16. *The 1952-1953 Submarine Eruption of the Myôjin Reef near the Bayonnaise Rocks, Japan (I)**.

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Contents:

I. Introduction

The present eruption was first found by the crew of the No. 11 Myôjin-maru, a fishing boat of Yaizu port, Shizuoka Prefecture early in the morning of September 17, 1952, at the sea about 10 km. east of the Bayonnaise rocks, about 420 km. south of Tokyo (Fig. 1). Thereafter, the eruption was recognized by the coastal patrol ship named "Shikiné" of the Marine Safety Board of the Japanese Government. The reef formed by the submarine eruption was named officially as "Myôjin-shô (Myôjin reef)" after the name of the boat of the first eyewitnesses, by the Hydrographic Office of the same Board in September 18.

The Bayonnaise rocks, less than 10 m. in height above sea level, are situated at 31°55.3′N in latitude and 139°54.5′E in longitude (Fig. 52). The rocks rest on the submarine ridge elongating southward from Izu peninsula to the Pacific Ocean, with many other Quaternary insular volcanoes, active or dormant, belonging to the so-called Fuji volcanic zone (Figs. 1 and 2). Near the Bayonnaise rocks, volcanic activities were recorded in our historic times, which are enumerated in the following table (Table I), though we have had no information on the petrographic characters of the rocks except the pumice collected at the time of the submarine eruption near the rocks in 1906[1].

* Dedicated to the Memories of Dr. Risaburô Tayama and thirty other persons who had met with their unfortunate deaths owing to the shock of a severe submarine explosion of the Myôjin reef.

1) T. WAKIMIZU, "The ephemeral volcanic island in the Iwôjima Group," *Bull. Earthq. Invest. Committee*, **22**c (1908), Appendix 31–33.

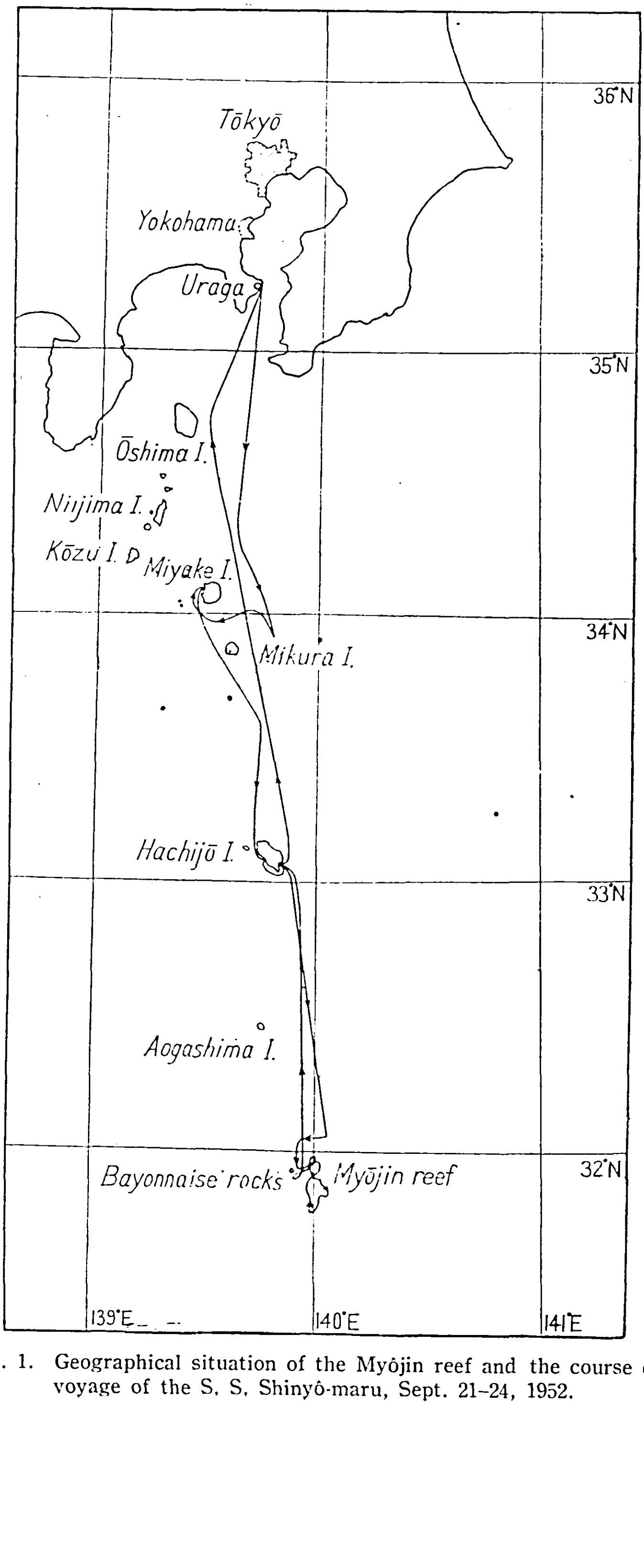

Fig. 1. Geographical situation of the Myôjin reef and the course of voyage of the S. S. Shinyô-maru, Sept. 21-24, 1952.

Table I. Volcanic activities recorded near the Bayonnaise rocks before 1952.

Date of report	Eyewitness	Localities	Remarks
Apr. 14, 1906	Okinawa-maru,*** a submarine-cable vessel of the Department of Communication.	5–8 M southeast of the rocks.	The eruption began abruptly on a day between Apr. 7 and 14. Ash clouds 130–330 m. in heights, 100 m. in dia. Large amount of pumice ejected were floating eastwards with the current covering the sea over an area of two miles in diam[1].
Feb., 1915	Tôtômi-maru	About 6 M east of the rocks****	Bank, 10 m. in depth[2].
Apr., 1915	Ditto	Ditto	Submarine eruption[2].
June 19, 1915	Daikoku-maru, a fishing boat	32°00′N., 140°05′E., about 10 M northeast of the rocks.	1st belching of smoke at 08h33m. Activity became remarkable at 10h25m in its 6th explosion ejecting mixtures of rock fragments with water blowing up cauliflower clouds, came to a climax at 11h55m, and declined at 12 h 30 m. No evidence of eruption on the next day[3].
	No. 3 Takané-maru, a fishing boat of Yaizu port.	Ditto	Belching of smoke and spray every 20–25 minutes around 09 h. Toward noon activity became larger in scale, high wave due to explosion attacked the deck and the bulwark was broken but the ship could escape the jaws of death. The high wave washed over the Bayonnaise rocks three times[4].
July 1, 1915	Ashitaka-maru, a fishing boat	Southwest of the rocks.	Around 17 h, yellowish smoke spread over 20 km. westwards. Smoke and water spray were rising at about 4 km. southwest of the rocks[3].
May, 1934	No. 2 Shôwa-maru	About 5 M east of the rocks.	Colour of the sea water changed into yellow over an area of 180m. in diam., sulphur-smell[2].

(to be continued.)

Table I. (continued.)

Date of report	Eyewitness	Localities	Remarks
Feb., 1946	British Navy Uranus	31°57′N., 140°01′E.	Birth of an island, 200 m. long, 150 m. in width[2].
Apr., 1946	Arimasan-maru	31°57′N., 140°01′E.	Several islets, including 2 spines about 36 m. in height, appeared[2].
Oct., 1946	No. 80 Sinkô-maru	Ditto	An island 100 m. high was observed[2].
Dec., 1946	U. S. Force broadcasting	Ditto	The island disappeared. Waves break on the bank[2].

On the "Izu Shichitô Shi" and "Hachijô Senkyô Shi", it is described that in May, 1870, an islet was born about 25 "ri" (probably nautical miles) southeast of Aogashima (Personal communication from Mr. Y. Tsukamoto of the Hydrographic Office and F. OMORI, *op. cit.*, 120).

In 1896, British S. S. Linjisfahrn* found the reef on which the waves broke at the sea about 7.5 M** north of the Bayonnaise rocks[2]. * Rewritten in occidental spelling from the Japanese literature. ** M: Nautical mile. *** A suffix "-maru" in Japanese means ship or boat. **** According to the survey of the Hydrographic Office in 1925, no reef or bank was recognized thereabout[2].

1) T. WAKIMIZU, *loc. cit.*, 2) R. MITA, *Hydrographic Bulletin* **12** (1946), 57–62, (in Japanese), 3) F. OMORI, *Rep. Imp. Earthq. Invest. Committee*, **86** (1918), 114, (in Japanese), 4) Y. TSUKAMOTO, "On the No. 3 Takané-maru attacked by the submarine explosion at the 1915-eruption near the Bayonnaise rocks", *Monthly Meeting of the Earthq. Res. Inst.*, (May 24, 1955).

It is still fresh in our memory that an ephemeral island was found in February, 1946 owing to the submarine eruption which took place at approximately the same position as the locality of the present eruption.

Bottom configuration in the vicinity of the Bayonnaise rocks according to the bathymetric chart No. 81 of the Hydrographic Office is shown in Fig. 2. Ryôichi Mita, a geographer of the Hydrographic Office who embarked on the missing boat "No. 5 Kaiyô-maru", had already pointed out that the Bayonnaise rocks were a portion of the wall of the crescent-shaped caldera of large scale, up to 10 km. in its diameter, and that the island ephemerally formed at the 1946-eruption might be one of the two or more tholoides built on the submarine double volcano[2]. However, we have still no satisfactory data on the submarine topography of the volcano, leaving room for further discussions on the shape and structure of the submarine volcano.

Submarine eruptions had often been observed in Japan, such as the

2) R. MITA, "The submarine volcanic activities near the Bayonnaise rocks", *Hydrographic Bulletin*, **12** (1946), 57–62, (in Japanese).

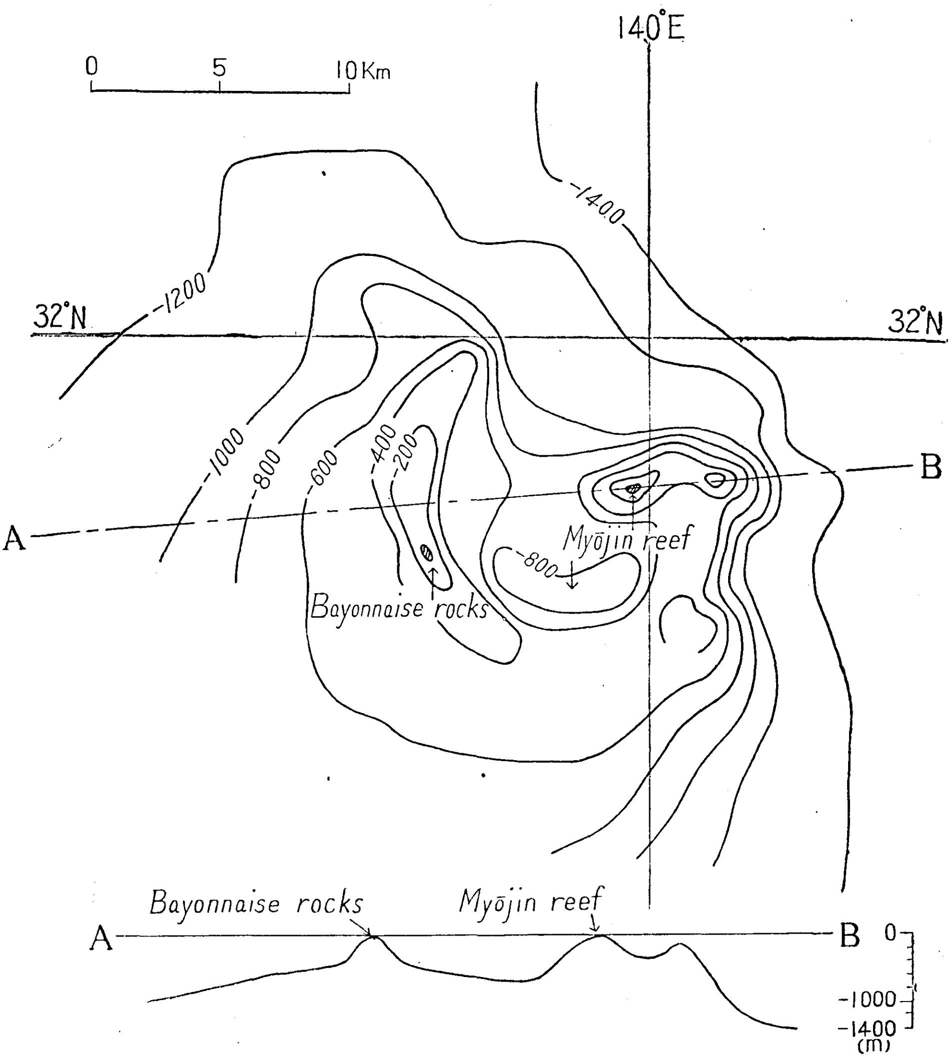

Fig. 2. Bottom configuration near the Bayonnaise rocks (after the bathymetric chart No. 81 of the Hydrographic Office, Marine Safety Board, the contour lines being drawn by the writers.)

1904 and 1914 eruptions east of South Sulphur Island[3], the 1934–1935

3) T. WAKIMIZU, *op. cit.*, 1–30.

T. OGURA, "The eruption of Shin Iwô-jima", *Rep. Imp. Earthq. Invest. Commitee*, **79** (1915), 4–15, (in Japanese).

T. TERADA, "On the recently appeared islands near South Sulphur Island", *Tôyô Gakugei Zassi*, **31** (1914), 149–158, (in Japanese).

eruption of Iwôgashima, Kagoshima Prefecture[4], the 1870 and 1916 eruptions southwest of Smith reef[5], etc. Nevertheless, it is quite rare for us to eyewitness the actual scene of submarine explosions. Fortunately the writers were given an opportunity to embark on the S. S. Shinyô-maru, a training ship of the Tokyo College of Fisheries, for investigating the eruption of the submarine volcano. The S. S. Shinyô-maru approached the actual place of eruption in the early morning of September 23, 1952. The writers along with other Japanese scientists eyewitnessed three spectacular scenes of submarine explosions within quite short distances from the centre of the eruption on the same day. In this matter, the writers owe much to Drs. H. Niino and T. Kumakori of the Tokyo College of Fisheries, and to Dr. H. Tsuya of the Earthquake Research Institute, and also to the crew of the S. S. Shinyô-maru, to whom the writers' sincere thanks are due.

On the next day, September 24, 1952, one of the most sorrowful accident in our research history of volcanoes took place: Thirty-one persons including 9 scientists and 22 crew threw in their lot with the vessel "No. 5 Kaiyô-maru" of the Hydrographic Office of the Marine Safety Board of the Japanese Government. Shattered wreckage with embedded volcanic rocks fragments ejected from the Myôjin reef, a tunami record at Hachijô Island about 130 km. north of the volcano, a volcanic explosion record at two underwater listening stations of the U. S. Navy off California, show that the ship was attacked by a shock of a severe submarine explosion at about 12h20m on September 24, 1952. The explosion by which the No. 5 Kaiyo-maru was attacked was estimated to be larger in scale than those the writers eyewitnessed on September 23. The writers mourn deeply over the death of these thirty-one persons here.

In this paper the writers intend to describe the history of the present eruption especially the submarine explosions eyewitnessed on September 23, 1952 and the petrography of the ejecta, a new petrological information on the submarine volcano.

In collecting the data on the history of the eruption, the writers owe much to the staff of the Hydrographic Office. The writers express their cordial thanks to Dr. Kanji Suda, Director of the Hydrographic Office and to Mr. Yûshirô Tsukamoto, Chief of the Astronomical Section

4) H. TANAKADATE, "Preliminary note on the volcanic eruption of Iwôgashima, Kagoshima Prefecture, Japan", *Bull. Volcanological Soc. Japan*, **2** (1935), 188–209, (in Japanese).

5) R. MITA, *loc. cit.*

of the same Office. In estimating the depths of the underwater explosions, the writers were kindly instructed by Professor Fuyuhiko Kishinouye of the Earthquake Research Institute to whom their sincere thanks are due. To Messrs. S. Hanzawa, K. Osawa, J. Kusaka, and R. Sugano of the Asahi Press, and to Messrs. F. Kojima, D. Miwa, Z. Ishii, T. Takei, T. Isoyama, C. Haraikawa, and T. Isa of the Yomiuri Press. The writers owe much for the use of their fine photographs. A part of the expenditure necessitated for the investigation was defrayed from the Funds for Scientific Researches of the Ministry of Education.

II. History of the eruption

In cases of submarine eruptions the opportunities for observations at sea are quite restricted. The present eruption, as well as other ones of this sort, is not an exceptional case: it occurred near a remote uninhabited islet always washed by the ocean current[6]—the Bayonnaise rocks; continuous and systematic observation of the actual scene of the activity could not be expected under such surcumstances. Indeed, the only thing the writers could do was to collect scatttering data on the activities obtained by many different eyewitnesses in describing a course of the present submarine eruption. The following table (Table II) concerning the history of the eruption was compiled by the present writers from the data chiefly collected at the Hydrographic Office of the Marine Safety Board[7], the Central Meteorological Observatory[8], and the Tokyo College of Fisheries[9], with other random observations by aeroplanes, regular liners, fishing boats, etc., in addition to the writers' own data.

It was reported by Dietz and Sheehy that the U.S. Navy SOFAR

6) Kuro-shio counter current.

7) MARINE SAFETY BOARD, Memoir of the investigations on the causes of disaster of the No. 5 Kaiyô-maru, 1953, (in Japanese).

Y. TSUKAMOTO, "Record of the eruptions of Myôjin-sho (1952–1953)", *Hydrographic Office, Tokyo, Japan*, April 14, 1954.

8) A. SUWA, "Submarine eruption of Myôjin reef", *Jour. Geography*, **62** (1953), 102–104, (in Japanese).

WADATI and SUWA, "The observation of the 1952 eruption of the Myôjin reef aboard aeroplanes", *Quart. Jour. Seismology*, **17** (1953), 71–77. (in Japanese)

S. MIURA, "The observation of the eruption of the Myojin reef aboard the weather ship, Chikubu-maru", *Ditto* 79–82 (in Japanese).

T. HOSHI, "Observation of Myojin reef aboard weather ship, Shiga-maru", *Ditto* **18** (1953), 41–42 (in Japanese).

9) TOKYO COLLEGE OF FISHERIES, "Report on the submarine eruption of Myôjin-sho", *Jour. Tokyo Coll. Fisheries*, **40** (1953), Special Number.

Table II. History of the 1952–1953 eruption of the Myôjin reef.

Date of observation	Eyewitness or author	Remarks
Sept. 16, 1952	SOFAR Tsunami record at Hachijô island	(0040, 0912, 1031, 1152, 1410, 1752, 1940) (1152)
Sept. 17, 1952	No. 11 Myôjin-maru	(0715) The eruption was first found, 32°10′N, 140°00.5′E, 17′ NNE of the Bayonnaise rocks. Ash clouds rose up to 500 m. Colour of the sea water near the reef changed into yellow.
	"Mercury" an aeroplane of Japan Air Line	(1839–1857) A new island, 120 m. long, 80 m. wide, 30 m. high was observed. 2 vents, several explosions every minute, ash cloud rose 200–1,000 m., red-hot lava was recognized.
	No. 5 Syôsei-maru, a fishing boat	(1829, 1830, 1840) Explosions every 3–5 minutes, ash columns 200 m high, were observed, red-hot lava flowed down into the sea.
	SOFAR	(0304, 0611, 1951, 2230)
Sept. 18, 1952	"Shikiné," a coastal patrol ship	(0900) Minor explosion. New island 150 m. in NS, 100 m. in EW, 30 m. in height was situated at 31°56.7′N, 140°00.5′E. Yellow sea current runs toward SSW. (Ca. 1000) Minor explosions repeated every 0.5–2.0 minutes (Fig. 8).
	"Wakakaze" an aeroplane of Asahi Press	(Ca. 1100) Ash cloud rose remarkably. Size of new island was larger than the Bayonnaise rocks (Fig. 9).
	"Venus" an aeroplane of Japan Air Line	(Ca. 1800) Minor explosions several times every minute, ash cloud rose 3,000–4,000m. high, 2 vents, with several ventlets, size of the island was same as above (Fig. 10).
	SOFAR	(0120, 0323, 0327, 0444, 0526, 0621, 0704, 0803, 0920, 1712, 1735, 1844, 1946, 2005, 2131)
Sept. 19, 1952	SOFAR	(0029, 0425, 0902, 1015, 1240, 1436, 1639, 1805, 2048, 2057)
Sept. 20, 1952	Ditto	(0613, 1312, 1400, 1649, 1819, 1850)
Sept. 21, 1952	Chikubu-maru of Central Meteorological Observatory	(Ca. 1700) Explosions every 3–5 minutes. (1734) Large explosion. Island could not be recognized.
	SOFAR	(0111, 0213, 0447, 0529, 1400, 1433, 1507, 1737, 2324)
Sept. 22, 1952	Soyokaze, aeroplane of Asahi Press	(Ca. 0900) Great explosion (Figs. 11–12).

(to be continued.)

Table II. (continued.)

Date of observation	Eyewitness or author	Remarks
Sept. 22, 1952	US Air Force	(Ca.1200) Several small rocks, several metres in diam. and in heights, were observed on the sea.
	Shinyô-maru	(1505) An explosion was observed from Hachijô island. (2345) Night view of an explosion was observed during voyage to the Myôjin reef.
	SOFAR	(0341, 0653, 0914, 1237, 1530, 1931, 2027, 2345)
Sept 23, 1952	Shinyô-maru	(0834, 1312, 1340, 1900) Severe submarine explosions. Cf. Chapter III of this paper. Volcanic island had almost collapsed down into the sea. Only 2 or 3 small rocks, 1–2 m. high were left appearing on on the sea (Fig. 13–51).
	SOFAR	(0025, 0828, 1143, 1308, 1335, 1901, 1914, 2233)
	Wave recorder at Hachijô island	Tsunami? considered to have been related to the explosion of (1312) was recorded during (1350–1425).
Sept. 24, 1952	No. 18 Umikata-maru	(0540) Great explosion, 10′E of the Bayonnaise rocks. Island had disappeared.
	Inhabitants in Aogashima island	Explosion was heard early in the morning. At noon, two columns of ash cloud rising from the Myôjin reef were observed, east one continuosly and other west one intermittently.
	Wave recorder at Hachijô island	A conspicuous tsunami was recorded (1253–1408), related to the explosion which presumably occurred between (1219–1231).
	SOFAR	(0148, 0539, 0552, 1221)
Sept. 25, 1952	Weather station at Hachijô island	(0500) Ash fell.
	No. 3 Nisshô-maru, a fishing boat	(1330?, 1830) Severe explosions.
	SOFAR	(0618, 1316, 1823)
Sept 26, 1952	Muroto and Shikiné, coastal patrol ships	(1235) Quite severe explosion with ash fall over wide area (Fig. 53 a–b).
	Weather station at Hachijô island	Tsunami-record (1303–1438) related to the explosion (1235).
	SOFAR	(0104, 1234)

(to be continued.)

Table II. (continued.)

Date of observation	Eyewitness or author	Remarks
Oct. 3, 1952	Muroto, a coastal patrol ship	(0545) Explosion. (0800) Explosion.
Oct. 11, 1951	Ditto	(0700) Island, 150 m. wide, 200 m. long, with three peaks, 80 m. above sea level at the highest point. Ash cloud rose up to 105m.
Oct. 21, 1952	No. 5 Shôsei-maru	(2150) Minor explosion. Island 30 m. high above sea level was observed.
Nov. 7, 1952	US Air Force	(Ca. 1200) Remarkable ash cloud. Island 30 m. high was recognized.
Nov. 12, 1952	Tonan-maru of Tokyo Metropolice	Two islands were observed.
Nov. 17–18, 1952	Awaji-maru of Tòkai-kisen Co.	Ash cloud and vapour emission. Ash cloud rose up to 500–600 m.
Nov. 24, 1952	No. 12 Daikoku-maru, a fishing boat	Emission of black cloud in the early morning. An island 300 m. long and 100 m. high was observed at 31°54′N., 140°02′E.
Dec. 9, 1952	Tonan-maru of the Fisheries Experiment Station, Tokyo Metropolitan Government	White vapours were emitted from whole island of 200 m. in diam., 50 m. in height. Small rock several metres above sea level was found 100? m. south of the island.
Dec. 13–14, 1952	Inhabitants of Aoga-shima island	Smoke-like ash cloud was found far above the Myôjin reef.
Dec. 16, 1952	Kyôei-maru, Fisheries Experiment Station, Chiba Prefecture	A volcanic island about 50 m. high emitting smoke was recognized.
Dec. 27, 1952	Aeroplane (No. 103) of Yomiuri Press	A volcanic island was recognized (Fig. 54).
Jan. 19, 1953	Genkai, a coastal patrol ship	An island was observed whose north and south peaks were 94m. and 56m. in heights respectively. Vapours were emitted along the shore of the island.
Feb. 1, 1953	Umitaka-maru, a training ship of Tokyo College of Fisheries.	A volcanic island surrounded by steep cliff, 220 m. in NW–SE, 151 m. in NE–SW was recognized. It consisted of two peaks, north spine (93.8 m) and south dome (54.8 m). Vapours were emitted from the summits of the island. The sea water was not so stained with the volcanic materials (Fig. 55).
Feb. 6, 1953	No. 2 Seiju-maru, a fishing boat	(1500) Explosion. Column of dark ash cloud 100 m. in dia. rose up to 200 m. high.
Feb. 7, 1953	Asakaze, an aeroplane of Asahi Press	The island about 90 m. above sea level was found. The sea water east of the island changed into yellowish green over an area of 1 mile in diam.

(to be continued.)

Table II. (continued.)

Date of observation	Eyewitness or author	Remarks
Feb. 8, 1953	No. 103 aeroplane of Yomiuri Press	(1020–1040) The island elongating in N–W direction had two peaks and no crater. North one was higher. Vapours were emitted between the two peaks (Fig. 56).
Mar. 3, 1953	Aogasima island	Emission from the Myôjin reef became remarkable.
Mar. 6, 1953	"Muroto", a coastal patrol ship	(Ca. 1200) Height of the island was 120 m. Vapours were emitted from whole island.
Mar. 9, 1953	Temporary observatory at Aogashima (Telescope) by the Hydrographic Office	Successive explosions began.
Mar. 10, 1953	No. 1 Kinsei-maru	Remarkable ash cloud probably at the great explosion of the Myôjin reef.
Mar. 11, 1953	No. 103 aeroplane of Yomiuri Press	(Ca. 1500) The island had disappeared into the sea. No subaerial emissions of ash or vapour. The sea water changed into yellowish colour over an area of 2 km. wide, 4 km. long (Fig. 57).
Mar. 17–18, 1953	Temporary observatory at Aogashima	Great explosion.
Mar. 18, 1953	No. 6 Sumiyoshi-maru and Enoshima-maru, fishing boats	(Ca. 1510, 0750, 1020) Submarine explosions with large water columns and explosion clouds.
	No. 5 Shôsei-maru and Kan'ei-maru, fishing boats	(1000–1540) Several great submarine explosions. Column of water with ash up to 1 km. in diam. (Ca. 1900) Explosion.
Mar. 17–25, 1953	Wave recorder at Hachijô island	Tsunamis were recorded intermittently.
Mar. 25, 1953	US Air Force	(1400) Submarine explosion, explosion cloud 900 m. high, 100 m. in diam.
Mar. 28, 1953	Tonan-maru, Fisheries Experiment Station, Tokyo Metropolitan Government	(1530) Remarkable rising of white smoke. No explosion, no island.
Mar. 30, 1953	Temporary observatory at Aogashima island	Explosion of quite large scale.
Apr. 1, 1953	Kuro-shio-maru, a regular liner of Tôkai-kisen Co.	(0540–1700) Explosion clouds were seen in the long distance south of Aogashima from Hachijô island.
	A lighthouse at Hachijô island.	(Ca. 1500) Clouds rising every several minutes were observed.

(to be continued.)

Table II. (continued.)

Date of observation	Eyewitness or author	Reference
Apr. 1, 1953	Horawazawa, Hachijô island.	Three columns of clouds of which easternmost one was largest, were visible.
Apr. 2, 1953	Torishima Weather Station	(1100–1500) Successive emissions of ash and vapour.
	A lighthouse at Hachijô island.	(1300–1600) Ash clouds were recognized in the same direction as preceding day.
Apr. 3, 1953	Hachijô Meteological Observatory	(Ca. 0100–0700) Weak tsunamis were recorded intermittently at the island.
Apr. 5, 1953	U. S. Air Force	An island about 1/4 sq. mile in area, 200 ft. in height, was recognized at 31°53′N., 140°10′E. (0941) Ash cloud was seen. Dark-reddish sea water containing pumice ran from the Myôjin reef.
Apr. 14, 1953	Shikiné and Genkai, coastal palrol ships	At 31°56.7′N., 140°10′E., an island 200 m. long in NE, with three peaks of equal heights 46 m above sea-level was recognized (Fig. 58a).
	U. S. Air Force	Water stained into yellowish colour with volcanic material are drifting southwestward from the Myôjin reef (Fig. 58b).
May 3, 1953	Shiga-maru of the Central Meteorological Observatory	An island, about 70 m. in height, about 250 m. in long diameter, 150 m. in short diameter was found. Fumarolic action was observed at the SSE margin of the islet.
May 9–21, 1953	Temporary observatory at Hachijô island, of the Hydrograhic Office.	An island with two peaks about 43 m. high, 151 m. wide, was seen. A western half of the island was covered by vapours. Situation of the Northeastern peak was at 31°56′40″N., 140°0′26″E.
May 14, 1953	U. S. Air Force	A volcanic island was recognized.
May 26, 1953	Temporary observatory at Aogashima of the Hydrographic Office	Weak sounds of explosion were heard.
July 17, 1953	Ryôfû-maru of the Central Meteorological Observatory	A volcanic island with dome was recognizable. No explosion cloud was observed.
July 18, 1953	Sakaé-maru, a fishing boat	Five rocks were visible on the sea surface.
July 23, 1953	Nikkô-maru, a fishing boat	A lava spine associated with two rocks on its southern side. Vapour was rising between the two.
Aug. 12, 1953	Temporary observatory at Aogashima of the Hydrographic Office	Size of the island became small, about half compared with that in May. Clouds were visible at the vent.

(to be continued.)

Table II. (continued.)

Date of observation	Eyewitness or author	Reference
Aug. 17, 1953	Ditto	Amount of the vapour rising from the reef increased.
Aug. 18, 1953	U. S. Air Force	The reef was in its eruption: ash cloud rose up to about 500 m. high.
Aug. 24, 1953	Temporary observatory at Aogashima of the Hydrographic Office.	(0600–0700, 1000) Ash clouds rose in a great scale from the reef. The island was invisible. (1400) Cloud rising from the island became white vapour.
Aug. 24, 1953	Tomihisa-maru, a fishing boat	(1300) Large explosion.
Aug. 26, 1953	Umitaka-maru, a training ship of the Tokyo College of Fisheries	(2200) Red-hot lava was pouring into the sea and the ash of andesitic composition was falling.
Aug. 27, 1953	Ditto	(Ca. 0100) Explosive cloud rose up to several thousand metres into the sky. An island about 200m. in width, unknown height, was visible.
	Kongô-maru, a fishing boat	An island showed explosive action.
Aug. 27–28, 1953	Temporary observatory at Aogashima of the Hydrographic Office	Explosive ash cloud arose on a large scale.
Aug. 30, 1953	Eikichi-maru, a fishing boat	(Ca. 0515) Great explosion with remarkable ash column.
Sept. 1, 1953	Temporary observatory at Aogashima of the Hydrographic Office	(0730) Explosion. (1300–1400) Explosion ejecting remarkable ash and sand. Ash columns being 250m. in diameter, 500m. in height.
Sept. 3, 1953	No. 12 Tomihisa-maru, a fishing boat	Explosion clouds were visible, no island was seen except breakers observed at two points thereabout. Water changed into yellowish colour being stained with volcanic material drifted SSW–wards.
Sept. 16, 1953	Temporary observatory at Aogashima of the Hydrographic Office	N o island was visible.
Sept. 17, 1953	No. 5 Sansha-maru, a fishing boat	Ash cloud was rising from the sea, no island being found. Sea water changed into yellow in colour owing to drifting volcanic material.
Sept. 27, 1953	Hakuyô-maru, a fishing boat	The water was changed into white in colour, NNE of the Bayonnaise rocks.
Oct. 5, 1953	S. F. Baird, research vessel of Scripps Inst. of Oceanography	No projecting rock or evidence of euption. Presence of a bank at slight depth.

(Sound Fixing and Ranging) Stations at Point Sur and Point Arena, California had received 76 signals due to submarine explosions at the Myôjin reef during the 11 days from September 16 to September 26, 1952[10]. According to the records at the underwater listening stations off California, the Myôjin reef had already been in her active state since the early morning of September 16, 1952 before the first discovery of the present eruption by the crew of the No. 11 Myôjin-maru at about 07h25m on the next day.

Several tsunamis which must have been derived from submarine explosions at the Myôjin reef were recorded by a wave recorder installed near Yaené port on Hachijo island, about 130 km north of the reef[11]. The wave recorder caught the tsunami of this sort at 12h20m during its operation from 10h55m to 15h33m on September 16, already. On the same day at 11h52m, a microseism whose maximum amplitude being 5 μ and mean period being 4.1 seconds was felt at the island. The microseism was said to have travelled from the same source of the above-mentioned tsunami, therefore Nakano estimated a travel time of these tsunamis being 28 minutes[12]. A tsunami corresponding to the explosion observed by the crew of No. 11 Myôjin-maru was eyewitnessed by some fishers at Hachijo island in the morning of September 17[13]. The wave recorder was not in continuous operation unfortunately. Dietz assumed the transpacific travel time of the underwater sounds being 1 hour 37 minutes 32 seconds in obtaining the origin time from the SOFAR records[14]. In the foregoing table (Table II), each "time" indicated by a number of the four figures bracketed such as (0834), (1312), etc., means a time of explosion or of observation at or near the Myôjin reef shown by the Japanese Standard Time, the above-mentioned travel times being taken into consideration.

As revealed in the above table (Table II), the submarine volcano repeated three times its emergence and submergence during the present eruption. Appearance and disappearance of the ephemaral island is fur-

10) MARINE SAFETY BOARD, *Ibid.*, 107–110.

R. S. DIETZ and M. J. SHEEHY, "Transpacific detection of Myojin volcanic explosions by underwater sound", *Jour. Oceanogr. Japan*, **9** (1953), 53–83. *Bull. Geol. Soc. Amer.*, **65** (1954), 941–956.

11) MARINE SAFETY BOARD, *op. cit.* 74–77.

12) MARINE SAFETY BOARD, *op. cit.* 74.

S. UOKI and M. NAKANO, "On the Cauchy-Poisson waves caused by the eruption of a submarine volcano", *Oceanogr. Mag.*, **4** (1953), 119–141.

13) MARINE SAFETY BOARD, *op. cit.* 75.

14) DIETZ R. S. and M. J. SHEEHY, *Bull. Geol. Soc. Amer.*, **65** (1954), 947.

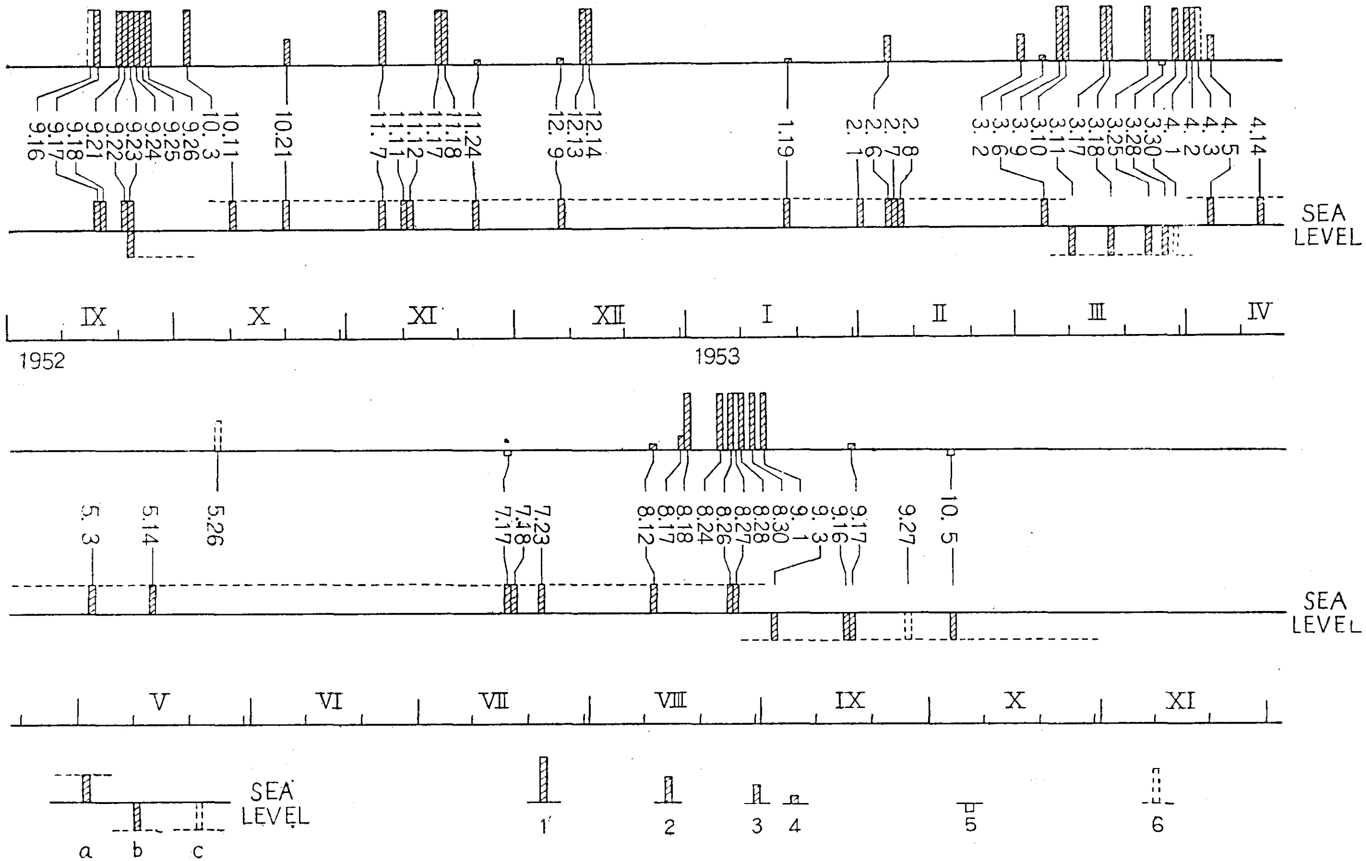

Fig. 3. Schematic representation of the 1952–1953 eruption of the Myôjin reef. a–c indicate whether the volcano being submerged or emerged; a: island visually recognized on the sea, b: the volcano completely submerged, and c: the volcano supposed to be submerged. 1–5 show a state of eruption visually observed; 1: major explosions, 2: vomiting of ash cloud and vapour with moderate explosive action, 3: remarkable vapour emission without visible explosion, 4: vapour emission only without visible explosion, and 5: no visible activity. 6 shows activities presumed from tsunami, sound, underwater listening, etc.

ther clearly shown schematically in the above-mentioned diagram (Fig. 3).

The volcano first appeared on the sea with its blocky lava head on September 16 or 17, 1952. Vomiting continuously ash clouds and vapours, the activities of the volcano became explosive several days after the outburst of the eruption (Figs. 8–12). On September 23, after two severe submarine explosions at 13h12m and 13h40m (Figs. 27–51), it submerged completely leaving the sea water changed into yellow in colour above its head. During the period of submergence, colour of the water above the volcano was changing into yellow owing to the continuous subaqueous emission of volcanic dusts. About half a month later the volcano appeared again on the sea probably on a day after 3rd and before 11th of the next month. Untill the beginning of March in the next year, perhaps March 9–10, 1953, when the island submerged after severe explosions (Fig. 57), the ocean current had presumably been breaking on the side of the island. Typical volcanic spines such as observed on the summit of Mt. Pelé were protruding from the vent during the second period of appearance (Figs. 54–56), from October 3–11, 1952 to March 9–10, 1953. In the succeeding three weeks or more, from the middle of March to the beginning of April, remarkable submarine explosions were reported many times. Explosions became frequent and emission of ash and vapour became continuous. Thus, at the beginning of April, 1953, probably between April 3 and 5, the third appearance of the island took place. The island had presumably been exposed on the sea with continuous vapour emission till the end of August (Fig. 58 a-b). No conspicuous explosions had been recorded in this subaerial period. Since the middle of August, 1953, the amount of vapours rising from the island had increased. Puffing of ash clouds became active toward the end of the month, sometimes up to 500 m. or more into the air. In the last week of that month the volcano turned into explosive state. The explosive actions at the end of the month were the most destructive of the present eruption. Large amounts of ash, sand, and pumice were ejected. Ash of andesitic composition whose chemical analysis will be shown in the fourth chapter of this paper were blown away, while the pumice grains drifted to the shore of Aogashima, about 50 km. north of the volcano were exclusively white dacite. About ten days' explosive activities led to the collapse of the island into the sea and the Myôjin reef has never emerged upon the sea level since the first few days in September 1953[15].

15) Two explosions during 14h–15h on Nov. 4, 1954 at the Myôjin reef were reported by the fishing boat Eikichi-maru of Yaizu port. But it was not recognized by the Hydro-

It is clearly shown also by the above-mentioned diagram (Fig. 3) that the successive explosive activites accompanied with outbursts of large amount of pumice continuing for several days or more always preceded the collapse of the island into the sea. The repetition of gradual formations of dome or spines followed by violent collapses owing to severe explosive activities were displayed by the Myôjin reef through the 1952–1953 eruption. Had the eruption occurred on the land, severe avalanche of domes or spines, pumice shower, nué ardente, phenomena characteristic to the Peléan eruption would have been observed.

III. Submarine explosions on September 23, 1952

The training ship Shinyô-maru, 229 tons, of the Tokyo College of Fisheries on which the writers embarked with other scientists left Uraga port, Kanagawa Prefecture, southwards for the Myôjin reef at 05h in the morning of September 21, 1952. At 17h30m of the same day the ship touched at Funato Bay of Miyake-jima, an active insular volcano of basaltic nature about 170 km. south of Tokyo, to avoid a centre of an atmospheric depression. On the next day at 05h, the ship left the island and at 14h30m of the same day cast her anchor at Horawazawa Bay of Hachijo island about 290 km. south of Tokyo to avoid arriving her destination at midnight. There, at 15h05m a white cloud (cumulonimbus formed by an explosion) was seen in far distance in the direction of the Myôjin reef. Leaving the bay at 19h15m of the same day, she continued to voyage southwards through the night at a speed of 10 knots every hour. At 23h45m of the same day after passing off Aogashima, a volcanic islet about 350 km. south of Tokyo, a night scene of an explosion was viewed far to the south.

On the next morning, at 04h, September 23, the ship first approached the Bayonnaise rocks and, next, at 06h05m, the Myôjin reef eastwards. The newly-born island had almost disappeared leaving three rocks on the sea. The three rocks, about 1.5 m. in height above sea level at the time of low water, were submerged completely at the time of full tide, where the difference between sea levels at high and low tides was about 2 m. at that time. It was quite clear and the sea was calm. There was nothing to predict any tremendous events except the breakers over

graphic Office. Activity at the Bayonnaise rocks was found by the No. 2 Hôshin-maru of the Fisheries Experiment Station of Aichi Prefecture on June 25, 1955 at 16h. (Personal communication from Mr. H. Katô, an eyewitness, of the Prefectural Fisheries Experiment Station at Gamagôri, Aichi Prefecture).

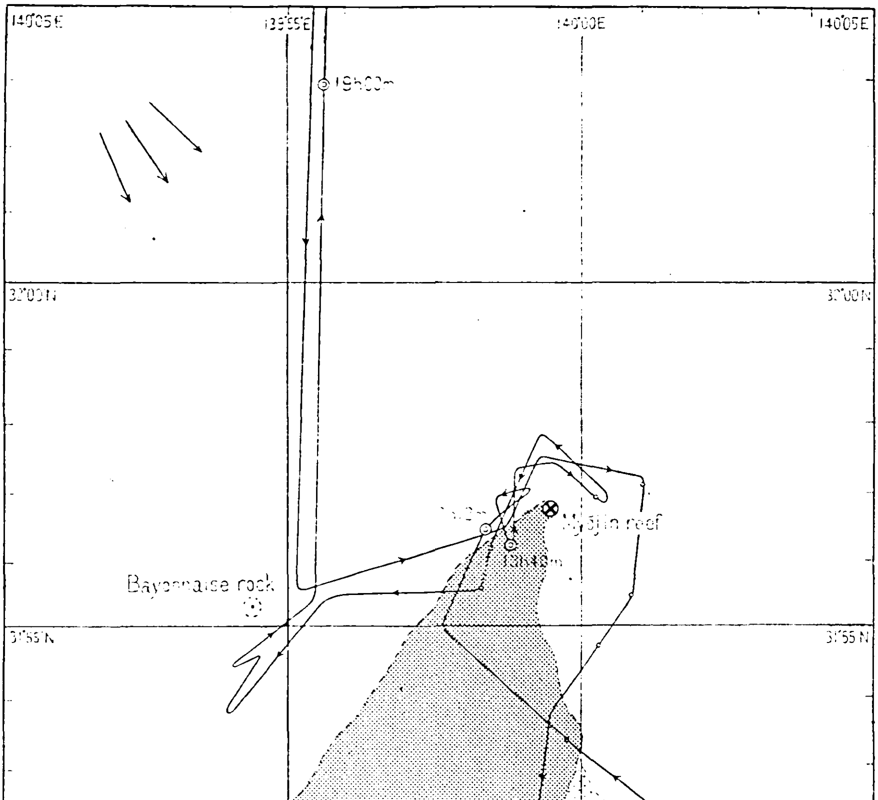
139°55'E
140°00'E
140°05'E
32°00'N
31°55'N
31°50'N
31°45'N
Bayonnaise rock
Myojin reef
0
5Km

Fig. 4.

an area of 1–2 km. in diameter near and around the above-mentioned three rocks, and the stationary SSE-ward Kuroshio counter current with a speed of 1.5–0.8 km every hour changing into yellow in colour being contaminated with volcanic dusts owing to the subaqueous emission of the volcano. The turbid current, starting from the Myôjin reef, suspended minute grains of white pumice, volcanic dusts, volcanic hairs, etc. Amounts of the suspensoids in the water were measured as 3–30 mg. per litre including traces of sulphur[16]. The yellowish-stained water[17] was clearly bounded by the non-contaminated water (Figs. 13–15) of the Kuroshio[18]. Smells of hydrogen sulphide were sometimes felt on the deck of the ship. The water deeper than 25 m. was not stained with volcanic ejecta.

During the half-a-day's stay near the reef that day, four explosions were witnessed of which the three submarine explosions at 08h34m, 13h12m, and at 13h40m were observed at short distances from the centre of the eruption and the last one at 19h00m exhibiting a spectacular night scene was viewed on our way back to Uraga.

Situations of the ship when each explosion took place are shown by double circles in the map prepared by the members of the first investigation of the Myôjin reef under the auspices of the Tokyo College of Fisheries on September 23, 1952 (Fig. 4). The locus of the sailing ship during the present investigation, the drift of the ship during oceanographical observations (Fig. 16), the direction of the wind of that day, the distribution areas of the floating fine pumice or ash and of the contaminated water are shown in the same figure by real lines or curves,dotted lines, arrows, dotted area, and shaded area respectively. Locality of the reef was estimated as 31°56.8′N in latitude and 139°59.5′E in longitude by the officer of the ship. Actual scenes of the submarine explosions are described in the following sections.

(*1*) *Narative of the explosions*

Features of the phenomena displayed by the underwater explosions are in general similar to those reported about the geyser activities[19] and

16) H. HAMAGUCHI and M. TATSUMOTO, "Chemical investigation on the sea water and the pumice stone", *Jour. Coll. Fisheries*, **40** (1953), Special Number, 20–21.

17) Transparency 3 m., pH 7.5–7.7 in surface 8.5 deeper than 25 m., olive yellow or olive green in colour after *Wada's Colour Chart.*

18) Transparency 23 m., pH 8.5, deep lyons blue in colour after *Wada's Colour Chart.*

19) C. A. COTTON, Volcanoes as Landscape Forms. Wellington 1944. p. 280. In the geysers verfical belches are predominating.

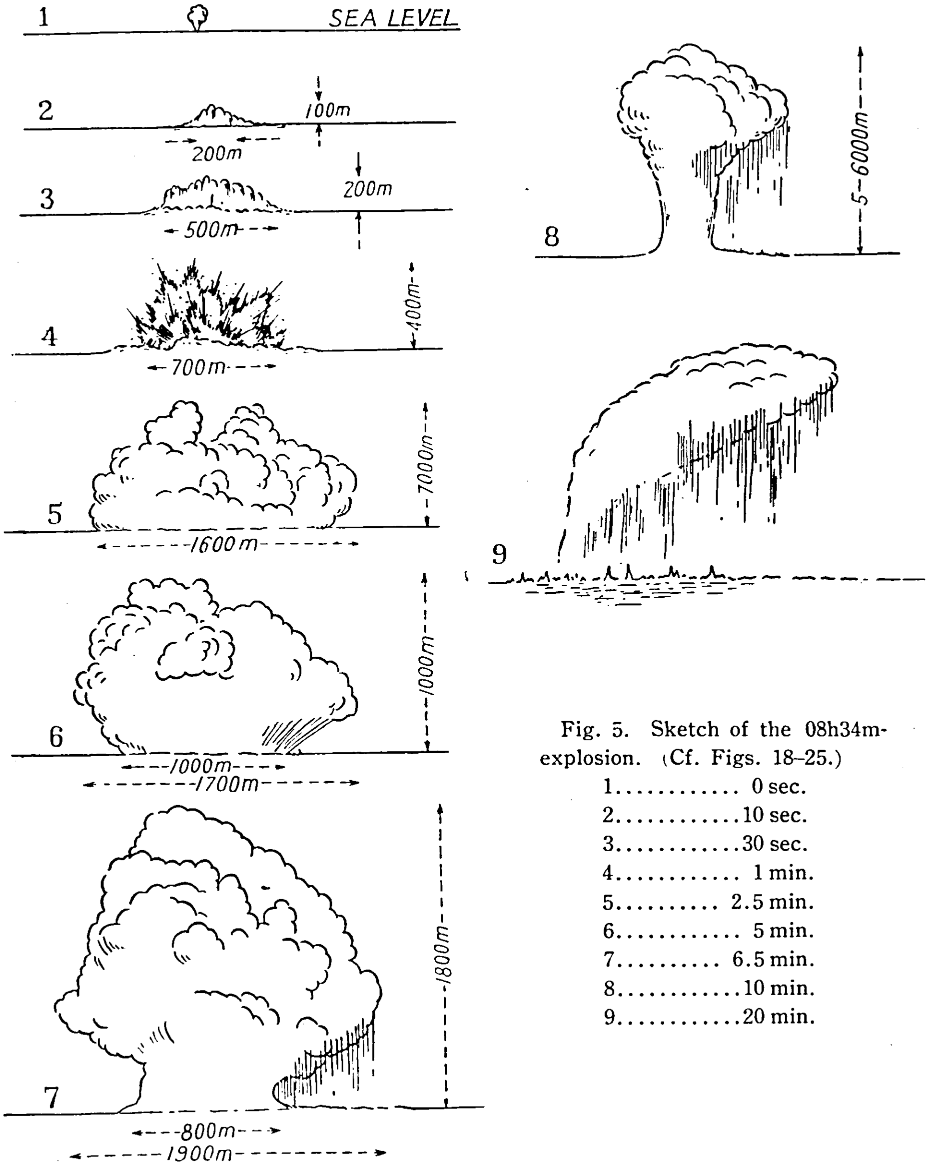

Fig. 5. Sketch of the 08h34m-explosion. (Cf. Figs. 18–25.)

1. . . . . 0 sec.
2. . . . . 10 sec.
3. . . . . 30 sec.
4. . . . . 1 min.
5. . . . . 2.5 min.
6. . . . . 5 min.
7. . . . . 6.5 min.
8. . . . . 10 min.
9. . . . . 20 min.

those of the eruption of Anak Krakatau in 1938[20]. But in detail, the Myôjin reef behaved in different ways from them, and was different even in each explosion as described below.

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20) R. W. van BEMMELEN, The Geology of Indonesia IA General Geology. Haue 1949 pp. 200–201, Fig. 63 (Stehn's photographs).

a) The 08h34m-explosion:

Several minutes before the explosion, bluish dark smokes rising were seen two or three times far from the centre of the eruption (1 in Fig. 5). At 08h34m, the water, dark purplish in colour, domed up abruptly, then dark plumes like a bush of swords broke through the surface of the dome followed by greyish white water columns. The sharp tops of plumes were led by the blocks ejected. The plumes grew larger and larger with great speed before our eyes in all directions and then turned downwards. White smokes which appeared among these plumes increased in volume accelarately and completely enveloped them (Figs. 19–20). The smokes, ash clouds and vapours, gushed out widely to form a large cabage-like group (Figs. 20–21), which began to rise as a whole. The upward movement increased its speed more and more to exhibit a cauliflower with a major leg such as is often seen on the occasion of an atomic bomb explosion. It reaches up to several thousands metres (Figs. 5, 17, 22, and Table III) changing its

Table III. Spreading of the ash cloud with time at the 08h34m-explosion on September 23.

Fig. No.	Diameter of the cloud or vapour at the sea surface	Maximum diameter of the cloud in the air	Height of the cloud above sea level	Time-lapse after the first manifestation at the sea surface of the explosion
18	780 m.	780 m.	390 m.	40—50 sec.
19	1,100 m.	1,100 m.	470 m.	1.5 min.
20	1,440 m.	1,800 m.	820 m.	2.5 min.
21	1,050 m.	1,830 m.	1,170 m.	5 min.
22	860 m.	2,110 m.	1,990 m.	6.5 min.
25	2,200 m.	2,220 m.	140 m.	30 min.

colour variously (e.g. white, pinkish, yellowish brown, and light purple) under the bright sun-shine. Vapours continued to rise from the sea surface. Ash began to fall leewards. The cauliflower-cloud diverged gradually in the sky leaving white horizontal cloud below (Figs. 23–24). The colour of the sea surface was dark greyish and boubling, vapour emission still continued even after the cloud separated itself upwards from the sea. All things dissolved into the blue sky at about 08h55m leaving the floating ejecta on the sea. No explosion sounds were heard on the ship even when the ship was drifting with her engine stopped. Temperatures of the surface water and of the atmosphere were estimated at 27.8°C and 25°C respectively. The atmospheric pressure was 1014.5 millibars, the weather was fine, the force of the wind was 2 in Beaufort's scale and its direction southwestward at that time, and the full-tide at the Bayonnaise rocks was 07h45m of that day. Observation station of the explosion is shown in the Fig. 4.

After the 08h34m-explosion and before the next explosion described below, no submarine explosion was felt on the ship. But during this calm period, the SOFAR stations off California was said to have recorded one remarkable Myôjin explosion at about 11h43m (JST)[21]. According to Dietz and Sheehy, an intensity of the 11h43m-explosion was stronger than those of the three submarine explosions witnessed at 08h34m, 13h12m, and at 13h40m. Every witnessed explosion was displayed in a visual field so clear that the Island of Aogashima about 60 km. north of the Bayonnaise rocks and even Smith reef about 55 km. south of the rocks could be seen distinctly. The weather was fine and the sea was calm. Large amounts of ejecta and of volcanic gas

21) R. S. DIETZ and M. J. SHEEHY, *Bull. Geol. Soc. Amer.*, **65** (1954), 948, Table 5:

Date	1	2	3	Corresponding explosion witnessed by the writers
	..	..	..	
	..	..	..	
	..	..	..	
Sept. 22	23h45m	4	1 explosion, 1 min.	23h45m-explosion
Sept. 23	00h25m	2	1 min.	
	08h28m	2	—	08h34m-explosion
	11h43m	3	10 min.	
4	13h08m	2	—	13h12m-explosion
	13h35m	2	—	13h40m-explosion
	19h01m	3	2 explosions, 1 min.	19h00m-explosion
	19h14m	2	4 explosions, $1\frac{1}{2}$ min.	
	22h33m	2	1 min.	
	..	..	..	
	..	..	..	
	..	..	..	

1. Calculated explosion time (nearest minute) in Japanese Standard Time after Dietz and Sheehy.

2. Intensity of explosion after Dietz and Sheehy.

3. Number of explosions and duration of received singnal or interval covered by series of signals after Dietz and Sheehy.

4. Time interval during which the writers stayed near the Myôjin reef in their present investigation.

were belched at every explosion witnessed by the writers. It was quite strange that under such preferable circumstance the writers should have found no manifestations on the sea of the explosion which ought to have taken place at about 11h43m according to the records of Dietz and Sheehy. When and where did the gas which should have been emitted at the time of the explosion in question escape? Did it dissolve into the water? Or did the 11h43m-explosion take place at other different vent opened at deeper place. It has never been assured that every Myôjin explosion had always taken place at the same vent. Two separate water columns arising simultaneously were observed from Aogashima in September, 1952 and three were from Hachijô island in April, 1953[22].

b) The 13h12m-explosion:

The 13h12m-explosion was witnessed at 31°56.5′N in latitude and 139°58.4′ E. in longitude about 1,800m. distant from the centre of the eruption, when the ship was sailing northeastwards along the western boundary between the turbid water and the non-contaminated "Kuroshio" counter current for observing the three projecting rocks, one in the east and two in the west about 200m. apart from the former (Fig. 4). The rocks were dark brown or sometimes brownish purple in colour under sun-shine and the waves were breaking on a bank over an area of 500–1,000 m. in diam. around the rocks.

The explosion was brought about on the sea at 13h12m without any visible forerunning phenomena except slight belching of dark smokes one or two times from the sea near the above-mentioned rocks. The sea surface of an area of 290 m. in diam. near the rocks suddenly domed up nearly to 20 m. in height (Fig. 27). Then the summit of the water dome of glassy lustre became dark purplish in colour as the dome increased its height. A number of blocks followed by dark water tails, mixtures of water and rock fragments, broke through the crest of the dome like plumes (Figs. 27–29). These numerous plumes of dark mixture of water and rocks were ejected to the heights of 400 m. or more and then turned downwards (Figs. 29–30). Some of the large blocks tailed with these dark plumes separated themselves from the tops of these plumes and flew farther away. As these ejecta turned downwards, white smokes, brown or grey ash clouds began to gush out successively (Fig. 30) to form a large mass of clouds about 600 m. high covering the sea over

22) Y. TSUKAMOTO, *Monthly Meeting of the Earthq. Res. Inst.*, (May 24, 1955).

an area of 1.5 km. in diam. (Figs. 31–34). Then the clouds moved rapidly upwards in a body (Fig. 35) to make a cauliflower cloud (Fig. 36) several thousands metres high, with an huge leg of one kilometre in diameter. Ash began to fall leewards, spouts of dark smokes rose from the dark bubling sea, and the cauliflower cloud faded into the sky leaving floating pumice blocks from 5–10m. to 30cm. in diameters on the sea, where white vapours were still rising. Low explosion sounds were slightly heard. Waves 2–3 m. high seemed to have been brought about by the explosion. Ten minutes later all things returned to their calm state. There was nothing left except the floating pumice blocks—some of them had already sunk into the sea—to show that such a conspicuous phenomenon had just been displayed there[23]. Fortunately the changing scenes of the activity were photographed successively as shown in Figs. 26–40, on which some measurements were tried as follows (Tables IV and V):

Table IV. Spreading of the ash cloud with time at the 13h12m-explosion, Sept. 23*.

Fig. No.	Diameter of the ash cloud at the sea surface	Height of the cloud above sea level	Time-lapse after the first manifestation at the sea surface due to the explosion.
27	290 m.		1 sec.
28	320 m.	290 m.	3 sec.
29	570 m.	410 m.	5 sec.
30	870 m.	430 m.	8 sec.
31		440 m.	12 sec.
32		450 m.	15 sec.
33		460 m.	20 sec.
34		650 m.	30 sec.
35	880 m.		1 min.
36			2 min.
37	520 m.		3 min.
38			4 min.
39	310 m.		5 min.

* MARINE SAFETY BOARD, *op. cit.*, 88–96.

23) Weather was fine, atmospheric pressure was 1,010 millibars, direction of the wind was southwestward, force of the wind was 2, in Beaufort's scale and the atmospheric temperature was 24.5°C, while temperature of the surface water being 27.7°C. Lower tide at the Bayonnaise rocks was 13h25m of that day.

Table V. Comparison of the observed lapse of time and height of the plume with those calculated.*

Fig. No.	Time photographed	Height of the plume above sea level read on the photograph	Time calc.	Height of the plume above sea level calc.
27	1 sec.	44 m.	1 sec.	86.9 m.
28	3 sec.	290 m.	4 sec.	289 m.
29	5 sec.	410 m.	7 sec.	403 m.
30	8 sec.	430 m.	9.4 sec.	430 m. **

* Every "time" on the table is represented exclusively by the "time-lapse" after the first manifestation of the underwater explosion at the sea surface.

** Maximum height of the plume to which a bomb was ejected was assumed as 430 m. reading on the Fig. 30.

c) *The 13h40m-explosion*:

When we entered into the contaminated sea current southwest of the centre of the eruption in order to collect the floating pumice blocks ejected by the 13h12m-explosion, the next 13h40m-explosion suddenly took place. It occurred so shortly after the previous explosion we had just observed that we were surprised to meet such a thrilling explosion. Situation of the ship at this event was 31°56.2′N., 139°58.8′E., about 1,500 m. southwest of the explosion point. Emerald blue sea water covering an area of about 210 m. in diameter was upheaved nearly to 40 m. in height to form a water dome of sharp curvature (Fig. 41). Simultaneously the water around the dome seemed to sink slightly. Rapid darkening in colour of the summit of the transparent bluish green water dome, successive belching of a number of dark plumes breaking through the crest of the dome, and the rolling down of water particles along the surface of the dome with the bending down of the plumes (Figs. 41–42) were clearly observed. Successive scenes of the explosion and the scale of the spreading ash clouds are shown in the following photograghs and table (Figs. 41–51 and Table VI). The succeeding processes of this explosion were similar to those displayed by the previous one, though the water dome formed by the 13h12m-explosion was flat and broader compared with that of the present explosion. The shape of the domes will be discussed in later pages. Sometimes exceptionally, bombs were ejected whose trajectories of flying were flat and close to the sea surface (Fig. 49). Further observation of the spreading explosion clouds was almost impossible, for they soon scaled out from our field of view (Figs. 48–50). Waves

Table VI. Spreading of the explosion-cloud with time at the 13h40m-explosion on sept. 23.

Fig. No.	Diameter of the cloud at the sea surface	Height of the cloud above the sea level	Time-lapse after the first manifestation at the sea surface of the explosion
41	210 m.	83 m.	5 sec.
42	300 m.	150 m.	7 sec.
43	450 m.	160 m.	10 sec.
44	540 m.	160 m.	12 sec.
45	680 m.	270 m.	15 sec.
46	860 m.	340 m.	17 sec.

50 m. long and 2 m. high[24] brought about by local impulse of the underwater explosion attacked the side of the ship slightly when she was going to turn for a safer place[25]. Low explosion sounds were heard faintly. Stimulating smell of sulphurous anhydride was felt on the deck. No remarkable change was found in the temperatures of the surface water before and after the explosion. Floating pumice block was picked up on the deck in hot state still about 60–80°C. The white two pyroxene-dacite containing porphyritic crystals of quartz, our first petrographic information on the volcano, warned us of the dangerous character of the eruption. By this explosion one of the three projecting rocks was blown off. The situation off.

After some oceanographical observations, the ship left the Bayonnaise rocks at 18h10m. On the way back to Uraga an explosion was witnessed from a point, 32°04.3′N., 139°55.3′E., about 13 km. NNW of the centre of the eruption. An acute pyramid of fire was seen on the horizon. It grew larger and larger and was enclosed by the spreading cloud at the periphery of which sparkings were seen. Lightnings were also observed around and above the cauliflower cloud. The scale of the explosion seemed to be larger than the 13h12m and 13h40m explosions. But all things occurred too remote to be observed in detail. The weather was fine, atmospheric pressure was 1,014.5 millibars, force of the wind was 2 in Beaufort's scale and northeastward, temperatures of the air and of the surface water were 24°C and 25.7°C respectively,

24) TOKYO COLLEGE OF FISHERIES, *op. cit.* 11. H. MIYOSHI and Y. AKIBA, "The tsunamis caused by the Myôjin explosions," *Jour. Oceanogr. Soc. Japan*, **10** (1954), 50.

25) Order of energy of the 13h40m-explosion was estimated to be 10^{13} erg by S. Murauchi (S. MURAUCHI, "Explosive activities of Myôjin reef, 1952", *Jour. Scis. Soc. Japan*, **5** (1952), 162. in Japanese).

and the full tide at the Bayonnaise rocks was 19h05m of that day. The S. S. Shinyô-maru returned to Uraga port on September 24 at 17h30m where we heard that the No. 5 Kaiyô-maru had missed.

(2) *Depths of the submarine explosions.*

Methods of estimating the depths of underwater explosions have been under much discussion. Recently Pekeris, relying upon his analysis of photographs of the dome of spray from some fifty statically-fired charges, proposed some methods of estimating the depth of an underwater explosion from the shape of dome of spray formed by the explosion[26]. One of his methods, a modification of Shaw's method (i.e. the distance from the centre of the dome to a radius where the dome-height has decreased to half of the central height is equal to the depth of the explosion, or in other words, half width of the dome is equal to the depth of explosion) may be applied to the present submarine explosions. Of course, strict accuracy cannot be expected in the estimations of the depths of the Myôjin explosions by this method, though Pekeris says that his estimates can be made with an accuracy of about 10 per cent in error in cases of controlled artificial explosions. Pekeris's method, as well as Shaw's, assumes that the initial rate of rise of spray is equal to the acoustic velocity imparted to particles of water in the superficial layer by the peak of shock wave from an explosive. According to the estimations at many active volcanoes, gas pressure at a volcanic explosion is not so great; 450-500 atmospheres at greater ones[27]. So in analysis of the mechanism of the dome formation, e.g. motion of the surface water, it may be treated as an effect of pressure waves due to the submarine volcanic explosions, as Pekeris did in his paper where he used the term "shock wave".

As the data available for this estimation, the writers have a series of photographs of the scene taken by a 35 mm. camera only, for unfortunately the movie cameras of other observers could not catch the complete scene of the explosion during the investigation. As to the explosions at 13h12m and at 13h40m, shapes of the water domes representing the initial states of the manifestations of the underwater explosions were

26) C. L. PEKERIS, "Determination of the depth of an underwater explosion from measurements of the dome of spray", *Annal. New York Acad. Sci.*, **51** (1949), Art. 3, 442–452.

27) T. MATUZAWA, "Gasdruck bei einigen vulkanischen Ausbruchen in Japan", *Bull. Earthq. Res. Inst.*, **11** (1933), 347–349.

Table VII. Estimations of depths of the 13h12m and 13h40m explosions.

	13h12m-explosion	13h40m-explosion
Central height of the dome	18.5 m.	39.2 m.
Half-width of the dome (right)	56.6 m.	45.6 m.
Hals-width of the dome (left)	77.3 m.	37.0 m.
Average of the above two (depth)	66.9 m.	41.3 m.

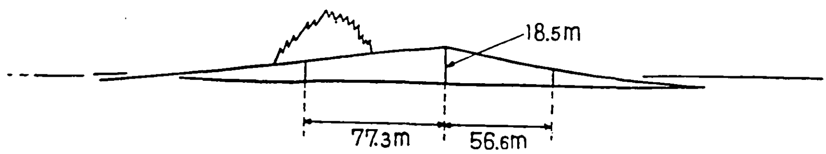

Fig. 6. (enlarged from Fig. 27.)

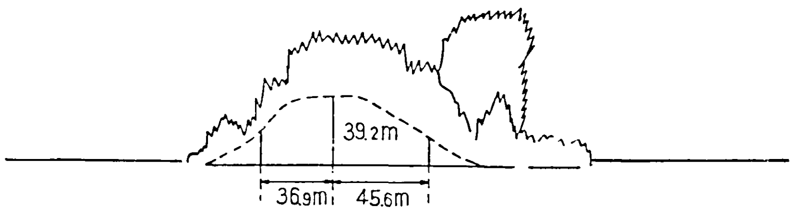

Fig. 7. (enlarged from Fig. 41.)

caught by the cameras. Applying the above-mentioned method to the photographs shown in Figs. 27 and 41, we obtained the depths of the explosions from Pekeris's formula as diagramatically shown in the Figs. 6–7, focal lengths of the cameras, and the distances to the objects from the observation stations being given. Such estimations on the photographs are subjected to more uncertainities than Pekeris's estimation on his artificially controlled underwater TNT-explosion[28]. The continuous changes in shape of the domes could not be checked by the writers' camera so successively as by a movie camera. Nevertheless, in the above estimations, it is assumed that an explosion took place always in the water which is distributed infinitely horizontally and also downwards. In fact, however, the Myôjin explosions never took place in free water but must have taken place at the submarine vent where the solid rocks are situated beneath the water. On the other hand the depths of the submarine explosions may be estimated as

28) C. L. PEKERIS, *op. cit.*, 445.

scores of metres judging from the submarine topography near the volcano before the eruption[29] and from the appearance of the activity after the outburst of the present eruption. As to the writers' estimations on the depths of the explosions of the Myôjin reef, the above-mentioned values themselves cannot indicate the actual depths but they accord with the values estimated geographically and geologically in order of their values.

(To be continued)

29) R. MITA, *op. cit.*, Text-fig. 2.

8. 明神礁の昭和 27—28 年の噴火 (1)

地震研究所 森 本 良 平
小 坂 丈 予

昭和 27 年 9 月 17 日午前 7 時 15 分頃，ベヨネイズ列岩 (31°55.3′N, 139°54.5′E) の東方約10km. の海面に，漁船「第十一明神丸」によつて海底噴火が発見報告された．この噴火によつて出現した島は，発見した船の名を取つて「明神礁」と命名された．明神礁は，第五海洋丸と共に殉職した三田亮一氏によれば，ベヨネイズ列岩を外輪山の一角とする複式火山の中央火口丘の一つといわれ，この附近には明治 29 年，39 年，大正 4 年，昭和 9 年，21 年に噴火の記録がある．しかし，海底地形の概略と，明治 39 年噴出安山岩質浮石の簡単な記載のほか，火山の詳細は知られていなかつた．今回の噴火は，9 月 24 日，調査に派遣された海上保安庁水路部測量船第五海洋丸の遭難という，火山研究史上未曽有の事件勃発のため，各方面の注目を惹くに至つた．第五海洋丸が海底爆発によつて遭難したと信じられる 9 月 24 日の前日，筆者らは，東京水産大学（旧水産講習所）練習船「神鷹丸」に乗船して現場に臨み，海底爆発を目撃観察する機会を得たので，(1) 今回の噴火の活動経過，(2) 昭和 27 年 9 月 23 日の海底爆発の情況，(3) 各種拋出物の岩石記載を詳細に述べることにした．本篇では，噴火の発見から活動が休止したと思われる昭和 28 年秋までの明神礁の活動の経過を，各方面の資料を集めて記載し，昭和 27 年 9 月 23 日の海底爆発の情況を詳述した．

この活動期間に，明神礁は 3 回，海面に出現しては海没した．すなわち，昭和 27 年 9 月 17 日に，その熔岩ドームの頭端を海面上に現わして数日後から，活動は爆発的となり，9 月 23 日の相続く水中爆発によつて水没し，10 月 3 日から 10 日の間に水面上に出現してそのご翌年 3 月 9 日まで，熔岩尖塔を海面上に見せていた．昭和 28 年 3 月に入つて，また爆発をくりかえし 3 月 10 日に水没した．第 3 回目に海面上に現れたのは 4 月のはじめで，このときの熔岩尖塔や熔岩円頂丘も，8 月下旬のひきつづいた爆発で崩壊水没し，そののちも，浮石，火山塵で海水を黄濁させる水中噴火を続けていたが，そのごは確実な消息なく，噴火活動を終息したものと思われる．明神礁はこのように，徐々に熔岩円頂丘或ひは熔岩尖塔を突出させたのち，大量の浮石拋出を伴う烈しい爆発活動をつづけて円頂丘や尖塔を崩壊するという過程を，今回の活動期間中に，3 回くりかえしたことになり，あとで述べる拋出岩石の岩石学的性質も，このような Pelé 式噴火の活動型式を裏づけている．

昭和 27 年 9 月 23 日の午前 8 時 34 分，午后 1 時 12 分，同 40 分の爆発は，爆発地点より，それぞれ南方約 9 km.，西南西 1.8 km.，西南方 1.5 km. の距離から目撃することができた．爆発は，まず，水中爆発の圧力波による海水ドームの形成，海水ドームを突き破つて火山岩塊の拋出，

ついで，水中を上昇してきた火山放出ガスの逸出による，原子爆弾の爆発に際して見られるような茸状雲の形成とその逸散，少量の降灰，拋出浮石の漂流，といつた順序で行われる．各爆発実況の規模とその経過時間は，写真（第 28–52 図）及び図表(第 5 図，第 III–VII 表）によつて示した．なお，海水ドームの盛り上りの写真から，推定計算した爆発点の深さは，海底地形その他から推測される値と矛盾しない程度の値（40–70 m.）が得られた．（未完）

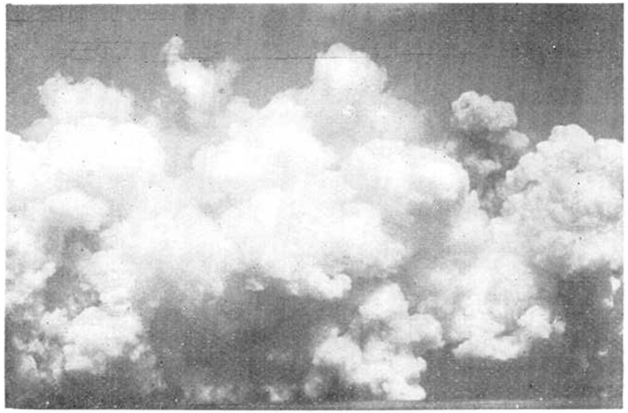

Fig. 34. Dito 30 sec. Upward movement of the cloud.

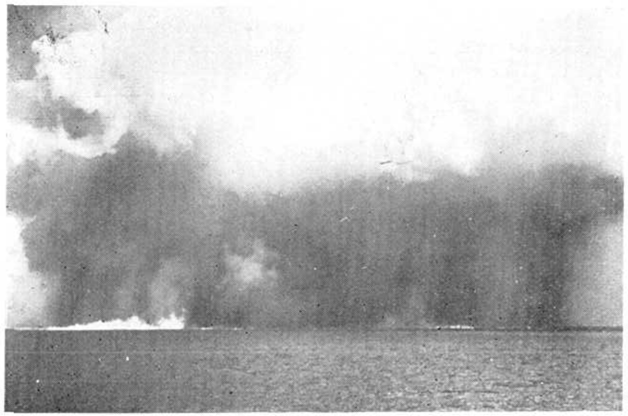

Fig. 35. Ditto 1 min. Head of the cauliflower cloud moved out of the camera field and the neck column of the cloud appeared.

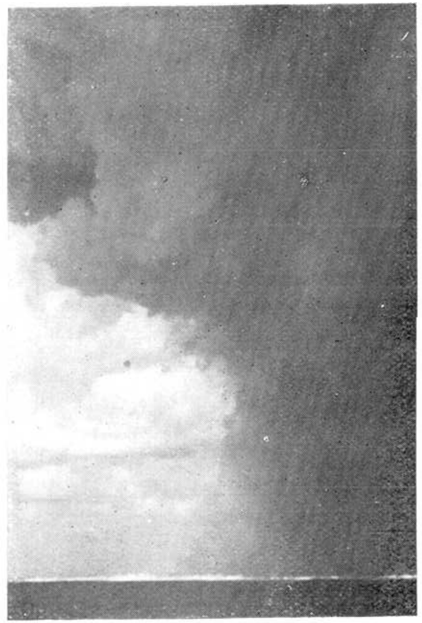

Fig. 36. Ditto 2 min. Lower part of the northern half the cauliflower cloud.

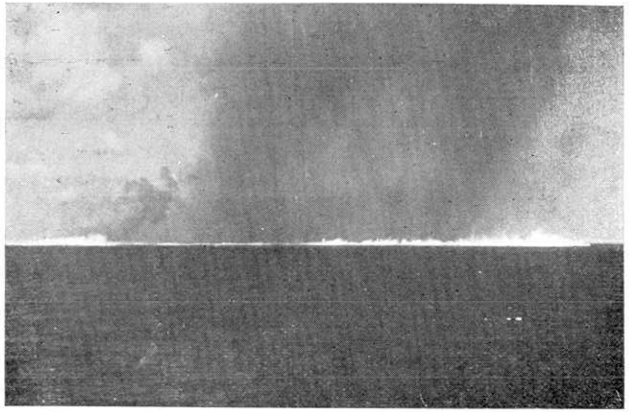

Fig. 37. Ditto 3 min. Vortical ash columns arose after the cauliflower cloud moved away.

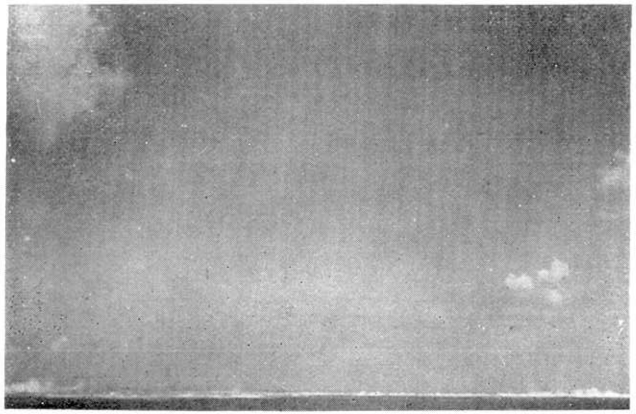

Fig. 38. Ditto 4 min. Ash began to fall and the explosion cloud became translucent gradually.

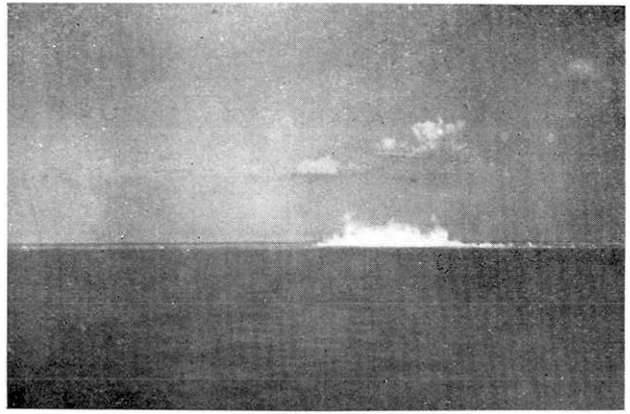

Fig. 39. Ditto 5 min. The explosion cloud dissolved into blue sky leaving only many floating pumice blocks on the sea from which white vapours were rising.

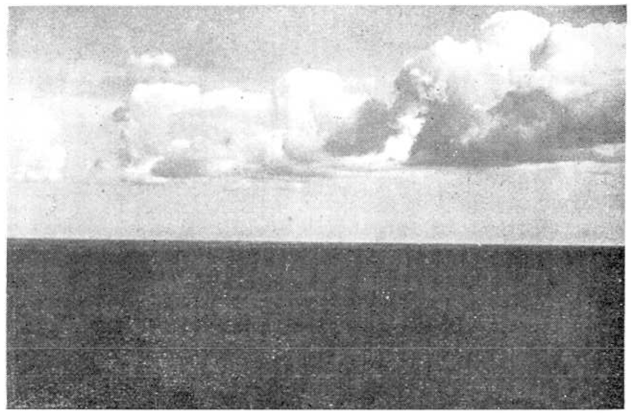

Fig. 40. Ditto 15 min. There was nothing to show any evidence of severe explosion. Yellowish turbid current only shows the continuous subaqueous emission from the volcano.

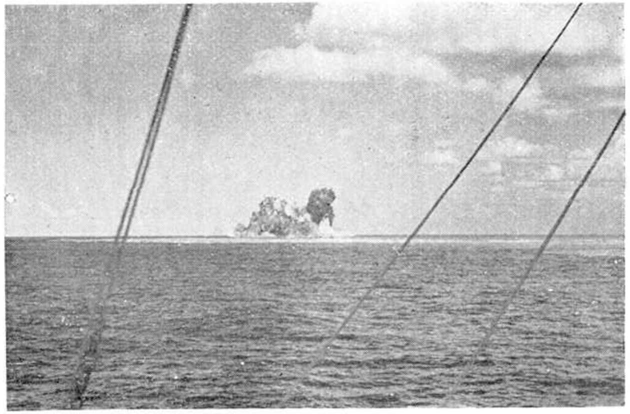

Fig. 41. 5 sec. after the first manifestation of the 13h12m-explosion on the sea.

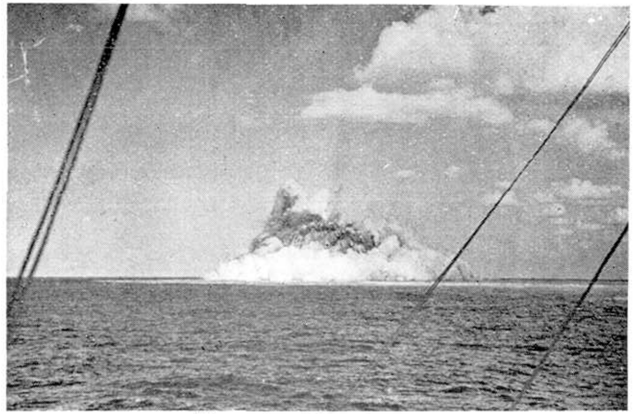

Fig. 43. Ditto 10 sec.

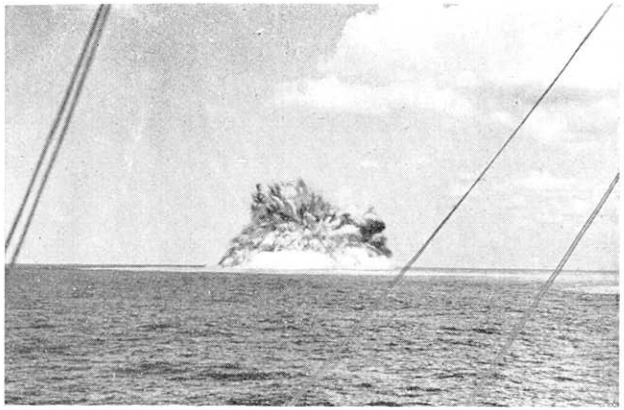

Fig. 42. Ditto 7 sec.

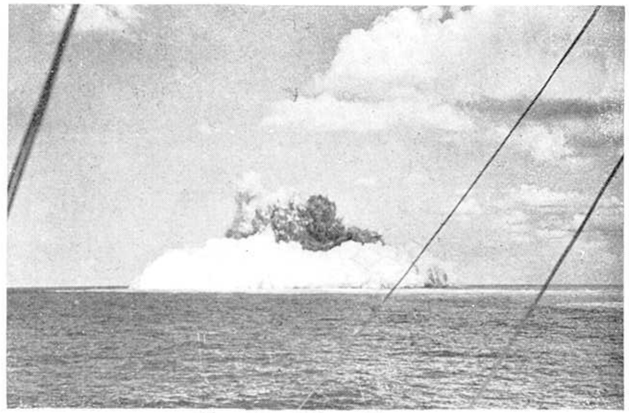

Fig. 44. Ditto 12 sec.

Figs. 41–51. Chaging scene of the 13h40m-explosion. Cf. p. 245 and Table VI. One millimetre on each photograph corresponds to about 12.5 m. in actual distance, i.e., 8.0 mm. on the photographs to 100 m. in actual distance (Figs. 41–46. were photogaraphed by R. Sugano of Asahi Press).

[Bull. Earthq. Res. Inst., Vol. XXXIII, Pl. LIII.]

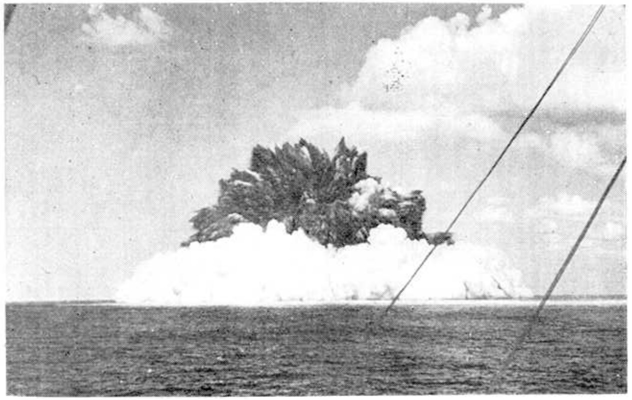

Fig. 45. Ditto 17 sec.

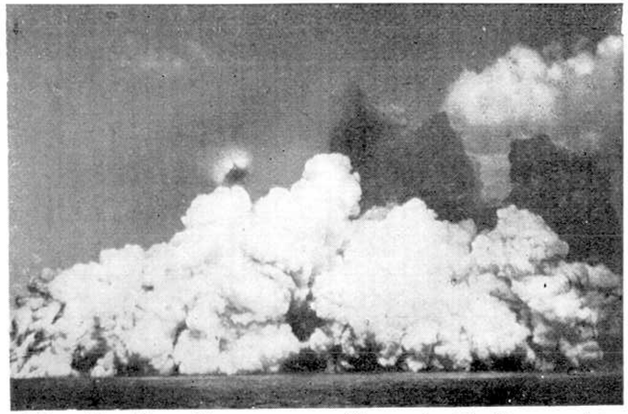

Fig. 47. Ditto 30 sec. Photo. by H. Hamaguchi

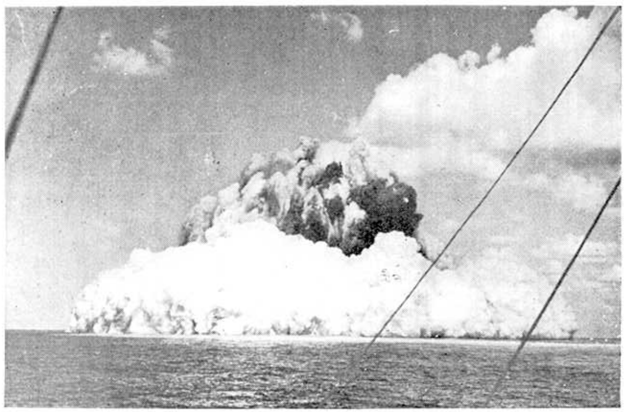

Fig. 46. Ditto 15 sec.

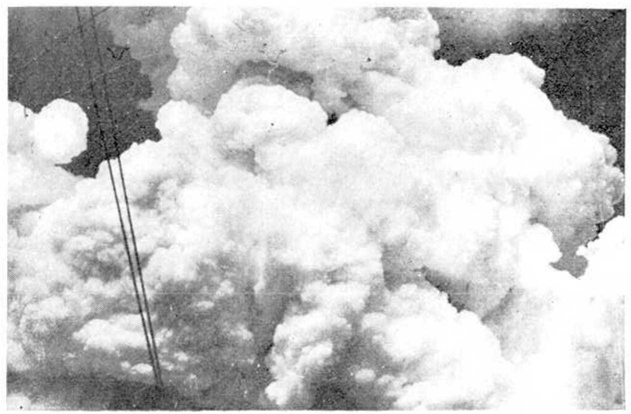

Fig. 48. Ditto 1 min.

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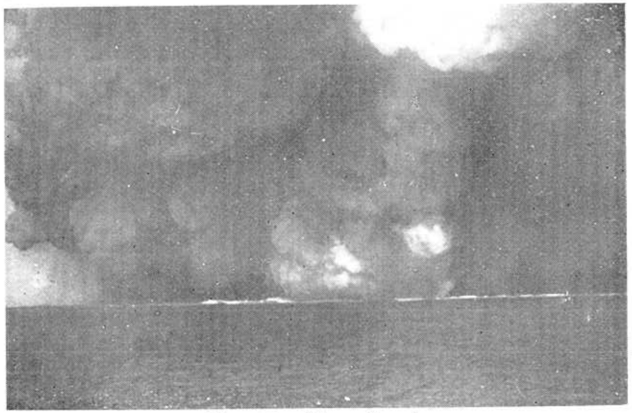

Fig. 49. Ditto 3 min.

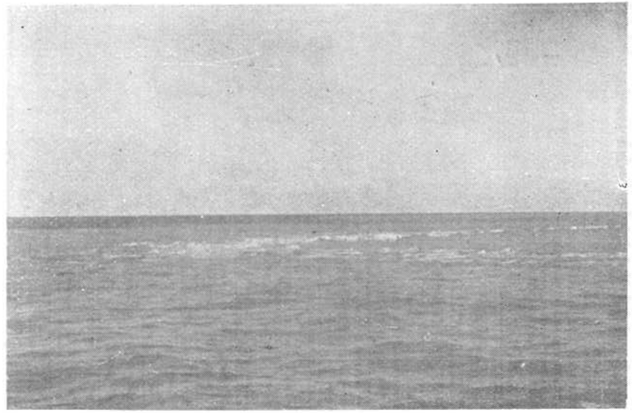

Fig. 51. Ejected pumice drifting southwestwards.

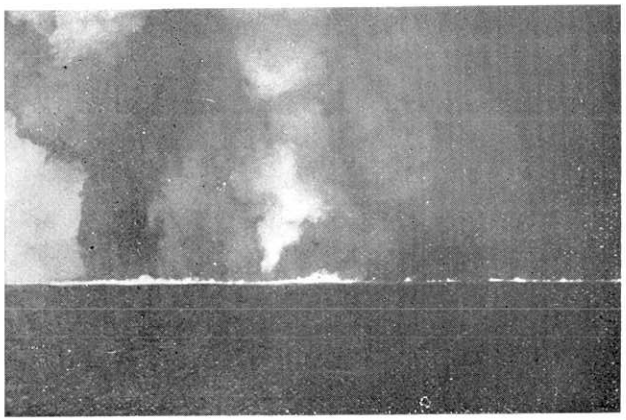

Fig. 50. Ditto 4 min.

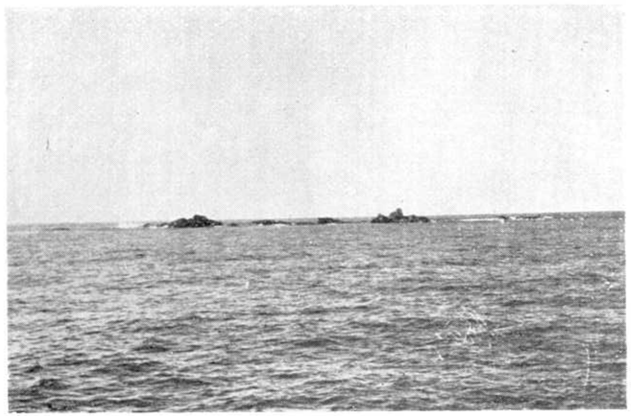

Fig. 52. The Bayonaise rocks.

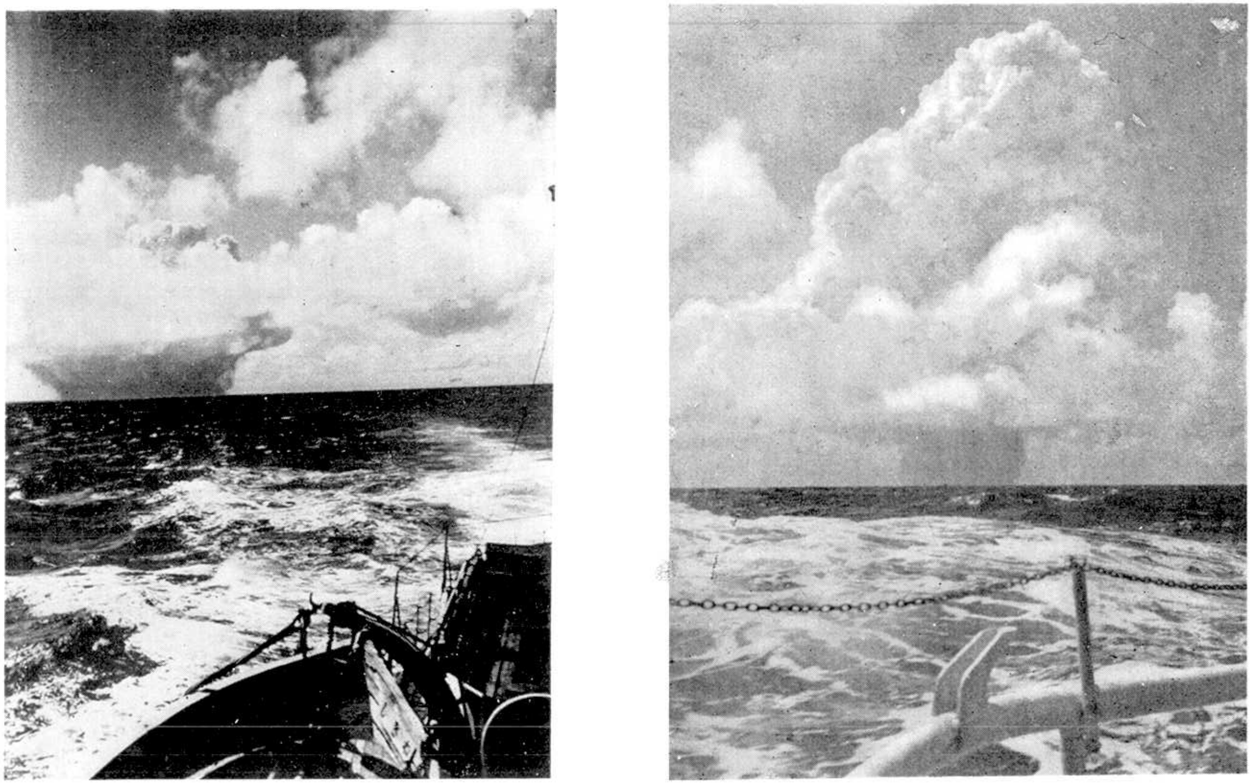

Fig. 53. A major submarine explosion at 12h35m on Sept. 26, 1952, viewed from the patrol ship "Shikiné". Left: Diameter of the cloud at sea surface was about 2,300 m. Right: A succeeding stage of the explosion shown in left.

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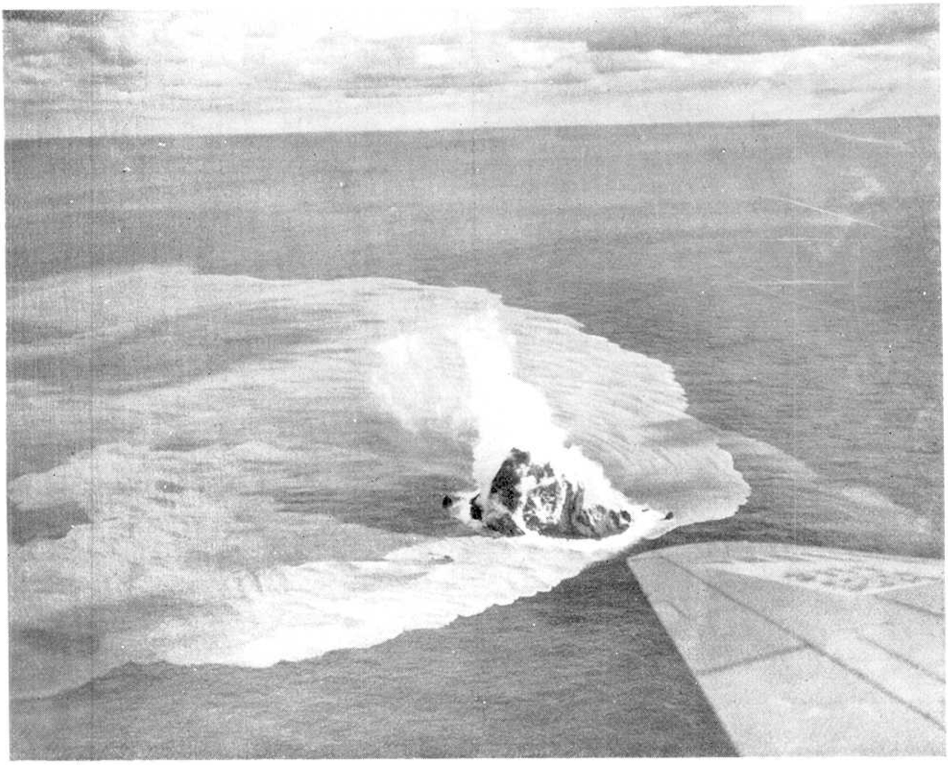

Fig. 54. An aerial view of the Myôjin reef in activity after its 2nd appearance from under the water. December 27, 1952. Photo. by Z. Ishii of Yomiuri Press.

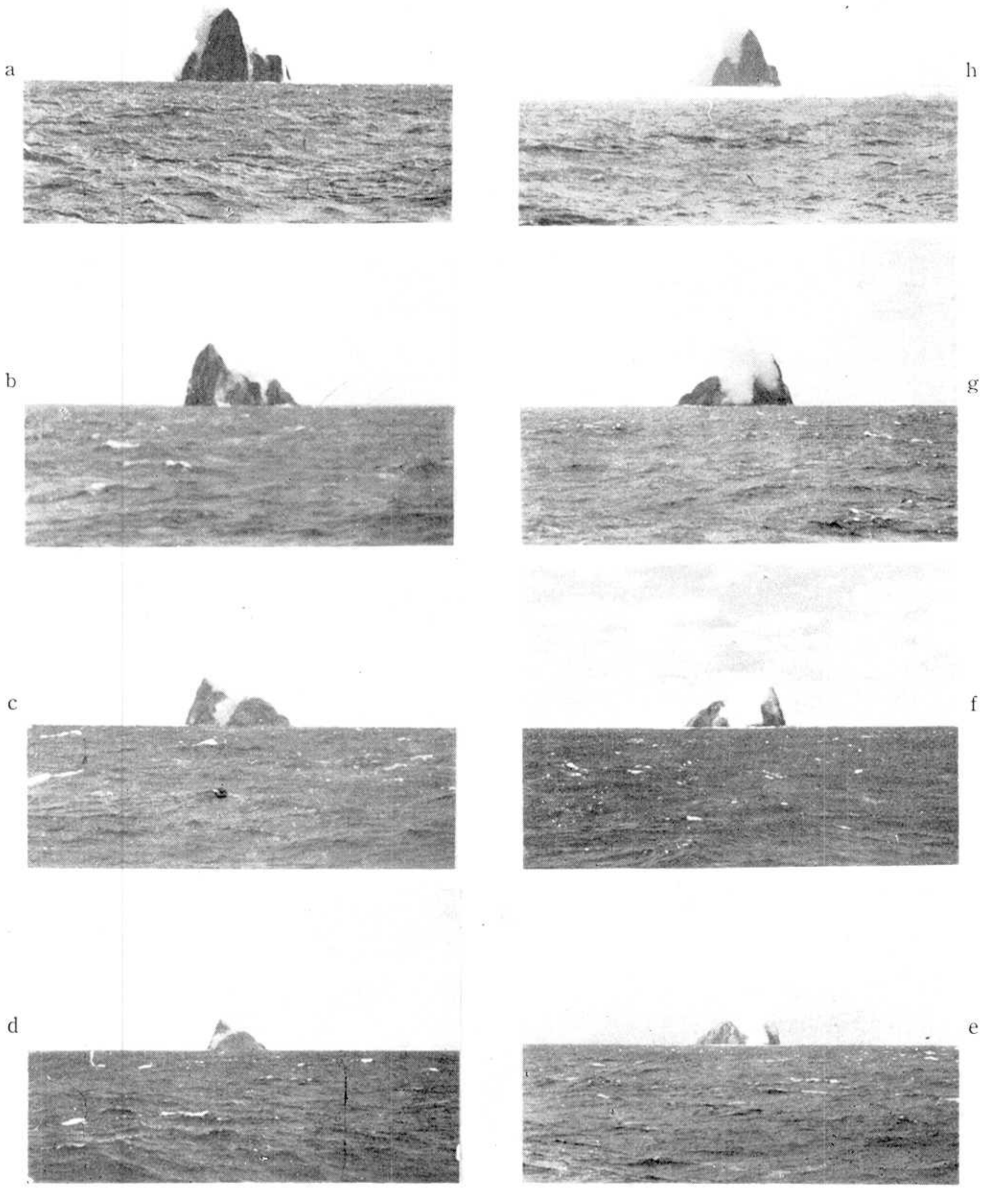

Fig. 55. Volcanic spines of the Myôjin reef after its second appearance on the sea: a, b,....h are southeastward, eastward, northeastward, northward, northwestward, westward, southwestward, and southward views respectively. Compiled by the writers from many photographs of J. Kusaka of Asahi Press. 07h–10h in the morning of February 1, 1953. Highest peak being estimated as about 94 m above sea level (Cf. TOKYO COLLEGE OF FISHERIES, *op. cit.* 39.)

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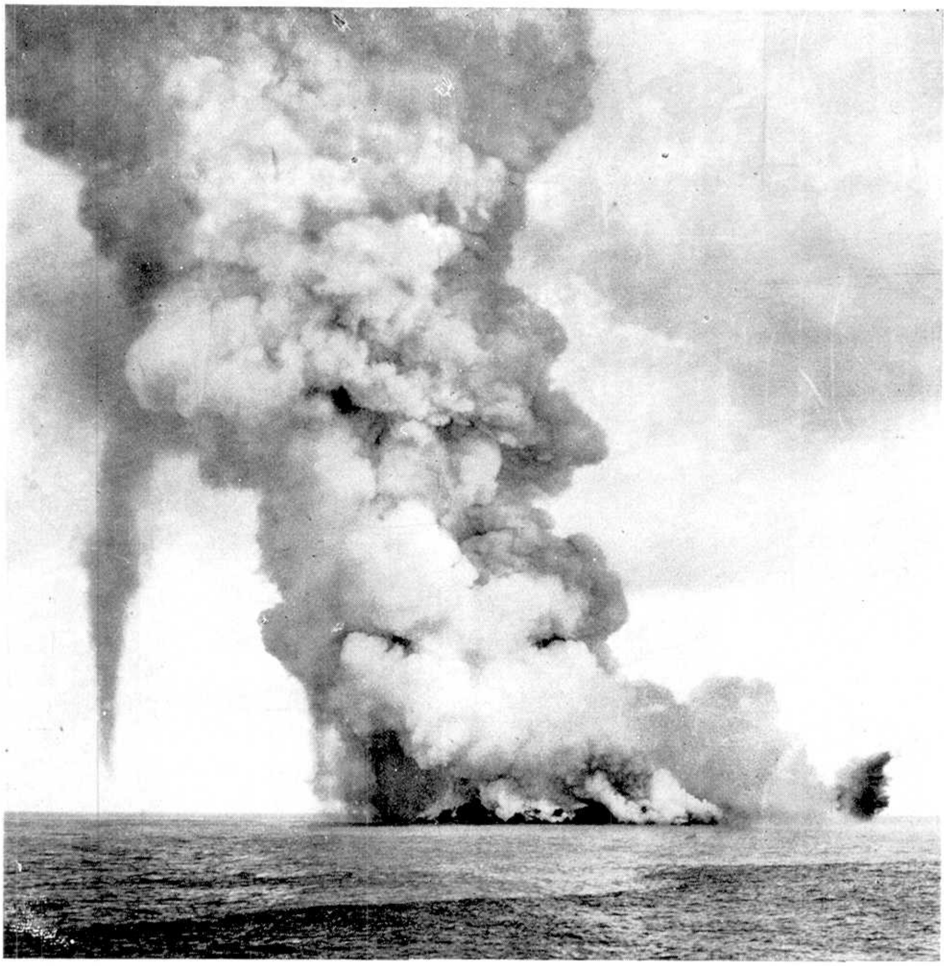

Fig. 8. Ash fall and emission of ash and vapour. The Myôjin reef viewed from the patrol ship "Shikiné", about 09h, September 18, 1952.

Photo. by C. Haraikawa of Yomiuri Press.

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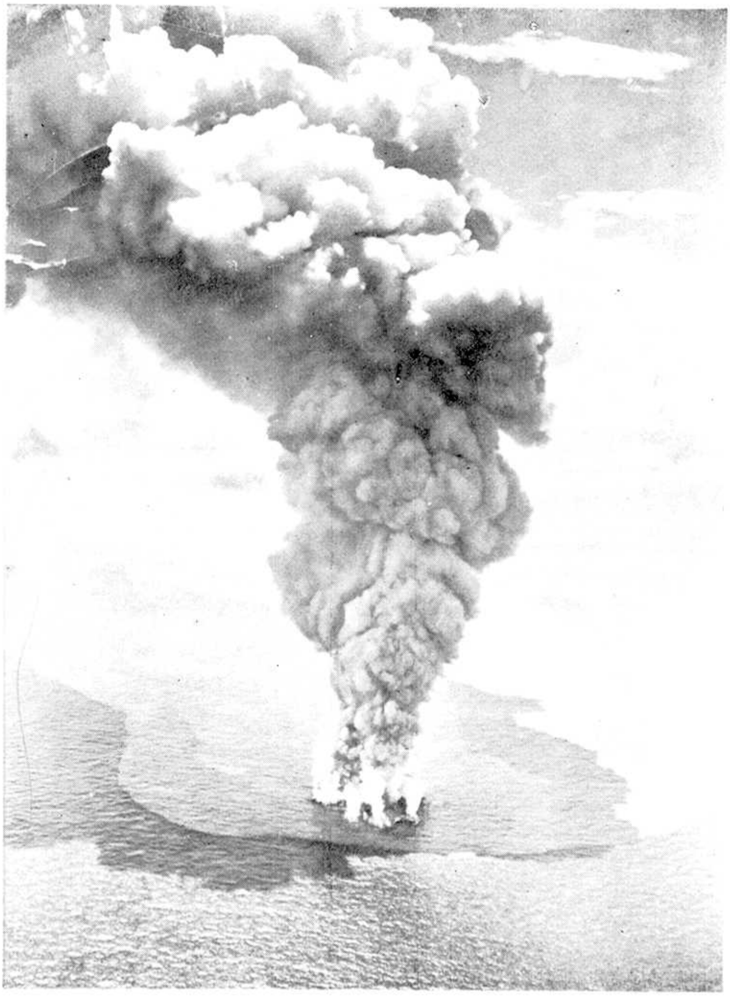

Fig. 9. An aerial view (southwestward) of the Myôjin reef in eruption, about 11 h, September 18, 1952. The sea water around the reef changes its colour into yellow being stained with volcanic material, and moves toward the background of the photograph.

(Asahi Press)

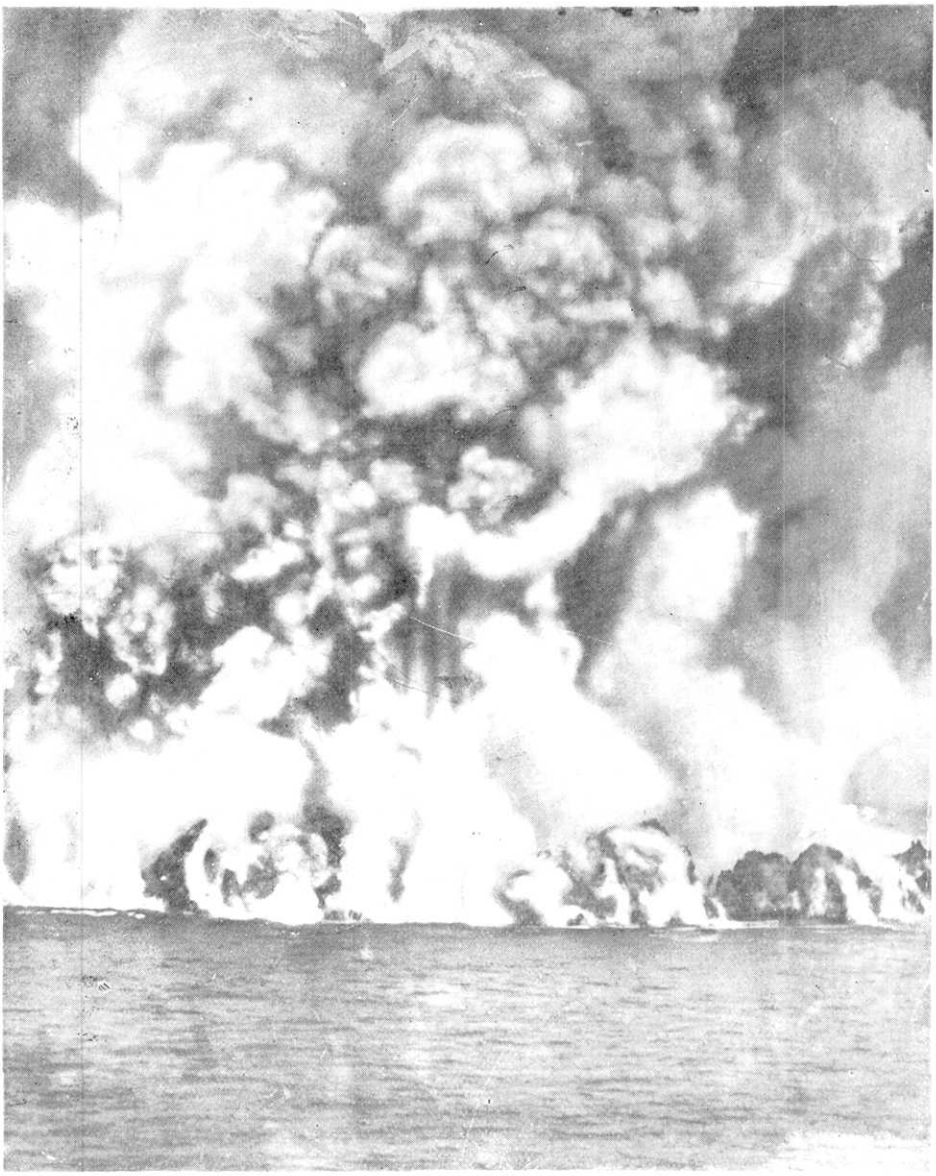

Fig. 10. Blocky head of the lava dome vomiting ash cloud and vapour, the Myôjin reef at its first appearance from the sea viewed down from an aeroplane about 70 m. above sea level. At about 18 h, September 18, 1952.

Photo. by T. Takei of Yomiuri Press.

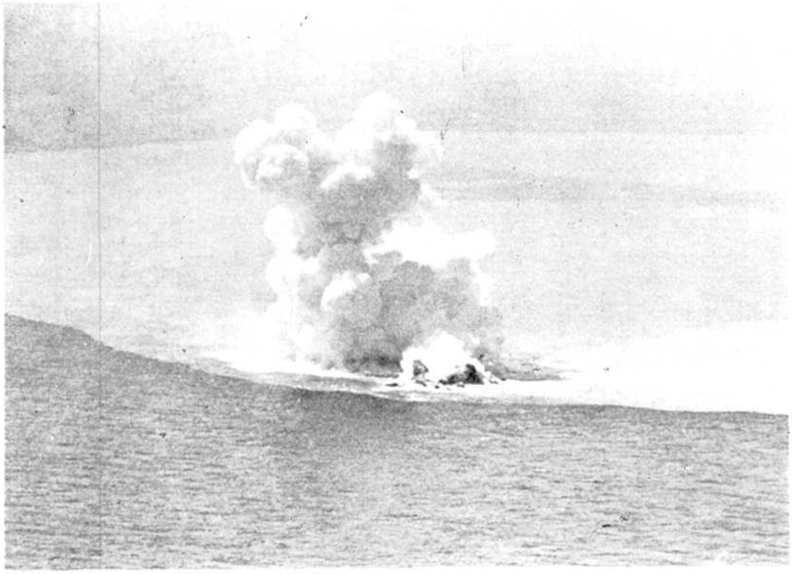

Fig. 11. An aerial view of the Myôjin reef in activity, about 09 h, Sept. 22, 1952 (Asahi Press).

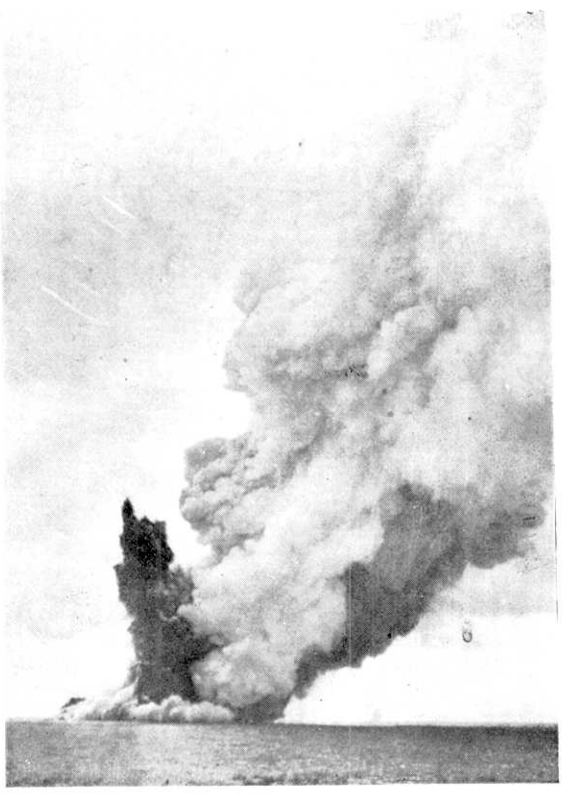

Fig. 12. An explosive activity of the Myôjin reef, about 09 h, Sept. 22, 1952 (Asahi Press).

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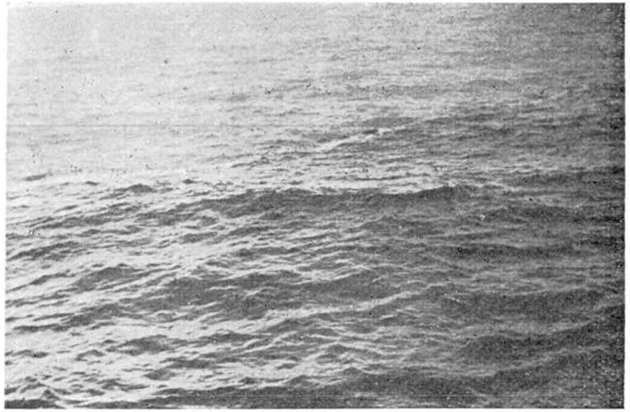

Fig. 13. Non-contaminated Kuroshio counter current (here) and the contaminated yellowish sea water (there). Along the boundary between the two, grains of white pumice were drifted.

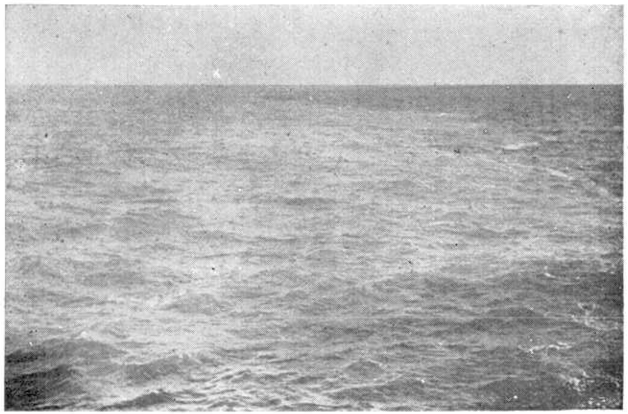

Fig. 14. The boundary between the yellowish sea water stained with volcanic dust (left) and the non-contaminated sea water (right). White drifting material in the foreground are pumice grains.

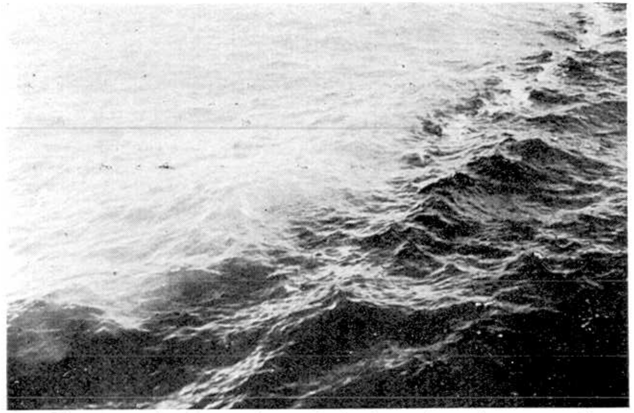

Fig. 15. A close view of the boundary between the contaminated sea water (left) and the non-contaminated water (right).

Fig. 16. Oceanographical observation of the yellowish sea water.

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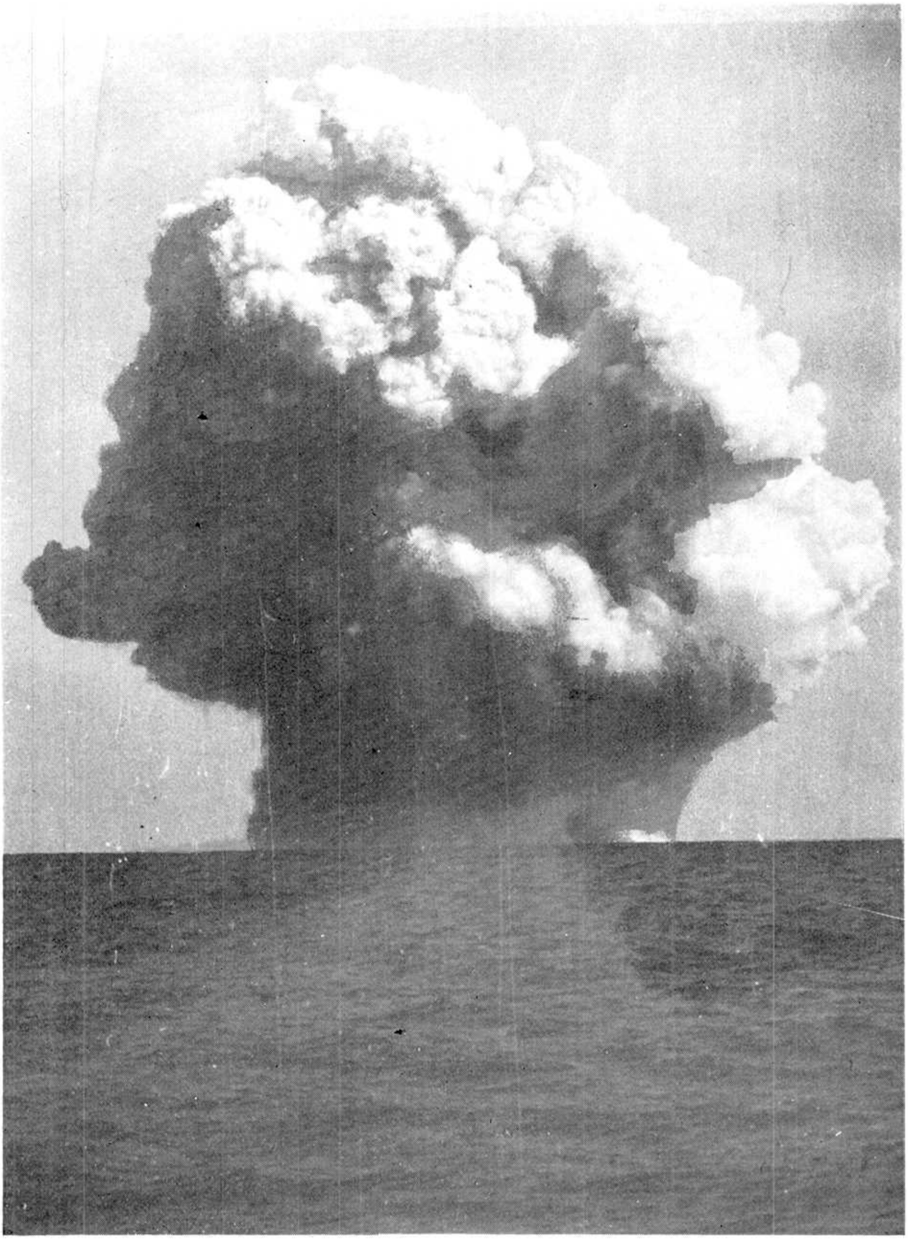

Fig. 17. A phase of a submarine explosion of the Myôjin reef which took place at 08h34m on Sept. 23, 1952. Cauliflower-shaped explosion cloud was rising about 1,800 m. high, neck column of the cauliflower being about 800 m. in diameter. A phase about several seconds after its first manifestation on the sea.

Fig. 18.

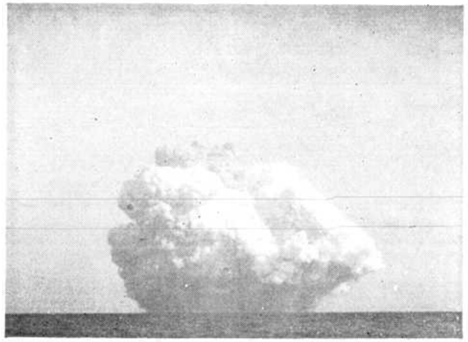

Fig. 21.

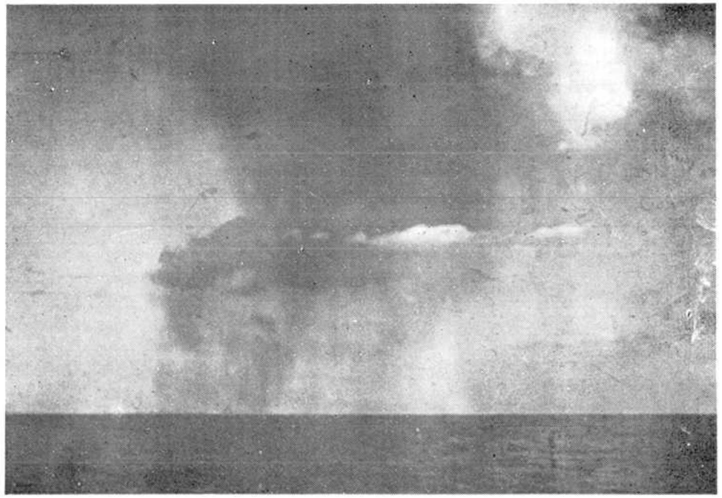

Fig. 23.

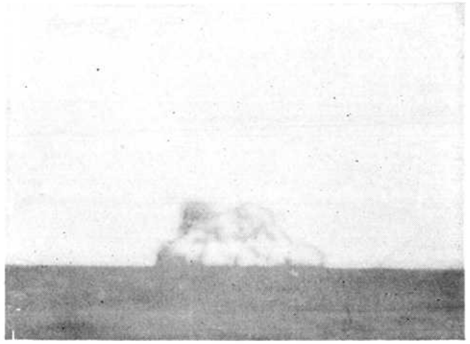

Fig. 19.

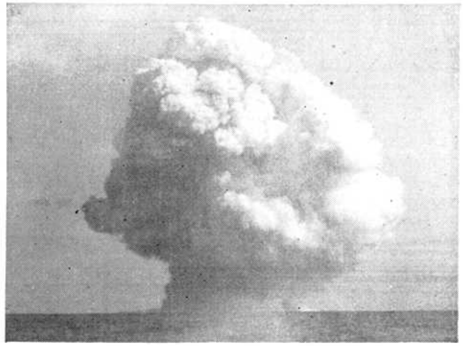

Fig. 22.

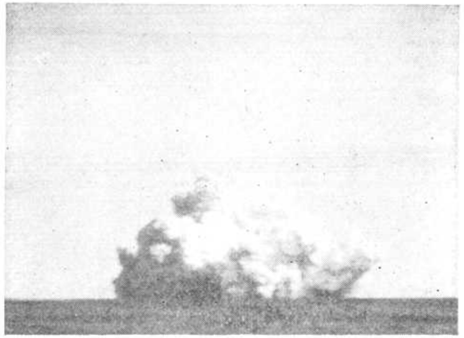

Fig. 20.

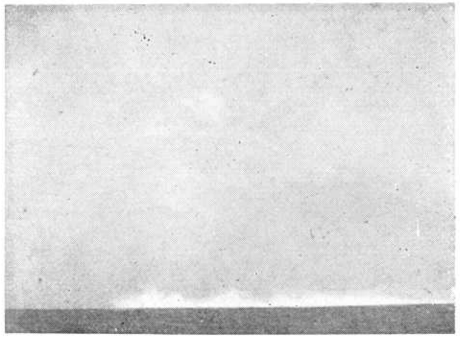

Fig. 25.

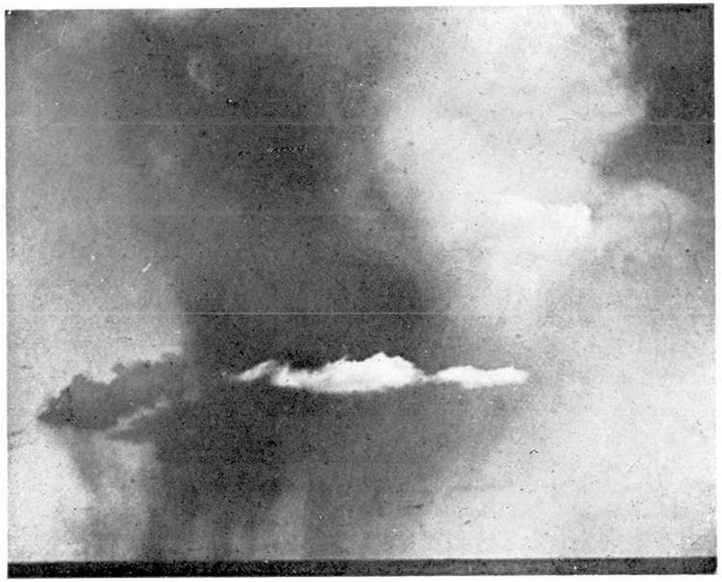

Fig. 24.

Figs. 20–27. The 08h34 m-explosion of the Myôjin reef on Sept. 23, 1952. Cf. pp. 241–242 and Table III.
One millimetre on the photographs corresponds to about 30 m. in actual distance, i.e., 3.3 mm. on the photographs to about 100 m. in actual distance.

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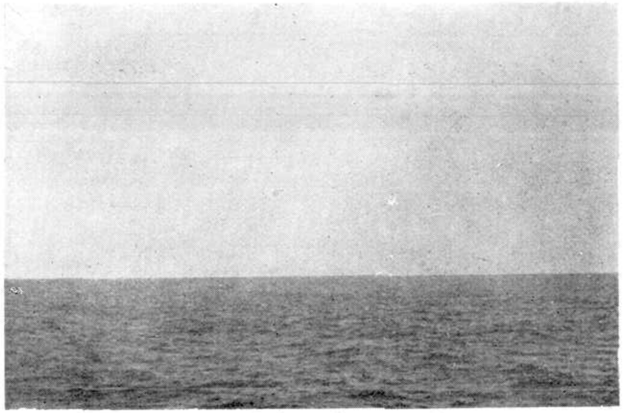

Fig. 26. Before the explosion.

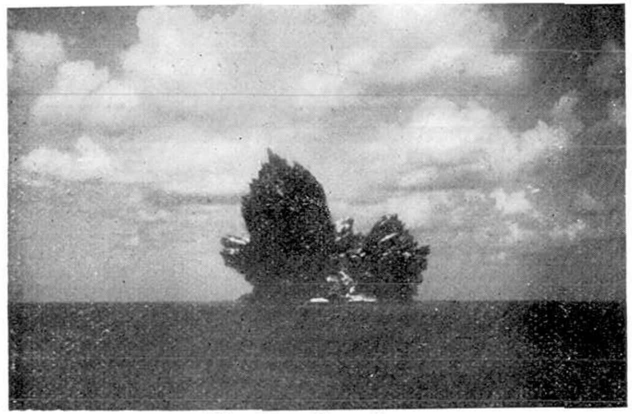

Fig. 28. Ditto 3 sec.

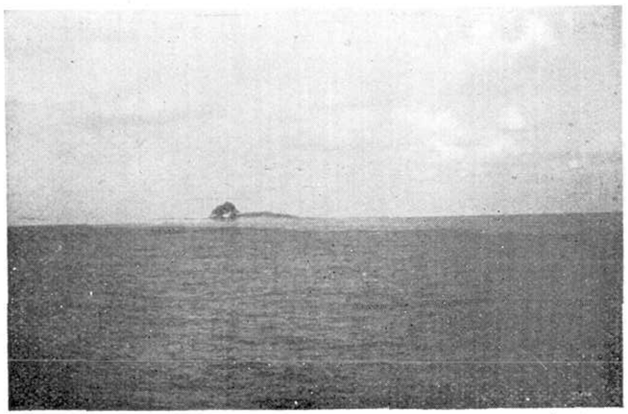

Fig. 27. 1 sec. after the 1st manifestation of the explosion on the sea.

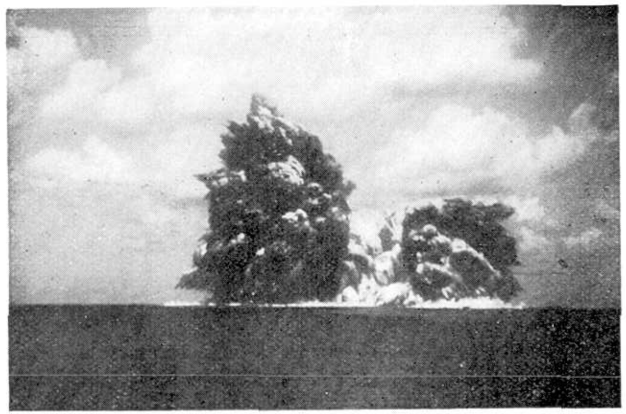

Fig. 29. Ditto 5 sec.

Figs. 26–40. Changing scene of the 13h12m-explosion. Cf. pp. 243–244 and Table IV. One millimetre on each photograph corresponds to about 138m. in actual distance, i.e., 7.2mm. on the photographs to 100m. in actual distance.

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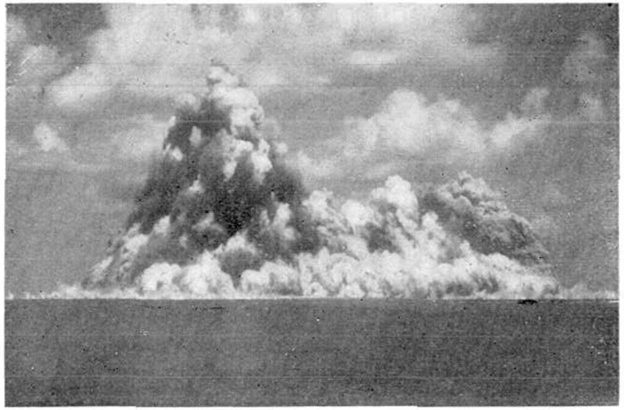

Fig. 30. Ditto 8 sec.

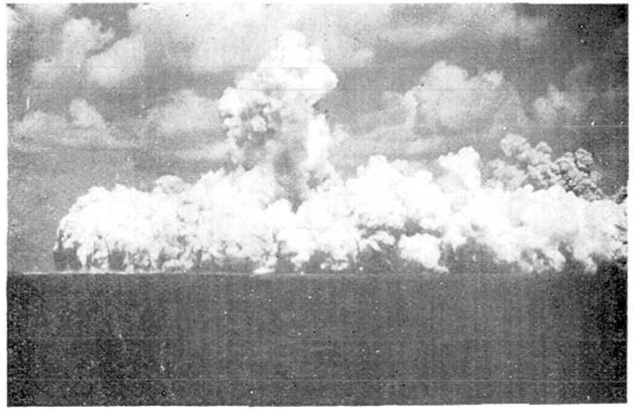

Fig. 32. Ditto 15 sec.

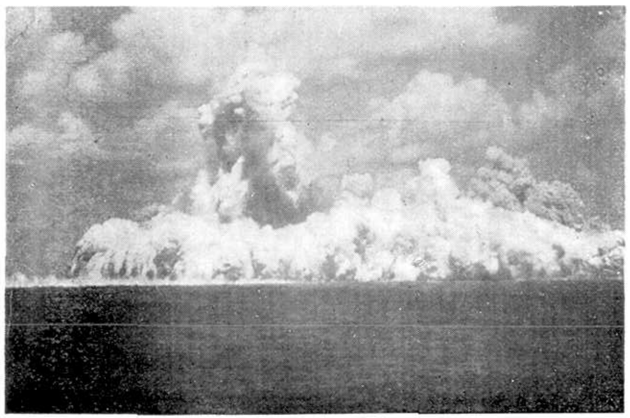

Fig. 31. Ditto 12 sec.

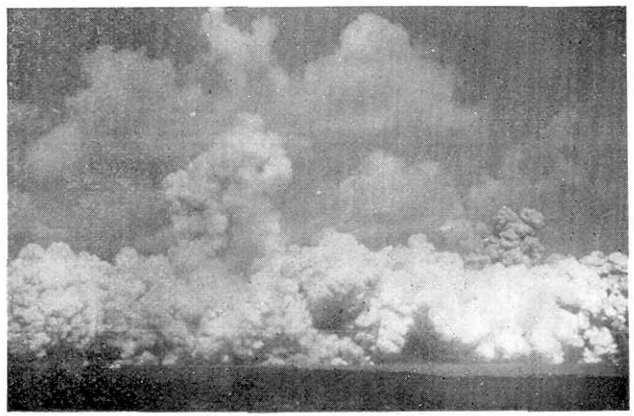

Fig. 33. Ditto 20 sec.

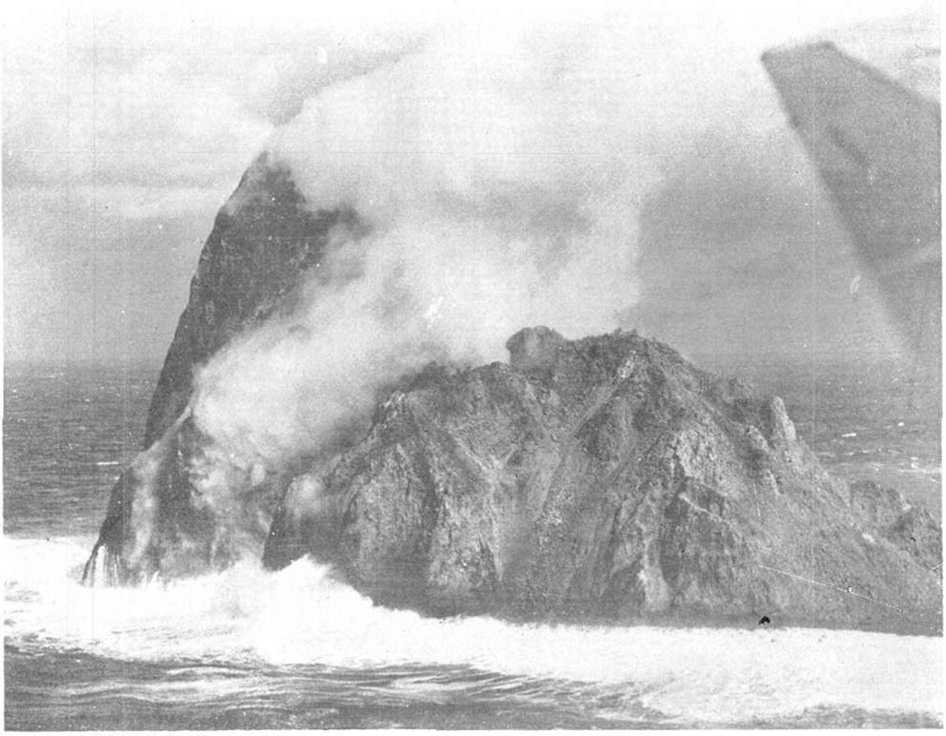

Fig. 56. Details of features of the lava dome and spine an aerial view of the Myôjin reef, February 8, 1953. Photo. by Z. Ishii of Yomiuri Press.

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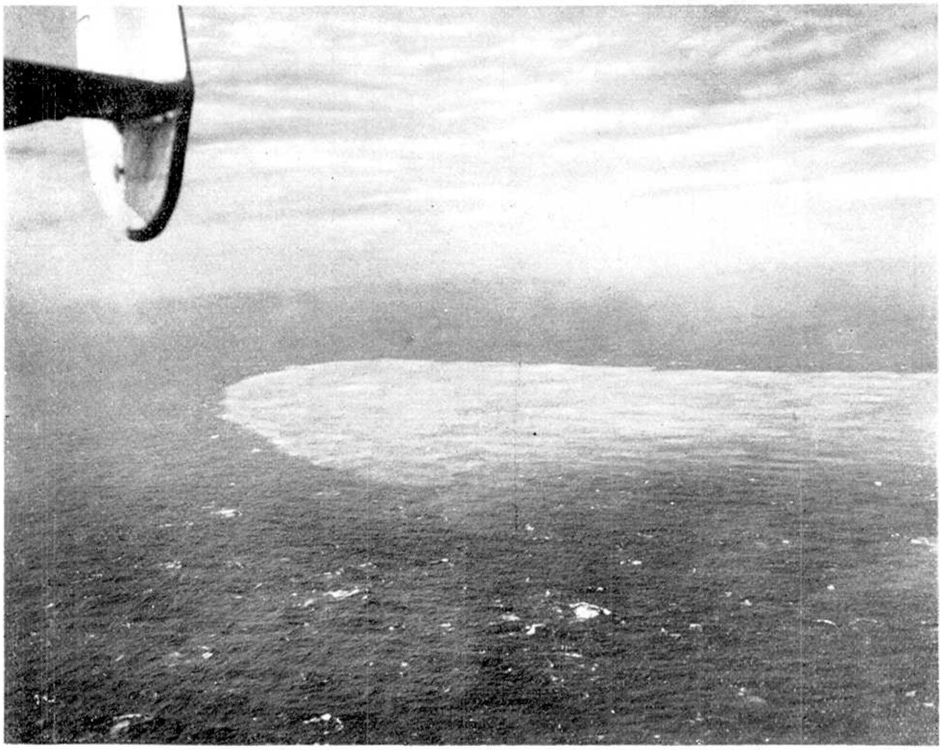

Fig. 57. After its second appearance on the sea since the beginning of October, 1952, the Myôjin reef submerged completely into the sea leaving the water stained with volcanic dusts on March 10, 1953.

Photo. by T. Isoyama of Yomiuri Press, March 11, 1953.

a)

b)

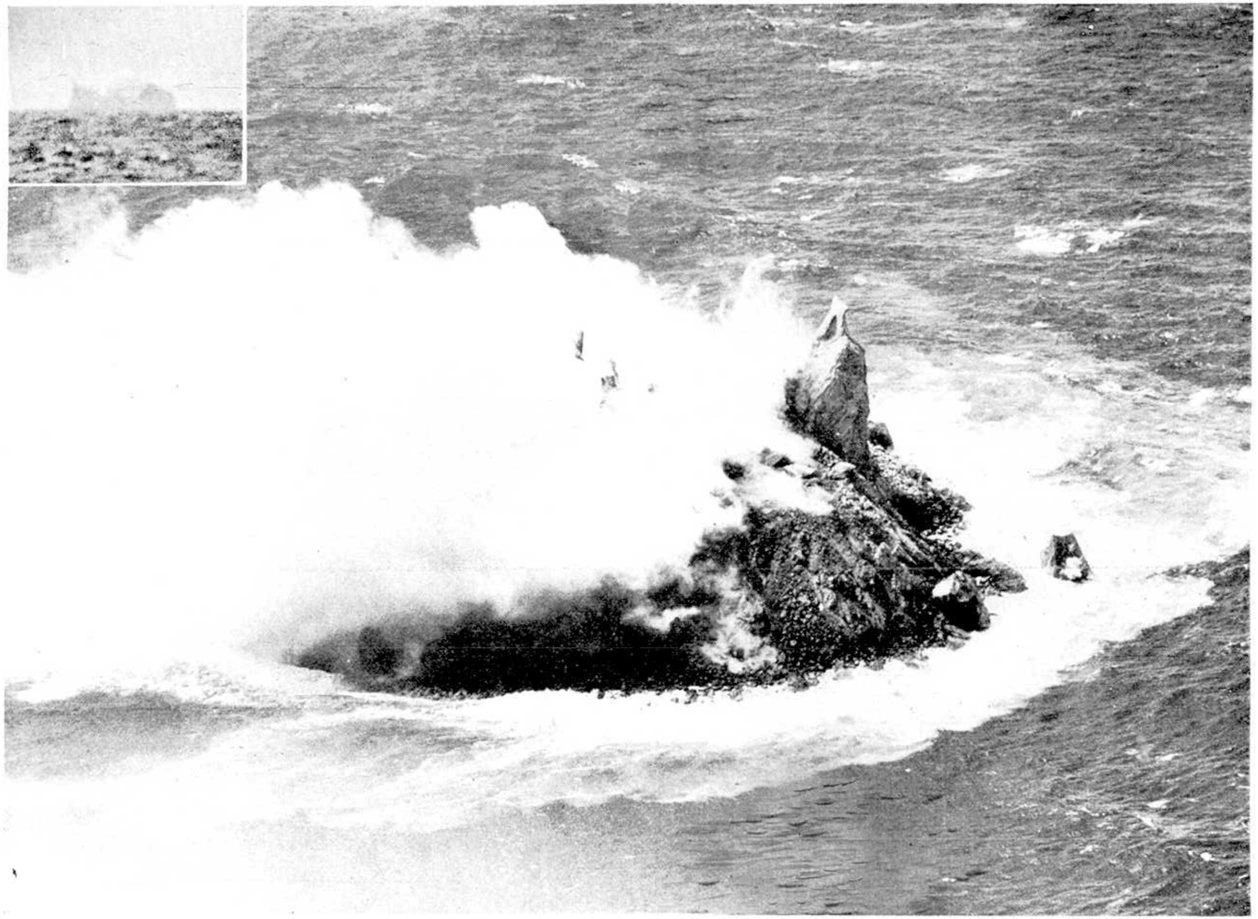

Fig. 58. Volcanic spine of the Myôjin reef in its third appearance on the sea, April 14, 1953. a) Southward view of the island from the patrol ship "Shikiné" of the Japanese Marine Safety Board, b) An aerial view (westward) from U. S. Air Force. By courtesy of the Hydrographic Office, Marine Safety Board of the Japanese Government.