Brief Report of Side-Scan Sonar Imagery Observations of the Archaean, Pika, and Urashima Hydrothermal Sites

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Abstract

A high-resolution acoustic investigation using AUV-*Urashima* reveals the geological features of three off-axis hydrothermal sites at the Southern Mariana Trough. They are developed ~5 km in distance from backarc spreading axis. The *Archaean* site is developed at the foot of axial horst and forms 60 m-high mound. Hydrothermal chimneys in the site are arrayed along the ridge of the mound. Our acoustic observations detect small structures along the ridge which could be interpreted as the chimneys. To the south of the *Archaean* mound, the seafloor is characterized by rough and elongated fabrics approximately trending in NE–SW direction, which coincides with the strike of background seafloor slope. Visual observation indicates that the area consists of lava tube slightly covered by sediment. The *Pika* and the *Urashima* sites are developed on top and at foot of a ~1,800 m-high off-axis knoll. Unprocessed sidescan sonar imagery above the *Pika* and the *Urashima* sites shows anomalous backscattering signatures in water column. A series of hills with convex shape develops on the southwestern slope of the off-axis knoll. It shows unique facies that is rough surface with high-backscattering intensity on the sonar imagery. Tube lavas are recognized in corresponding seafloor by visual observation.

Keywords

Hydrothermal signature • Side-scan sonar • Southern Mariana Trough

37.1 Introduction

The southern Mariana Trough is one of the intensive study areas of TAIGA project (Chap. 1). Three active off-axis hydrothermal sites are known in this area (Kakegawa et al. 2008; Nakamura et al. 2013) as well as two other sites on the backarc spreading axis. The *Archaean* site is located at foot of the axial high (Fig. 37.1), the *Pika* site and the *Urashima* site are located at the top and the foot of an off-axis knoll (Fig. 37.4). These sites are found within 5 km from

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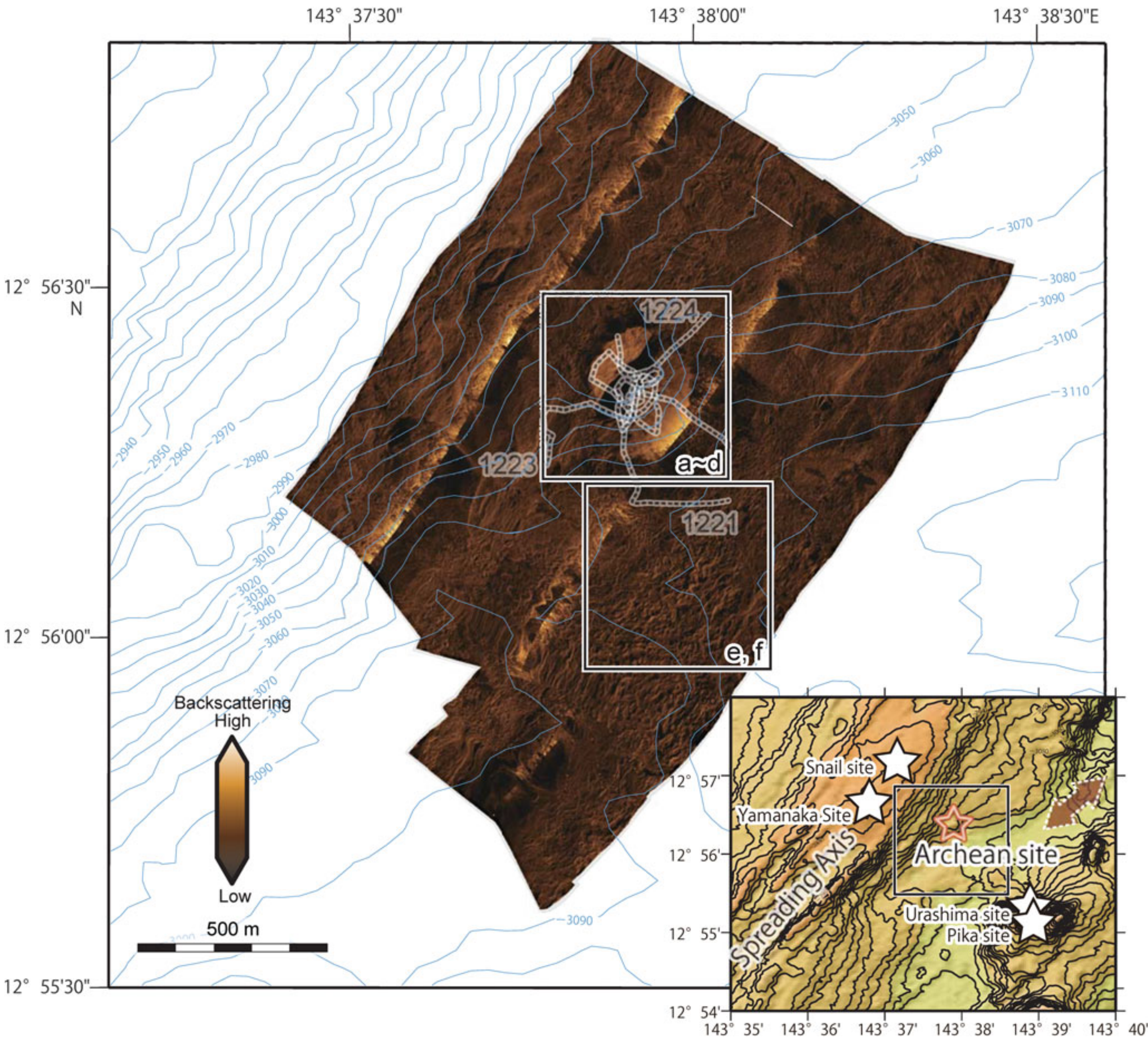

Fig. 37.1 Sidescan sonar imagery of the *Archaean* hydrothermal site and surrounding seafloor obtained using an *Edgetech2200* system (120 kHz) mounted on the AUV-*Urashima*. *Darker color* indicates lower backscattering intensity. *Dotted lines* indicate tracks of the submersible-*Shinkai6500* during cruise YK10-11 in 2010. *Blue lines* and *annotations* show background bathymetry obtained by a *Seabeam2112* system (11 kHz) mounted on R/V *Yokosuka*, for reference. *Squares* are locations of Fig. 37.2. *Inset* (*right*, *down*) is location map of hydrothermal sites in this area. On- and off-axis hydrothermal sites are indicated by *stars*. A *double-headed arrow* roughly indicates local trend of valley on the background bathymetry

spreading axis, and along single line nearly perpendicular to the spreading axis. There are two on-axis hydrothermal sites, the Snail and the Yamanaka sites, near these off-axis sites, and the Snail site is located on the same line linking the off-axis sites. To investigate the geological background of these hydrothermal sites and to understand the if these sites are related to each other in terms of the heat source and/or tectonic background, we conducted high-resolution acoustic observations using the AUV-*Urashima* in 2009 and visual observations using the submersible *Shinkai6500* in 2010. In this report, we present the survey results at the three off-axis hydrothermal sites (the *Archaean*, *Pika*, and *Urashima* sites). The results on two on-axis sites are reported in Asada et al. (Chap. 36).

37.2 Data Acquisition

Meter-scale, high-resolution, bathymetric and sidescan sonar data were acquired by the AUV-*Urashima* (JAMSTEC), which was developed in 1998 (Tsukioka et al. 2005; Kasaya et al. 2011). The AUV-*Urashima* is equipped with a 400 kHz multi-beam echo sounder (MBES) for meter-scale bathymetry data (*Seabat7125*), a 120 kHz sidescan sonar (SSS) for backscattering strength data, and a 1–6 kHz (charp) sub-bottom profiler (SBP) for subseafloor information (*EdgeTech2200*). Dive-92 around the *Archaean* site (Fig. 37.1) and Dive-93 around the off-axis knoll on which the *Urashima* and the *Pika* sites (Fig. 37.4) are conducted. In each dive, the AUV collected the data along nine, parallel, NE–SW trending lines roughly 100 m (Dive-92) and 140 m (Dive-93) intervals. The average survey altitude and speed of the AUV were about 100 m and 2 knots, respectively. The along-track width of acoustic beam is 0.5° for MBES and 0.9° for SSS, equivalent to 2–5 m on the seafloor. The resolutions for the 120 kHz SSS is approximately 7.5 cm (when acoustic velocity in seawater is 1,500 m/s). The 400 kHz MBES bathymetry data are gridded at interval of 2 m.

Visual observation using the *Shinkai6500* submersible was performed in YK10-11 cruise in 2010. We utilized the videos and photographs recorded along the dive tracks as ground references for the acoustic imagery.

37.3 Processing Methods

Acoustic data sets obtained by the AUV-*Urashima* are extracted from data logger on board. The converted SSS data is processed and mosaiced using software CleanSweep3 (Oceanic Imaging Consultants, Inc.). Bathymetric data were processed using software HIPS and SHIPS (Caris) and plotted using the Generic Mapping Tools software program (Wessel and Smith 1991).

Deficiencies and artifacts in the bathymetric data occur near the top of the *Archaean* mound and the off-axis knoll where the *Pika* site is located. The quality of SSS imagery is also low in the same part of the survey lines. They are caused by unstable attitude control of the AUV during these dives, mainly due to mal-function of DVL (Doppler Velocity Log).

We interpreted the patterns on the sonar imagery as geological features, referring to many previous studies on mid-ocean ridges (Smith et al. 1995; Briais et al. 2000; Sauter et al. 2002; Cann and Smith 2005; Searle et al. 2010). Generally, lava outcrops have high backscattering signatures while seafloor covered by sediment has lower backscattering signatures. A seafloor covered by rabbles shows higher backscattering intensity rather than a flat lava. Acoustic shadows are used to estimate the height of seafloor structures. Geological information can be obtained from facies which are identified based on backscattering intensity and patterns of the acoustic shadows and distributions.

37.4 Results

37.4.1 Observation of the *Archaean* Site

The *Archaean* site is located on an approximately 60 m-high conical mound at the foot of the axial high (Fig. 37.1). The facies of the conical mound was generally smooth with a wavy surface texture and the backscattering intensities are high (Fig. 37.2a–d). Visual observations from the *Shinkai6500* submersible revealed that the surface of the mound was extensively covered by sulfide deposits (Fig. 37.3ii). Our SSS and MBES data detect small structures with acoustic shadow along the ridge of the conical mound (Fig. 37.2a–d). The positions of the small structures are confirmed by visual observation by submersible observation. The distribution of the small structures on the SSS imagery could be useful as an indication of chimneys on the seafloor.

The facies of the seafloor to the south of the mound was characterized by the presence of rough and elongated fabrics approximately trending in NE–SW direction (Fig. 37.2e, f), which coincides with the strike of background seafloor slope (see bathymetry map in Fig. 37.1). Visual observations revealed the presence of relatively old tube lavas covered with sediment (Fig. 37.3iv). This characteristic fabrics appears to develop on the surrounding seafloor and the distribution does not show any connection to the current spreading axis nor the *Archaean* mound, suggesting the possibility of off-axis volcanism further to the south.

37.4.2 Observation of the *Urashima* Site and *Pika* Site

The *Pika* site, discovered in 2003 (Kakegawa et al. 2008), is characterized by high-temperature black and clear smokers. The site develops at a part of the western top of the off-axis knoll, which is ~5 km east from spreading axis. The Urashima site was newly discovered in 2010 at the northern foot of the same knoll, following the detection of acoustic and geomagnetic anomalies during our AUV survey (Nakamura et al. 2013).

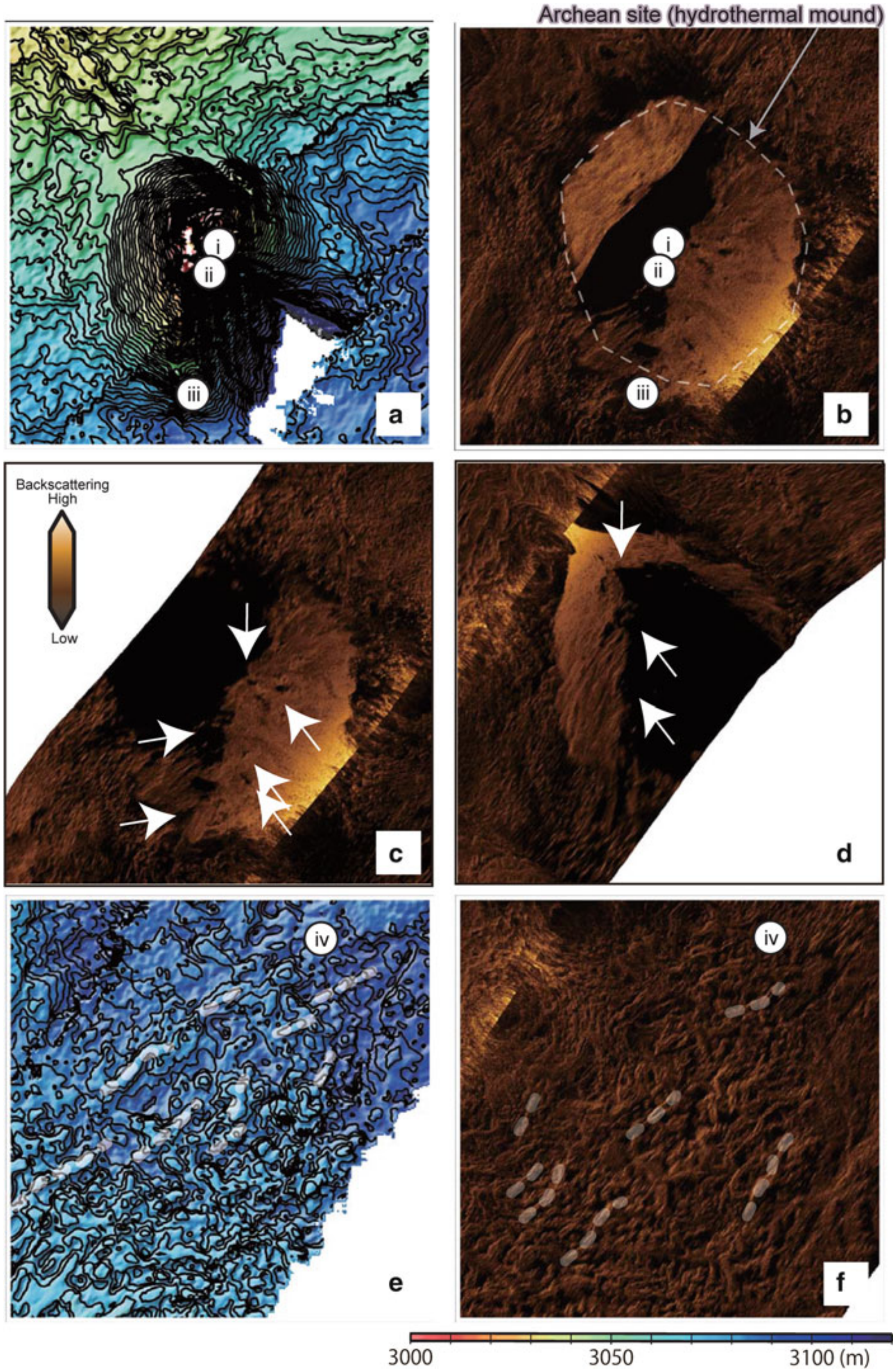

Fig. 37.2 Detailed views of sidescan sonar imagery and bathymetry. (**a**) Bathymetry map obtained by the *Seabat7125* system (400 kHz) mounted on the AUV-*Urashima*. (**b**) Sidescan sonar imagery of the the hydrothermal sulfide mound of the *Archaean* site. (**c**) Single swath of sidescan sonar imagery taken from south of the mound. *White arrows* indicate small structures with acoustic shadow. (**d**) Single swath of sidescan sonar taken from the north of the mound. *White arrows* indicate small structures. (**e**) Bathymetry map of seafloor lies at southern sides of the mound. *White transparent dotted lines* indicate suggested trend of represented examples of the rough and elongated fabrics. (**f**) Sidescan sonar image of the seafloor. *White transparent dotted lines* indicate suggested trend of represented examples of the rough and elongated fabrics, too. (*i*)–(*iv*) are locus of photographs shown in Fig. 37.3

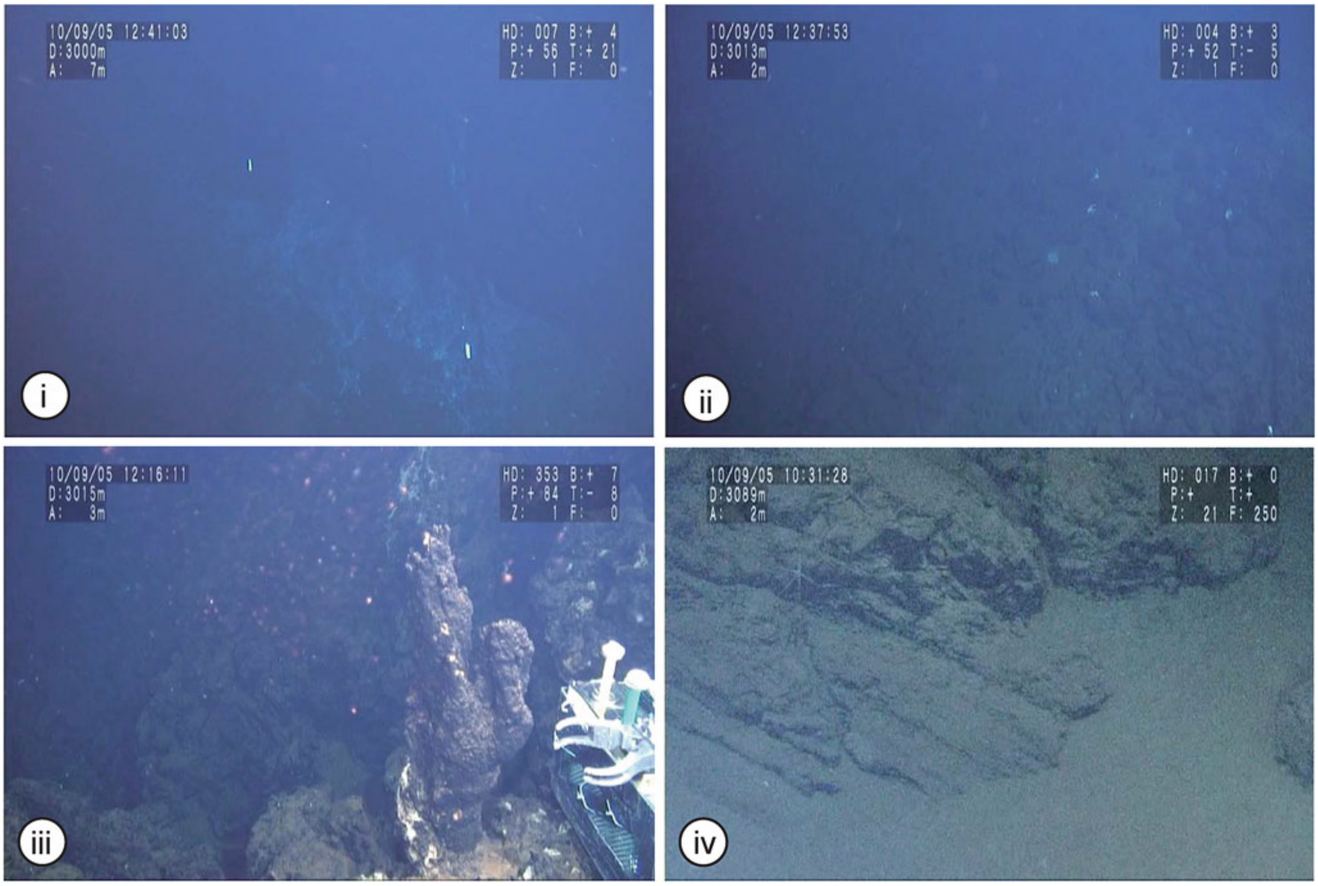

Fig. 37.3 Photographs taken at (*i*)–(*iv*) shown in Fig. 37.2. (*i*) Active hydrothermal chimney on the top of a mound, (*ii*) rubbles at the foot of a hydrothermal chimney, (*iii*) active hydrothermal chimney at the foot of the mound, and (*iv*) seafloor lies at southern ~ southwestern sides of the mound, showing lava covered by sediment

We detected anomalous backscattering signals in the water column by SSS above the *Pika* and the *Urashima* sites (Fig. 37.5c, d), where the active hydrothermal chimneys are observed (Fig. 37.6i, ii).

A series of hills with a convex shape (Figs. 37.5e, f, 37.6iii) extend from the southern to the southwestern sides of the off-axis knoll. The diameter and relative elevation of the hills are approximately 100 m and several tens of meters, respectively. SSS imagery shows unique facies, that is rough surface with high-backscattering intensity. Dive photos show that the surface of the hills is covered by tube lavas (Fig. 37.6v) with thin sediment. The tops of the hills are flat and partially covered by sediment, and a rocky outcrop with a web-like surface structure was observed (circle in Fig. 37.6iii, iv). SBP data shows obscured image of sediment layers in this area, meaning that the thickness of the sediment layer is less than catalogue resolution of 1–6 kHz (~15 cm in vertical) acoustic signals.

The SSS imagery shows relatively high-backscattering terrain over the area of western top of the off-axis knoll, although the *Pika* site is recognized at the limited area. Due to higly distorted SSS imagery, we could not estimate distribution of high-backscattering terrain, small structures, and linear features in detail.

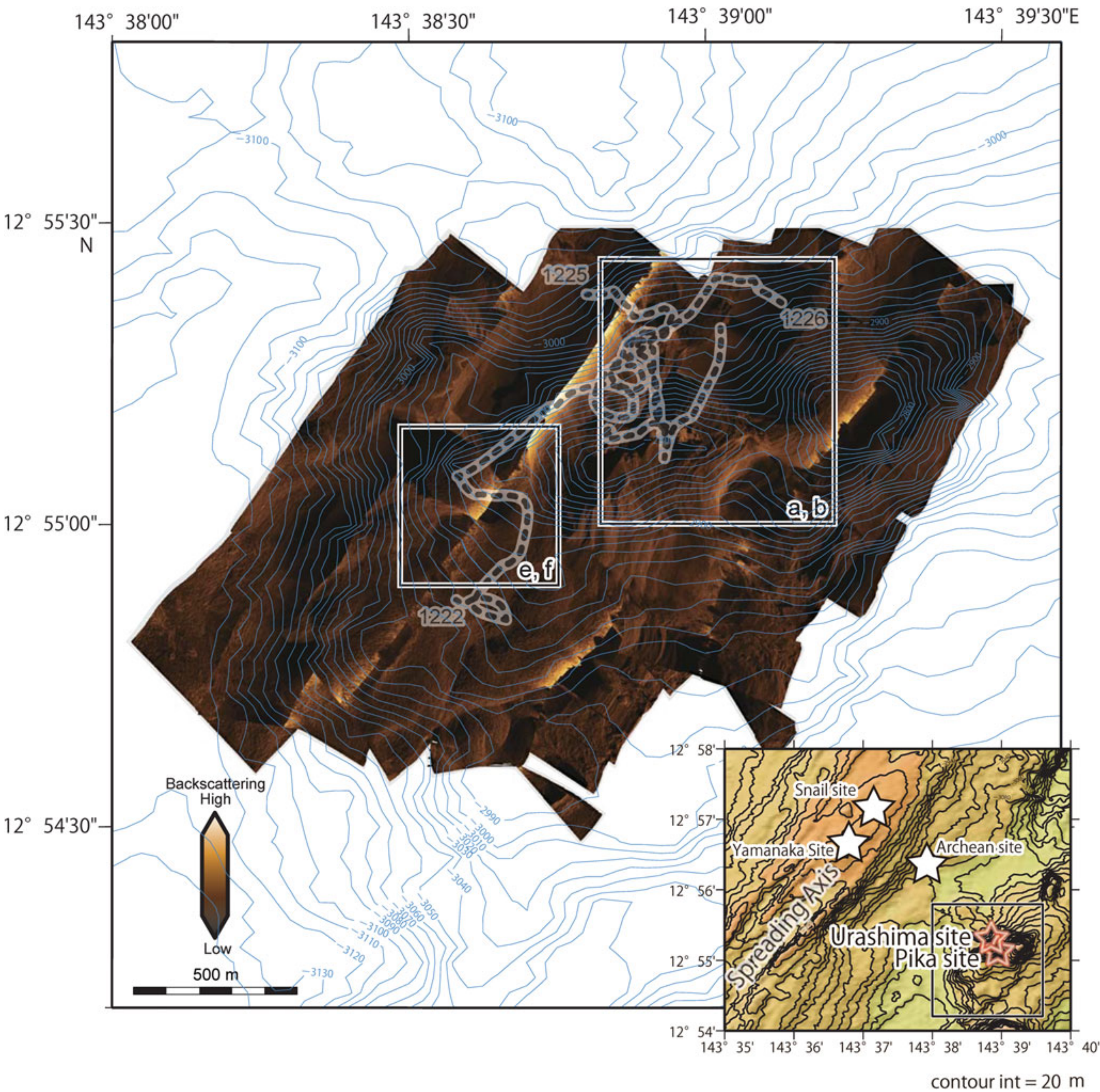

Fig. 37.4 Sidescan sonar imagery of the off-axis seamount on which the *Pika* site and the *Urashima* site. See Fig. 37.1 for description

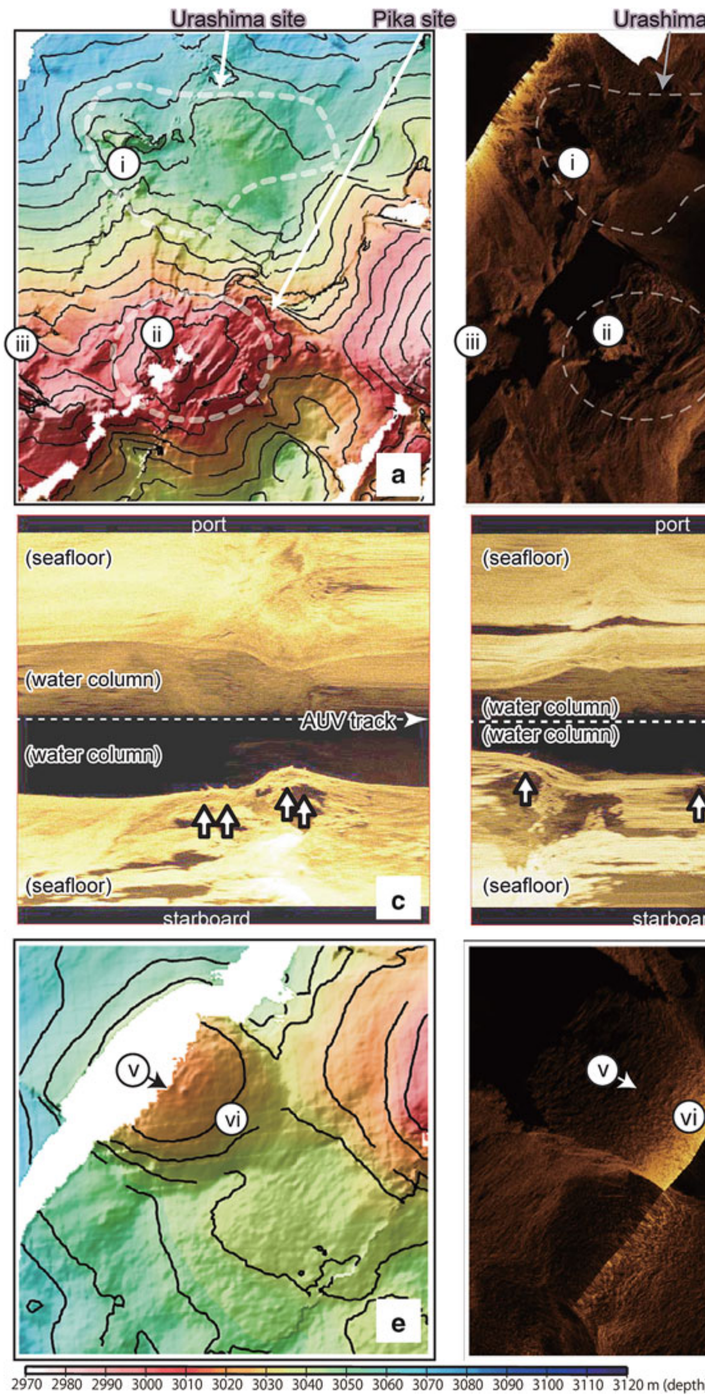

Fig. 37.5 Sidescan sonar imagery, bathymetry of the *seabat7125* system at a same location to the sidescan sonar image, and unprocessed sidescan sonar imageries plotted along time. (**a**) Bathymetry map of *seabat7125* system. *Dashed areas* indicate approximate locations of the *Pika* site and the *Urashima* site. (**b**) Sidescan sonar imagery of the location shown in (**a**). (**c**) Unprocessed sidescan sonar data obtained above the *Urashima* site. Backscattering signals in water column suggest the presence of materials associated with hydrothermal activity. (**d**) Unprocessed sidescan sonar data above the *Pika* site and showing backscattering signals in the water column. (**e**) Bathymetry map of southwestern foot of the off-axis seamount. (**f**) Sidescan sonar imagery of the location shown in (**e**). (*i*), (*ii*), (*iv*) and (*v*) are locus of photographs shown in Fig. 37.6

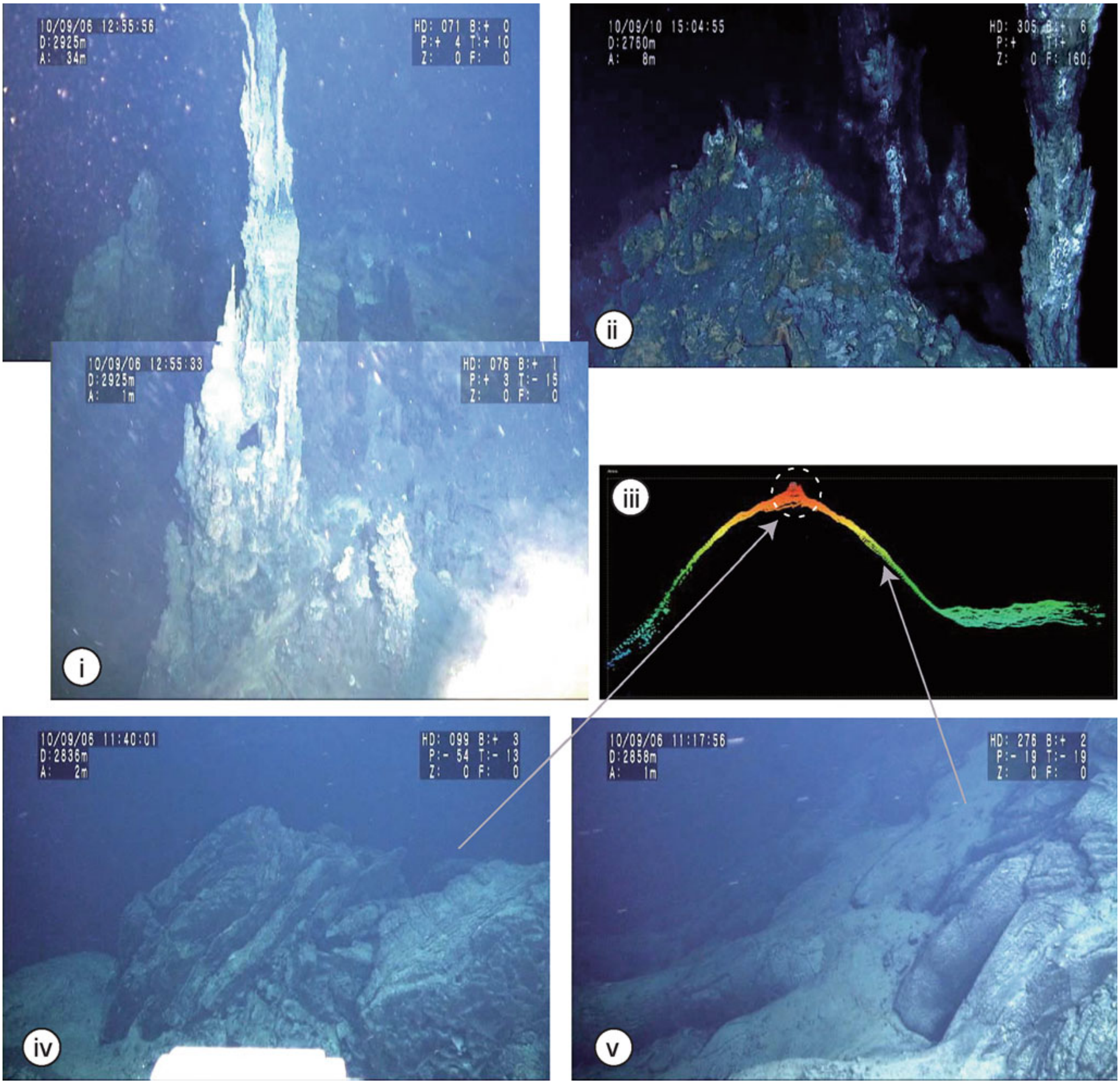

Fig. 37.6 Photographs of locations (*i*), (*ii*), (*iv*), and (*v*) in Fig. 37.5, and (*iii*) snapshot of unprocessed multi-beam bathymetry data. (*i*) Active hydrothermal chimney at the Urashima site. (*ii*) Active hydrothermal chimney at the Pika site. (*iii*) unprocessed bathymetry data consisting of 50 pings of *seabat7125* system, showing a cross-section of hill with a *convex* shape. (*iv*) Rocky outcrop with the "web structure" on surface sitting at top of the hill with a *convex* shape. (*v*) Example of tube lava covering slope of the hill with a convex shape

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