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ABOUT THE METHANE FLUX INTO THE ATMOSPHERE IN THE BIEN DONG (EAST SEA OF VIETNAM)

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Abstract. The methane is an active "greenhouse" gas and is over 200 times more potent than CO_2 in the atmosphere. Its concentration in the atmosphere is increasing; the mapping of its emission zones in the oil and gas aquifers is one of the important tasks of modern oceanography. In the East Sea of Vietnam - Bien Dong, its basins develop in complex geodynamic conditions, and the water column is characterized by considerable variability of hydrodynamic parameters. The data (methane concentrations, methane flux and accompanying data) are obtained for the first time in this research.

Keywords: Methane gas, Bien Dong.

INTRODUCTION

East Sea of Vietnam represents a promising oil and gas area, in the southern part, oil and gas deposits are discovered with the active participation of the USSR (Union of Soviet Socialist Republics) organizations. At present, the hydrocarbon reserves are growing and developed by joint Vietnamese-Russian companies. Some of the deposits are unique, formed in crystalline rocks (Thanh Long, White Tiger,...). The central and northern regions of the sea have not been adequately studied in this respect, and the data obtained can be used to predict hydrocarbon sources.

DATA AND METHODS

Within the framework of the complex expedition of the Russian Academy of Sciences, a regional profile (3,180 km, 140 points) of gas geochemical studies in the Bien Dong during the winter period (January 10–16, 2017) was performed on the R/V "Academic Boris Petrov" (Cruise No. 42). In this vessel with course from the Taiwan Strait to the shelf of the Malacca Peninsula, measurements of temperature and salinity in the surface layer of the water column (SeaCat equipment); meteorological observations (the digital Davis II meteorological station) and measurement of methane concentrations (GC ECHO-PID) for calculating its flux at the water-atmosphere interface were conducted (see fig. 1).

The methane flux calculation was performed by the method of [1]. According to it, the methane flux does not always have a linear relationship with its concentration. This value is alternating and, under certain conditions, strongly depends on hydrological

and meteorological parameters. The total value of the methane flux was 663 mol/km^2 × day in the interval of 1.45–28.4 mol/km^2.day (at the median of 3.65). Concentrations of methane were 0.6–9 nmol/l correspondingly.

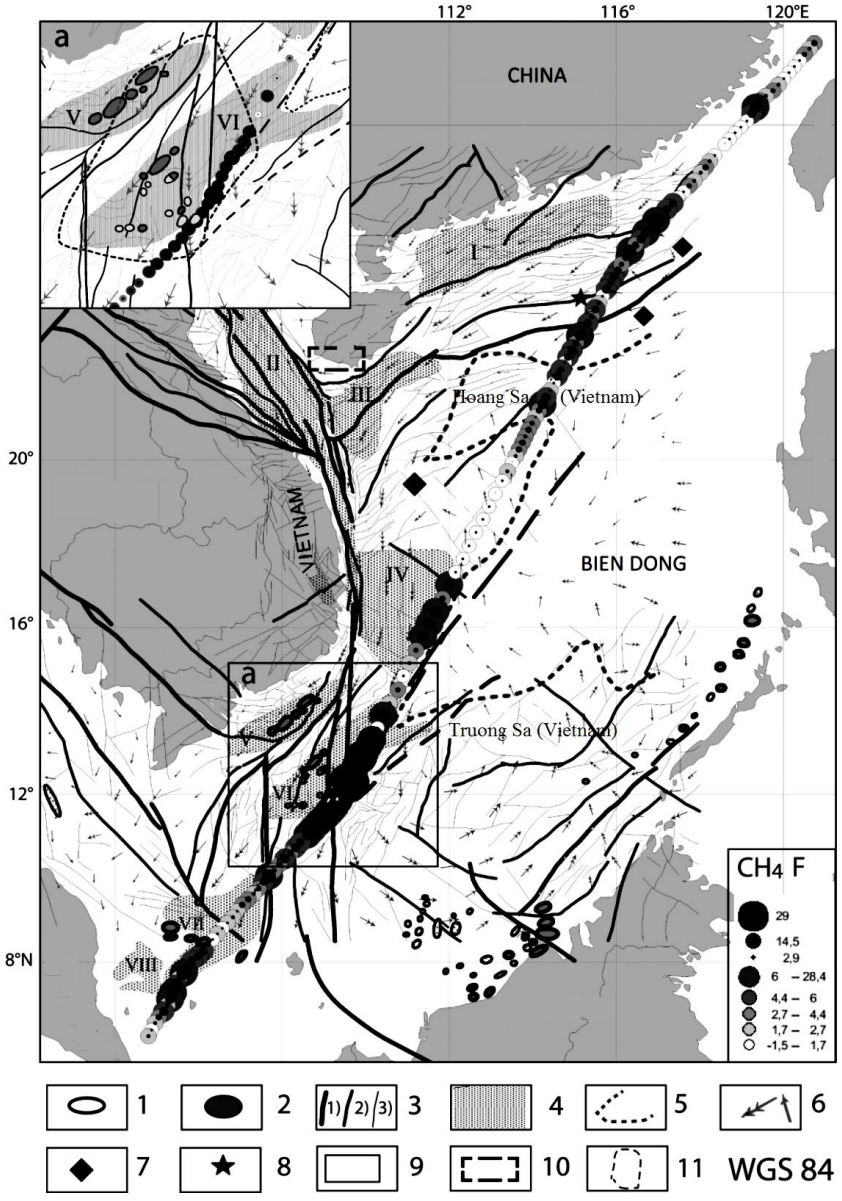

Fig. 1. The regional profile of the methane flux and the geo-structural map of the Bien Dong with a flux pattern. Legend: 1- gas deposits; 2- oil deposits; 3- faults: 1)- the first order, 2)- the second order, 3)- the third order; 4- the main sedimentary basins (Paleocene, synphrite sedimentary strata with a high carbon content) (I- Pearl river deltas, II- Sean Khon, III- Kyongdongnan, IV- Fu Han, V- Ku Long, VI- Nam Con Son, VII- Natunsky, VIII- Malay); 5- schematic contour of the boundaries of the oceanic crust block; 6- direction of surface currents in winter; 7- oil and gas exploration drilling areas of the PRC; 8- gas hydrate section; 9- cut-in; 10- active hydrocarbon gas outlet to the bottom of the shallow shelf of Hainan island [2], 11- an anomalous field of methane in the bottom layer (70–120 nl/l), discovered in 1992 [3]

RESULTS AND DISCUSSIONS

As a result of the analysis of the obtained data on the profile, five main zones of methane emission into the atmosphere were identified (fig. 2).

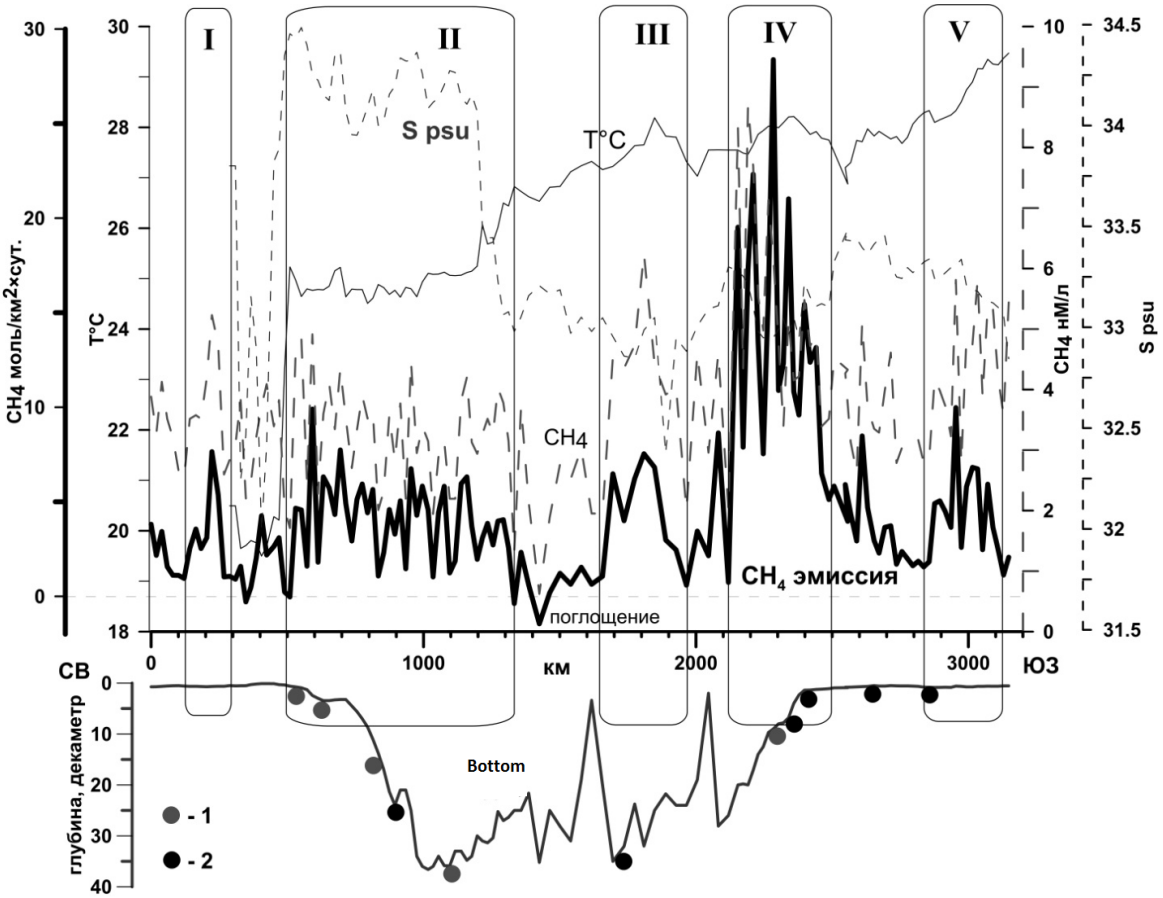

Fig. 2. Methane flux integrated diagram on the interface "water-atmosphere" along the profile; I-V: Zones of methane emission into the atmosphere; Projections of tectonic faults to the bottom of the sea: 1- second order, 2- first order; S psu- salinity, T°C- temperature, CH4 nM/l- methane concentration in nmol/liter, CH4 mol/sq2 × day- methane flux into the atmosphere

1) The first, with a length of 110 km (at depth 50–72 m), was found in the Taiwan Strait with a maximum flux of methane 7.7 mol/km^2. Its emergence is controversial, but it may be related to the emission of methane in the zone of intersection of the transverse shear zone and the longitudinal fault within the sedimentary basin (Paleocene).

2) The second, the most extended zone (about 800 km) with sawtooth methane emission profile (up to 10 mol/km^2) was recorded at the diagonal intersection of the continental slope at depths from 75 m to 3,665 m. This area is characterized by a dense network of tectonic faults with 1st, 2nd and 3rd ranges and predominated by northeasterly strike. The section in the profile 500–630 km is located above the fault tracing the upper stage of the continental slope. Near the central part of the zone, a gas hydrate-bearing region and oil and gas bearing features in deep-sea drilling have been discovered (fig. 1) [4]. In the neighboring regions (the sedimentary basin of the Pearl River Paleo Delta), gas-geochemical and mineralogical indicators for large scale paleo-emission of methane are established

under its intensive biogenic oxidation [5]. This vast zone of methane emission may reflect the presence of modern activated foci of discharging this gas from still undiscovered lithospheric sources. Scheme of surface currents in winter does not imply the supply of methane from other regions (fig. 1).

3) The third zone marks the eastern side of the sedimentary basin of Fu Han almost throughout its entire length (300 km, depth 2,000–3,500 m). The zone has a generally domed shape with a methane flux from 1 mol/km^2 at the edges and up to 7.54 mol/km^2 in the central part. The flux diagram also does not indicate the methane supply from any known sources. The oil and gas bearing prospects of this basin have not been studied yet, but the signs of its hydrocarbon potential in the form of rare gas flares on the shelf (VPI), the presence of complex reservoirs of a reef-carbonate nature on the de-compact protrusions of the crystalline basement [6], large sedimentary cover capacities (up to 11 km in the centers of sedimentation) characterize them positively. Along this methane emission zone and the eastern side of the Fu Han river, the boundary of the oceanic type crust passes. The deep permeability zones formed under such conditions have a special significance for prospecting. This is particularly evident in the next zone IV.

4) The fourth zone is the most contrasting in the flux of methane (maximum 28 mol/km^2, methane concentration up to 9 nM/l) and has the clearest relationship with the geological structure. In general, the zone can be traced for 500 km at depths of 200–2,000 m with the most contrasting central section about 300 km long, marking the eastern side of the Nam Son oil and gas basin. Zone IV is a classic example of the flux of methane from hydrocarbon deposits (a group of gas deposits of Lan Do, Dan Tai, etc.) along the zones of deep faults that control the ledge of the continental slope (fig. 1, fig. 1a, fig. 2) in the relict spreading center region [7] at the southern end of the progradation wedge of the oceanic crust (fig. 1). The flux pattern in this region during the observation period is such that it also allows one to speak of the local origin of the methane emission zone (fig. 1). Further, a separate section with a methane emission peak up to 8.5 mol/km^2 above the first-order fault (depth) with a depth of 66 m is clearly visible along the profile.

5) The last zone, about 260 km in length, was discovered above the Natunsky and Malaya sedimentary basins on the shelf with depths of 50–100 m. At least five oil fields are discovered there, and methane flux reaches 10 mol/km^2 at methane concentrations up to 4–6 nM/l in the central part of the zone and the absolute value of the flux is comparable with zone II.

COMMENTS AND CONCLUSIONS

It should be noted that between the 1st, 2nd and 3rd emission zones, which differ from each other by spatial distribution, and in which methane flux values depend on the gas lithospheric sources and meteo-hydrodynamic mode, areas with minimum methane flux values up to its absorption (sink or runoff) from the atmosphere are established (up to -1.45 mol/km^2). Between the zones III, IV and V of areas the absorption of methane from the atmosphere into the water is not revealed. The linear dimensions of the detected zones of methane emission into the atmosphere are comparable with the corresponding depths of the sea. Assessing the possible impact of the Pearl, Red and Mekong rivers (methane from the continent), at this stage it can be said that it has not been shown: the effect of river runoff on the distribution of hydrological parameters and suspended matter ends much closer to the shore than the detected methane emission zones.

The established facts of spatial coincidence of extended zones of methane emission into the atmosphere with geological structures, established and predicted sources of hydrocarbons, indicate the high oil and gas prospects of the Bien Dong. In general, according to the profile, the maximum amount of methane flux in the Bien Dong is ten times less than, for example, in the Sea of Okhotsk (up to 300 mol/km^2.day or more). But for a representative comparison, it is necessary to continue research, during which this difference

can be substantially refined. One of the factors explaining the low values of the methane flux in the Bien Dong is its low seismicity [8], which strongly affects the intensity of natural gas fluxes in the marginal seas of the northwestern Pacific [9, 10]. In this relation, the anomalous fields of methane and hydrocarbon gases of low and medium intensity, but in the presence of thermogenic and metamorphogenic migratory components, found in the southern and northern regions of the sea [3, 11], indicate good preservation of deposits, which also increases the prospects for their development. Quite clear geological control of methane emission zones confirms this conclusion. Concentrations of methane in the atmospheric drive layer amounted to 1.43–1.72 ppm (30 measurements) and show a weak growth trend from north to south.

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