Distribution and Characteristics of Sediment-related Disasters Induced by the Great Kanto Earthquake in 1923

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The Great Kanto Earthquake (M7.9), which occurred in the Kanto Region on September 1, 1923, cost the lives of 105,000 people, including the dead and missing, as a result of the direct seismic impact and ensuing fires. Among the earthquake damage, sediment-related disasters alone occurred at 167 locations and produced at least 1,056 victims, including the dead and missing, though this fact is less known among the general public. The characteristics of the distribution of sediment-related disasters caused by the Kanto Earthquake was the subject of a report that focused mainly on the survey results of the most devastating sediment disaster. It was a deep-seated landslide that presumably started on a mountain slope named Obora and struck a hamlet called Nebukawa in Kataura village, which is the southern part of today's Odawara City, Kanagawa Prefecture, and went down the Shiraito River as debris flow. In Yokohama City, 27,000 people were killed due to the collapse of buildings and the ensuring fires. I trailed the escape route in Yokohama taken by O.M. Poole, the Japan regional manager of a British trading company.

Key words: Kanto Earthquake, sediment-related disasters, deep-seated landslide, Shiraito River, debris flow

1. INTRODUCTION

The authors researched the large sediment-related disasters in the historical age and reported on them in Interpraevent 2004, 2008, 2010 and 2012 (Mizuyama et al., 2004, Inoue et al., 2008, 2010 and Inoue, 2012).

The Great Kanto Earthquake (M7.9), which occurred in the Kanto Region on September 1, 1923, caused unprecedented damage, leaving 105,000 people dead or missing due to its severe shaking and ensuring fires. Another fact not commonly known is that the earthquake triggered sediment-related disasters at 167 locations and produced at least 1,056 victims, including the dead and missing (Inoue, 2013a, b, 2014). The deadliest sediment-related disasters occurred in Odawara City (former Kataura Village), Kanagawa Prefecture.

We conducted a survey of the disaster site, focusing on the deep-seated landslide and the ensuring debris flow that started at Obora and ran down the Shiraito River, engulfing the Nebukawa community.

This paper describes the characteristics regarding the distribution of sediment disasters induced by the Great Kanto Earthquake.

2. DISTRIBUTION OF SEDIMENT-RELATED DISASTERS

Figure 1 is a distribution diagram of the total housing destruction ratio (the number of totally destroyed houses/the total number of houses) of the Great Kanto Earthquake damage by a district unit. Since the total housing destruction ratio is closely related to the seismic intensity scale of Japan Meteorology Agency (JMA), this diagram may be read as a seismic intensity distribution diagram of the Kanto Earthquake. The fault plane location of the epicenter zone of the Kanto Earthquake is shown in this figure.

The area immediately above the fault plane of the epicenter zone, shown with a broken line, records over 1% in total destruction ratio in almost the entire area. This suggests that strong motions, which, at a minimum jolted at 6 or greater on the JMA scale, occurred in those areas. In particular, a total destruction ratio of over 30% was observed in the Sagami Plain and the Ashigara Plain in Kanagawa Prefecture as well as the Tateyama Plain at the front end of the Boso Peninsula. These plains were hit by strong motions measuring 7 in seismic intensity.

The total destruction ratio is generally low in the

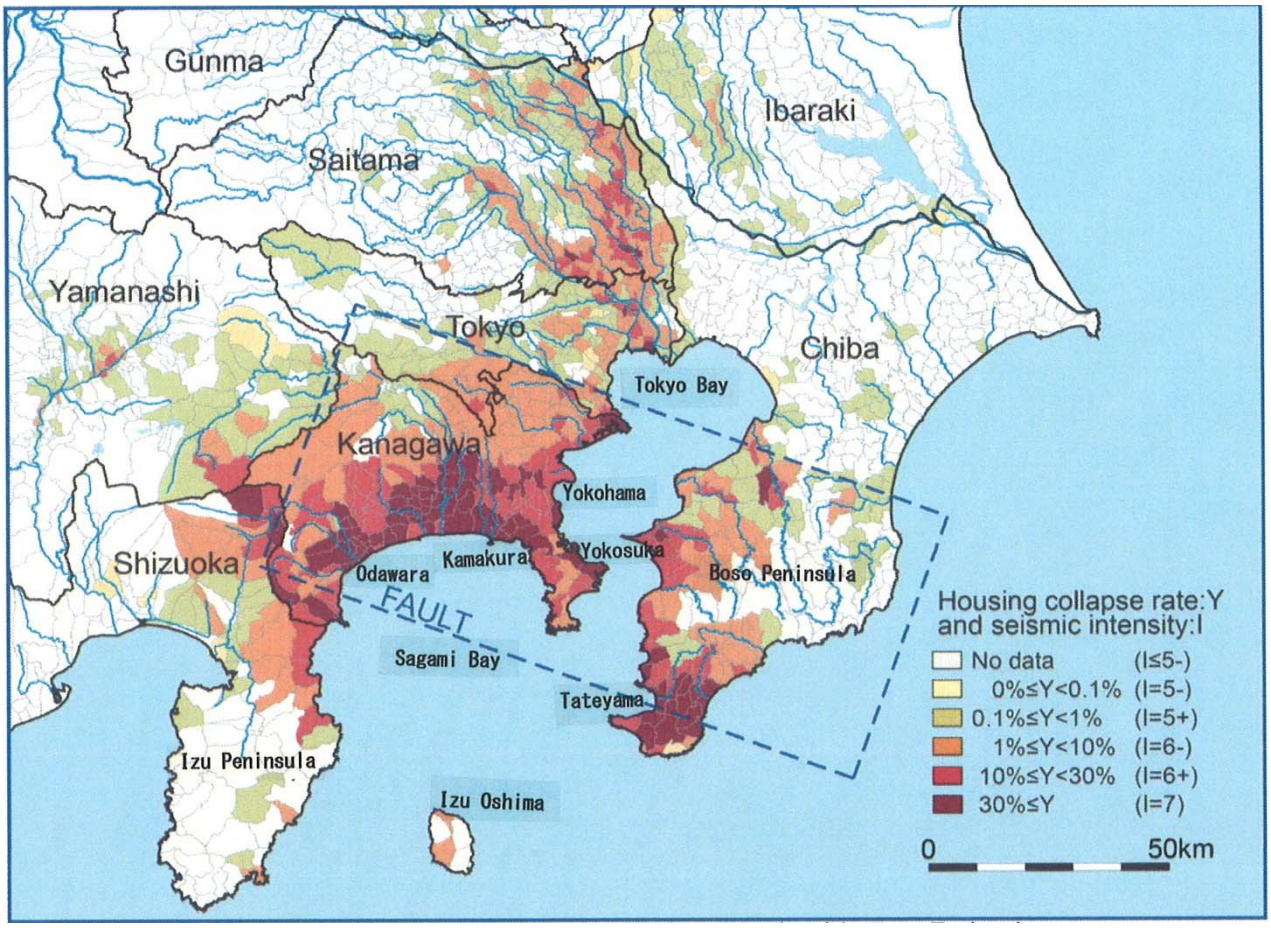

Fig. 1 Distributions of the total housing destruction ratio and seismic intensity of the Kanto Earthquake (Moroi and Takemura, 2002, and Moroi, 2008)

areas away from the fault plane. A seismic intensity of 6 plus or 7 was recorded sporadically from the eastern part of Saitama Prefecture to the waterfront of Tokyo Bay, with a total destruction ratio of over 10%.

These shaky areas correspond to the areas referred to as alluvial lowlands and almost agree with the former watercourses of the ancient Tone River or the Arakawa River, which were located in different positions from where they are presently. The facts surrounding the total housing destruction ratio of the Kanto Earthquake demonstrate that the intensity of seismic motion is greatly affected not only by the distance from the epicenter, but also by the ground conditions.

Figure 2 is a schematic diagram of the landslide zones in the wooded areas damaged by the Kanto Earthquake and it was attached to the back of the Taisho Earthquake Report (Social Bureau of the Home Ministry, 1926).

The background of the diagram is a geologic map of the Kanto Region.

a. Paleozoic strata
b. Misaka strata
c. Neogene strata
d. Diluvial strata
e. Alluvial strata
f. Volcanic rock
g. Granite
h. Diorite
i. Serpentine
j. Diabase
k. Mesozoic strata

The landslide zone in the damaged wooded area is divided into three types.

A: devastating landslide zone
B: frequent landslide zone
C: minor landslide zone

This figure additionally indicates 167 locations of sediment disasters caused by the Kanto Earthquake, including 66 in the eastern part and 35 in in the eastern part of Kanagawa Prefecture, 7 in the eastern part of Shizuoka Prefecture, 12 in Yamanashi Prefecture, 5 in Tokyo Metropolis, and 42 in the southern part of Chiba Prefecture. The schematic landslide diagram is in good agreement with the distribution of sediment-related disasters.

There was heavy rainfall that began on the day

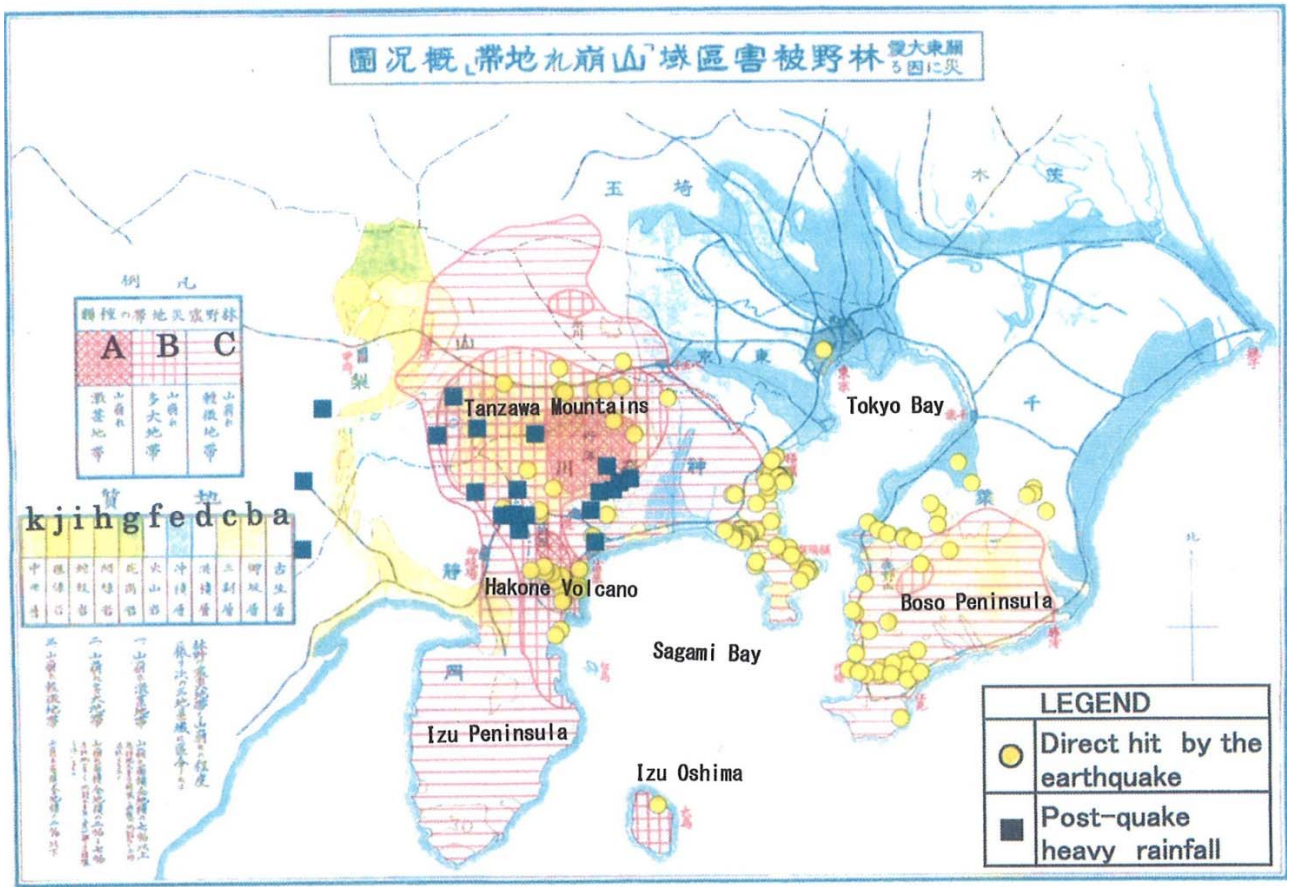

Fig. 2 Schematic diagram of the landslide zones in the wooded areas damaged by the Kanto Earthquake (Modified from Social Bureau of the Home Ministry, 1926) and the landslide disaster locations by the same earthquake (Inoue, 2013a, b).

before the Earthquake and lasted until the morning of the Earthquake (Inoue and Ito, 2006), and the severe shaking of the Earthquake caused sediment-related disasters in various areas (marked with a "○"). Sediment-related disasters frequently occurred because of torrential rainfalls brought by a typhoon that passed through the area from Sept. 13 to 15, about two weeks after the Earthquake (marked with a "■").

Table 1 shows the fatalities, the number of damaged houses, and the number of river channel closures resulting from the sediment-related disasters caused by the Kanto Earthquake.

The eastern part of the Tanzawa Mountains in the western area of Kanagawa Prefecture falls under A: devastating landslide zone, while the area around the Tanzawa Mountains and the Hakone volcanic area fall under B: frequent landslide zone. Sediment -related disasters was frequently caused by the direct impact of the Earthquake and the heavy rainfall two weeks thereafter.

From September 6 through 15, 1923, immediately after the Earthquake, the Japanese Imperial Land Survey in the General Staff Office of the Imperial Army conducted a detailed site survey and added the survey results in red onto the topographic maps published in those days (made up of 63 topographic maps). Figure 3 is an original emergency survey map of the damaged area in the southern part of Odawara City based on a 1:50,000 scale map "Odawara" corrected in 1916. The status of sediment-related disasters and the conditions of earthquake damage are written on the map in detail.

Table 1 Sediment disasters caused by the Great Kanto Earthquake (Inoue, 2013a, b)

Area	No. of Locations	Dead or Missing	No. of Damaged houses	No. of closed River Channels
Western part of Kanagawa Prefecture	35	644 amd 74 respectively	264	5
Eastern part of Kanagawa Prefecture	66	295 and 65 respectively	203	0
Inside the city of Yokohama	27	68 and 60 respectively	83	0
Inside the city of Yokosuka	20	220 and 5 respectively	111	0
Inside the town of Kamakura	19	7	9	0
Eastern part of Shizuoka Prefecture	7	64	8	1
Yamanashi Prefecture	12	4	0	0
Tokyo Metroporis	5	12	2	0
Southern part of Chiba Prefecture	42	37	16	6
Total	167	1056 and 139 respectively	493	12

In the Nebukawa area in the former Kataura Village, which is currently part of the present Odawara City facing Sagami Bay, the somma of the Hakone volcano, 64 houses were buried, 420 people

Fig. 3 Earthquake damage emergency survey map (1:50,000) of Odawara (Society of Historical Earthquake Studies, 2008)

died, and 68 went missing as a result of large-scale debris flow in the Shiraito River and the landslide near Nebukawa Station. Immediately north of Nebukawa was an area called Komekami, in which a landslide started at a mandarin orange field and rolled downward as debris flow, burying 21 houses and killing 62 villagers.

Many sediment-related disasters occurred inside the Hakone volcano and the area along the coast. Back in the days when the Earthquake occurred, one of the main trunk roads connecting Tokyo and Osaka, the Tokaido Highway, crossed through the Hakone volcano, and many hot spas, collectively called Hakone's 12 Hot Spas, were located in Hakone. A large number of people, including foreigners, visited Hakone to enjoy the hot spa. As severe tremors hit this mountainous area, many hot spa inns crumbled, leading to the death of 48 people. The Hakone Tozan Railway and motor roads were destroyed at various locations. This traffic severance left Hakone marooned, preventing many hot spa visitors from returning to their homes in Tokyo or Yokohama.

Slope failures and landslides occurred at various places in urban areas in the eastern part of Kanagawa Prefecture, including Yokohama, Kamakura and Yokosuka. In particular, the old urban area of Yokohama City, stood on soft ground, and the number of fatalities, including the dead and missing, went up to 27,000 people due to the destruction of houses and fires that spread from various places. Although Yokohama’s citizens tried to run toward the hilltops around their residences to escape from housing destruction and fire, many of them were burnt to death because they could not go up on the hilltops because of the stairs installed on the steep slopes leading to the hilltops had collapsed. In Yokohama city, 27 locations were damaged by sediment-related disasters, 68 citizens were killed and 60 citizens went missing. It is highly likely that this total contained a large percentage of sediment-related disaster victims.

In Yokosuka City, which has steeper slopes than

Yokohama, sediment-related disasters occurred at 20 locations, causing many fatalities, leading to over 220 deaths and 5 missing persons. In Kamakura Town, although the death toll was low, Shinto shrines and Buddhist temples collapsed. Steep slopes along mountain passes or the entrances of mountain tunnels along roads connecting Kamakura and the surrounding areas also collapsed. Coupled with the damage caused by the tsunami, this ancient capital of Japan temporarily became marooned.

As shown in Figure 2, many sediment disasters occurred in Yamanashi Prefecture, the eastern part of Shizuoka Prefecture, Tokyo Metropolis (including Izu Oshima Island), and the southern part of Chiba Prefecture.

Sediment-related disasters occurred in an area larger than conventionally understood. These areas suffered not only sediment-related disasters caused by the direct impact of the Kanto Earthquake, but also sediment and flood disasters resulting from the arrival of a typhoon two weeks later.

3. DEEP-SEATED LANDSLIDE AT OBORA AND SHIRAITO RIVER DEDRIS FLOW DAMAGE

Large-scale, sediment-related disasters occurred on the eastern slope of the somma of Hakone Volcano in the west part of Kanagawa Prefecture, namely Nebukawa, and Komekami, as a result of the Great Kanto Earthquake. Figure 4 is a distribution map of the debris flow in the Shiraito River and the landslide that hits Nebukawa Station. Accurate information on the debris flow and the landslide was obtained from survey maps prepared in 1975 by Kazumasa Uchida. He was 10 years old at the time of the earthquake, and later became a mandarin orange farmer who served as a village assemblyman, made efforts to pass his records of the Great Kanto Earthquake down to other generations. He wrote his personal notes 60 year after and his son, Akimitsu Uchida published in 2000.

Figure 5 shows the status of sediment-related disasters compiled by Uchida in 1975, and clearly shows the status of debris flow. The center figure shows the plain of the downstream movement of the debris flow, the right figure shows the longitudinal sections of the riverbed and the left figures shows the sections of the river valley of the Shiraito River. Kobayashi(1979) and Kamai(1990, 1991) conducted detailed topographic and geological surveys in this area, with Kazumasa Uchida as a guide.

Obora is the name of the place where the debris flow started. A clear sign of the deep-seated landslide can still be seen there. We conducted a field survey at the headwaters of the Shiraito River in December 2012 and April 2013 with Akimitsu Uchida as a guide.

A great number of photos of Obora are placed in the reports published by the Social Bureau (1926) or the Restoration Bureau (1927) of the Home Ministry.

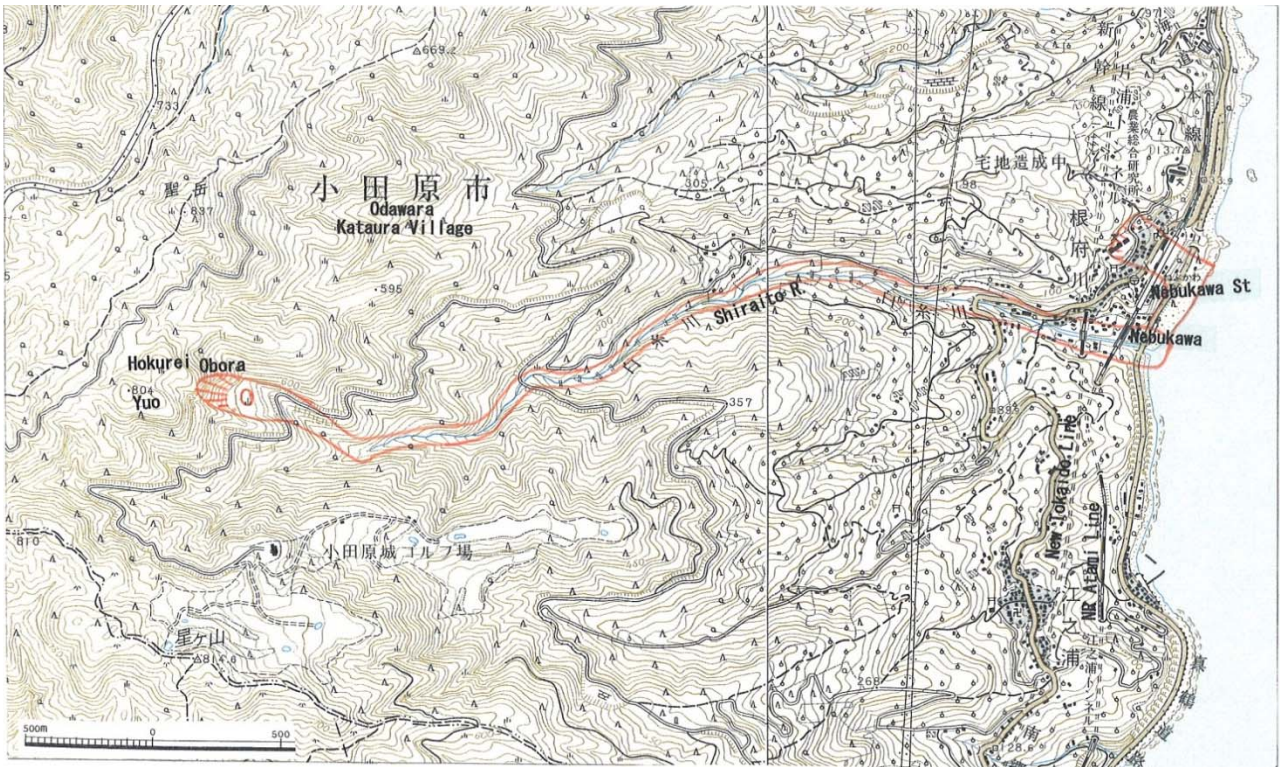

Fig.4 Distribution of the debris flow in the Shiraito River and the landslide at Nebukawa Station

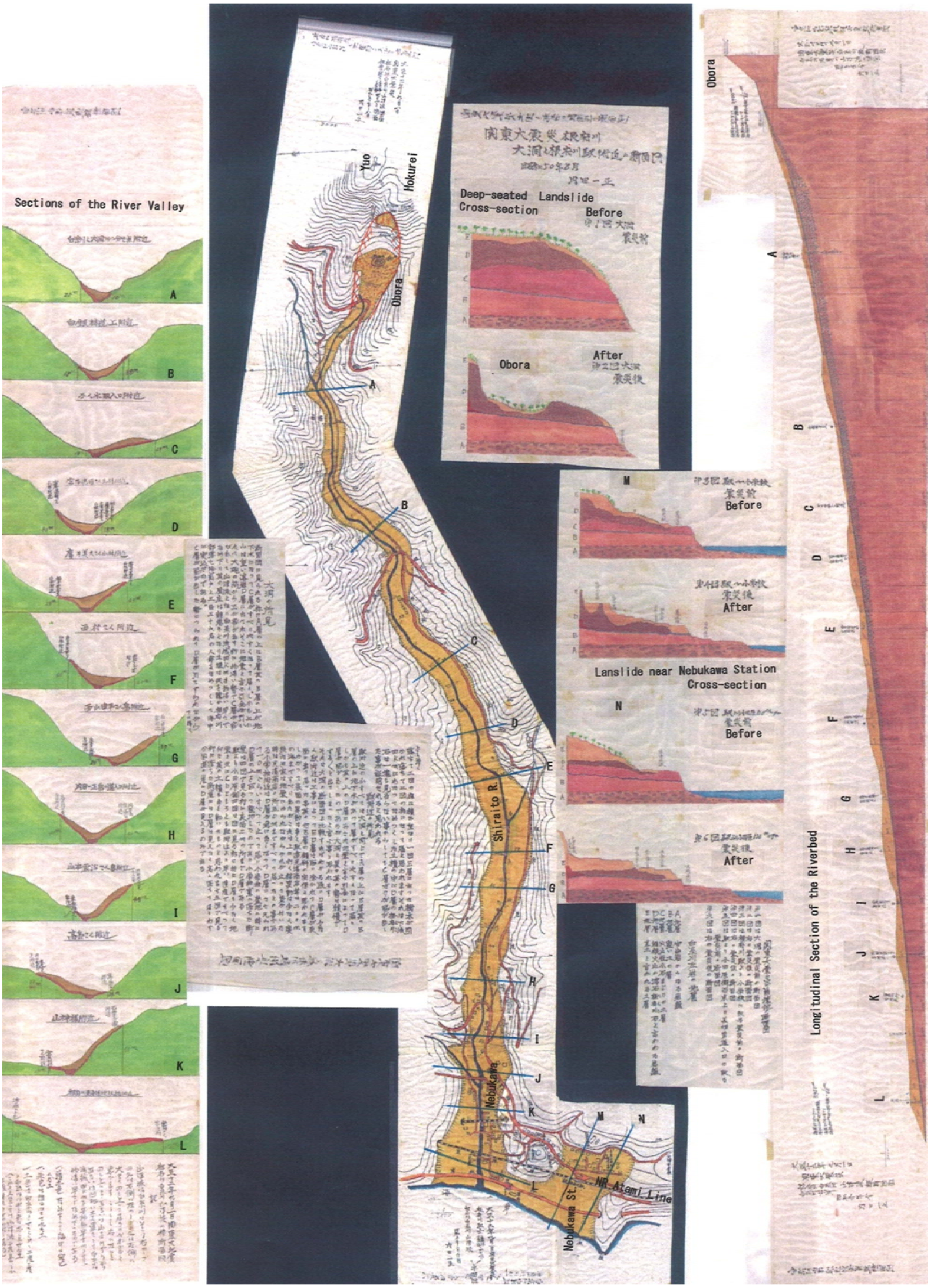

Fig.5 Sediment related-disaster in the Shiraito River basin (Nebukawa hamlet and Nebukawa Station) (Uchida 1975, source : Kanagawa Prefectural Archives)

Photo 1 Topography of the Obora failure site and flow mound at the lower part of the failure site (Restoration Bureau, 1927)

Photo 1 is a picture taken by an employee of the Restoration Bureau who climbed up the headwaters of the Shiraito River, to a point near Obora as part of the survey to develop restoration measures for the Atami Line of the National Railways (since there was an ongoing plan to complete the constructing the Tanna Tunnel and open the Tokaido Main Line). It shows a flow mound (small hill) formed at the lower part of the slope as a sign of the large-scale, deep-seated landslide.

Photo 2 is a three-dimensional aerial photo of the area near Obora, upstream of the Shiraito River, and it was taken in 1962.

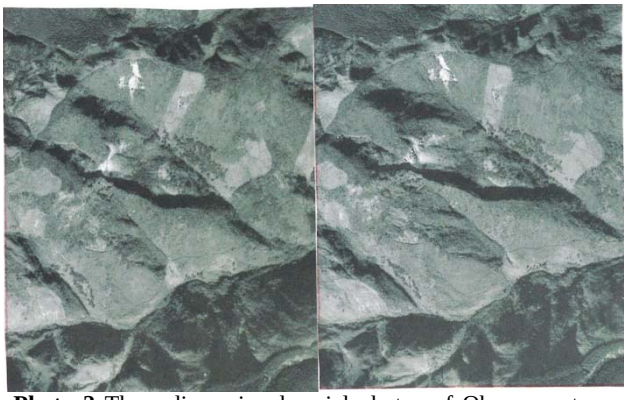

Photo 2 Three-dimensional aerial photos of Obora, upstream of the Shiraito River (taken in 1962, CKT-62-3X, C6-10, 11)

The Shiraito River is a steep river flowing eastward from the somma of the Hakone volcano. From an old topographic map, it is estimated that 1,080,000 m^3 of debris collapsed in the deep-seated landslide at Obora. Of this volume, an estimated 260,000 m^3 remained at hummocky hills (small hills) immediately below the collapsed site. The remaining 820,000 m^3 ran down the Shiraito River as debris flow over a channel length of 3,500 m and with an elevation difference of 500 m. Since the debris flow hit the Nebukawa hamlet in five minutes, the flow is estimated to have moved at a velocity of about 12 m/s (42 km/hr.).

According to a geological exploration, we found that two lava domes, called Hokurei (North Peak) and Yuo (South Peak), as well as a number of linear depressions existed near Obora. The deep-seated landslide of Obora is characterized by lava with conspicuously developed tabular joints (Nebukawa Lava and O_{18} lava as defined by Kuno, 1938), and the flow mound (small hill) at the foot of the slope contains a large amount of tabular lava pieces.

Since heavy rain fell on August 31, one day prior to the occurrence of the Great Kanto Earthquake, it is estimated that the groundwater level rose in the Obora area and that the strong tremor of the earthquake triggered the start of a deep-seated landslide.

According to the personal notes of Uchida (2000), he fled from his house as soon as he heard someone screaming “A mountain is coming! Get away quickly!" soon after the second earthquake subsided (the M7.3 aftershock at 12:03 on the same day). He ran up to a point in a mulberry field about 30 m from a house located north of his house. As he turned back, he saw that many houses in the hamlet, including his, were swept away by the debris flow in less than a minute.

Based on analysis of the passage of time, it is thought the large-scale, deep-seated landslide of Obora occurred following the major tremor caused by the Earthquake at 11:58. With the aftershock at 12:03, the Obora landslide went down as debris flow together with the water of the Shiraito River, with a rising water level.

Of all the 159 houses in Nebukawa hamlet, 78 were buried in the debris, and 289 villagers were killed. In addition 20 children, who were playing on the beach, were killed by a combination of the tsunami and debris flow. The landslide near Nebukawa Station

killed a total of 131 people, including 109 train passengers and 22 at the station and on the platform.

This debris flow totally washed away the Shiraito River Bridge of the NR Atami Line (today's Tokaido Line). The bridge was reconstructed in March 1925 (the Tanna Tunnel was completed in 1934).

4. TRAILING THE EBACUATION ROUTE OF O. M. POOLE IN YOKOHAMA

Otis Manchester Poole, who was 43 at that time, was the general manager of Dodwell & Co. Ltd. in Japan, a British trading firm, and had lived in Yokohama for 35 years prior to the occurrence of the Kanto Earthquake. He maintained a detailed record of how he fled for a few hours on September 1, the day of the Great Kanto Earthquake, immediately after its outbreak in his book titled "The Death of Old Yokohama in the Great Japanese Earthquake of September 1, 1923," published in 1968, 45 years later, and translated by Madoka Kanai in 1976.

I walked along his escape route for the purpose of the survey based on Figure 6 (survey map in 1922), Figure 7 (survey map in 2005) and Table 2 (View Point). The view-points related to the sediment-related disasters were given in the following. The office of Dodwell & Co. Ltd. was located in Kannai (Point 0, 72-banchi, Yamashita-cho).

"Although the building did not collapse, almost all the surrounding buildings were destroyed, and fires occurred in various parts of the neighborhood. He headed to his home on the hilltops (Point 7, 68-banchi Yamate-cho) together with his employees to see his wife Dorothy and his three children. Almost all buildings in China-town, etc. were destroyed, and fire broke out in various parts of the neighborhood. They passed beside China-town, where there were no fires, continued to the long of gay, open-fronted native shops had disappeared, its location indicated only by a V-shaped channel of jack-straws (present reconstructed the shopping street of Motomachi). They moved up to the hilltops residential area where his home was located. However, they found that the hundred steps (Point 5) leading from Motomachi to the uptown area had severely collapsed (Photo 3). One of them had meanwhile gone ahead; and at this point another person and he also separated. Therefore, He found took a detour to Daikanzaka and managed to reach his home on the hill-side. Since he found nobody at home, he looked for his family members while calling out their names. At long last, he found his wife and children taking shelter at No.89, where

Fig. 6 Escape route taken by O. M. Poole
1:10,000 scale topographic map of the southern part of Yokohama neighborhood (survey map in 1922)

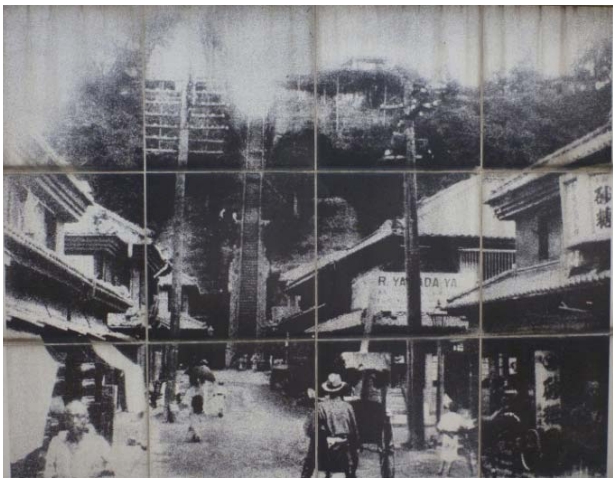

Photo 3 The Hundred Steps leading to Asama Shrine from Motomachi (before the Earthquake)
(Porcelain panel photo located at the Hyakudan Park)

Poole had lived for thirty years until Mother's death. He and his family members discussed what to do and decided that they should all flee to his father-in-law's yacht moored at the French wharf (Point 15) in the Port of Yokohama. However, the fierce fire that came from the surroundings blocked all the routes they could take to go to the wharf. He considered various ideas to go down a steep slope with a drop of 40 m from the British Navy Hospital.

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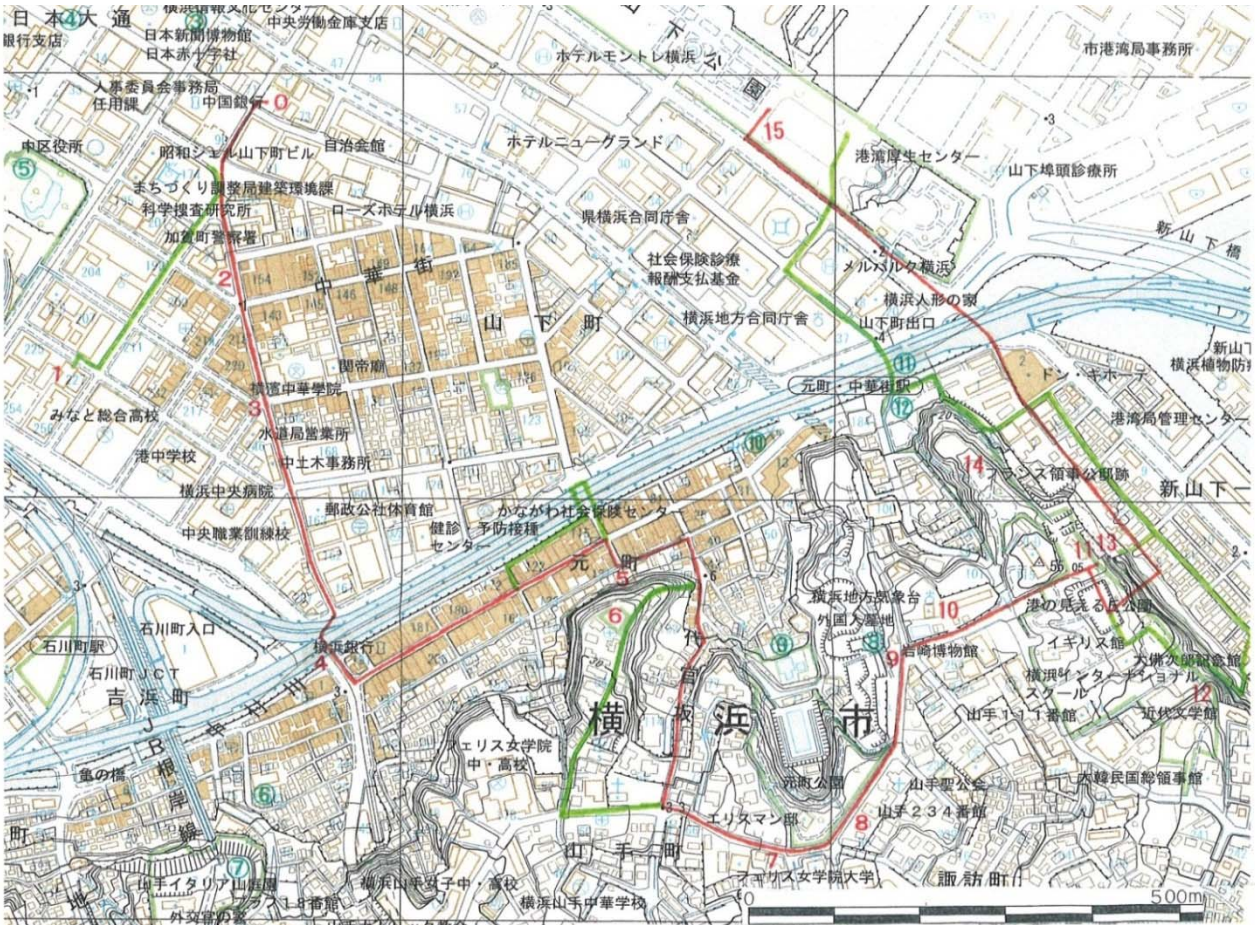

Fig. 7 O. M. Poole's escape route (red line) and the route taken by the field tour (green line)
The background is the 1:10,000 scale map of Kannai (edited in 2005).

considered various ideas to go down a steep slope with a drop of 40 m from the British Navy Hospital (present Harbor View Park) to a reclaimed site (with almost no houses or buildings standing there in those days), but he found there was devastating fire coming very close to his house. That made them decide to climb down the cliff (Point 13). They stripped the tennis courts of their surrounding nets and dropped them down the cliff. The nets didn't reach even the middle of the cliff. He carried his child on his back, climbed down to the middle with the net, and fortunately found a foothold half way down the cliff. He finally succeeded in bringing all of his family members down the cliff.

Neighboring Japanese saw the foreigner success -fully landing on the reclaimed site and decided to jump over the cliff as they couldn't stand the heat of the looming fire. It was reported that many people were injured as they jumped down the cliff.

Although Poole's family safely arrived at the reclaimed site, they could not reach the French wharf as the urban area of Yokohama was devastated by the tremor and fierce flames. They went past the Grand Hotel building which was still on fire and successfully found an escape route to their yacht on the wharf. All his family members at last reached his father-in-law's yacht."

Table 2 View Points of Escape route taken by O. M. Poole

No.	Point
0	Vestige of Dodwell & Co. Ltd.
1	Yokohama YWCA
2	Kagamachi Police Office
3	Westside of China-town
4	Nishi-no-hashi brige over the Hori River
5	Hundred Steps (before rhe earthquake)
6	Motomachi Hyakudan (Hundred Steps) Park
7	Poole's Home
8	Yamate Museum
9	Foreign Graveyard
10	Yokohama Meteorogical Observatory
11	Harbor View Park (British Navy Hospital)
12	Kanagawa Museum Mordern Literature
13	Criff of Yamate Terrace
14	Vestige of France Consular Office
15	Yamashita Park (Vestage of French wharf)

5. AFTERWORD

Some 91 years have passed since the occurrence of the Kanto Earthquake. The earthquake-afflicted areas in the southern part of the Kanto Region

developed road, and railroad networks of high importance and there is highly advanced use of land. Concrete structures and quakeproof and fireproof houses have increased in number. Considering this, even if a big ocean-trench earthquake or inland earthquake occurs, it is expected that the number of destroyed houses or subsequent fires will be fewer than those seen in 1923 (although flammable items such as vehicles are increasing in number).

It is however feared that many sediment-related disasters could occur at such steep slopes in the mountains and hills, where no serious damage occurred due to the Great Kanto Earthquake, because housing construction has been widely promoted near or on the steep slopes. Areas available for shelters, namely wooded areas, farmland, or parks, have also greatly decreased. It is likely that sediment disasters in densely populated areas would cause damage greater than that in 1923. From this viewpoint, it is considered necessary to revise the current earthquake-induced sediment disaster control or response measures in areas expected to be affected by large-scale earthquakes that are predicted to occur, such as a large ocean-trench earthquake or a major inland earthquake under Tokyo Bay.

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