Relationship of the Latest Seismicity of an Active Fault with Variations of Geophysical Fields

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Abstract. With using of geophysical equipment deployed in the vicinity of the active southern Sakhalin fault, variations of natural geophysical fields were obtained and studied. It is shown that a significant change in the background values of subsurface radon and telluric potentials occurs some time before the seismic event in the instrument observation area, as well as after the events. Together with the medium-term earthquake forecast and geomechanical modeling, these observations can significantly detail the place of preparation for an earthquake, as well as monitor the subsequent development of the implementation of seismic events.

1. Introduction

Sakhalin island is located in one of the most tectonically active places on Earth - on the North-Western border of the so-called Pacific ring of fire. Most of the population of the Sakhalin region lives in the southern part of the island, in the immediate vicinity of the Central Sakhalin Fault (CSF). Researchers of the Institute of Marine Geology and Geophysics of the Far Eastern Branch of the Russian Academy of Sciences (IMGG FEB RAS) made a number of medium-term earthquake forecasts using LURR and SDP methods that indicated the presence of potential danger in the vicinity of the active Central Sakhalin Fault [1]. It can be stated that these methods met expectations and allowed us to identify an area of interest for geomechanical modeling [2] as well as the deployment of geophysical equipment for continuous observations of seismic and geodynamic processes in the vicinity of the fault [3, 4]. Calculation of excess tangential stresses in the geomechanical model of the area under consideration shows that their maximum value is concentrated in the fault zone. The maximum value of these stresses is 289 MPa, corresponds to a depth of 9 km, and gradually decreases to the minimum values on the free surface. Regions of increased values of excessive tangential stresses correspond to areas of increased seismic activity. These territories coincide with areas of intense deformation of the earth's surface [5]. Geographically, zones with increased values of excessive tangential stresses in the southern part of the model zone correspond to areas near from the villages Kirilovo and Petropavlovskoe; in the Northern part – the localities of Starodubskoe and Dolinsk [2]. In the central part, at shallow depths, relatively small values of excess tangential stresses in the range from 7 to 10 MPa were obtained. The southern part of the modeled segment of the active fault was selected for the organization of the point of geophysical observations and on June 10, 2018 in Petropavlovskoe village, installed the first equipment for seismological observations. All the subsequent time, the point was supplemented with other equipment: hydrophones, a subsurface radon sensor, a seismometer, and at the end of 2019, equipment for geoelectric observations. For a year and a half, a significant amount of geophysical information was...
obtained that allows us to characterize the seismic and geodynamic activity of the fault. This article is devoted to the first results of these observations.

2. Results of observations
Detailed characteristics of most of the equipment used at the test site in Petropavlovskoe village, given in [3, 4]. The geological characteristics of the research area are also given in these papers. Geoelectric research is a method for measuring telluric potentials described in [6]. Employees of IMGG FEB RAS have been making similar observations of variations in natural geophysical fields since 2006. In contrast to these works, the research presented in this paper is continuous year-round. In addition, the observations are not focused on long-range regional seismic events for tens or hundreds of kilometers, but on earthquakes occurring directly in the selected segment of the southern part of the CSF, often in the immediate vicinity of the placed equipment.

During the period of operation of the monitoring system from 2018 to 2019, no strong seismic events occurred. At the same time, we can show an example of the reaction of the subsurface radon level to a small seismic event with $M = 3.3$ that occurred directly on the CSF on July 23, 2019. (figure 1).

![Figure 1](image1.png)

**Figure 1.** The subsurface radon level change for the earthquake with $M=3.3$ occurred on 23.07.2019. The top part is an overview map with radon stations: Yuzhno-Sakhalinsk (YSSR), Ozhidaevo (OJDR), Petropavlovskoe (PETR). 1 – Central Sakhalin Fault. 2 – Aprlovskiy fault. The lower part is the variation of the level of subsurface radon in the stations Yuzhno-Sakhalinsk (YSSR), Ozhidaevo (OJDR), Petropavlovskoe (PETR).
From figure 1, it follows that the level in Yuzhno-Sakhalinsk practically did not change, the main reaction to the seismic event on 23.07.2019 with $M = 3.3$ occurred in the points of Ozhdadaevo and Petropavlovskoe. At the same time, the level of subsurface radon decreased on 25.07.2019 in Petropavlovskoe, and in Ozhdadaevo, on the contrary, increased from 27.07.2019. This result is quite consistent with the local geodynamic condition, which is reflected in the change of compression and stretching zones in this area of the CSF \[7\]. The lack of response to this event in Yuzhno-Sakhalinsk is also understandable from the point of view of structural geology: Yuzhno-Sakhalinsk is located to the east of the fault zone (figure 1), in this area, activity does not seem to have significantly changed the level of subsurface radon.

The next very remarkable reaction of the equipment to a series of earthquakes occurred in the zone located between the monitoring points for subsurface radon in Ozhdadaevo and Petropavlovskoe. The table 1 of seismic events is given below.

| Time          | Latitude | Longitude | Depth, km | Class | Magnitude |
|---------------|----------|-----------|-----------|-------|-----------|
| 09/01/20 5:37 | 46.9441  | 142.2162  | 5         | Ks=3.2 | ML=0.3    |
| 09/01/20 5:40 | 46.9449  | 142.2153  | 5         | Ks=3.4 | ML=0.5    |
| 09/01/20 6:24 | 46.9419  | 142.2186  | 5         | Ks=3.7 | ML=0.6    |
| 09/01/20 8:15 | 46.9445  | 142.2157  | 5         | Ks=3.6 | ML=0.1    |
| 09/01/20 10:08| 47.12    | 142.5856  | 2.4       | Ks=4.7 | ML=0.9    |
| 09/01/20 11:00| 46.89    | 142.3453  | 9         | Ks=5.2 | MPSP=3.2  |
| 09/01/20 11:02| 46.9446  | 142.2156  | 5         | Ks=3.6 | ML=0.3    |
| 09/01/20 12:06| 46.9449  | 142.2153  | 5         | Ks=4.6 | ML=1.1    |
| 09/01/20 19:24| 46.9434  | 142.217   | 5         | Ks=3.6 | ML=0.1    |
| 09/01/20 19:30| 46.9858  | 142.3898  | 5         | Ks=4.4 | ML=0.7    |
| 09/01/20 19:30| 46.8866  | 142.4302  | 10        | Kr=7.3 | ML=1.6    |
| 09/01/20 19:37| 46.9814  | 142.39    | 5         | Ks=4.2 | ML=0.9    |
| 09/01/20 19:45| 46.9448  | 142.2154  | 5         | Ks=2.9 | ML=0.4    |
| 09/01/20 20:18| 46.8938  | 142.4321  | 17.31     | Kr=9.2 | MS=2.3 / ML=2.4 |
| 09/01/20 21:19| 46.8841  | 142.4324  | 10.95     | Kr=8.1 | ML=2.0    |

It should be noted that the seismic events themselves are relatively weak, but in total, they are undoubtedly of some interest. Figure 2 shows a map of the distribution of seismic events.

If, for example, the function has exceeded base level two or more times, this means the sign appearance.
Figure 2. Distribution map of seismic events that occurred on January 9 2020.

The reaction of the subsurface radon level in three observation points (Yuzhno-Sakhalinsk, Ozhidaevo, Petropavlovskoe) is shown in figure 3.

Figure 3. Reaction of the subsurface radon level to a series of earthquakes that occurred on 09.01.2020.

As in the case of a stronger seismic event that occurred on 23.07.2019, there is a different reaction of the level of subsurface radon at different points. It is known from the works of [3, 8] that radon...
measurements are significantly influenced by atmospheric phenomena such as pressure, humidity, temperature, ground water level and a number of other parameters. In this situation, of course, the influence of these factors takes place, but since the observation points are located at a relatively small distance from each other (approximately 27 km), such influences are almost the same and simultaneously affect all the observation points. If in the case of an earthquake on 23.07.2019 we observe the reaction of subsurface radon after a seismic event, then in a series of earthquakes on 09.01.2020 we can see changes in the radon level starting 4 days before the event. Similar to the 2019 earthquake shown in figure 1, the readings at the observation point Yuzhno-Sakhalinsk are almost unchanged. Reactions of radon level at Petropavlovskoe and Ozhidaevo observation points are different. In Ozhidaevo, the level first falls from 3.5 to 2.6 kBq/m³ on January 5, 2020, and then sharply increases to 3.5 kBq/m³ from January 6, 2020. The diametrically opposite situation is observed in Petropavlovskoe: readings first increase from 2.6 to 3.5 kBq/m³, then return to the level of 2.6 kBq/m³ and increase to 3.2 kBq/m³ after a series of earthquakes. It should be noted that all seismic events are shallow, and variations of subsurface radon are quite understandable as a result of dilatation of rocks before and after earthquakes.

Since the equipment for geoelectric observations was installed relatively recently - on November 16, 2019, the reaction of telluric potentials to the 2019 earthquake is not known, the reaction to a series of seismic events that occurred on 09.01.2020 is shown in figure 4.

![Figure 4. Reaction of telluric potentials to a series of seismic events that occurred on 09.01.2020.](image-url)

1st series of 8 earthquake events from 05:37 to 12:06 with ML from 0.1 to 1.1
2nd series of 7 earthquake events from 19:24 to 21:19 with ML from 0.1 to 2.4 (at 20:18)
The graphs show that before the start of the series of seismic events at 5:37, January 9, 2020, approximately 10 hours before the start of their implementation, variations in telluric potentials were observed across several electrode systems. Early variations of the potentials was preceded by a certain "calm" or flattening values.

3. Conclusion
The presented results show the effectiveness of complex geophysical observations in the vicinity of the active Central Sakhalin Fault. Together with the methods of medium-term forecasting and geomechanical modeling, it is possible not only to refine various forecast methods, but also to observe the development of the seismic and geodynamic regime of the fault. The results obtained are preliminary, since the geophysical observations were started relatively recently. For comparison, similar observations of teams from other regions of the country and abroad date back decades. To date, observations are carried out in "post-seismic" mode. In other words, the event occurs first, then it is processed together with the results of natural geophysical fields. It is clear that in this case, that is impossible to quickly refine the medium-term forecast and monitor the current activity of the fault. To this end, we are currently working on creating software that will automate the processing and presentation of complex results of natural geophysical fields in real time.

4. References
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