Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SCG67-05 Room:106 Time:May 22 15:15-15:30

Mapping hydrothermal sites in the Bayonnaise knoll caldera using acoustic sonars with an autonomous underwater vehicle

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The Bayonnaise knoll caldera is one of a number of submarine calderas in the Izu-Ogasawara island arc. Since a large active hydrothermal field associated with sulfide deposit, the Hakurei site or deposit, was discovered on the southeastern margin of the caldera floor in 2003, the caldera has attracted much attention because of its potential importance as submarine resources. We conducted autonomous underwater vehicle (AUV) surveys during the YK11-11 research cruise of the R/V Yokosuka in December 2011. Two dives of the AUV Urashima, a vehicle developed by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), were devoted for mapping the southern half of the caldera using a multi-narrow beam echo sounder and a side scan sonar.

The multibeam bathymetric data were first examined each ping to remove obvious outliers, and then combined with the vehicle's position and attitude data to determine their precise locations. Because some of the track lines over the Hakurei site were arranged densely, data from adjacent tracks commonly overlapped. Data misfits in these overlapped areas were dissolved by correcting the position data as required. All the located bathymetric data were finally compiled to produce a fine bathymetric map, the resolution of which is several tens of centimeters. It was confirmed that the Hakurei hydrothermal site is associated with the rugged seafloor surface, which probably represents sulfide mounds and chimneys.

The side scan sonar data were first processed by forcing a flat bottom assumption. However, the resulting mosaic suffers from significant geometric distortion because of the large relief observed at small altitudes. Moreover, the backscattering intensities are rather influenced by the actual slopes in spite of radiometric corrections. We then tried to take advantage of the multibeam bathymetric data to determine actual footprints of each ping and to correct these geometric distortions and intensities. The mosaic was greatly enhanced by this processing: it well agrees to the topography and the effect of the incident angle was adequately removed. The image around the Hakurei site is characterized by the short-wavelength alternation of strong and weak backscattering, which probably represents reflections and acoustic shadows due to sulfide mounds and chimneys. We made a seabed classification of the mosaic, and four categories were chosen as representing major features. The Hakurei site is adequately classified to one of the categories.

The intensity data from the multibeam sonar were processed to create another backscatter mosaic. The Hakurei site is characterized by a distinctive spotty pattern unlike the side scan image that shows many acoustic shades due to topographic relief. One of the reasons for the different expressions of the hydrothermal site by the multibeam and side scan sonars might be the difference in the sound frequency. Another reason could be the geometric distortion in the side scan image signals from soaring chimneys. The spots of strong backscattering are from several to ten meters in diameter, and they were recognized to be actually associated with topographic highs in the multibeam bathymetric map. This conspicuous pattern was utilized to delineate areas that have similar characteristics, and several areas other than the Hakurei site were found to have similar patterns. The distribution is generally in good agreement with that of the classification from the side scan image to which the Hakurei site belongs. We suggest that hydrothermal activity at various scales would occur in several places in the caldera.

It was inferred from this study that hydrothermal sites are distinguishable by their acoustic characteristics. We suggest that deep-sea acoustic surveys with AUVs are effective means to seek unknown hydrothermal sites efficiently in a wide area.

Keywords: hydrothermal sites, AUV, side scan sonar, multibeam sonar