

## Distribution and Behavior of High-turbidity Water in Shallow Water Area around Miyake-shima Island, Japan

Hisayuki ARAKAWA\*, Yumiko NAKAYAMA, Tsutomu MORINAGA

**Abstract:** High-turbidity water was observed in the shallow water area around Miyake-shima Island, southern Japan, (latitude: 34°06' N, longitude: 139°32' E), specifically, on the southwest and northeast sides of the island. On the other sides, clear ocean water was observed, which is comparable to that the Kuroshio. It was found that the localization of high-turbidity water to the northeast was caused by the Kuroshio current, which encompassed the island. This is due to the effect of the island mass. The distribution of high-turbidity water in the northeast ocean area shows a near-circular pattern with two spots at a distance of 1.0–2.0 km from the shore. The turbidity increased with the increased water depth, showing a maximum of  $1.2 \text{ m}^{-1}$  of the beam attenuation coefficient at a depth of 50 m. The content of inorganic materials in the suspended particles was very high (76%), and they are considered to be land-based materials that originate on Miyake-shima Island. The particle size of volcanic ash on land was in a wide range between 1–2000  $\mu\text{m}$ . The sediment of the seabed near the shore contained clay minerals such as smectite and chlorite, indicating that they originated from volcanic products. Moreover, the sediments did not contain particles smaller than 60  $\mu\text{m}$  in size. The following process can explain these observations. When rainfall flushes out muddy water containing volcanic ash from the shore area into the coastal waters, large particles—more than 60  $\mu\text{m}$  in size—immediately settle to the bottom. Particles smaller than this size are dispersed by the flow of the current and sediment; these fine suspended particles disperse 3 km offshore and intrude into the pycnocline, forming a high-turbidity water layer.

**Keywords:** *Turbidity distribution, Miyake-shima Island, Volcanic ash, High-turbidity water, Sediment*

### 1. Introduction

Mt. Oyama on Miyake-shima Island, one of the Izu islands in the North Pacific Ocean, erupted on July 8 and 14, 2000, and volcanic products (also known as volcanic ashes), were clearly visible in the atmosphere. On August 18, 2000, volcanic smoke climbed higher than 5000 m, and an enormous quantity of volcanic ash fell on Miyake-shima and its surroundings. Subsequent rainfall washed away the accumulation of volcanic ash from the coast into the surrounding sea area, causing ocean discolora-

tion. This led to considerable concern about the effects of volcanic sediments, which originated directly from the volcanic ash that had fallen into the ocean and the ash washed away from the island, on the bountiful marine resources in the shallow water regions around Miyake-shima. These included the marine life of the surrounding ocean area such as spiny lobsters, abalones, and agar weeds.

The eruption of a marine volcano in 1974 led to the creation of Nishino-shima Shinto Island in the abovementioned ocean area. MATSUIKE *et al.* (1975) investigated the turbidity of the inner bay formed between Kyuto (the old island) and Shinto (the new island) of Nishino-shima and the turbidity of the island's surrounding ocean area. The results revealed that the water temperature of the inner bay was 8 °C higher

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Department of Ocean Sciences, Tokyo University of Marine Science and Technology, Konan 4, 5-7, Minato-Ku, Tokyo, 108-8477 Japan

\*Corresponding Author

Fax: 81-3-5463-0467

E-mail: arakawa@kaiyodai.ac.jp

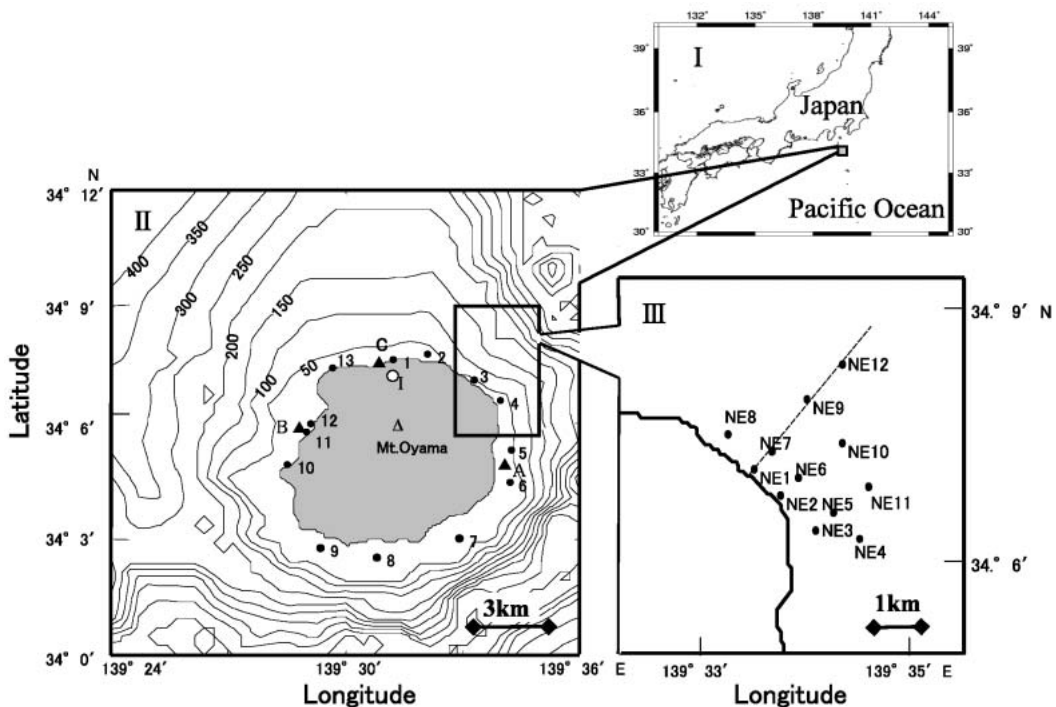


Fig. 1. Geographic location of Miyake-shima Island and the stations studied. Graph I: Geographical location. Graph II: Stations for general observation. (Sta. 1–13). Graph III: Stations for detailed observations along the North-East direction of Miyake-shima Island. (Sta. NE1–NE12). Stas. A, B, C, and I in Fig. 1–II indicate the locations for the collection of seabed sediments and volcanic ash, respectively.

than that of the surrounding ocean water and the amount of suspended matter was approximately 15 times higher. They also reported that a discolored ocean area, which occurred by the outflow of the inner bay water to the surrounding ocean area on surface, was observed within 0.5–0.6 nautical miles from the island.

After a period of three and four months following the Oyama eruption, ARAKAWA *et al.* (2003) investigated the turbidity distributions of the offshore area around Miyake-shima Island. They reported high-turbidity water layers at a depth of 60–90 m in the east and northwest ocean areas that are approximately 3 km offshore. More importantly, the suspended particles in the high-turbidity water layers corresponded to the terrestrial particles originating from Miyake-shima and not from phytoplankton. This conclusion was based on the high content of inorganic materials (approximately 57.7–63.4% of the total particles measured in that area); however, the formation process of the high-turbidity water layers

remains unknown.

In this investigation, we studied the detailed turbidity distributions in the inshore areas approximately 3 km from shore. The purpose of this study was to clarify the flush-out process and the behavior of muddy water containing volcanic ash from the island.

## 2. Observation Methods

The oceanic observations were carried out aboard the research vessel Yashio (40 Gt) of the Oshima Branch, Tokyo Metropolitan Fisheries Experiment Station, on August 27–28, 2001. Fig. 1 illustrates the 13 observation stations (Stas. 1–13) that were set up to encompass all coastal areas around Miyake-shima (distance from the shore: 0.1–1 km). The figure also shows the 12 observation stations (Stas. NE1–NE12) that were set up in the ocean area northeast of the island (distance from the shore: 0.1–2.4 km). Sta. NE1 and Sta. NE3 correspond to Sta. 3 and Sta. 4, respectively. Measurements were performed for water tempera-

Table 1 Water color on the Forel scale and transparency in the shallow sea area for stations 1–13 around Miyake-shima.

Sta.	Water color	Transparency (m)
1	2	24
2	2	26
3	2	21
4	3	30
5	2	25
6	2	21
7	2	19
8	3	16
9	2	26
10	2	24
11	2	30
12	2	28
13	3	30

ture, salinity, turbidity, water color, and transparency. The water temperature and salinity were recorded using a CTD instrument (Ocean Sensors Inc.), and the turbidity was recorded using an *in situ* beam transmissometer (Martek Inc.; light path length: 1 m, measured wavelength: 486 nm). A continuous measurement was performed from the surface layer to the vicinity of the ocean floor. The water color was determined by the Forel-Ule scale and the transparency was determined using the Secchi disc. Using a Van Dorn sampler, the water was collected to determine the concentration of suspended solids (SS), ignition loss, concentration of chlorophyll *a*, and the particle size distribution. The concentration of suspended solids was determined by the following method: the filter cake was obtained by passing the sample water through a Millipore HA filter (pore size: 0.45  $\mu$  m), dried at 60 °C for three days, and the residue thus obtained was weighed. To determine the ignition loss (for calculating the concentration of suspended inorganic matter), the filter cake was heated at 550 °C for one hour and the residue thus obtained was weighed. After the sample water filtration through a Whatman GF/F filter and chlorophyll extraction with a DMF, the chlorophyll *a* concentration was determined using a fluorometer (Turner 10AU). The fluorometric method was devised by SUZUKI and ISHIMARU (1990). The particle-size distribution was determined by

freezing water samples on-site, transporting them to the laboratory, allowing the samples to thaw, and immediately analyzing them using a Coulter Counter Multisizer II in the range of 2–60  $\mu$  m.

An illustration of the sampling stations for the volcanic ash on the land and for the sediment at the bottom of the ocean is included in Fig. 1. A sample of volcanic ash was taken from the parking lot (Sta. I) of the Miyake-shima Branch Office, Tokyo Metropolitan Government, immediately following the accumulation of ash on August 18, 2000. This was the day of the main Mt. Oyama eruption. On July 10, 2001, a sample of sediment from the seabed was collected from three stations and more specifically, from the east side of the island (Sta. A), west side of the island (Sta. B), and north side of the island (Sta. C). The depths of the sampling points were 7 m, 6.5 m, and 6 m, respectively, and the sampling was performed by scuba diving. The particle size distribution was determined using a particle size analyzer (LS200, Beckman Coulter Inc.), and it was found to be in the range of 0.4–2000  $\mu$  m. Species and quantities of minerals were determined using an X-ray diffractometer (Rigaku Corporation, RINT2000) (SUDO *et al.*, 1961; OINUMA, 1968). To determine the density of volcanic ash, the standard method of JSF T 111–1990 (Japanese Society of Soil Mechanics and Foundation Engineering, 1990) was used.

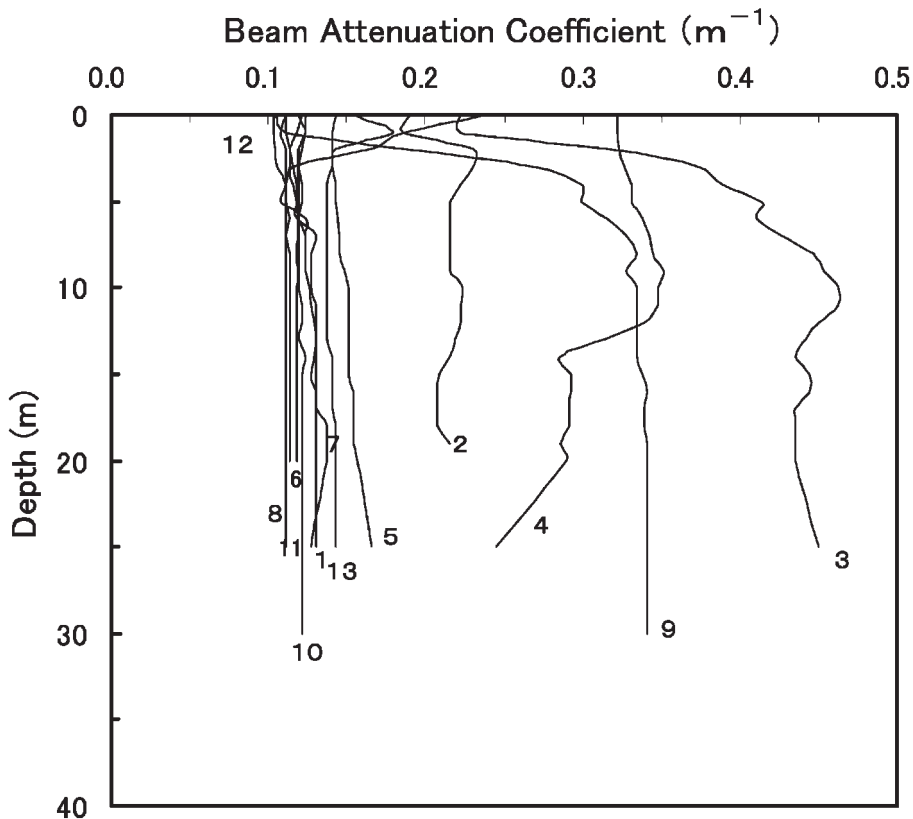


Fig. 2. Vertical profiles of turbidity in the shallow waters at Stations 1–13 in the coastal areas around Miyake-shima Island.

### 3. Results and Discussion

#### 3-1 Distribution and Characteristics of High-turbidity Water in Shallow Water Areas

Over the two-day period of August 21–22, 2001, typhoon No. 11 passed over the sea and along the southern coast of Honshu Island in Japan and brought 70 mm of rain to Miyake-shima (specifically, the Tsubota district). The oceanographic observations were carried out six days after the typhoon. On that day (August 27, 2001), the Beaufort wind scale was zero to one, with very weak winds. From on board, we made naked eye observations, but we did not see any scenes of flushed-out muddy water from the shore or regions of discolored water.

Table 1 lists the water color and transparency in the shallow water areas around the island. The water color was found to be in Forel scale range of 2–3, and there was no drastic

difference in the water color among the observation stations. The transparency among stations was 16–30 m, with slightly lower transparencies at Stas. 3, 6, 7, and 8.

Fig. 2 illustrates the vertical profiles of turbidity in the shallow water areas around the island. We found high-turbidity water on the southwest side (Sta. 9) and the northeast side (Stas. 2, 3, and 4) of the island, which exhibited beam attenuation coefficients between 0.20–0.46 m<sup>-1</sup>. The turbidity in the other areas was 0.10–0.15 m<sup>-1</sup>, which is comparable to the turbidity of the Kuroshio, which had a range between 0.1–0.2 m<sup>-1</sup> (MATSUIKE and MORINAGA, 1977). This result indicates that the seawater was very clear, except on the southwest and northeast sides of the island. During the observations, the Kuroshio directly affected the sea area of Miyake-shima, causing the current to flow to the northeast around the island with a

velocity of *ca.* 1.5 knots (Quick bulletin of fisheries ocean condition on Metropolitan and 3 prefectures, No. 4068, Kanagawa Pref. Fisheries Experiment Station, 2001). With regard to the area of high-turbidity water, it was observed that the water distributed into the downstream and upstream areas of the current.

When an isolated island is directly aligned with a current's flow, a vortex is formed on the leeward side of the island by the effects of the land mass. This affects the distribution of suspended material and the underwater biological production (e.g., DOTY and OGURI, 1956; UDA and ISHINO, 1958; BARKLEY, 1972). HAMNER and HAURI (1981) reported that when a current flows against a reef or a small island, the flow of ocean water is retarded at the upstream and downstream sides and plankton accumulates in the areas of retarded flow.

In this investigation, it is not possible to clarify the vortex downstream of the island since the current was not measured. HEYWOOD *et al.* (1996) and Baines and Davies (1980) examined the conditions for vortex formation. If the radius of Miyake-shima Island is 4000 m at a depth of 50 m, the eddy viscosity is  $10^2 \text{ m}^2 \text{ s}^{-1}$ , and the current velocity is  $0.77 \text{ m s}^{-1}$  (*ca.* 1.5 knots), then the Reynolds number (*Re*) is 62. Applying the results of HEYWOOD *et al.* (1996), this proves that a vortex can be formed at this time in the downstream direction of Miyake-shima Island and the island mass effect seems to act. However, we do not have results for the extent of effects of the island mass on the distribution of high-turbidity water along the northeast direction of the island. The relationship between the vortex and the accumulation of suspended particles is a subject for future examination.

Fig. 3 illustrates the horizontal distribution profiles of turbidity in the northeast ocean area. The top and bottom panels in this figure display the distributions in the surface layer and at a depth of 20 m. The turbidity distribution in the surface layer (Fig. 3, top) was  $0.14 \text{ m}^{-1}$  at Sta. NE1. With an increase in the distance from the shore, the turbidity increased, reaching  $0.98 \text{ m}^{-1}$  at Sta. NE9. Farther offshore, the turbidity decreased to  $0.17 \text{ m}^{-1}$  at Sta. NE12. The turbidity at Sta. NE6 and Sta.

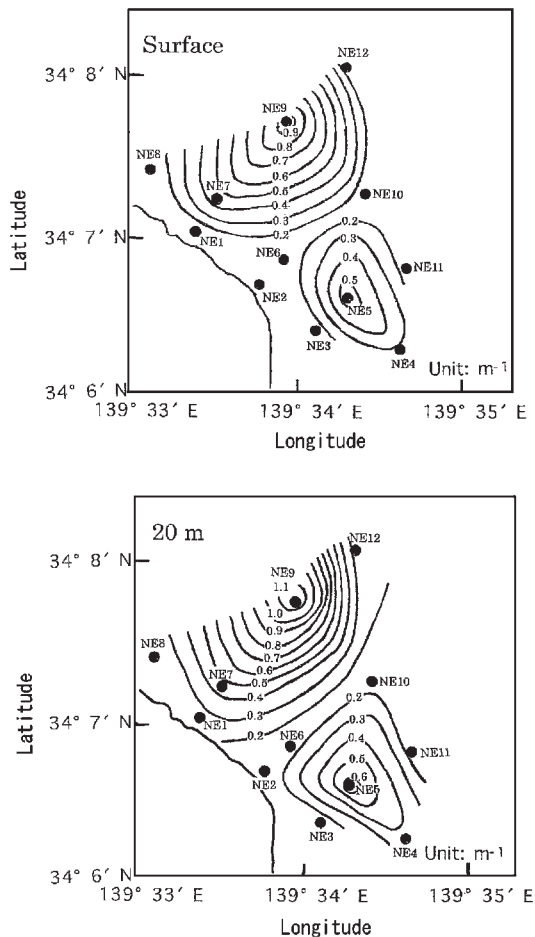


Fig. 3. Horizontal distribution of turbidity in the high-turbidity water area. The top and bottom panels show the turbidity distribution in the surface layer and at a depth of 20 m, respectively.

NE10, located 0.5–2 km from NE2, had lower values ranging between  $0.11$  and  $0.13 \text{ m}^{-1}$ . The turbidity at Sta. NE3 was  $0.14 \text{ m}^{-1}$ ; this value increased with the distance from the shore, reaching a maximum of  $0.57 \text{ m}^{-1}$  at Sta. NE5. Farther offshore, the turbidity decreased to  $0.12 \text{ m}^{-1}$  at Sta. NE11. The distribution at a depth of 20 m (Fig. 3, bottom) showed maxima  $1.11 \text{ m}^{-1}$  and  $0.63 \text{ m}^{-1}$  at Sta. NE9 and Sta. NE5, respectively. This was also the case for the surface layer. From these observations, we can conclude that the high-turbidity water was near-circularly localized in two areas, where the maxima (beam attenuation coefficients:  $0.98$  and  $0.57 \text{ m}^{-1}$ ), were located at a distance of

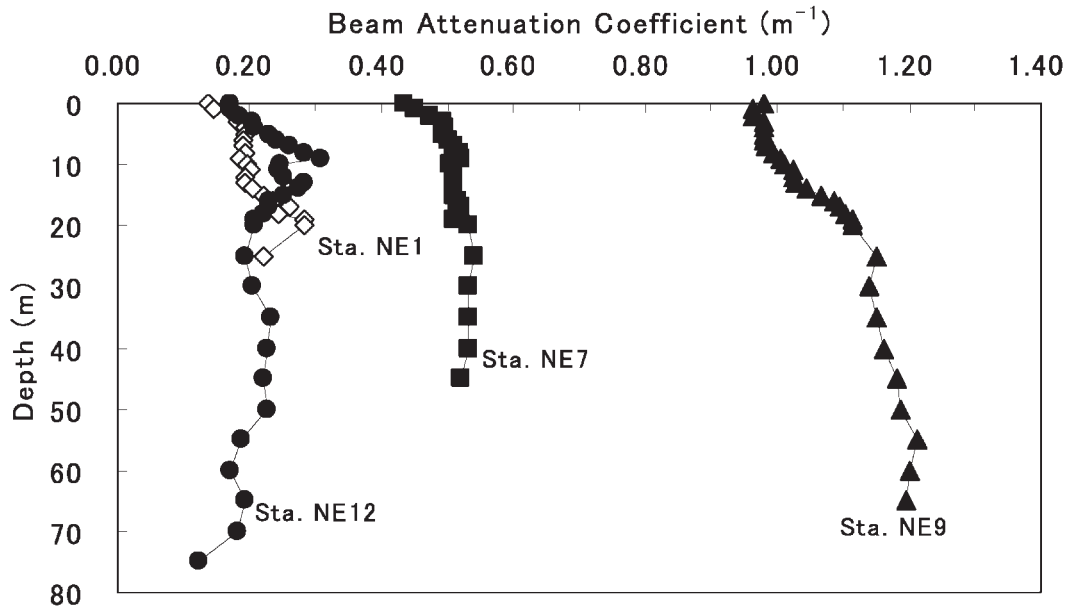


Fig. 4. Vertical distribution turbidity profiles in the high-turbidity water area, as illustrated in Fig. 1. The symbols  $\diamond$ ,  $\blacksquare$ ,  $\blacktriangle$ , and  $\bullet$  represent Stas. NE1, NE7, NE9, and NE12, respectively.

Table 1 Concentration of suspended solids, inorganic matter, and chlorophyll *a* in the surface layer at Sta. NE6 and Sta. NE9.

Sta.	NE6 0m	NE9 0m
Suspended solid (mg/L)	0.38	0.70
Inorganic matter (mg/L)	0.19	0.53
Chlorophyll <i>a</i> ( $\mu\text{g/L}$ )	0.60	0.96

approximately 1.0–2.0 km from the shore.

Fig. 4 illustrates the vertical distribution of the turbidity between Stas. NE1 and NE12. The turbidity in the surface layer was highest at Sta. NE9, which was located at the center of the circular turbidity distribution. At Sta. NE9, the turbidity exceeds its value in the surface layer to a depth of 65 m and the turbidity decreases with an increase in the distance from this water column. The turbidity at Sta. NE9 increased with the depth of water, showing a maximum of  $1.2 \text{ m}^{-1}$  at a depth of 55 m.

Next, we examined the characteristics of the suspended particles distributed in this high-turbidity water. Table 2 lists the concentrations of suspended solids (SS), inorganic matter (determined from the SS and ignition loss), and chlorophyll *a*. From this table, it is seen that the surface water at Sta. NE9 has a high turbidity and the that at Sta. NE6 is

relatively clear oceanic water. The SS of the high-turbidity water at Sta. NE9 was  $0.70 \text{ mg L}^{-1}$  and the concentration of the suspended inorganic matter was  $0.53 \text{ mg L}^{-1}$ . This means that approximately 76% of the suspended particles in the high-turbidity water were inorganic particles. The concentration of chlorophyll *a* at Sta. NE9 was  $0.96 \mu\text{g L}^{-1}$ , which is one and a half times greater than that at Sta. NE6. This small difference in the chlorophyll *a* concentration has almost no influence on the variation of water turbidity (MORINAGA *et al.*, 1988). In other words, it was proved that the high-turbidity water had its origins in inorganic particles.

According to the observations immediately following the eruption in 2000, it was observed during a survey that the inorganic matter concentrations of the high-turbidity water of sea areas at a distance of *ca.* 3 km from the island

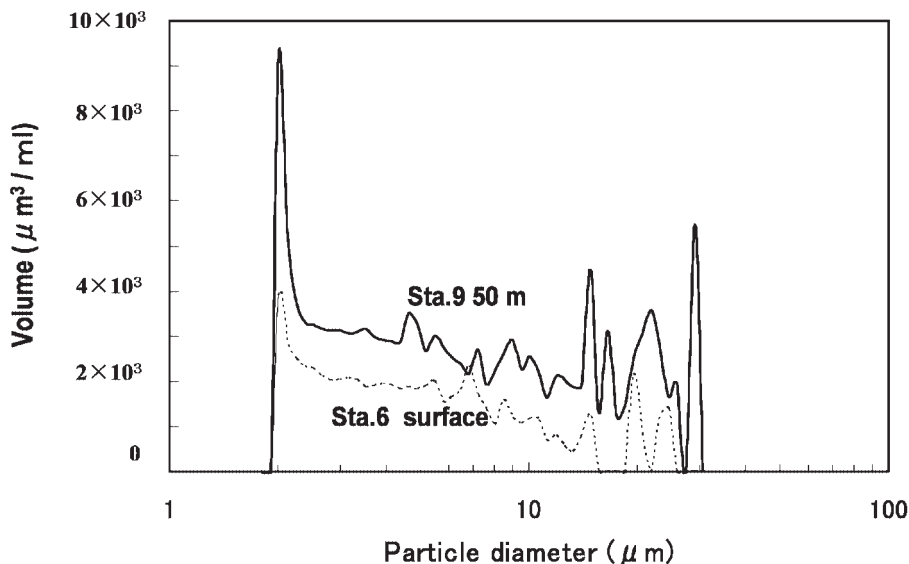


Fig. 5. Particle-size distributions in the high-turbidity water area. The solid and dotted lines indicate the distributions at a depth of 50 m at Sta. NE9 and in the surface layer at Sta. NE6, respectively.

were 57.7 % and 63.4 %. (ARAKAWA *et al.*, 2003). From this, we understood that the high-turbidity water measured in this survey contained inorganic particles more than the ratio right after the eruption.

Fig. 5 illustrates the particle-size distributions at Stas. NE6 and NE9. The suspended particle sizes in the surface layer at Sta. NE6 were in the range of 2–30  $\mu\text{m}$ , and the total volume concentration was approximately  $3.4 \times 10^4 \mu\text{m}^3 \text{mL}^{-1}$ . While the suspended particles at a depth of 50 m at Sta. NE9 also had particle sizes in the range of 2–30  $\mu\text{m}$ , the total volume concentration was found to be approximately  $7.0 \times 10^4 \mu\text{m}^3 \text{mL}^{-1}$ , which is twice that at Sta. NE6. In the offshore high-turbidity water (observed in October and November of 2000), the particle size distribution showed a prominence in the particle size range of 8–14  $\mu\text{m}$  (ARAKAWA *et al.*, 2003). As a result, we can see that the particles suspended in the high-turbidity water in the shallow water area comprise a much wider range of particle sizes.

It is clear that the particles in the high-turbidity water are mainly inorganic matter and have sizes in the range of 2–30  $\mu\text{m}$ .

### 3-2 Characteristics of Volcanic Ash on Land and Sediment at Ocean Bottom

Fig. 6 illustrates the results of X-ray diffraction for volcanic ash on land and for the sediment on the seabed. In the volcanic ash that was collected immediately following the eruption at Sta. I, a dominance of kaolinite and non-clay minerals such as quartz and feldspar was observed. The content of smectite and chlorite, which originate from volcanic material, was especially high. This trend is very similar to that of the sediment from the seabed at Stas. A, B, and C. At Stas. A and B, illite was not found, but at Sta. C, illite was found in the sediment. AOKI *et al.* (2000) collected mineral core from the Iwo Jima ridge area of the Izu islands at a depth of 3000 m and investigated the components of the clay minerals. They reported that smectite, which originates from volcanic ash, constitutes a small amount of the clay minerals in the ridge area. Based on these facts, it is evident that the particles deposited on the seabed near the shore are volcanic products. However, we cannot report in detail whether the particles are from the volcanic ash that was directly deposited following the eruption of 2000 or the volcanic ash that was indirectly deposited after being flushed-out from

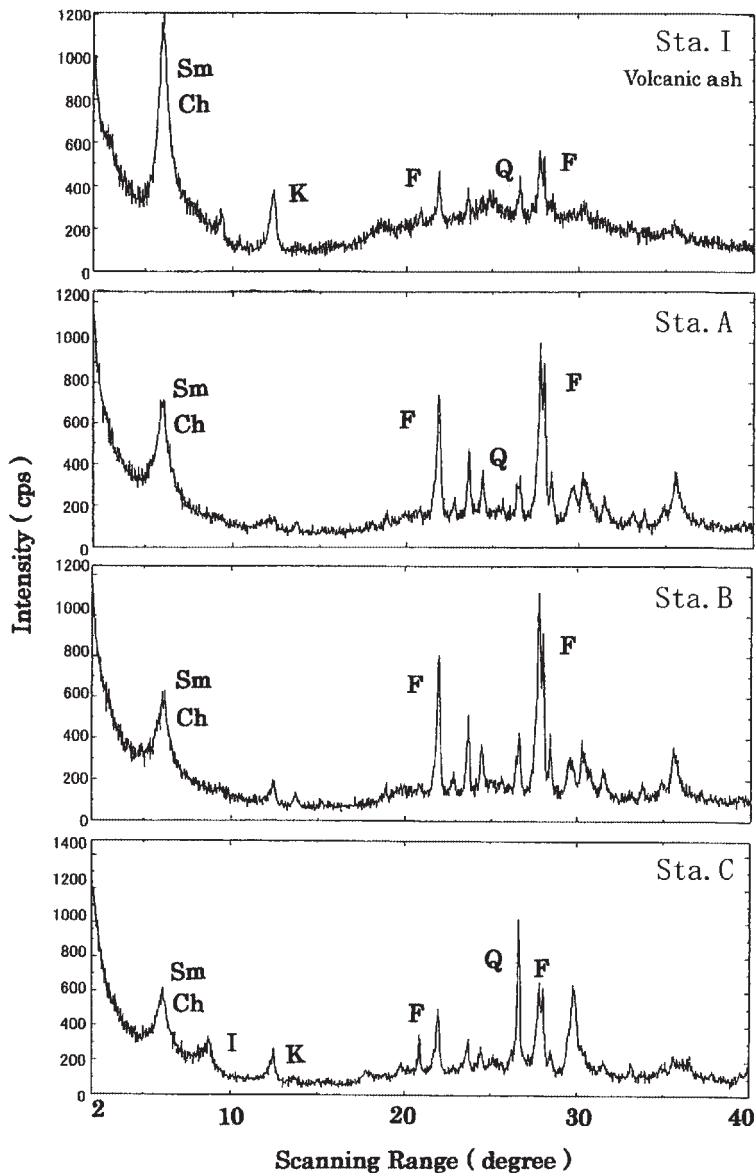


Fig. 6. X-ray diffraction analyses for volcanic ash on land and for sediment at the bottom of the ocean. Sm: smectite, Ch: chlorite, I: illite, K: kaolinite, F: feldspar, Q: quartz.

the land by rainfall.

To understand the behavior of the high-turbidity water, we need to investigate the movement of the volcanic ash that has fallen into the ocean and the ash that has been flushed out from the land as muddy water. This requires an investigation of the size of the particles that were deposited into the seabed

and the size of particles that were suspended in the ocean water. This investigation was carried out by comparing the particle size distribution for the volcanic ash deposited on land as well as that deposited on the seabed. Fig. 7 illustrates the particle size distribution immediately following the eruption on August 18, 2000, for the land-deposited volcanic ash and the sediment



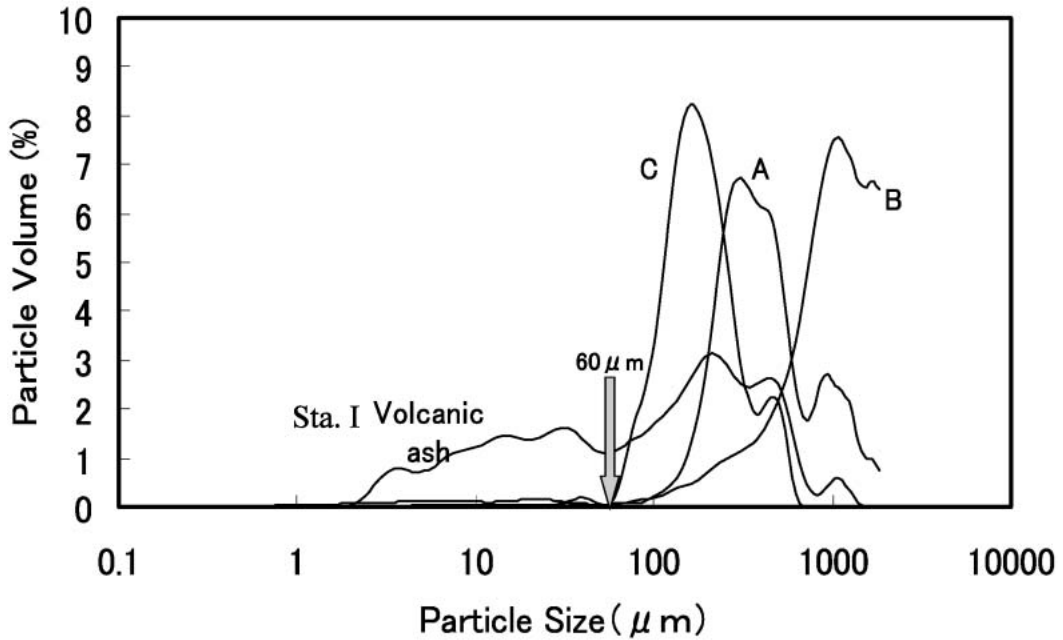


Fig. 7. Particle-size distributions for volcanic ash on land and for sediment at the bottom of the three stations. Fig. 1 shows Stas. I, A, B, and C.

from the seabed that was near the point of the muddy outflow of the deposited volcanic ash. The distribution curve for the land-deposited volcanic ash had a small peak in the range of 200–500  $\mu\text{m}$ , and most particles were in the range of 1–2000  $\mu\text{m}$ . At Sta. A, the distribution curve for the sediment from the seabed had a prominent peak in the range 300–350  $\mu\text{m}$ ; for Sta. B, the range was 1100–1200  $\mu\text{m}$ ; and for Sta. C, the range was 150–200  $\mu\text{m}$ . Particles smaller than 60  $\mu\text{m}$  were found only in a very small quantity at Sta. A, and they were not observed at the other seabed stations.

To calculate the settling velocity ( $\nu$ ) for the particles of size 60  $\mu\text{m}$  ( $D$ ), the following Stokes' equation is used:

$$\nu = \frac{1}{18} D^2 g \frac{\rho_s - \rho}{\mu},$$

where  $g$  is gravitational acceleration,  $\rho_s$  is the density of the particles,  $\rho$  is the density of seawater (1.023  $\text{g cm}^{-3}$ ), and  $\mu$  is the viscosity coefficient of seawater ( $1.0 \times 10^{-2}$   $\text{dyn s cm}^{-2}$ ).

Since the specific gravity of the land-deposited volcanic ash is 2.81, the settling

velocity of particles with a size of 60  $\mu\text{m}$  is estimated to be approximately 3.50  $\text{mm s}^{-1}$ . Accordingly, particles with sizes greater than 60  $\mu\text{m}$  will sediment to the bottom within about 48 min after being flushed out to shallow water areas that have a depth of less than 10 m.

Judging from this, among the particles (of volcanic origin) flushed out from the island, particles with a size greater than 60  $\mu\text{m}$  are expected to sediment rapidly to the seabed, and particles smaller than this size are expected to be dispersed in the suspension.

### 3-3 Flush-out Process of Muddy Water Containing Volcanic Ash from the Island

As mentioned previously, it is known that the suspended particles in high-turbidity water are particles of volcanic origin with sizes less than 30  $\mu\text{m}$ . If we assume the average particle concentration in the water column (centered at Sta. NE9, with a radius of 1 km and depth of 50 m) is 0.5  $\text{mg L}^{-1}$ , the total weight of the suspended particles amounts to 78,500 kg. The spouting of volcanic ash from the crater diminished from September of 2000, and no large-

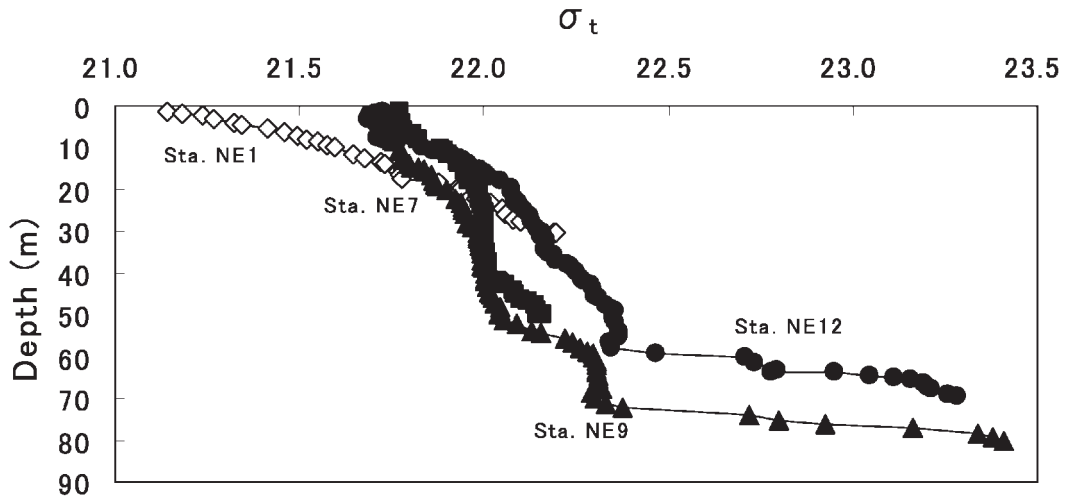


Fig. 8. Vertical distribution profiles of density in the high-turbidity water area. Symbols  $\diamond$ ,  $\blacksquare$ ,  $\blacktriangle$ , and  $\bullet$  represent Stas. NE1, NE7, NE9, and NE12, respectively.

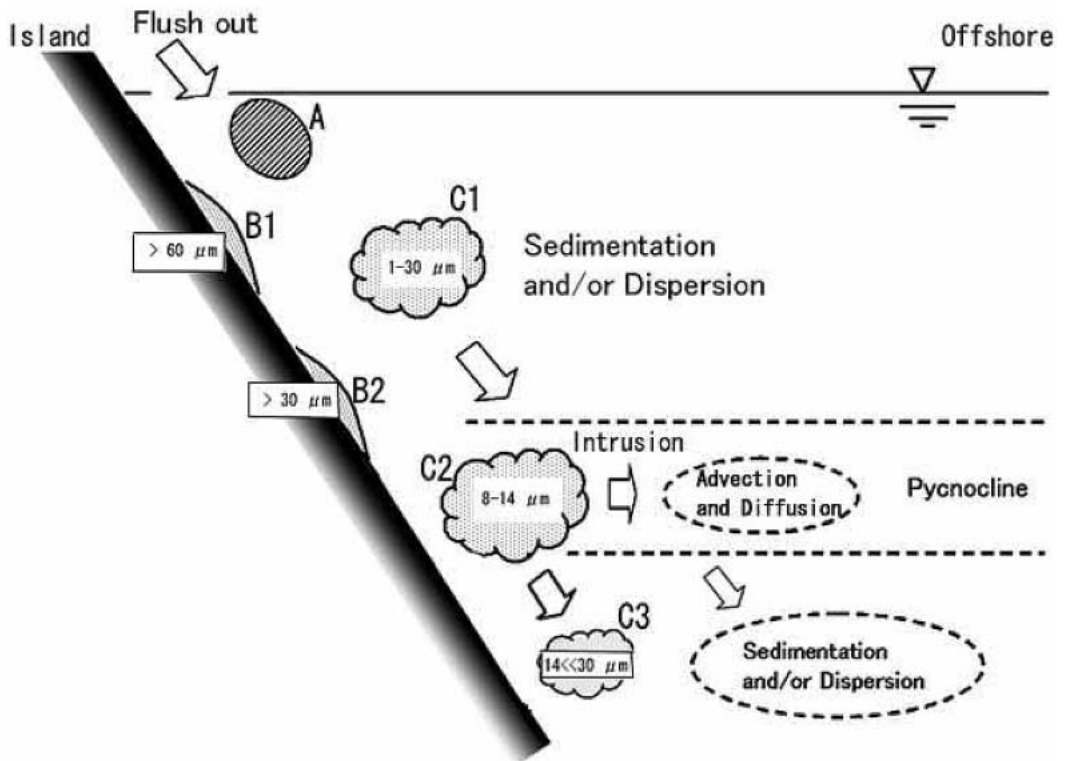


Fig. 9. Sketch of the flush-out process of volcanic ash. Numerical numbers indicate the particle diameters in  $\mu\text{m}$ .

scale spouting occurred until August of 2001. Therefore, the high-turbidity water observed during this period did not result from the volcanic ash that had fallen directly into the ocean from the crater.

DOI *et al.* (2005) investigated the effect of rainfall intensity on the sediment that was transported into the river on Miyake-shima Island after the eruption in 2000. They reported that some rivers on the island continue to discharge considerable volumes of sediment. Fig. 8 illustrates the vertical distribution profile of sigma-t along the line from Sta. NE1 to Sta. NE12. We see that low-density ocean water, less than 22 in sigma-t, distributes inward from the shore (Sta. NE1) to the center (Stas. NE7 and NE9) of the near-circularly localized high-turbidity water. Let us compare this with the distribution profiles for the turbidity illustrated in Fig. 4. It is clear that high-turbidity water is present at a depth of less than 70 m at Sta. NE9, where a pycnocline is observed. Therefore, we can conclude that the appearance of particles in high-turbidity water is due to muddy volcanic ash that was flushed out by rainfall that had taken place 4–5 days before the observation date.

Particles with sizes of 8–14  $\mu\text{m}$  were prominent in the high-turbidity water in October and November of 2000 (3–4 months after the eruption of Mt. Oyama), and they were located in the pycnocline at a depth of 60–90 m (ARAKAWA *et al.*, 2003). We then considered how many days are required for the formation of this high-turbidity layer. To do this, we calculated the settling velocity of the particles with sizes of 8–14  $\mu\text{m}$  from Stokes' equation by assuming the specific gravity of volcanic ash as 2.81, as previously mentioned. The settling velocity in the mixed layer on October and November 2000 ( $\sigma_t = ca. 23.5$ ) was calculated to be  $0.62 \times 10^{-1} - 1.9 \times 10^{-1} \text{ mm s}^{-1}$ . Therefore, particles with a diameter of 8  $\mu\text{m}$  take 11.2 days to reach the pycnocline, and those that are 14  $\mu\text{m}$  in size take 3.6 days.

MORIKAWA *et al.* (1996, 1997) examined the intrusion phenomenon of turbid water in Lake Biwa and explained that the intrusion of turbid water with particles that are 5–10  $\mu\text{m}$  in diameter from the pycnocline resulted easily. In

other words, the following should be considered: the particles discharged from the land settle in the mixed layer (requiring a period of 4–11 days), and then they intrude into the pycnocline layer; as a result, the high-turbidity layer observed in 2000 was formed.

By combining these results, we can obtain a schematic view of the flush-out process for volcanic ash particles, as illustrated in Fig. 9. When muddy volcanic ash (A) from land is flushed out by rainfall into the ocean, particles larger than 60  $\mu\text{m}$  settle rapidly (B1), and smaller particles (C1) disperse and form sediments. Since the settling velocity is high, particles larger than 14  $\mu\text{m}$  in the muddy water and especially those larger than 30  $\mu\text{m}$  are deposited on the seabed (B2) and/or pass through the pycnocline (C3). Fine particles (C2) between 8 and 14  $\mu\text{m}$  in size disperse offshore over a period of 4 to 11 days. After this period, they intrude into the pycnocline and form a high-turbidity layer. The settling velocity of the particles decreases slightly in the pycnocline. The sigma-t of the high-turbidity layer in 2000 was approximately 25, and the high turbidity-water requires more than 1.8–5.6 days to pass through the pycnocline at a depth of 60–90 m. In addition, the high-turbidity water may be advected by entrainment into the ocean current.

In the near future, it will be possible to quantitatively estimate the damage to fishing grounds by the movement of high-turbidity water and flushed-out volcanic ash.

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