Bathymetric monitoring of submarine active volcanoes: an example of island-forming eruption of Nishi-no-shima volcano

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1. JCG's mission on active volcanoes in the seas around Japan

In the sea areas of Japan exist about 40 active volcanoes (volcanic islands/submarine volcanoes) (Fig.1). For securing safety of navigation, Japan Coast Guard (JCG) conducts

(1) aerial monitoring of the volcanoes (regularly and in an emergency), and

(2) bathymetric mapping as well as marine geophysical and geological surveys of the volcanoes.

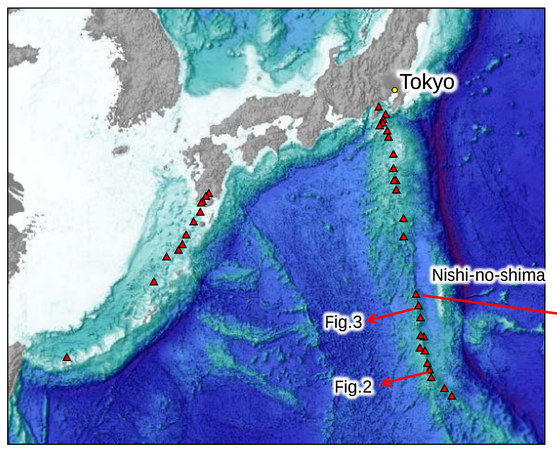

Fig.1 Distribution of active volcanoes in the seas around Japan (red triangles) which JCG conducts monitoring and surveys.

(1) Aerial monitoring of the volcanoes

Discolored water (Fig.2) is an indication of subaqueous volcanic activities at a relatively shallow water. In case that discolored water or other signs of eruptions are observed, JCG immediately issues Navigational Warnings for notifying mariners of volcanic activities.

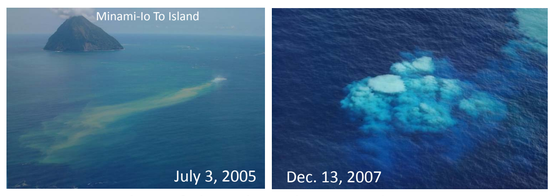

Fig.2 Examples of discolored water due to activities of a submarine volcano, "Fukutoku-okanoba".

(2) Bathymetric mapping of the volcanoes

Bathymetry of submarine volcanoes provide the primary information for understanding the nature of the volcanoes and assessing possible volcanic hazards. In 1998, JCG started a mapping campaign for the active volcanoes shown in Fig. 1. This campaign is still ongoing.

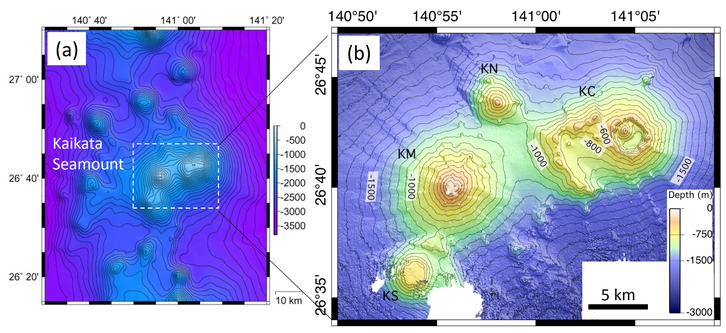

Fig.3 Comparison of two mapping results of a submarine volcano, Kaikata Seamount. (a): survey in 1985 using "SEABEAM"; (b): survey in 2009, using "SEABEAM2112". The new survey data (b) shows that

1. Kaikata Seamount consists of four major volcanic peaks KC, KM, KN and KS,
2. the KC peak underwent multiple caldera-forming events, and
3. the KM has a conical-shaped edifice with a flat top (wave-cut surface).

2. Nishi-no-shima volcano and its eruption events

Nishi-no-shima volcano, which is located about 1000 km south of Tokyo, Japan (see Fig.1), is one of the active submarine volcanoes on the volcanic front. The volcanic edifice rises ~3,500 m above the surrounding seafloor (Fig.4). Its summit forms Nishi-no-shima Island. Two eruption events occurred at the Nishi-no-shima volcano (1973-74 and 2013-2015).

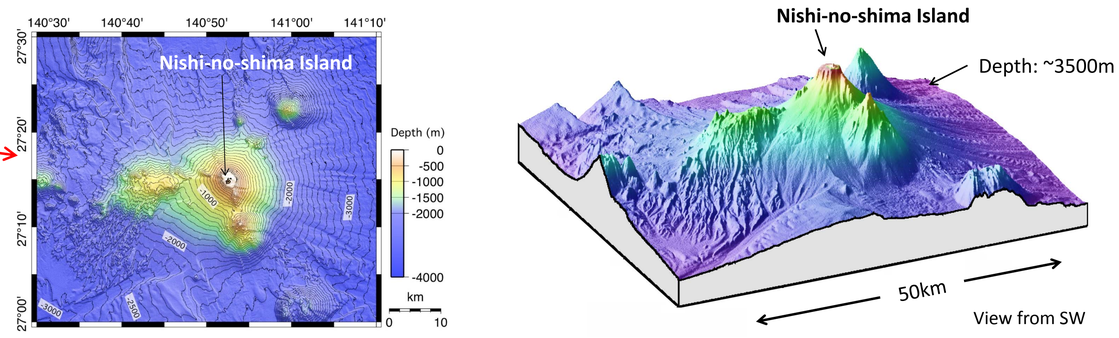

Fig.4 Bathymetric map of Nishi-no-shima volcano (left) and its 3-D bathymetric view (right).

(1) Eruption in 1973–1974

The 1973–1974 eruption is the first event in recorded history and lasted for one year. Immediately after the eruption ceased, a newborn island was connected to the pre-historic Nishi-no-shima Island due to drifted sediment, forming a single island (Fig.5).

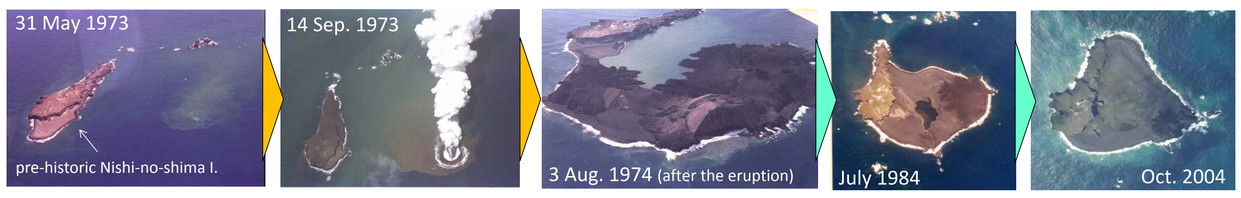

Fig.5 Aerial photographs of the 1973-1974 eruption of Nishi-no-shima volcano and change of the island's shape. After the eruption, the island has greatly changed its shape due to wave erosion and sedimentation.

(2) Eruption in 2013–2015

The eruption and occurrence of a new islet was discovered on November 20, 2013 (Fig. 6). The new island merged with the pre-existing island and almost fully covered it one year later. The eruption lasted for two years. The total area of the island (2.68 km^2) is twelve times as large as that of the pre-existing island (0.22 km^2) (Figs.7 and 8).

Fig.6 Aerial photographs of the 2013-1974 eruption and growth of the newborn land.

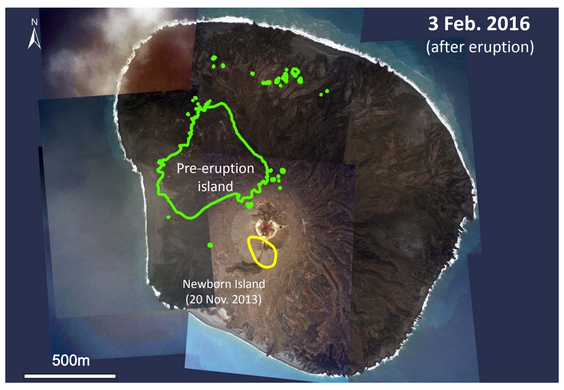

Fig.7 Change of Nishi-no-shima Island during the 2013-2015 eruption

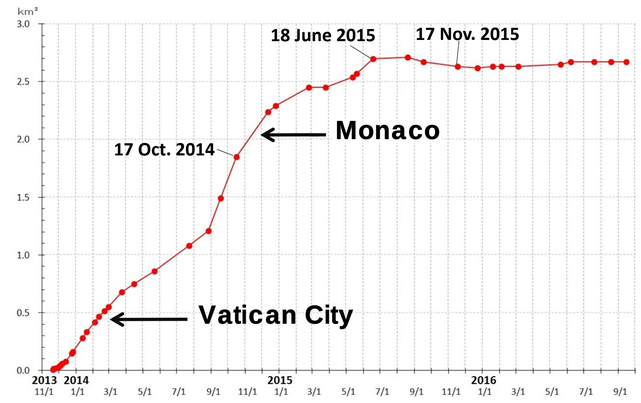

Fig.8 Growth of the newborn land area

* Not include remaining parts of the pre-eruption island

3. Bathymetric change during the 2013-2015 eruption of Nishi-no-shima volcano

(1) Bathymetric mapping in June-July 2015

In June to July 2015, JCG conducted bathymetric mapping around the growing Island, which was the first seafloor mapping after the eruption began. As of June to July 2015, growth of the island by lava flows was active (see Fig.9). The MBES mapping, therefore, was conducted using autonomous survey boat "Manbo II" (Fig.10).

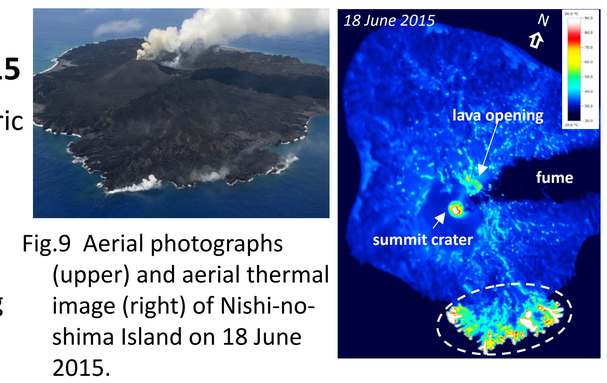

Fig.9 Aerial photographs (upper) and aerial thermal image (right) of Nishi-no-shima Island on 18 June 2015.

Fig. 10 Autonomous survey boat "Manbo II" (left), her mother vessel "Shoyo" (upper right), and a MBES (R2sonic2022) mounted on the Manbo II (lower right). Manbo II was designed for survey of active submarine volcanoes and was commissioned in 1998.

The survey lines were designed as a series of similarity-shaped polygons with the minimum spacing of 25 meter. The survey line closest to the shoreline was set 200 meters away from the shoreline. Manbo II surveyed the area with the water depth of ca.10-200 m around the Island in five days (Fig. 11).

Table.1 Specifications for MBES bathymetric survey

Frequency	350kHz (200kHz－400kHz)
Beam width	(1°×1° at 400kHz－2°×2°at 200kHz)
Number of beam	256
Swath angle	130° (max.160°)
Survey speed	~2 knot (relative to the water)
survey line	25-50 m spacing, total length of 110 km

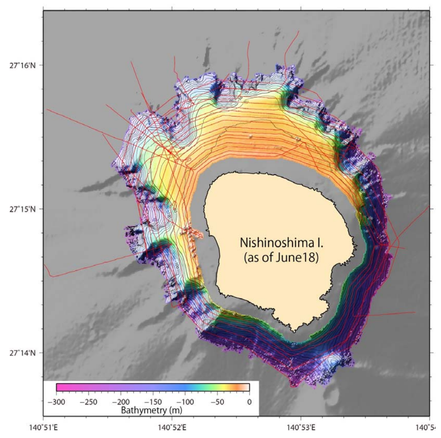

Fig. 11 Bathymetric map with Manbo II survey lines (indicated by red lines).

(2) Construction of Digital Elevation Models (DEMs)

Two DEMs were constructed by combination of bathymetric data with land topography data from GSI*; one for topography before the eruption (Old DEM) and the other for topography as of July 2015 (New DEM) (Figs.12 and 13). *GSI: Geospatial Information Authority of Japan

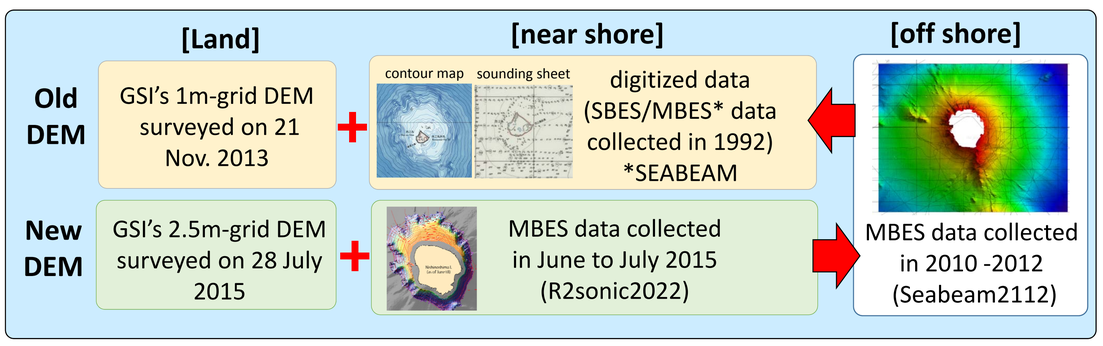

Fig.12 Schematic diagram on construction of the DEMs. Red arrows point to overridden data sets.

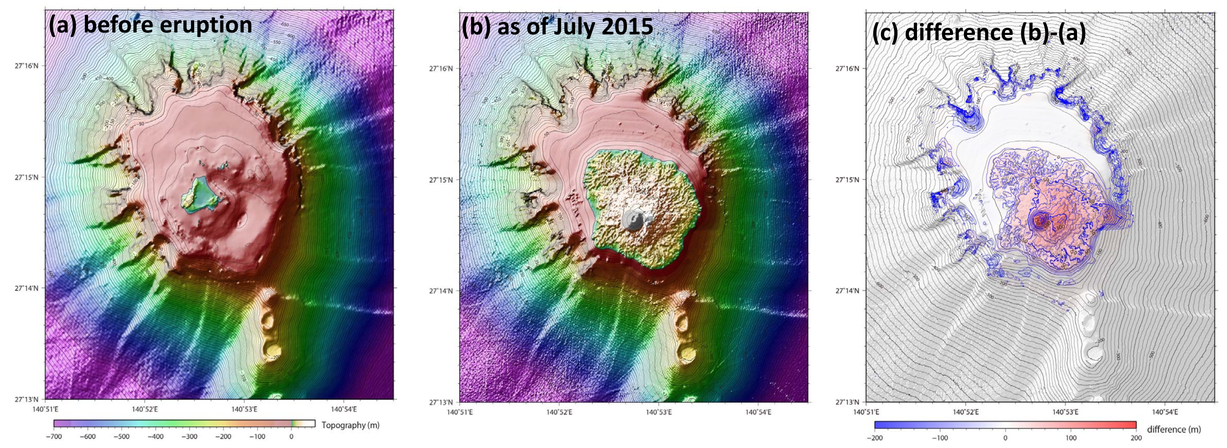

Fig.13 DEMs constructed; (a) before eruption, (b) as of July 2015, and (c) difference between (a) and (b). The grid size of the DEMs is 10 m. Difference between (a) and (b) over the shelf edge (shown in pale blue) is considered as a bias between old-fashioned and modern echosounders.

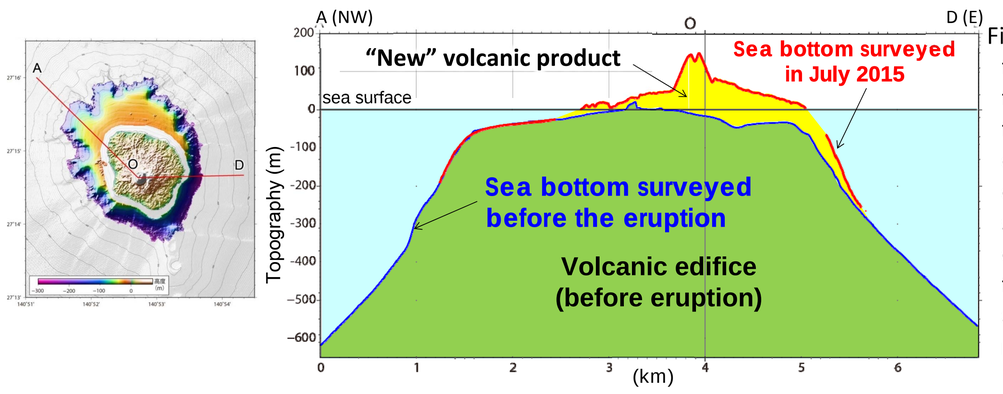

Fig.14 A representative topographic profile along the line A-O-D, comparing topography before the eruption (blue line) and as of July 2015 (red line). A significant bathymetric change is recognized in the eastern shelf edge, and vice versa in the northwestern shelf edge.