Submarine Volcanoes and Autonomous Survey Vehicles

Fringed by deep trenches, Japan is a country composed of seismic and volcanic active island arcs, where the huge Pacific Plate and the smaller Philippine Sea Plate converge to the Eurasian Plate. Integration of tectonic and volcanic activity since the geological Tertiary period formed beautiful mountainous landscapes and scattered small plains with rich soil. At sea around Japan, two volcanic ridges are extending to south and southwest from the mainland Japan. It means Japanese waters are not free from volcanic hazards.

In the morning of 17 September 1952, the Chief Hydrographer of Japan received a telegram from a fishing boat that intense submarine eruption at sea 400km south of Tokyo formed a new island of 150m dia-
|meter. The Chief Hydrographer immediately dispatched notices to mariners and ordered reconnaissance. Since no survey vessel was available for the immediate action, a patrol vessel Shikine steamed out.

Violent Eruptions

Next morning the Shikine conducted courageous observations and confirmed violent eruption and a new island of roughly 150m N-S by 100m
E-W with a height of 30m. After several dangerous close observations and narrow escapes, the captain sent a telegram. With recognition by the Shikine, the Chief Hydrographer gave a name to this submarine volcano as Myojin-sho quoting the name of the fishing boat which accidentally found the steaming new island.
Curiously enough, positions of eruption reported from various ships scattered in an about 10nm radius circle. The Chief dispatched survey vessel No.5 Kaiyo-maru to conduct precise positioning and scientific investigation. He formed a survey team with 22 crew members and 9 excellent scientists, which include a 26 years old geographer Mr Ryoichi Mita. Mr Mita was an officer of Chart Division of the Hydrographic Department (H.D.) with geographic background. Once he had interested by a nameless isolated shallow, which had grown up to an islet several times by volcanic eruption since 1870, (and named as Myojin-sho afterwards) collected all the available data, carefully examined them, and concluded that the shallow is a top of a post caldera cone associated with a 10km diameter caldera.

Scientific Report

From the study, he noticed past violent eruptions and wrote a scientific report, which appeared in a Japanese Hydrographic Bulletin (No.12, June 1949) with his warning to mariners.
Survey vessel No.5 Kaiyo-maru left Tokyo Port in the morning of 23 September 1952. At 8:30 p.m. of the same day a routine telegram was received, but after that the vessel became completely silent. In spite of all the efforts of the MSA (Maritime Safety Agency or mother body of H.D.) telecommunication officers, there was no response from the vessel. In the morning of 25 September the MSA started a search and rescue operation with full strength. After all, only they could find were fragments of the survey vessel. The case became the worst tragic accident in the history of Japanese Hydrography (Figure 1).
To predict and monitor submarine volcanic eruption, the Hydrographic Survey Division had made continuous effort to conduct surveys and investigations. But the most important areas, or volcanic active areas, were left as data vacancy because manned vessels had to avoid danger. With a timely advise from Prof. Dr Joyo Ossaka of Tokyo Instute of Techology, an officer of H.D., Dr Masakazu Tsuchide, initiated a project to develop an autonomous survey vehicle in 1983. The vehicle was completed in 1985, and named Manbou (Japanese for sunfish) because it was designed to have strong righting moment, which made her a little poor to go straight ahead (Figure 2a). Manbou was a 6.5 ton, 10m length vehicle equipped with depth sounder, temperature/salino meter, sea-water sampler and XBT (expendable bathy-thermometer). The system installed enabled her to navigate in program mode or in remote controlled mode.

Earthquake Swarm

On 30 June 1989, an earthquake swarm happened once again at and around Ito city, which is a famous touristsâ€™ coastal resort 90km southwest of Tokyo. From 1977 through 1988 people had already experienced earthquake swarms 11 times in Ito city, but the 12th one was much severe than the preceded. Characteristics of the earthquakes showed magmatic activity. On 9 July the Chief Hydrographer ordered Survey Vessel Meiyo to survey the details. Meiyo covered the epicentral zone with her side-scan-sonar, but there was nothing unusual. In the evening of 11 July, a large amplitude continuous tremor happened, and scientists anticipated magma intrusion. After a careful sea surface monitoring by a helicopter, it was decided to survey the area again with the sub-bottom profiler (3.5 KHz) installed in Survey Vessel Takuyo. The survey was conducted on 13 July. At 18:28 hours in the evening she passed the point just above the new sea-knoll (or a just born volcano). Her sub-bottom profiler clearly draw a 25m high sea-knoll but nobody in the observation room realised it as a newly born volcanic knoll filled with red-hot magma. At 18:33 hours crew members and officers noticed strange intermittent bang noises. Shortly the noise became very loud as if a giant is hitting the ship with a huge hammer every few seconds. In the operation room a communication officer was fighting with acute fear to maintain regular communication. In the engine room circuit boards of engine monitor knocked off, a pitch controller for propellers breakdown, main engine cooling water pressure dropped, main engine fuel pressure dropped. All the breakdowns triggered loud alarms which doubled their fear. Fortunately backups for these machines immediately started.
In the bridge, the captain ordered careful observation. In a few minutes, an officer found a swell and ripples at 45 degree portside ahead at distance 500m. It looked like an underwater detonation. The puzzle was solved, it was a volcanic eruption happened very close. The officer of the watch shouted â€˜hard starboardâ€™. The captain took over the control and ordered â€˜full speedâ€™. At the eruption point, black water jets of a few tens metres high stood up frequently, and finally a water dome of 230m diameter with 113m high stood up. At 18:46 hours the captain thought the ship had narrowly escaped from the dangerous area.

Mapping the New Vulcano

The next task at that time was mapping the new volcano and a prediction of the next eruption. If the new underwater volcano is big, then the next phreatomagmatic eruption would endanger tens of thousands of people. The Chief Hydrographer ordered a survey with the autonomous survey vehicle Manbou. The survey with the Manbou was carried out two days
after the eruption, and mapped a small sea-knoll of 450m diameter with only 10m high. It looked there was no danger of anticipated phreatomagmatic eruption.

The first autonomous survey vehicle Manbou was, frankly, not good enough for surveyors. Since they really wanted higher precision and higher maneuverability, an improved one was built. The second autonomous survey vehicle Manbou II was completed in 1998 (Figure 2b). This vehicle is capable of precise depth sounding, water sampling and XBT observation in program mode or in remote-controlled mode. Survey equipments consist of Trimble DGPS DSMpro for positioning and ODOM Echotrack MK II single beam echo sounder. Precise depth sounding at and around the top of Myojin-sho by Manbou II revealed the whole figure of Myojin-sho (Figure 3).

In the evening of 26th June 2000, earthquake swarm by magma intrusion happened in Miyake Shima (Island), situated 180 km south of Tokyo. Three hours later the seismic activity moved northwest to the sea associated with magma migration along an undersea unknown weak zone. In collaboration with an academic group, the Chief Hydrographer dispatched survey vessels and scientists. They conducted a side-scan sonar survey at the point where discolored water was observed, and seismic observations with Ocean Bottom Seismometers (OBSs). The side-scanning sonar survey detected four small spatter cones. OBS observation revealed that the unknown weak zone is extending northwest from the island for more than 20km. Seismic activity along this weak zone was very high for about 2 months, while very frequent earthquakes including M6 (on the Richter scale) occurred. From the characteristics of OBS data, scientists found that magma intruded along this tectonic weak zone. Magmatic activity was mainly happened in the sea, but magma migration from the Miyake Island to the sea caused a collapse of the top of the island. Before the eruption, Miyake Island was an 8km diameter conical basaltic volcano of which the top was 814m above sea level, with a population of about 3,800. Covered by dense subtropical forests, the island was a resort to enjoy swimming, diving and bird watching. But the eruption which happened in the year 2000 forced them to evacuate from the island. To compensate loss of mass caused by the westward magma migration, the summit of the volcanic island subsided considerably, finally formed a caldera of 1.5km diameter and 500m deep. Moreover, the island lost the underground cleaning system for volcanic gas. Emission of SO2 gas from the vent increased from late August, reached a few tens of thousands of tons per day. On 4 September, evacuation of all the islanders took place. Huge amount SO2 gas emission continued for years.

Considering recent volcanic and seismic activity in the Japanese waters, as mentioned above, a much more sophisticated autonomous survey vehicle was built. The newest autonomous high-tech survey vehicle, named Jinbei, was completed in 2002. Though the length of the boat is only 10m, the name Jinbei originates from one of the biggest animal in the sea â€˜Whale Sharkâ€™. Major features of Jinbei (Figure 4) are as follows:

General

- Length Overall: 10.0m
- Draft: 1.4m
- Gross Tonnage: 6 tons
- Speed:
- Cruising: 9 knots
- Maximum: 10 knots
- Range: 200 nautical miles
- Propulsion: Diesel 110kw (3,000 rpm)
- Accommodations: 6 (crew and scientists)

Instrumentation

- Multi-beam echo sounder: SEABAT8125 (Reson)
- Single-beam echo sounder: Hydro-star 4300 (Elac)
- GPS/Inertial navigation system: POS-MV 320 (TSS)
- Salinometer: MDM-310 (DKK-TOA Corporation)
- Water thermometer/ PH meter: TDIC-7 (DKK-TOA Corporation)
- XBT digital converter: MK-30N (The Tsurumi Seiki Co., Ltd.)
- Video transmitter: Video Modulator (Ikegami Tsushinki Co. Ltd.)
- Satellite communication System: Satellite Marine Phone (NTT DoCoMo)
- Surveillance Equipment: PV130 (Canon)

Postscript

Fortunately or unfortunately, we have not experienced major volcanic activity at sea after the completion of Jinbei. It means we have not tested its real capability yet.

On 1 February 2005, evacuation instructions for Miyake Shima (Island) were lifted, because the daily rate of SO2 gas emission decreased to 2,000 â€“ 5,000 tons/day. A small number of islanders returned to their sweet homes with their gas mask at hand.