ISSN 0001-4370, Oceanology, 2024, Vol. 64, No. 6, pp. 908–910. © Pleiades Publishing, Inc., 2024.

INFORMATION

Studies of the Structure and Formation History of the Submarine Borderland of Chukchi Sea on Cruise 70 of the R/V *Akademik Oparin*

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Received May 29, 2024; revised June 11, 2024; accepted August 8, 2024

Abstract—During the cruise 70 of the R/V *Akademik Oparin*, geophysical, hydrological, and atmospheric studies within the shelf of the Chukchi Sea were conducted. New data were obtained on the structure of the sea bottom, sedimentary cover, features of the magnetic field, and the spatial distribution of greenhouse gases at the water–atmosphere boundary.

Keywords: seismoacoustic, subsurface gas accumulations, submarine permafrost, magnetic field, methane, Chukchi Sea

DOI: 10.1134/S0001437024700528

From October 24 to December 3, 2023, in accordance with the plan of the state assignment of the Il'ichev Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences, for 2023 under the topics "Paleoceanology and Paleoclimatology of the Marginal Seas of East Asia and Adjacent Areas of the Arctic and Pacific Oceans, Modern and Mesozoic–Cenozoic Sedimentation, Geodynamics, Magmatism, and Ore Genesis" and "Research of Climatic, Geological, Biogeochemical, and Ecological Consequences of Degradation of the Relict Coastal-Shelf Cryolithozone of the Seas of Northern Eurasia," carried out an expedition on the R/V *Akademik Oparin* (cruise 70), the objective of which comprised integrated oceanographic studies of the structure and evolutionary history of the underwater margins of northeastern Eurasia, the state and dynamics of waters, sedimentation in areas of active shelf and slope water circulation, and their contribution to the formation of geological structures.

The expedition carried out bathymetric, seismoacoustic, and magnetometric research of the Chukchi Sea floor to determine the geological structure of the shelf, refine the nature of degradation of submarine permafrost, and the formation of near-surface gas accumulations. To assess the interannual dynamics of methane emissions in the seas of Russia's Pacific and East Arctic sectors, a hydrological survey was carried out, the parameters of the lithosphere–hydrosphere–atmosphere geosystem were measured, the concentrations of carbon dioxide and methane in the atmosphere and seawater along the vessel's route were quantitatively determined, and isotopic determination of methane components was carried out.

During the expedition, 415 km of high-resolution seismoacoustic profiles were obtained with a high-frequency GeoPulse Subbottom Profiler; 400 km of 16-channel seismic profiles with an electric sparker; 7000 km of echo sounding profiles; and 66650 magnetic field determinations. Two oceanographic stations were made, accompanied by measurements of greenhouse gas (GHG) concentrations at the water–atmosphere interface (Fig. 1).

During the study of the Chukchi Sea shelf, new data were obtained on the bottom relief, the structure of sedimentary deposits, the structure of the magnetic field, and the nature of the GHG concentration distribution.

Gas flares were discovered in the water column on the northern Chukchi Sea shelf, located in the part of the shelf where acoustic anomalies of gas nature were established in the structure of upper sedimentary deposits. A detailed study of the sedimentary cover was carried out to a depth of approximately 300 m. Numerous buried erosional river valleys up to 20 m deep and paleolakes up to 40 m deep were discovered in upper sedimentary deposits. The presence of the latter indicates local soil thawing due to permafrost soil degradation. Within and on the western wall of the Herald Canyon, signs of modern hydrological activity have been established, expressed in the formation of an extensive gully network up to 6 m deep on the seabed. The existence of a long-lived system of gas inclusions in sedimentary deposits has been confirmed in the canyon. A repeat of the high-resolution seismoa-

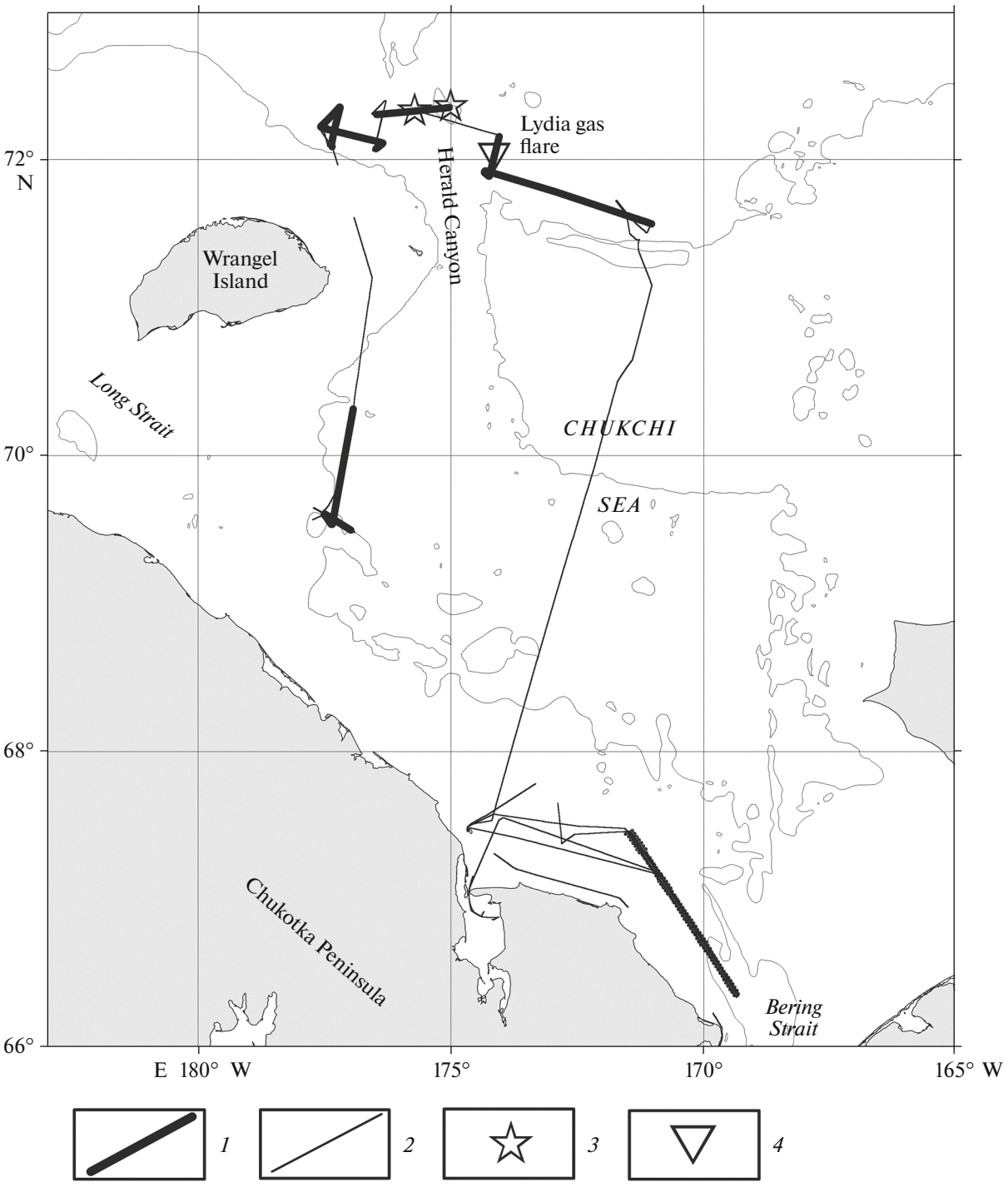

Fig. 1. Locations of geophysical profiles and oceanographic stations obtained on cruise 70 of R/V *Akademik Oparin* in Chukchi Sea. (*1*) 16-channel seismic profiles, work with profiler, magnetometer, echo sounder, and GHG measurements at the water–atmosphere boundary; (*2*) GHG measurements at water–atmosphere interface and echo sounding; (*3*) oceanographic stations; (*4*) location of gas flare in water column.

coustic profile, previously completed in 2008, was completed. Comparison of the sections showed that over the past 15 years, a slight increase in a gas-related acoustic anomaly in the axial part of the canyon has been observed. As a result of echo sounding measurements, a bathymetric dataset was obtained, refining the relief of the Chukchi Sea floor. New geomagnetic data have been obtained, make it possible to categorize the nature of the magnetic field distribution in the Chukchi Sea. It was found that the amplitude of the

measured magnetic field varies from 56773.01 to 58759.22 nT. The normal geomagnetic field at the study site during the measurement period was 57044–57594 nT. The anomalous magnetic field is characterized by a significant spread of amplitudes from –437.65 to 1199.22 nT.

Concentrations of dissolved methane in the surface water layer of Pacific sector seas along the vessel's route varied from 4.2 to 65 nM/L, indicating supersaturation of the surface water layer with respect to the atmosphere. This makes it possible to consider the studied water areas as a significant source of atmospheric methane emissions. Analysis of the vertical distribution of methane obtained at two integrated hydrological stations in the Herald Canyon shows that surface concentrations of methane are, on average, typical of the entire East Arctic shelf, exceeding the background by two to three times. Bottom concentrations at sampling points indicate the presence of a powerful local source of methane emission from bottom sediments. The profile reveals horizons of high methane concentrations (with respect to the surface and bottom horizons), correlating with a wedged warm water layer. This may be evidence of a methane influx from the formation area of the initial anomaly, generated by emission from bottom sediments at the 30–40-m isobaths. Based on monitoring of the methane content in air with Picarro G2301 analyzers at two horizons, no manifestations of increased methane discharge in the Chukchi Sea have been noted. At the same time, the minimum level of methane concentration in surface air was 2.02 ppm with an average value of about 2.03 ppm, which is much higher than the mid-latitude methane concentration of 1.85 ppm. The source of these elevated methane concentrations in surface air may be sea surface waters, into which methane enters from sources bottom located.

In the sea surface layer, three main water masses are distinguished. In the southern part of the sea (up to latitude 66°), warm (2–3°C) and saline (27–30 PSU) waters are formed as a result of the inflow of Pacific waters from the Bering Sea and their mixing with colder and fresher waters of the Chukchi Sea. Off the coast of Chukotka and in the western part of the sea, there was a cold and freshened surface water mass with a temperature of –1 to 0°C and salinity of about 25.5 PSU. In the northwestern part of the sea, on the floating ice boundary, a cold and saline water mass was noted, characterized by a temperature of –1.4°C and salinity of 31.5 PSU.

Thus, oceanographic research carried out during cruise 70 of the R/*V Akademik Oparin* made it possible to establish new features of the geological structure of the Chukchi Sea shelf and to refine the nature of the GHG distribution.

FUNDING

The study was supported by the Ministry of Science and Higher Education of the Russian Federation (topic nos. 124022100084-8, 124022100083-1) and the Russian Science Foundation (grant no. 21-77-30001).

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.