QUICK REPORT OF THE DAMAGE CAUSED BY THE AUGUST 11th 2009, OFF THE COAST OF SURUGA BAY EARTHQUAKE

Kazuo KONAGAI[1] and Takeshi ARITA[2]

ABSTRACT: An earthquake of Magnitude 6.3 occurred about 35 km east off the west coast of Suruga Bay at a depth of about 23km. Though the shakes "6 minus" on the JMA scale recorded at Izu, Yaizu, Makinohara and Omaezaki cities were noticeably large in years past, no house was reportedly flattened, and the prefectural task force was disbanded two days after the earthquake. However, since the area has been under a serious threat of a possible mega-quake described in the "Act on Special Measures concerning Countermeasures against Large-scale Earthquake" enacted in 1978, this event can be viewed in such a way that we have gotten a rare opportunity to check all weak points revealed this time. This report provides a brief overview of the damage caused by the earthquake and discusses geological conditions that may have been reflected in the damage distribution patterns.

Key Words: Off the Coast of Suruga Bay Earthquake, stone walls, Tomei Express Way, fills, inundation area map.

INTRODUCTION

A 6.3 magnitude earthquake jolted coastal areas of the Suruga Bay, Shizuoka Prefecture on 11th August, 2009. Its source was in the Suruga Bay at N34°47.1', E138°29.9', about 35 kilometers from the coast, at a depth of about 23 kilometers (Fig. 1). One person was killed and total 245 were reportedly injured [1]. Though the shakes "6 minus" on the JMA scale recorded at Izu, Yaizu, Makinohara and Omaezaki cities were noticeably large in years past, only minor damages to total 7048 house were reported, and the prefectural task force was disbanded two days after the earthquake. The private advisory body to the Director General of the Japan Meteorological Agency convened on Aug. 11th drew a conclusion that the earthquake was neither the scenario Tokai Earthquake described in the "Act on Special Measures concerning Countermeasures against Large-scale Earthquake" enacted in 1978, nor the one that could trigger the Tokai Earthquake [2].

However, there were precedents in the past that some regional earthquakes in the Suruga Bay area were followed by much larger Tokai-type earthquakes. They include the 1935 Shizuoka Earthquake (M6.3), 1841 Kunozan Earthquake (M6.4) and 1686 Mikawa-Totoumi Earthquake (M6.5), which were followed by the 1944 Tou-Nankai earthquake (M7.9), 1854 Ansei-Tokai Earthquake (M8.4) and 1707 Houei Earthquake (M8.4), respectively. Since the area has been under a serious threat of the scenario Tokai earthquake, this event can be read as a rare opportunity for us to check all weak points that emerged this time. This report summarizes findings that the authors obtained through their survey trips on July 11th 2009, one month before the earthquake, August 11th, the day of the earthquake, and September 11th and 12th 2009, one month after the earthquake.

[1] Professor, Institute of Industrial Science, University of Tokyo
[2] Graduate student, Department of Civil Engineering, University of Tokyo

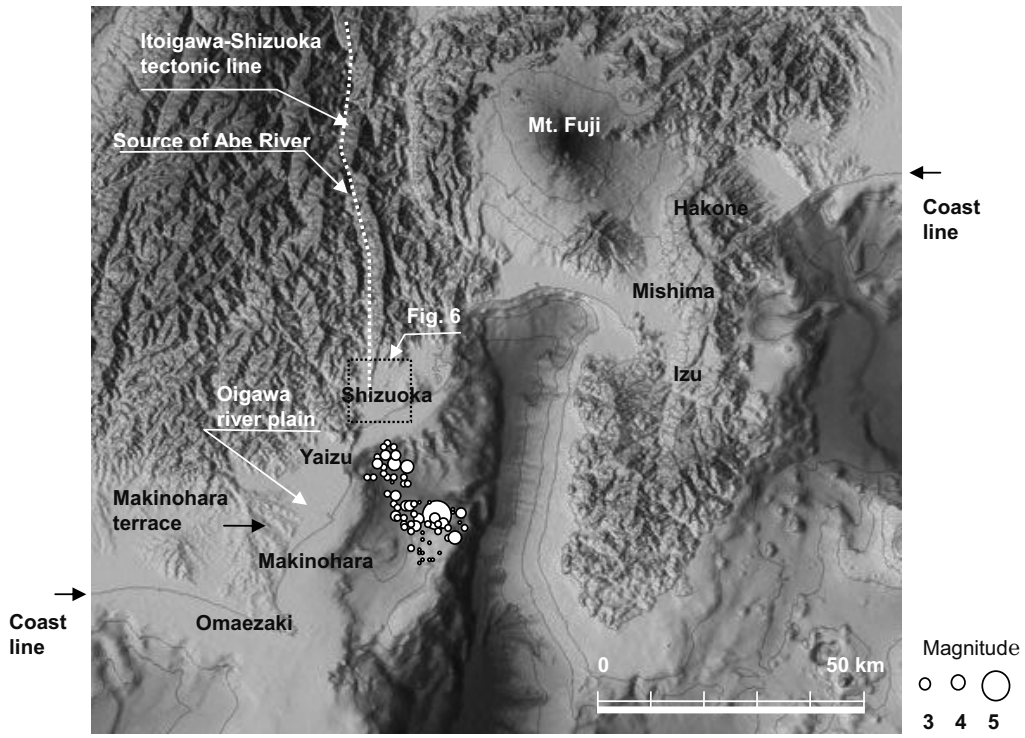


Fig. 1. Main event and pre/aftershocks during the period of Aug.1st to 12:00 Aug. 11th, 2009 (Epicenters from National Institute of Earth Science and Disaster Prevention. Map from Geological Survey of Japan)

DAMAGE TO STONE WALLS OF SUNPU CASTLE

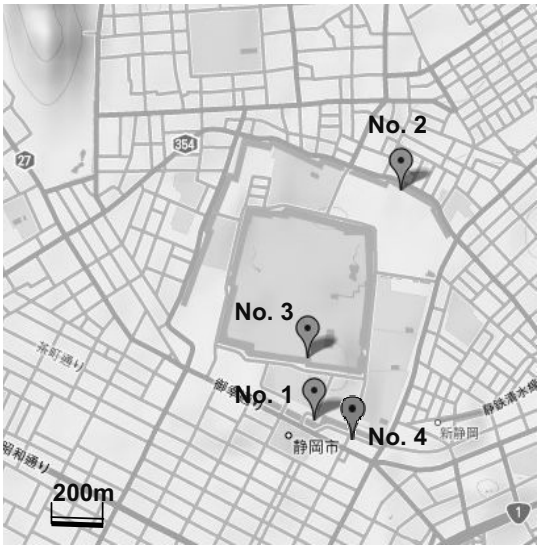
The first author surveyed the areas affected by the 1935 Shizuoka earthquake (M6.4) and took photographs of the locations of damages described in a series of reports that appeared in the Bulletin of Earthquake Research Institute, University of Tokyo (ERI Bulletin hereafter), Vol. 13, No. 4, 1935 [3]-[6]. As it would happen, the date of the survey, namely July 11th, 2009, was exactly one month before the August 11th 2009 Off-the-Coast-of-Suruga Bay Earthquake. The photographed location included a stone wall of Sunpu Castle(5) showing a slight sign of bulging towards the outer moat of the castle (Fig. 2(a)). As things turned out, this part collapsed in the 2009 earthquake. Sunpu Castle had outer, middle and inner water moats as its original shape in 1607 with the formation of the Tokugawa shogunate government. After the castle grounds became property of Shizuoka city in 1889, much of the inner moat system was filled in, and the 1935 Shizuoka Earthquake was responsible for the collapse of a part of its stone wall facing the outer moat (Fig. 2(c), [6]). In the 2009 earthquake, collapses of stone wall were reported at four locations as shown in Fig. 3.

(a) One month before the 2009 EQ (2009.07.12) Location: N34.975931°, E138.383633°

(b)The day of the 2009 EQ (2009.08.11 13:30) Location: N34.975931°, E138.383633°

(c) Broken stone wall in the 1935 Shizuoka EQ [6] Estimated location: N34.976511°, E138.382249°

Fig. 2. Broken stone wall (No. 1 in the map below)



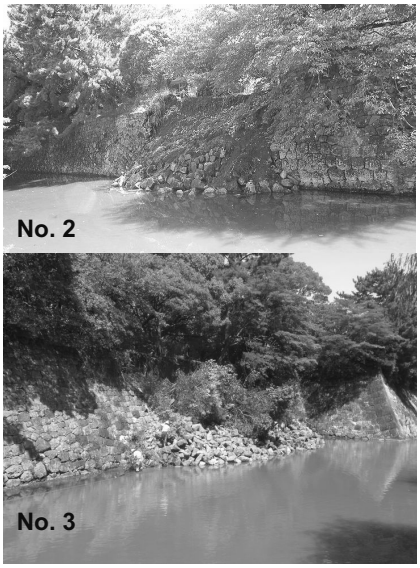


Fig. 3. Locations of broken stone walls of Sunpu Castle (Photos taken on 2009/08/11). Latitude and longitude for the center of the map: N34.979623°, E138.382287°

DAMAGE TO FILL SECTION OF TOMEI EXPRESS WAY

Makinohara diluvium terrace has its major geomorphic surface gently sloping southeast with deeply indented slopes on its northeast and southwest sides (Fig. 1). Tomei Express way runs longitudinally over a thin ridge extending from this terrace to the Oigawa river-plain. This ridge path was constructed by cut-and-fill earth-moving. One of fill sections along this ridge (N34.755506°, E138.191013°) was damaged in the earthquake. Fig. 5 shows a pair of aerial photographs of the damaged fill taken in 1975, namely 6 years after the completion of the express way. When these two photographs are perceived as a single image in terms of depth by either naked eyes or a stereoscope, it is found that the north toe of the embankment is retained by a concrete wall. Highway retaining walls are designed to have proper drainage behind them, and subjected to frequent inspections. However drainage systems can be gradually clogged up with fine substances of weathered soils. Moreover the area was reportedly receiving up to 80mm rain until early morning of August 11th. The Central Nippon Expressway Company (Central NEXCO hereafter) has set up an independent panel for investigation of causes, and officially stated on September 28th that the slope failure occurred within the fill above the retaining wall [7]. NEXCO also stated that the lower toe part of the embankment behind the retaining wall was a fill of crushed mudstones, and weathering of the mudstones has caused clogging of the drainage channels behind the retaining wall. Fig. 5 shows a pair of aerial photographs of the damaged fill section taken in 1988. The fill is covered up with rich vegetation including bamboos. Bamboos often indicate the presence of shallow underground water.

Fig. 4. Stereogram of the fill-section of the Tomei Express way in 1975 before the 2009 earthquake (Photos from Geographical Survey Institute of Japan). Latitude and longitude for the center of each photo: N34.75577°, E138.191614°, Width of each photo = 710m.

Fig. 5. Stereogram of the fill-section of the Tomei Express way in 1988 before the 2009 earthquake (Photos from Geographical Survey Institute of Japan). Latitude and longitude for the center of each photo: N34.75577°, E138.191614°, Width of each photo = 710m.

DISTRIBUTION OF DAMAGE TO HOUSES

The 1935 Shizuoka Earthquake (M6.4) was followed by the killer 1944 Tou-Nankai earthquake (M7.9). Differing from the killer 1944 earthquake that occurred during the media blackout time of the World War II, there were a series of reports of the 1935 Shizuoka Earthquake in the ERI Bulletin, Vol. 13, No. 4. Terada, T., Professor at ERI, also an essayist of the time, wrote in his essay [8] that the most damaged houses seemingly made up wide brushes along hillsides, slightly inlands of sand dunes, etc. Details were more clearly described in the reports of the Numazu Observatory of the Japan Meteorological Agency [9], [10]. These brushes of damaged houses have some similar features as those observed in past earthquakes including the 2007 Noto Earthquake. Konagai et al. [11] reported that most houses which suffered substantial damage in Toge hamlet of Wajima city were found lining along the toe part of a gently sloping alluvial fan where open cracks on road pavements clearly showed that this part of ground slightly spread sideways causing uneven deformations of continuous footings for these houses. This fact indicates that not only intense shakes but also slight deformations of soils, which may have been built up even before the earthquake, can be crucial in discussing earthquake-inflicted damages.

Tiles chopped off roof ridges were most frequently found in the areas affected by the 2009 earthquake. An attempt was thus made to plot locations of the damaged roof ridges that the authors found during their surveys (August 11th, September 11th and 12th) on maps of inundated areas and/or areas of scenario inundation. Inundated areas that appear in record heavy rains often indicate the presence of wet flood-prone areas before the rapid growth of the city.

Shizuoka City

Balloons in Fig. 6 show the locations of damaged roof ridges plot on the inundation map of Shizuoka (Japan River Association, [12]). The dark colored area spreading northeast of the city was inundated in the heavy rain of July 7th, 1974. Shizuoka Observatory of the Japan Meteorological Agency saw its record-high 508 mm rail fall in just 24 hours (9:00 AM, July 7th to 9:00AM, July 8th, 1974). Water topographically stagnated northeast of the city. Shizuoka city spreads over an alluvial fan, which has been formed with sand, boulders, soils and other suspended matters that Abe River has carried over centuries. Abe River flows about 50 km straight through valley walls from north to south along the Itoigawa-Shizuoka Tectonic Line, one of the largest tectonic lines in Japan (see Fig. 1). The mountain ridge on its eastside becomes thinner as it goes south, and dies out at around Shizuoka City. Abe River sediments, which have been confined within valley walls until this point, suddenly spread out over the city area. Beyond the depositional reach, there remain swampy areas. Damaged houses are mostly found along depositional reach of Abe River sediments. The distribution of damaged houses also overlaps the areas damaged by the Shizuoka Earthquake of 1935 (Fig. 7). One exception is found north of the city where the urbanization was quite rapid after the World War II, and therefore few houses were there when the 1935 Earthquake occurred. The second exception is near Kuni-Yoshida, which is now developed as an industrial area and dwelling houses are rather small in number. It is also remarkable that damaged houses are found slightly inland of a sand dune along the coast of Suruga Bay.

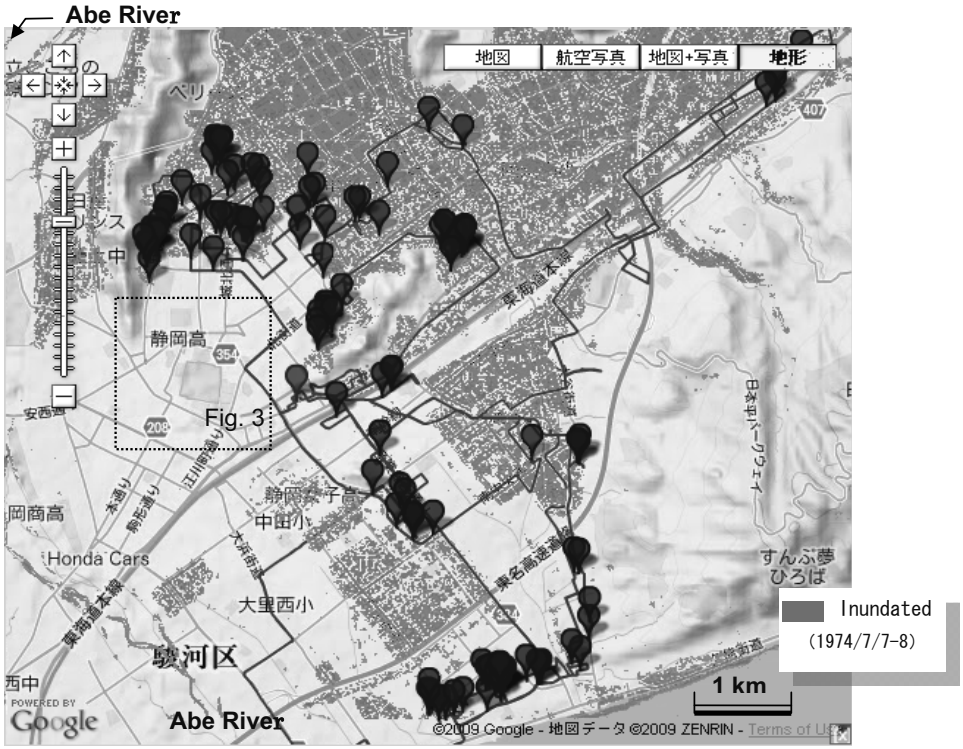


Fig. 6. Locations of damaged roofs (Baloons) observed in Shizuoka City (Aug. 17, Sept. 11th and 12th): Dark colored areas were inundated in the heavy rain of July 7th to 8th, 1974 (10). The area shown in Fig. 3 is boxed with broken line. Latitude and longitude for the center of the map: N34.979483°, E138.408723°

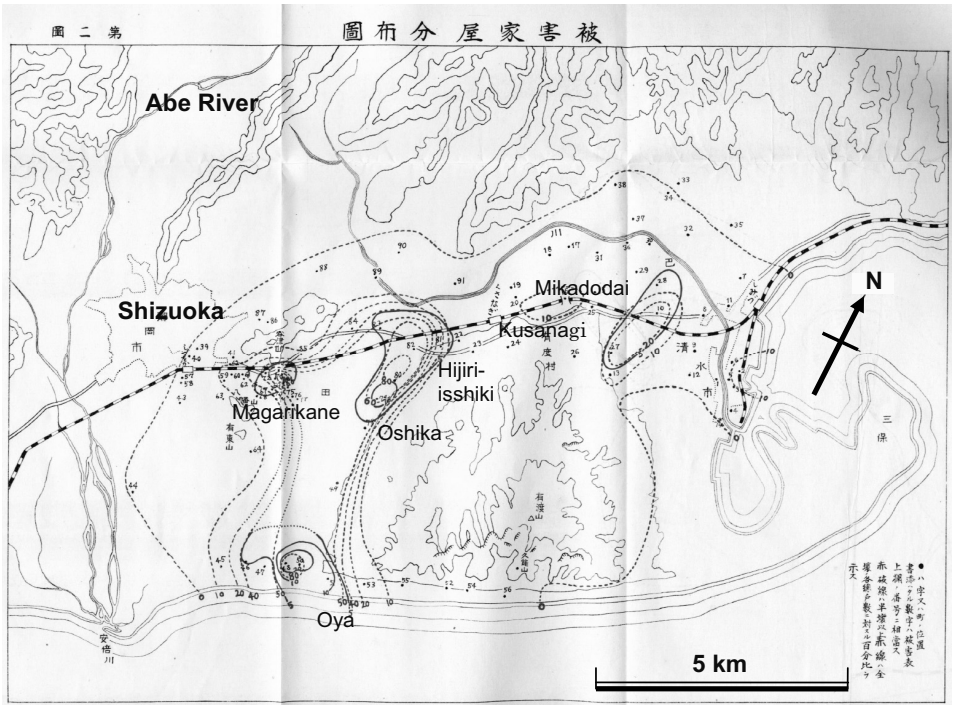


Fig. 7. Distribution of damaged houses in the 1935 Shizuoka Earthquake: Solid and broken contour lines show percentages of half-broken and completely destroyed houses, respectively（from the 2nd Report of the Shizuoka Earthquake, Numazu Observatory of JMA [10]）. Latitude and longitude for the center of the map: N34.990629°, E138.450737°

Yaizu City

Both the 1:20,000 scale map of Yaizu (Imperial Japanese Army, [14]) and the aerial photo taken by US Army in 1946 [15] show that Yaizu was developed as a fishing village near the mouth of Kuroishi River (Fig. 8). Kuroishi River is a small stream that flows from west to east on a wet flat plane until it reaches the sand dune along the Suruga Bay Coast. Then it takes a sharp turn, and flows north being confined behind the sand dune until it joins Koishi River and finally flows into Suruga Bay.

Fig. 9 shows the estimated inundation areas in Yaizu for the scenario rain that we can expect once every 30 years (Shimada Branch Office, Department of Construction, Shizuoka Prefecture). Balloons are locations of damaged roof ridges that the authors observed in their survey of September 12th, 2009. Balloons are found in “Jonokoshi”, “Iwashigashima” and “Ogawa” areas; these names are also found in old documents of the 1854 Ansei Tokai Earthquke (Emergency Management Agency, Shizuoka Prefecture, [16]) indicating that these areas have been susceptible to same damage in intense earthquakes.

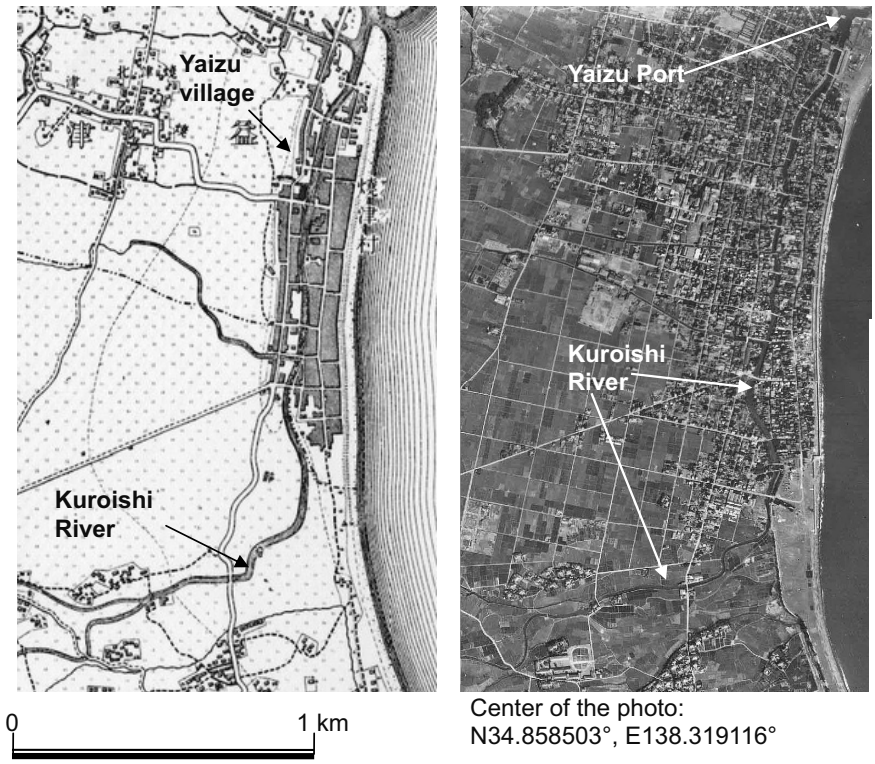


Fig. 8. 1:20,000 scale map of Yaizu (left, 1891) and the aerial photo taken by US Army (right, 1946)

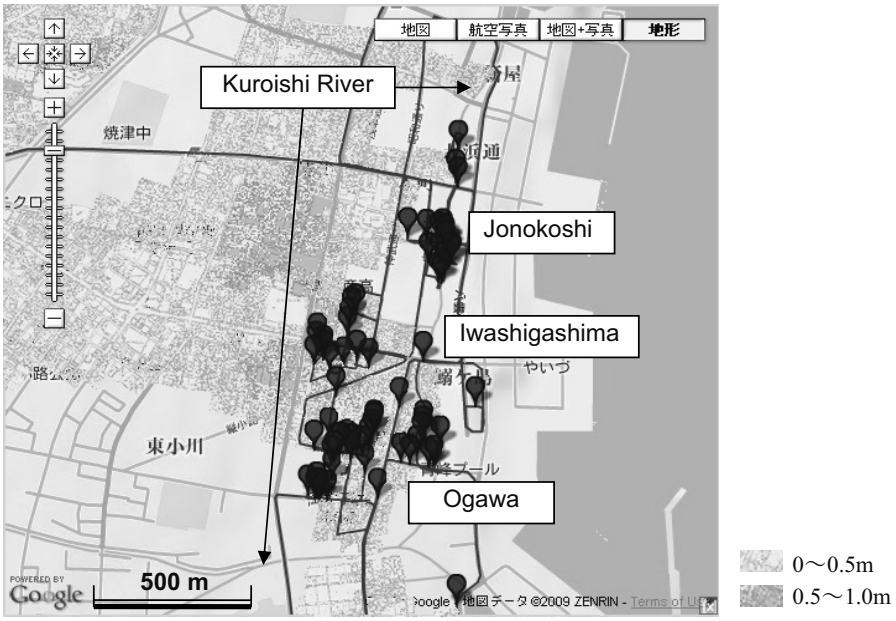


Fig. 9. Locations of damaged roofs (Baloons) observed in Yaizu City (Sept. 12th 2009): Dark colored areas were estimated inundated areas for the scenario rain that we can expect once every 30 years. Latitude and longitude for the center of the map: N34.859031°, E138.320446°

SUMMARY

Japan Meteorological Agency convened on Aug. 11th its private advisory body, and the advisory body drew a conclusion that the earthquake was neither the scenario Tokai Earthquake, nor the one that could trigger the Tokai Earthquake based on the followings:

(1) Magnitude 6.5 for this earthquake was far too small for the M8 class scenario earthquake.
(2) It was an intra-plate earthquake while the scenario earthquake is expected to occur at the boundary between Eurasia and Philippine Sea Plates.

However, since the area has been under a serious threat of a scenario mega-quake described in the "Act on Special Measures concerning Countermeasures against Large-scale Earthquake" enacted in 1978, this event can be viewed in such a way that we have gotten a rare opportunity to check all weak points revealed this time. Houses that suffered damage to their ridge roof tiles are to be carefully inspected for their seismic integrities. Owners of these houses can compile the records of what happened in their houses so that they can be well prepared for the scenario earthquake. These houses were often found in the labyrinth of narrow streets, and therefore, one of the foremost concerns is that these roads can be clogged up with debris discouraging evacuations and rescue operations. The problems that came out in this earthquake will be best resolved through a through discussion among both experts involved in disaster-prevention measures and local people.

ACKNOWLEDGEMENT

The authors are indebted to Toshihiko Katagiri, Tomohiro Fujita and Yumiko Matsumura at Konagai Laboratory, Institute of Industrial Science, University of Tokyo, who have devoted much of their energies especially to surveys in Shizuoka City. The authors are also thankful to Mr. Koji Iwata, Shizuoka Prefectural Earthquake Preparedness Education Center, for providing the authors with useful pieces of information.

REFERENCES

[1] Disaster Risk Management Office of the Fire and Disaster Management Agency (2009). Off-the-Coast of Suruga Bay Earthquake, Report No. 18, 2009-08-19.
[2] Private advisory body to the Director General of the Japan Meteorological Agency, "Press release No. 3", http://www.jma.go.jp/jp/quake_tokai/20090811112000.html, Aug. 11th, 2008.
[3] Nasu N., Yasuda C. (1935). The Shizuoka Earthquake of July 11, 1935, Bulletin of the Earthquake Research Institute, Vol. XIII, No. 4, pp.942-950.
[4] Hagiwara T. (1935). The Shizuoka Earthquake of July 11, 1935, Bulletin of the Earthquake Research Institute, Vol. XIII, No. 4, pp.951-965.
[5] Kinbara T. and Takemura T. (1935). Report on the Shizuoka Earthquake of July 11, 1935, Bulletin of the Earthquake Research Institute, Vol. XIII, No. 4, pp.966-984.
[6] Saita T. (1935). The Shizuoka Earthquake of July 11, 1935, Bulletin of the Earthquake Research Institute, Vol. XIII, No. 4, pp.985-1009.
[7] Independent Panel for investigation of causes of the damage to Makinohara fill section of Tomei Expressway (2009). Estimated causes, Minute of the 3rd Meeting, The Central Nippon Expressway Company, http://www.c-nexco.co.jp/corp/construction/maintence/pdf/makinohara3_02.pdf
[8] Terada T. (1935). Record of personal experiences in Shizuoka after the 1935 Shizuoka Earthquake, Fujin-no-tomo, 1935.
[9] Shimamura K. (1935). Report of the Shizuoka Earthquake, Report No. 3, Numazu Observatory of

the Japan Meteorological Agency.
[10] Shimamura K. (1935). Follow-up report of the Shizuoka Earthquake, Report No. 4, Numazu Observatory of the Japan Meteorological Agency.
[11] Konagai K. (2008): Damage to Civil Infrastructures, in the General Report of the 2007 Off-the-coast-of-Chuetsu Earthquake, Grant-in-Aid for Special Purposes of 2007, Ministry of Education, Culture, Sports, Science and Technology (MEXT). No. 19900003, Iwasaki T. eds., pp.145-146.
[12] Japan River Association (1991). Inundated area map, Vol. II for Hokuriku, Chubu and Kinki Regions.
[13] River and debris flow control bureau, Shizuoka Prefecture (2008). Envisioned inundated areas in Shizuoka Prefecture, http://doboku.pref.shizuoka.jp/kasen/measures/measures02_2.html
[14] Imperial Japanese Army (1891), 1:20,000 map of Yaizu, Topographical maps of Chubu Districts, 1886-1891, Vol. 1, p.89.
[15] US Army (1946). Aerial photograph of Yaizu, USA-M85A-6-103, Lands going through changes, Geographical Survey Institute, http://archive.gsi.go.jp/airphoto/ViewPhotoServlet?workname=USA&courseno=M85A-6&photono=103
[16] Shizuoka Prefectural Earthquake Preparedness Education Center (1996-2003). Histories of disasters of municipalities in Shizuoka Prefecture, Yaizu City, http://www.e-quakes.pref.shizuoka.jp/data/saigaishi/sh035.htm.