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INFORMATION

Comprehensive Research of Ecosystems of Hydrothermal Vents and Cold Seeps in the Bering Sea (Cruise 82 of the R/V *Akademik M.A. Lavrentyev*)

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Abstract—On cruise 82 voyage of the R/V *Akademik M.A. Lavrentyev*, comprehensive studies of ecosystems associated with hydrothermal vents and cold seeps in the Bering Sea were carried out. New data on the composition and structure of benthic communities of the Piip volcano were obtained. A new area of cold seeps has been discovered on the Chukchi slope of the Bering Sea. At present, the chemosynthesis communities of the Chukchi slope are the northernmost of their kind known in Pacific, and the Chukotka population of Calyptogena is the northernmost Recent population of pliocardiines in the World Ocean.

Keywords: Bering Sea, hydrothermal vents, cold seeps, benthic fauna, Pliocardiinae

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The depletion of land and coastal resources has generated significant interest in marine resources beyond the shelf. Of particular interest for resource management are areas of hydrothermal vents and cold seeps, where, in particular, hydrocarbon and various metal deposits have been noted. Currently, resource-extraction companies of the leading world powers have increased their activity in areas with deep-water deposits. Meanwhile, evidence is increasing that anthropogenic activity poses environmental risks to hydrothermal vent and seep communities. Deep-sea hydrothermal activity has been discovered in Russian territorial waters of the Bering Sea [4]. In addition, representatives of cold seep fauna have been identified here [3, 5].

Comprehensive research of these ecosystems was the mission of cruise 82 of the R/V *Akademik M.A. Lavrentyev*, organized by the Zhirmunsky National Scientific Center for Marine Biology, Far East Branch, Russian Academy of Sciences. The expedition lasted from June 2 to July 16, 2018, and was a continuation of work carried out on cruise 75 in 2016 [1].

The research focused on the following key tasks:

—localize hydrothermal vents and cold seeps in the Bering Sea, determine their types and structural geometry, study the geological conditions and geochemical processes in areas of hydrothermal vents and seeps, analyze the physicochemical parameters of bottom sediments, fluids, and the water column;

—determine the composition, structure, and distribution characteristics of macro- and meiobenthos in the study areas, map the main biogeocenotic complexes, study the diversity of phyto-, zoo- and bacterioplankton, study the trophic relationships and food strategies of mass hydrobiont species, apply biomarker analysis to assess the contribution of chemosynthesis and methanotrophy to the overall organic matter balance, select hydrobionts for screening studies of bioactive substances for antitumor activity;

—perform en route radiochemological monitoring.

Figure 1 shows schemes of the vessel's route, location of survey areas, and sampling stations.

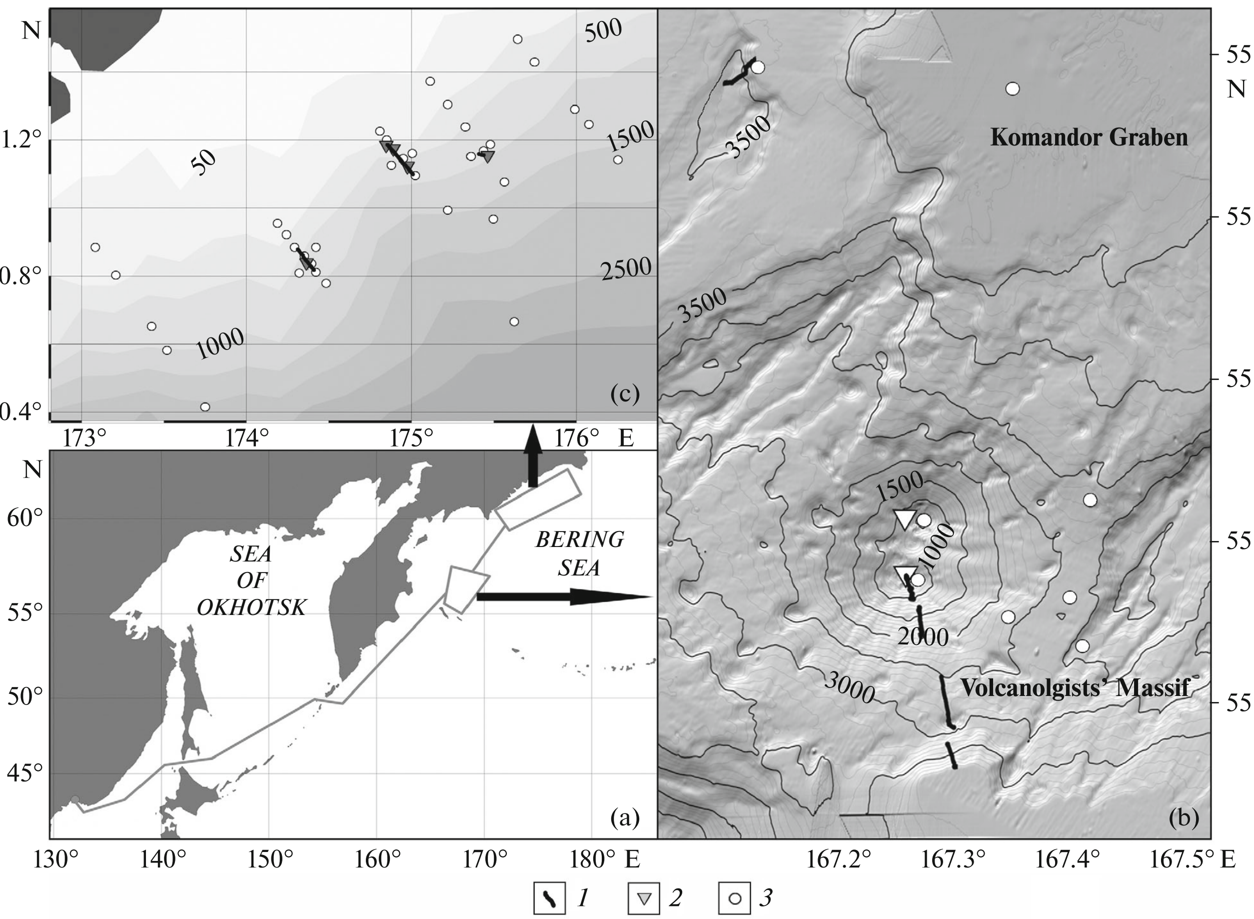

Fig. 1. Map of expedition (a), dives of UUV Comanche, and water sampling stations in survey areas 1 (b) and 2 (c); legend: (*1*) dive tracks; (*2*) water sampling stations with UUV; (*3*) water sampling stations with case of bathometric bottles and CTD.

During the expedition, in total, 21 dives were executed with the Comanche-18 unmanned underwater vehicle (UUV) at depths from 356 to 3931 m; 4634 photos and more than 32 h of video recordings of deep-sea ecosystems were obtained, more than 500 specimens of macrofaunal representatives were preserved, and extracts from 148 samples of hydrobionts were taken to screen for specific antitumor activity, as well as 118 meiobenthic samples.

Within the program for studying the plankton communities of Russia's northern marginal seas, 12 zooplankton samples, 21 phytoplankton samples, and 28 microplankton samples were obtained.

To study the characteristics of the water composition in the discharge areas of deep-sea hydrothermal vents and cold seeps, 51 water samples were taken at various depth horizons; 321 samples were taken to establish the methane content, and 434 samples, to determine the hydrogeochemical parameters of seawater.

For the radiochemoecological monitoring of Russia's Far Eastern seas, 55 water and 15 bottom sediment samples were taken to determine the following isotopes: $^{239, 240}Pu$, ^{137}Cs, ^{90}Sr.

In survey area 1 (Volcanolgists' Massif), the geological zoning and distribution of bottom fauna along the bathymetric gradient from 475 to 3931 m were studied. It is shown that the vertical zoning of the southern slope of the Piip volcano generally corresponds to the patterns identified for its northern slope, which had been studied in detail in 2016. The most characteristic features of the vertical distribution of bottom fauna were the presence of benthopelagic Trachimedusae colonies at depths of about 2600 m, enteropneusts (Torcharatoridae) at depths of around 1900 m, and the development of a fauna-rich sponge reef at depths of 1010–760 m. In areas of hydrothermal vents around the Piip volcano, the temperature of fluids within was measured for the first time on both summits. On the North Summit, the maximum temperature was 132.79°C, which falls in the range of experimental temperatures for the formation of hydrothermal anhydrite making up the hydrothermal edifice [4]. On the South Summit, where lower-temperature carbonate structures are developed, the maximum value was

10.59°C. The background seawater temperature on both peaks varied from 3.54 to 3.71°C.

The highest concentrations of methane in water (387–2364 nL/L) in the area of the Volcanologists' Massif were recorded at stations made above the summits, with maximum values in the bottom layer above the North Summit. At the remaining stations, methane concentrations did not exceed the background values characteristic of this region (43–118 nL/L).

Works in survey area 2 were carried out within the marine part of the Khatyrsky Trench (from Cape Olyutorsky to Cape Navarin). Based on materials of seismic surveys conducted by OJSC Dalmorneftegeofizika in 1988 and 2007, promising gas hydrate areas were identified on the slope of the Bering Sea in the Khatyrsky sedimentary basin at depths of 300–900 m, [2]. In addition, at depths of 360–475 m, shells of the chemosymbiotrophic bivalve mollusks Pliocardiin (Vesicomyidae) and Solemiid were found [3, 5]. This gave grounds to assume the existence of two methane seeps and characteristic "seep" communities within survey area 2 [5]. During the expedition, gas methane seeps were recorded over the vast area of survey area 2. At all stations made at depths from 126 to 1509 m, there were significant excess methane concentrations compared to the background values (46–113 nL/L). The maximum detected methane concentration in survey area 2 was 12473 nL/L. According to our preliminary data, the main gas seep areas in the studied water area of the Bering Sea are at depths of 332–708 m.

The UUV operated in survey area 2 in a 68.5-km-long sector on three transects in a depth range from 906 to 356 m. The cold seep fields that were first discovered and explored on the Chukotka slope differ considerably in occurrence. These seeps are located at different depths, which may, to a certain extent, determine their specifics. In total, five more or less isolated seep fields were surveyed at depths from 693 m to 400 m. In general, the identified communities can be divided into three types:

(1) Communities of the first type are encountered at depths of 695–647 m surrounded by a background community of Ophiuroidea + Macrura Natantia. They are characterized by the development of numerous settlements of the symbiotrophic bivalve pliocardiin *Calyptogena pacifica*. The abundance and diversity of fauna in such seep zones increases sharply compared to the background. For example, anemones of the genus *Tealidium* (Actinostolidae) in seep zones are much more common than in the background. Representatives of the genus have been found for the first time in the last 100 years and for the first time for the Pacific. The abundance and diversity of the fauna, in particular, is due to the presence of a significant amount of carbonate formations and ice-rafted material. Carbonate formations have the most diverse shapes, from tubes to crusts, covering an area of up to 100 m. With an increase in the height of local bottom uplifts, more intensive development of carbonate mineralization is observed, up to the formation of bizarre carbonate structures up to 1 m in height, called carbonate hills.

(2) Communities of the second type are encountered at depths of 429–417 m within the background community *Protoptilum*/*Asteronyx* + *Brisaster latifrons*. Among the specialized forms, *C. pacifica* is represented in a small amount. The abundance and diversity of fauna in the seep zone somewhat increases in comparison to the background; in particular, there are anemone species that have not been seen before. The density of the dominant species, sea urchins *Brisaster latifrons*, in areas of local seeps is noticeably higher compared with the background, while pennatularians clearly avoid seeps.

(3) Communities of the third type are noted at depths of 400–402 m within the community dominated by the anemone *Sagartiogeton* cf. *californicus* (Sagartiidae). Numerous and extensive seeps, often more than 1 m in size, are marked by widespread bacterial mats. Single calyptogens are present on the periphery of seeps. No apparent reaction of macrofauna to such seeps is observed.

The discovery of benthic communities associated with hydrocarbon seeps on the Chukotka slope is one of the most important results of the cruise. The gas seeps discovered and explored on the cruise at depths of 400–700 m represent a new area of chemosythesis biotopes for the World Ocean. In the Pacific, these are the northernmost chemosynthesis communities known to date and the northernmost Recent population of pliocardiines in the World Ocean.

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