DECLASSIFIED E.O. 11652 SEC. 3(E) AND 5(D) OR (E) NNDG # 773012

EARTHQUAKE HOKURIKU REGION, JAPAN

28 JUNE 1948

VOLUME II, ENGINEERING

Prepared by

DESIGN BRANCH
NGINEERING AND OPERATIONS DIVISION
OFFICE OF THE ENGINEER
RAL HEADQUARTERS, FAR EAST COMMAND

FEBRUARY 1949

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FOREWORD

Earthquakes are concentrated, with a few exceptions, into two grea
belt borders the Pacific Ocean on the east, north, and west, and a seco
circles the globe from the Mediterranean and Alps through the Caucasus
sects the Pacific belt in the East Indies. The Japanese Islands lie al
the circum-Pacific seismic belt, and have been subjected to particularl
within historic time. These islands commonly suffer at least one shock
within their boundaries and since the beginning of the 17th Century hav
major earthquakes each of which resulted in the death of more than 1,00
two such major earthquakes in Japan within the relatively short period
of the United States Army of Occupation - the Nankaido earthquake of 21
Fukui earthquake of 28 June 1948.

On the afternoon of June 28, 1948, at about 5:16 p.m., as people i
preparing to leave, offices and other places of work, a slight rocking
slow vibrations were not felt by people riding in moving vehicles but o
from the usual higher frequency motions experienced in the area. Howev
few people realized that the phenomenon was the result of a disastrous
occurred about three minutes earlier on the other side of the central i
quake, originating approximately 9 miles below the surface in the north
fecture, 200 miles to the west and north of Tokyo, caused widespread de
homes, concrete buildings, bridges, railroad facilities, utilities, and
usually the case, by widespread conflagrations.

Radio reports released from Tokyo at about 8:30 p.m. the same even
announcements of the disaster. By that time both the United States Arm
ment had set in motion relief efforts previously planned for such emerg
Reconnaissance Group, Fifth Air Force, Far East Air Forces, flew photog
disaster area early the next morning, thus obtaining an immediate picto
of the disaster.

Early news photographs and reports confirmed the seriousness of th
of the devastation which had occurred. In order that a first hand stud
an intense earthquake, rarely observed by American Engineers, might be
effected for representatives of this Office to visit the Fukui area. M
Helen Foster, Geologists, of the Intelligence Division were assigned to
of the phenomenon. Mr. Don W. Butler, Civil Engineer, of the Engineeri
accompanied by two Japanese consultants to that Division, Dr. Kiyoshi M
Engineering of Tokyo University, and Professor J. Kazuo Minami of the St
Department of Waseda University, was designated to study the engineering

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FOREWORD

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the east, north, and west, and a second belt partically en-
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Indies. The Japanese Islands lie along the western side of
nd have been subjected to particularly severe disturbances
ds commonly suffer at least one shock a day at some place
the beginning of the 17th Century have had over a score of
sulted in the death of more than 1,000 people. There have been
n within the relatively short period of time since the arrival
ation - the Nankaido earthquake of 21 December 1946, and the

1948, at about 5:16 p.m., as people in Tokyo were leaving, or
her places of work, a slight rocking of the area was felt. The
eople riding in moving vehicles but others noted the difference
tions experienced in the area. However, there was no alarm and
menon was the result of a disastrous earthquake which had
er on the other side of the central island - Honshu. The earth-
miles below the surface in the northern part of Fukui Pre-
north of Tokyo, caused widespread devastation. It demolished
railroad facilities, utilities, and was followed, as is
flagrations.

kyo at about 8:30 p.m. the same evening were the first general
that time both the United States Army and the Japanese Govern-
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ed. In order that a first hand study of the effects of such
ved by American Engineers, might be made, arrangements were
Office to visit the Fukui area. Mr. John J. Collins and Miss
telligence Division were assigned to study the geologic aspects
er, Civil Engineer, of the Engineering and Operations Division,
nts to that Division, Dr. Kiyoshi Muto, Professor of Structural
Professor J. Kazuo Minami of the Structural Engineering
designated to study the engineering aspects.

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The final report consists of two volumes, I and II. Volume
seismological background of the Fukui area. It presents in deta
of this earthquake. Volume II describes the damages sustained b
facilities, factories dwellings, and buildings. The failures of
Department Store, undoubtedly the most important structure destr
examined in detail. Detailed studies of other reinforced-concre
and tanks are also presented. Conclusions have been drawn and r
sive evidence is available. This volume was prepared by Mr. But
Muto and Professor Minami. Mr. Cecil L. Triplett, Architect, En
assisted in editing the manuscript.

The 64th Engineer Topographical Battalion furnished a photo
Gordner, and has accomplished the reproduction of both volumes o
to the photography obtained by the survey group, some of the gro
tration was furnished by the Engineer Section, Eighth U. S. Army
of the Japanese Government.

In this report, following the usual past procedure in Japan
name of the largest city in the area, when classed as a local ea
designated as the "Fukui Earthquake". The Japanese Earthquake R
Meteorological Observatory have given this earthquake the same d

It is hoped that this volume of the final report will aid i
mation serving to advance engineer's general and specialized kno
effects. As additional information to engineers, an appendix to
pared by the Engineering and Operations Division for publication
entitled "Notes on Earthquake Resistant Construction", will pres
earthquakes and practical considerations in design and construct
methods, and design application with actual examples will also b
Japanese structural engineering authorities are contributors.

A report along somewhat parallel lines is being prepared by
tion Committee composed of about 100 Japanese seismologists, eng
sored by the National Research Council of the Japanese Governme

Tokyo, Japan
17 March 1949

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ists of two volumes, I and II. Volume I discusses the geological and
f the Fukui area. It presents in detail seismic and geologic features
e II describes the damages sustained by utility systems, transportation
lings, and buildings. The failures of the reinforced concrete Daiwa
dly the most important structure destroyed by the earthquake, are
led studies of other reinforced-concrete structures, namely, chimneys
ed. Conclusions have been drawn and recommendations made where conclu-
. This volume was prepared by Mr. Butler with the assistance of Dr.
Mr. Cecil L. Triplett, Architect, Engineering and Operations Division,
nuscript.

ographical Battalion furnished a photographer, Staff Sergeant Ralph B.
ned the reproduction of both volumes of the final report. In addition
d by the survey group, some of the ground photography used in illus-
he Engineer Section, Eighth U. S. Army, and by the Railway Ministry
.

wing the usual past procedure in Japan to call an earthquake by the
n the area, when classed as a local earthquake, this earthquake is
arthquake". The Japanese Earthquake Research Institute and the Central
have given this earthquake the same designation.

volume of the final report will aid in the dissemination of infor-
ngineer's general and specialized knowledge of earthquakes and their
ormation to engineers, an appendix to this volume is now being pre-
d Operations Division for publication at a later date. The appendix,
ke Resistant Construction", will present the engineering aspects of
onsiderations in design and construction. Theory of design, design
tion with actual examples will also be treated in detail. Leading
ring authorities are contributors.

t parallel lines is being prepared by the Special Fukui Investiga-
about 100 Japanese seismologists, engineers, and architects, spon-
rch Council of the Japanese Government.

HUGH J. CASEY
Major General, CE

Engineer
General Headquarters
Far East Command

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TABLE OF CONTENT

CHAPTER	I.	INTRODUCTION	Page 3
CHAPTER	II.	PUBLIC UTILITIES	17
	A.	WATER SYSTEMS	17
	B.	ELECTRICAL SYSTEMS	20
	C.	GAS SYSTEM	22
	D.	COMMUNICATIONS FACILITIES	22
CHAPTER	III.	TRANSPORTATION FACILITIES	27
	A.	RAILROADS AND ELECTRIC INTERURBAN LINES	27
	B.	ROADS AND HIGHWAYS	33
	C.	BRIDGES	36
	1.	HIGHWAY BRIDGES	37
	2.	RAILROAD BRIDGES	47
	D.	LEVEES	51
CHAPTER	IV.	BUILDINGS	57
	A.	WOODEN HOUSES	57
	1.	U.S. ARMY HOUSING FACILITIES	57
	2.	JAPANESE HOUSES	68
	3.	SCHOOLS	78
	B.	REINFORCED CONCRETE BUILDINGS	81
	1.	GENERAL	81
	2.	DAIWA DEPARTMENT STORE	81
	3.	JINKEN SOKO WAREHOUSE	139
	4.	FUKUI TAX OFFICE	139

CHA

TABLE OF CONTENTS

Page	3		5. PREFECTURAL OFFICE BUILDING	Page 141
	17		6. NIPPON TSU-UN WAREHOUSE	141
	17		7. SHOCHIKUYA THEATER	141
	20		8. FUKUI CITY HALL	141
	22		9. HOKURIKU LIGHT AND POWER BUILDING	143
	22		10. FUKUI BROADCASTING COMPANY	144
	27	C.	STEEL CONSTRUCTION	147
N LINES	27		1. GENERAL	147
	33		2. ALL-STEEL STRUCTURES	147
	36		3. STEEL-FRAMED BUILDINGS	150
	37	D.	BRICK BUILDINGS	152
	47	E.	FACTORIES	153
	51		1. GENERAL	153
	57		2. FUKUI SEIREN FACTORY	153
	57		3. DAIWA BOSEKI FACTORY	155
	57		4. SAKAI SENI FACTORY	158
	68		5. OTHER FACTORIES	161
	78	CHAPTER V.	CHIMNEYS AND ELEVATED TANKS	165
	81	A.	REINFORCED CONCRETE CHIMNEYS	165
	81		1. GENERAL	165
	81		2. DAMAGES	165
	139		3. ANALYSIS OF DAMAGE	170
	139		4. DYNAMICAL PROPERTIES OF CHIMNEYS	174

5. FACTORS INFLUENCING FAILURE Page 175

B. REINFORCED CONCRETE ELEVATED TANK 175

1. GENERAL 175

2. FUKUI CITY RAILROAD YARD WATER TANK 176

CHAPTER VI. FIRE DAMAGE

CHAPTER VII. RECONSTRUCTION

CHAPTER VIII. CONCLUSIONS AND

CHAPTER VI. FIRE DAMAGE Page 185

CHAPTER VII. RECONSTRUCTION 187

CHAPTER VIII. CONCLUSIONS AND RECOMMENDATIONS 193

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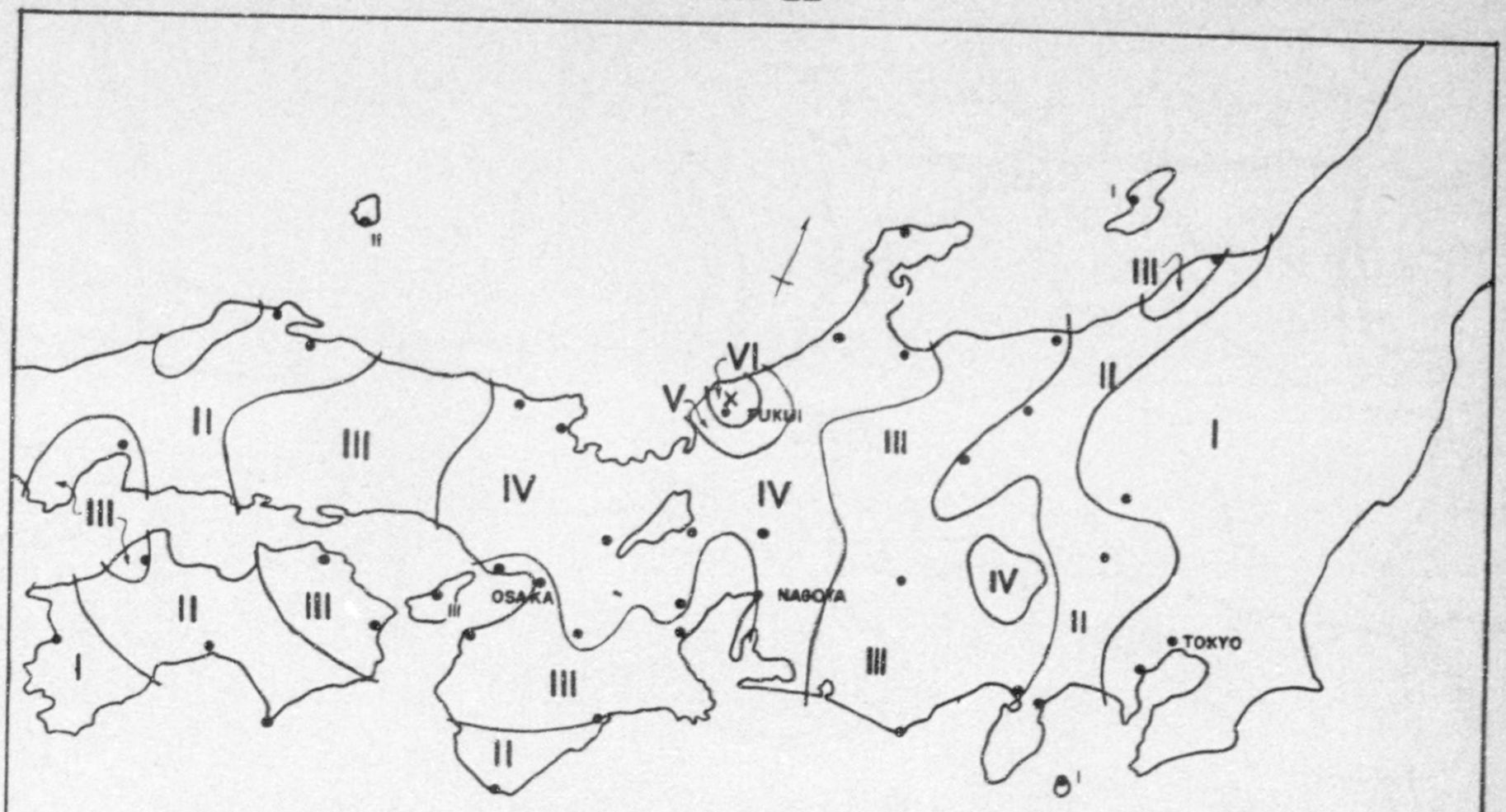
FUKUI EARTHQUAKE, JAPAN

HOKURIKU REGION

ENGINEERING STUDIES

VOLUME II



JAPANESE INTENSITY SCALE

VI	DISASTROUS	BRIDGES, HOUSES AND SOME CONCRETE STRUCTURES COLLAPSE: ROADS SINK OR CRACK OPEN, UNDERGROUND UTILITIES DAMAGED.
V	VERY STRONG	PERMANENT STRUCTURES CRACK: CHIMNEYS FAIL. UNDERGROUND UTILITIES MAY BE DAMAGED.
IV	STRONG	STRUCTURES SHAKE VIOLENTLY.
III	RATHER STRONG	STRUCTURES SHAKE: WINDOWS RATTLE.
II	MODERATE	PEOPLE FEEL EARTHQUAKE: WINDOWS RATTLE SLIGHTLY.
I	SLIGHT	EARTHQUAKE FELT BY PEOPLE NOT MOVING.
O	NO FEELING	

INTENSITY DISTRIBUTION
OF
FUKUI EARTHQUAKE
28. JUNE. 1948.

Fig. 1

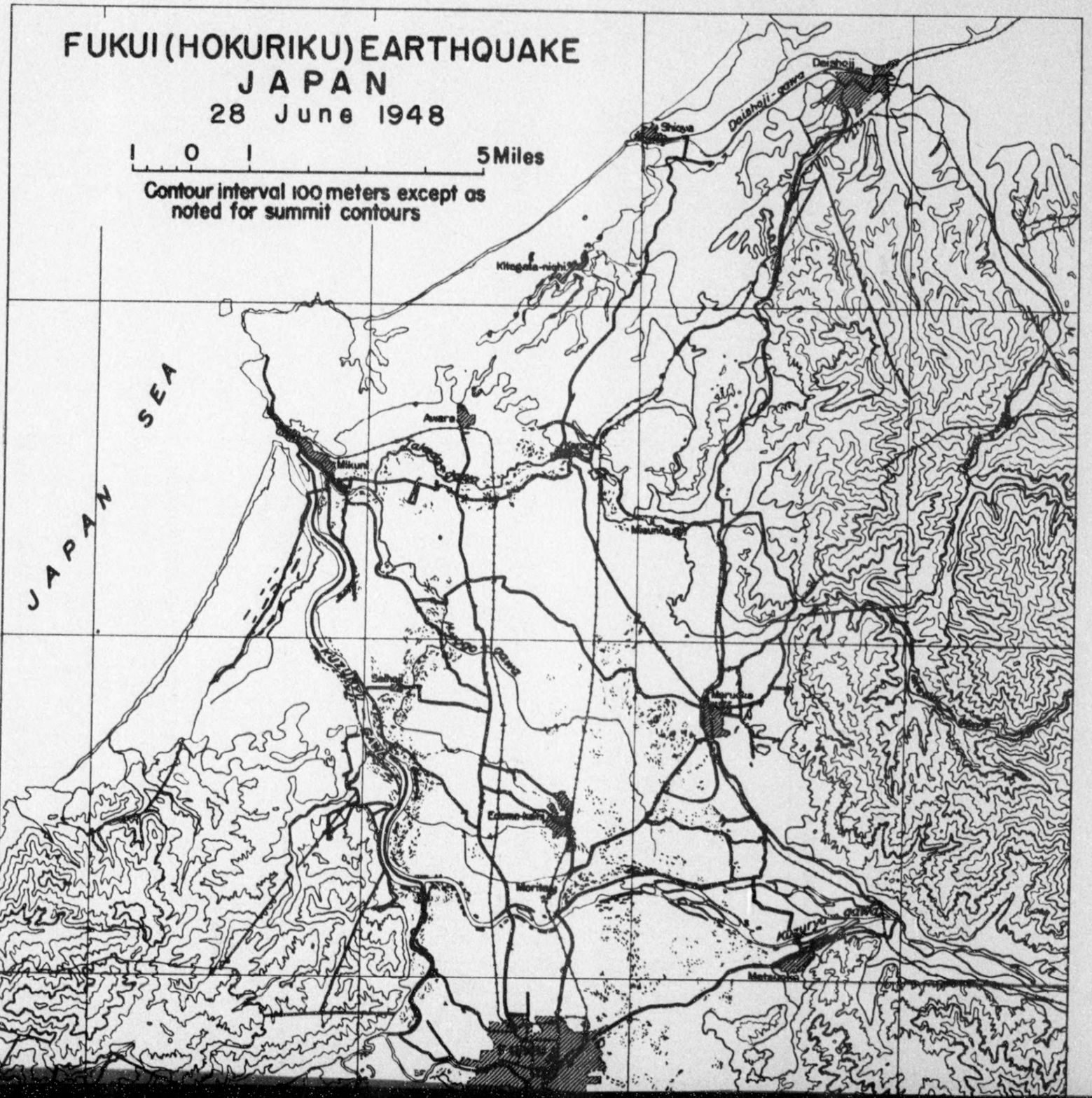
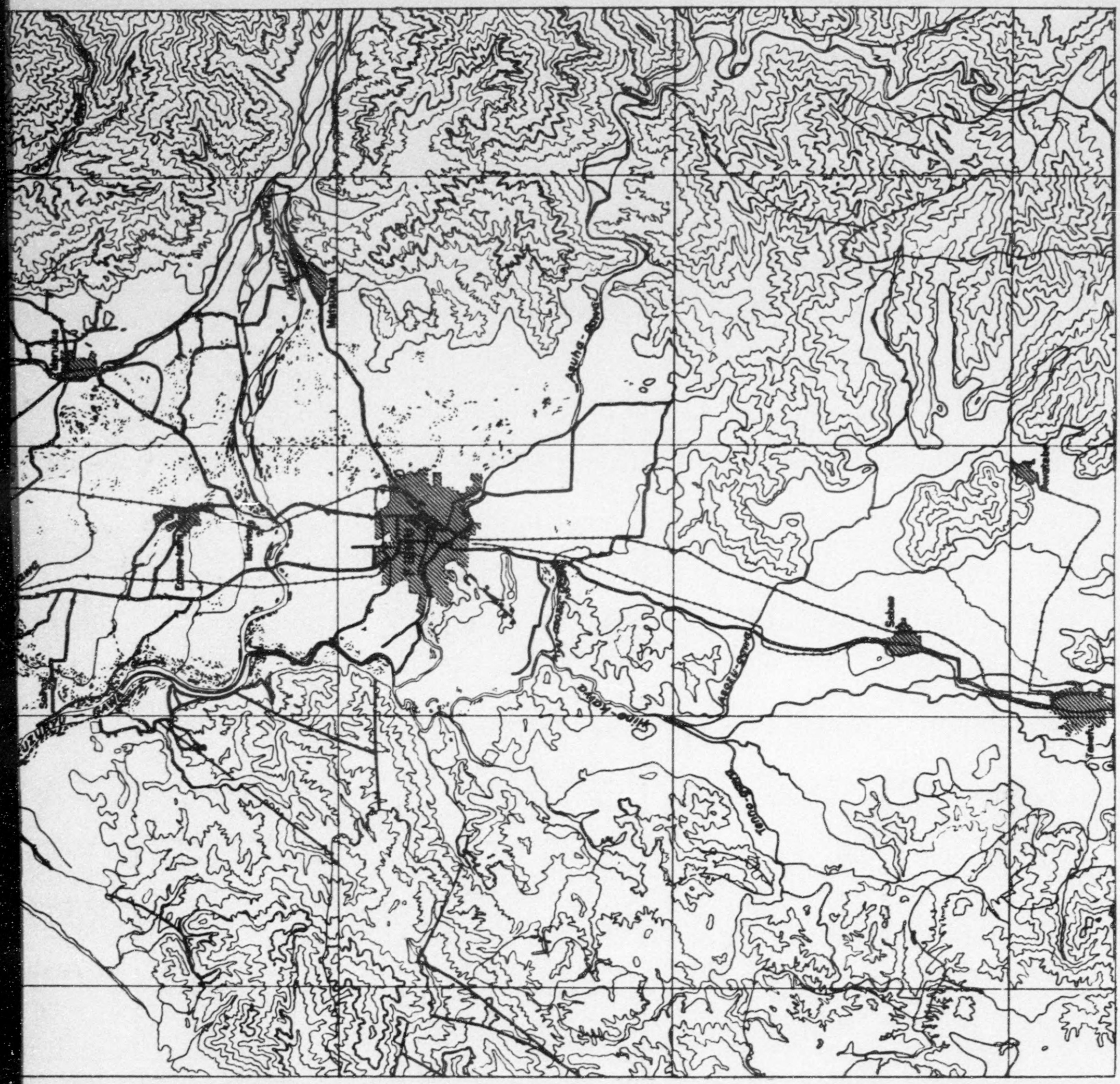


Fig. 2

Contour Map of the Fukui Area



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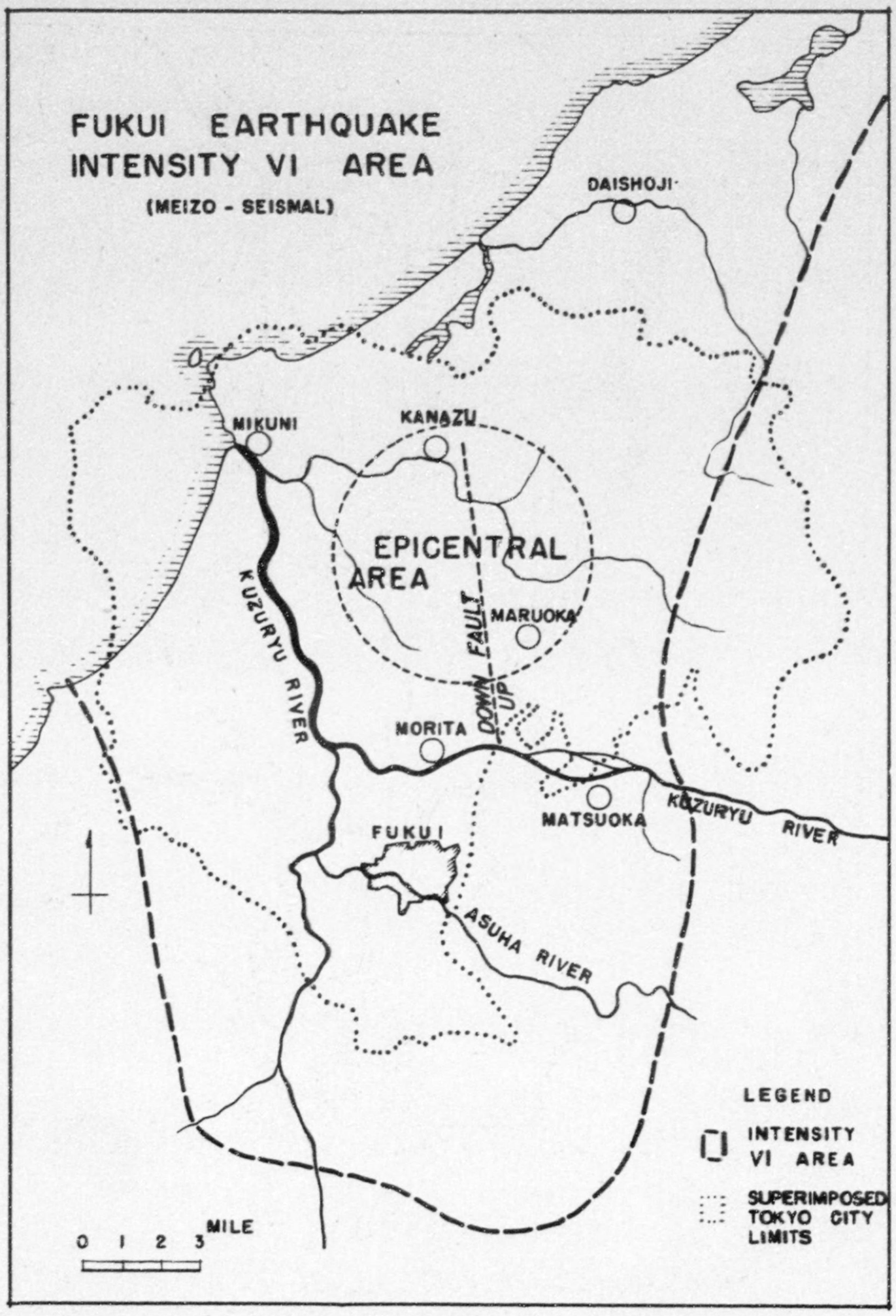

Fig. 3

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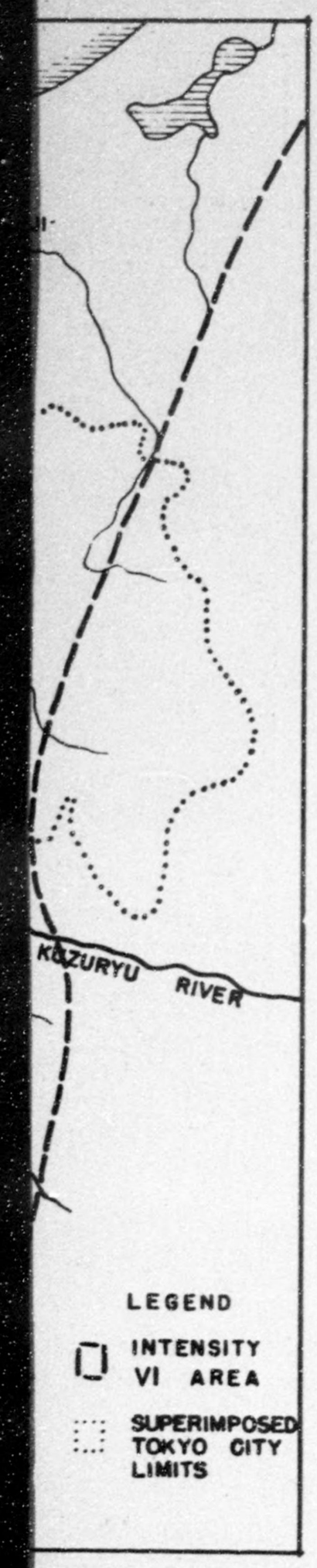

CHAPTER I

INTRODUCTION

On June 28, 1948, at 1713 and 27 seconds (daylight saving time), an earthquake of maximum intensity shook the plains area composing the northeastern part of Fukui Prefecture and the southern part of Ishikawa Prefecture about 200 miles north of west from Tokyo, Japan. The map, Fig. 1, gives the intensity distribution (isoseismals) throughout central Honshu Island and the island of Shikoku. The physical manifestations of each intensity scale are explained by the legend.

The violent effects of the earthquake were confined to the 8 x 15 mile Fukui alluvial plains area and to the region of semi-consolidated sand and sandstone extending 6 miles farther to the north. A contour map of the Fukui plains area is shown by Fig. 2. Fig. 3 is a map of the same region which shows the meizo-seismic area, that is the area of greatest intensity, in this case, scale VI. Also shown on this map is the superimposed outline of the city limits of Tokyo given as a comparison of the area affected. The epicenter of the earthquake was originally believed to be located north of Mikuni, the town shown at the mouth of the Kuzuryu River. Checking the residual ground movement, after shocks, aerial observation, and releveling of the area have placed the epicenter, according to majority

opinion, within the area shown on Fig. 3. Some observers believe the epicenter to be located just north of the Kuzuryu River, outside of the area shown, along the line marked FAULT.

A definite fault line was not discovered but levelings of the area disclosed that an almost straight line could be drawn generally north of the Kuzuryu River separating the upheaved side of the Fukui plain area from the subsided area. It is believed that any existence of a definite fault zone in bedrock might be concealed by the alluvial blanket above. Fig. 4 gives the area of, and amount of, upheaval and subsidence in the disaster area. The maximum subsidence was about 84 centimeters (33.1 inches) and the maximum upheaval was 41 centimeters (16.1 inches).

Reference to the map, Fig. 2, will show that the Fukui plains area is practically surrounded by mountainous terrain on three sides and the ocean on the remaining side. The definite depth of the alluvium layer is unknown. Well borings indicate it at least 300 feet in depth in places around Fukui City and indications are that the greatest depth in the plains area is well over 1000 feet. The northern part of the plains area is composed of semi-consolidated Pleistocene (geologically young) sand in the form of small hills. The northwest plains area is separated from the ocean by coastal sand dunes

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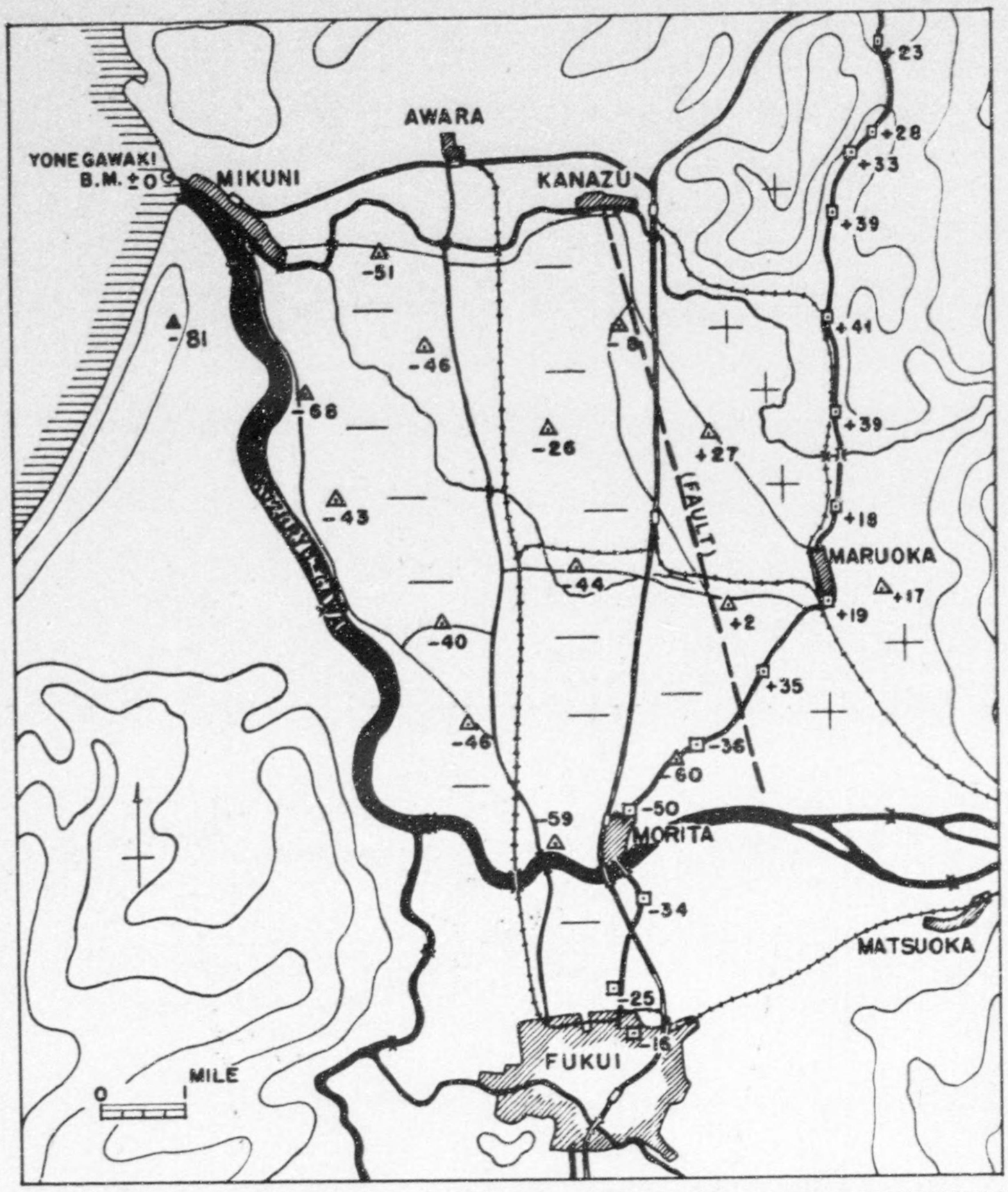


LOCATION LAYOUT OF
TRIANGULATION AND LEVELING POINTS AND
VERTICAL DISPLACEMENT AFTER THE HOKURIKU
EARTHQUAKE REFERRED TO 1928 ELEVATIONS.

Fig. 4

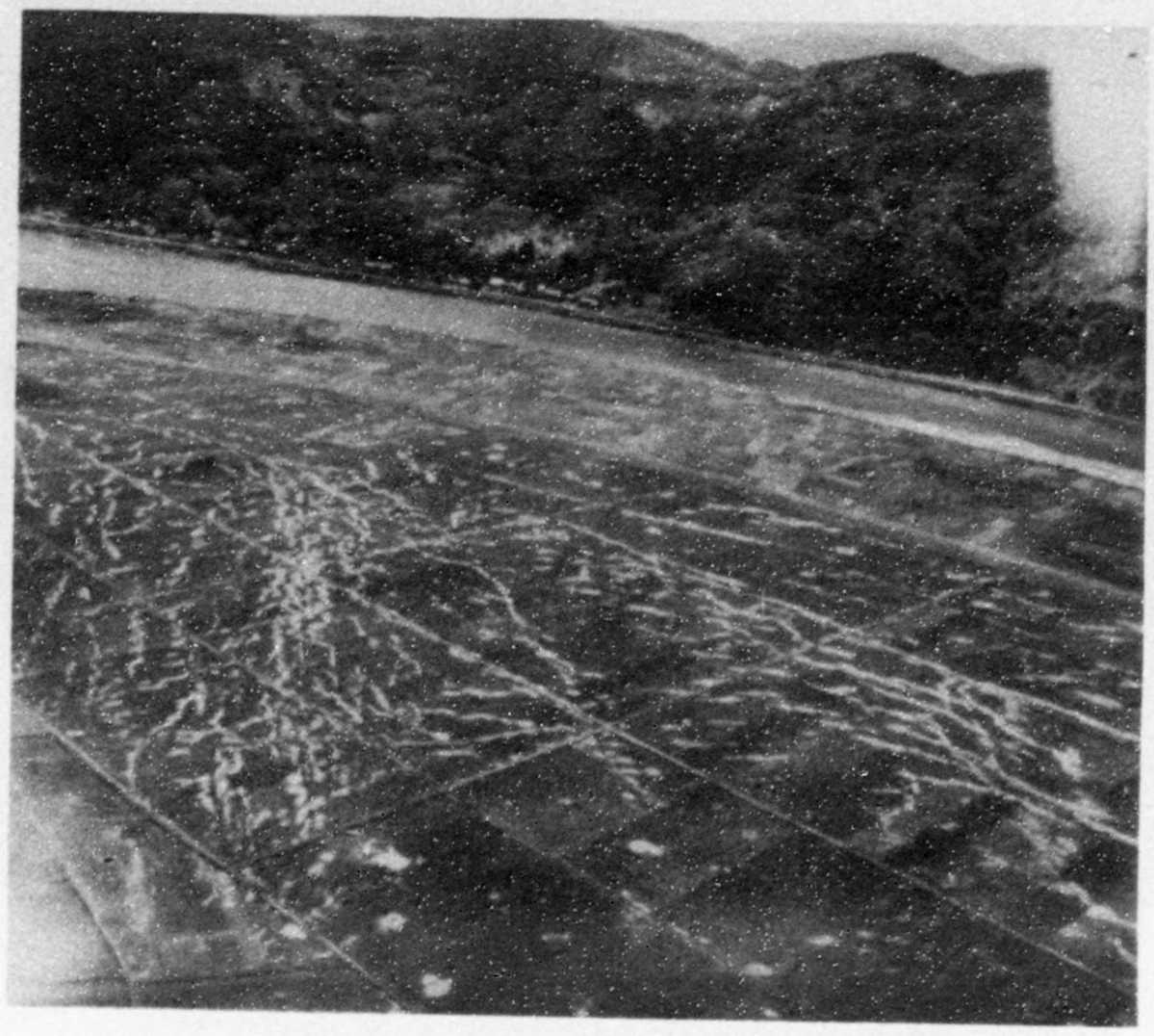


Fig. 5

Aerial View of Elongate Sand Boils

which extend south of the town of Mikuni, at the mouth of the Kuzuryu River. The western boundary is Tertiary rock hills and small mountains. South of, and adjacent to, the Fukui Plain is the Takefu Valley. This small alluvial valley might also have been expected to undergo heavy damage but is cut off from the Fukui Plain by small hills of Tertiary rock, which evidently screened the valley from the most violent shocks. The eastern edge of the valley is bounded by Tertiary rock mountains.

The focus of the earthquake was at the relatively shallow depth of approximately 9 miles and it would be classified as local destructive. Several areas were notably undamaged. As

Fig. 6

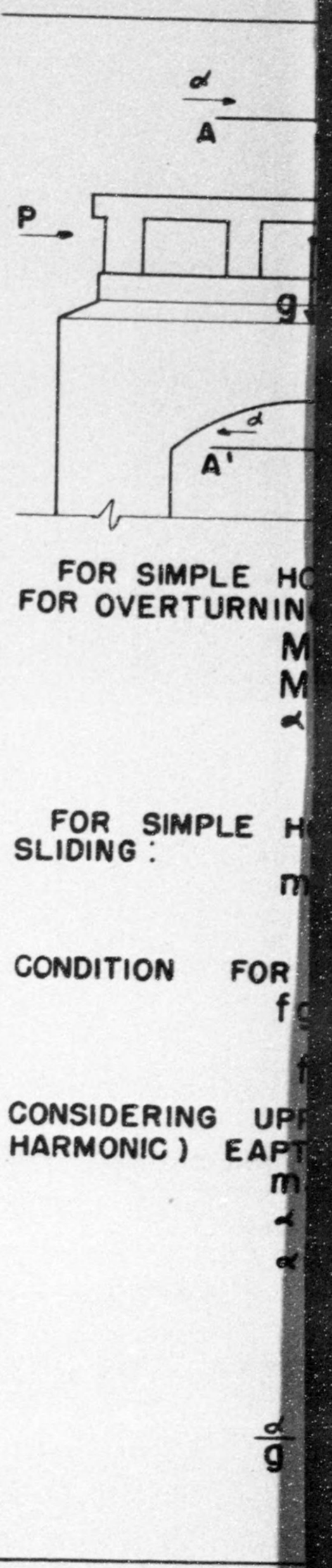
Photo Showing Residual Displacement of a
Deck Unit of the Itagaki Bridge

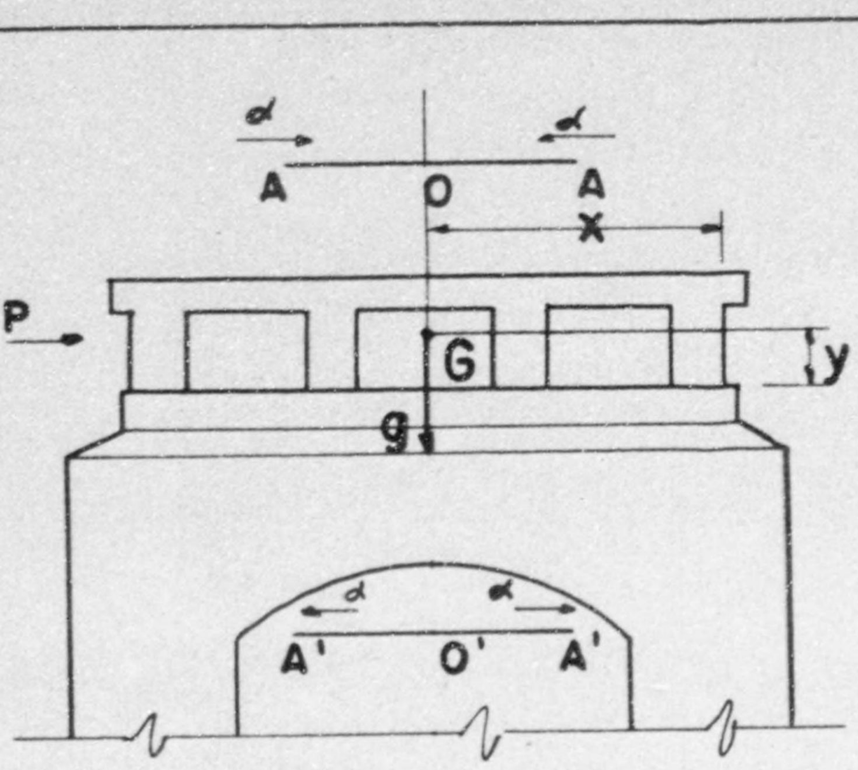
expected, buildings on the mountain slopes rimming the plain were only slightly damaged. The buildings in the sand dune region on the northwest edge of the plain should have been almost completely destroyed, because the area was so close to the epicenter, but damage was not exceptionally heavy. Houses built on gravel at the foot of the mountains also generally escaped with but slight damage. In the sand dune region, it seems that the unconsolidated sand probably acted sufficiently to absorb a high percentage of the energy of the seismic shocks and thus transmitted only relatively small amounts of energy to the buildings and structures.

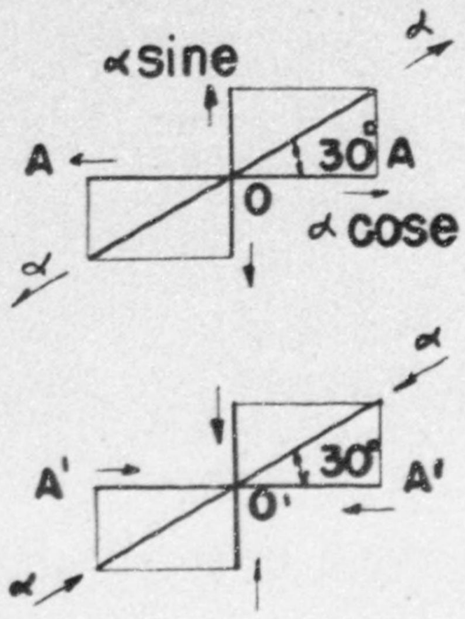
Aerial reconnaissance and photography showed circular and elongate sand boils to be one of the geologic features of the earthquake. Fig. 5 is an aerial view of these sand boils

This phenomenon is supposedly caused by the oscillations of a very soft, semi-liquid soil layer, namely, in this case, rice paddy land that for generations has been in a soft, saturated condition. The fissuring of the ground allows the escape of water, sand, and mud from the areas of higher pressure. In this particular area, the large amounts of light sand thrown up and out of the fissures have left very visible patterns.

The maximum acceleration attained during the earthquake is believed, by some Japanese scientists, to have been about 60 percent of the acceleration of gravity. Displacements of bridge girders over pier heads were observed where single movement displacements of as much as 2.5 feet were effected. This movement in one case (Itagaki Bridge) was concrete over concrete. The integral reinforced concrete parallel girders and bridge deck, Fig. 6, were not anchored to pier head, consequently, the coefficient of friction would be the determining factor of the amount of force necessary to move the deck unit. The coefficient of friction is the ratio of the force required to slide a body along a horizontal plane surface to the weight of the body. The coefficient of friction between concrete and concrete, dry and at rest, is 0.785. Fig. 7 gives the conditions in this case for estimating what might be the value of the acceleration. Lacking seismograms which would give the necessary information, the angle of the resultant vector of







FOR SIMPLE HORIZONTAL MOTION, CRITICAL CONDITION FOR OVERTURNING IS:

$$M_B^{+} = m\alpha y$$
$$M_B^{-} = mgx$$
$$\alpha y = gx$$
$$\alpha = \frac{x}{y} g \quad \text{(WEST'S FORMULA)}$$

FOR SIMPLE HORIZONTAL MOTION, CONDITION FOR SLIDING:

$$mfg \leq m\alpha$$
$$f \leq \frac{\alpha}{g}$$

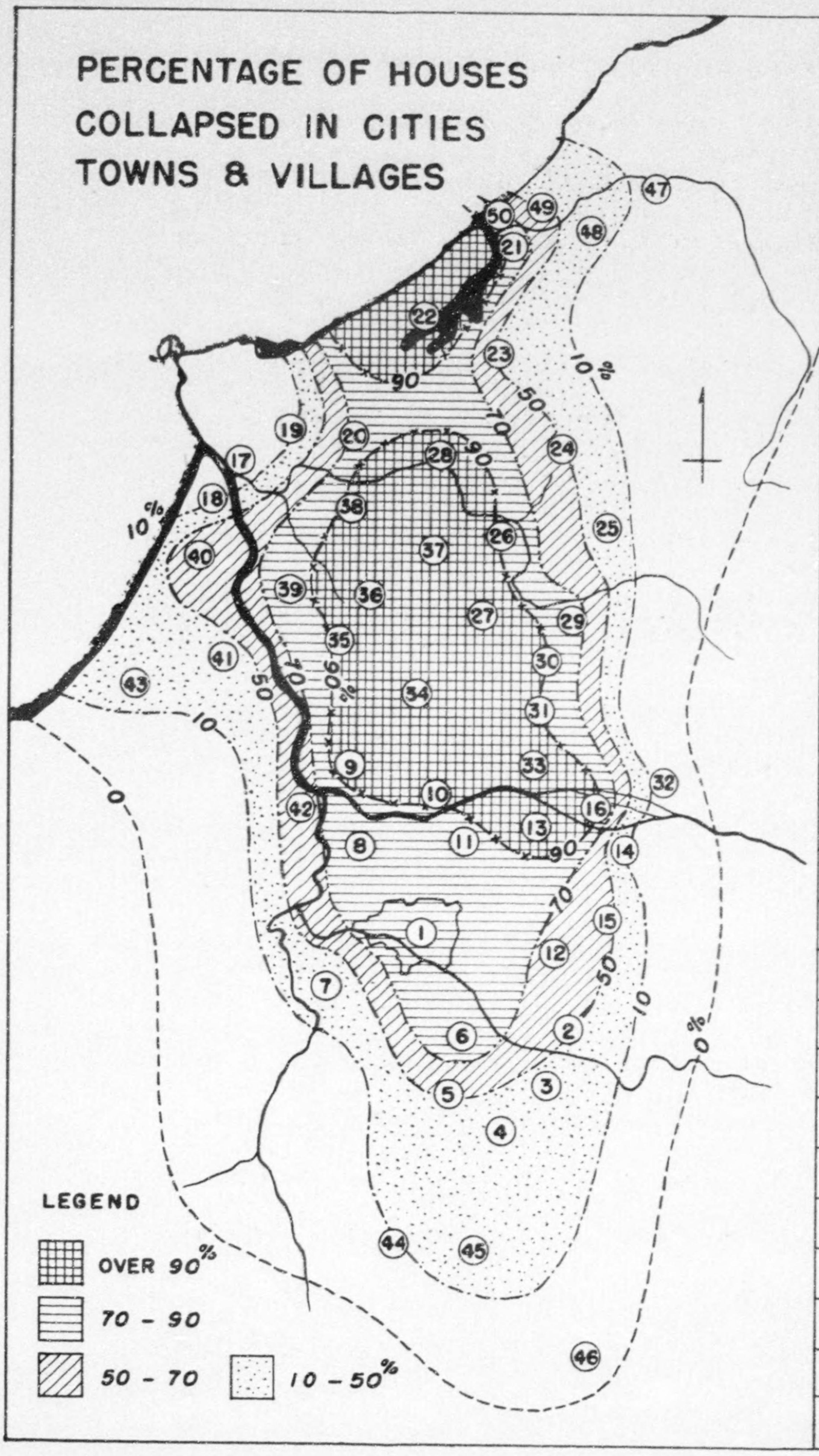
CONDITION FOR SLIDING WITHOUT OVERTURNING:

$$fg \leq \alpha \leq \frac{x}{y} g$$
$$f \leq \frac{x}{y}$$

CONSIDERING UPPER HALF OF OBLIQUE (SIMPLE HARMONIC) EAPTHQUAKE MOTION:

$$m\alpha\cos e = mf(g - \alpha\sin e)$$
$$\alpha\cos e = fg - f\alpha\sin e$$
$$\alpha(\cos e + f\sin e) = fg$$
$$= \frac{fg}{\cos e + f\sin e}$$
$$= \frac{0.785}{0.866 + 0.785(0.5)} = 0.62$$
$$\frac{\alpha}{g} = 0.62$$

Fig. 7



LIST OF CITIES TOWNS & VILLAGES			
NO.	NAME	NO.	NA
1	FUKUI	26	II
2	SAKŌ	27	HIGAS
3	TŌGŌ	28	KANA
4	KAMIMONJU	29	NAUN
5	SHIMOMONJU	30	MARU
6	ROKUJŌ	31	TAKA
7	YASHIRO	32	NARU
8	NISHI-FUJISHIMA	33	ISO
9	KAWAI	34	HAR
10	MORITA	35	ŌISH
11	NAKA-FUJISHIMA	36	HYŌ
12	OKABO	37	ŌSE
13	HIGASHI-FUJISHIMA	38	HON
14	MATSUOKA	39	KI B
15	YOSHINO	40	HAMA
16	GORYO-GA-SHIMA	41	UZU
17	MIKUNI	42	DAIA
18	SHINBO	43	NATS
19	KADO	44	NAKA
20	AWARA	45	KITA NAKA
21	YOSHIZAKI	46	FUKU
22	KITAGATA	47	DAISH
23	HOSOROGI	48	MIGI
24	TSUBOE	49	SEGO
25	TSURUGIDAKE	50	SHIO

Fig. 8

LIST OF CITIES TOWNS & VILLAGES

NO.	NAME	NO.	NAME
1	FUKUI	26	11
2	SAKŌ	27	HIGASHIJŪGŌ
3	TŌGŌ	28	KANAZU
4	KAMIMONJU	29	NAUNE
5	SHIMOMONJU	30	MARUOKA
6	ROKUJŌ	31	TAKABOKO
7	YASHIRO	32	NARUKA
8	NISHI-FUJISHIMA	33	ISOBE
9	KAWAI	34	HARUE
10	MORITA	35	ŌISHI
11	NAKA-FUJISHIMA	36	HYŌGO
12	OKABO	37	ŌSEKI
13	HIGASHI-FUJISHIMA	38	HONJŌ
14	MATSUOKA	39	KIBE
15	YOSHINO	40	HAMASHIGŌ
16	GORYO-GA-SHIMA	41	UZURA
17	MIKUNI	42	DAIANJI
18	SHINBO	43	NATSUME
19	KADO	44	NAKAGAWA
20	AWARA	45	KITA-NAKAYAMA
21	YOSHIZAKI	46	FUKUMA
22	KITAGATA	47	DAISHOJI
23	HOSOROGI	48	MIGI
24	TSUBOE	49	SEGOE
25	TSURUGIDAKE	50	SHIOYA

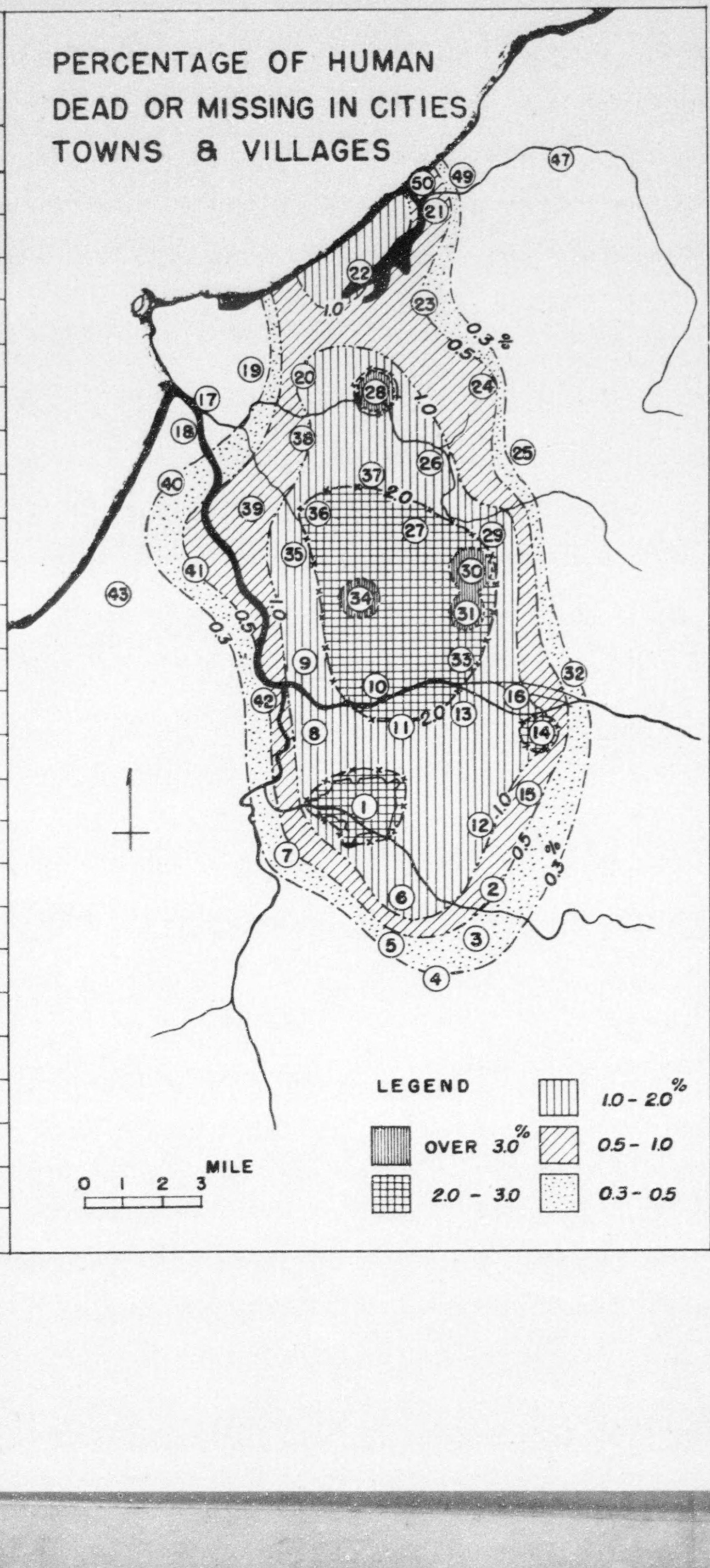


Fig. 8

oblique earthquake motion (conversely, the angle of repose for static friction) is assumed to be 30 degrees off horizontal. The value of the acceleration thus becomes 0.62g. Two possibilities may have existed which might have reduced the value of the coefficient of friction. The resultant motion may have acted at a larger angle from the horizontal, and it is known that in the epicentral area of violent earthquakes, besides the violent motions that cause destruction, there exist sharp motions with very short periods (1/10-1/20 sec.). These motions have accelerations sometimes exceeding that of gravity and, if they occur simultaneously with the main waves, may (similar to vibration) lower the normal value of the coefficient of friction. It is entirely possible that this occurred in this case and the figure of 0.60g may be a reasonable, if not high, assumed value of the acceleration achieved in this earthquake.

A study of a map showing the area affected by the great Mina-Owari earthquake in 1891 will reveal that the Neo-Valley fault, established as a result of that earthquake, extends in the direction of, and almost visibly to, the Fukui Plain. However, although some Japanese seismologists point out that the fault line, suspected of existing below the alluvium of the plain area, is an extension of the Neo-Valley fault, no definite facts warrant such an assumption.

A map, Fig.
by the area poli
centages collaps
shows the percen
disaster area.
city, town, and
aftermath of ear
for a large majo

In the cons
the Plain, there
which had been ma
appears that some
old north-east tr
by far the larges
noticeable zones
city. Fig. 10 is
This is of partic
town Fukui City w
crete buildings i
of the north-sout
showed evidence t
side moved south.

Fig. 11 is a
Fukui City. The

A map, Fig. 8, has been prepared, based on figures obtained by the area police, which shows the damage to houses, as percentages collapsed, throughout the disaster area. It also shows the percentages of human dead and missing throughout the disaster area. Fig. 9 is a tabulation of the totals in each city, town, and village in the disaster area. Fire, the usual aftermath of earthquakes, broke out in many areas and accounted for a large majority of the lives lost.

In the consolidated rock composing the hills surrounding the Plain, there is no direct evidence of movement along faults which had been mapped previous to the earthquake. However, it appears that some small faulting occurred along the zones of old north-east trending faults. In the city of Fukui, which is by far the largest center of population in the area, two quite noticeable zones were traced across the downtown area of the city. Fig. 10 is a map which gives the location of these zones. This is of particular interest because of the fact that in down town Fukui City was located a majority of the reinforced concrete buildings in the disaster area. Generally speaking, all of the north-south trending faults, in the area observed, showed evidence that the east side moved north and the west side moved south.

Fig. 11 is an aerial oblique view of the downtown area of Fukui City. The picture was taken from above the railway

TABLE 3

PERCENTAGE OF DEAD & MISSING IN TOWNS & VILLAGES AND PERCENTAGE OF COLLAPSED HOUSES

NO.	NAME OF TOWNS & VILLAGES	POPULATION			HOUSES		
		TOTAL	DEAD & MISSING	PERCENTAGE OF DEATHS	TOTAL	COLLAPSED	PERCENTAGE OF COLLAPSE
	FUKUI PREFECTURE						
1	○ FUKUI	86,141	2,520	2.92	15,525	12,270	79.
2	SAKŌ	3,437	19	0.55	702	390	56.
3	TOGŌ	4,452	18	0.40	830	229	28.
4	KAMIMONJU	2,700	7	0.26	546	107	20.
5	SHIMOMONJU	3,443	12	0.35	752	389	52.
6	ROKUJO	2,838	46	1.62	514	445	87.
7	YASHIRO	5,141	22	0.43	1,040	354	34.
8	NISHI -FUJISHIMA	7,468	96	1.3	1,039	847	82.
9	KAWAI	3,405	54	1.6	692	638	92.
10	MORITA	7,800	202	2.6	1,779	1,621	91.
11	NAKA -FUJISHIMA	4,150	78	1.9	806	619	77.
12	OKABO	3,200	38	1.2	650	400	62.
13	HIGASHI -FUJISHIMA	4,812	58	1.2	865	833	96.
14	MATSUOKA	5,414	160	2.9	1,613	186	12.
15	YOSHINO	1,635	10	0.6	257	130	51.
16	GORYŌ GA - SHIMA	1,320	13	1.0	242	218	90.
17	MIKUNI	10,715	9	0.08	2,015	17	0.8
18	SHINBO	1,580	1	0.06	430	37	86
19	KADO	2,605	1	0.04	470	40	85
20	AWARA	6,330	83	1.3	1,283	912	71.
21	YOSHIZAKI	650	5	0.8	165	150	91.
22	KITAGATA	4,285	68	1.6	631	631	100.
23	HOSOROGI	4,299	24	0.56	795	402	51.
24	TSUBOE	3,654	27	0.74	703	389	55.
25	TSURUGI -DAKE	1,459	2	0.14	297	132	44.
26	11	2,683	36				
27	HIGASHI JŪGŌ	4,647	123				
28	KANAZU	5,330	191				
29	NAUNE	3,880	65				
30	MARUOKA	6,800	286				
31	TAKABOKO	6,685	227				
32	NARUKA	2,069	8				
33	ISOBE	4,364	100				
34	HARUE	11,050	388				
35	ŌISHI	3,028	50				
36	HYŌGO	1,760	39				
37	ŌSEKI	2,179	26				
38	HONJŌ	4,097	30				
39	KIBE	4,035	21				
40	HAMASHIGŌ	2,862	9				
41	UZURA	3,866	19				
42	DAIANJI	2,313	11				
43	NATSUME	2,766	2				
44	NAKAGAWA	3,897	1				
45	KITA -NAKAYAMA	4,006	0				
46	FUKUMA	3,480	1				
	ISHIKAWA PREFECTURE						
47	DAISHŌJI	13,864	15				
48	MIGI	2,173	0				
49	SEGOE	401	0				
50	SHIOYA	1,680	15				
	OTHERS		32				
	TOTAL		5,268				

NOTE : ○ ---- FUKUI CITY
X ---- DOUBTFUL FIGURE

Fig. 9

Tabulation of Damage Totals

NO.	NAME OF TOWNS & VILLAGES	POPULATION			HOUSES		
		TOTAL	DEAD & MISSING	PERCENTAGE OF DEATHS	TOTAL	COLLAPSED	PERCENTAGE OF COLLAPSE
26	11	2,683	36	1.34	496	411	83.
27	HIGASHIJŪGŌ	4,647	123	2.6	904	904	100.
28	KANAZU	5,330	191	3.6	1,230	1,195	97.
29	NAUNE	3,880	65	1.7	762	590	77.
30	MARUOKA	6,800	286	4.2	1,760	X 1,048	89.
31	TAKABOKO	6,685	227	3.4	1,342	1,176	88.
32	NARUKA	2,069	8	0.39	428	37	8.6
33	ISOBE	4,364	100	2.3	882	852	97.
34	HARUE	11,050	388	3.5	2,504	2,504	100.
35	ŌISHI	3,028	50	1.67	588	522	89.
36	HYŌGO	1,760	39	2.2	330	318	96.
37	ŌSEKI	2,179	26	1.2	421	406	96.
38	HONJŌ	4,097	30	0.75	760	677	89.
39	KIBE	4,035	21	0.5	768	575	75.
40	HAMASHIGŌ	2,862	9	0.31	528	308	58.
41	UZURA	3,866	19	0.5	756	185	25.
42	DAIANJI	2,313	11	0.47	451	275	65.
43	NATSUME	2,766	2	0.07	536	92	17.
44	NAKAGAWA	3,897	1	≒0	794	74	9.3
45	KITA-NAKAYAMA	4,006	0	0	834	148	18.
46	FUKUMA	3,480	1	≒0	680	17	2.5
	ISHIKAWA PREFECTURE						
47	DAISHŌJI	13,864	15	0.11	3,156	252	8.0
48	MIGI	2,173	0	0	409	90	22.
49	SEGOE	401	0	0	115	13	11.
50	SHIOYA	1,680	15	0.9	427	300	70.
OTHERS			32			82	
TOTAL			5,268			35,437	

NOTE : ○ ---- FUKUI CITY
X ---- DOUBTFUL FIGURE

Fig. 9

Tabulation of Damage Totals

FAULT ZONES IN DOWNTOWN FUKUI CITY

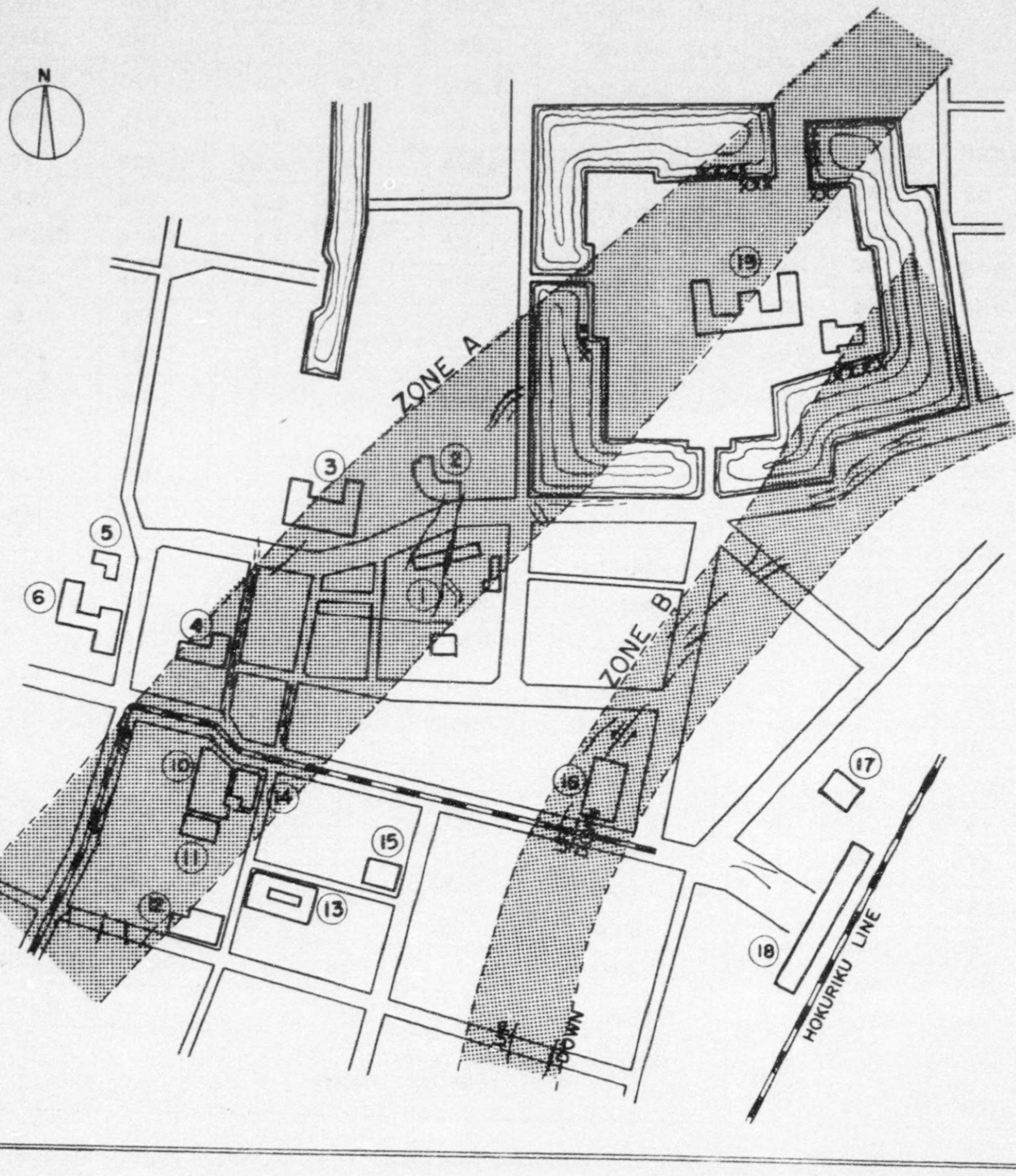
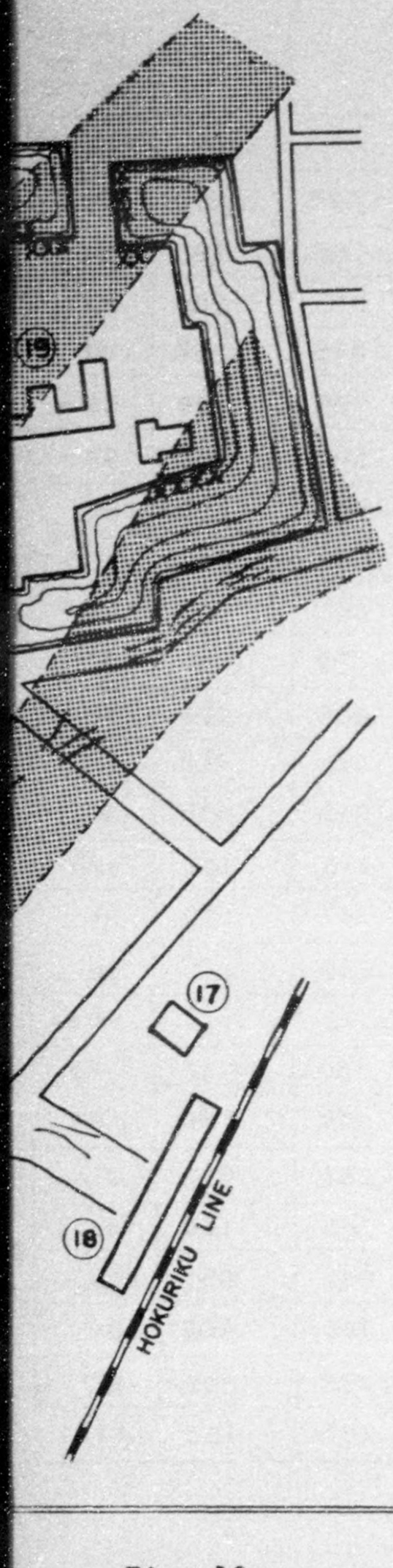


Fig. 10

NTOWN FUKUI CITY



/ FAULTS & FISSURES

XXX DISRUPTED STONE WALLS

BUILDING KEY NUMBERS

1	U.S. ARMY HOUSING EMPLOYEES DORMITORY BURNED OUT U.S. HOUSING
2	POLICE BUILDING
3	CITY HALL
4	MILITARY GOVERNMENT
5	TAX OFFICE
6	FUKUI BANK
10	DAIWA DEPARTMENT STORE
14	SAKAI BUILDING
11	RAYON WAREHOUSE
12	NIPPON KANGYO BANK
13	COMMUNICATIONS BUILDING
15	SHOCHIKUZA THEATRE
16	KORENORI WAREHOUSE
17	NIPPON TSŪ-UN WAREHOUSE
18	FUKUI STATION
19	PREFECTURAL OFFICE

Fig. 10

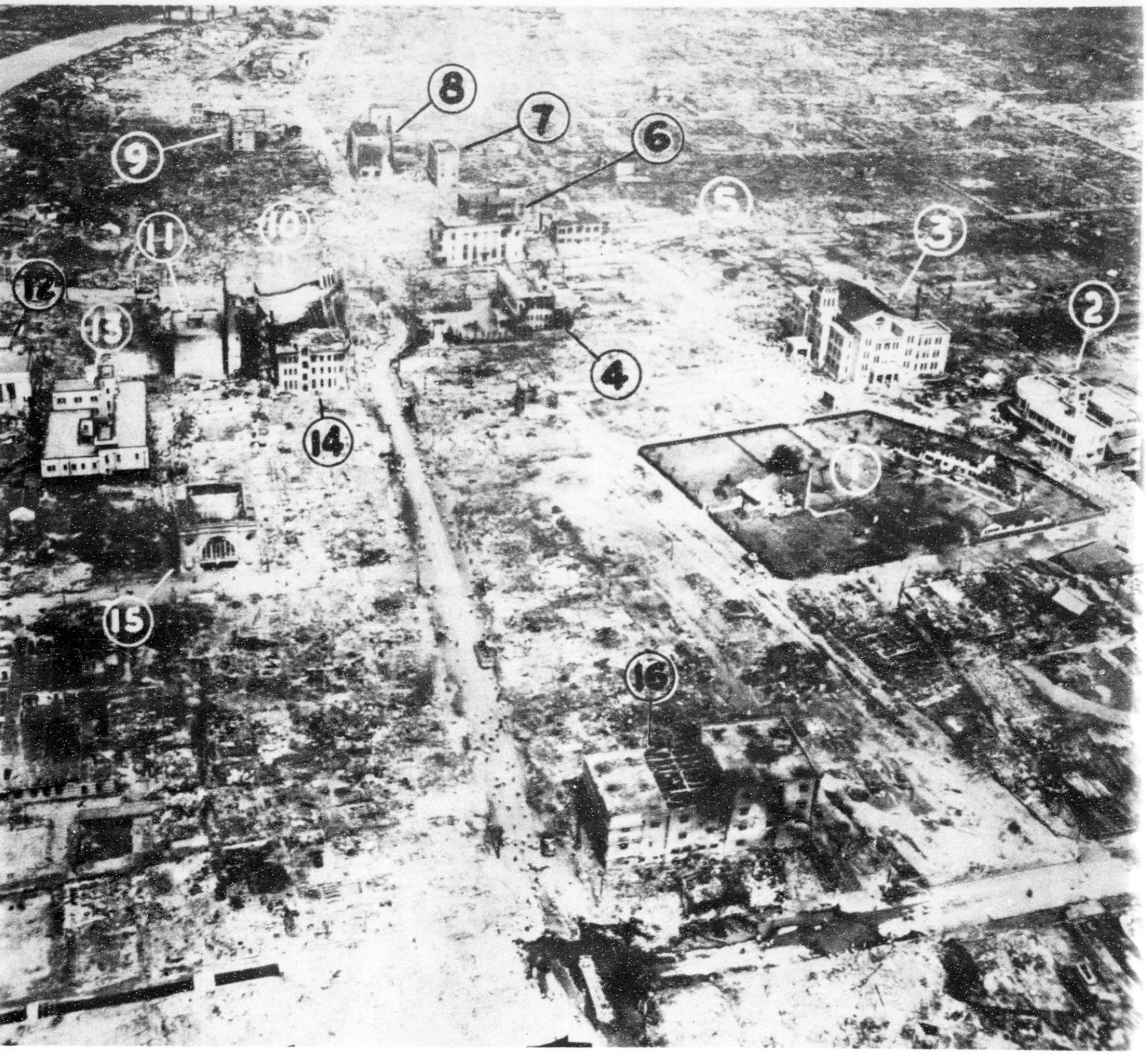
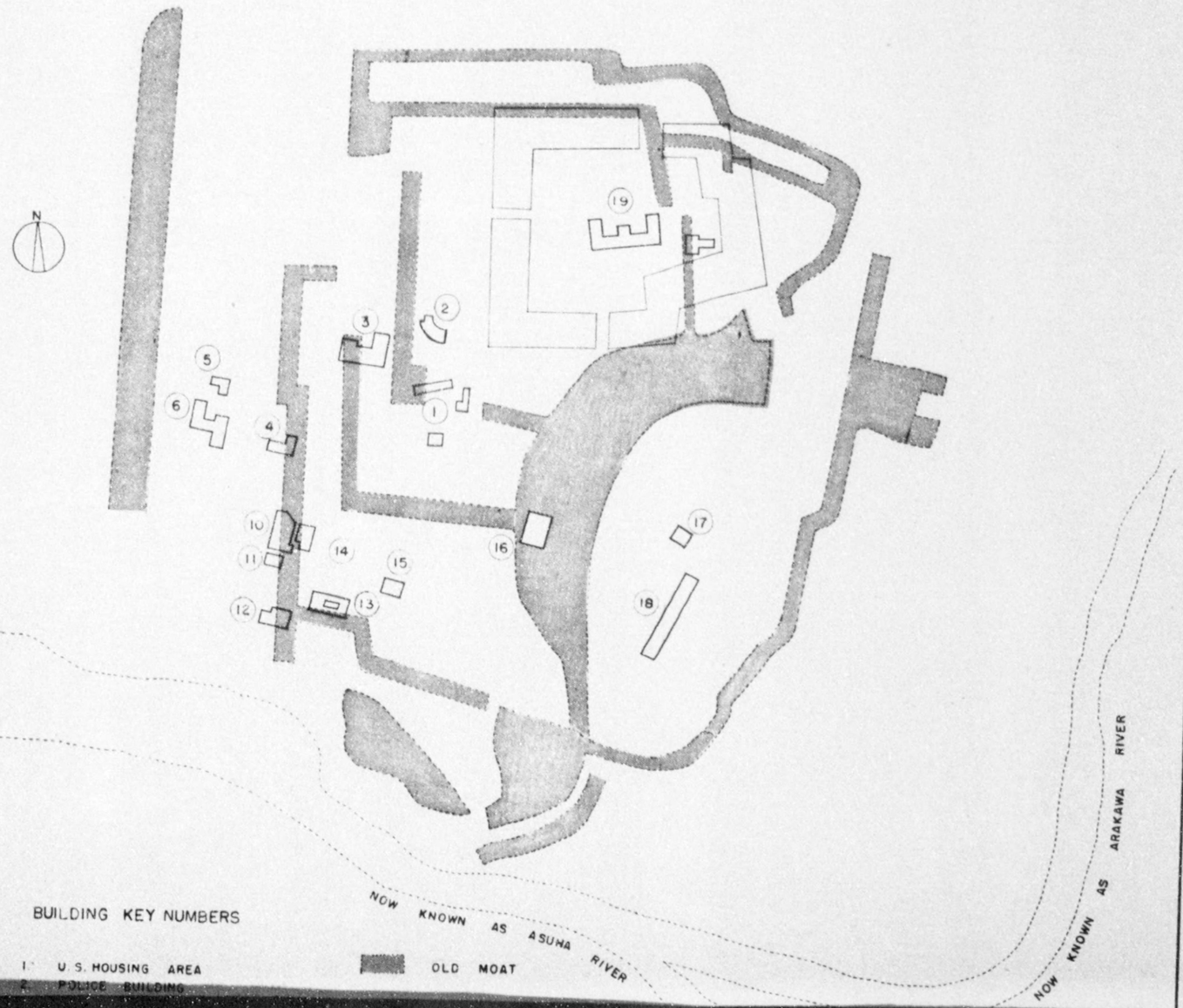


Fig. 11

Aerial View of Downtown Fukui City

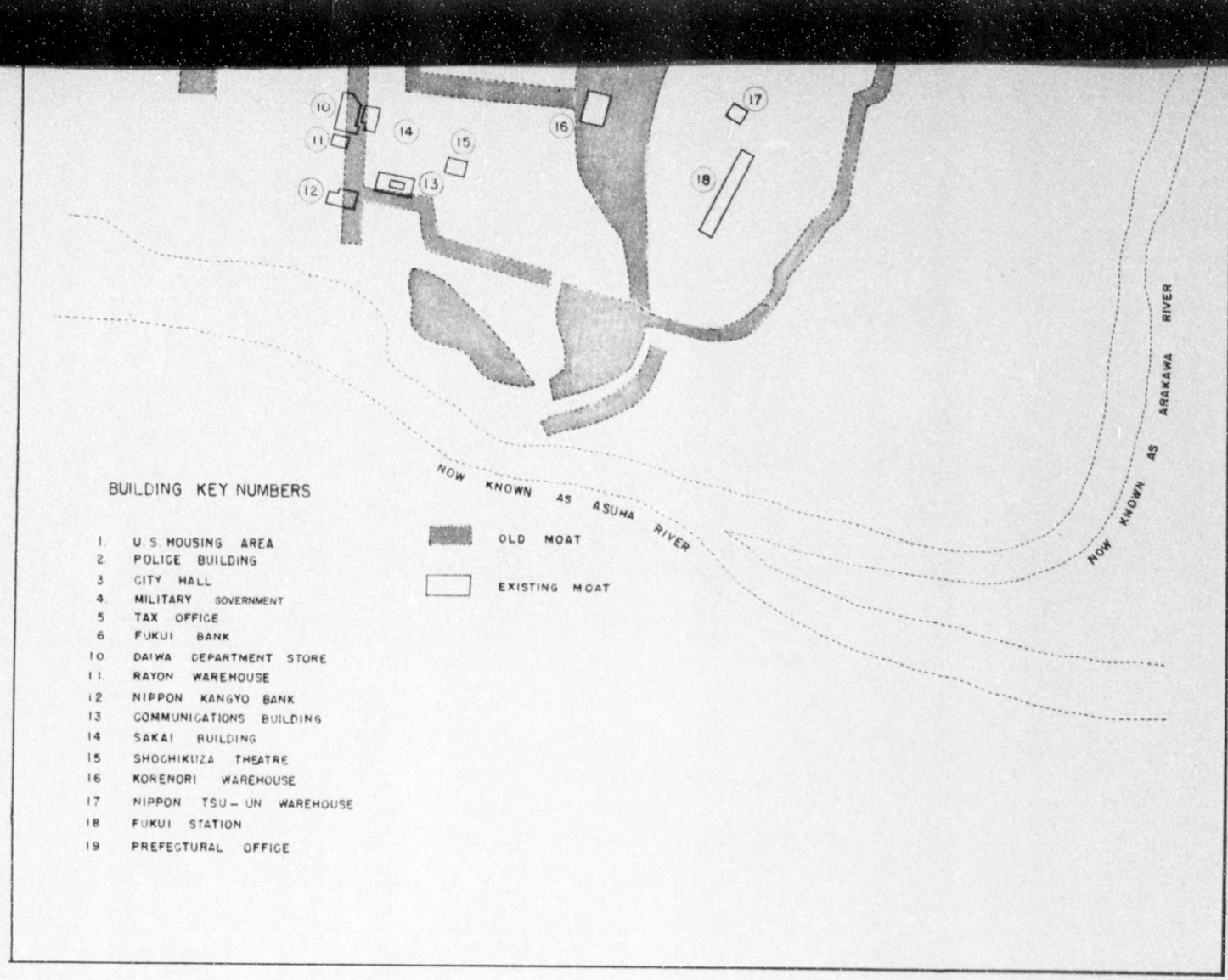
MAP SHOWING OVERLAY OF DOWNTOWN FUKUI CITY OVER OLD MOATS



BUILDING KEY NUMBERS

1. U. S. HOUSING AREA
2. POLICE BUILDING

OLD MOAT



BUILDING KEY NUMBERS

1. U. S. HOUSING AREA
2. POLICE BUILDING
3. CITY HALL
4. MILITARY GOVERNMENT
5. TAX OFFICE
6. FUKUI BANK
10. DAIWA DEPARTMENT STORE
11. RAYON WAREHOUSE
12. NIPPON KANGYO BANK
13. COMMUNICATIONS BUILDING
14. SAKAI BUILDING
15. SHOCHIKUZA THEATRE
16. KORENORI WAREHOUSE
17. NIPPON TSU-UN WAREHOUSE
18. FUKUI STATION
19. PREFECTURAL OFFICE

Fig. 12

station (building number 18, Fig. 10) and looks west on the downtown area of the city. The Asuha River is visible in the upper left of the picture. Also clearly visible is the downtown area which was ravaged by fire after the earthquake. An original map, estimated to be several centuries old, was turned up in the investigation of the area history. This map showed quite an extensive system of moats existing as part of the castle fortifications of that period. The only landmarks on the old map recognizable were a temple, that still exists, and the present Asuha and Arakawa Rivers. The map was not drawn to scale but, by means of the three landmarks, was superimposed as closely as possible over the existing downtown layout. The results and the resultant locations of the various present day buildings relative to the old moat system are shown by Fig. 12.

The damage to houses suffered in the city of Fukui as a result of the Mina-Owari earthquake of 1891 is shown by Fig. 13. In Chapter IV, Section A-2, the results of damage to this same city area as a result of the Hokuriku earthquake are shown.

The detailed geology of the area is given in Volume I of the report on this earthquake. The natural period of vibration for the alluvium in the plains area is about 0.4-0.5 seconds. The exact period of the seismic wave in the disaster area is

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not known but calculations and deduction place it at about 1.5 seconds in the epicentral area. The seismograph station in Fukui City was destroyed by fire. It is doubtful that it recorded accurately, as seismographs much farther away from the epicentral area (Kanazawa-40 miles north) failed to make record seismograms. The violent S phase waves were of an amplitude beyond that of the instrument's capacity to record and accordingly dislodged the scribers. The severity of the earthquake can be estimated from the fact that a grand piano is said to have been turned up-side down, that locomotives and freight cars were overturned, and that a six-story reinforced concrete department store in Fukui City crumbled.

During the inspection of the Itagaki Bridge, a tragic event frequently described in fiction buy rarely occurring in actuality was verified. The party learned of the fact that a young woman had been crushed to death in a fissure in the near neighborhood. The site was visited and the witnesses interviewed. The victim, Mrs. Sadako Nankyo, age 37, was working in a rice paddy, located closeby the house at 33 Shissaku-machi, Fukui City, when the shocks were felt. She started out of the paddy but fell into a fissure which, it was said, opened to about 4 feet in width. It closed upon her to the chin, instantly crushing her to death. The body was immediately dug

DAMAGE IN FUKUI CITY DUE TO MINO-OWARI

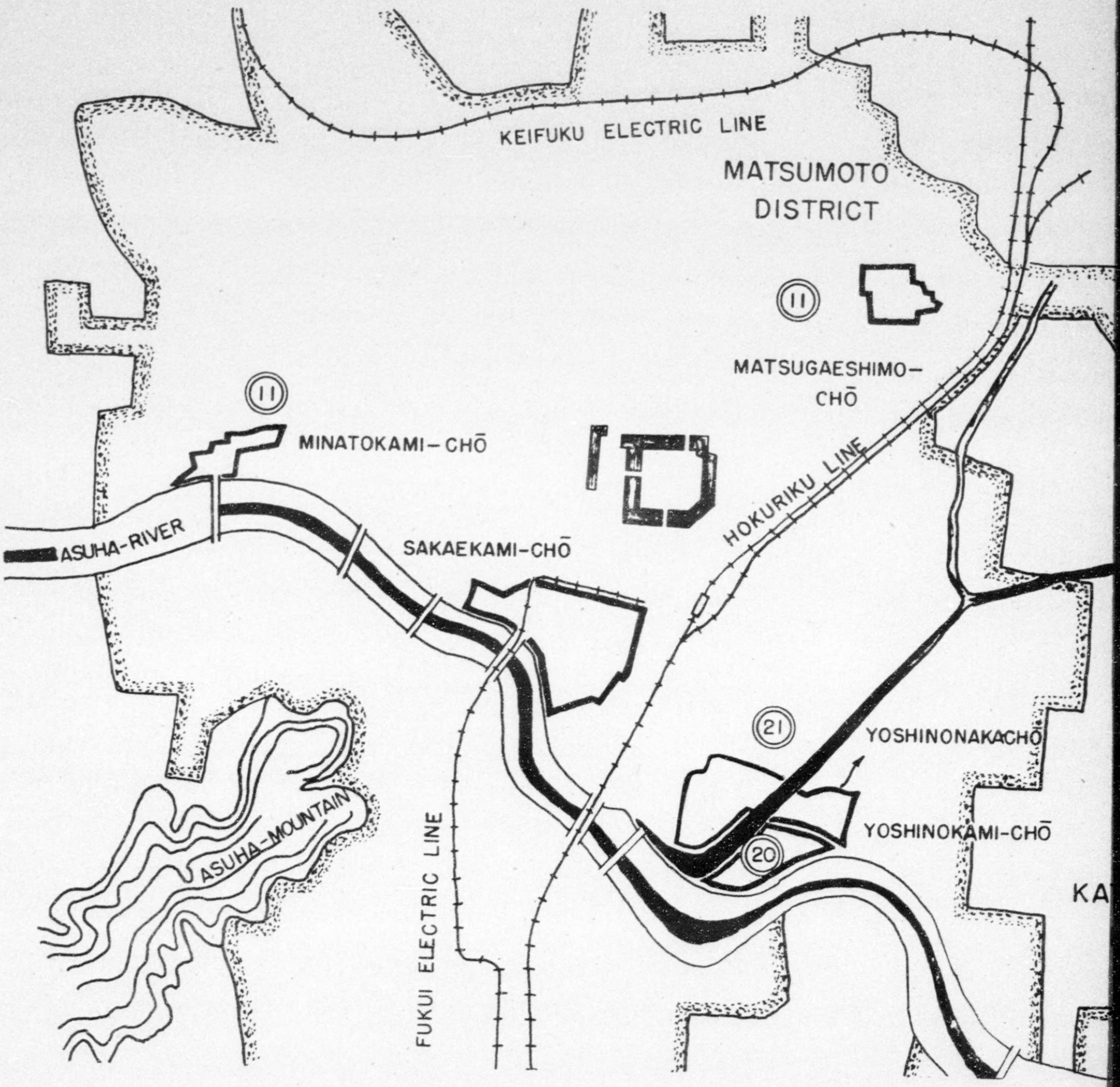

Fig. 13

UE TO MINO-OWARI EARTHQUAKE (1891)

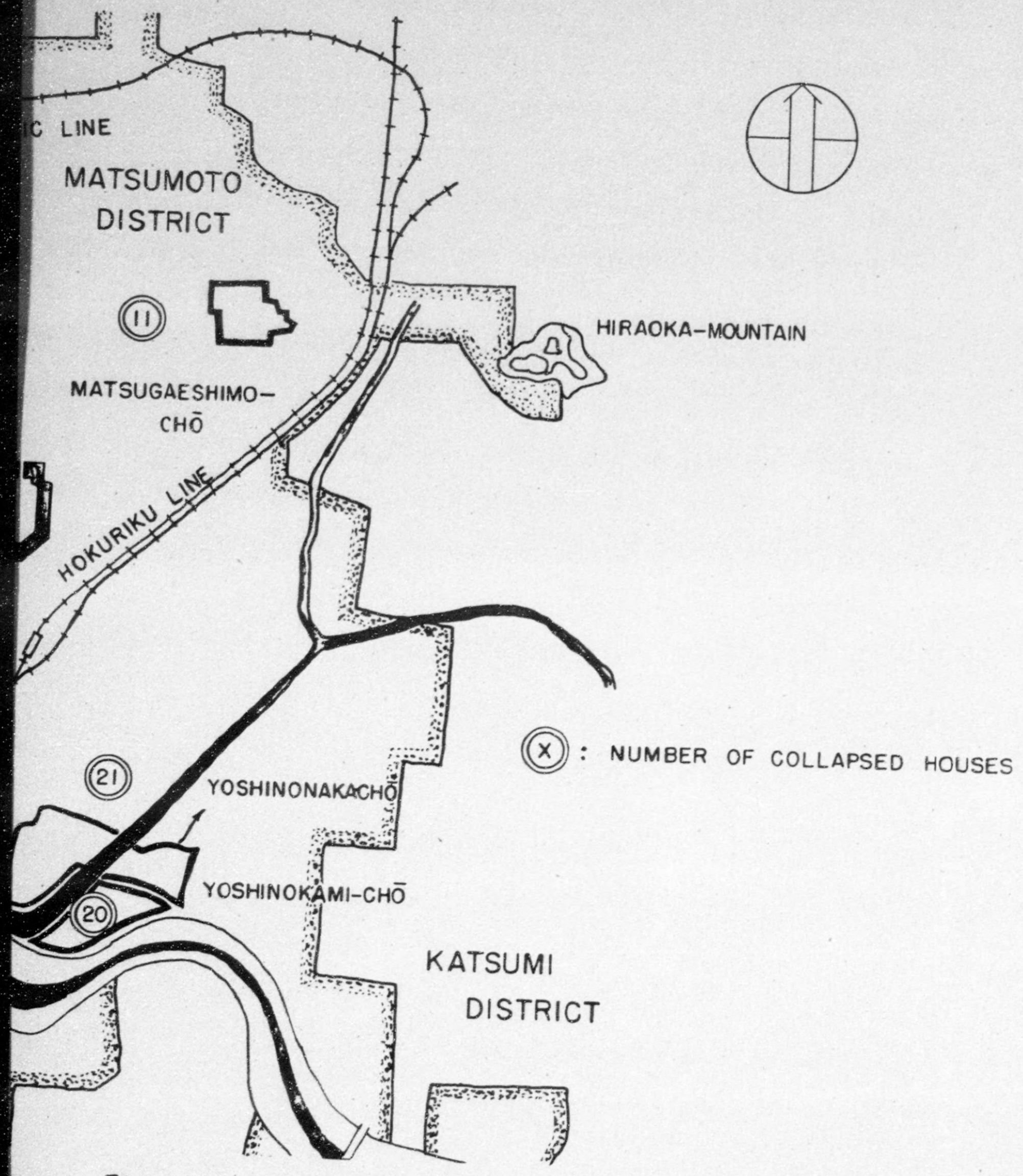

Fig. 13

out of the ground (only a faint remainder of the course of the fissure could be traced) by neighbors and the woman's husband.

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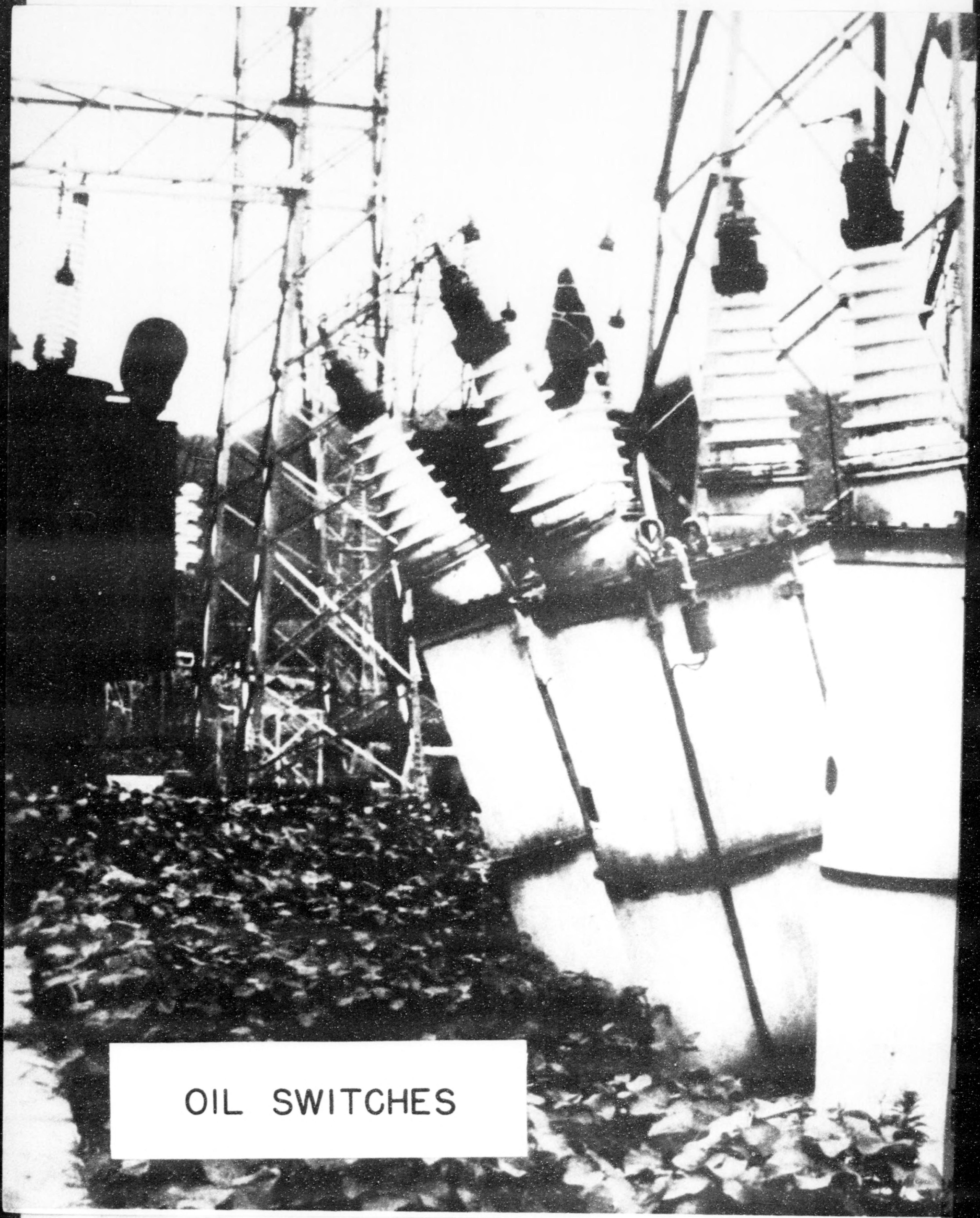
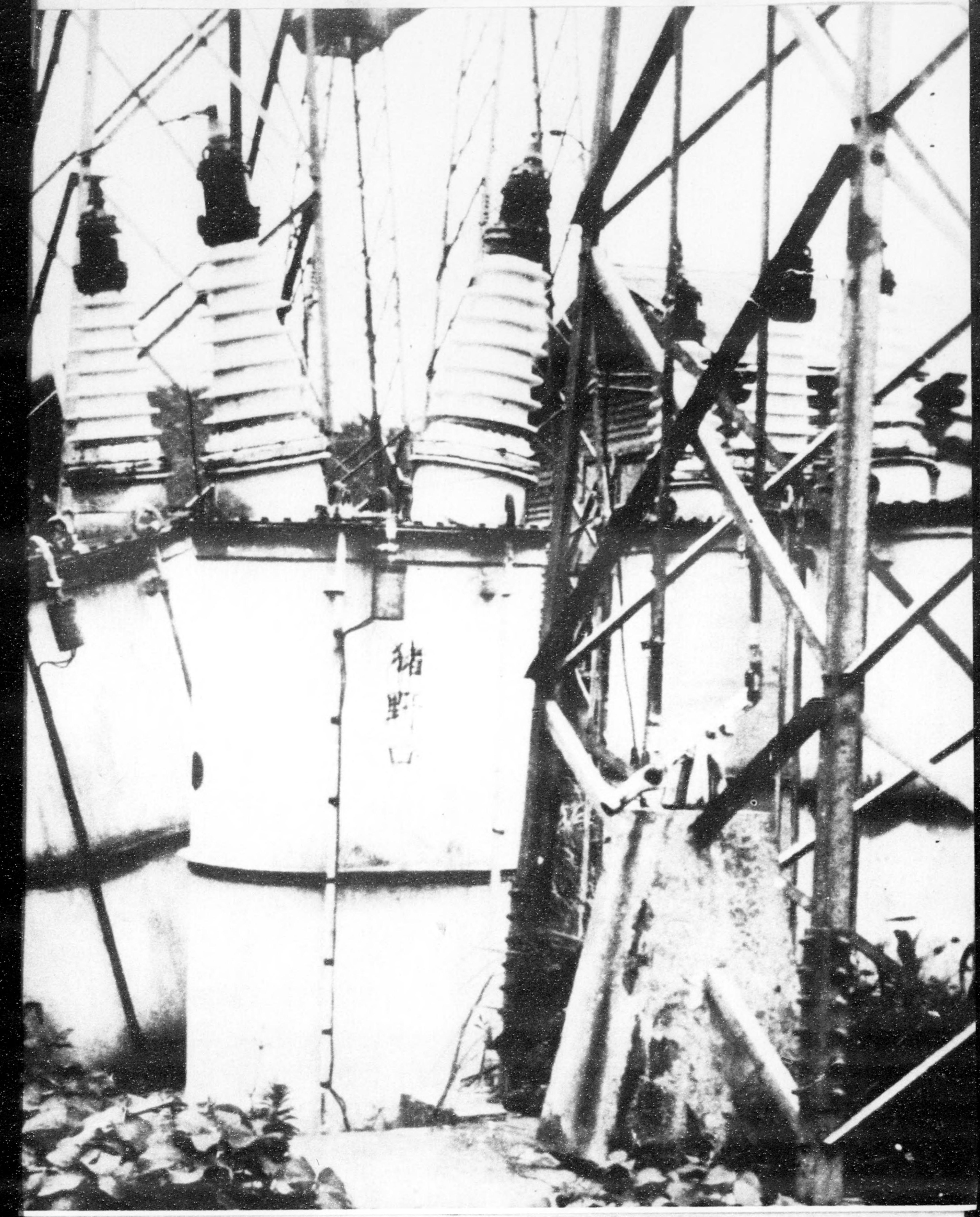
Seven people saw the woman in the ground after the quake and several of them were eye-witnesses of the happening.



OIL SWITCHES



CHAPTER II

PUBLIC UTILITIES

A. WATER SUPPLY SYSTEMS

1. Fukui City - The water for Fukui City comes from five wells located southeast of the city. The wells are located south of the Asuha River in a straight north and south line. The water from these wells is pumped to an underground reservoir located just north of the wells on the south bank of the Asuha River. The water is pumped from a pumping station, located in conjunction with this underground reservoir, through a 24" cast-iron line to the suction pit of a booster pumping station at the base of the Asuha Mountain (hill to be exact). This station pumps the water up to two concrete reservoirs, located on top of Asuha Mountain, from which reservoirs it flows by gravity throughout the city distribution system.

The wells each have a depth of 303 feet. The top diameters of six feet, concrete cased, extend 35 feet deep, from which point the wells are 12 inches in diameter and cased with steel pipe. Three of the wells are used with two on standby. Each well had a circular pumphouse of reinforced concrete. Fig. 14 shows an interior view through the door of the 1st well, in line south from the underground reservoir. This well house subsided about a maximum of 18 inches. This depth of subsidence can be traced on the exterior of the well casing

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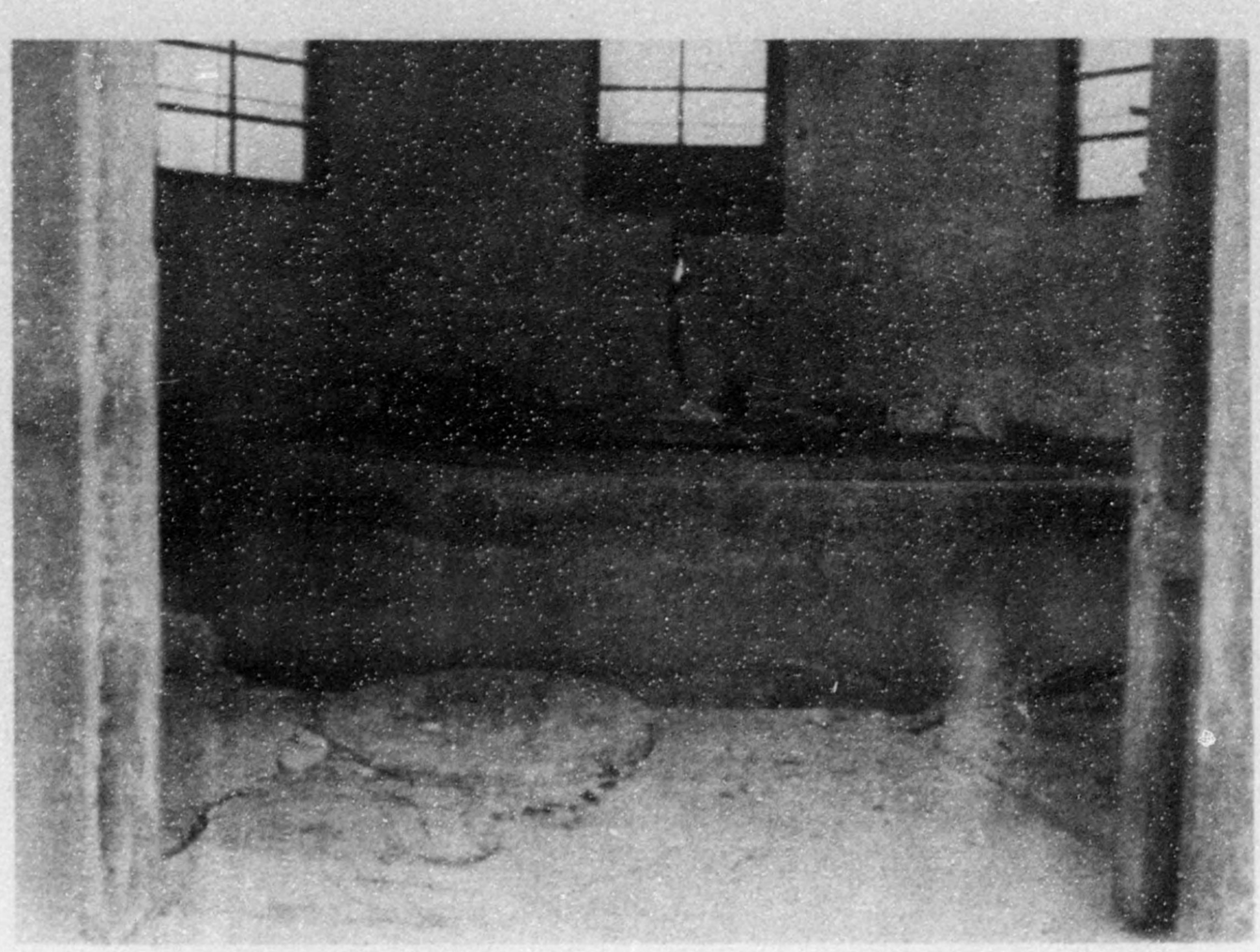

Fig. 14

Interior View of Well House

which shows the original position of the floor. The well house floor and wall opposite the entrance were broken up due to much smaller subsidence on that side. This well proper showed no sign of subsidence or of damage to the casing or to its alignment. The well houses were all constructed with a continuous wall footing. The floor slabs were poured directly on the ground. All of the well houses, with the exception of the center one, suffered the same type of damage with subsidences ranging from 4 to 12 inches. The center well house, however, was constructed with floor beams which were tied into the well

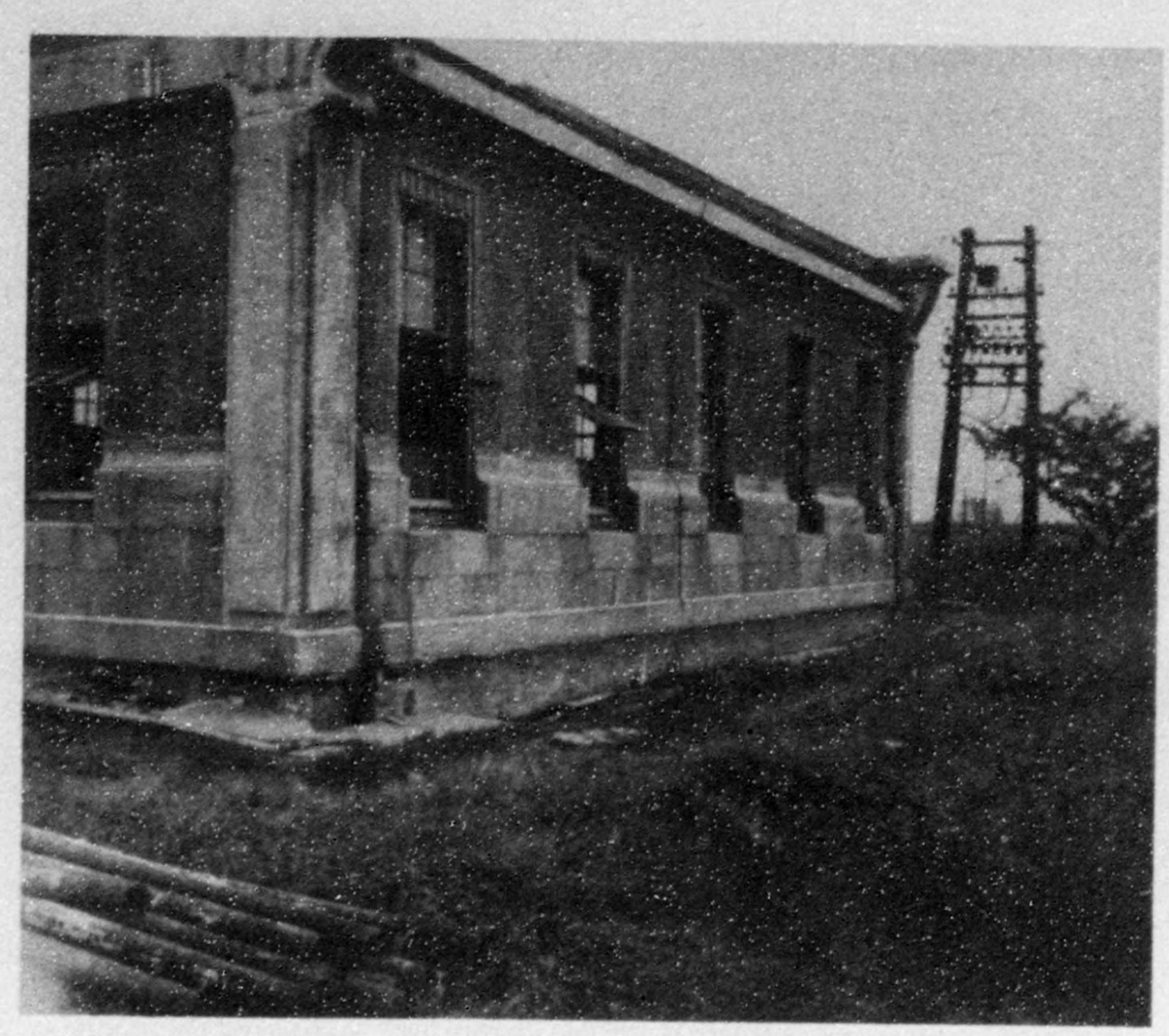

Fig. 15

Photo Showing Ground Subsidence Around
Pumping Station

casing and, on preliminary investigation, showed little damage suffered. The levelings which were later made showed that the center well house and the well casing as a unit subsided with damage being suffered subsurface on the well casing, presumably at the 35 foot mark which is the juncture point of the 6 foot casing section and the 12 inch casing section.

The reinforced concrete pumping station located near the underground reservoir suffered no structural damage. The ground subsided around the outside of the building about a maximum of 14 inches, see Fig. 15. The pumphouse floor and

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pump foundations were cracked and upheaved, shearing off pipe and electrical connections thereto.

The booster pumping station was a reinforced concrete building with steel roof trusses and a cement-asbestos, corrugated sheet roof. The pump foundations were integral with the pump suction well top slab. The four horizontal single-stage, single-suction, centrifugal pumps, direct connected to 65 H.P. electric motors, discharged into an overhead 22 inch cast iron header. The pumps, suction well and building moved as a unit out of phase with the header, which was not rigidly anchored to the building unit, with the result that the header had a residual displacement of about 8 inches. This displacement can be noted in Fig. 16, which shows the header displacement relative to the bracket supports. This displacement caused the fracture of the pump volute casings at the scroll section.

The two reinforced concrete reservoirs atop the mountain were damaged to the extent of a few cracks in the walls and the waterproofing. The two reservoirs were connected by non-reinforced concrete pipe which was badly fractured.

The distribution system consists of 50 miles of cast-iron water pipe ranging in size from 3 to 18 inches. The depth of bury of the mains varies from 3.5 to 6.5 feet. The downtown distribution system was looped and gridironed, with the outlying districts gridironed. 537 fire hydrants were connected

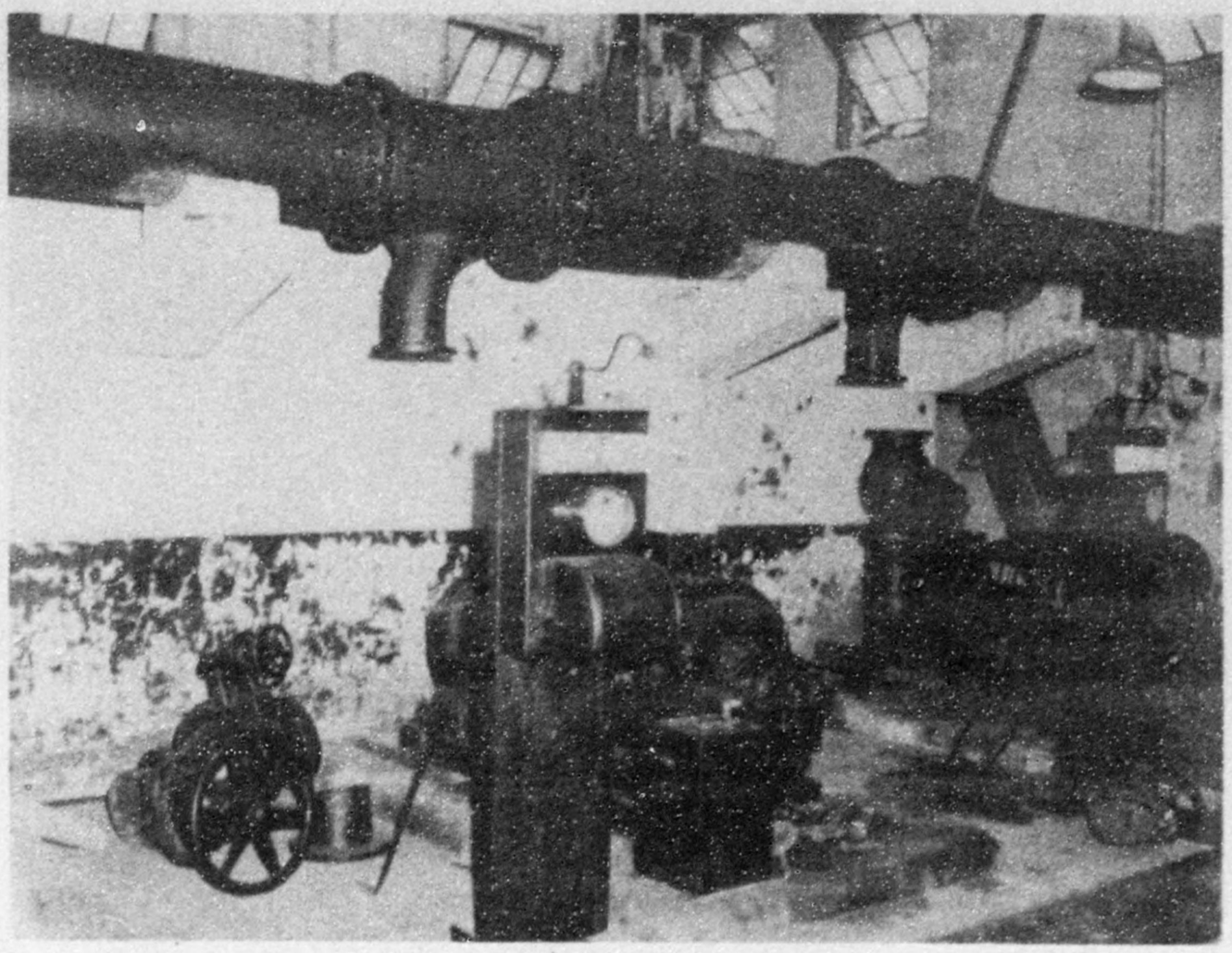

Fig 16

Photo Showing Residual Displacement of
Pump Discharge Header

into the system. The main ground motion in Fukui City was in a north-south direction and the majority of the pipe fractures were on pipe lines running in this direction. It was generally found that the pipe was subjected to shearing at hydrant connections, tee and wye connections, and anchor points. These connections and changes in directions provided a rigidity which induced fracturing. Pipe lines were also found fractured and joints pulled apart at bridge approaches, due to the marginal action of the seismic waves. Flanged joints tended to cause fracturing of the pipe, while bell and spigot joints usually pulled apart. It was found that ground subsidences of from 12

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to 16 inches occurred throughout the area of coverage by this system.

2. Maruoka - The water for this town, close to the suspected epicentral area, comes from two wells 320 feet deep, each cased with 6 inch steel pipe. The water, having a high iron content, is aerated with compressed air, settled in an around-one-turn sedimentation basin, and then filtrated in two pressure filters. From the filters it goes to a clearwell reservoir, thence to elevated ground storage by two 30 H.P. turbine pumps, and by gravity to the distribution system. The distribution system piping, mainly of cast-iron, 3 inch to 10 inch, suffered the same type of damage as the Fukui City system.

The clearwell reservoir was badly cracked and the waterproofing broken. Although on piles, the north portion of the reservoir subsided. The wells, normally with a static water table level of 32 feet, flowed under artesian conditions for three days and the casings subsided about 5 inches. Large quantities of sand were deposited out of the well water during the three days mentioned. The pump and filter piping and foundations were badly strained and fractured.

3. Komatsu - This town of 3,000 pumps its water from the Tedori River through coagulation-sedimentation basins, slow-sand filters, and to a clearwell reservoir. The distribution system consists of 13 miles of pipe of which 5 miles is seam-

less steel pipe. Only slight damage to any part of the system, excepting the distribution piping, was sustained. It is of note that the steel pipe and fittings suffered far less damage than the cast-iron pipe and fittings.

4. Conclusion - Several towns and cities in the area used concrete pipe in part of their distribution systems. The failure of concrete pipe was general throughout the disaster area. Building units, which are not rigidly connected structurally, should be connected by flexible jointed pipe. Steel pipe, although not as satisfactory underground as cast-iron pipe, resists to a greater degree the shearing action of seismic waves. Pipe lines should be buried at as shallow a depth as possible. Flexible joints and connections should be made wherever possible. Perhaps swing-joints and in-line expansion joints could be advantageously used in underground water lines. Cross connections between neighboring towns should be provided where possible.

B. ELECTRICAL SUPPLY SYSTEMS

1. General - The electricity for power and light in the Fukui area is practically all generated in hydroelectric plants located in the mountains, and transmitted overland to consumer points. There are no large power generating stations in this area utilizing steam as the prime mover. A main 154,000 volt transmission line crosses over the Fukui plains, from north to south, and carries current from Toyama to Kyoto, Osaka and Kobe. There are also lines which crisscross th

2. Matsuoka Substat

stations is located near
30,000 KVA transformer ca
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not topple over, but did
Fig. 17 shows a transform
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The oil-switches wer
Fig. 20 show views of oil
Neither foundations nor f
enough.

3. Transmission Lin

Kobe transmission line is

and Kobe. There are also several 77,000 volt transmission lines which crisscross the Fukui area.

2. Matsuoka Substation - One of the two largest substations is located near the town of Matsuoka. It has a 30,000 KVA transformer capacity and receives current from the main Toyama-Kobe line and three hydroelectric stations. The transformers, four 10,000 KVA each, using one as standby, did not topple over, but did receive damage to leads and anchors. Fig. 17 shows a transformer foundation which has subsided and which has had an anchor rod pulled out. Fig. 18 shows how an anchoring clip has been sheared off the structural steel transformer base. It will be noted that this transformer base does not provide the same rigidity and support transverse to the foundation as it does longitudinally. The foundation should be made wider and the structural steel base extended out in four directions (not just two) and securely anchored, keeping anchor rods sufficiently far away from the face of the foundations to prevent pulling out.

The oil-switches were considerably damaged. Fig. 19 and Fig. 20 show views of oil-switches that were toppled over. Neither foundations nor foundation anchor bolts were large enough.

3. Transmission Lines - The main 154,000 volt Toyama-Kobe transmission line is supported across the disaster, and

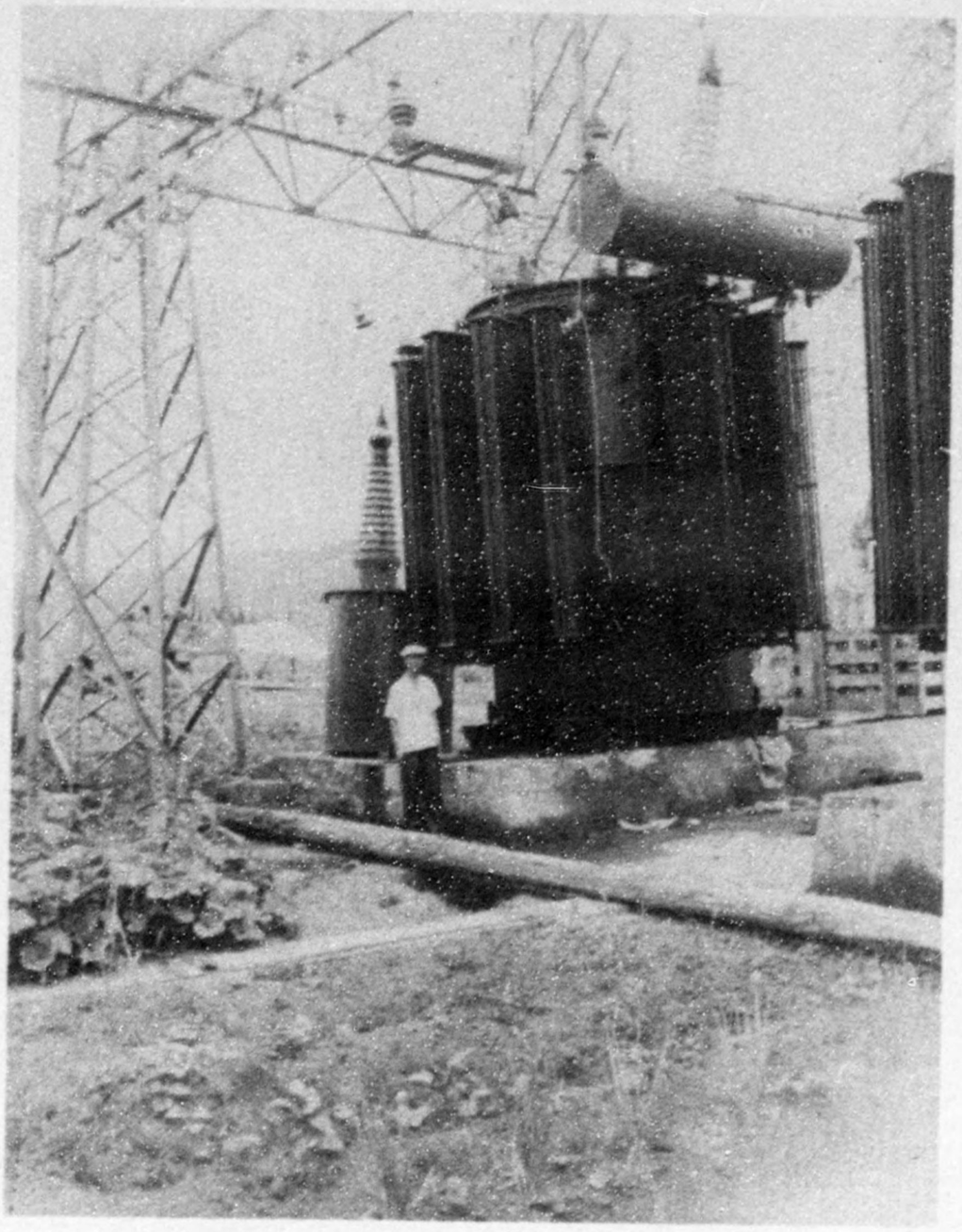

Fig. 17

Transformer Foundation - Matsuoka Substation

also the epicentral, area by 298 steel towers. These towers are 115 feet high and support wire spans ranging from 825 feet to 1150 feet. The tower leg foundations extend 16 feet below ground and 6.5 feet above ground and are approximately 4 feet in diameter with an integral apron 16 inches thick and 13 feet in diameter. 32 of these towers received minor damage to the foundation aprons and some small amounts of subsidence.

The secondary-primary lines of 77,000 volts were supported

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Fig. 18

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by towers 80 feet high with wire spans of approximately 850 feet. Foundation damage was sustained by 6 of these towers. Porcelain insulators were damaged on both types of towers.

Secondary transmission lines were supported, in the main, by wood poles. 245 of these poles were left in an inclined position and 482 of them were broken off. A collar-type foundation at the ground line, to be used in soft ground and designed to give large resistance to lateral movements, would perhaps have prevented inclination of a large percentage of the inclined poles.

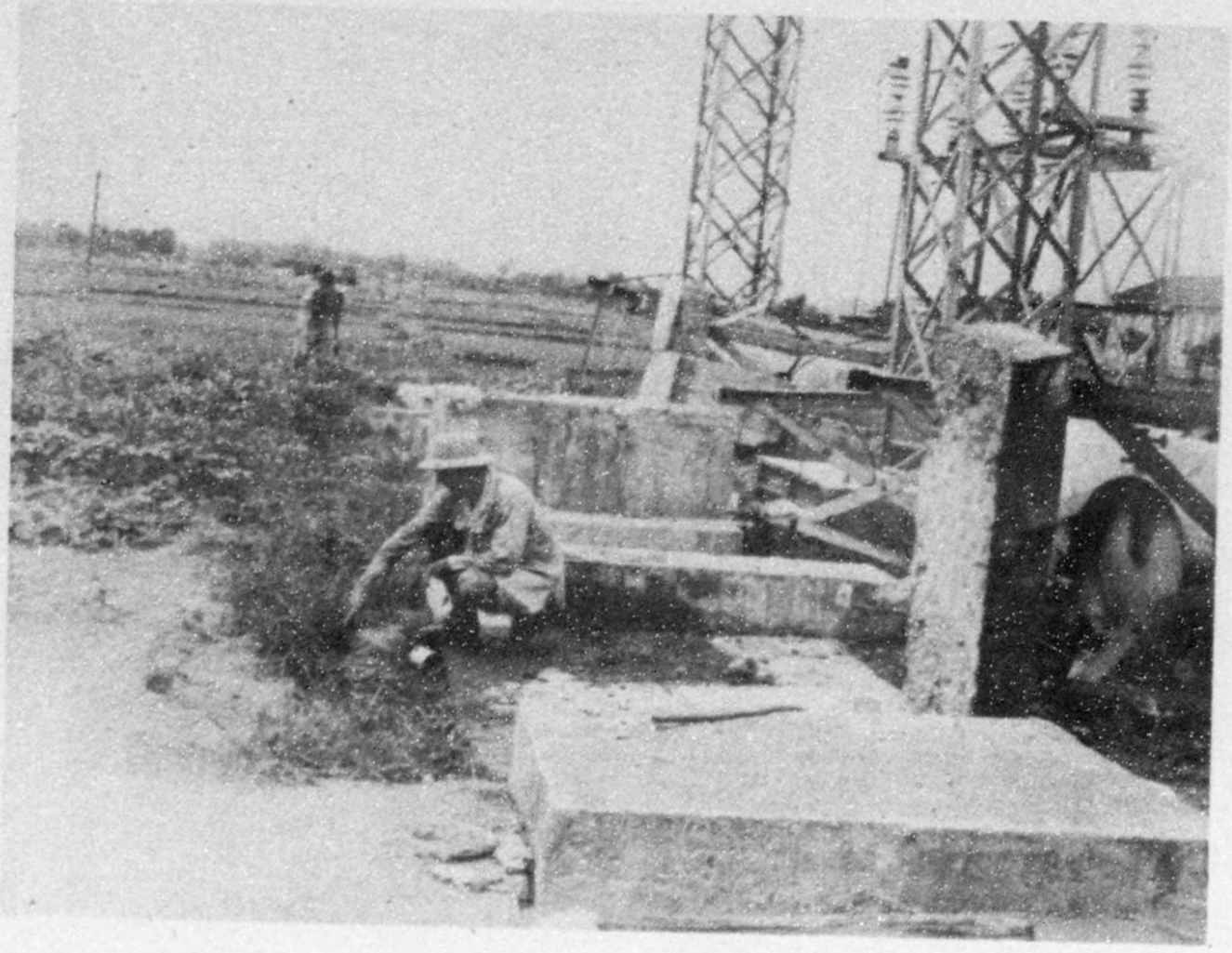
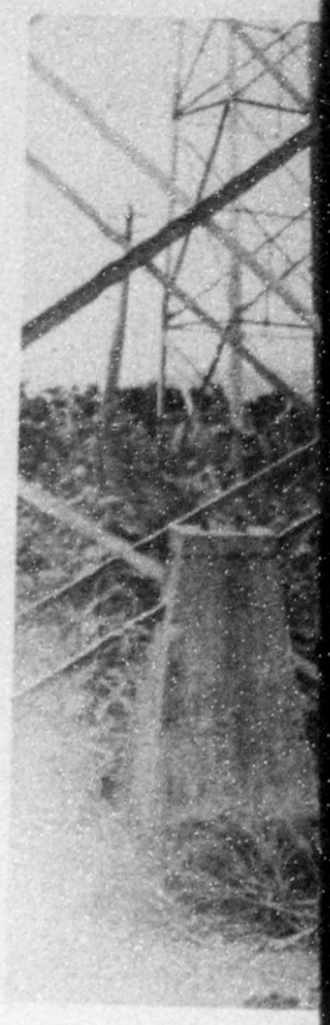


Fig. 19

Oil Switches - Matsuoka Substation



Oil

C. GAS GENERATING PLANT AND DISTRIBUTION SYSTEM

The Fukui City gas system consists of a small (25 tons of coal per day) generation plant located in the eastern section of the city and a distribution system which services only the downtown part of the city. The generation station consisted, in the main, of brick buildings which will be described in Chapter IV, Section D, BRICK BUILDINGS, and two small gas-holders which are described in Chapter IV, Section C, STEEL

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D. COMMUNICATION

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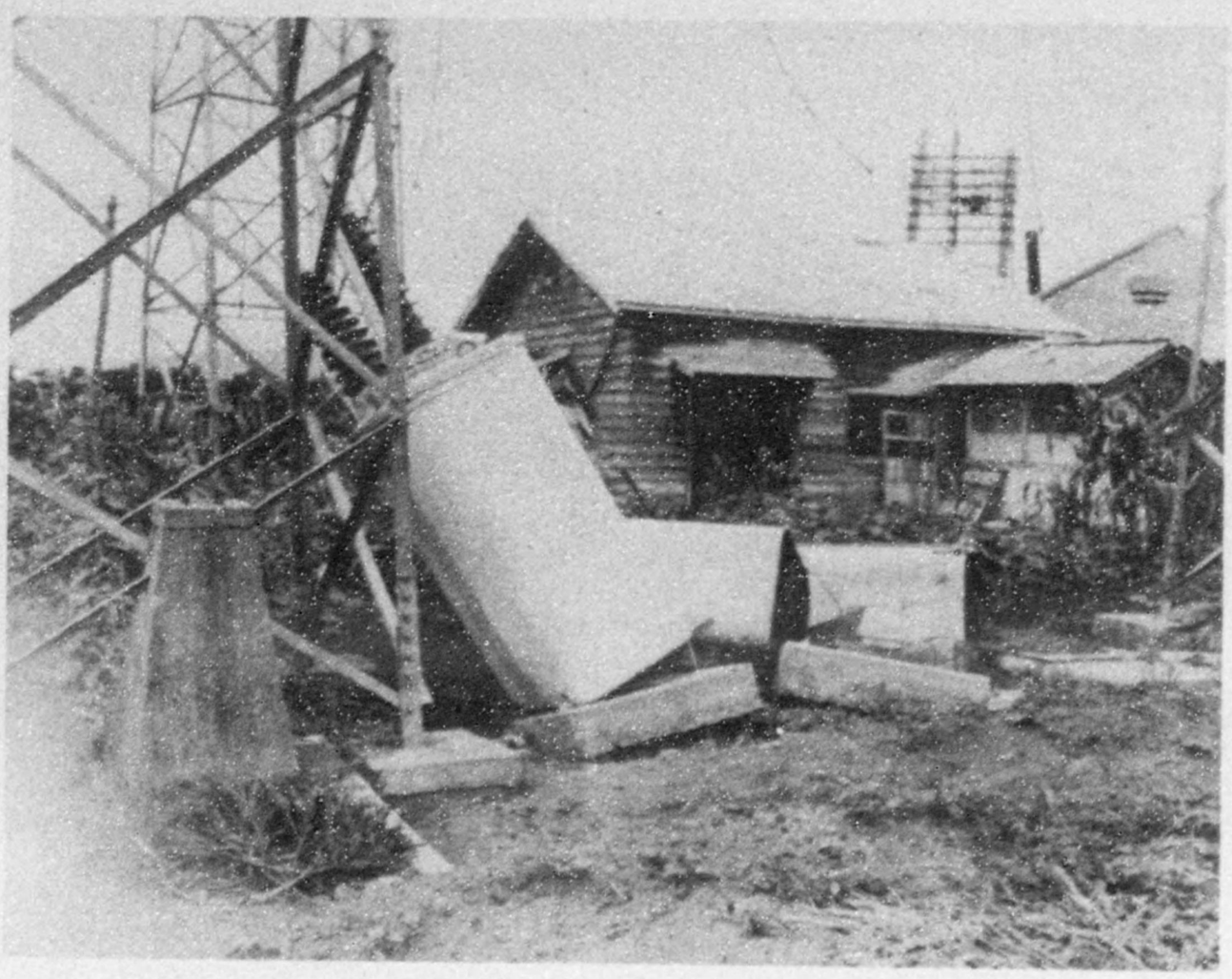

Fig. 20

Oil Switches - Matsuoka Substation

CONSTRUCTION. The damage to the underground cast-iron distribution system was great. The types of damage closely paralleled that, as described in this chapter, sustained by the cast-iron water supply piping.

D. COMMUNICATION FACILITIES

The telephone and telegraph lines in the disaster area suffered heavy damage to the supporting poles and transmission wires. Wooden poles suffered inclination and fracturing, rupturing, in most cases, the supported lines. The damage, in

the areas of the cities and towns that were later burned over, was almost total. Field lines to the outside of the devastated area were erected by the U.S. Army Military Government Team. Railroad telephone and telegraph lines, to the south of

later burned over,

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litary Government

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Fukui City, were repaired quickly but it required almost two weeks to establish partial repair to lines which would allow the resumption of communications with the towns in the northern part of the disaster area.

NAKATSUNO BRIDGE

CHAPTER III

TRANSPORTATION FACILITIES

A. RAILROADS AND ELECTRIC INTERURBAN LINES

1. GENERAL - The Fukui plains area is served by a government railroad line and two private electric interurban lines.

The government line, called the Hokuriku Main Line, runs north and south through Fukui City. The Mikuni Branch Line, which is an adjunct of this line, branches off the main line at Kanazu, about 11 miles north of Fukui City, and runs west to the harbor area of the town of Mikuni.

The Fukui Electric Railroad Line starts in Fukui City and runs southward through the town of Sabae and reaches to the city of Takefu. The Keifuku Electric Railroad Company operates mainly in the northeastern part of Fukui Prefecture. It has the Echizen Line which runs eastward from Fukui City and the Mikuni-Awara Line which runs north from Fukui City to the town of Awara where it turns west and runs parallel to the government line to Mikuni harbor. The Eiheiji Line starts from the town of Kanazu and runs southeast through Maruoka and, after crossing the Echizen Line at Eiheijiguchi, terminates at the town of Eiheiji. See Fig. 36 for a map of railroads in the disaster area.

2. GOVERNMENT RAILROADS

a. General - Damages to the Hokuriku Main Line

occurred between the towns of Sabae and Iburibashi, a distance of about 32 miles. The most severe damage was suffered between the towns of Odoro and Ushinoya, a town north a distance of about 18 miles. In this distance the railroad embankments suffered subsidence, upheaval, and fissuring. A great amount of rail was bent and twisted and all the bridges suffered damages, ranging from subsidence of the approaches to total collapse. Starting from the town of Odoro to the south, the damages will be described progressively to the north.

b. Odoro Station - The structures of this station were completely collapsed. The railroad employees' housing area was about 50 percent demolished.

c. Fukui City Railroad Yard

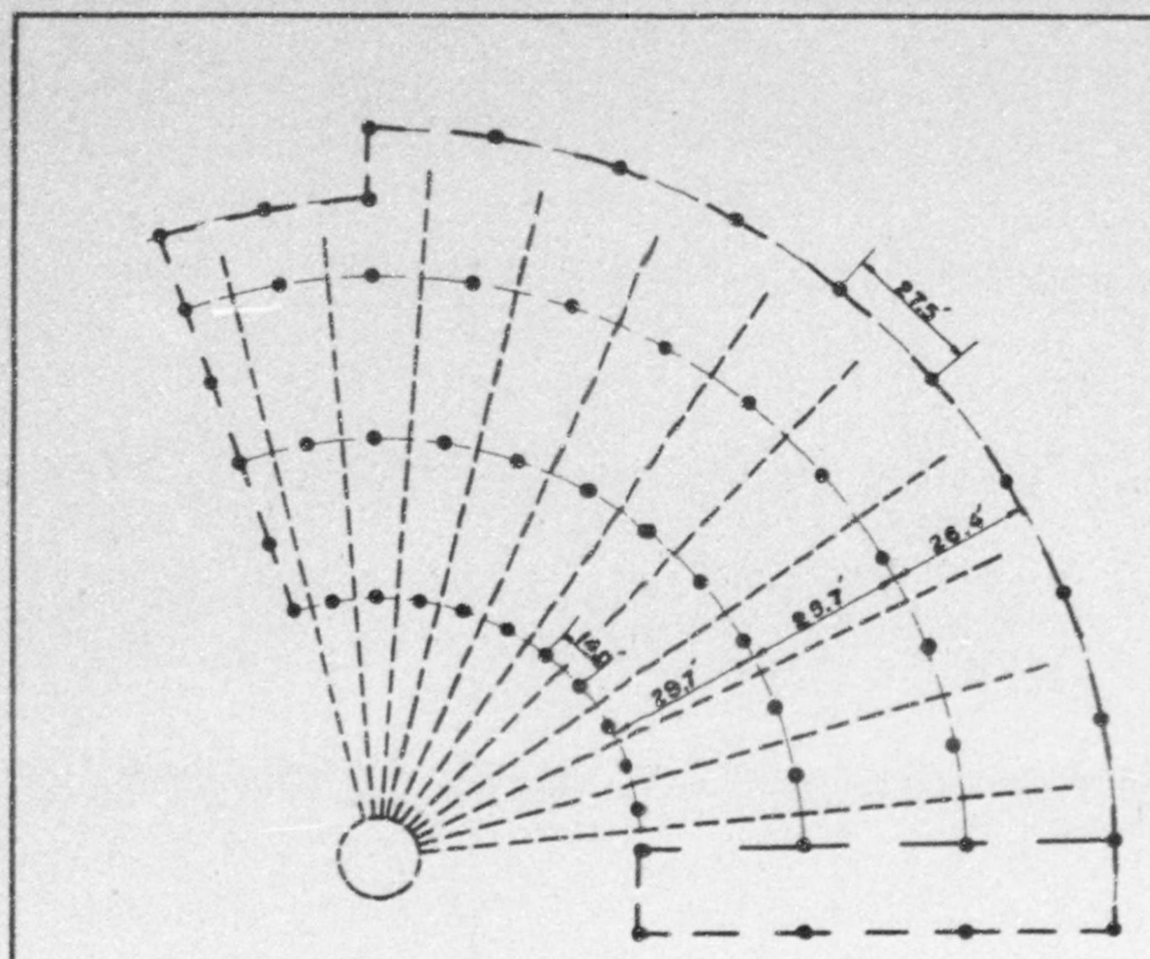
(1) General - Damage to the track and switching gear was large. All of the important structures in the yard were rendered useless by the earthquake. An all-steel, elevated coal bunker collapsed, a reinforced concrete chimney was badly cracked and inclined, 10 out of 17 locomotives in the yard or roundhouse were overturned, and the roundhouse completely collapsed. An oblique aerial view of the roundhouse and coaling area of the yard is shown by Fig. 21.

(2) Roundhouse - The roundhouse was a wood-framed structure with corrugated cement-asbestos sheet on the sides and the roof. The plan of this structure and a section showing

Fig. 21

Aerial View of Fukui City Railroad Roundhouse

the wood trusses of the radial framing are shown by Fig. 22. Beams were used in a circular direction. All splices in framing timbers were bolted. This building was built in 1943 and, being restricted by the wartime building code, the sections of structural members are, in general, undersized. The inspection party found evidence which showed that many of the connections between the circular tie beams and the columns were weakly made and defective. The foundations of this building are supported



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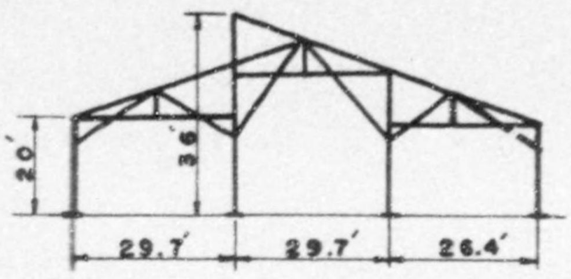

SECTION

FUKUI ROUND HOUSE

Fig. 22

Fukui City - Railroad Roundhouse

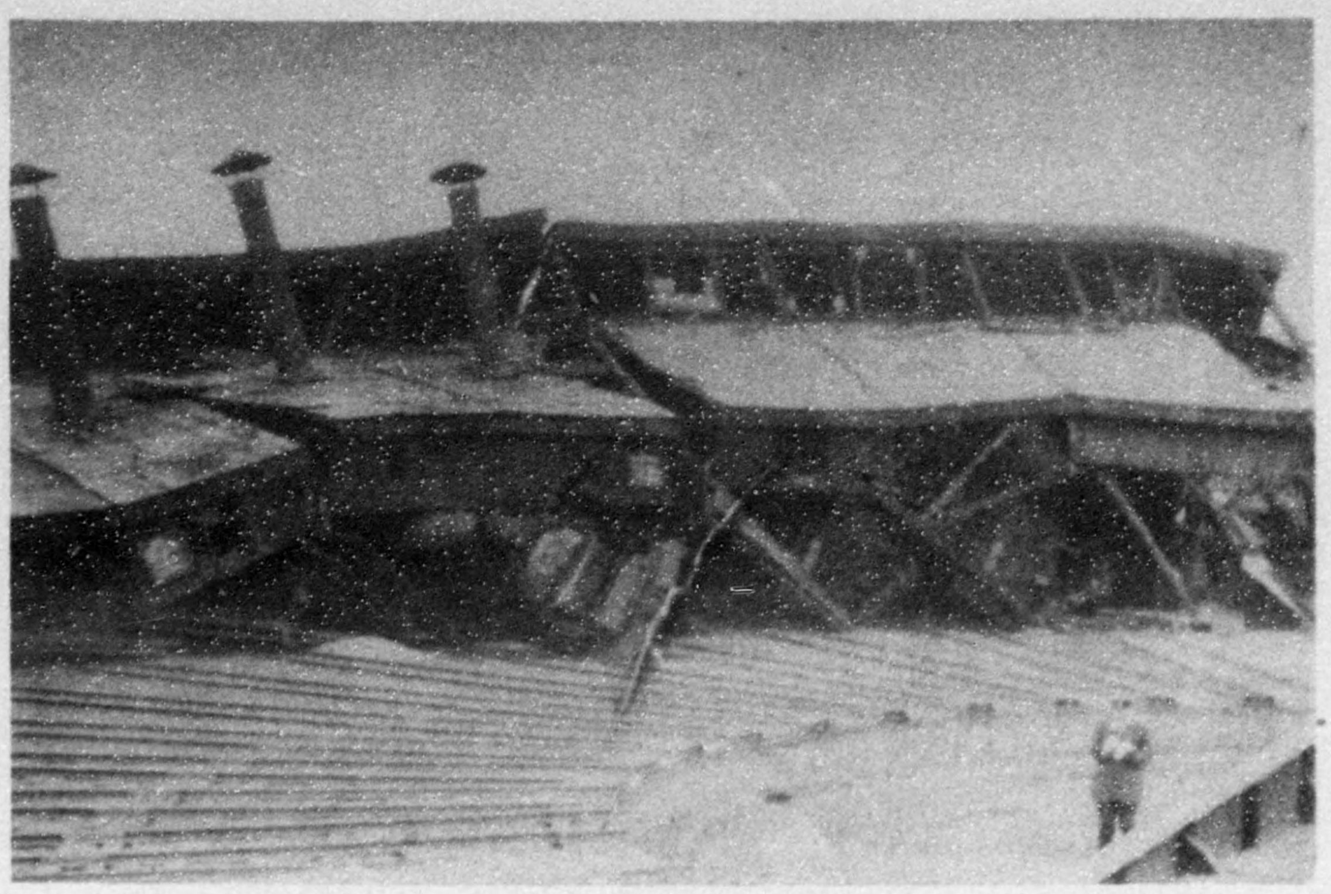

Fig. 23

View of Locomotives Under Collapsed Roundhouse

on pine piles.

The general shape of the building, being semi-circular in form, should have given it an added rigidity in resisting earthquakes. However, being inherently structurally weak, it did collapse, the general movement of the building being to the eastward. The cause of the failure can be traced to the fact that despite the radial framing being relatively strong, the framing in the circular direction did not provide the strength and rigidity necessary.

There were 7 locomotives in this structure at the time. One was derailed and 6 were overturned. Fig. 23 shows a view of the roundhouse with the overturned locomotives visible under the wreckage. A steel framed building, in view of the experi-

ndhouse

Fig. 24

Lateral Flow of Ground - Southside of
Roundhouse Area, in Fukui City

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ence of structures in this earthquake, would have been ideal for this type of structure.

(3) Ground Subsidence and Fissures - The railroad yard was constructed by reclaiming rice paddy land. As a consequence, the ground was soft and unconsolidated. Under the track that had been consistently used the ground seems to have consolidated enough to prevent appreciable subsidence. The marginal ground showed the large slumping, consolidation, and lateral flow that is visible in the aerial photograph of the yard area, Fig. 21. This same lateral flow is shown by Fig. 24 and Fig. 25.

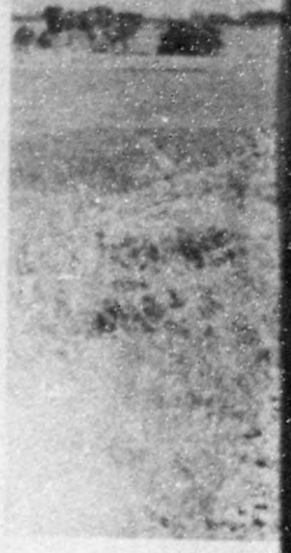
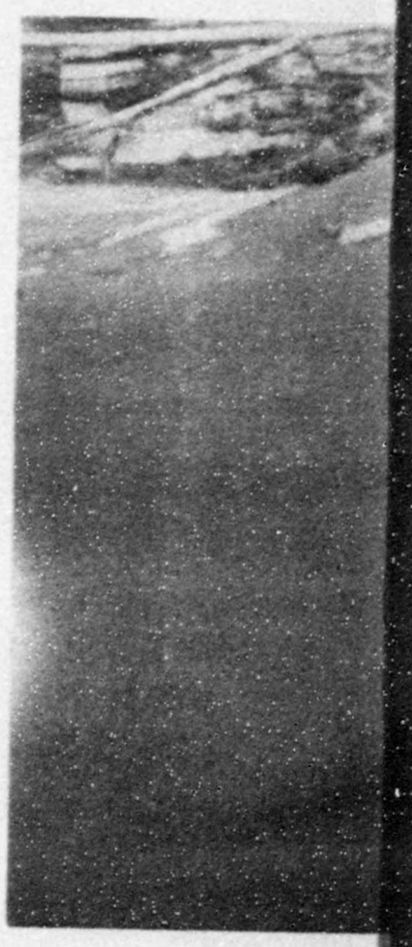


Fig. 25

Overturning of Locomotives Due to Unequal
Compaction of Roadbed and Lateral Flow



(4) Coal Bunker - The all-steel coal bunker is described in Chapter IV, Section C, STEEL CONSTRUCTION.

(5) Reinforced Concrete Chimney - This chimney is described in Chapter V, CHIMNEYS AND TANKS.

d. Fukui Station - The station structure itself received slight damage, although it was apparent by residual ground fissures in the area that the ground movement was severe. Some parts of the main platform subsided as much as two feet with other parts upheaving. Some sections of track were up-

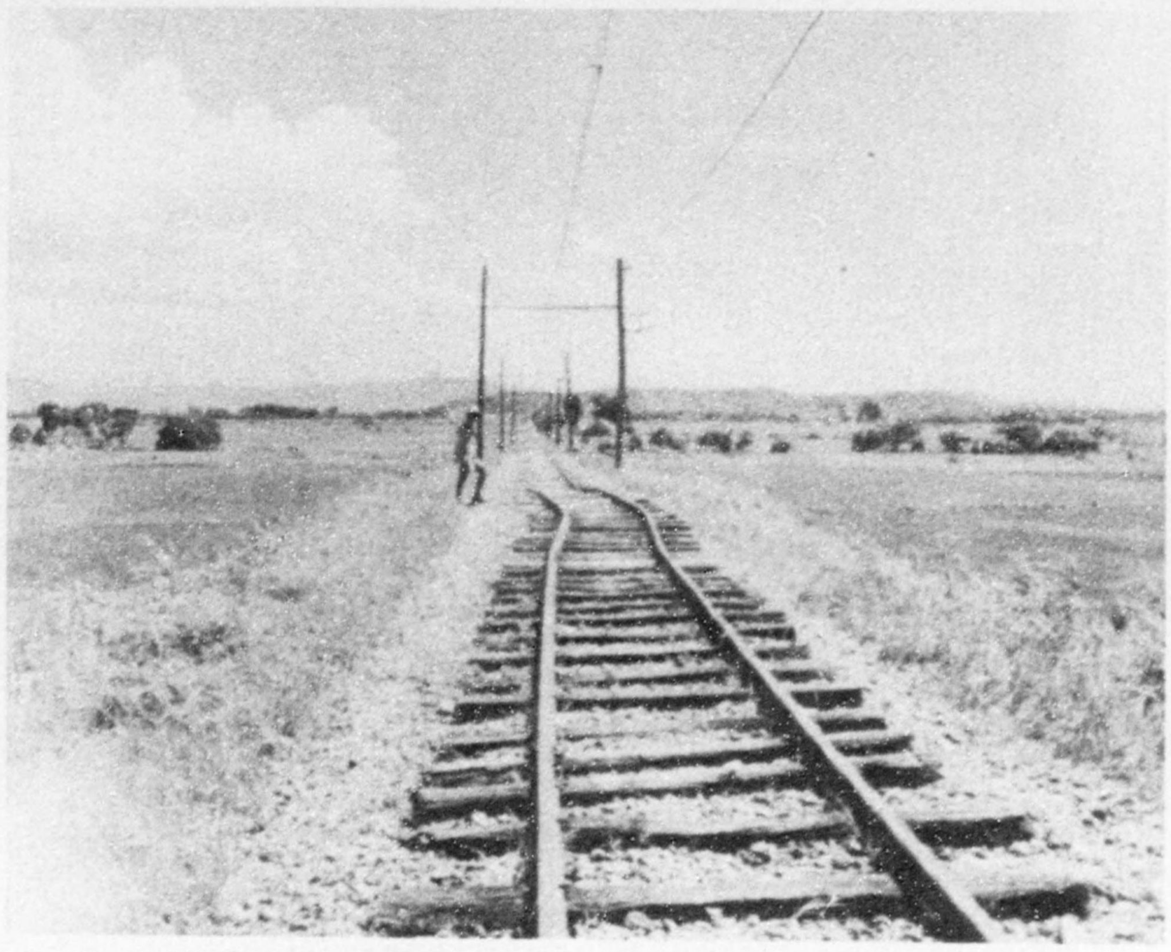


Fig. 25 a

Track Displacement

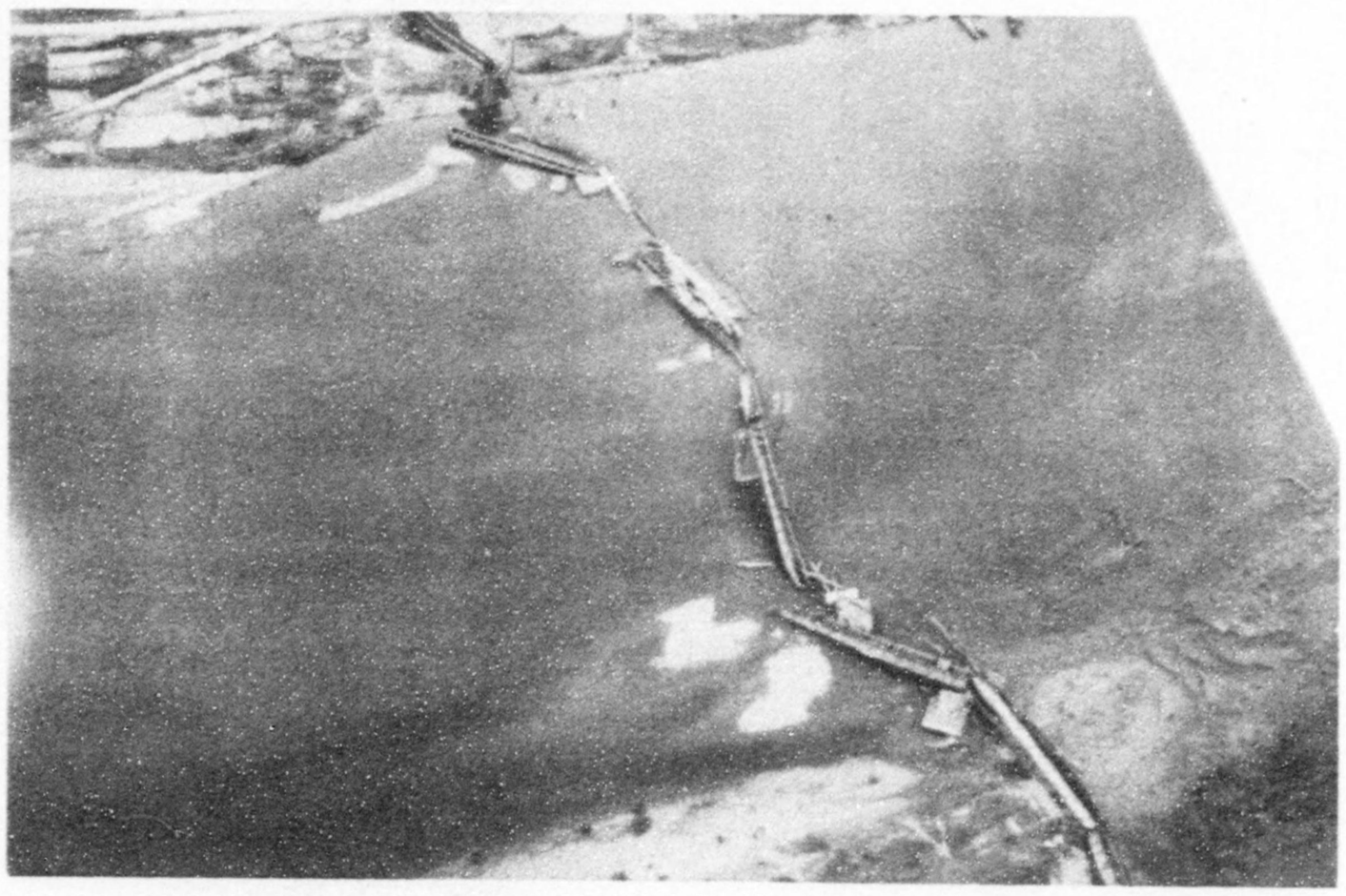


Fig. 25 b

Damage on the Kuzuryu River

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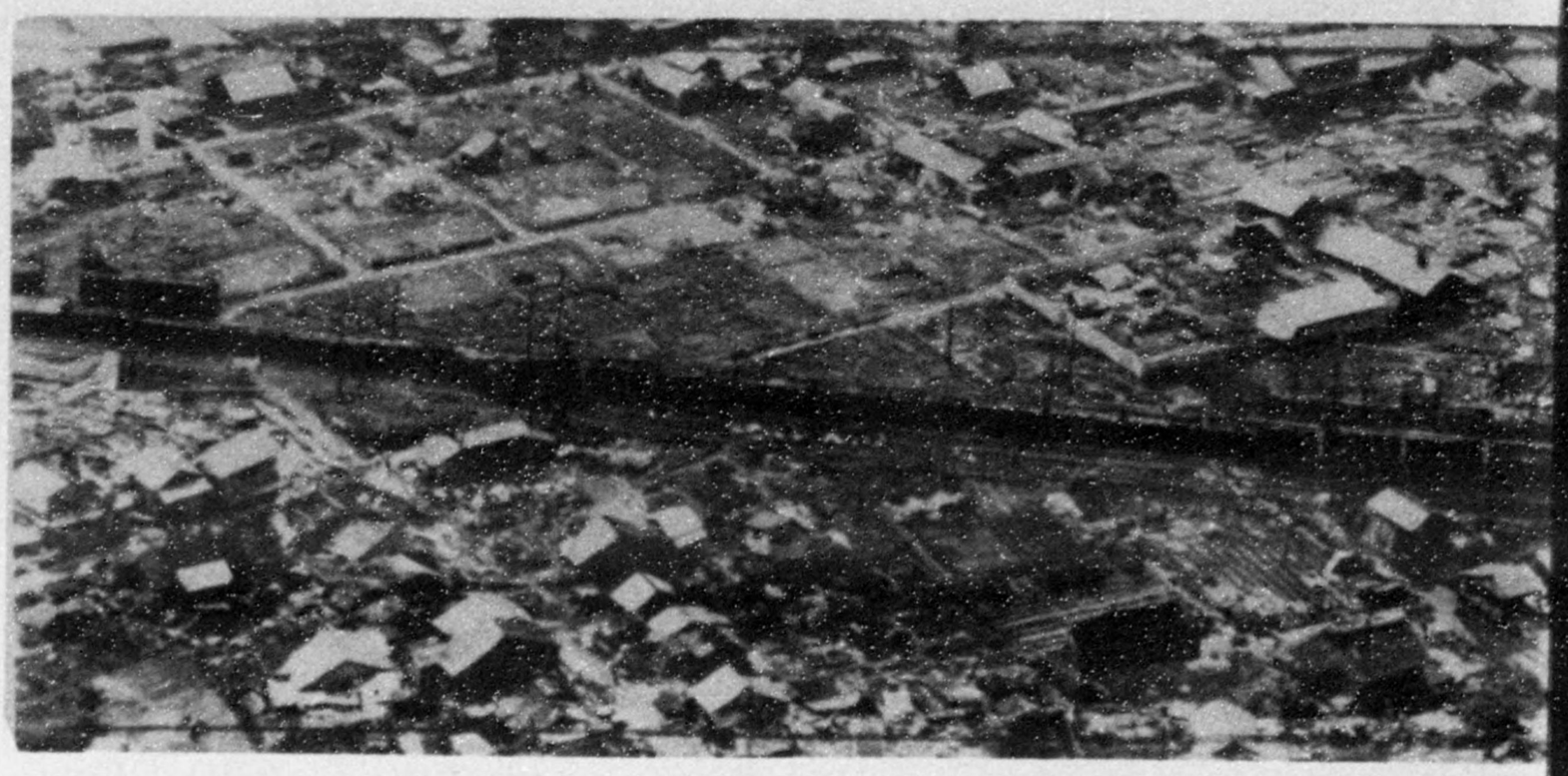

Fig. 26

Aerial View of Derailed, Overtu

heaved almost 3 feet, becoming almost level with the top of the adjacent platforms. The concrete slabs covering the platforms and station floor were fractured in many places, displaced, and tilted.

e. North Fukui Station - Between the Fukui City station and North Fukui, a freight train composed of 45 cars was moving north. Of the 45 cars, 43 were derailed and overturned. Fig. 26, which is a low-level oblique aerial photograph, shows this train in the overturned condition.

In the station proper a passenger train was standing headed toward Fukui City. The aerial photograph, Fig. 27, shows how the engine, tender, and the first 4 cars were derailed and overturned. The undamaged steel electrical transmission tower in the foreground is an example of the general undamaged condition

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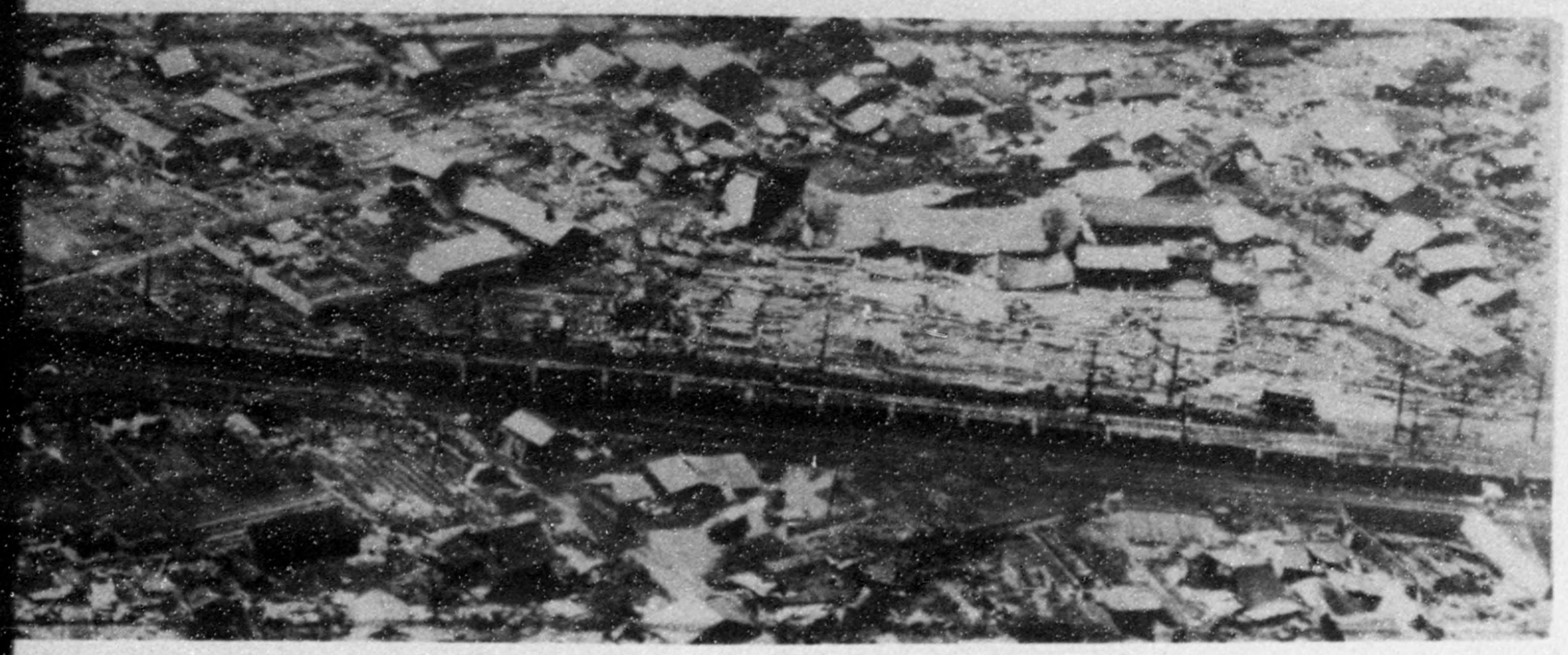

Fig. 26

Aerial View of Derailed, Overturned Train

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f. North Fukui City - Morita - The railroad line crossed the Kuzuryu River between these two stations by means of the Kuzuryu bridge, which was totally destroyed by the earthquake, see this Chapter, RAILROAD BRIDGES.

g. Morita-Kanazu-Iburibashi - Between the town of Morita and the town of Kanazu, the embankments suffered heavy slumping, subsidence, and upheaval. The location of the railway here crosses the very center of the meizo-seismic area. Fig. 28 gives a view of a stretch of embankment just south of the town of Kanazu. It will be noted that the residual displacement of the embankment left the track very twisted and sinuous. The extreme subsidence of the immediate approaches to a small bridge will be noted in Fig. 29. A close-up view of a

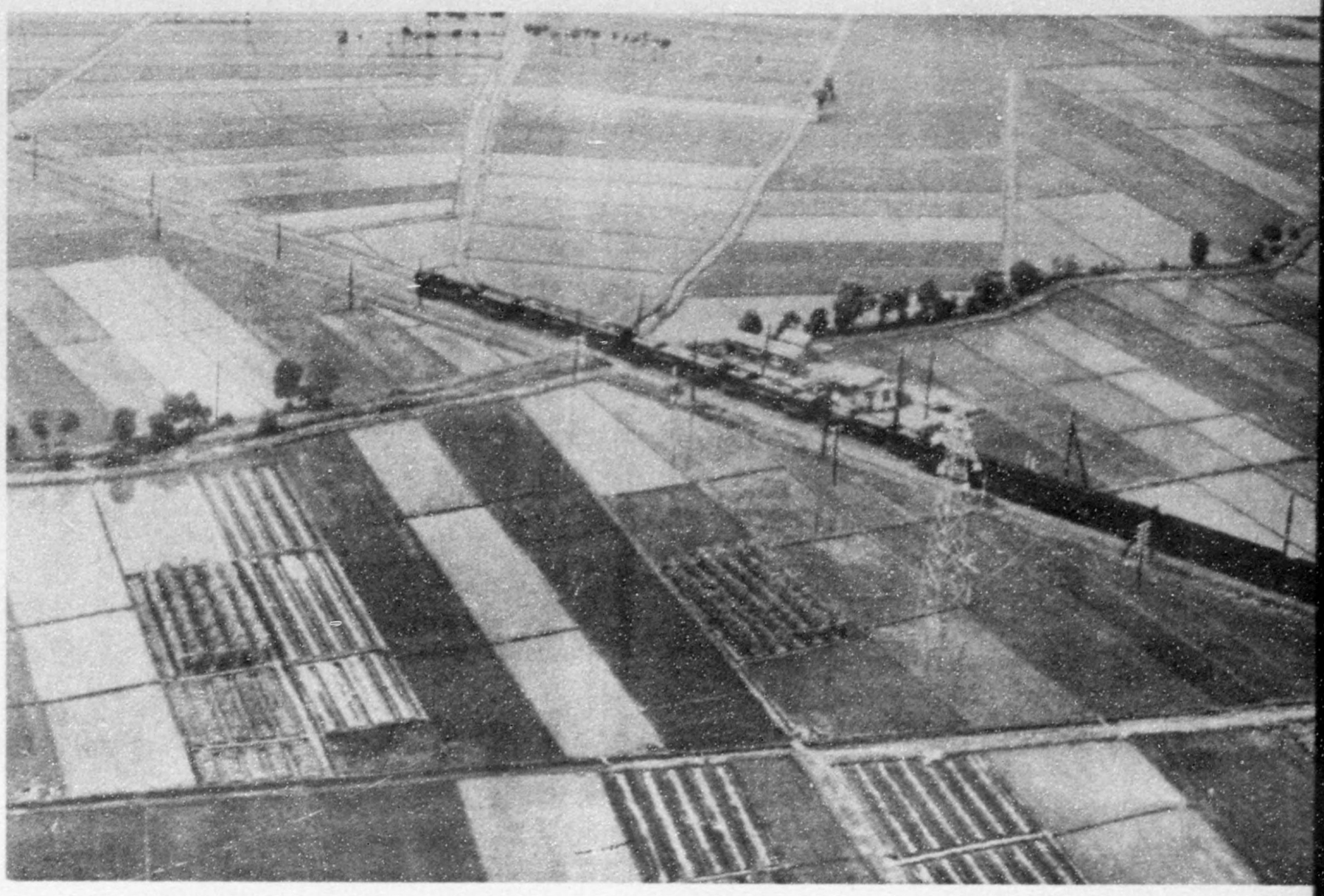

Fig. 27

Aerial View of Overturned Railroad Passenger C

large fissure in a section of roadbed, between the rails, is shown by Fig. 30.

North of the town of Kanazu, at Kumasaka, the terminal effect of seismic waves was noted in the damage to the portals of a brick-lined tunnel. The portal arches were cracked and partially fractured, see Fig. 31. Somewhat north of this point, near Hosorogi, about 2000 feet of high embankment was very severely damaged. Extreme slumping and subsidence, which in

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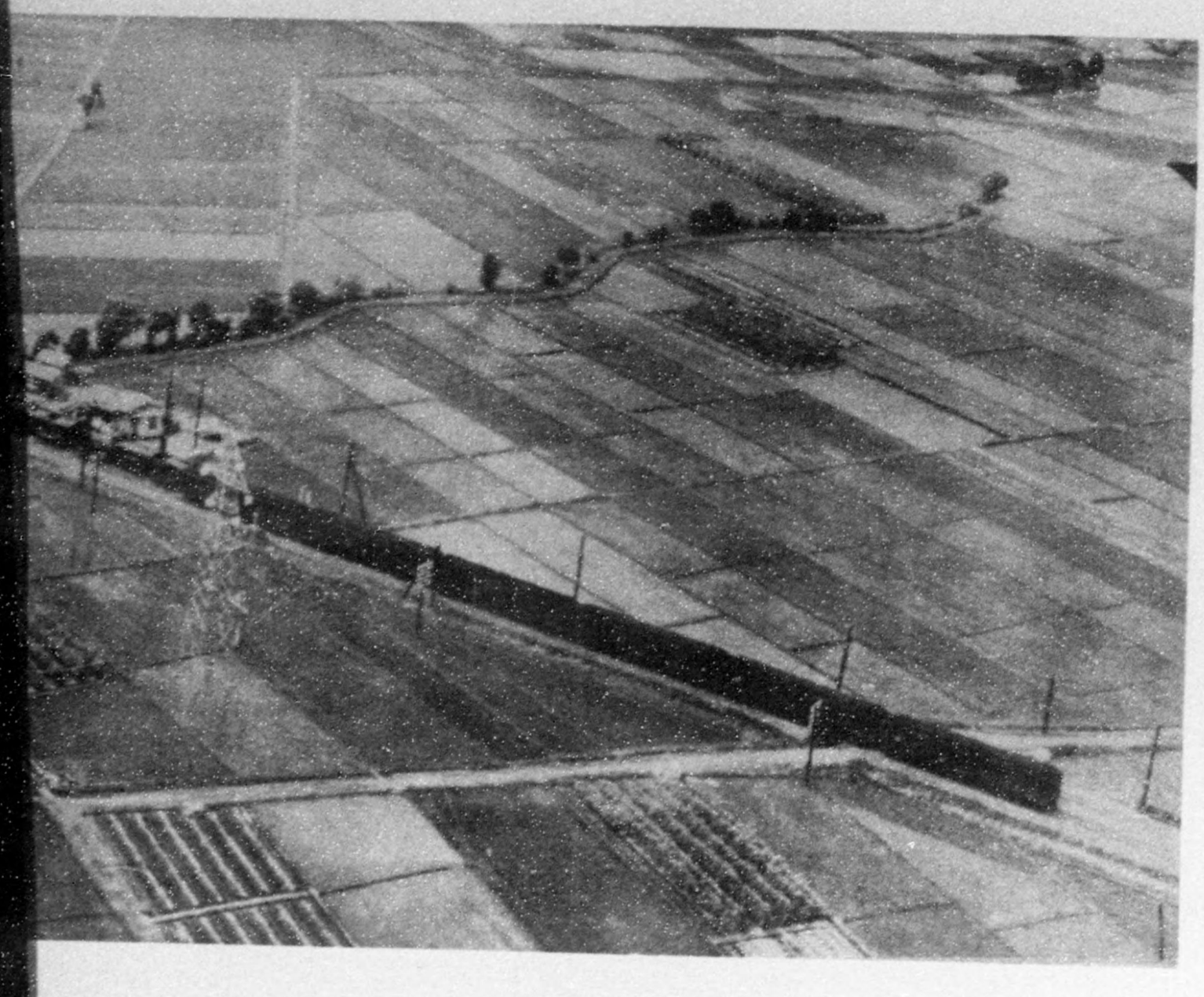

Fig. 27

Overturned Railroad Passenger Cars

places was as much as 13 feet, occurred. From this point to the northwards the damage diminished.

h. Mikuni Branch Line - Along this branch line the embankment was extensively damaged. Fig. 32 shows a typical stretch of this line's track and roadbed condition. About 41,000 feet of the line was in such a condition. In some places the movement of the embankment was such as to leave the rails and ties in an upside-down state, as shown in Fig. 33.

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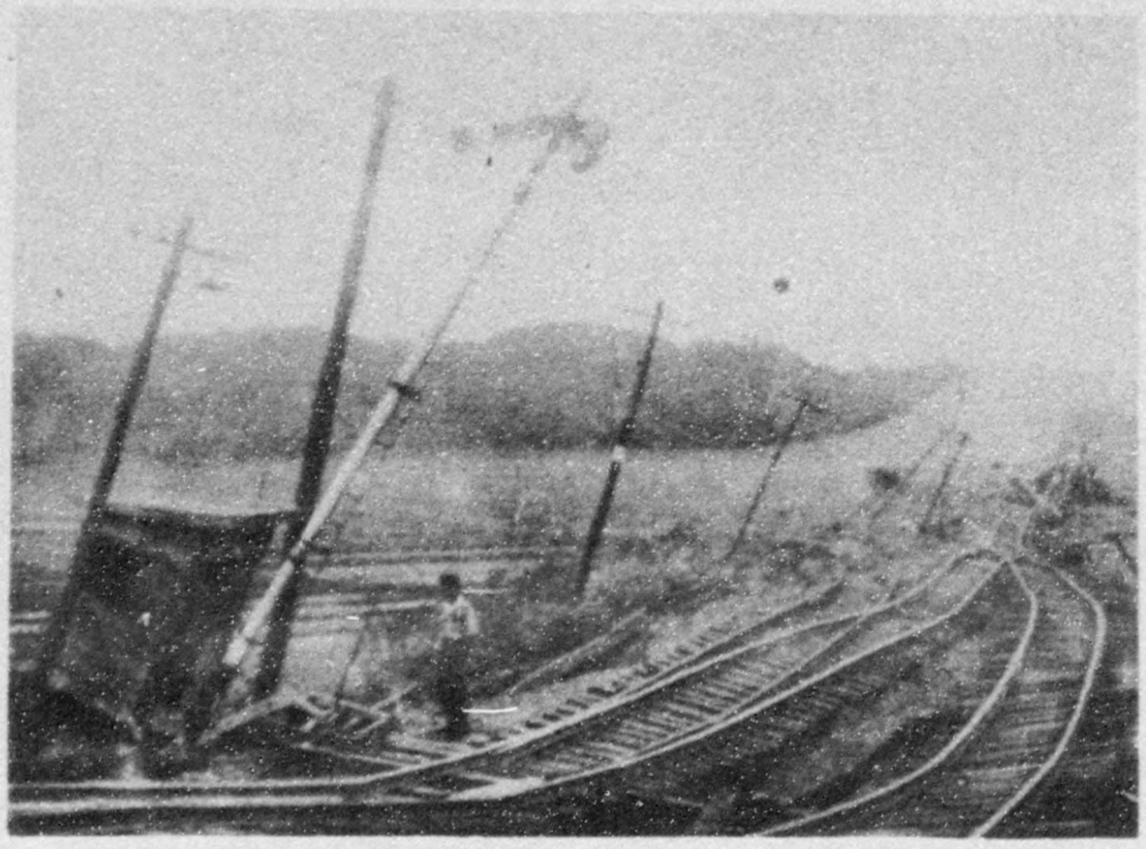

Fig. 28

Aerial View of Railroad Embankment - Kanazu

i. Summary of Damages - The government railroad line suffered considerably as described from roadbed and embankment displacement. A total of 24 bridges was destroyed. 27 retaining walls failed, allowing the walls of cuts and embankments to slide.

The damage to buildings was very severe also. A total of 170 buildings, with a combined floor area of 191,070 square feet, was completely collapsed. 440 other buildings, with a floor area of 268,180 square feet, were partially (about 50 percent) collapsed.

A total of 12 locomotives and tenders were overturned or derailed, with one being damaged beyond repair. A total of 52 freight and 4 passenger cars was overturned and damaged.

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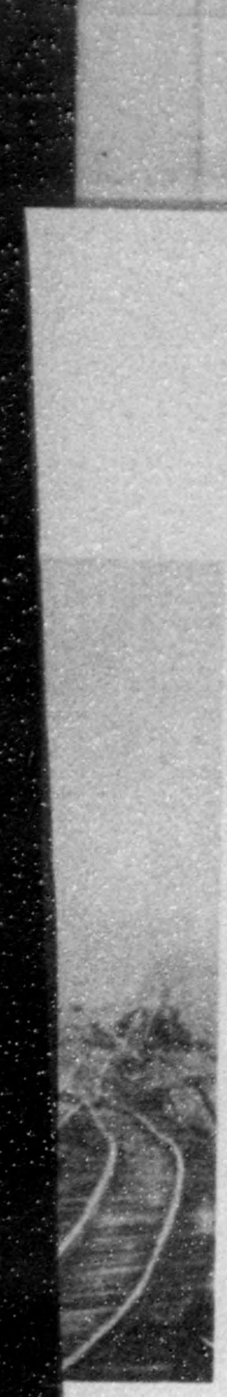

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Fig. 29

Subsidence of Bridge Approaches

3. ELECTRIC INTERURBAN LINES

a. Fukui Electric Railroad Line - This line running south of Fukui City suffered only slight damage, that being the collapse of four station buildings.

b. Keifuku Electric Railroad Co. - This line which had track located all over the Fukui plains area suffered heavy damage. One main bridge over the Kuzuryu River suffered partial collapse and is described in this Chapter, Section C-2, RAILROAD BRIDGES. 19 other bridges of small size were seriously damaged. It had 27 station buildings which were totally col-

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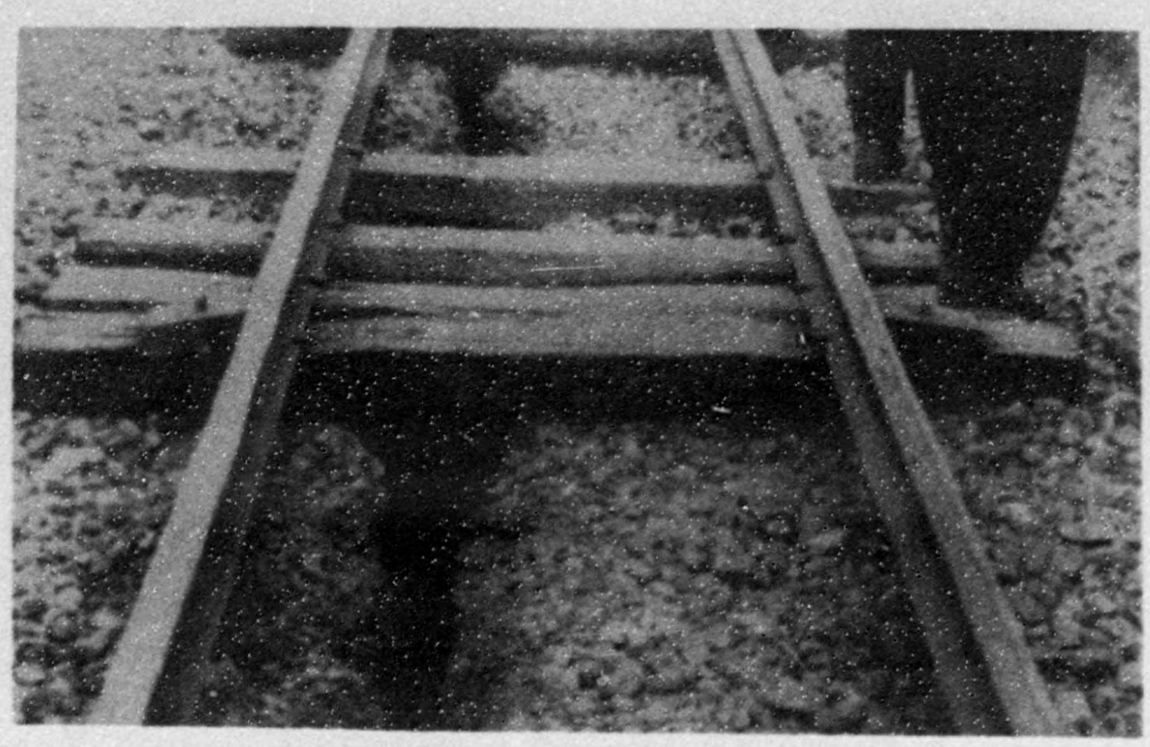
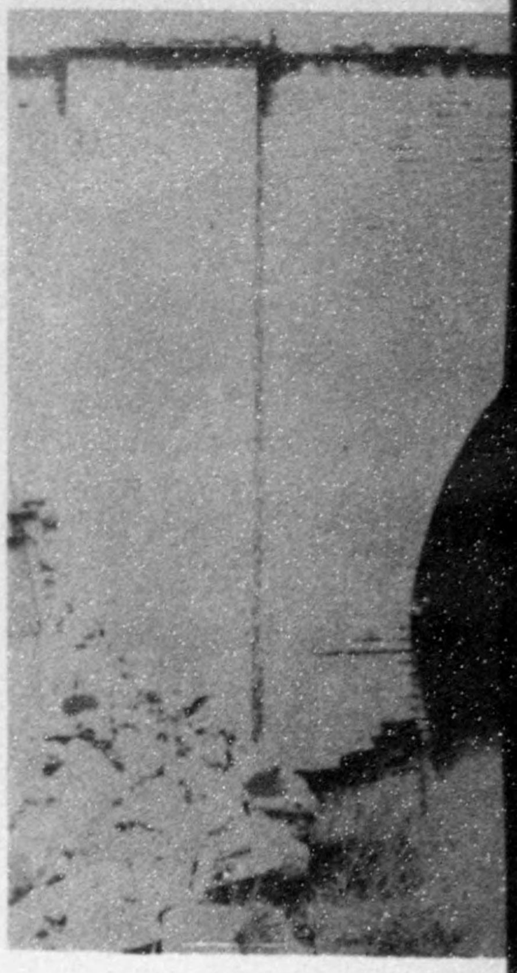


Fig. 30

Closeup of a Railroad Embankment Fissure



lapsed and 16 that were partially (50 percent) collapsed. Fig. 34 shows an interurban car which was crushed by the collapse of of a station platform canopy. Fig. 35 shows two overturned interurban passenger and freight cars, some tank cars, and a damaged car barn which is located in the northeastern part of Fukui City.

4. CONCLUSIONS AND RECOMMENDATIONS - Considering a railroad as it actually is, a very vital communications and transportation facility, the most important items of the railroad to to be maintained are, first, its roadbed and bridges, second, its rolling stock, and third, its buildings and communications facilities. Extensive damage to all of these items was suffered in this earthquake. The most critical, insofar as the ability of the system to supply badly needed relief supplies, was, how-

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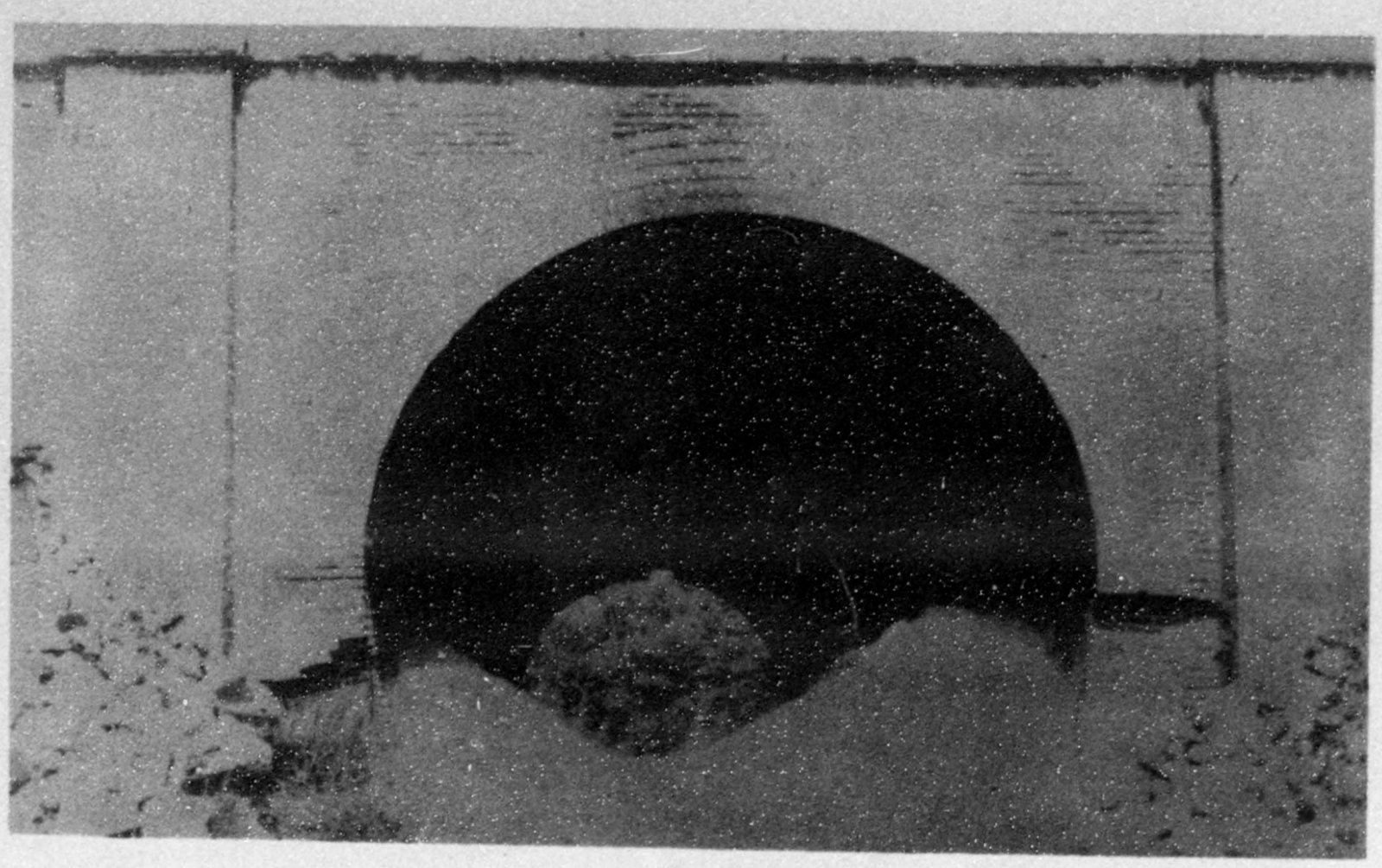

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Fig. 31

Cracked Tunnel Portals and Tunnel Cave-In
Near Town of Kumasaka

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ever, the damage to bridges and roadbed embankments. The damage to bridges is considered later in this Chapter. The embankment damage consisted mainly of slumping of the embankment itself and sometimes lateral flow of the embankment supporting ground.

The slumping of the embankment appeared to be caused mainly from the changing of the embankment materials' normal angle of repose by the action of the seismic waves. Proper slope ratios should be provided, bearing in mind that for most soils the action of seismic waves tends to change the normal angle of repose by 5 degrees for each 0.1 component of the acceleration of gravity. Proper base soil stabilization, compaction, and

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Fig. 32

Track and Road Bed Near Town of Kanazu

selection of materials with as high a cohesive strength as possible are also factors to be closely watched, particularly when the embankments are of considerable height.

B. ROADS AND HIGHWAYS

1. GENERAL - The roads that criss-cross the Fukui plains are of all types; dirt and gravel surfaced roads, water bound macadam roads, asphalt surfaced roads, and concrete highways.

A map of the roads, highways, and bridges is shown by Fig. 36. Through this plain runs a national highway, known to the Japanese as the Hokuriku-do. This highway runs parallel to the

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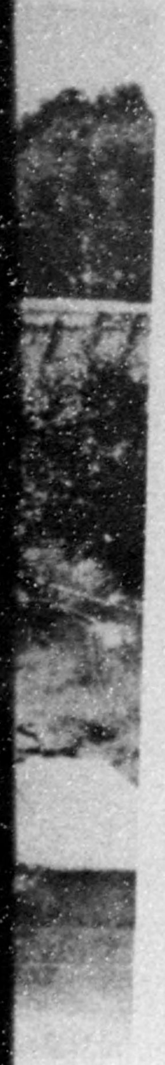

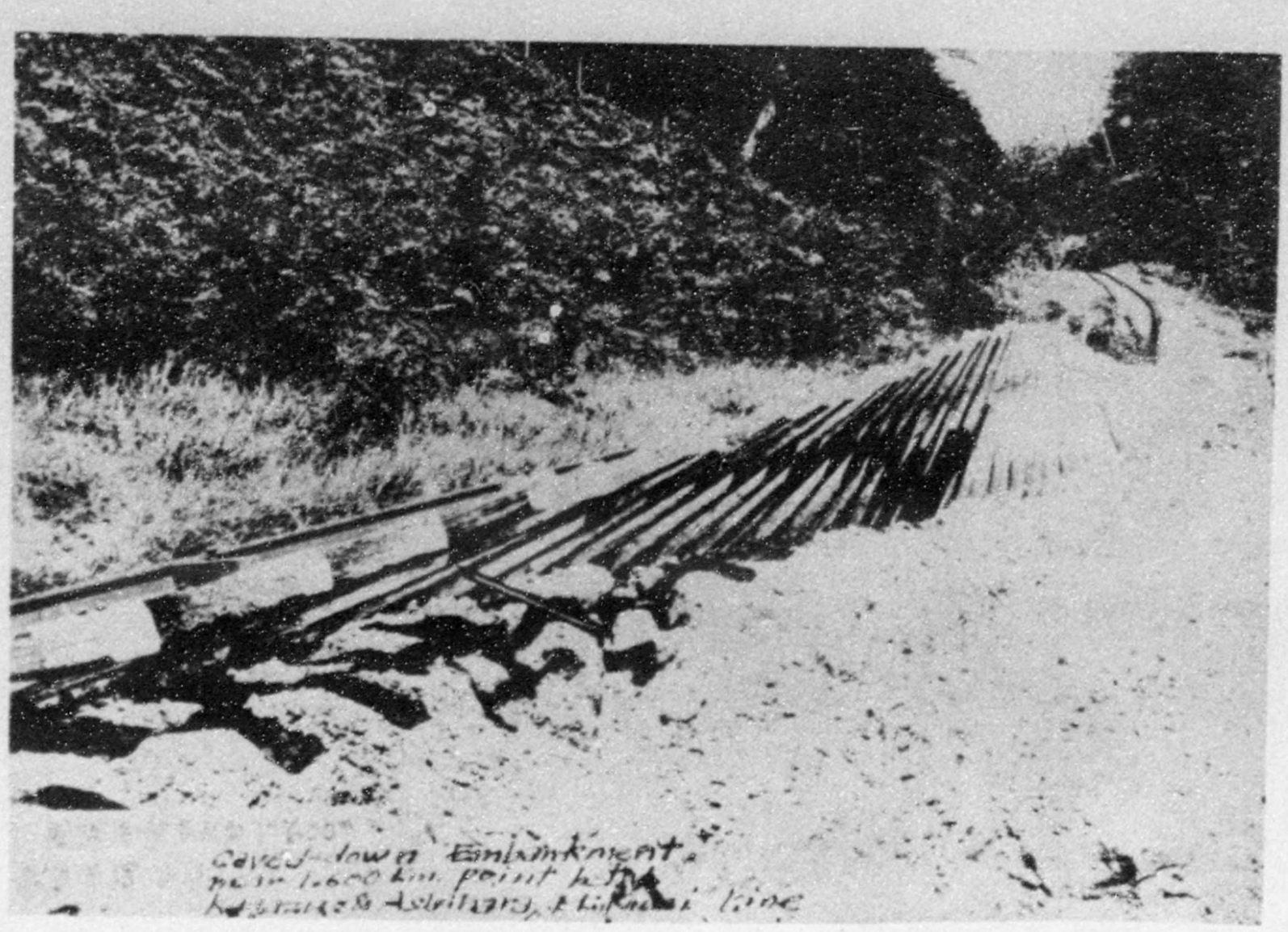

Fig. 33

Railroad Embankment Movement Resulting in
Upside Down Stretch of Rails and Ties

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government railroad from Sabae northwards, enters Fukui City, crosses the Kuzuryu River by means of the Funa Bridge, runs northward across the plain to Maruoka, crosses the mountains to Daishoji, and continues north to the city of Kanazawa. The Fukui-Awara highway runs north from Fukui City, crosses the Kuzuryu River by the Nakatsuno Bridge and continues north to the town of Awara.

2. DAMAGES - The damage to the roads and highways was subsidence, upheaval, fissuring, and the damage to bridges. Fissuring occurred everywhere, to a greater or a lesser degree.

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Fig. 34

Interurban Car Crushed By Station Collapse

Fig. 37 shows general cracking of concrete streets in Fukui City. Fig. 38, Fig. 39, and Fig. 40 show some examples of large fissures and slumping in gravel surfaced roads. In the areas near the epicenter, the damage to the roads was generally similar, regardless of the type of road surfacing. Fig. 41 shows the displacement of concrete highway slabs on the Hokuriku highway north of Fukui City.

Road embankments and bridge approaches received damage typical to that suffered by the railroads. Fig. 42 shows the slumping of the approach embankment to a railroad overpass structure. The center of the roadbed was somewhat repaired at the time this picture was taken. Fig. 43 shows the approach subsidence at the overpass structure itself. The approach apron dropped away but the roadbed has been temporarily repaired.

Most small highway bridges were monolithic concrete structure and suffered but very slight damage. The larger

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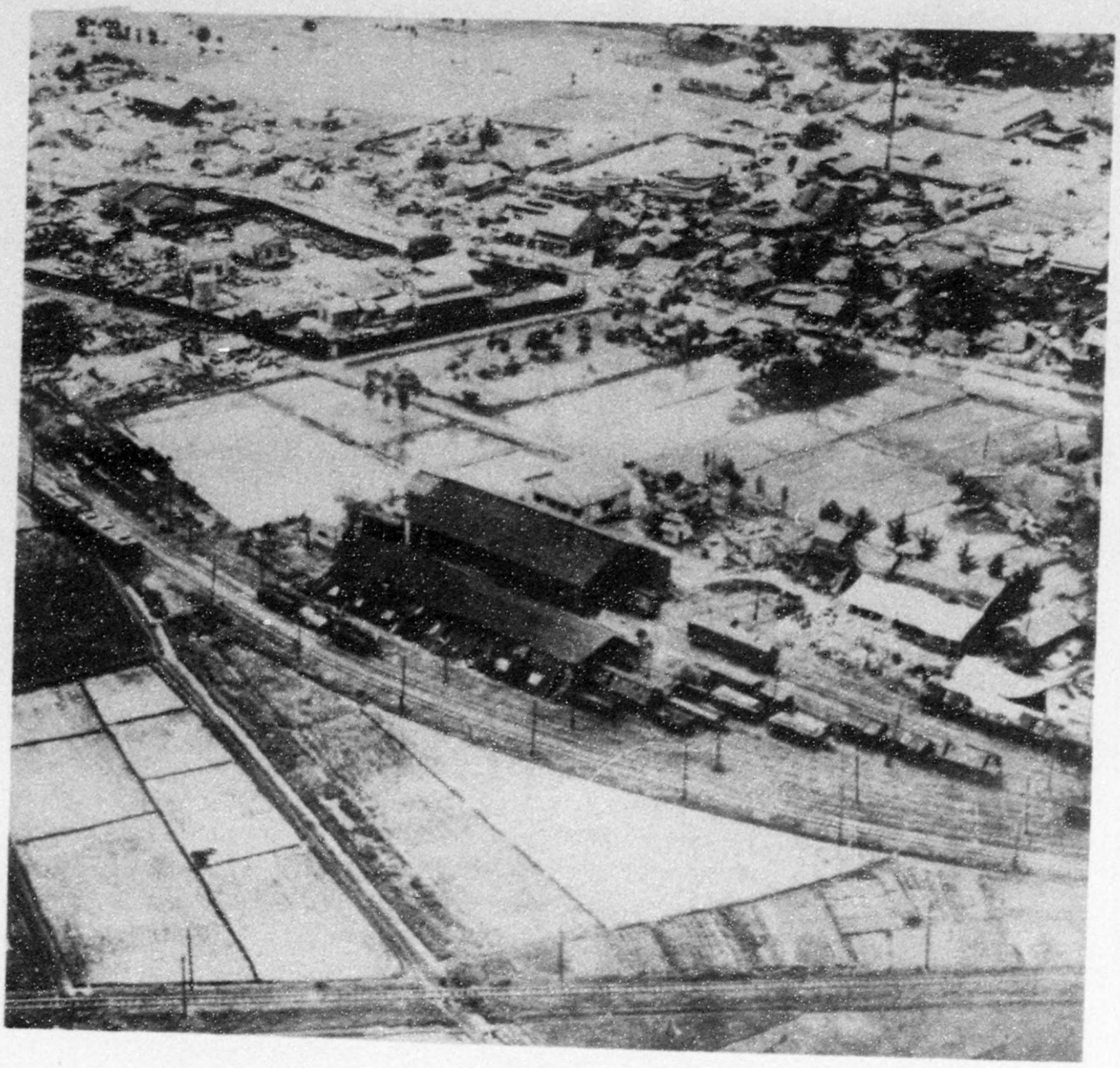
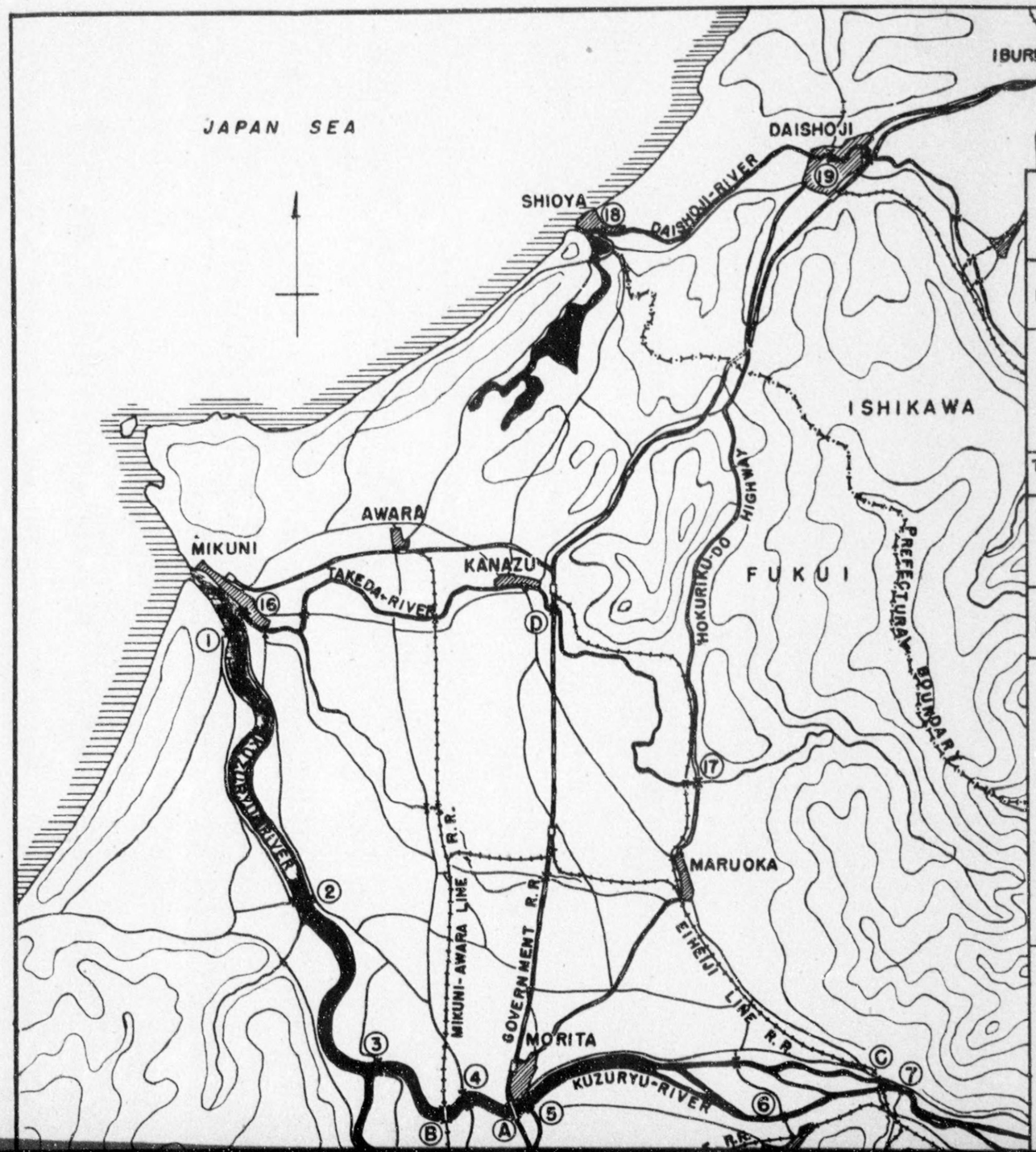


Fig. 35

Interurban Car Barn - Northeast Fukui City

bridges crossing the Kuzuryu and Asuha Rivers were, in some spectacular cases, totally collapsed. Two large concrete and steel bridges which collapsed, namely, the Itagaki and the Nakatsuno Bridges, are described in this Chapter under BRIDGES.

Fig. 44 shows the vertical displacement to the Hokuriku-do Highway from Fukui City north to city of Daishoji. The reader must bear in mind that the releveling surveys of the meizo-

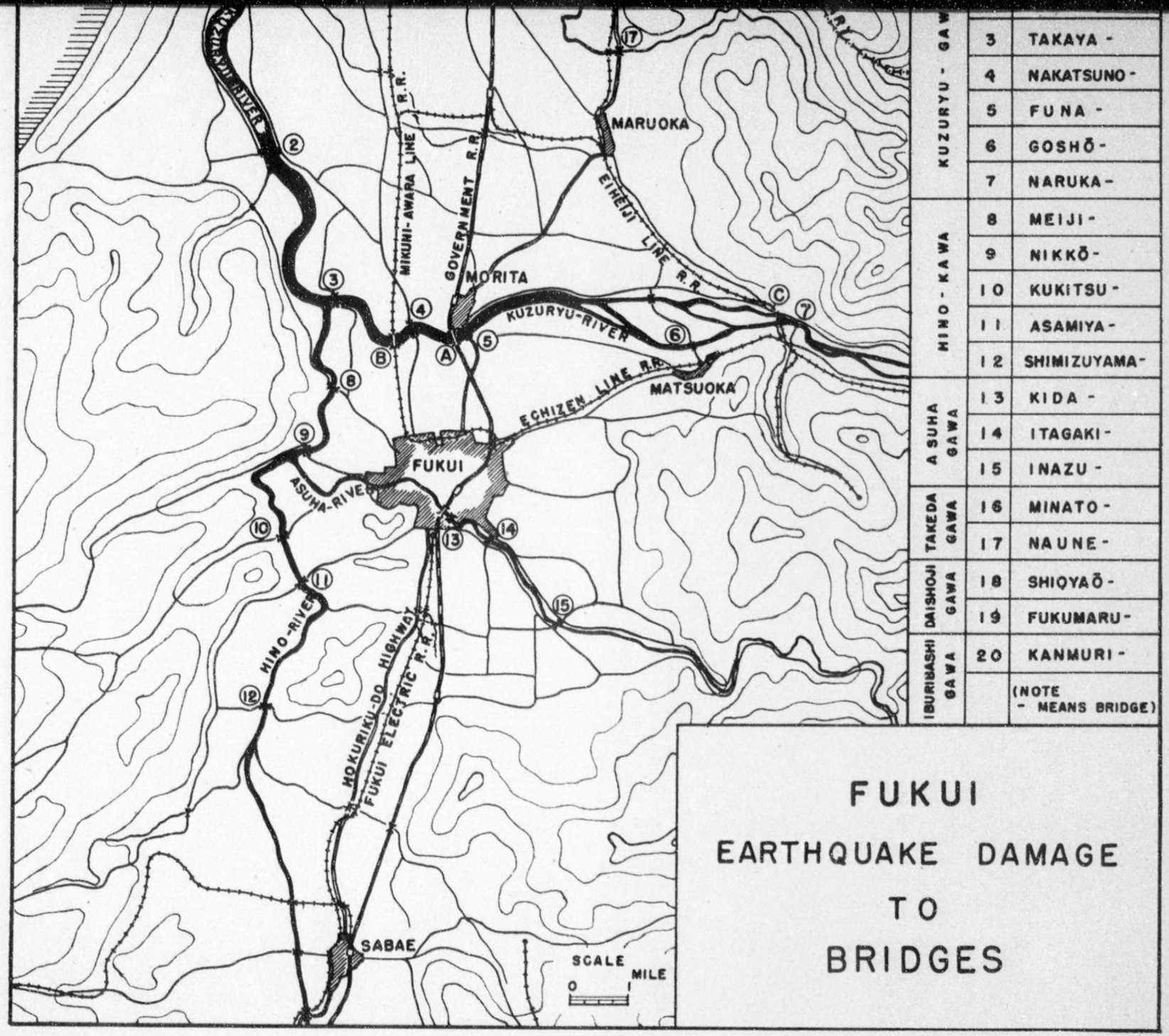


RAILROAD BRIDGES

RIVER	NOTE	NAME OF BRIDGE
KUZURYŪ-GAWA	A	KUZURYŪ -
	B	KEIFUKU KUZURYŪ -
	C	NARUKA -
TAKEDA GAWA	D	TAKEDAGAWA -

HIGHWAY BRIDGES

RIVER	NO.	NAME OF BRIDGE
KUZURYU-GAWA	1	SHINBO -
	2	FUSEDA -
	3	TAKAYA -
	4	NAKATSUNO -
	5	FUNA -
	6	GOSHŌ -
	7	NARUKA -
HINO-KAWA	8	MEIJI -
	9	NIKKŌ -
	10	KUKITSU -
	11	ASAMIYA -
	12	SHIMIZUYAMA -



KUZURYU-GAWA	3	TAKAYA-
	4	NAKATSUNO-
	5	FUNA-
	6	GOSHŌ-
	7	NARUKA-
HINO-KAWA	8	MEIJI-
	9	NIKKŌ-
	10	KUKITSU-
	11	ASAMIYA-
	12	SHIMIZUYAMA-
ASUHA GAWA	13	KIDA-
	14	ITAGAKI-
	15	INAZU-
TAKEDA GAWA	16	MINATO-
	17	NAUNE-
DAISHOJI GAWA	18	SHIOYAŌ-
	19	FUKUMARU-
IBURIBASHI GAWA	20	KANMURI-
		(NOTE - MEANS BRIDGE)

FUKUI
EARTHQUAKE DAMAGE
TO
BRIDGES

Fig. 36

Fig. 37

Concrete Streets - Fukui City

seismic area show that the eastern part of the plains area north of the Kuzuryu River generally showed upheaval and the western part showed subsidence.

3. CONCLUSIONS AND RECOMMENDATIONS - Roads and highways did not suffer as much damage from slumping, subsidence, and base flowing as did the railroad embankments. This of course was mainly due to the much larger average height of railway embankments in the plains and foothill areas. Damage was sustained to road and highway railroad overpass approaches showing that the same careful consideration for angles of repose,

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most important as
solidation than l
approaches should
C. BRIDGES - The
Kuzuryu River. T
Asuha and the Hin
the larger bridge
The largest

Fig. 38

Fissure in Hokuriku-Do Highway

soil selection, etc. as applies to railway embankments applies equally well to roads and highways. Subgrade compaction is most important as subsidence seemed to be caused more from consolidation than lateral flowing of the subgrade. All bridge approaches should receive careful compaction.

C. BRIDGES - The main river crossing the Fukui plains is the Kuzuryu River. The principal branches of the Kuzuryu are the Asuha and the Hino Rivers. River locations and locations of the larger bridges are shown by the map, Fig. 36.

The largest bridges were located over the Kuzuryu River

Fig. 39

Fissuring of a Secondary Road Near Maruoka

and those that completely failed were, with the exception of one, located directly north of Fukui City. With the exception of the Gosho and the Naruka suspension bridges, the damage to bridges in the area was startling. However, as the reader progresses through the descriptions of the various bridge failures, it will perhaps be quite apparent, in most cases, what was the basic cause of failure. Failure of bridges was the thing that most handicapped the arrival of relief supplies into Fukui City, and railroad transportation between that city and the north was stopped for well over one month's time. The two suspension bridges mentioned above, located at the eastern edge of the meizo-seismic area, permitted reaching Morita to

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Fig. 40

Fissuring and Slumping of a Section of the
Fukui-Awara Highway

the north of Fukui, normally a distance of about 2.4 miles, by a detour of about 9 miles over inferior roads through rice paddies and farm lands. A table listing the bridges, types of construction, lengths, and types of damage is shown by Fig. 45.

1. HIGHWAY BRIDGES

a. Nakatsuno Bridge - This bridge is over the Kuzuryu River north of Fukui City and is a link in the Fukui-Awara highway. It consisted of thirteen concrete piers which supported reinforced concrete slab decks on four parallel, steel-plate

Fig. 41

Displacement of Highway Concrete Slabs

Fig. 42

Slumping of Railway Overpass Approach

Approach

girders running the l
simple span principle
were constructed of d
in a lengthwise direc

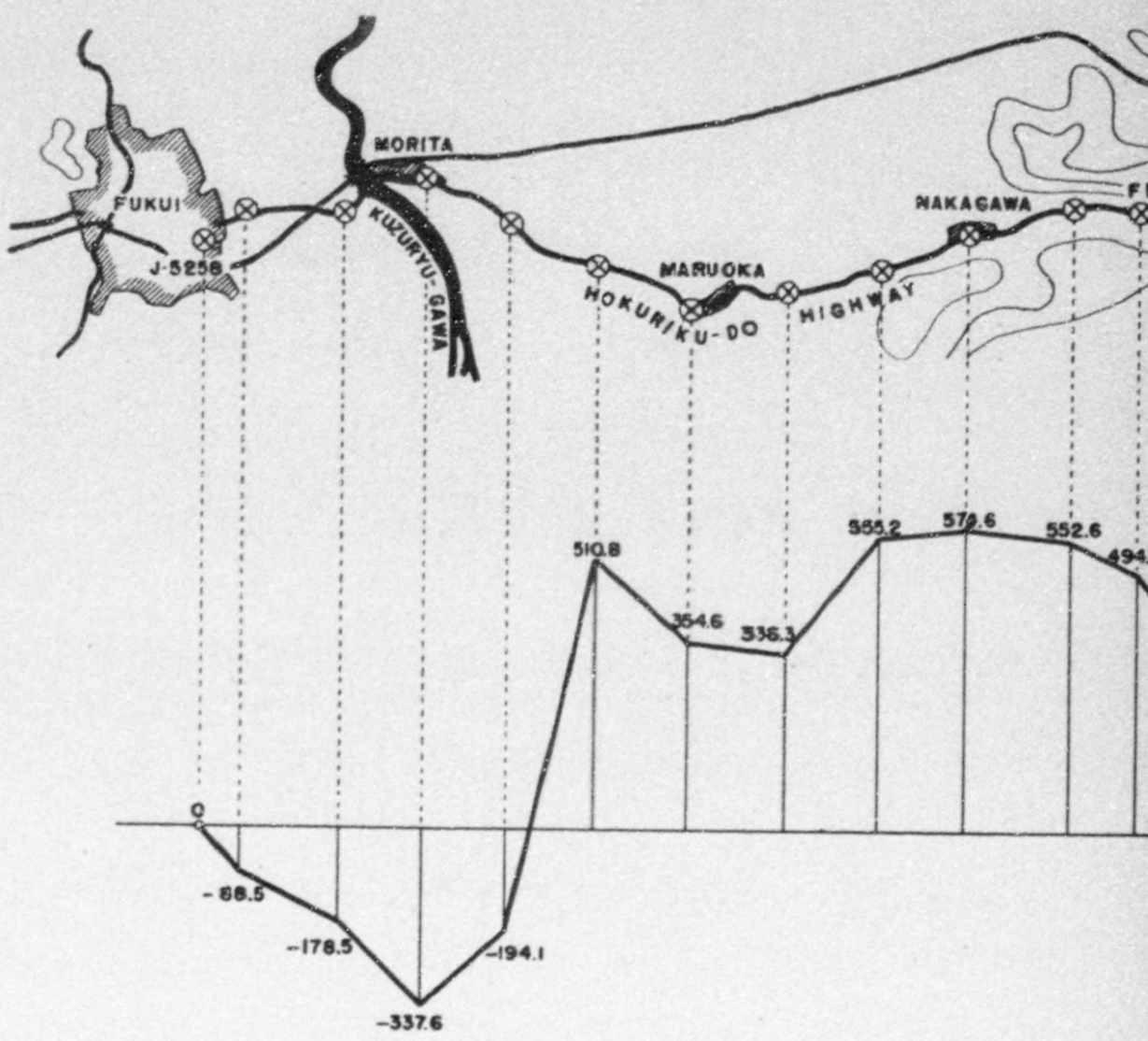
An aerial view o
view was taken looking
A ground picture taken
shown by Fig. 47. Thi
side, the 6th to the

Fig. 43

Approach Subsidence at Railway Overpass Structure

girders running the length of the bridge and was designed on the simple span principle. It appeared, from a distance, as if it were constructed of dominoes and had been given a violent push in a lengthwise direction by a mischievous hand.

An aerial view of the bridge is shown by Fig. 46. This view was taken looking down at the bridge from the southwest. A ground picture taken from the west side of the bridge is shown by Fig. 47. This shows, from the south side to the north side, the 6th to the 13th piers. Fig. 48, also taken from the



VERTICAL DISPLACEMENT OF HOKUR
AFTER HOKURIKU EARTHQUAKE (28 JUNE
BASE ELEVATIONS IN 1927 (REFERRED TO FUK

Fig. 44

west side, shows the 1st to the 4th piers from the south side to the north.

Fig. 49 shows the 12th and the 13th piers and the north abutment. The abutment overturned to the south and is now in a position directly under the girders. The 13th pier is inclined to the south while the 12th pier remains upright, with the girders being displaced about 5 feet to the south. Fig. 50 is a close-up of the west side of the overturned 10th pier.

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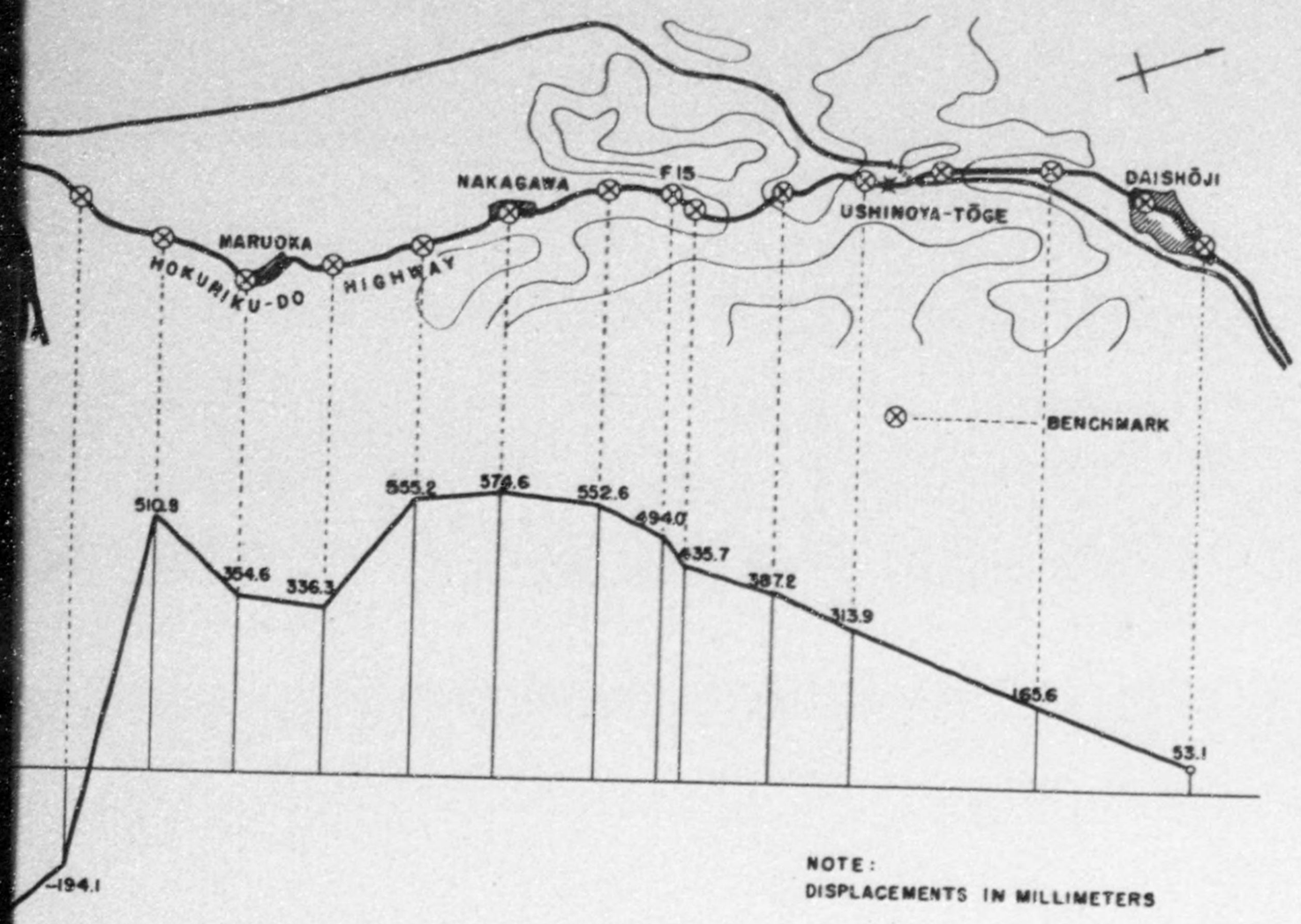

RTICAL DISPLACEMENT OF HOKURIKU-DO HIGHWAY.

ER HOKURIKU EARTHQUAKE (28 JUNE 1948) REFERRED TO
E ELEVATIONS IN 1927 (REFERRED TO FUKUI BENCHMARK J-5258)

Fig. 44

he south side

nd the north

and is now in

pier is in-

upright, with

south. Fig.

rned 10th pier.

A member of the investigation party is pointing at the upper edge of the pier foundation. It is not known whether this concrete spalled off due to the rocking of the pier or whether it had been removed previous to the earthquake.

Fig. 51 is a view of the north side of pier No. 3. It is evident that the pier columns rocked back and forth, in the north-south direction, on the pier base. Fig. 52 is a view of the top of pier No. 2 and shows the displacement, to the south,

RIVER	NO		NAME OF BRIDGE	LENGTH (IN FT.)	CONSTRUCTION	DAMAGE
KUZURYU	1		SHIMBO	1968	1870FT. R.C. 98 - WOOD	PIERS BROKEN
	2		FUSEDA	1968	WOOD	COLLAPSED
	3		TAKAYA	950	"	"
	4	*	NAKATSUNO	950	PLATE GIRDER	"
	5	*	FUNA	1082	WOOD	"
	6		GORYO		"	SLIGHT DAMAGE
	7		AIOI	66	"	COLLAPSED
HINO	8		MEIJI	558	"	"
	9		NIKKO	545	"	"
	10		KUKITSU	873	"	"
	11		ASAMIYA			"
	12		SHIMIZUYAMA	558	WOOD	"
ASUKA	13		KIDA		"	"
	14	*	ITAGAKI	590	R.C.	"
	15		INAZU	640	WOOD	"
TAKEDA	16		MINATO	210	"	"
	17		NAUNE	236	"	"
DAISHOJI	18		SHIOYA-O		"	PIER SUNK
	19		FUKUMARU		"	ABUTMENT
IBURIBASHI	20		KAMURI		"	COLLAPSED
KUZURYU	21	*	GOSHO		SUSPENSION	SLIGHT DAMAGE
	22	* *	NARUKA		"	NO DAMAGE
KUZURYU	A	*	GOV. R.R. KUZURYU		PLATE GIRDER	DROPPED
	B	*	KEIFUKU R.R. KUZURYU		"	"
	C	* *	KEIFUKU R.R. NARUKA		STEEL TRUSS	NO DAMAGE

NOTE ——
1—22 HIGHWAY BRIDGES
A—C R.R. BRIDGES
* DESCRIBED
* * NOT DAMAGED

Fig. 45

Table Showing Bridge Types, Lengths and Damages

of span No. 3. The small size of the anchor bolts is apparent. The top of the pier shows the spalling off of but a little concrete, caused by the anchor bolts being pulled out.

Fig. 53 is a view of the east edge of the south abutment. The man with the sun helmet, standing on the broken section of wingwall, has his right foot marking the original location of the abutment's east side. This abutment was also displaced and inclined towards the south. Fig. 54 shows rivet head indentations in the bottom side of the reinforced concrete bridge

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Two main

deck. The only anchorage vided the deck were the rivet heads on the tops of the steel plate girders.

The movement of the bridge was to the south. The long axis of the bridge was on a radial line from the suspected epicenter location. The movements of the bridge show that the shock waves were of large amplitude and provided a large acceleration. Movements of girder angle bracing, over the tops of piers, provided a means of determining the initial displacement, which was more than 2.5 feet. A great deal of the damage was done by the falling bridge spans as they were displaced.

Two main faults are apparent in this bridge. The foun-

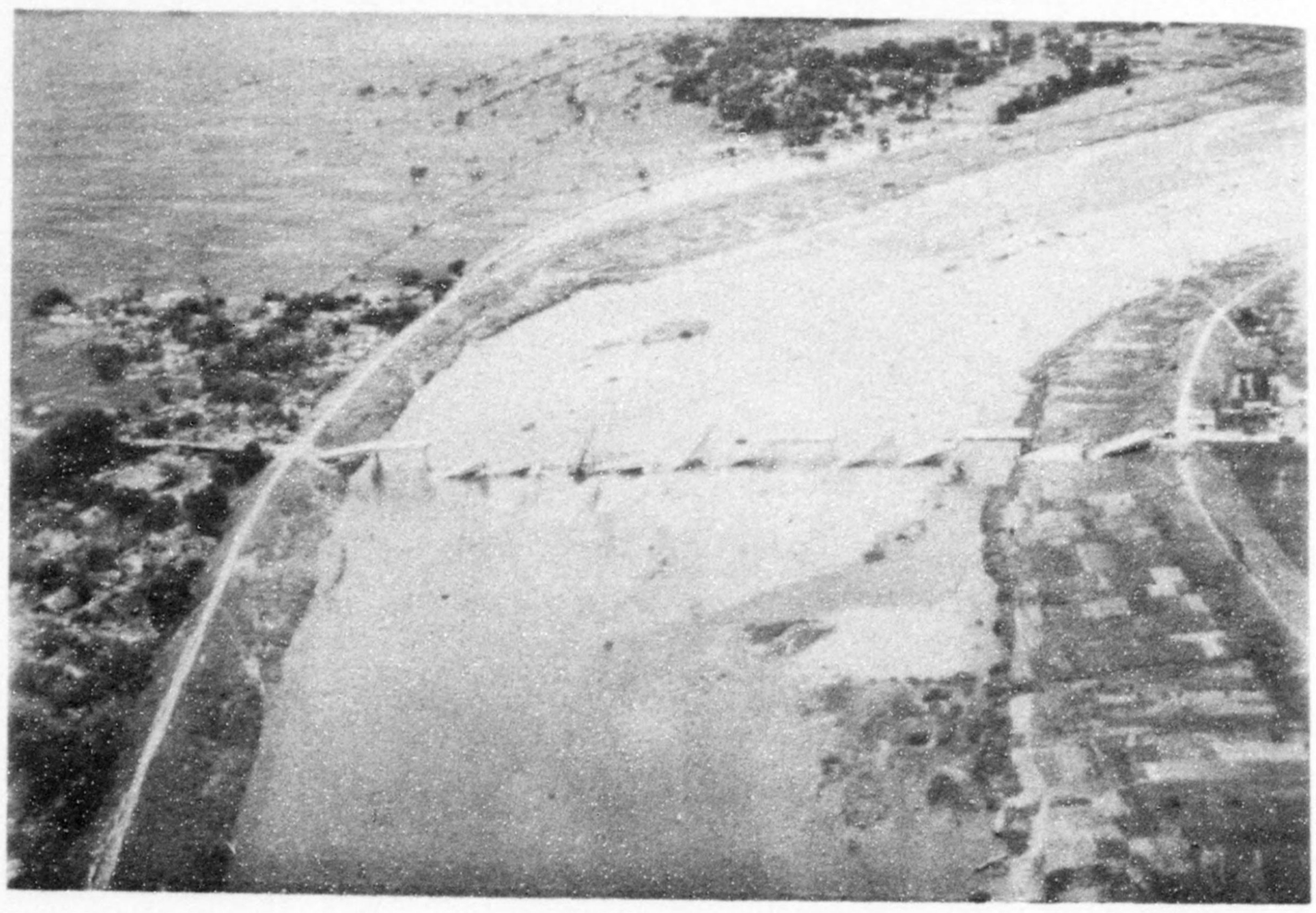

Fig. 46

Aerial View of the Nakatsuno Bridge

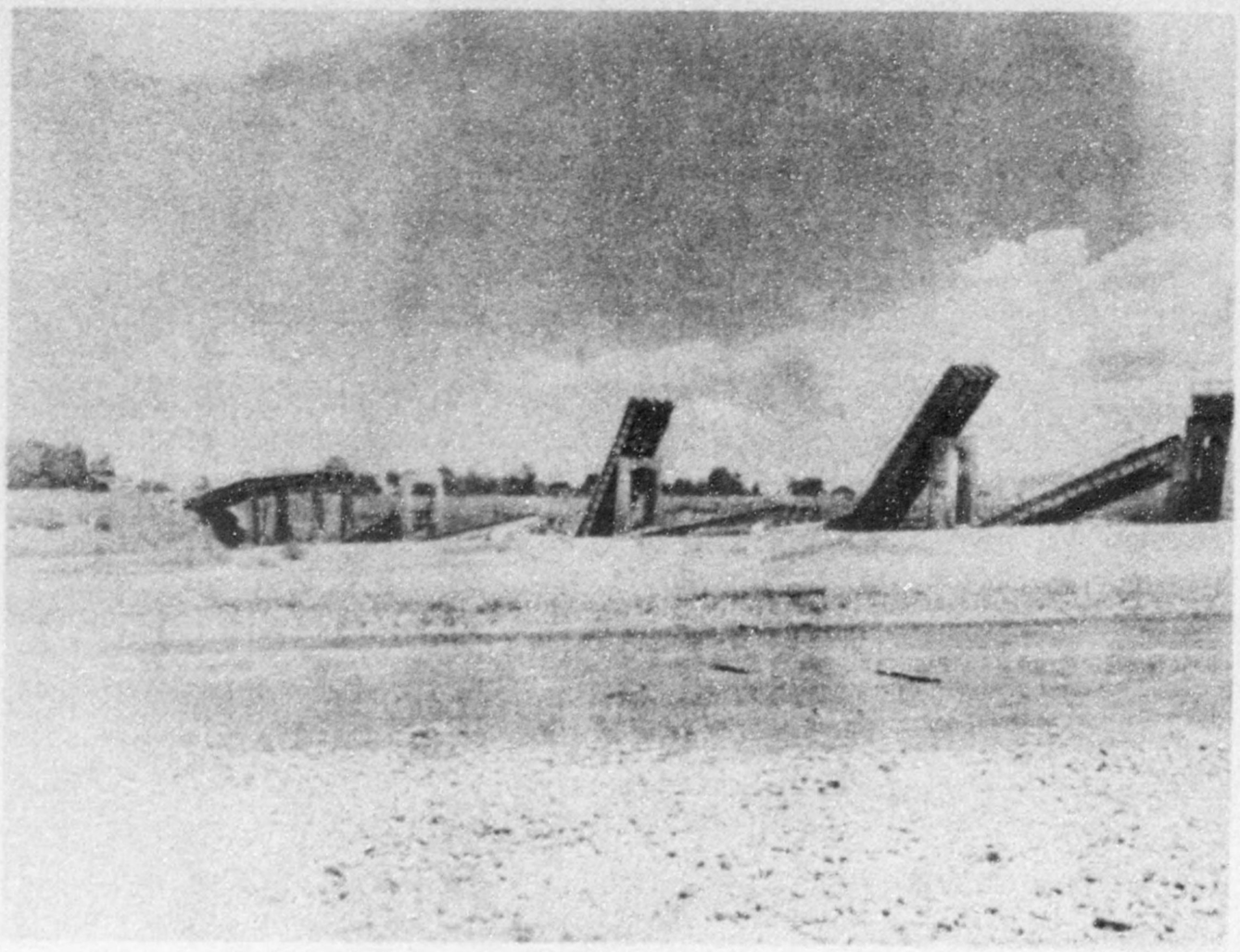

Fig. 47

View From West of North Portion of the
Nakatsuno Bridge

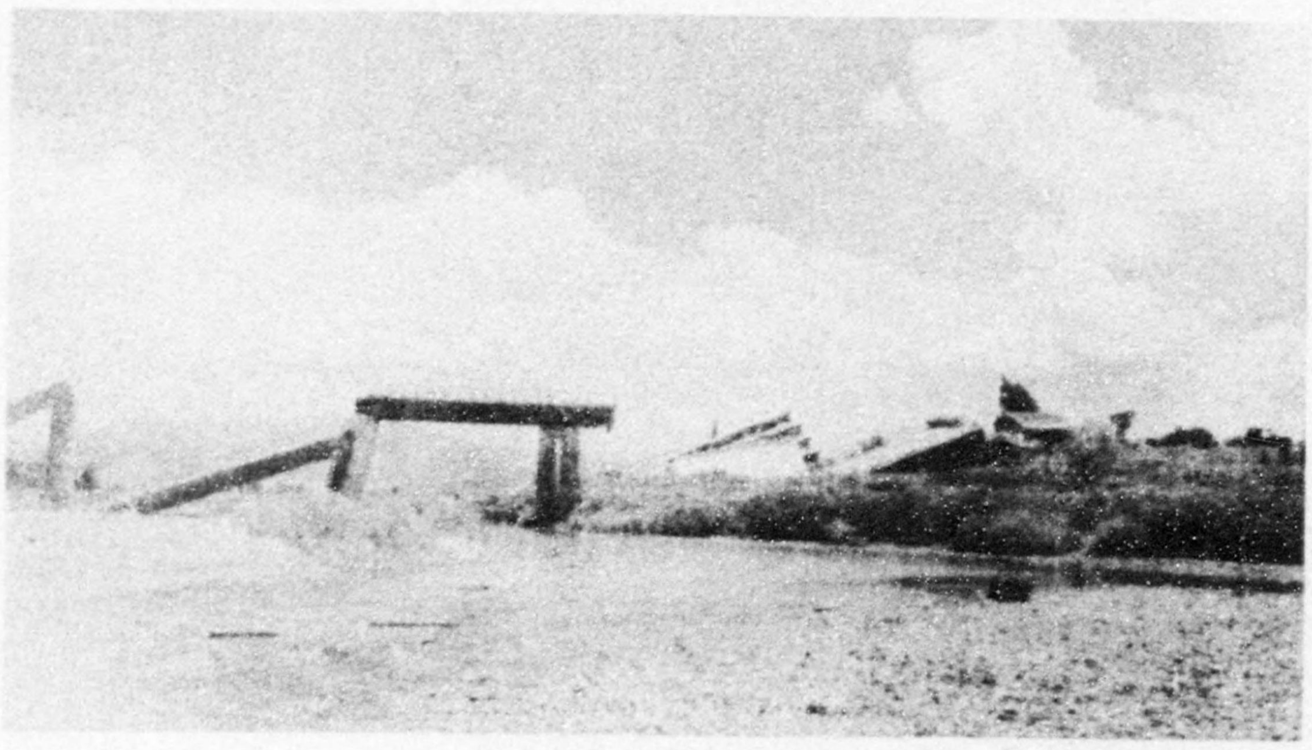

Fig. 48

View From West of South Portion of the
Nakatsuno Bridge

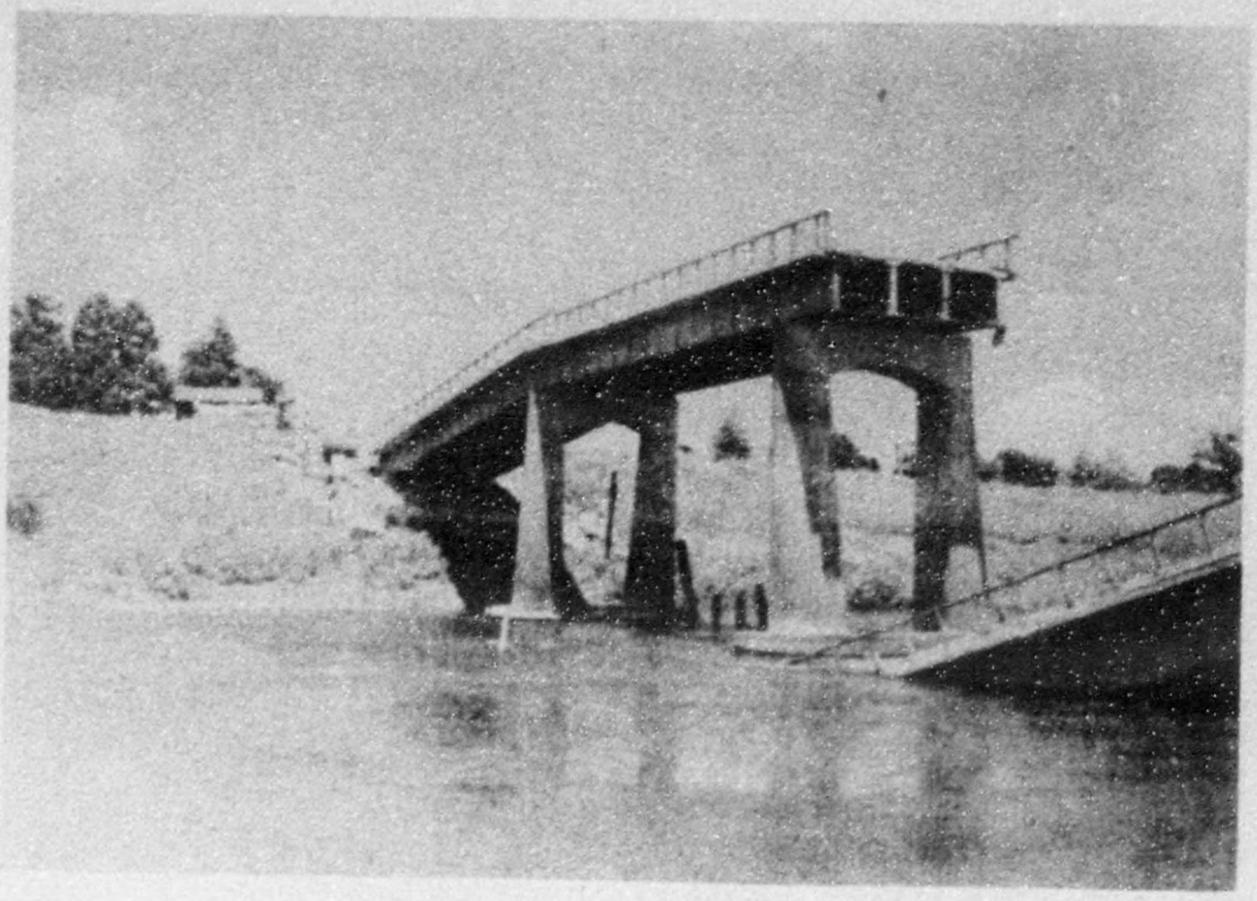

Fig. 49

View From Southwest of the North Abutment
Nakatsuno Bridge

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dations were not rigid and stable enough, and girder anchorage to the piers was practically non-existent. The foundation construction, see Fig. 55, consisted of wood piling upon which was poured a mat covering, approximately 2 feet thick. It was on top of this mat that the pier foundation was poured. This construction joint created a plane of weakness to lateral movement, particularly movement in the direction of the short axis of the pier. The violent movements to which the bridge was subjected no doubt would have damaged the bridge, even though the units had been anchored properly; but it is doubted that total collapse would have resulted.

b. Itagaki Bridge - This bridge is over the Asuha River and is located southeast of Fukui City. It was an all

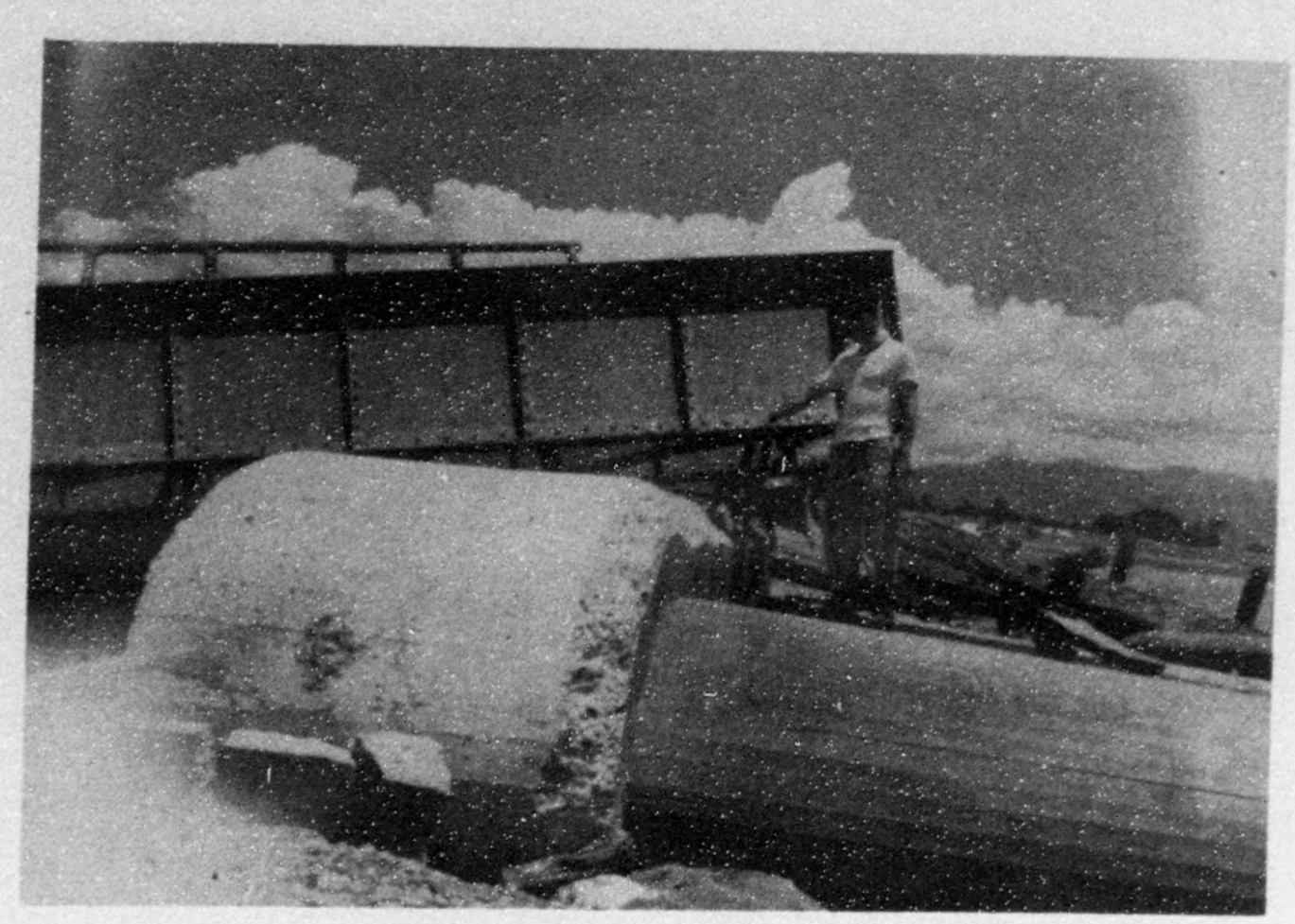

Fig. 50

Close-up View of West Side of 10th Pier
Nakatsuno Bridge

reinforced concrete bridge consisting of twelve piers and thirteen spans. The floor deck, of unit span construction, was cast integral with four supporting girders running parallel to the long axis of the bridge, forming a deck structure of unit span construction. The long axis of this bridge was from the northeast to the southwest.

Fig. 56 shows a view of the bridge from the east. The general appearance of failure is very much similar to that of the Nakatsuno Bridge. The integral floor deck and girder units were displaced to the northwest in a direction almost perpendicular to the long axis. The displacement took place in about

three movements.

marks on the top o
shows a view down
directly over the
southwest. It sho
also shows that th
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Damage to pie
perfect alignment

View of

three movements. The initial displacement was measured, from marks on the top of the piers, as about 2.5 feet. Fig. 57 shows a view down the center line of the bridge taken from directly over the 3rd pier, from the northside, and looking southwest. It shows the displacement of the deck units. It also shows that there were no anchors of any kind provided to prevent movement of the deck units.

Damage to piers was very slight. Fig. 58 shows the almost perfect alignment of the east side of the piers. The only in-

Fig. 51

View of the North Side of Pier No. 3
Nakatsuno Bridge

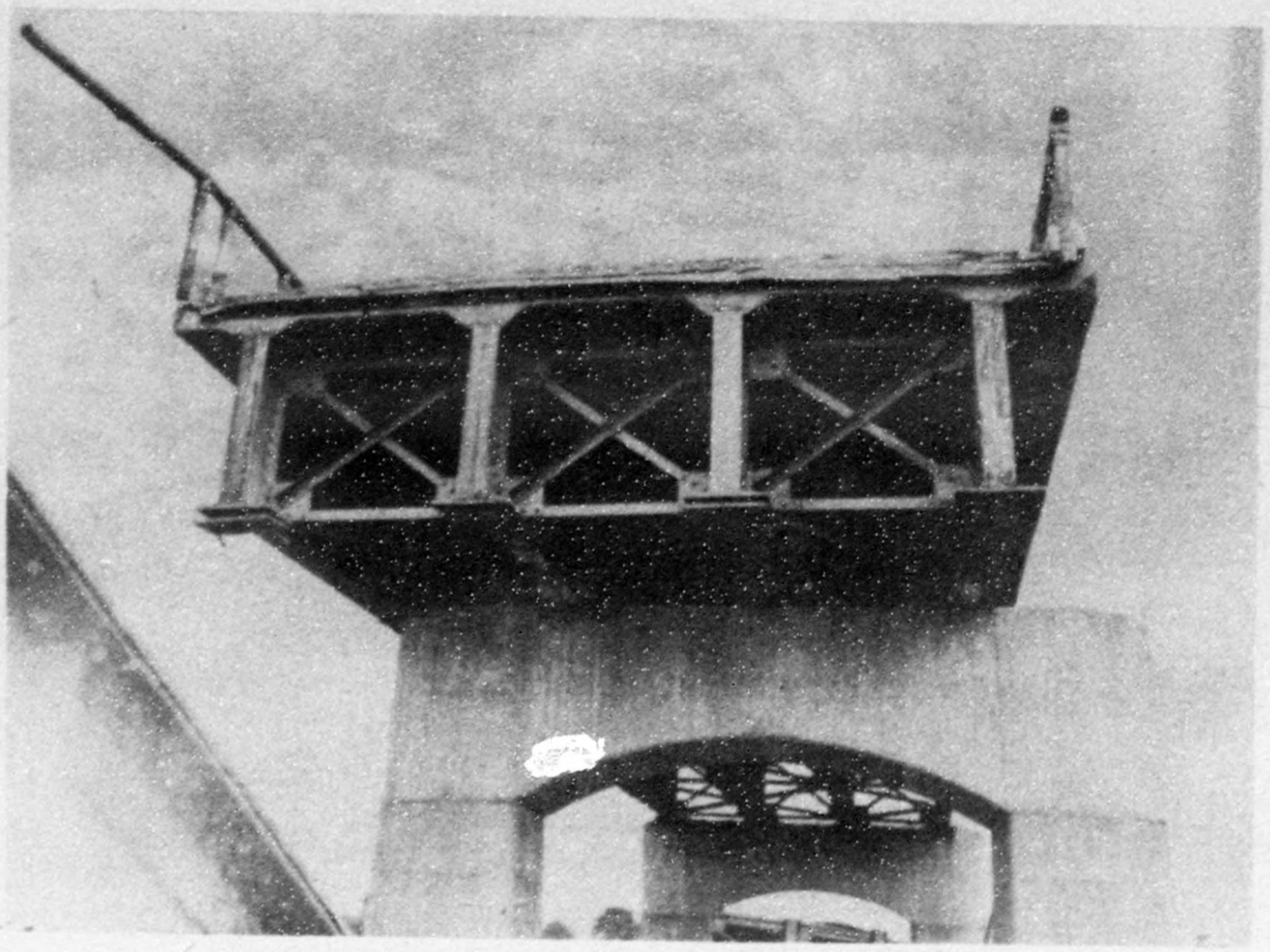

Fig. 52

View of the Top of Pier No. 2
Nakatsuno Bridge

clination of piers was caused by the falling and wedging of displaced deck units as shown by Fig. 59. The secure anchorage of the deck units to the piers perhaps would have prevented all but the slight damage to abutments, which showed some displacement and cracking due to the terminal effect of the seismic waves.

c. Saiwai Bridge - In and around Fukui City there are many bridges over the Asuha River, but except for the Itagaki Bridge and a wooden bridge that should have fallen of its own weight long before, slight damage was sustained. The Saiwai Bridge spans the Asuha River in the center of Fukui City. The only damage was to the north and south abutments. This damage

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Fig. 53

East Edge of South Abutment
Nakatsuno Bridge

is shown by Fig. 60 which shows the east side of the south abutment. It is a good example of the effect of the marginal vibrations caused by reflected and refracted waves which are set up when the seismic wave passes from one medium into a dissimilar medium.

Fig. 61 shows the distorted interurban railroad line rails which were twisted by the action of the aforementioned marginal vibrations on the bridge approaches. The bridge is located close to the rising slopes where the tuff is exposed. The

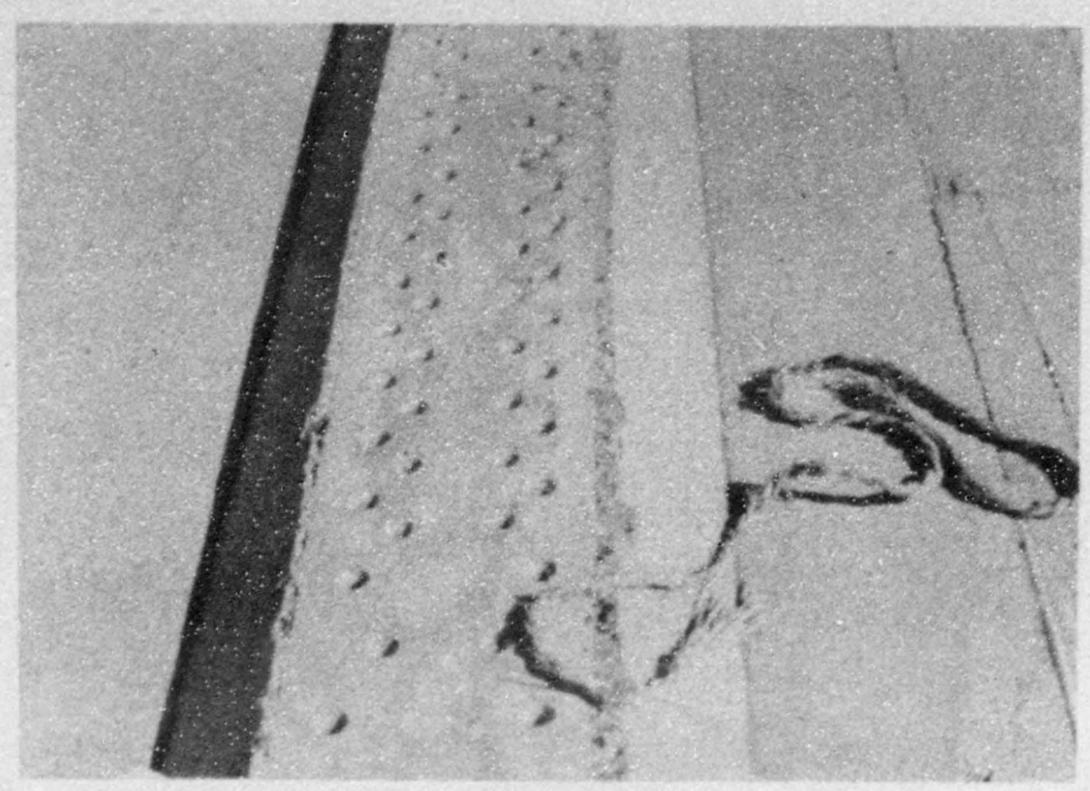

Fig. 54

Rivet Head Indentations - Bottom Side of Bridge Deck
Nakatsuno Bridge

ground conditions are therefore much superior to those at the location of the Itagaki Bridge.

d. Small Bridges - The damage to small bridges was slight, usually affecting the abutments. Subsidence of approaches was also noticeable in most cases.

(1) Asahi Bridge - This bridge is located in the eastern part of Fukui City and spans the Arakawa River. It is all reinforced concrete with two piers and separate, integral, continuous deck and girders. The deck and girders were rotated counter clockwise, which displaced the structure as seen by Fig. 62, which is viewed from underneath the south side, and Fig. 63, which is a view on the south side of the west abutment. Of six parallel girders, only two were left bearing on the west abutment. This bridge had no provision for anchorage between the

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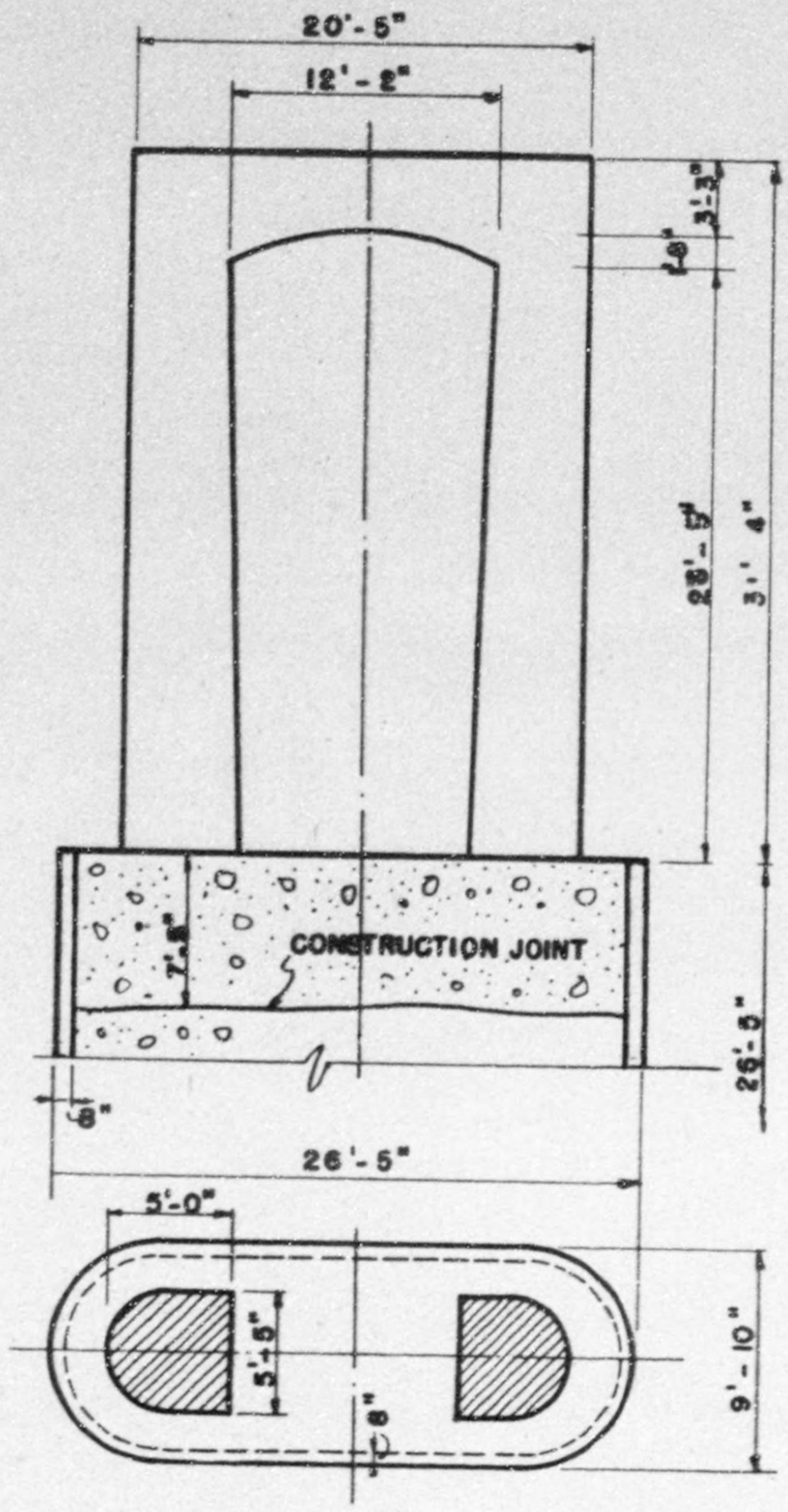

Fig. 55

Pier Foundation Construction
Nakatsuno Bridge

deck and girder units and the piers or abutments. It is believed that during the earthquake the east bank of the river moved north and the west bank of the river moved south. Additional evidence supporting this belief was found upon examining a small arch trussed bridge supporting a gas main,

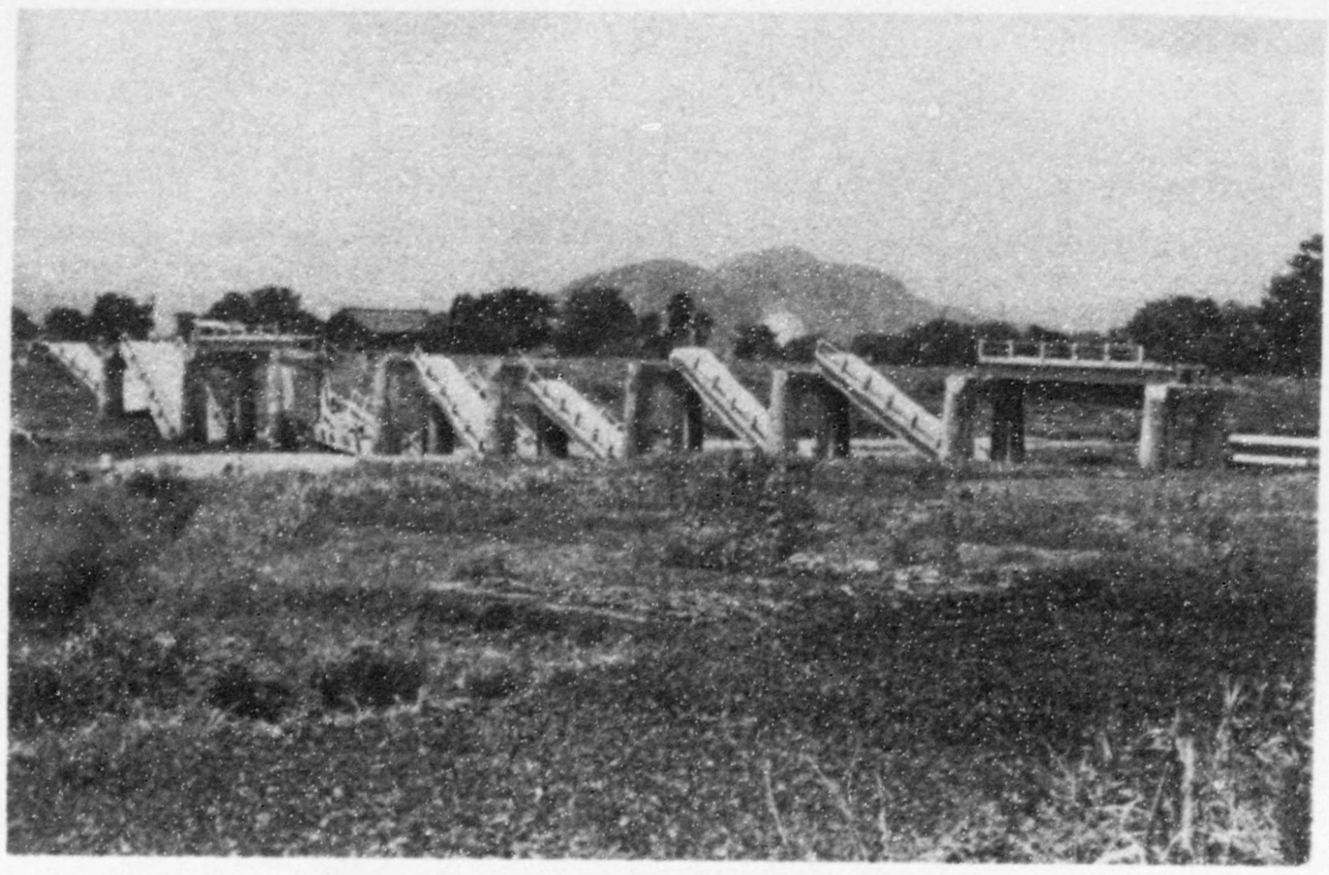

Fig. 56

East Side View - Itagaki Bridge

Fig. 57

Centerline View - Itagaki Bridge

Bridge

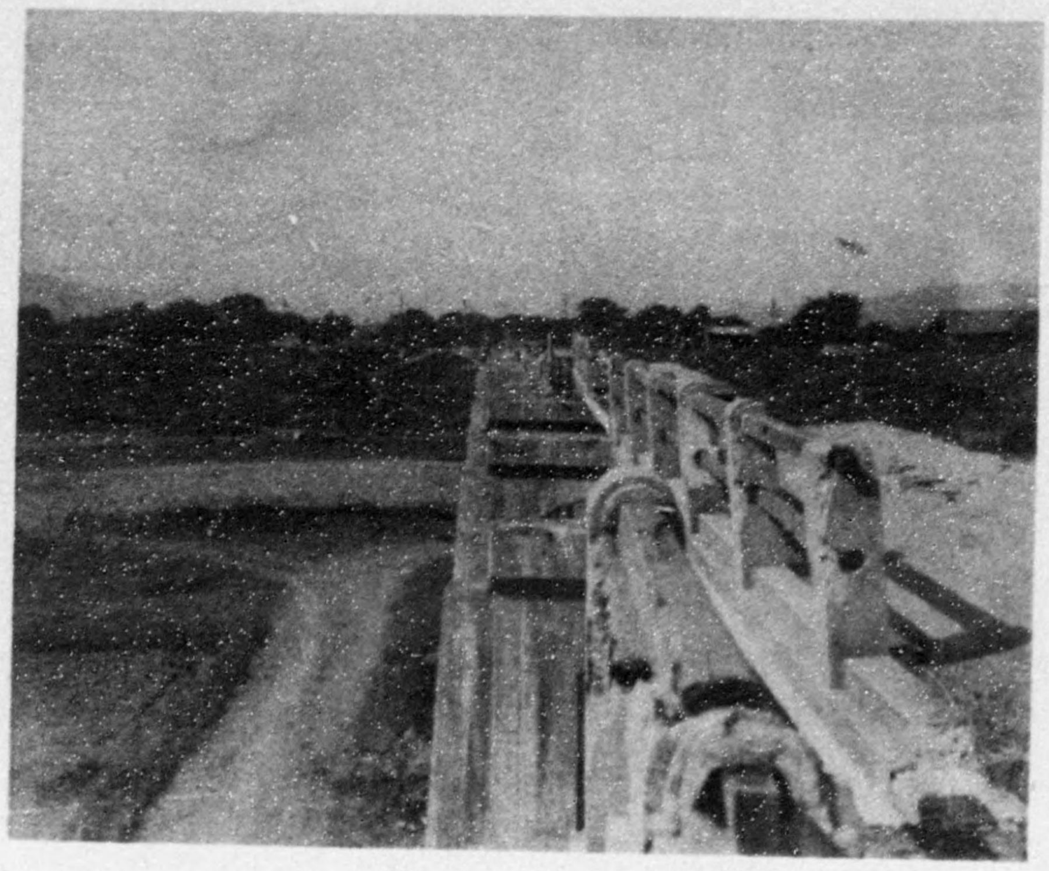

Fig. 58

Pier Alignment - Itagaki Bridge

Bridge

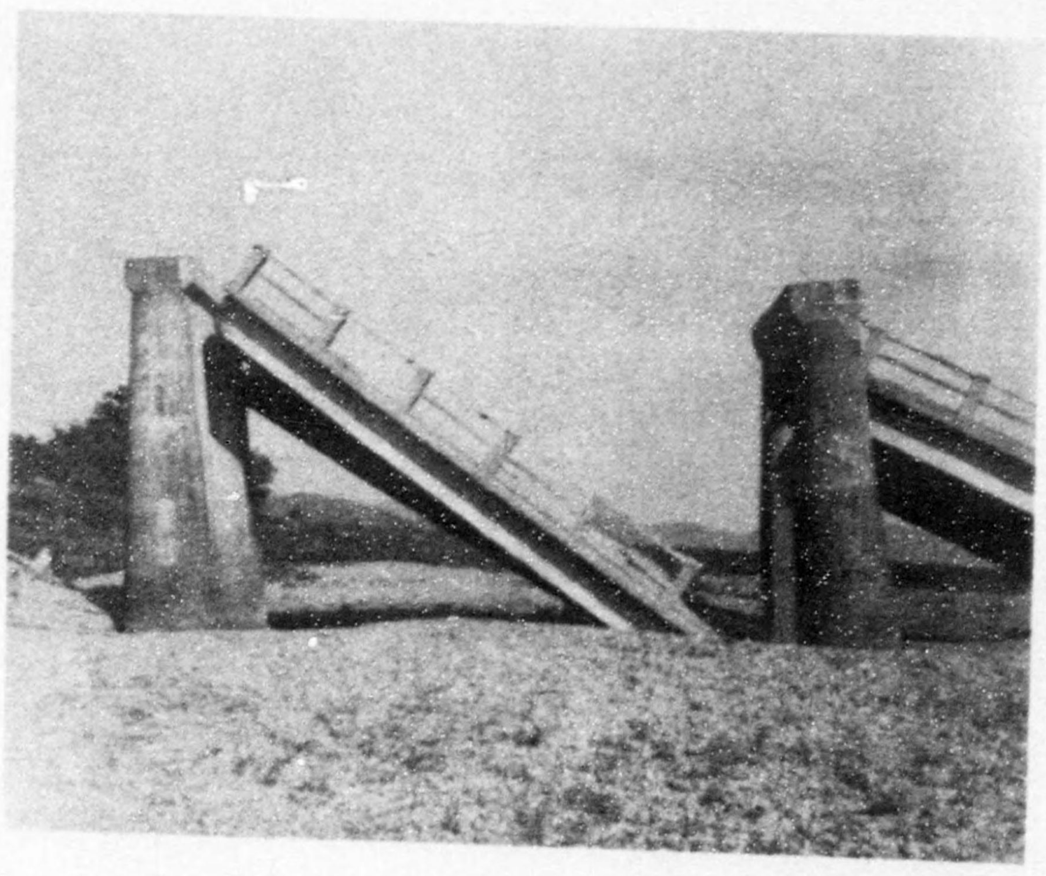

Fig. 59

Pier Inclination - Itagaki Bridge

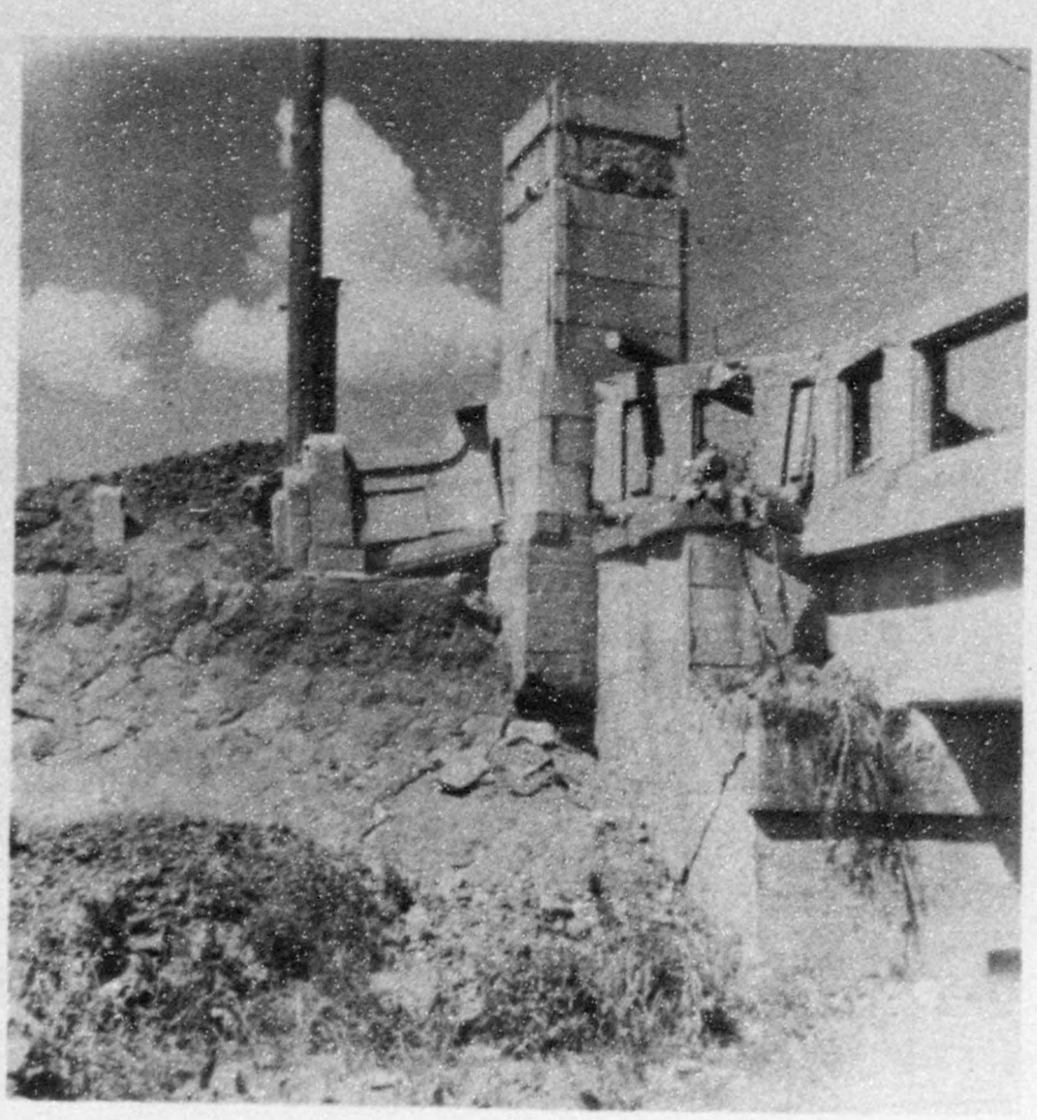

Fig. 60

East Side View of South Abutment
Saiwai Bridge

located about 150 feet north of the Asahi Bridge. Fig. 64 is a view of the south side of this structure's west abutment. The residual position of the abutment cap shows the effect of the same rotative motion which affected the Asahi Bridge.

e. Suspension Bridges - The Gosho and the Naruka suspension bridges are located near the town of Matsuoka at the eastern edge of the meizo-seismic area. The Naruka Bridge is a single span suspension bridge with a central span length of 453 feet. This bridge is located about 1500 feet upriver, east, of

Rai

the Naruka plate
damaged.

The Gosho Br
span lengths of 3
miles west of the
noticeable damage
bridge, taken fro
65. The bridge r
being at the left

Fig. 61

Rails Distorted by Approach Movement
Saiwai Bridge

the Naruka plate girder railroad bridge, neither of which was damaged.

The Gosho Bridge is a double span suspension bridge with span lengths of 398.5 feet each. It is located about three miles west of the Naruka Bridge and is in an area that received noticeable damage from the seismic shocks. A view of this bridge, taken from the east (upstream) side, is given by Fig. 65. The bridge runs almost due north and south, with the south being at the left hand side of the photograph. The deck stiffen-

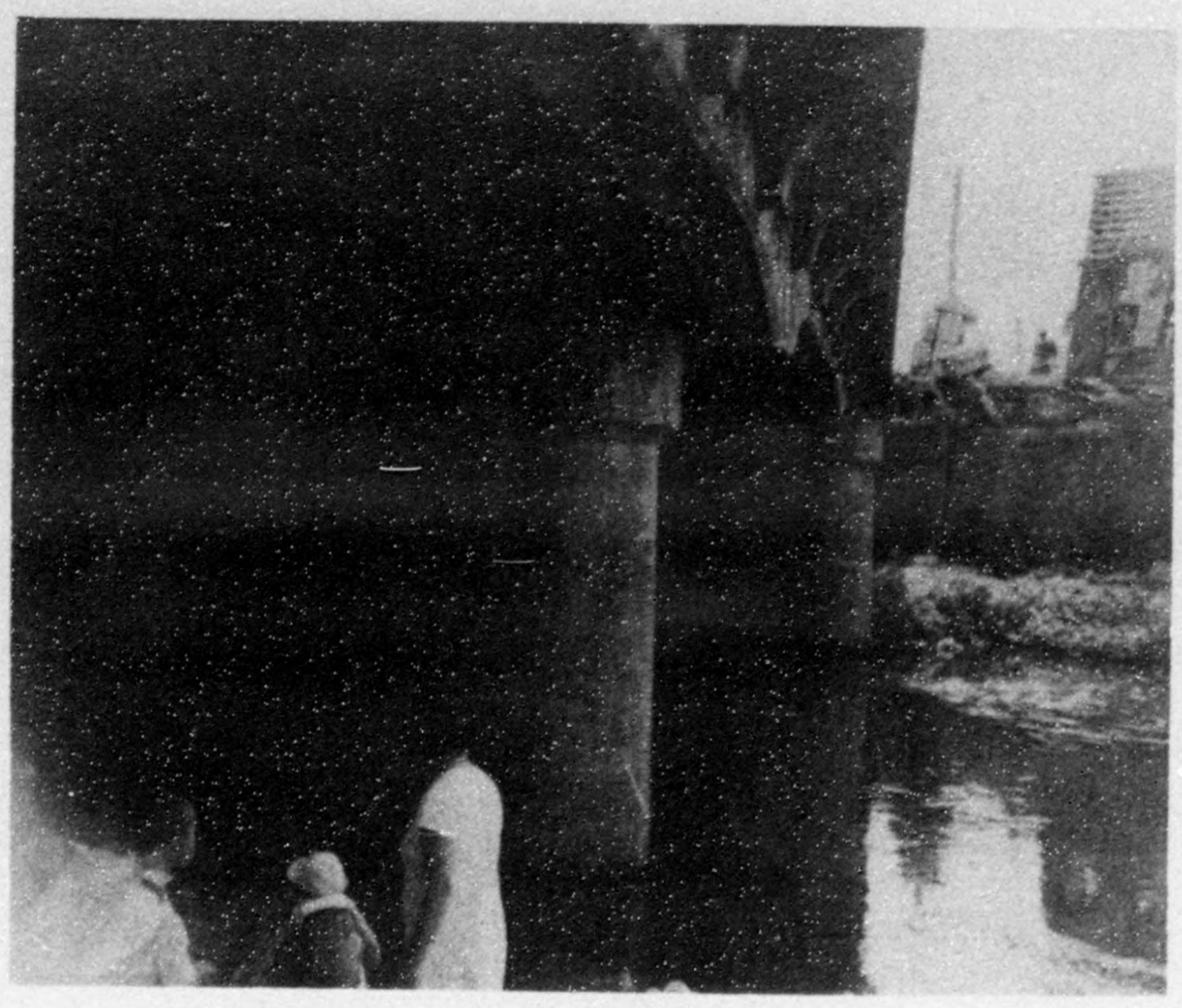

Fig. 62

Rotation of Bridge Deck
Asahi Bridge

ing truss is framed double Warren type. The bridge deck was provided initially with a fairly large camber but flattened out during the earthquake, with the north span flattening out more than the south span. The buckling of the top chords, in the north span stiffening trusses, occurred more on the downstream side than on the upstream side. In the south span stiffening trusses, the buckling of the top chord occurred only on the upstream side.

The anchor block on the right hand side moved about 8 inches towards the river, with this movement the larger on the downstream side of the block. The north tower cable saddles

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