

# The Tarama Knoll: Geochemical and Biological Profiles of Hydrothermal Activity

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## Abstract

Tarama Knoll is located about 60 km north of Tarama Island, Sakishima Islands, southwestern Japan. The knoll has an almost conical shape, with foot and summit depths of 2,000 and 1,490 m (total relief = 510 m) from the sea surface, respectively. This area has been identified as a possible active submerged volcano called “Tarama Knoll” (Otani et al. 2004). However, there are actually two separate knolls in the area. This knoll is located northeast of the other, which is named Tarama Hill. During the KT05-26 cruise on the R/V

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*Tanseimaru*, a methane anomaly was detected near the seafloor around the area and was considered to be of possible hydrothermal origin. Based on visual observation of the seafloor and its bathymetry, this knoll is considered a pumice cone. Dense turbid water is often observed around summit of the knoll, and a methane anomaly was detected in the water. These observations suggest that the turbid water is a hydrothermal plume. An iron-rich, red-brown sediment-covered area was discovered at a depth of 1,510–1,540 m on the southwestern slope near the summit. At the red-brown sediment area, a weak shimmering of clear fluid could be observed, and the fluid temperature reached 20 °C. Sampled shimmering fluid showed a high silica concentration ( $\geq 1$  mM), indicating an interaction between the fluid and the surrounding rock. These chemical data support the occurrence of active hydrothermal circulation at Tarama Knoll.

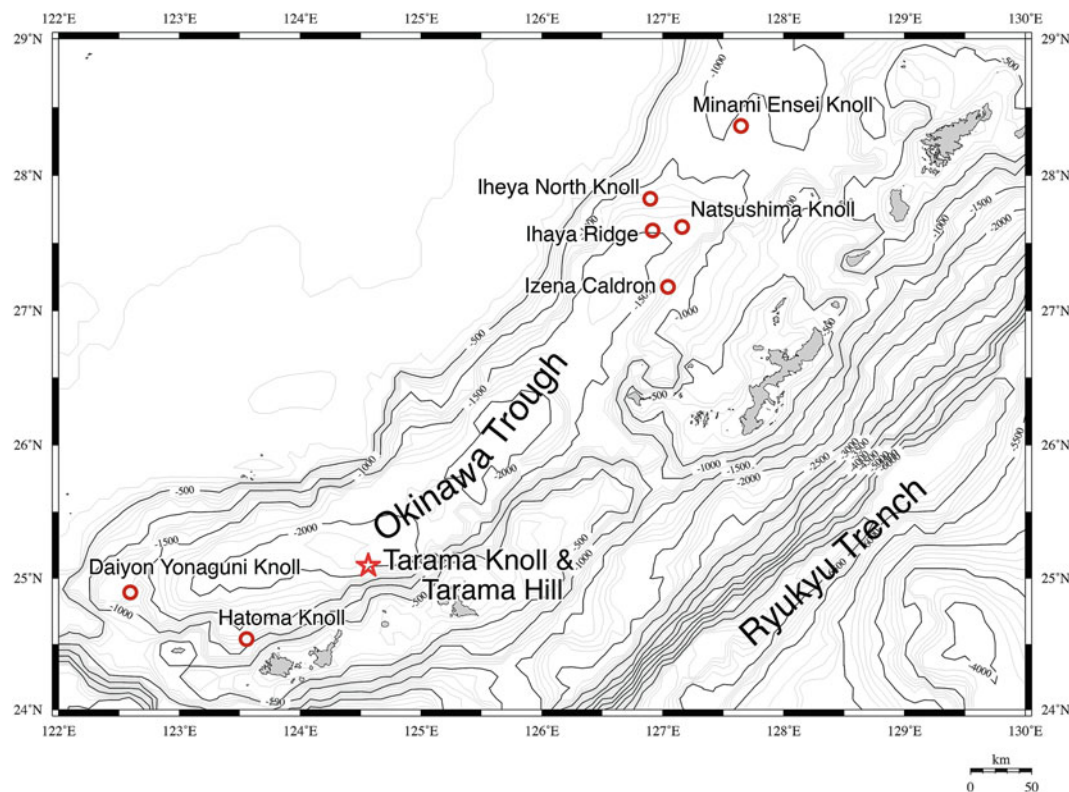
#### Keywords

Hydrothermal activity • Hydrothermal plume • Southern Okinawa Trough • Tarama Knoll

### 40.1 Location and Bathymetric Features of Tarama Knoll

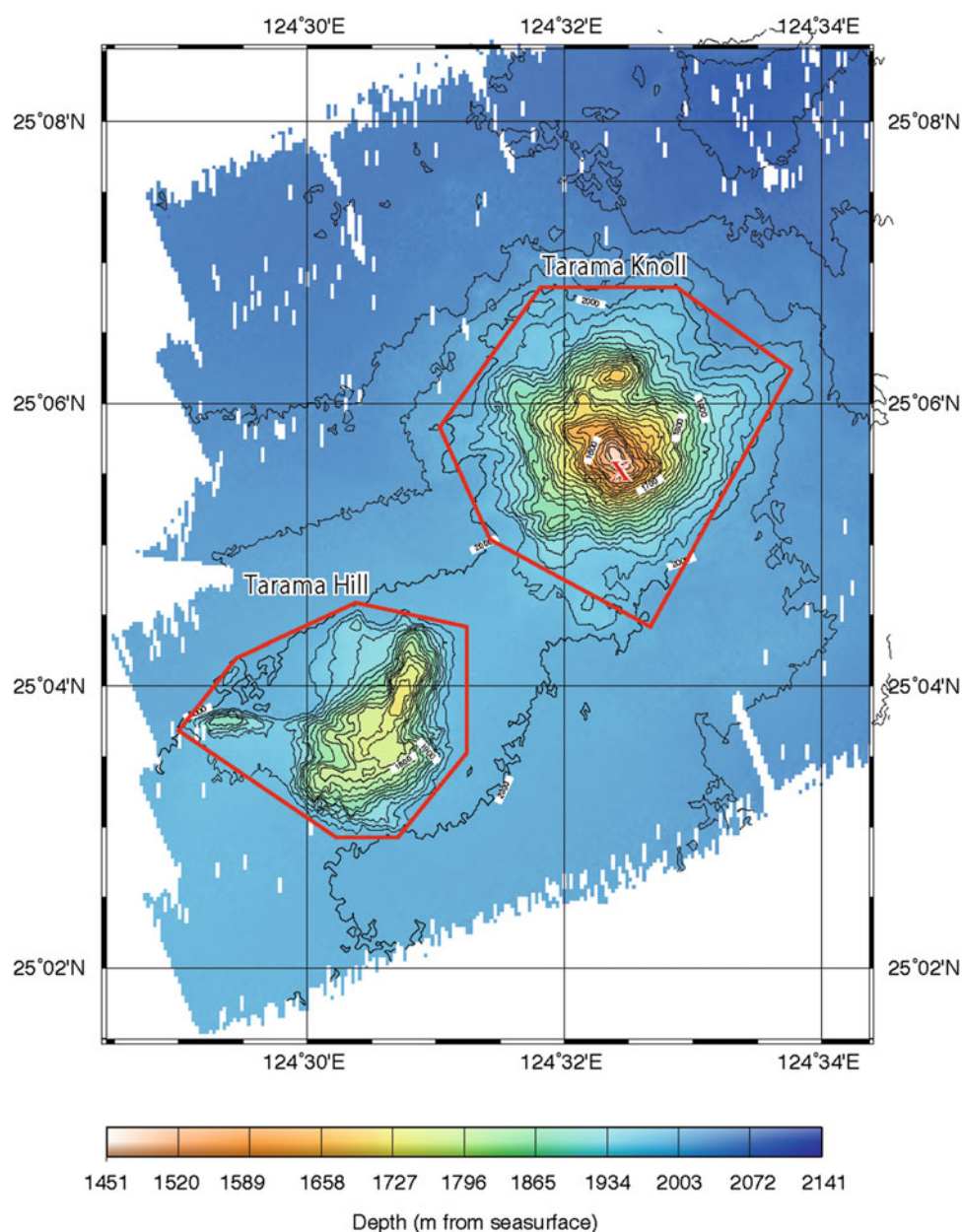
Tarama Knoll is located at 25°05.50'N, 124°32.50'E (Fig. 40.1). The knoll lies almost at the foot of the south fault scarp in the rift graben of the southern Okinawa Trough (Letouzey and Kimura 1986). The knoll has an almost conical shape and an additional small peak on the northern slope

(Fig. 40.2). The depths of the main summit and foot are 1,490 and about 2,000 m from the sea surface, respectively, and the total relief from the foot to summit is 510 m. The average steepness is *c.* 18°, and the steepness does not change significantly from the foot to the summit. Another smaller knoll named Tarama Hill is located about 4 km southwest of Tarama Knoll.



**Fig. 40.1** Locations of Tarama Knoll and Tarama Hill and other hydrothermal fields in the Okinawa Trough

**Fig. 40.2** Bathymetric map of Tarama Knoll and Tarama Hill obtained by the SeaBat 8160 multibeam echosounder on the R/V *Natsushima* during NT09-10 Leg. 2 and NT10-06 Leg. 2 cruises. The X indicates the sampling point during the KT05-26 cruise



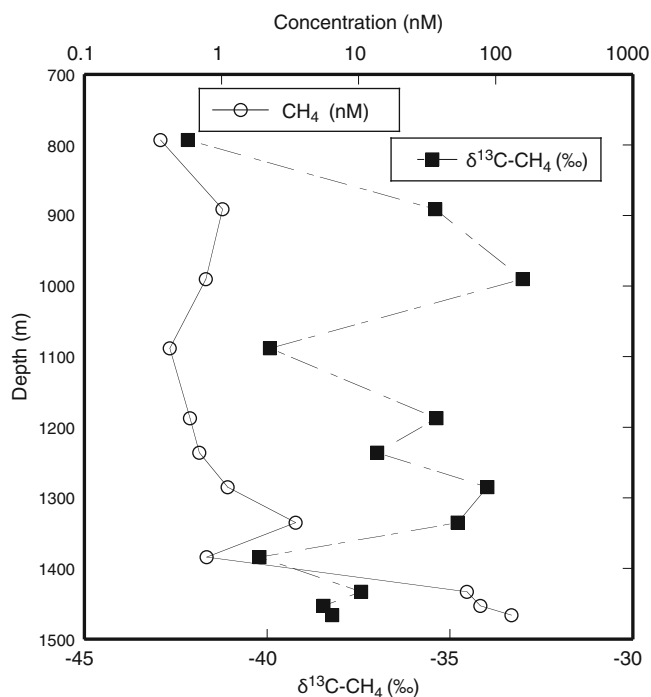
## 40.2 Observation History of Tarama Knoll

Tarama Knoll was originally described as a single-summit active volcano based on low-resolution seismic and geomagnetic observations carried by the Hydrographic Surveys Division of Japan Coast Guard (Otani et al. 2004). Tarama Knoll and Tarama Hill were then identified as one elongated knoll due to insufficient resolution (Fig. 40.2). This area was visited by the R/V *Tanseimaru* during the KT05-26 cruise, and a methane anomaly was detected near the seafloor that was considered of possible hydrothermal origin (Fig. 40.3). During the NT09-10 Leg. 2 cruise in 2009, a high-resolution seismic survey was done by the R/V *Natsushima* (which

belongs to JAMSTEC) using a SeaBat 8160 multibeam echosounder, and the results showed two independent knolls. A methane anomaly was detected near the Tarama Knoll, and therefore dive surveys using the ROV/ *HyperDolphin* were carried out at the knoll in 2009, 2010, and 2011.

## 40.3 Dive Observations at Tarama Knoll

Since 2009, we have done seven dives using the ROV/ *HyperDolphin* (which belongs to JAMSTEC) at the Tarama Knoll (Table 40.1). All dive tracks are shown in Fig. 40.4. During the dives, we often observed dense turbid water



**Fig. 40.3** Vertical profiles of the methane concentrations and  $\delta^{13}\text{C}$  values of methane dissolved in seawater. Samples were obtained during the KT05-26 cruise

resembling hydrothermal plumes, and many planktonic tunicates were observed in the water. As such planktonic tunicates have often been observed in hydrothermal plumes emitted by active hydrothermal vents in the Okinawa Trough (Miyake et al. 2009), hydrothermal venting from a nearby area was expected. However, no active venting site has yet been found. Visual observation of the seafloor indicated rubble and angular gravel covering the slope (Fig. 40.5a). Although benthic animals were rarely found on the slope, dense sponge colonies were found in the area where dense turbid water covered the seafloor (Fig. 40.5b).

Weak shimmering of clear warm fluid (up to 23 °C) was found on the southwestern slope near the summit at a depth of 1,510–1,540 m in an area covered with red-brown sediment. Many finger-like chimneys consisting of the red-brown sediment were observed in this area (Fig. 40.5c, d), which was named the “Fox site” (Makita et al., in prep.). The shimmering fluid was sampled.

#### 40.4 Fluid, Rock, and Sediment Chemistry

Turbid water, shimmering fluid, rocks, and red-brown sediments were sampled during dive studies and subjected to chemical analyses. The results of the analyses are summarized in Tables 40.1 and 40.2. Analysis of the turbid water showed that the concentrations of major cations

(sodium, magnesium, calcium, and potassium) and anions (chloride and sulfate) were similar to those in ambient seawater, but the methane concentration in the turbid water was one or two orders of magnitude higher than that of the ambient seawater (Table 40.1). These observations suggest that the turbid water may be from a hydrothermal plume. The shimmering fluid showed high concentrations of silica, ammonium, and alkalinity relative to seawater, whereas concentrations of magnesium, sodium, and potassium were slightly lower than those of the ambient seawater. Although the data are insufficient for accurate hydrothermal endmember estimation, the estimated endmember concentration of silica reached around 11 mM. The endmember silica concentration corresponds to a reservoir temperature of 260 °C based on the silica geothermometer, assuming equilibrium with quartz (Fournier 1977). The chemical signature enriched in ammonium, methane, and alkalinity suggests interaction with sedimentary organic matter during hydrothermal circulation, similar to other hydrothermal fluids in the Okinawa Trough (Ishibashi and Urabe 1995). The decreased levels of major cations in the fluid may suggest phase separation or segregation in the subseafloor. Hydrogen sulfide was not detected in the fluid.

Most sampled rocks seemed to be pumice and lava fragments based on their visual texture and whitish color (Fig. 40.6). Bulk chemical composition of one lava fragment sample collected during *HyperDolphin* dive #1109 (Table 40.2) showed a high silica content (>75 %) suggestive of rhyolitic magma activity.

The red-brown sediment was rich in iron oxide and was composed mainly of ferrihydrite or possibly microcrystalline goethite (Makita et al., in prep.).

#### 40.5 Biological Observation

Some animal samples were collected during the dive studies, and details were reported by Yamanaka et al. (Chap. 10). Although typical vent endemic species, such as vesicomyid clams, mytilid mussels, and vestimentiferan tubeworms, were not found during the dive studies, one liparid snailfish specimen (Fig. 40.7) obtained during *HyperDolphin* dive #1322 contained remains of undigested *Alvinocaris* shrimp and shell of *Provanna* snail in its gut. These shrimp and snail species are endemic to hydrothermal vents and methane seeps (e.g., Fujikura et al. 2012) and represent feed of snailfish in hydrothermal vent areas (Takemura et al. 2010). The migrating ability of liparid snailfish is not known, and the possible habitat area may be less than several kilometers square. Isotopic signatures obtained from the sponges had significantly low  $\delta^{34}\text{S}$  values (about +2.5 to +5.0 ‰), indicating that they rely on thioautotrophic products (e.g., sulfur-oxidizing bacteria) that utilize reduced sulfur



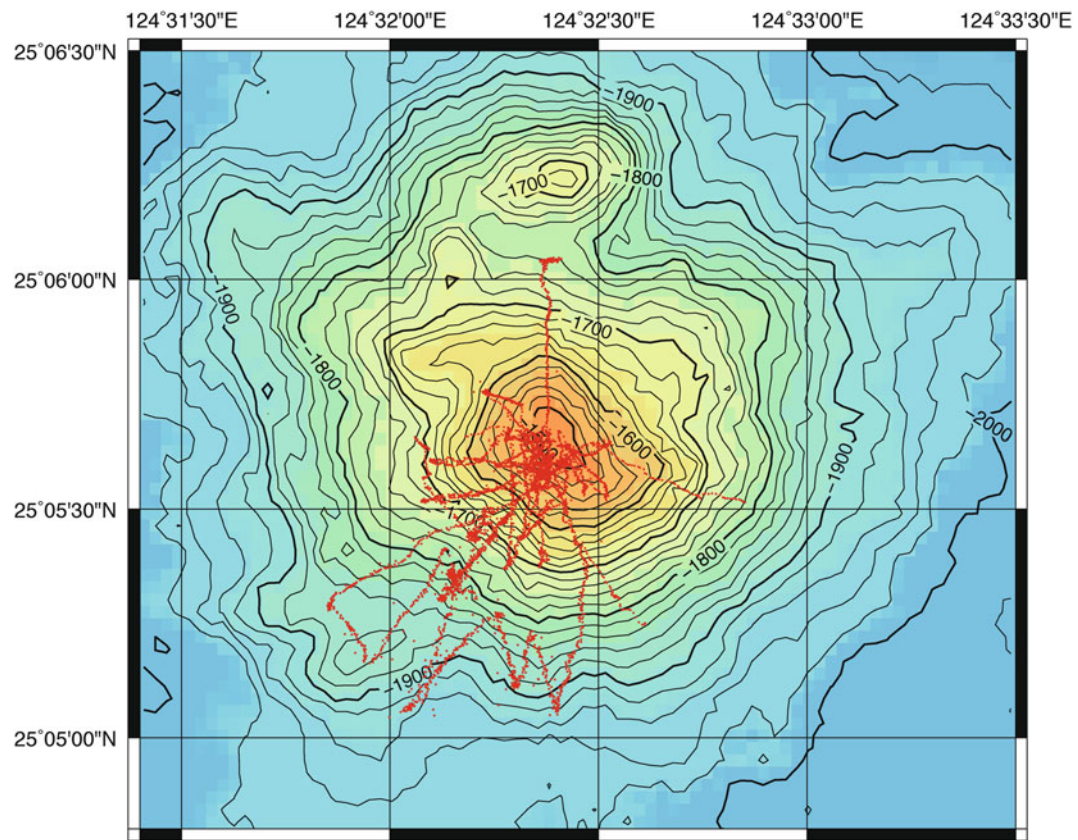
**Table 40.1** Results of chemical analyses of seawater and shimmering fluid obtained from Tarama Knoll

Date	HPD Dive No.	ID <sup>a</sup>	Mg (mM)	Ca (mM)	Na (mM)	K	SO <sub>4</sub> (mM)	Cl (mM)	Fe (μM)	Si (μM)	NH <sub>4</sub> (μM)	pH	alk. (mM)	CH <sub>4</sub> (nM)	δ <sup>13</sup> C-CH <sub>4</sub> (‰)	δD-CH <sub>4</sub> (‰)	Note
2009.7.20	1032	N1	53.1	10.3	472.5	9.1	27.4	539.3	na.	124.0	3.0	7.72	2.56	30.3	−35.4	na.	Turbid water
		N2	53.8	10.4	471.6	10.0	27.7	540.4	na.	124.0	2.0	7.81	2.34	16.4	−34.9	na.	Turbid water
2009.7.21	1033	N1	52.2	10.3	474.1	10.3	27.3	540.4	na.	123.0	nd.	7.72	2.50	2.07	−43.1	na.	Ambient seawater
		N2	52.0	10.3	465.5	10.0	27.4	535.9	na.	123.0	1.0	7.64	2.35	45.2	−33.4	na.	Turbid water
2009.7.22	1034	N1	52.5	10.3	472.4	10.2	27.4	539.3	na.	126.5	6.9	7.75	2.37	654	−39.1	−105	Turbid water
		N2	53.8	8.4	480.2	10.3	29.0	538.2	na.	123.7	8.0	7.77	2.42	52.7	−36.5	−132	Turbid water
		V	48.5	9.7	435.0	9.5	na.	na.	na.	na.	na.	na.	na.	2,320	−35.9	−143	Shimmering fluid
		B	50.0	10.0	452.0	9.6	27.7	538.2	na.	128.4	10.8	7.80	2.51	na.	na.	na.	Shimmering fluid
		M	52.0	10.7	474.9	9.0	30.8	539.3	52.9	314.5	38.8	7.57	3.15	na.	na.	na.	Shimmering fluid
2010.4.9	1107	N	53.0	10.5	471.3	10.1	28.3	522.9	na.	131.2	1.2	na.	na.	na.	na.	na.	Turbid water
		M	53.4	10.5	474.5	10.2	28.9	531.4	na.	131.3	1.8	na.	na.	na.	na.	na.	Shimmering fluid
2010.4.10	1108	N1	53.1	10.5	472.3	10.1	21.7	433.4	na.	123.0	1.8	na.	na.	na.	na.	na.	Turbid water
		N2	53.3	10.5	473.1	10.1	28.5	526.4	na.	124.2	1.8	na.	na.	na.	na.	na.	Turbid water
		BW1	47.9	10.5	439.9	10.3	27.0	526.5	na.	562.9	78.8	na.	na.	na.	na.	na.	Shimmering fluid
2010.4.11	1109	N1	53.6	10.6	477.2	10.2	29.1	533.8	na.	121.3	0.5	na.	na.	na.	na.	na.	Turbid water
		N2	53.5	10.6	476.6	10.2	28.8	529.9	na.	121.5	1.0	na.	na.	na.	na.	na.	Turbid water
		N3	53.6	10.6	476.6	10.2	28.6	527.9	na.	122.0	1.2	na.	na.	na.	na.	na.	Turbid water
		W1	48.6	12.1	463.5	11.6	na.	na.	na.	na.	na.	na.	na.	na.	na.	na.	Shimmering fluid
		W2	50.0	11.1	461.1	10.8	25.8	523.9	0.078	662.9	59.5	na.	na.	na.	na.	na.	Shimmering fluid
		W3	50.7	12.6	483.0	12.1	na.	na.	na.	na.	na.	na.	na.	na.	na.	na.	Shimmering fluid
		W4	48.8	12.0	463.7	11.6	25.6	523.2	0.14	1,030	98.2	na.	na.	na.	na.	na.	Shimmering fluid
		B	48.2	11.6	454.5	11.2	25.6	522.4	na.	891.7	88.2	na.	na.	na.	na.	na.	Shimmering fluid
		EW1	49.4	12.0	467.6	11.6	26.5	522.1	0.109	948.8	95.8	na.	na.	na.	na.	na.	Shimmering fluid
		EW2	50.0	12.1	473.1	11.7	25.1	519.1	0.082	891.7	93.2	na.	na.	na.	na.	na.	Shimmering fluid
2011.9.15	1322	W1	45.8	11.7	465.1	11.8	26.4	539.6	na.	1,045	94.3	6.39	6.84	na.	na.	na.	Shimmering fluid
		W2	na.	na.	na.	na.	na.	na.	na.	na.	na.	na.	na.	5,170	na.	na.	Shimmering fluid
		W3	51.2	9.5	462.9	10.1	27.7	556.0	na.	198.5	10.1	6.94	2.69	na.	na.	na.	Shimmering fluid
		W4	na.	na.	na.	na.	na.	na.	na.	na.	na.	na.	na.	2,750	na.	na.	Shimmering fluid
		CW2	50.8	9.9	468.2	10.4	27.7	546.5	na.	204.3	12.1	6.80	2.78	11,800	na.	na.	Shimmering fluid
		B	na.	na.	na.	na.	na.	na.	na.	na.	na.	6.92	na.	na.	na.	na.	Shimmering fluid
		N1	51.5	9.8	469.3	10.4	27.8	544.9	na.	113.0	3.2	7.69	2.40	na.	na.	na.	Turbid water
		N2	51.5	10.4	468.4	10.3	28.0	547.3	na.	110.7	2.4	7.65	2.42	na.	na.	na.	Turbid water

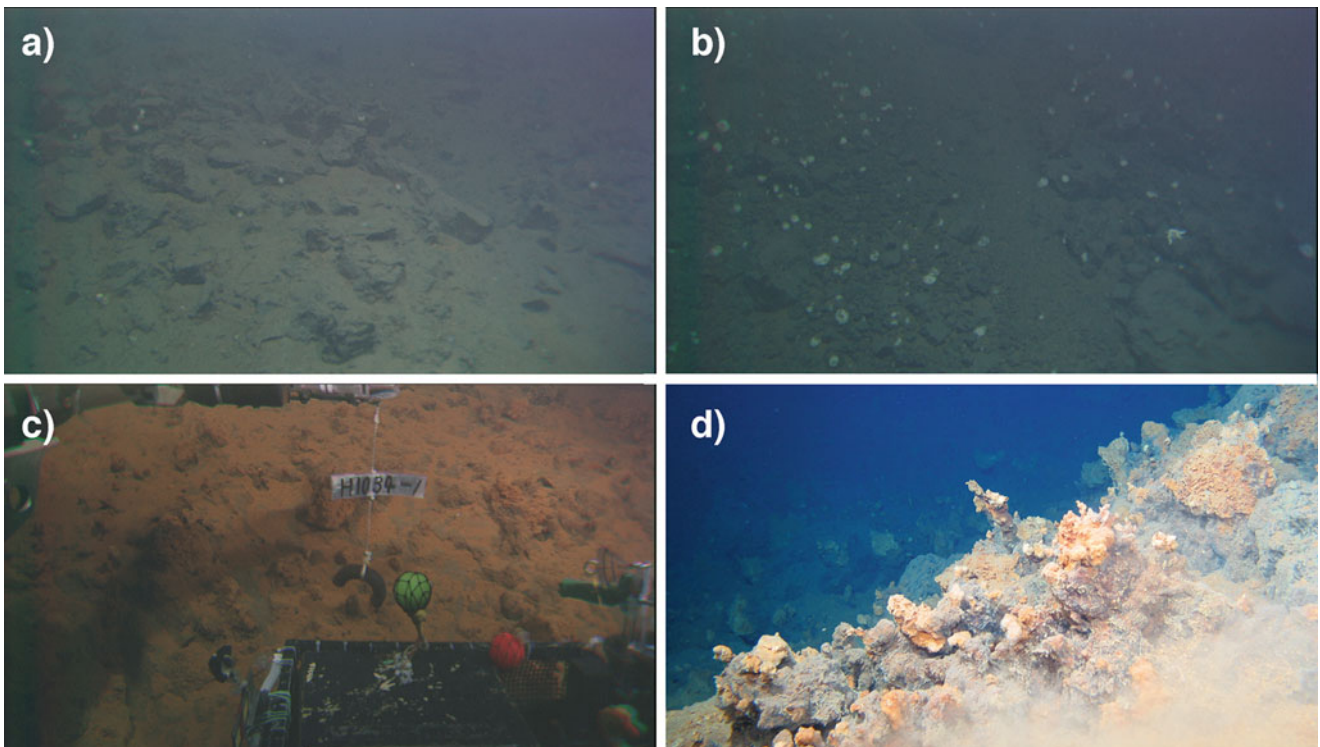
<sup>a</sup>Alphabets indicate sampler type, *N* Niskin bottle, *V* Vacumed metal bottle, *B* Plastic bag, *M* M-type sediment sampler, *W*, *BE*, *CW* and *EW* WHATS fluid sampler

na. not analysis

nd. not detected



**Fig. 40.4** Dive tracks of ROV/HyperDolphin surveys of this area are shown as red dotted lines. Seven dives (Dive Nos. 1032–1034, 1107–1108, 1132) were done



**Fig. 40.5** Photographs of the seafloor on the slope of Tarama Knoll. (a) Rubble and angular gravel covered the slope. (b) Dense sponge colonies were observed in some areas on the slope. (c) Red-brown

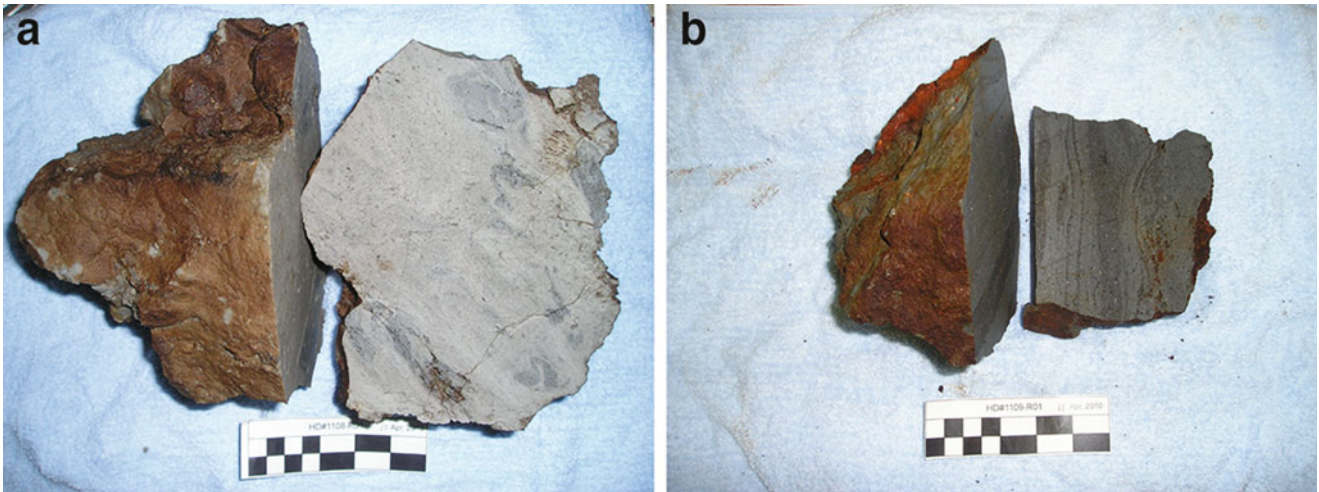
sediment widely covered the southwestern slope near the summit. (d) Many “finger” chimneys were found



**Table 40.2** Bulk chemical composition of a rock sample obtained from Tarama Knoll

Sampling point			Depth (m)	SiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (T) (%)	MnO (%)	MgO (%)	CaO (%)	Na <sub>2</sub> O (%)	K <sub>2</sub> O (%)	TiO <sub>2</sub> (%)	P <sub>2</sub> O <sub>5</sub> (%)	LOI (%)	Total (%)
Sample No.	Latitude	Longitude													
HPD1109R01	25°05.581'N	124°32.363'E	1,536	75.25	12.44	3.17	0.102	0.12	2.2	4.61	1.04	0.164	0.02	0.98	100.1

All elements were analyzed using fusion-inductively coupled plasma (FUS-ICP). Detection limit was less than 0.01 %



**Fig. 40.6** Photographs of rock samples. (a) Pumice-like porous and whitish rock. (b) Lava fragment



**Fig. 40.7** Photograph of liparid snailfish specimen that contained *Alvinocaris* shrimp and shell of *Provanna* snail in its gut. The specimen was sampled during *HyperDolphin* dive #1322 in 2011. This photograph was provided by Mr. M. Miyazaki

compounds (e.g., hydrogen sulfide), possibly of hydrothermal origin, as energy sources (Yamanaka et al., Chap. 10).

Microbial communities in turbid water (plume) were investigated and documented by Sunamura and Yanagawa

(Chap. 3). The microbial community structures based on 16S rRNA genes revealed that potential thiotrophic and methanotrophic microbial phylotypes were predominant in the plume. The results were comparable to the microbial communities associated with the active hydrothermal areas in the Okinawa Trough.

The observed dense turbid water (possibly hydrothermal plume water) and biological studies suggest that active hydrothermal venting is occurring in this area, and the venting fluid is expected to contain hydrogen sulfide and venting as a black smoker.

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