PRELIMINARY RESULTS OF THE MOLECULAR HYDROGEN REGISTRATION AT THE PETOPAVLOVSK-KAMCHATSKY GEODYNAMIC TEST SITE

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At Petropavlovsk-Kamchatsky geodynamic test site since 1997 a network of subsoil gases monitoring stations has been working with the aim of studying gases dynamics and search for precursors of strong earthquakes (Firstov, 1999; Makarov, 2017). The points of the network are located in different structural elements of the coastal area of the Avacha Bay, in addition, each point has its own structural features of the strata of alluvial-deluvial deposits, in the aeration zone of which the sensors placed (Firstov et al., 2015). As the long-term experience shows, this allows us to record in the dynamics of the concentration of subsoil gases an individual response in connection with the different reactions of individual blocks of the earth's crust to geodeformation processes, related to the preparation of strong earthquakes in the Kurile-Kamchatka seismogenic zone.

At all points, the concentration of subsoil radon is primarily recorded. At present, three out of five points are equipped with Japanese-made molecular hydrogen sensors (Fig. 1). In addition, atmospheric pressure, air temperature and carbon dioxide in the subsoil air, are recorded at the network points.

Before a number of strong earthquakes in the Kurile-Kamchatka seismogenic zone at the points of the Petropavlovsk-Kamchatsky geodynamic test site, anomalies of the subsoil radon were recorded, which are attributed by the authors to the passing of "deformation waves", arising at the last stage of preparation of the future earthquake focus, as well as with the processes of redistribution of stresses, affecting water-saturated rocks (Firstov, Makarov, 2015; Firstov et al., 2018).

Study of the dynamics of molecular hydrogen in subsoil gas at the Paratunsky geothermal deposit in the period 1999-2003 showed that against the background of a quasi-permanent signal of subsoil hydrogen concentration, pulse bursts of high intensity were registered, coinciding with the increase in seismicity in the Kurile-Kamchatka seismogenic zone (Firstov, Shirokov, 2005).

For the period 2006-2016 before some strong earthquakes of the said zone, well-visually diagnosed anomalies of molecular hydrogen were recorded on the network of points. The parameters of these earthquakes are given in the table, and epicenters are shown in Fig. 1.

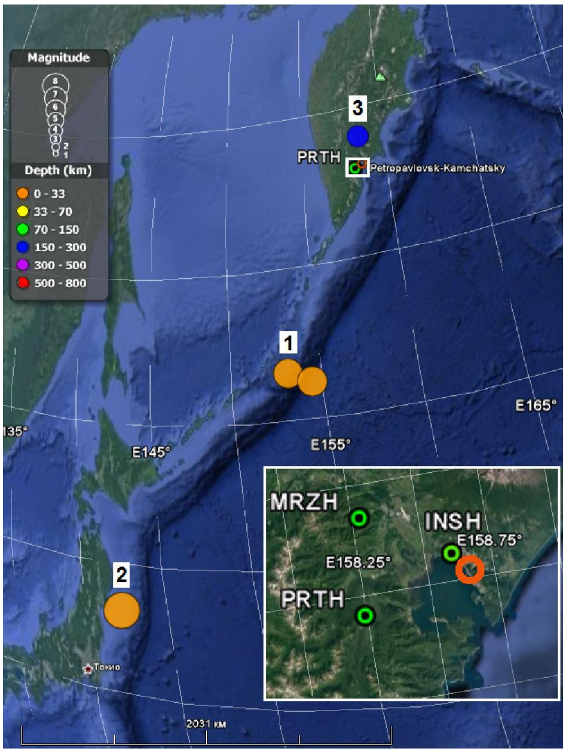

Fig. 1. The network of molecular hydrogen registration points in the Petropavlovsk-Kamchatsky geodynamic test site and epicenters of earthquakes from Table.

INSH - point based on the NIS-1 well near the building of Institute of Volcanology and Seismology FEB RAS; PRTH - point in the valley of the creek Korkino (graben "Paratunsky"), MRZH - the area of the mountain "Moroznaya".

In the area of the average Kurile Islands November 15, 2006 there was a Simushir earthquake with *M*=8.3 (Fig. 1, No.1 in the table). At point PRTH two days before this earthquake two bipolar pulses with δ=75% were synchronously observed at two hydrogen concentration sensors (Fig. 2*a*), and radon sensors recorded an increase radon concentration for 12 and 5 days with a relative amplitude of the anomaly up to 150% (Firstov et al., 2015). Before the second Simushir earthquake with *M*=8.1, which occurred in the same area January, 13 2007 (Fig. 1), anomalies in the concentration of subsoil gases were not revealed.

Before the Tohoku earthquake (No.2 in table), an anomaly was recorded in 28 days in the hydrogen concentration (Fig. 2*b*), and also for 42 days in the concentration of subsoil radon (Makarov et al., 2012; Shirokov et al., 2014). Before this earthquake in the Petropavlovsk-Kamchatsky geodynamic test site, anticipating anomalies in a number of other geophysical parameters were also observed.

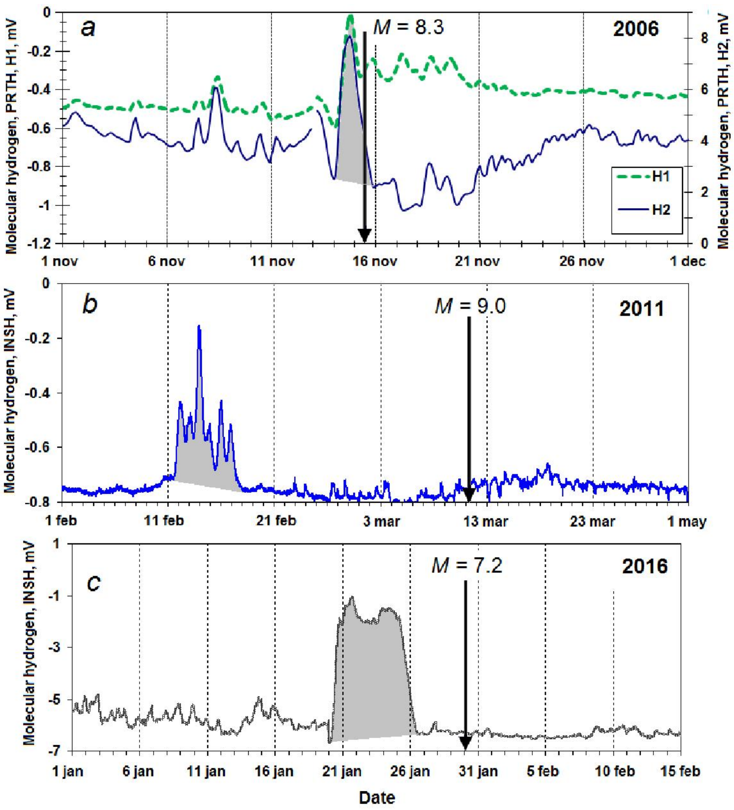

Fig. 2. Curves of the concentration of molecular hydrogen at monitoring points of subsoil gases. The anomalies are highlighted in a gray background, the time of the earthquake is shown by an arrow.

The third earthquake with *M*=7.2 occurred near the eastern coast of Kamchatka on January 30, 2016. Its epicenter was ~100 km north of the city of Petropavlovsk-Kamchatsky (Fig. 1, No.3 in table), where it was felt with an intensity of 4÷5 points on the MKS-64 scale (Chebrov et al., 2016). This earthquake is characterized by a large depth of its focus, which is estimated to be more than 160 km. Despite this, predictive anomalies before the earthquake No.3 (table) are recorded according to six methods that allow monitoring of some parameters of geophysical fields (Chebrov et al., 2016).
A precursor anomaly on two molecular hydrogen sensors, which were located in the wellbore of INSH [Makarov et al., 2012] at depths of 5 and 9 m from the head, began on January 20, 2016. The anomaly was a quasi-rectangular pulse lasting ~6 days and a relative amplitude $\delta \approx 73.5\%$ and was visually diagnosed in real time with standard signal processing (Fig. 2*c*). In the concentration of subsoil radon, a weakly pronounced negative anomaly were recorded in the network of points during this period (Firstov et al., 2017). Formed anomalies were the basis for issuing a forecast of strong earthquake, which was partially justified (Chebrov et al., 2016).

Table. The parameters of earthquakes, before of which the anomalies of molecular hydrogen were registered at monitoring points of subsoil gases of Petropavlovsk-Kamchatsky geodynamic test site.

№	Date	Time	Coordinates of epicenter		*M* (NEIC)	D, km	R_{PRTH}, km	Parameters of precursor anomalies		
			φ, N	λ, E				$\delta\%$	t_{an}	T_{ant}
1	Nov 11, 2006	11:14:13	46.59	153.27	8.3	10	780	75	2	2
2	Mar, 11 2011	05:46:24	38.30	142.37	9.0	29	2100	80	7	28
3	Jan, 30 2016	03:25:12	53.98	158.55	7.2	177	100	73.5	6	10

Note. φ, N – degrees north latitude; λ, E – degrees east longitude; M – magnitude; D – depth; R_{PRTH} – distance to the reference point PRTH; δ% – relative amplitude of anomaly; t_{an} – anomaly duration, day; t_{ant} – anticipation time, day.

Throughout the entire geological history of the Earth, the streams of water-gas fluid are constantly emitted from its bowels. This streams vary noticeably over time and are unevenly distributed over the surface of our planet, reflecting its geodynamic regime and block structure (Letnikov, 2000). In the last decade, undeniable data have been obtained, indicating the significant role of hydrogen in the structure of the Earth and the interaction of geospheres (Larin 2005, Syvorotkin, 2002).

The nature of occurrence of the detected molecular hydrogen anomalies before some earthquakes in the Kurile-Kamchatka seismogenic zone remains unclear, since various mechanisms are possible of their generation (shifting along a fault, changing hydrogen migration paths, interaction of water with rock during fracturing with the release of hydrogen as a result of chemical reactions, impulse degassing of the Earth, etc.).

In (Gufeld, Novoselov, 2014) have shown that a significant, if not the main, role in continuous and various-scale variations of the parameters of the geo-environment from the surface layer to the Moho boundary, plays the processes of interaction of the ascending streams of molecular hydrogen with the solid phase, influencing to the geological environment in the interblock zones and the volumetric-stress state of the environment, associated with the process of preparing its destruction. Hydrogen degassing of the geo-environment are influences to the discontinuous intra-bloc, interblock structures and plate boundaries, controlling their superplastic movement relative to each other (Gufeld, Novoselov, 2014).

The obtained preliminary results show that this type of observation is promising for solving problems of geodynamics and earthquake prediction, especially due to the combination of radon and hydrogen data and give grounds for increasing the number of points on which the concentration of molecular hydrogen is monitored. Analysis of continuous series of data from the network of points and their comparison with the seismicity of the region will contribute to a better understanding of the processes occurring in the bowels of the earth at the last stage of the preparation of a strong earthquake.

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