Chapter 1 Review of the Response to the GEJE

The 2011 off the Pacific coast of Tohoku Earthquake and the tsunami caused enormous damage to a wide area centered on the Tohoku district and ranging from Hokkaido to the Kanto district. The earthquake and tsunami caused a nuclear accident at the Fukushima Nuclear Power Stations (NPSs) of Tokyo Electric Power Company (TEPCO) as well, which discharged a large quantity of radioactive substances into the environment. Over one year and three months have passed since the disaster, however, a large number of residents are still compelled to live in shelters. The Great East Japan Earthquake (GEJE) caused great damage to Japan's society and economy as well. Section 1 in this chapter briefly describes the occurrence of the disaster, extent of damage caused and its various impacts (on the domestic and international societies and economies, and Japan's scientific and technical activities). Furthermore, Section 1 describes the progress of governmental measures taken after the GEJE and the progress of those taken after the nuclear accident at the TEPCO Fukushima NPSs, along with various problematical points that came to light, and lessons learned from the earthquake and nuclear accidents.[1]

The disaster made a change in the Japanese people's consciousness of S&T. Japan's cutting-edge S&T, in which it took pride showed its limits in the rage of Nature. In that sense, it can be said that Japan's cutting-edge S&T could not fully respond to expectations of the Japanese people. Section 1 in this chapter takes a real look at the change in the people's consciousness of S&T after the disaster based on the results of surveys, such as awareness surveys, and summarizes action assignments that the disaster imposed on Japan's S&T policy.

Section 1 Impact of the GEJE and Responses to it

1 Impact of the GEJE

(1) Occurrence of the GEJE

1) The 2011 off the Pacific coast of Tohoku Earthquake and Tsunami

The great earthquake with a magnitude of 9.0 (a scale of M9.0) occurred at 14:46 on March 11, 2011. Its epicenter was approximately 24 km deep off the coast of Sanriku and 130 km to the east-southeast of the Oshika Peninsula in Miyagi Prefecture. A seismic intensity of seven on the Japanese scale was observed in Kurihara City, Miyagi Prefecture, and a seismic intensity of six upper was observed in 37 municipalities in four prefectures, i.e., Miyagi Prefecture, Fukushima Prefecture, Ibaraki Prefecture, and Tochigi Prefecture.

The range of source area was approximately 500 km north and south and 200 km east and west. It was considered that there was a fault slippage of a maximum of 50 m or over. The earthquake motion continued for a long time in each district. A seismic intensity of four or over continued for 190 seconds in Onahama in Iwaki City, Miyagi Prefecture. The earthquake caused a great coseismic crustal deformation, where a horizontal crustal movement of approximately 5.3 m and a vertical crustal movement of

1 This White Paper describes the situation of the earthquake and accidents along with measures taken as of the end of FY 2011.

approximately 1.2 m were observed. Ground subsidence and liquefaction occurred in the extensive area from the Tohoku district to the Kanto district. It has been confirmed that the seafloor reference points off Miyagi Prefecture, which is almost above the epicenter, moved approximately 24 m in the east-southeast direction and rose approximately 3 m.

The seismic activity continued in mainshock-aftershock type[1]. Aftershocks were concentrated in the area that is approximately 500 km long and 200 km wide from the offshore of Iwate Prefecture to that of Ibaraki Prefecture, which corresponds to the hypocentral region. An aftershock of M7.6, which occurred off Ibaraki at 15:15 on March 11, 2011, was the greatest. Up to March 31, 2012, 661 aftershocks of M5.0 or greater were observed. In addition, the level of seismic activity outside the aftershock area increased. The occurrence of an earthquake of M6.7 was observed close to the prefectural boundary of Nagano and Niigata at 3:59 on March 12, 2011, and another earthquake of M6.4 was observed in the eastern part of Shizukoka Prefecture at 22:31 on March 15 with a maximum seismic intensity of six upper.

The GEJE was an ocean-trench earthquake[2] that occurred in the boundary (fault) of the Pacific Ocean plate (oceanic plate) and the North American plate (continental plate). Not only the deep plate boundary but also the shallow plate boundary slipped and moved greatly at the same time causing the earthquake. This caused a tsunami of a scale far beyond expectations.

The Japan Meteorological Agency (JMA) issued a tsunami warning (a warning of a major tsunami) for the coastal areas of Iwate Prefecture, Miyagi Prefecture, and Fukushima Prefecture three minutes after the occurrence of the earthquake. In addition, JMA issued a tsunami warning (a warning of a tsunami) and tsunami advisory for the Pacific Ocean coast ranging from Hokkaido to Kyushu and for the Ogasawara Islands (the Bonin Islands). JMA consecutively issued follow-up announcements to expand the applicable range of the tsunami warning and tsunami advisory. JMA issued a tsunami warning and tsunami advisory for all the coastal areas of Japan before dawn on March 12. A tsunami with a height[3] of 9.3 m or over was observed in Soma of Fukushima Prefecture and that with a height of 8.6 m or over was observed in Ayukawa of Ishinomaki City, Miyagi Prefecture. The tsunami was observed in a wide area ranging from Hokkaido to Okinawa, centered on the Pacific Ocean side from the Tohoku district to the northern part of the Kanto district. According to the 2011 Tohoku Earthquake Tsunami Joint Survey Group organized under the initiative of the Japan Society of Civil Engineers, a flow upstream[4] of 40 m or over, which was the greatest flow upstream in domestic observation history, was confirmed in Iwate Prefecture. The Geographical Survey Institute announced that the approximate flooding range of the tsunami was 561 km^2 (approximately nine times as large as the area within the Yamanote Line).

The earthquake and tsunami caused serious human and property damage centered in the Tohoku district and caused the accident at the TEPCO Fukushima NPSs.

2) Accident at TEPCO Fukushima Daiichi and Daini NPSs

With the occurrence of the 2011 Off the Pacific Coast of Tohoku Earthquake, the nuclear reactors of

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1 A pattern of seismic activity in which a great earthquake (called mainshock) is followed by subsequent aftershocks that are less greater than the mainshock.

2 Distortions are accumulated in the boundary of a continental plate and oceanic plate when the oceanic plate pulls the continental plate while the oceanic plate sinks. When the distortions reach a breaking point, the boundary of the plates slips suddenly, and an earthquake occurs close to the trench. This type of earthquake is called an ocean-trench earthquake.

3 The height of a tsunami is the difference in height between normal sea level and elevated sea level caused by the tsunami.

4 A flow upstream is the height of a tsunami rushing to the inland from the shore.

Unit 1 to Unit 3 in operation at TEPCO Fukushima Daiichi NPS came to a stop automatically. The NPS lost all external power supplies. The emergency generators of the NPS came to a stop as well due to the influence of the tsunami, and the NPS lost all AC power supplies. Afterwards, Unit 1 to Unit 3 lost the cooling function of the reactors, which resulted in core meltdown and eventually led to a hydrogen explosion. This caused a discharge of a large quantity of radioactive substances (hereinafter referred to as radioactive substances from the accident). TEPCO Fukushima Daini NPS escaped loss of external power supplies. As a result, Unit 1 to Unit 4 reached cold shutdown conditions on March 15, 2011 March.

Instructions on evacuation with restrictions on food shipments and intake were given to the residents in the area, due to a large quantity of radioactive substances from the accident discharged as a result of the accident at TEPCO Fukushima Daiichi NPS. In addition, the economic damage of harmful rumors spread throughout Japan. Furthermore, rolling blackouts were implemented and power usage restrictions were imposed due to power shortages in the service area of TEPCO.

The GEJE became a compound disaster that the Off the Pacific Coast of Tohoku Earthquake, the tsunami and the accident at TEPCO Fukushima NPSs. Japan had to face a large number of unprecedented difficult problems.

(2) Situation of Damage

1) Human Damage and Building Damage

The 2011 off the Pacific coast of Tohoku Earthquake and the tsunami caused heavy human damage and building damage centered in the Tohoku district. The earthquake and tsunami claimed 15,854 lives and totally destructed 129,431 houses with 3,089 people missing[1] (as of March 28, 2012). Due to the enormous damage caused by the earthquake and tsunami and the influence of the radioactive substances from the accident, the number of evacuees throughout Japan reached 344,345 (as of March 22, 2012)[2] (refer to Figure 1-1-1). In Fukushima Prefecture, where evacuation directive had been issued, approximately 161,000 people were evacuated, out of which approximately 98,000 people and 63,000 people were evacuated within the prefecture and outside the prefecture, respectively.[3]

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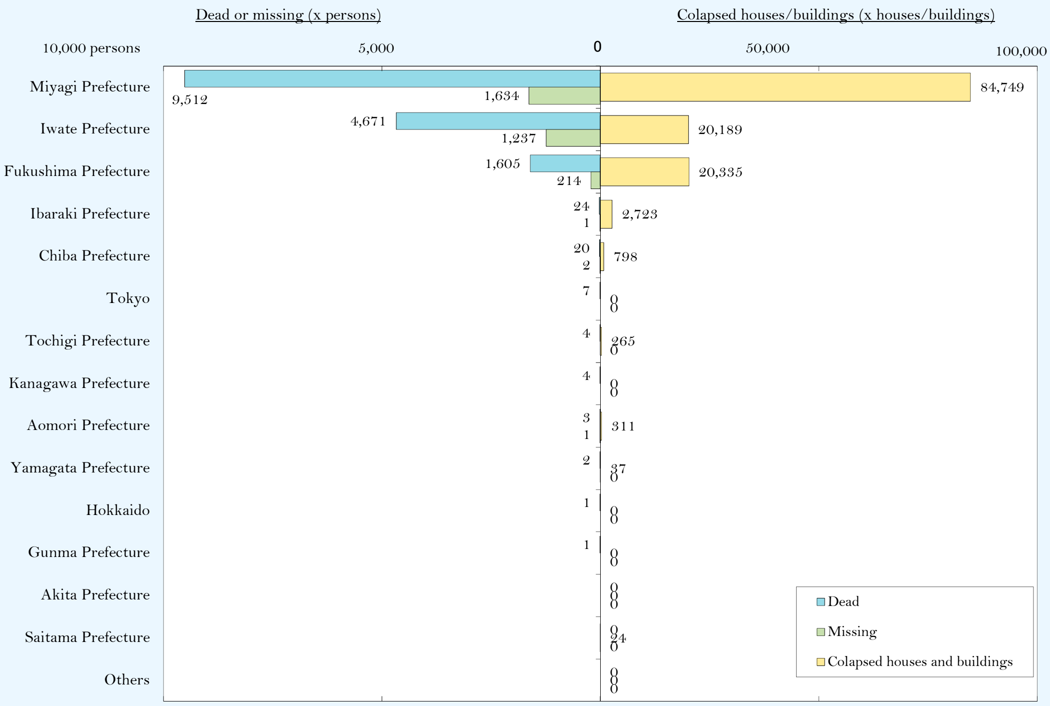
1 Investigated by the National Police Agency
2 Investigated by the Reconstruction Agency
3 Based on *Flash Report No. 523 on Damage Caused by the 2011 Earthquake off the Pacific Coast of Tohoku* and *Progress of Securing Emergency Temporary Housing, Rental Housing, and Public Housing (the Great East Japan Earthquake)*, both of which were released by Fukushima Prefecture (as of 18:00 on February 23, 2012). The number of people evacuated to their relatives' houses is not included.

Figure 1-1-1 / Human and Building Damage Caused by the GEJE (as of March 28, 2012)



Material: Created by MEXT, based on data provided by the website of the National Police Agency.

2) Lifeline Damage

The earthquake and tsunami had a devastating influence on the lifelines. The earthquake damaged a number of substations, and approximately 4.66 million houses and buildings in the service area of Tohoku Electric Power Company and approximately 4.05 million houses and buildings in the service area of TEPCO lost power immediately after the earthquake. TEPCO implemented rolling blackouts in the Tokyo Metropolitan Area and eight prefectures in the service area of TEPCO from March 14, 2011 as emergency measures against the reduction of available power supply caused by the accident at TEPCO Fukushima NPSs. The blackouts resulted in a suspension of most railroad lines or a reduction in the number of train operations, and an operational suspension and curtailed operation of factories in the Tokyo Metropolitan Area. As a result, the residents' lives and industrial activities were greatly affected. Under the cooperation of the residents and industry to power saving, TEPCO announced that it would change its principle policy of implementing rolling blackouts to a principle policy of not implementing them. After that, based on the Electricity supply-demand measures in summer time of the Electricity Supply-Demand Emergency Response Headquarters on May 13, 2011, the residents and industry decided to pull together and make efforts toward power saving, which included a 15% suppression of power in demand in the service areas of TEPCO and Tohoku Electric Power Company.

A total of 16 gas supply businesses suspended gas supply to approximately 460,000 houses. Water supply suffered damage from the earthquake and aftershocks, which resulted in a suspension of water supply to approximately 2.3 million houses in 19 prefectures. Sewage pipes of 1,140 km in length out of a total length of 66,208 km suffered damage in 140 municipalities.

The information and telecommunications infrastructure in a wide range suffered damage, which included the collapse, submerging, and washout of equipment inside communications buildings, disruption and destruction of underground cables and conduits, collapse of utility poles, destruction of aerial cables, and collapse and washout of cellular phone base stations. Approximately 1.9 million access lines and 29,000 cellular phone and personal handy phone (PHS) base stations malfunctioned. Heavy telecom traffic congestion[1] occurred immediately after the earthquake because the number of user calls rapidly increased for the purpose of checking the safety of their relatives and acquaintances. Therefore, restrictions were imposed on a maximum of 80% to 90% of fixed-line phone calls and 70% to 95% of mobile phone calls, which made voice telecommunication difficult. There are 37 municipalities along the Pacific coast of three disaster-stricken prefectures (i.e., Iwate Prefecture, Miyagi Prefecture and Fukushima Prefecture), out of which 35 municipalities were equipped with the disaster administration wireless communications system.[2] Because of the collapse or destruction of wireless equipment, the system became unavailable to 11 municipalities.[3]

3) Transportation Infrastructure Damage

The earthquake had a serious adverse influence on the traffic network. A maximum of 15 freeway routes, 69 routes of national highway under government direct control, 102 routes of national highway managed by prefectures, and 540 prefectural road routes were damaged and closed. Approximately 1,200 sections of the Tohoku Shinkansen Line and 4,400 sections[4] of East Japan Railway's local railroad lines suffered damage to their electrification poles, overhead wires, tracks, station buildings, transformation installations, etc. 177 local transportation, including six Shinkansen Lines, of 42 companies services stopped operating. In addition, all railroad and subway lines in the Tokyo Metropolitan Area stopped operating immediately after the earthquake. Four airports, i.e., Sendai Airport, Hananomaki Airport, Fukushima Airport, and Ibaraki Airport, were damaged. Among these, Sendai Airport was not operable for some time because of trash that the tsunami carried to the runways. Breakwaters, quays and cargo handling equipment of 14 international hubports and major ports between Ibaraki Prefecture and Hachinohe in Aomori Prefecture were damaged, and the ports stopped functioning for some time as well.

(3) Impact on Domestic and International Societies and Economies

1) Overview of Influence on Japan's Society and Economy

As mentioned above, the damage caused by the GEJE was enormous. In addition, outside of disaster stricken area, the earthquake had a great influence on Japan's society and economy, because it resulted in restrictions on electric power supply, disruptions in supply chains, food shipment restrictions, and the economic damage of harmful rumors, which suppressed production activities and deteriorated consumer confidence. According to the estimated economic damage announced by the Cabinet Office on June 24,

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1 Telecom traffic congestion occurs to telephone lines, Internet lines, and other telecommunications lines as a result of a great increase in communications traffic, which causes contact difficulty.

2 The disaster administration wireless communications system is a communications network connecting prefectures, municipalities, and disaster prevention organizations together to collect and relay disaster prevention information.

3 The Fire and Disaster Management Agency made a questionnaire survey on 35 municipalities' operating conditions of the disaster administration wireless communications system after the Great East Japan Earthquake and obtained responses from 27 municipalities. These 35 municipalities along the Pacific coast of three disaster-stricken prefectures were equipped with the system. Due to the accident at TEPCO's Fukushima Nuclear Power Stations, however, eight of the municipalities could not respond to the questionnaire.

4 The reported railroad-related damage was caused by the mainshock that occurred on March 11, 2011.

2011, the damage excluding that caused by the accident at TEPCO Fukushima NPSs, was said to have amounted to loss of 16.9 trillion yen.

The disaster had an adverse effect on Japan's real gross domestic product (GDP), which had been in recovery tendency, and posted negative growth on a quarter-to-quarter basis continuously in the first quarter (January to March) and the second quarter (April to June) of 2011.

Furthermore, the accident at TEPCO Fukushima NPSs caused difficulty in resuming the operation of domestic commercial nuclear power plants after periodic inspection. Thermal power generation and other means supplemented a shortage in power supply. Under these circumstances, a further adverse influence on Japan's society and economy is expected in the future, which will involve tight power supply with a power price hike and a reduction in production activities.

2) Impact on Agriculture, Forestry, and Fisheries

Japan's agriculture, forestry and fisheries greatly suffered from the wide-ranging damage centered on the Tohoku district owing to the 2011 off the Pacific coast of Tohoku Earthquake and tsunami, shipment restrictions on many types of food due to detection of radioactive substances, the economic damage of harmful rumors to food shipments, and import restrictions imposed by other countries on Japanese food products. The agriculture and fishing industries had been active in the coastal areas of the three earthquake-stricken prefectures (i.e., Iwate Prefecture, Miyagi Prefecture, and Fukushima Prefecture), in particular, and their damage caused by the disaster became very serious.

The damage to agriculture, forestry, and fisheries caused by the earthquake and tsunami resulted in loss of a total of 2 trillion 426.8 billion yen. That is, loss of 1 trillion 263.7 billion yen in fishing boats and fishing port facilities, loss of 884.1 billion yen in farmland and farm facilities, and loss of 215.5 billion yen in forestry (as of March 5, 2012).

After the accident at TEPCO Fukushima NPSs, radioactive substances were detected in food, the levels of which exceeded the provisional regulation value set forth on March 27, 2011 by the Health, Labour and Welfare Ministry. Therefore, the Nuclear Emergency Response Headquarters instructed the governors of the prefectures concerned to limit agricultural product shipments (e.g., vegetable and tea shipments) and aquatic product shipments (e.g., young lancefish shipments). In addition, the Nuclear Emergency Response Headquarters instructed cropping restrictions on rice in a part of Fukushima Prefecture. The levels of radioactive substances exceeding the provisional regulation value were detected in some beef, because local fodder was fed to the cattle. Most countries entirely rejected Japanese agricultural products after the accident. There were some countries showing their intention to accept Japanese agricultural products, but many of the countries stated that they would do so, only on the condition that certificates of inspection issued by the Japanese government be submitted for such product shipments (as of March 31, 2012).

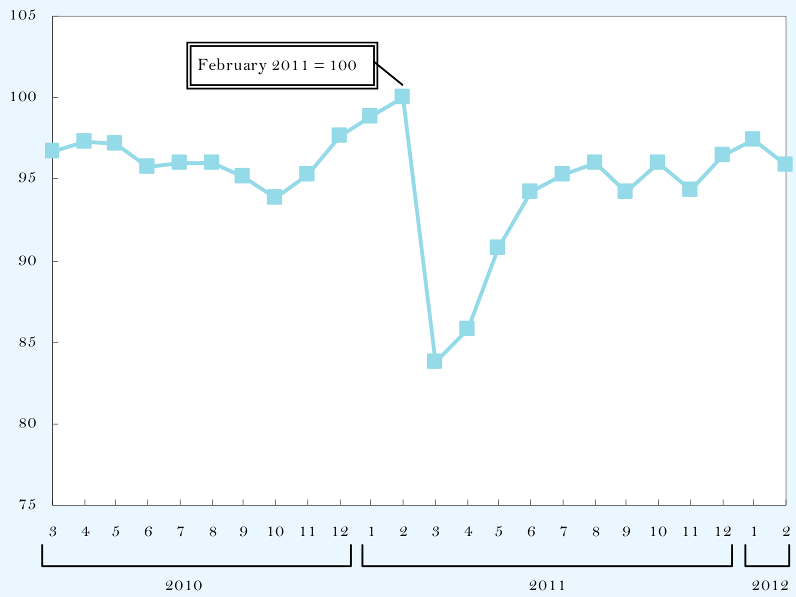
3) Impact on Manufacturing Industry

The 2011 off the Pacific coast of Tohoku Earthquake and the tsunami caused enormous damage not only to the social infrastructure, but also to factories providing parts, which obstructed activities of regional enterprises that were providing integral parts and materials for supply chains. Furthermore, TEPCO's rolling blackouts and succeeding restrictions of electricity use had a serious adverse effect on

Japan's manufacturing industry. As a result, the indices of industrial production of March and April 2011 (seasonal adjustment), which indicated the production activity status of the manufacturing industry after the disaster, showed great falls (i.e., a 16.2% fall and a 14.2% fall) from the index value of February, i.e., before the disaster (refer to Figure 1-1-2).

As for the entire automobile industry, for example the production of certain parts, such as tire and rubber components, electronic parts, and communications equipment and related devices, highly depended on subcontractors located in the Tohoku district. With the influence of the disaster on the supply chain, the actual production of four-wheel vehicles in April 2011, i.e. immediately after the disaster, showed a year-on-year decrease of 60%.[1] This adversely affected the production of automobiles not only in Japan but also in the United States and other countries.

Figure 1-1-2 / Transition of Indices of Industrial Production (Seasonal Adjustment)



Data: Created by MEXT based on the Indices of Industrial Production (released by the Ministry of Economy, Trade and Industry)

4) Impact on Tourism

The disaster had a great adverse influence not only on the disaster-stricken region that suffered serious damage, but also on Japan in general, because of the economic damage of harmful rumors.

The number of overseas visitors to Japan showed a year-on-year decrease of at least 10% on average between March (after the disaster) and December 2011, and showed a decrease of 62.5%[2] in April, in particular. The number of lodging visitors to the three earthquake-stricken prefectures (i.e., Iwate Prefecture, Miyagi Prefecture, and Fukushima Prefecture) is slowly recovering. Immediately after the disaster, however, the number dropped[3] greatly partly because of voluntary restraints on a variety of activities.

1 Calculated from the Officially Announced Statistics of the Japan Automobile Manufacturers Association. Inc.
2 Calculated by MEXT based on data of the Japan National Tourism Organization (JNTO).
3 Calculated by MEXT based on a statistical survey report on overnight trips (Japan Tourism Agency).

(4) Impact on S&T Activities in Japan

The GEJE caused enormous damage to S&T activities in Japan.

The disaster damaged research facilities and installations of universities, , and national research institutes in the Tohoku district and Kanto district, which are 177 universities, 34 independent administrative agencies and research and development (R&D) institutes. To be concrete, the disaster caused building destruction, exterior damage, piping damage, inner wall destruction, ground subsidence around the facilities, and the breakdown of cutting-edge research equipment. In order to support the restoration of these facilities and installations, the Japanese government appropriated 91.6 billion yen from the supplementary budget for FY 2011 for national university corporations[1] (37.5 billion yen for facilities of 21 organizations and 54.1 billion yen for installations of 26 organizations)[2] and 27.5 billion[3] yen for 20 R&D institutes.[4]

Some organizations had to wait for a long time to restore lifelines (electric, gas and water lines) that were partly disrupted. In addition, the disaster had an adverse effect on the R&D activities of a number of research facilities that were compelled to reduce the scales of their operations owing to rolling blackouts and power-saving arrangements.

Under these circumstances, universities and R&D institutes have been providing various types of R&D support, such as use of research facilities and equipment for researchers who suffered from the disaster. Organizations in other countries, such as Australia and Germany, accepted researchers and students from Japan.

The GEJE caused enormous damage to research facilities and equipment. The disaster affected foreign researchers as well. A large number of research-related foreigners left Japan. This was accelerated by foreign embassies in Japan, which prompted the research-related foreigners to return to their home countries immediately after the disaster. Several months later, however, the number returned to last year's level (refer to Figure 1-1-3). The number of foreign researchers who left Japan increased by 1,621 (or 61%) in March 2011 from that in the previous year, and most of them received a re-entry permit.[5] The monthly number of foreigners who left Japan in or after April returned to a typical year's level, while the number of foreigners who entered Japan in March, June, or after June 2011 recovered to previous levels. Foreigners who entered Japan in April and those who entered in May increased by 843 (or 52%) and 424 (or 21%) respectively, from the corresponding months of 2010. Most of the foreigners who entered Japan in April or May had a re-entry permit, which means that there were many foreigners who left Japan temporarily and re-entered one or two months later.

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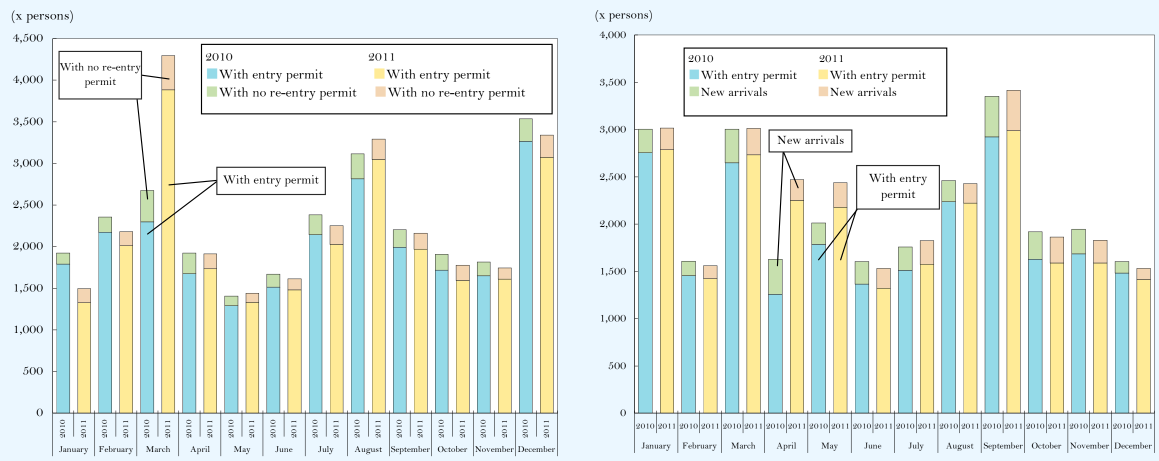
1 Refers to National University Corporations, Inter-University Research Institute Corporations, and Incorporated National Colleges of Technology.
2 Facilities and installations other than research facilities were included.
3 Calculated from subsidies appropriated from the supplementary budget for fiscal 2011 in accordance with the Act to Strengthen R&D Capacity by Advancing R&D System Reform and Promote R&D Efficiency [literal translation] (Act No. 63 of June 11, 2008).
4 A part of expenses for restoration from the Great East Japan Earthquake was appropriated from the initial budget for fiscal 2012.
5 A re-entry permit may be granted from the Minister of Justice to foreigners residing in Japan, provided that they apply for the permit with an intension of re-entering Japan because they wish to leave Japan before their period of stay expires.

Figure 1-1-3 / Transition of Research-related Foreigners (Left: People who left Japan; Right: People who entered Japan)



Note: The National Institute of Science and Technology Policy calculated the number of foreigners whose resident status was Professor and the number of foreigners whose resident status was Researcher by extracting the corresponding foreigners from the *Annual Report of Statistics on Legal Migrants* of the Ministry of Justice. According to the *Statistics on the Foreigners Registered in Japan 2010* of the Ministry of Justice, the number of research-related foreigners with the resident status of Professor and the number of those with the resident status of Researcher were 8,050 and 2,266, respectively.

Data: Created by MEXT based on the Japanese Science and Technology Indicators 2011 of the National Institute of Science and Technology Policy.

2 Responses to the GEJE and Various Challenges

(1) Responses to the GEJE and Challenges

1) Response of Government

After the 2011 off the Pacific coast of Tohoku Earthquake, the Japanese government immediately established the Headquarters for Emergency Disaster Control led by the Prime Minister in order to establish a structure enabling all the members of the Japanese government to respond to the disaster in an integrated manner.[1] To strengthen the government's life support system for all victims, the government established the Headquarters for Special Measures to Assist the Lives of Disaster Victims under the Headquarters for Emergency Disaster Control on March 17, 2011, grasped problems that municipal corporations had difficulty in handling and summarized a policy in dealing with these problems.

While the Japanese government continuously endeavored to recovery and give support to those who suffered from the disaster, established the Reconstruction Design Council in Response to the Great East Japan Earthquake on April 11 to make recommendations on reconstruction. The Council summarized its recommendation "Towards Reconstruction -Hope beyond the Disaster-" on June 25.

On June 20, the Basic Act on Reconstruction in Response to the Great East Japan Earthquake was established, in order to advance the reconstruction of the regions suffered from the GEJE smoothly and promptly for the vital revival of Japan. The government established the Reconstruction Headquarters on June 24 and decided on the “Basic Guidelines for Reconstruction in response to the Great East Japan

[1] Arrangements for the accident at TEPCO Fukushima NPSs are described in (2) *Response to Accident at TEPCO Fukushima NPSs and Challenges.*

Earthquake" on July 29. In order to promote creative efforts along with the spirit of the Act, the Law for Special Zone for Reconstruction was established on December 7. The Act on Establishment of Reconstruction Agency was established on December 9 for the smooth implementation of cross-ministerial arrangements for revival. The Reconstruction Agency came into operation on February 20, 2012. The Reconstruction Promotion Council, chaired by the Prime Minister, and the Reconstruction Promotion Committee, responsible for investigating the progress of reconstruction measures, had set up at the Agency and the Agency started full-fledged arrangements toward the revival.

Furthermore, the Cabinet Office established the Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunamis Based on the Lessons Learned from the 2011 off the Pacific coast of Tohoku Earthquake (hereinafter "the Committee for Technical Investigation") on April 27, 2011 under the Central Disaster Management Council chaired by the Prime Minister. The Committee for Technical Investigation investigated and analyzed the generation mechanism of the 2011 off the Pacific coast of Tohoku Earthquake and the tsunami, as well as the damage conditions, then studied countermeasures for future earthquakes and tsunamis. Based on the results of the study, the Cabinet Office is amending the basic disaster prevention plan,[1] reviewing the presumption of earthquakes and tsunamis, and reviewing assumed damage. Other Ministries and Agencies are also verifying the countermeasures for the GEJE and discussing arrangements for the future.

As budgetary support for the GEJE, the government appropriated a primary supplement budget of approximately 4 trillion yen promptly after the disaster. The government formulated additional supplementary budgets up to the fourth budgets, and took measures for the recovery and restoration of the disaster-stricken regions. Furthermore, the government amended a part of the Special Account Act to establish the Great East Japan Earthquake Reconstruction Special Account, and appropriated 3.25 trillion yen for FY 2012.

The disaster also impacted Japan's science technology policy. Considering the great influence of the disaster on Japan's society and economy, the Fourth Science and Technology Basic Plan, a five-year plan beginning with FY 2011, was revised. The Science and Technology Basic Plan (hereinafter "the Basic Plan") requires a serious review on any problems in the S&T policy over the disaster and responses to it. The Basic Plan also indicates the necessity for S&T to contribute to society much more than ever, especially on reconstruction and revival of Japan.

Thus, the government has been making every effort toward restoration from the GEJE and the recovery and reconstruction of Japan. In addition, Japan must fully verify the great disaster that caused the heaviest damage since the end of World War II and learn the lessons of anti-disaster measures in the future.

2) Issues raised by the review on the GEJE and the responses to it (especially on the earthquake and tsunami)

As described above, the 2011 off the Pacific coast of Tohoku Earthquake, with a scale of M9.0, was an ocean-trench earthquake with a number of focal areas linking together in a wide range. The scale of this

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1 The basic disaster prevention plan is compiled by the Central Disaster Management Council in accordance with paragraph 1, Article 34 of the Disaster Countermeasures Basic Act (Act No. 223 of 1961).

earthquake was the largest ever recorded in Japan since the Meiji era. Furthermore, this is the fourth greatest earthquake ever recorded in the world since the 1900s.[1] The height of the tsunami was significantly large, and the flooding area of the tsunami was significantly wide. The earthquake and tsunami caused serious damage in a wide range as well.

Why did Japan fail to prepare for this kind of great earthquake and tsunami to prevent the enormous damage caused by the disaster? This section investigates various problems revealed from the verification of this disaster based upon the governmental discussions, including the discussions at Central Disaster Prevention Council, Headquarters for Earthquake Research Promotion,[2] and Japan Meteorological Agency.

(i) Problems discussed at the government level for various fields related to earthquake and disaster prevention

a) Various issues identified through the verification of damage caused by the GEJE)

The verification of the disaster that caused enormous damage to humans and property revealed a problem on S&T: that is Japan's conventional techniques to presume earthquakes and tsunamis had limitations. The following section provides concrete information on this point.

The Committee for Technical Investigation reported a number of points of reflection.[3]

- The earthquakes considered to be impending from among the very largest earthquakes experienced in Japan over the past few hundred years have been used for replication of seismic intensities and tsunami heights recorded in the past using seismic source models, and these have been treated as the hazard assumptions for the next largest-scale earthquake to occur.
- As a result, if the seismic intensity or tsunami heights of an earthquake were not reproducible by the model, as like Jogan Sanriku Earthquake of 869, the Keicho Sanriku Earthquake of 1611, and the Enpo Boso Earthquake of 1677, the earthquake was regarded as having a low probability of occurrence, and disregarded from the hazard assumptions.

Furthermore, there is another problem that the seismic assumption for the GEJE was imperfect. Even after Japan started scientific observation, activities of the area along the Japan Trench have not been fully grasped because the Japan Trench was far from the land area and no earthquakes with a scale of M9.0 had occurred close to Japan in the past.

As explained above, the conventional techniques to presume earthquakes did not fully take into consideration earthquakes of the largest class that may have occurred in the past. In addition to this, there was a lack of basic knowledge on the great ocean trench earthquakes (to be explained later), and there was a problem in the capability of the present earthquake occurrence model. Thus, it can be said that the conventional techniques had limitations.

Therefore, the largest class of earthquakes or tsunamis through the all possibilities were not discussed,

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1 The list of the earthquakes larger than M9.0 in the world since 1990 is following; The Kamchatka Earthquake in 1952 (M9.0), Chile Earthquake in 1960 (M9.5), Alaska Earthquake in 1964 (M9.2), Sumatra Earthquake in 2004 (M9.1), and the 2011 off the Pacific coast of Tohoku Earthquake (M9.0)

2 The Headquarters for Earthquake Research Promotion was established as the government's special organization (under paragraph 3, Article 8 of the National Government Organization Act) following the Great Hanshin-Awaji Earthquake (in January 1995) for the integrated promotion of Japan's earthquake research in accordance with Article 7 of the Act Concerning the Special Fiscal Measures for the Urgent Earthquake Countermeasures Improvement Project to be Implemented in the Areas where Measures against Earthquake Disaster are Intensified (Act No. 101 of 1995).

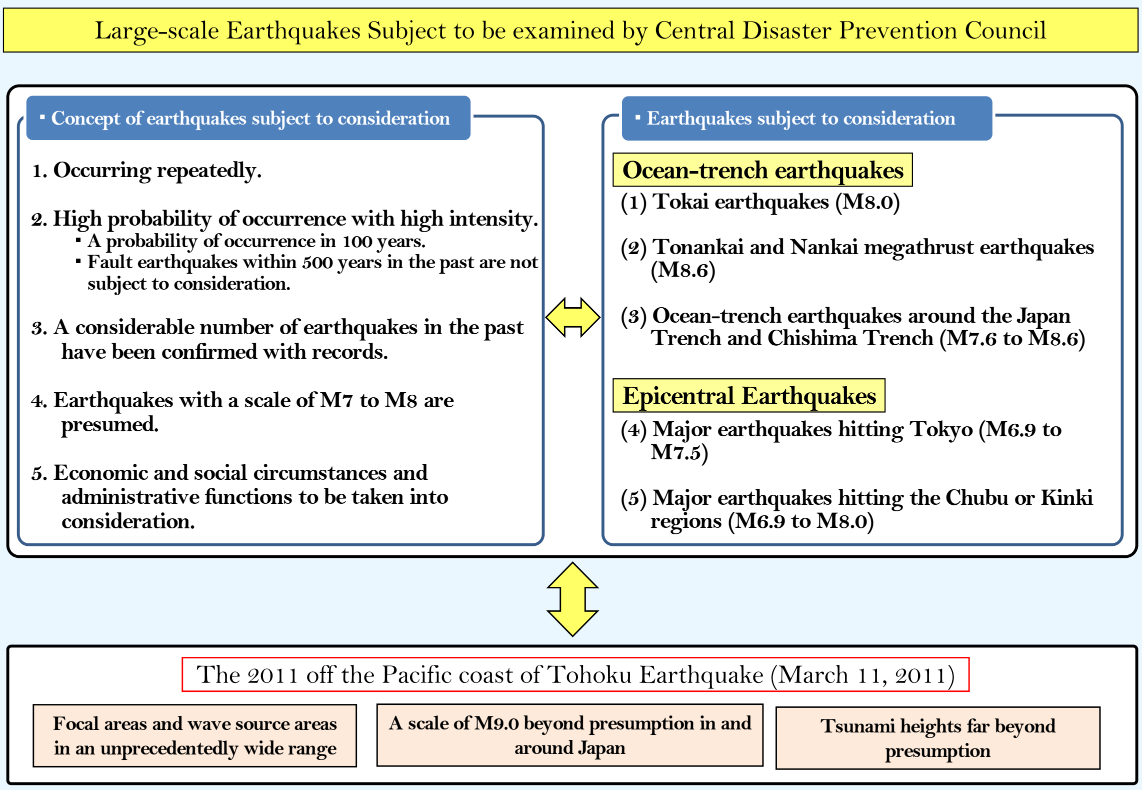
3 Report of the Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunamis Based on the Lessons Learned from the "2011 off the Pacific coast of Tohoku Earthquake" (September 28, 2011).

which resulted in the following serious consequences (refer to Figure 1-1-4).

- Japan could not presume the great earthquake with a scale of M9.0 in the area.
- The presumed damage based on the past earthquakes and tsunamis was very different from the actual damage, which resulted in enormous loss.

The government must take the problems seriously, and drastically change the conventional concept.

Figure 1-1-4 /
(1) Comparison of Large-scale Earthquakes Subject to Consideration under Conventional Presumption with the GEJE

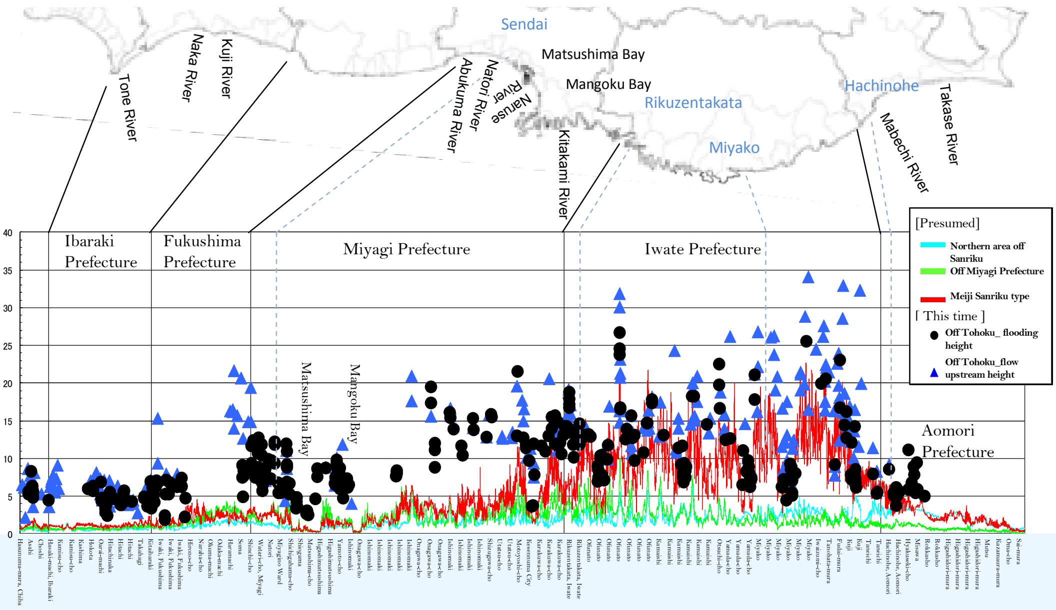


Data: A reference table attached to Report of the Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunamis Based on the Lessons Learned from “the 2011 off the Pacific coast of Tohoku Earthquake" under the Central Disaster Prevention Council

(2) Tsunami heights far beyond Presumption

~ Based on Presumed Damage Caused by Ocean-trench Earthquake around Japan Trench in Comparison with Damage Caused by the GEJE and Tsunami ~

▪ Tsunami Heights Caused by the GEJE far beyond Presumption



(Source) • Tsunami heights caused by three presumed earthquakes: The results of a technical investigation made by the Committee for Technical Investigation on measures in preparation of ocean-trench earthquakes around the Japan Trench and Kuril Trench

• Flooding and upstream heights caused by the 2011 off the Pacific coast of Tohoku Earthquake : Values immediately reported by the 2011 Tohoku Earthquake Tsunami Joint Survey Group (May 9, 2011)

Note: Data at reliability level A (highly reliable and traceable data with minimal measurement errors) obtained within 200 m off the coast is used.

▪ The damage caused by the disaster was far beyond presumption

	Magnitude		Inundation area	Killed or missing (x persons)	Building damage (number of buildings completely destructed)
The 2011 off the Pacific coast of Tohoku Earthquake	9.0	Nationwide	561km²	19,800	113,300
		Iwate Prefecture	58km²	6,315	20,209
		Miyagi Prefecture	327km²	11,618	75,391
		Fukushima Prefecture	112km²	1,843	17,740
Meiji Sanriku type (Damage presumed)	8.6	Nationwide	Approximately 270 km²	Approximately 2,700	Approximately 9,400
		Iwate Prefecture	Approximately 50km²	Approximately 2,100	Approximately 6,400
		Miyagi Prefecture	Approximately 60km²	Approximately 360	Approximately 2,000
		Fukushima Prefecture	Approximately 20km²	Approximately 60	Approximately 300

(Source) • The 2011 off the Pacific coast of Tohoku Earthquake : Magnitude: The Japan Meteorological Agency's report number 15 of March 13, 2011 on the 2011 off the Pacific coast of Tohoku Earthquake

Inundation area: The Geographical Survey Institute's report number 5 of April 18, 2011 on the approximate flooding range of the tsunami

Killed or missing (x persons) and building damage: The National Police Agency's report of September 26, 2011 on damage from the 2011 off the Pacific coast of Tohoku Earthquake and police arrangements

• Meiji Sanriku type (Damage presumed): Magnitude: Page 67 of a report on an ocean-trench earthquake around the Japan Trench and Kuril Trench (January 25, 2006). * Values obtained from a fault model as a result of numerical simulation.

Inundation area: The calculation value of presumed damage from an earthquake of Meiji Sanriku type is used (on the condition that embankments are installed).

Killed or missing (x persons) and building damage: According to the presumed damage on page 55 and page 57 of a report on an ocean-trench earthquake around the Japan Trench and Kuril Trench (January 25, 2006)

Data: Reference tables attached to Report of the Committee for Technical Investigation on Countermeasures for Earthquake and Tsunami Based on Lessons Learned from "the 2011 off the Pacific coast of Tohoku Earthquake" under the Central Disaster Prevention council.

Column 1-1

Necessity for Investigation and Analysis of Past Earthquake Data

Tohoku region residents in each Pacific coastal area have handed down over generations the arrival of great tsunamis in the past. According to Nihon Sandai Jitsuroku (the History of Three Reigns of Japan, an officially commissioned Japanese history text compiled by a number of scholars including Sugawara no Michizane), there was a great earthquake in Mutsu Province (an old province in Japan in present-day Tohoku district) in 869, and castle buildings, warehouses, gates, fences, and walls were destroyed. The sea became rough and deviated, a high adverse current rose and travelled along the river and reached the castle, and the flooding area spread to the extent that boundary between the sea and the land became unclear. People did not have the time to use boats or climb the mountain to escape the tsunami, and approximately 1,000 people drowned. Nihon Sandai Jitsuroku described that it was such a serious disaster that the people lost almost all their property and crops.[1]

Graduate School of Science at Tohoku University and the Active Fault and Earthquake Research Center of the National Institute of Advanced Industrial Science and Technology, worked on the elucidation of this earthquake, known as the Jogan Sanriku Earthquake of 869 and the enormous tsunami in their tentative research program "intensive investigation and observation in an area off Miyagi Prefecture (from fiscal 2005 to 2009) " The National Institute of Advanced Industrial Science and Technology made a geological survey of each coastal area of Miyagi Prefecture and Fukushima Prefecture, and closely investigated all the tsunami deposits in the layer of the earth. The result showed that the tsunami caused by the Jogan Sanriku Earthquake of 869 flooded the inland at least 3 to 4 km away from the shoreline at that time. This revealed that the scale of this tsunami, which flooded the entire Sendai plain, was similar to that of the tsunami caused by the GEJE. The result of the numerical simulation of the wave source of the tsunami based on the reproduced inundation area suggested that the Jogan Sanriku Earthquake of 869 possibly caused a fault movement of approximately 200 km long and 100 km wide in the plate boundary zone along the Japan Trench off the coast of Miyagi Prefecture and Fukushima Prefecture. This revealed that the earthquake was of a scale of approximately M8.4. Furthermore, a tsunami of a similar scale occurred at intervals of 450 to 800 years, and it was pointed out that the possible arrival of a similar tsunami in the near future could not be denied.

The Earthquake Research Committee Headquarters for Earthquake Research Promotion (hereinafter "the Earthquake Research Committee") reflected the results of this research on the Jogan Sanriku Earthquake of 869 in its "Long-term Evaluation of Seismic Activities in Region from Off-Sanriku to Off-Boso." The GEJE and the enormous tsunami took place while Earthquake Research Committee was preparing for the announcement of the evaluation.

A great ocean-trench earthquake like the GEJE can occur not only in the Japan Trench but also in the Kuril Trench, Sagami Trough, Suruga Trough, Nankai Trough, Ryukyu Trench, and almost all the areas of the Japanese Archipelago, thus the investigation and research of past earthquakes and tsunamis become increasingly important. The estimated scale of the Jogan Sanriku Earthquake of 869 in Miyagi Prefecture and Fukushima Prefecture was approximately M8.4, which was considerably smaller than the scale of the GEJE. This study revealed the necessity of earthquake evaluation estimated from tsunami deposit in a wider area and the fact that the tsunami flooding area expands wider than the distribution area of tsunami deposits. As explained above, the GEJE revealed the necessity for improvements in techniques to estimate the scales of tsunamis highly precisely.

In the future, it will be important to integrate knowledge of history, geology and archeology, and investigate and analyze past earthquake records (e.g., those of paleography investigation, tsunami sediment investigation, trace investigation of ruins and crustal deformation investigation), and construct a great-earthquake model considered from the viewpoint of seismology linking with the investigation and analysis.

Even the greatest earthquake or tsunami that occurred in the last several thousand years can be reproduced based on data currently available, the reproduced one, however, may not be an earthquake or tsunami of the largest class that can occur in the future. This points out the necessity for the

[1] The original description of Nihon Sandai Jitsuroku about the Jogan Sanriku Earthquake of 869 quoted in Tokushi Taikei (history text in four volumes) is as follows (a literal translation of the original text written in classical Chinese):
On 26th day of 5th month (9 July 869 AD), a large earthquake occurred in Mutsu Province with some strange light in the sky. People shouted and cried, lay down and could not stand up. Some were killed by the collapsed houses, others by the landslides. Cattle got surprised, madly rushed around, and injured the others. Enormous buildings, warehouses, gates, and walls were destroyed. Then the sea began roaring like a big thunderstorm. The sea surface suddenly rose up and the huge waves attacked the land. They raged like nightmares, and immediately reached the city center. The waves spread thousands of yards from the beach, and we could not see how large the devastated area was. The fields and roads completely sank into the sea. About one thousand people drowned in the waves, because they failed to escape either offshore or uphill from the waves. The properties and crop seedlings were almost completely washed away.

construction of a great-earthquake model with consideration of all possibilities based on seismological knowledge and the results of the investigation and research of the structures, shapes, and movement mechanisms of plates and the generation mechanism of tsunamis.

In response to the GEJE, the Earthquake Research Committee in response to the GEJE reviewed the conventional long-term evaluation of earthquakes based on observation records, history data, and topographical and geological investigation under the concept that earthquakes with similar scales repeat in the same area. The Earthquake Research Committee is studying a long-term evaluation with higher accuracy by improving in evaluation techniques so that earthquakes not confirmed with history data or observation records can be estimated scientifically in the future. Improvements in long-term evaluation techniques are required with sufficient consideration of the greatest earthquake that can possibly occur theoretically in the future from a scientific viewpoint, as well as the greatest earthquake in the past.

The Geodesy Subcommittee of the Council for Science and Technology is also studying the cause of failures in predicting the possible occurrence of this massive earthquake. The Geodesy Subcommittee reported a review of observation plans for the prediction of earthquakes and volcanic eruptions (deliberation progress report of February 2012). According to the review, the massive earthquake was not predicted due to the following reasons: Limitations of current earthquake models[1], lack of knowledge of plate boundaries close to ocean trenches as a prerequisite for simulation by current model, and lack of investigation and research on past earthquakes including tsunami deposit investigation. The Geodesy Subcommittee has not concluded why the mechanism of the earthquake this time developed into a great slip, and considers it is a very important action assignment to elucidate the mechanism of such massive earthquakes from the viewpoint of alleviating the extent of damage caused by possible massive earthquakes in other areas. Therefore, the Geodesy Subcommittee is reviewing conventional earthquake occurrence models while studying a variety of other models, and thoroughly elucidating the possibility of occurrence of massive earthquakes, including investigation and research on past earthquakes.

(Issues on information)

Some pointed out the possibility of inaccurate and/or inadequate information might have expanded damage. The scale of the earthquake and the predicted height of the tsunami announced by the Japan Meteorological Agency immediately after the earthquake were far below the actual figures. Its announcement of the first wave observed was 0.2 m, and the evacuation activity of residents and firefighters might have slowed down on the wrong recognition.

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1 The earthquake model called asperity model has been generally used to explain the locations and scales of earthquakes with a maximum scale of M8.0 repeatedly occurring off the Pacific coast of the Tohoku district. The plate boundary side of this model (the boundary where the oceanic plate that slides in and the continent plate overhang) is not uniform, but considered to consist of the following parts: (1) A part (asperity) that is usually fixed both plate each other but slips suddenly if an earthquake occurs. (2) A part that slips slowly in usual time with the motion of the plates. A portion of the asperity with strong fixation (i.e., the fixation area and extent of fixation is great) is an area where the friction of the plates is high. This portion does not slip with ease, and is said to accumulate high friction for a long time to cause a great earthquake. On the other hand, a portion with weak fixation is an area where the friction of the plates is low. This portion slips with ease, and is said to cause minor earthquakes repeatedly at short intervals.
Great earthquakes with a scale of M8 repeatedly occur in the subduction zones of the world (zones where the plates are close to each other and one of the plates is sinking to the bottom of the other plate). Each zone, however, seems to have unique regional characteristics, i.e., massive earthquakes of a scale of M9 sometimes occur in South America while earthquakes of a scale of as great as M8 rarely occur in the Mariana Trench. The asperity model has been introduced to explain the regional characteristics. In Japan, the asperity model is used to explain seismic events of a maximum scale of M8.0 that occur repeatedly in the same plate boundary areas. The Headquarters for Earthquake Research Promotion has been using the asperity model for the long-term evaluation of potential earthquakes. This, however, means that the asperity model has been used on the premise that massive earthquakes do not occur in the Japan Trench off the Pacific coast of the Tohoku district.
It can be said that seismological data on fixation and slippage in the plate boundary obtained in only a few decades could not make a perfect model explaining and predicting various seismic events occurring in a long time scale.