601 shocks between 288 A.D. and 1936 A.D., that is, 30 destructive shocks in the span of 1649 years or approximately one in every 60 years on average. This observed return period of about 60 years of destructive earthquakes in Kwangtung is not incompatible with the return period of about 400 years for earthquakes near Hong Kong with magnitude 6.0 or above considering that the larger area of Kwangtung province would be likely to have more destructive earthquakes in a given period than the smaller area under study.

APPLICABILITY OF THE RECURRENCE-MAGNITUDE RELATIONSHIP

In applying the recurrence-magnitude relationship $\log_{10}N = A - bM$, it is generally assumed that incidence of earthquakes in any one tectonic zone is probably, in the mean, uniform. It has to be noted that this condition of continuous seismicity does not always apply. The existence of sporadic activity at times seriously limits the applicability of the average recurrence-magnitude relation to estimating long term seismicity. (16)

It is necessary to point out also that last occurrence of an earthquake in year X in a region where the recurrence period was established to be Y years for similar earthquakes does NOT imply that the next similar earthquake will occur Y years after year X. Over a certain period, earthquake occurrences in a given region are more often clustered together or spaced apart in time, as shown in Table 4, which lists chronologically 30 destructive earthquakes in Kwangtung. Whilst the Kwangtung earthquakes cannot necessarily reflect any typical trend, some idea of the irregular sequence of earthquakes in the area may very roughly be obtained.

TABLE 4

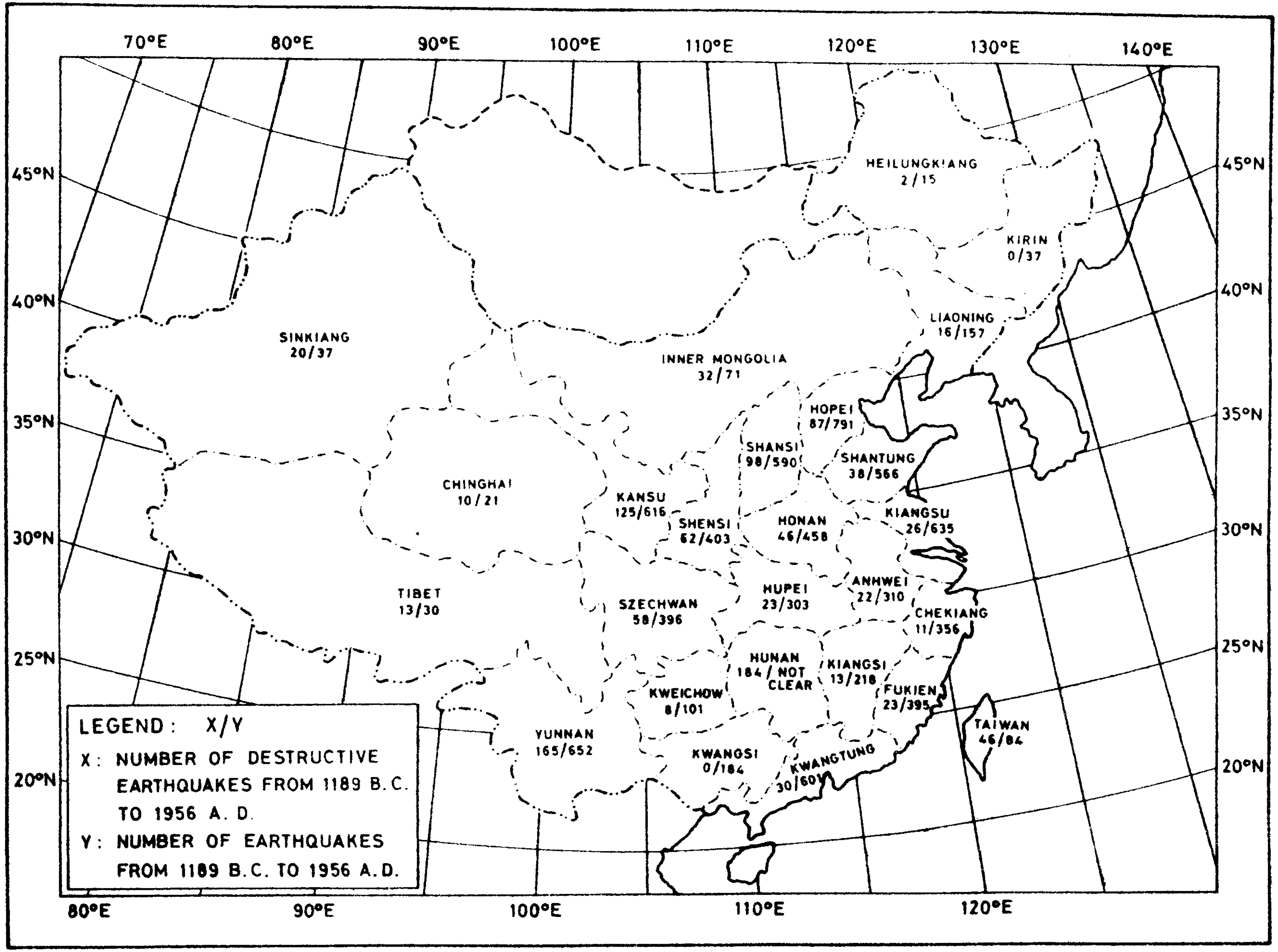
DESTRUCTIVE EARTHQUAKES IN KWANGTUNG

BETWEEN 288 A.D. AND 1936 A.D.

Date	Location
7 Jun. 288	South Kwangtung
28 Aug. 1045	South Kwangtung
6 Nov. 1067	East Kwangtung
24 May 1372	South Kwangtung
1445	South Kwangtung
5 Apr. 1524	Southwest Kwangtung
1542	North Kwangtung
Jun. 1556	West Kwangtung
Jun. 1558	South Kwangtung
29 Sep. 1600	East Kwangtung
13 Jul. 1605	Southwest Kwangtung
19 Jul. 1605	South Kwangtung
15 Dec. 1605	West Kwangtung
19 Feb. 1629	East Kwangtung
26 Nov. 1641	East Kwangtung
11 May 1666	East Kwangtung
10 Oct. 1683	South Kwangtung
Jul. 1688	Northeast Kwangtung
Mar. 1752	Southwest Kwangtung
8 Apr. 1791	East Kwangtung
9 Sep. 1858	East Kwangtung
1877	Southwest Kwangtung
Feb. 1895	North Kwangtung
15 Nov. 1895	East Kwangtung
12 Aug. 1905	South Kwangtung
13 Feb. 1918	East Kwangtung
13 Sep. 1923	Central Kwangtung
12 Mar. 1934	East Kwangtung
23 Apr. 1936	West Kwangtung
1 May 1936	West Kwangtung

DISTRIBUTION OF EARTHQUAKES IN CHINA

DERIVED FROM HISTORICAL SOURCES



REFERENCE: CHRONOLOGICAL TABULATION OF CHINESE EARTHQUAKE RECORDS. THE SCIENCE PRESS. 1956. PEKING.

Fig. 3

EARTHQUAKES FELT IN HONG KONG

From September 1921 to December 1969, 69 earthquakes are known to have been felt by residents in Hong Kong. On average, about 1 earthquake was felt each year between 1921 and 1940 and about 3 earthquakes were felt per year in the more recent period from 1951 to 1969. Most of the shocks felt were shallow (1) and emanated from the Ho Yuan area of Kwangtung centred about 160 km north-northeast of Hong Kong; others came from epicentres in the bed of the China Sea to the south and southeast of Swatow and to the south of the Pratas Shoal. Some also originated from the Circum-Pacific Seismic Belt.

The most severe earthquake shock experienced in Hong Kong occurred on February 13, 1918 and has already been discussed. Apart from this, and three other shocks, in 1924, 1962 and in 1969, the remainder of the shocks were of low intensity and gave rise to minor effects. Figure 4 shows a rough distribution of the epicentres of those earthquakes which were felt in Hong Kong and originated in Kwangtung Province. Figures 5 to 7 are plots of some relevant aspects of these shocks. A list of earthquakes reported felt in Hong Kong from 1874 to 1969 is included in Appendix II.

KWANGTUNG EARTHQUAKES FELT IN HONG KONG

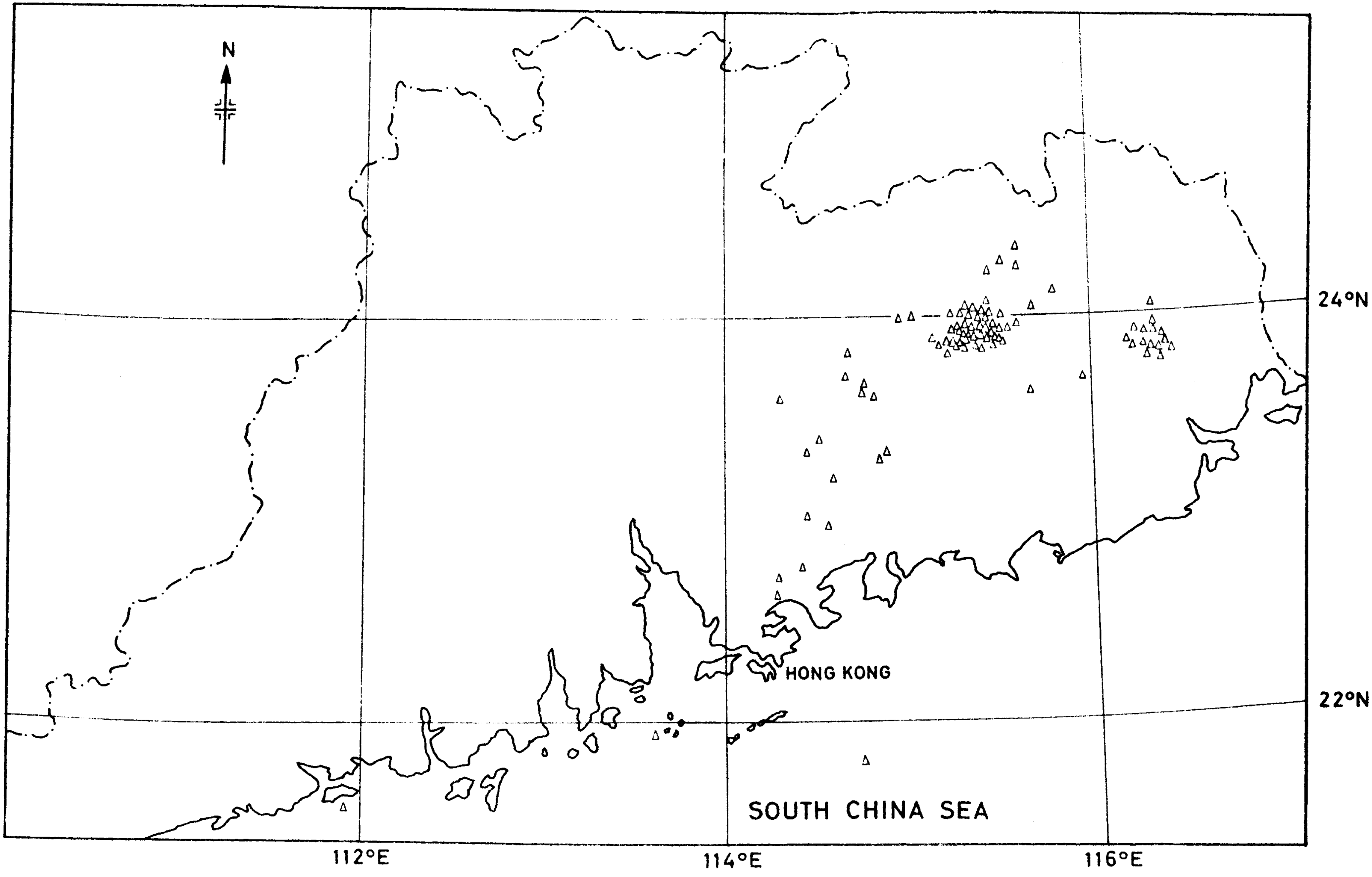
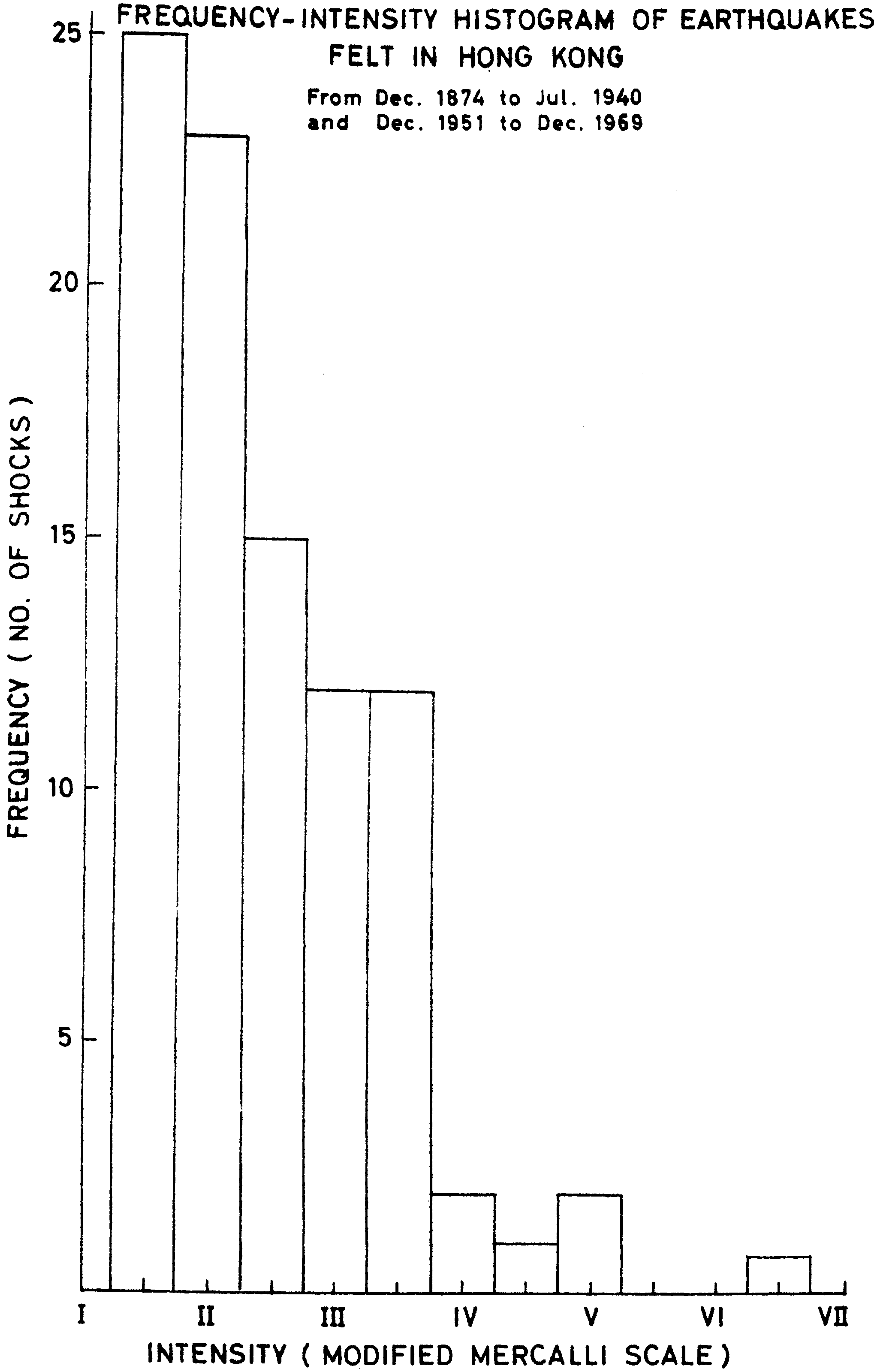


Fig. 4


FREQUENCY-INTENSITY HISTOGRAM OF EARTHQUAKES
FELT IN HONG KONG
From Dec. 1874 to Jul. 1940
and Dec. 1951 to Dec. 1969
25
20
15
10
5
FREQUENCY (NO. OF SHOCKS)
I
II
III
IV
V
VI
VII
INTENSITY (MODIFIED MERCALLI SCALE)
Fig. 5

FREQUENCY - EPICENTRAL DISTANCE GRAPH OF LOCAL EARTHQUAKES AND EARTHQUAKES FELT IN HONG KONG

From Sept. 1931 to July 1940
and Dec. 1951 to Dec. 1969

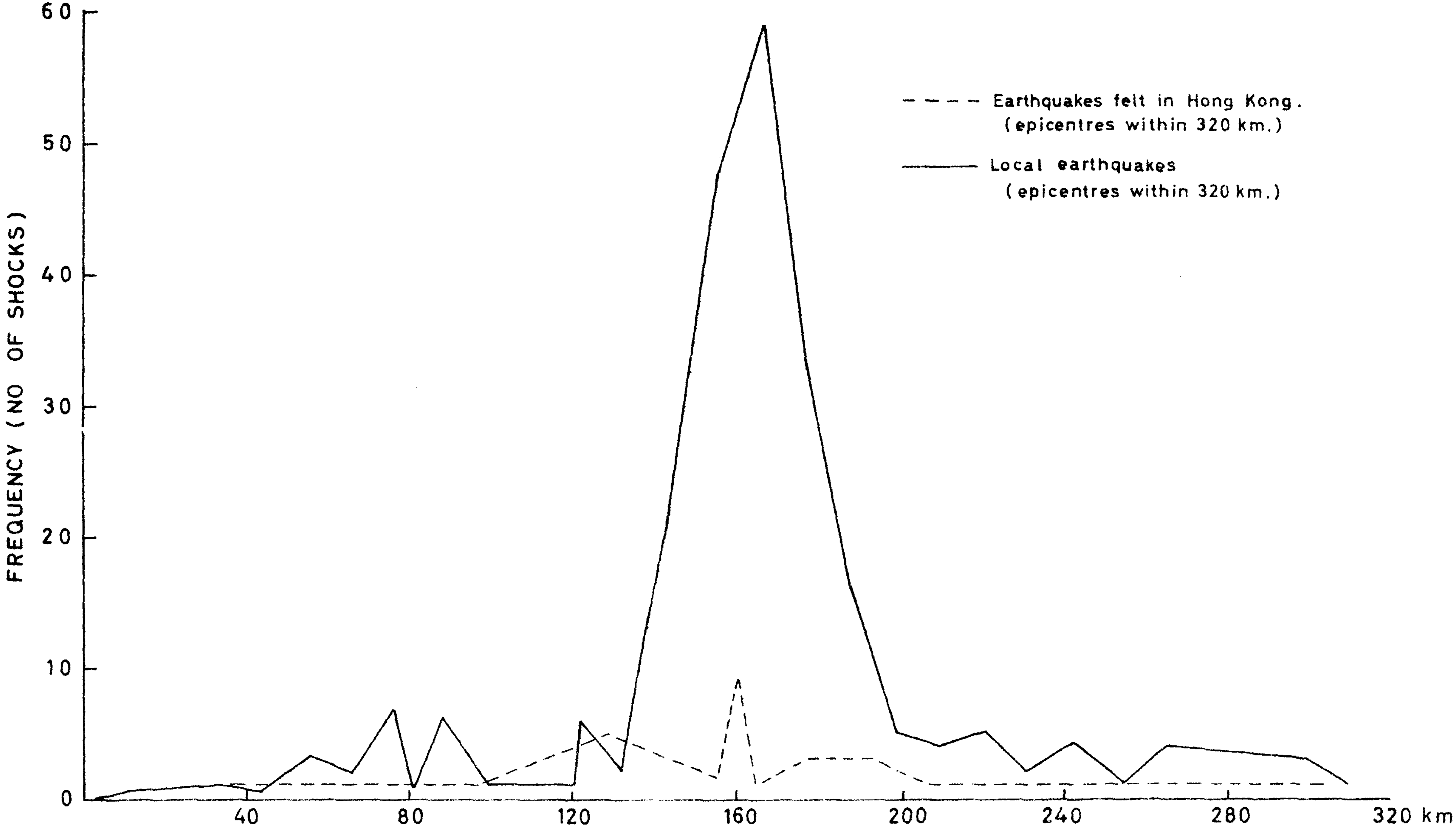


Fig. 6 EPICENTRAL DISTANCES IN KILOMETRES FROM HONG KONG

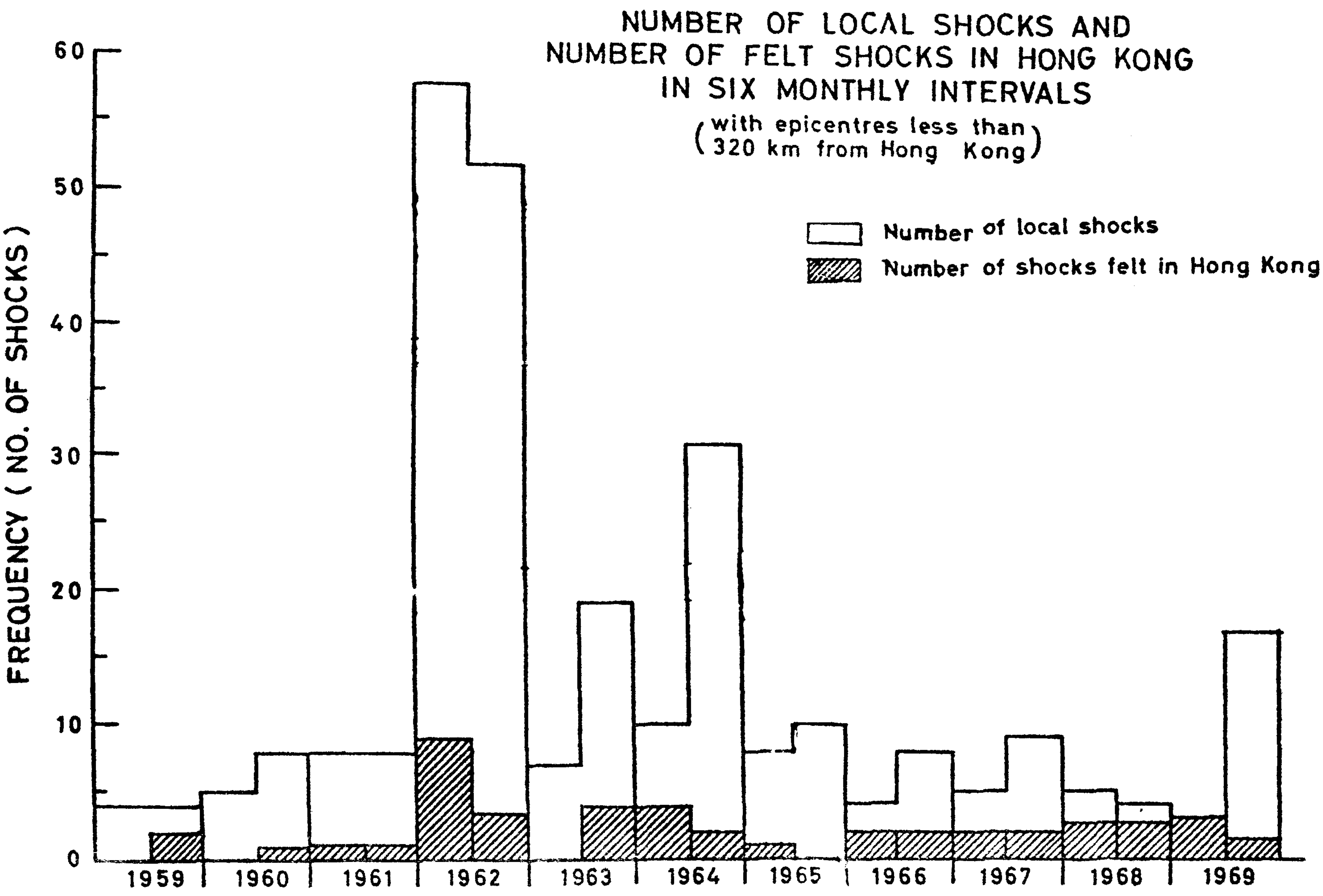

NUMBER OF LOCAL SHOCKS AND
NUMBER OF FELT SHOCKS IN HONG KONG
IN SIX MONTHLY INTERVALS
(with epicentres less than
320 km from Hong Kong)
Number of local shocks
Number of shocks felt in Hong Kong
FREQUENCY (NO. OF SHOCKS)
0
10
20
30
40
50
60
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
YEARS

Fig. 7

THE EARTHQUAKES RISK IN HONG KONG

Instrumental records of earthquakes in Hong Kong were not made before the autumn of 1921. The interval since 1921 is far too short to permit any but tentative conclusions to be drawn regarding the true degree of seismicity in Hong Kong and the corresponding earthquake risk. However, the records for Hong Kong can be compared with those for the same interval in other regions. On such a basis, although possibly an insufficient one, the earthquake risk in Hong Kong is significantly less than in seismic areas such as Taiwan or the Philippines.

On the other hand, although the non-destructive shocks which could be felt were not very numerous in Hong Kong and only gave rise to minor effects, there is still some degree of risk. Four shocks, in 1918, 1924, 1962 and 1969 were felt here with intensity (Modified Mercalli Scale) greater than 4.

The effects of earthquakes on buildings and structures are twofold:-

i) Earthquake wave motion: strictly vertical vibrations are less destructive to structures which are generally built to withstand vertical stresses, than inclined or horizontal vibrations. Surface waves, especially Rayleigh waves are far more destructive than body waves. Also, surface waves are generated and developed more effectively at small distance from the epicentre than at the epicentre itself. The size and shape of the areas where these surface waves may be most effectively developed will depend not only upon the path from the origin of the earthquake but also upon the mechanism of slipping at the geological faults, about which we know very little.

ii) Foundation ground: the risk of earthquake damage is more dependent upon the nature of the ground locally than on the wave motion or disturbance from the source. The energy of the shock is carried outwards by elastic waves, but the effect produced at some distant surface is very dependent on the kind of ground. In general, destructive effects are less on hard rock than on soft ground and will probably be high on reclaimed land which has a high water content.

The strongest shock so far recorded since seismographs have been in operation in Hong Kong, was of intensity 5 on the Modified Mercalli Scale, and occurred on March 18, 1962. The epicentre was approximately 145 km north-northeast of the Royal Observatory. The U.S. Coast and Geodetic Survey estimated that the focus was less than 33 kilometres below ground so it falls into the class of shallow shocks. This shock caused displacement of small objects, rattling of windows and doors and loosening of plasters. Acceleration was not recorded in the Observatory, but, based on a relationship between intensity and acceleration given by Richter (1958),

$$\log_{10} a = \frac{I}{3} - \frac{1}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

it was probably be around 0.02 g ($0.20 m/s^2$) in the 1962 earthquake.

When including the Swatow Earthquake of 1918 which occurred prior to instrumental recordings in Hong Kong, a seismic acceleration of 0.07 g ($0.69 m/s^2$) will then be the key acceleration value to be considered. This is the equivalent of intensity 7 on the Modified Mercalli Scale (see equation 6) and is three and halftimes the acceleration for the 1962 shock, the second most severe earthquake experienced in Hong Kong. The difference in the derived accelerations due to the two most severe earthquakes is large. Whilst 0.07 g may be the maximum acceleration value to accept in the design of seismic resistant structures, the coverage of the risk of a recurrence of a MM 7 earthquake is much higher than that of a MM 5 earthquake. In an area of low seismicity such as southern Kwangtung, it may be economically feasible to accept the risk of a recurrence of a MM 7 tremor. It suffices to conclude here that structures built to withstand seismic accelerations of 0.07 g in Hong Kong will probably have survived all historical earthquakes since 288 A.D. in Kwangtung. Also the risk to such buildings arising from earthquakes originating from known sources such as the Ho Yuan County to the north-northeast of Hong Kong and near Swatow will be minimised.

There is nothing in this paper to rule out the risk, albeit small, of a major earthquake occurring closer to Hong Kong, From the standpoint of the seismicity of southern Kwangtung, it has been shown earlier that there is a recurrence period of one earthquake of magnitude 6.0 or above in the span of 400 years on average. It is recognised in various isoseismal studies that such earthquakes are capable of causing structural damage within 100 to 200 kilometres of the epicentre. This fact must also be considered when important sturctures are designed with possible seismic disturbance in mind.

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APPENDIX I: Earthquakes with epicentres less than 320 km from Hong Kong.

YEAR	MONTH	DAY	DISTANCE (km)	MAGNITUDE
1931	Sept	21	167	3.9
1932	Aug	7	33	3.6
1938	Dec	1	300	4.1
1939	June	3	138	3.9
1940	Mar	2	267	4.0
1954	Jan	19	167	4.3
1956	Nov	10	167	4.2
1959	Jan	21	138	3.2
1959	Jan	28	33	3.0
1959	May	22	222	3.7
1959	Jul	2	78	3.1
1959	Aug	26	56	3.0
1959	Oct	2	100	3.4
1959	Nov	14	256	3.8
1960	Jan	13	178	3.6
1960	Mar	8	56	3.1
1960	Apr	13	11	3.0
1960	May	12	300	3.8
1960	Jun	20	178	3.6
1960	Jul	18	156	3.9
1960	Jul	21	189	3.6
1960	Jul	27	156	3.6
1960	Sep	16	78	3.4
1960	Sep	21	83	3.2
1960	Oct	4	189	3.6
1960	Dec	17	156	3.4
1961	Jan	3	122	3.3
1961	Feb	3	200	3.7
1961	Mar	7	310	4.3
1961	Apr	5	222	3.7
1961	Apr	11	189	3.7
1961	Apr	28	133	3.4
1961	May	1	89	3.3
1961	Jun	29	244	3.7
1961	Jun	30	156	3.2
1961	Aug	30	167	3.6
1961	Nov	10	178	3.6
1961	Nov	14	222	3.7
1961	Nov	17	156	3.4
1961	Nov	28	167	3.4
1961	Dec	10	193	4.3
1962	Jan	31	167	3.4
1962	Feb	3	178	3.6
1962	Feb	5	178	4.4
1962	Feb	17	189	4.0
1962	Feb	19	167	3.4
1962	Feb	21	178	3.6
1962	Feb	26	200	3.7
1962	Mar	1	167	3.4
1962	Mar	11	167	3.4
1962	Mar	19	167	4.8
1962	Mar	19	167	3.8
1962	Mar	22	144	3.3
1962	Mar	27	144	3.3
1962	Mar	28	178	3.4
1962	Mar	29	138	4.2
1962	Mar	29	189	3.6
1962	Mar	29	156	3.4
1962	Mar	30	167	3.4

APPENDIX I (CONT'D)

YEAR	MONTH	DAY	DISTANCE (km)	MAGNITUDE
1962	Apr.	2	156	4.2
1962	Apr.	2	167	3.6
1962	Apr.	3	144	3.3
1962	Apr.	3	156	3.4
1962	Apr.	5	167	4.5
1962	Apr.	5	156	3.3
1962	Apr.	5	122	3.2
1962	Apr.	5	178	3.6
1962	Apr.	6	144	3.3
1962	Apr.	6	167	3.4
1962	Apr.	9	156	3.4
1962	Apr.	11	156	3.3
1962	Apr.	12	178	3.4
1962	Apr.	12	167	3.3
1962	Apr.	13	167	3.3
1962	Apr.	13	156	3.3
1962	Apr.	13	156	3.4
1962	Apr.	15	167	3.4
1962	Apr.	16	167	3.4
1962	Apr.	17	156	3.4
1962	Apr.	17	122	3.3
1962	Apr.	17	156	3.4
1962	Apr.	17	156	3.4
1962	May	12	178	3.4
1962	May	12	178	3.4
1962	May	18	189	3.6
1962	May	18	167	3.4
1962	May	19	138	3.3
1962	May	19	144	3.2
1962	May	20	178	3.4
1962	May	25	167	3,3
1962	May	30	156	3.3
1962	May	31	156	3.3
1962	May	31	189	3.6
1962	June	4	156	3.3
1962	June	14	156	3.3
1962	June	14	178	3.4
1962	June	14	167	3.4
1962	June	16	178	3.4
1962	June	16	167	3.4
1962	June	16	156	3.3
1962	June	17	189	4.1
1962	June	20	167	3.3
1962	June	21	167	3.3
1962	June	21	167	3.3
1962	June	24	156	3.2
1962	June	29	167	3.3
1962	July	1	167	3.4
1962	July	2	138	3.1
1962	July	2	156	3.3
1962	July	5	144	3.1
1962	July	6	178	3.5
1962	July	8	167	3.4
1962	July	10	144	3.4
1962	July	13	167	3.4
1962	July	13	178	3.5
1962	July	15	144	3.3
1962	July	17	178	3.3
1962	July	19	156	3.8
1962	July	22	178	3.4
1962	July	25	156	3.2
1962	July	25	144	3.2
1962	July	29	156	4.7

APPENDIX I (CONT'D)

YEAR	MONTH	DAY		DISTANCE (km)	MAGNITUDE
1962	Aug	8		144	3.2
1962	Aug	9		178	3.6
1962	Aug	17		138	3.2
1962	Aug	25		178	3.5
1962	Aug	29		189	3.6
1962	Aug	30		156	3.4
1962	Sep	7		167	3.4
1962	Sep	11		178	3.5
1962	Sep	20		178	3.5
1962	Sep	29		167	3.4
1962	Nov	6		138	4.0
1962	Nov	15		167	3.4
1962	Nov	23		167	3.4
1962	Nov	26		138	3.2
1962	Dec	10		138	3.1
1962	Dec	10		178	3.4
1962	Dec	28		222	3.7
1963	Jan	1		167	3.3
1963	Jan	5		178	3.4
1963	Jan	12		167	3.3
1963	Jan	16	-1963 May 7	NO RECORD	
1963	May	26		156	3.4
1963	Jun	9		178	3.6
1963	Jun	23		267	3.9
1963	Jul	24		144	3.3
1963	Jul	26		144	3.3
1963	Jul	30		167	3.4
1963	Aug	1		167	3.4
1963	Aug	5		156	3.2
1963	Aug	25		156	3.2
1963	Sep	9		300	3.8
1963	Sep	15		156	3.8
1963	Oct	6		144	3.7
1963	Oct	8		167	3.4
1963	Oct	9		167	3.4
1963	Oct	13		144	3.2
1963	Dec	5		189	3.5
1963	Dec	7		167	3.9
1963	Dec	10		138	3.2
1964	Feb	23		138	3.2
1964	Mar	2		144	3.2
1964	Apr	15		156	4.3
1964	Jun	20		167	4.1
1964	Jun	20		178	3.9
1964	Jul	11		167	3.4
1964	Aug	2		144	4.1
1964	Aug	13		156	3.3
1964	Aug	29		156	3.4
1964	Sep	23		167	4.6
1964	Sep	26		178	3.7
1964	Sep	30		167	3.4
1964	Oct	27		167	3.4
1964	Nov	20		156	3.2
1964	Nov	27		167	3.4
1964	Dec	1		156	3.4
1964	Dec	27		178	3.5
1965	Jan	2		189	3.8
1965	Jan	18		156	3.4
1965	Feb	11		211	3.6
1965	Feb	15		156	3.4
1965	Feb	16		156	3.9

APPENDIX I (CONT'D)

YEAR	MONTH	DAY	DISTANCE (km)	MAGNITUDE
1965	Mar	19	167	3.4
1965	Apr	25	138	3.2
1965	Jul	24	156	3.3
1965	Oct	12	178	3.4
1965	Oct	12	78	3.0
1965	Oct	31	144	3.2
1965	Nov	3	122	3.1
1965	Nov	3	178	3.4
1965	Nov	24	56	3.0
1965	Nov	29	167	3.4
1966	Jan	15	178	3.4
1966	Feb	28	167	3.4
1966	May	1	138	3.4
1966	Jun	15	156	3.3
1966	Jun	16	44	3.0
1966	July	21	133	3.1
1966	Aug	9	78	3.1
1966	Sep	16	67	3.0
1966	Sep	16	144	3.2
1966	Sep	18	144	3.2
1966	Nov	28	256	4.2
1967	Jan	26	133	4.0
1967	Feb	14	222	4.5
1967	Feb	27	211	3.4
1967	Apr	15	156	3.3
1967	Apr	27	167	3.4
1967	Jul	4	233	3.8
1967	Jul	4	233	3.8
1967	Jul	22	67	3.1
1967	Jul	23	78	4.6
1967	Jul	29	178	3.4
1967	Sep	9	156	3.3
1967	Oct	2	156	3.3
1967	Oct	2	200	3.8
1967	Oct	17	89	3.1
1968	Jan	11	189	3.4
1968	Jan	28	89	4.0
1968	Mar	1	244	3.8
1968	Mar	18	167	3.4
1968	Jun	14	89	3.1

APPENDIX II: Earthquakes felt by residents of Hong Kong.

YEAR	MONTH	DAY	H.K.ST. T.	INTENSITY (MM SCALE)	LOCATION
1874				II-III	
1878	Nov	23	Between 0300 & 0400	II-III	
1912	Jun	1	Between 0000 & 0100	III-IV	
1918	Feb	13	1407	VI-VII	24.0N 116.5E 80km NNW of Swatow about 290km from Hong Kong
1918	Feb	13	1448	I-II	
			1609	I-II	
			1611	I-II	
			2127	II	
			2236	II-III	
			2255	I-II	
			2310	I-II	
1918	Feb	14	0112	II-III	26N 115E 400km N by E of Hong Kong
1918	Mar	6	0522	II	
1918	May	8	2139	II	
1918	May	25	0003	II	
1918	Jun	26	0329	II	
1918	Jul	20	2016	II	
1918	Aug	23	0136	II	
1918	Nov	18	1129	II	
1921	Mar	19	1621	II-III	24.0N 116.5E
1921	Oct	11	1425	I-II	
1921	Oct	11	2211	I-II	
1921	Oct	12	0107	I-II	
1921	Oct	13	2019	I-II	

APPENDIX II (CONTD.)

YEAR	MONTH	DAY	H.K.St.T.	INTENSITY (MM SCALE)	LOCATION
1921	Oct	20	0837	I-II	
1923	Oct	1	1209	II	
1923	Dec	16	0545	I-II	
1924	Jan	10	2245	IV-V	
1924	June	13	1638	I-II	
1926	June	13	1004	I-II	24.0N 116.5E
1928	Jan	29	2258	I-II	
1929	Oct	24	1435	I-II	22.5N 117.5E
1931	Sept	21	1828	I-II	19.5N 113.2E 167km from Hong Kong
1932	Aug	7	0750	I-II	33km from Hong Kong
1934	Feb	14	1201	I-II	933km from Hong Kong
1936	Apr	1	1016	I-II	756km from Hong Kong
1938	Dec	1	1303	I-II	300km from Hong Kong
1939	June	3	1825	I-II	145km from Hong Kong
1940	Mar	2	0529	I-II	267km from Hong Kong
	NO SEISMOLOGICAL RECORDINGS FROM AUGUST, 1940 TO NOVEMBER, 1951.				
1954	Jan	19	2116	III	
1956	Feb	12	1951	II	18.9N 119.7E off NW coast of Luzon, Philippine Islands
1956	Nov	10	0204	III-IV	167km from Hong Kong
1957	Feb	24	0428	III-IV	24.01N 121.42E off the east coast of Taiwan
1957	June	12	0251	II-III	17.88N 120.24E near coast of Luzon, Philippine Islands
1958	Mar	11	0828	I-II	25.5N 125E Ryukyu Islands
1958	Sept	25	0907	II-III	740km from Hong Kong
1959	Aug	15	1659	II-III	23N 121E
1959	Sept	25	1039	III	22N 122E east of Taiwan
1960	July	18	0639	I-II	156km NNE of Hong Kong
1961	Mar	5	0706	II	310km NNE of Hong Kong
1961	Dec	10	1840	III	193km NNE of Hong Kong
1962	Feb	5	1001	IV	178km NNE of Hong Kong
1962	Feb	17	1059	II	189km NNE of Hong Kong

APPENDIX II (CONTD.)

YEAR	MONTH	DAY	H.K.ST.T.	INTENSITY (MM SCALE)	LOCATION
1962	Mar	19	0419	V	23.7N 114.5E Ho Yuan County NE of Canton, Kwangtung Province, China. 167km from Hong Kong.
1962	Mar	19	0911	II	
1962	Mar	22	1528	II	
1962	Mar	29	2146	III	
1962	Apr	2	2008	II-III	160km NNE of Hong Kong
1962	Apr	5	2111	III-IV	122km NE of Hong Kong
1962	June	17	0303	III	156km NE of Hong Kong
1962	July	19	1731	II	156km N of Hong Kong
1962	July	29	1658	IV	23.6N 114.3E Kwangtung Province, China. 156 km NNE of Hong Kong
1962	Nov	6	1715	III	138km NE of Hong Kong
1963	Sept	15	1543	II	156km NE of Hong Kong
1963	Oct	6	0931	II	144km from Hong Kong
1963	Oct	7	0510	II	144km from Hong Kong
1963	Dec	6	0231	III-IV	189km NNE of Hong Kong
1964	Jan	18	2006	III-IV	
1964	Apr	15	0801	II	156km NNE of Hong Kong
1964	June	21	0717	II-III	178km NNE of Hong Kong
1964	June	21	0737	II-III	167km NNE of Hong Kong
1964	Aug	2	1646	II-III	144km NNE of Hong Kong
1964	Sept	23	0805	III-IV	167km NNE of Hong Kong
1965	May	18	0121	III-IV	22.5N 121.3E Taiwan Region, 597km E of Hong Kong
1966	Mar	13	0033	III-IV	24.1N 122.6E, Taiwan, 922km E of Hong Kong
1966	June	11	1102	III	611km E of Hong Kong
1966	Sept	26	1224	III	378km E of Hong Kong
1966	Nov	28	1118	II	256km NNE of Hong Kong
1967	Jan	26	0719	II	133km NNE of Hong Kong
1967	Feb	14	0144	III	222km NNE of Hong Kong
1967	July	23	1435	III-IV	78km WSW of Hong Kong
1967	Oct	25	0901	III	844km E of Hong Kong
1968	Jan	28	2104	II-III	89km SE of Hong Kong
1968	Feb	26	1852	II	720km ENE of Hong Kong
1968	Apr	1	1706	III	479km NE of Hong Kong
1968	Aug	23	1246	II-III	156km ENE of Hong Kong
1968	Nov	19	1536	III-IV	354km east of Hong Kong
1968	Dec	30	1840	II-III	166km east of Hong Kong
1969	July	26	0650	V	21.6N, 111.9E 211km WSW of Hong Kong

APPENDIX III

Modified Mercalli Intensity Scale

I. Not felt. Marginal and long-period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favourably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquakes.

IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.

V. Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly or heard to rustle).

VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Crakcs in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations). Frame structures, if not bolted. Shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.

X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines completely out of service.

XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Masonry A,B,C,D. To avoid ambiguity of language, the quality of masonry, brick or otherwise, is specified by the following lettering (which has no connection with the conventional Calls A, B, C construction).

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.