Arctic
Environmental
Research

Arctic Environmental Research 19(1): 11–19
UDC 550.34.06
DOI 10.3897/issn2541-8416.2019.19.1.11

Research Article

Updated data on the current seismicity of the White Sea and the Karelian region during the period 2005–2016

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Academic editor: *Aleksandr I. Malov* ♦ **Received** 7 February 2019 ♦ **Accepted** 15 February 2019 ♦ **Published** 8 March 2019

Citation: Konechnaya YaV, Morozov AN, Vaganova NV, Zueva IA (2019) Updated data on the current seismicity of the White Sea and the Karelian region during the period 2005–2016. Arctic Environmental Research 19(1): 11–19. https://doi.org/10.3897/issn2541-8416.2019.19.1.11

Abstract

This article is the result of previous studies to clarify the seismicity of the White sea, supplemented by similar studies on the continental part of the Republic of Karelia. The relocated catalog of earthquakes was created for the period from 2005 to 2016 for White Sea and the Karelian region. With the help of proven methods, the parameters of the epicenters of identified earthquakes were relocated and a map of current seismicity was obtained. The parameters of the epicenters were specified using BARENTS travel-time model, a single methodological approach (using Generalized beamforming) and all currently available source data and bulletins of Russian and foreign seismic stations. The obtained seismic catalog allowed us to identify the main patterns of the distribution of current seismicity in the White Sea region. Seismicity of the White sea and the Karelian region is characterized as low-magnitude (generally of low magnitude with $ML<2.0$). Most earthquakes in the White Sea are characterized by a focal depths up to 20 km. Analysis of catalog shows that the majority of earthquakes are concentrated in the north-western part of the defined area, in the continental part of Karelia and Kandalaksha graben. Some earthquakes were recorded in the eastern and central part of the White sea.

Keywords

Current seismicity, earthquake, seismic network, epicenter, map, White Sea

Introduction

The White Sea area, which includes the White Sea water area and surrounding areas of the Republic of Karelia, is one of the most fragmented, movable and active regions throughout the entire Eastern European platform. Distinct tracks of paleoearthquakes were encountered in all major parts of the White Sea region in the Kandalaksha, Dvina, and Onega bays, as well as in the Gorlo Belogo Morya area (Nikonov and Shvarev 2013).

The data for the historical and instrumental period of observation indicate an increased seismic activity in the western part of the region, especially in the Kandalaksha graben area, the main active structure of the White Sea (Nikonov 2004; Assinovskaya 2004). The particular interest are present adjacent plots, which are located responsible objects and conducting active mining operations. With the development of seismic networks in the Karelia region (Sharov et al. 2007), in the Murmansk and Arkhangelsk regions (Yudakhin and Frantsuzova 2006) in the 1990s and 2000s, the area of the White Sea has been the highest density of seismometric observations since 2004. In addition, events from the considered region are recorded by stations in Finland, Sweden and Norway and data about them contained in the catalogs of foreign seismological services.

However, no common data processing of available seismic data has been carried out yet. Thus, the most important problem was the joint processing of all available seismological data using a unified velocity model and calculation algorithm. It allows to determine the parameters of earthquake hypocenters based on seismic stations located in wide azimuth and epicentre ranges, and to obtain high precision of earthquake hypocenter location. In addition, some studies have already been successfully carried out on parts of the White Sea (Morozov et al. 2019) and are now supplemented by data from the western part of the White Sea – the territory of the Karelia Republic, which is also characterized by seismicity (Sharov et al. 2007). The boundaries of the study area are shown in Fig. 1.

Materials and methods

The receipt of the specified catalog was completed in several phases.

1 phase

Based on data from the Institute of Seismology of the University of Helsinki (Finland) (Institute of

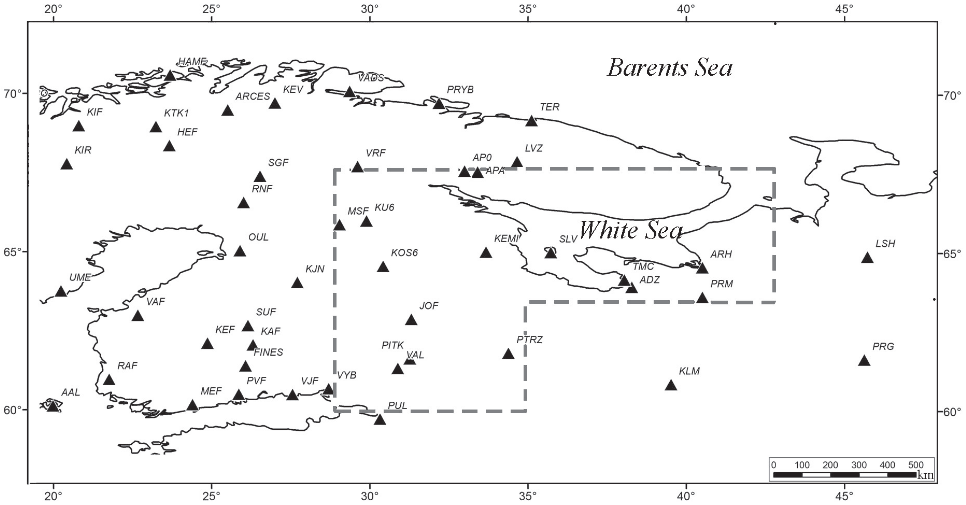

Fig. 1. Seismic networks of Finland, Sweden, Norway and Russia, which monitor seismic events occurring in the White Sea region. Dotted line covers study area

Seismology), the preliminary catalog of the earthquake in the area of the White Sea during the period from 2005 to 2016 was compiled. The advantage of the catalog (Institute of Seismology) is not only the presence of low-magnitude events, but also a note about the expected nature of the event (earthquake or explosion) that in the first stage enabled the exclusion of career blasts from bulletin creation. Event selection was performed within the range of the considered area (Fig. 1). During 2005–2016 period in the preliminary catalog, 66 earthquakes with magnitude ML (HE) values of 0.4 to 2.4 were selected. In addition, only three earthquakes have a value greater than 2.0. This again confirms the views and opinions of modern researchers on the predominantly weak regional seismicity (Sharov et al. 2007; Assinovskaya 2004).

2 phase

For each earthquake from the preliminary catalog, a summary bulletin was compiled with the times of seismic phases

Bulletins were compiled based on data from following seismic stations of several networks:

- the Federal Center of Multidisciplinary Studies of the Arctic of the Russian Academy of Sciences (RAS) (the network code is AH);
- the Geological Institute of the Karelian Research Center (RAS);
- the Kola Branch of the RAS Unified Geophysical Survey Federal Research Center or UGS FRS (the network code is KOGSR);
- the Central Department of the RAS Unified Geophysical Survey Federal Research Center (the network code is OBGSR);
- the Institute of Seismology at the University of Helsinki, Finland (the network code is HE);
- the Sodankylä Geophysical Observatory at the University of Oulu, Finland (the network code is FN);
- the NORSAR Agency, Norway (the network code is NO)
- the Norwegian National Seismic Network, University of Bergen, Norway (the network code is NS).

Should be noted that data from domestic stations (seismic networks AH, KOGSR, OBGSR and RAS) have been supplemented for 34 events from the preliminary catalog. The location of the seismic stations data of which appear in the bulletins and will be taken in further processing is shown in Fig. 1.

3 phase

Since open pit mining operations are actively conducted in considered region, further studies have been carried out to determine the nature of the events from the preliminary catalog. All events were verified by the recognition criteria (Asming and Kremenetskaya 2002), developed at the Kola branch of FITS EGS RAS. As a result, 3 events identified as explosions were excluded from the list. The completed catalog with predetermined hypocenters contains 63 earthquakes.

4 phase

The redefinition of hypocenter parameters based on summary bulletin was carried out by using the Generalized beamforming method (Ringdal and Kværna 1989) in an improved form implemented in the NAS program (Asming et al. 2017; Asming and Prokudina 2016). The algorithm for calculating hypocenters is described in details according to (Morozov et al. 2019).

Previous studies have shown (Morozov et al. 2019) that using the advanced algorithm implemented in the NAS program in conjunction with the rapid BARENTS model provides relatively accurate hypocenter parameters and allows the use of this technique to recalculate all subsequent earthquakes in the White Sea region. The resulting redefinition of hypocentres does not differ fundamentally from the catalog of the Institute of Seismology in Helsinki, despite the extensive use of other additional data.

Results

The main results of the study consist in creation of an updated catalog and mapping of a modern seismicity according to the Table 1 and Fig. 2.

Table 1. The catalog of revised hypocenter parameters for the earthquakes recorded in the White Sea and the Karelian region for the period 2005–2016

No.	Date			Origin time			Hypocenter parameters			Error ellipse			Calculation parameters			Magnitude		
	Year	Month	Day	Hour	Minute	Second	φ,°	λ,°	h, km	AzMajor, °	Rminor, km	Rmajkm	Nstations/ Nphases	Range of distance, km	Azimutal angle,°	ML (HE)	ML (KOGSR)	ML (AH)
1	2005	2	16	6	48	31.2	67.41	32.05	16, 6–32	150	4	5.1	10/17	48–814	97	1.7		
2	2005	3	18	1	49	43.7	67.14	31.91	3, 0–17	140	5	8.4	6/10	70–789	121	1.1		
3	2005	5	17	2	44	11.6	66.98	31.27	20, 0–99	140	2.9	7	4/7	100-209	175	1.3		
4	2005	8	22	2	42	41.2	66.39	30.8	10, 4–16	90	4.3	7.4	6/11	52-293	267	0.8		
5	2005	10	1	1	22	59.1	67.24	32.54	10, 0–24	120	4.2	7.9	10/16	47–583	143	1.6		
6	2005	10	19	3	15	44.6	66.88	31	8, 0–22	90	4.6	10.7	5/8	80-195	275	1.2		
7	2005	10	22	17	46	44.8	64.49	40.95	0, 0–13	70	10.4	14.5	11/22	24–1020	235	2.8		2.9
8	2005	10	23	0	34	6.3	66.64	33.29	16, 0–51	100	5.6	11.8	12/21	107–639	200	1.6		
9	2005	12	2	0	3	57.7	66.89	31.36	15, 8–22	110	2.7	4.8	10/20	97-382	140	1.6		
10	2005	12	12	1	46	3.8	66.87	31.02	14, 5–22	120	2.9	5.4	10/15	84-441	133	1.2		
11	2006	1	13	21	35	1.3	66.64	31.09	0, 0–2	130	1.9	5.5	7/11	72-291	174	0.9		
12	2006	2	2	12	29	10.8	66.59	29.3	5, 0–99	60	3.8	9.8	4/8	27-287	205	1.1		
13	2006	2	18	8	10	2.8	66.84	32.44	0, 0–13	120	4	10.1	10/18	88–632	189	1.7		
14	2006	3	30	10	46	2.1	70.68	52.88	35, 0–99	110	19	40	13/19	836-1555	272	2.6		
15	2006	4	4	1	47	2.6	66.28	31.01	3, 0–10	130	2.9	4.8	11/19	64-423	148	1.1		
16	2006	4	13	13	25	14.2	66.72	29.33	11, 0–21	100	3	5.1	8/12	37-354	113	1		
17	2006	7	11	18	24	41.9	67.31	32.27	10, 0–27	120	4.3	6.6	15/27	45–715	149	2.1		
18	2006	7	23	1	32	8.8	66	39.58	29, 2–99	60	7.3	10.9	19/33	218–1036	192	2.3		
19	2006	10	25	12	24	42.7	66.94	31.07	10, 0–33	130	2.6	12.9	5/7	91-144	175	0.7		
20	2006	12	31	5	35	56	65.66	32.02	0, 0–3	60	4.2	11.2	7/10	104–313	235	0.5		
21	2007	3	13	14	31	28.6	66.29	31.16	2, 18–30	130	2.9	5.5	18/30	63-549	146	1.9		
22	2007	3	29	22	53	21.9	66.15	30.54	0, 0–5	90	2.8	5.8	9/14	28-240	264	0.8		
23	2007	4	8	14	35	13.7	66.15	33.09	5, 0–15	120	3.6	7.1	13/23	142–625	189	2.4		
24	2007	8	1	4	31	57.1	66.58	31.28	10, 2–18	130	2.1	5.1	8/16	78-226	183	1.3		
25	2007	8	3	0	59	38.4	66.02	30.36	18, 15–22	90	2.6	5	7/12	16-227	258	0.4		
26	2007	8	19	22	56	3.3	69.64	33.1	33, 3–98	40	6.3	12.7	29/56	226-1377	242	3		
27	2007	9	11	8	4	48.7	69.73	29.99	0, 0–99	40	6.6	20.9	4/6	108-406	268	1.3		
28	2007	10	30	0	19	16	66.63	30.91	20, 0–99	100	2.7	9.2	4/6	60-135	238	0.5		
29	2007	11	23	4	22	30.3	66.3	32.75	0, 0–10	120	3.4	7.7	11/20	130–596	219	1.4		
30	2008	1	27	1	54	25.5	68.19	29.74	8, 0–14	40	2.5	3.4	9/16	48-254	143	1.6		
31	2008	1	27	3	24	23.8	68.18	29.76	12, 0–27	30	3	3.9	5/9	49-228	143	1.2		
32	2008	5	10	15	5	8.4	66.86	31.77	6, 0–14	110	2.9	5.5	16/28	98–531	151	1.6		
33	2008	6	22	18	1	41.2	68.19	30.79	16, 8–23	60	3.6	5	12/21	70-298	164	1.3		
34	2008	7	12	17	17	14.8	68.39	35.78	25, 12–52	60	7.4	10.8	14/22	135-856	227	2.7		
35	2008	9	12	20	14	25.6	68.72	33.29	15, 0–65	70	6.8	18	7/9	185-331	248	1.2		
36	2008	10	19	23	29	10	66.87	29.16	6, 0–23	70	1.4	2.7	9/18	58-146	149	0.5		
37	2008	10	25	3	9	45.3	66.54	32.42	0, 0–7	120	2.9	7.2	11/20	122–422	220	1.3	1.6	
38	2009	5	25	20	58	4.3	67	31.77	7, 0–21	80	4.6	10	8/12	171-455	213	1.1		
39	2009	8	31	15	17	50.8	66.31	31.05	28, 22–33	110	3.3	6.1	16/30	62-548	183	1.5		
40	2009	9	8	0	23	48.3	66.78	31.13	18, 11–24	100	3	4.1	21/38	81-777	82	2.1		
41	2009	9	8	4	42	16.9	66.79	31.08	14, 8–22	110	2.5	5.6	11/18	79-383	168	1.4		
42	2009	11	16	4	27	26.6	66.04	30.03	7, 3–10	110	2.4	4.7	20/37	5.5-495	167	1.6		
43	2009	11	28	14	32	23.6	66.26	33	1, 0–13	100	3.6	4.6	10/16	138-315	167	1.6		
44	2009	12	3	19	55	45	66.35	31.28	13, 7–21	100	3.5	6.1	9/16	70-236	247	0.8		
45	2009	12	11	23	53	52	67.08	31.8	11, 3–18	120	2.4	4.7	11/20	78-376	171	1.2		
46	2010	2	25	1	42	13.8	66.43	30.53	0, 0–7	90	2.2	4.7	10/17	40-254	220	0.7		
47	2010	3	27	23	6	55.8	66.24	32.02	18, 1–24	170	7.4	12.9	6/10	93–180	333	0.7		
48	2010	4	6	4	49	3.4	66.9	31.08	6, 0–12	110	1.9	3.5	12/23	87-358	159	1.3		
49	2010	5	20	1	33	48.3	66.31	32.12	25, 16–34	30	7.9	8.5	6/11	98–268	316	0.7		
50	2010	9	5	5	17	33.2	66.2	30.74	2, 0–7	130	2.8	5.2	17/29	42-529	176	1.4		
51	2011	1	20	14	37	0	65.35	30.54	10, 2–16	60	2.3	4	10/17	52-273	123	0.9		
52	2011	6	16	15	44	6.5	66.59	31.58	0, 0–5	100	4.5	9.4	9/15	89–523	214	1.6		
53	2011	8	13	11	54	52.2	66.18	34.23	0, 0–48	120	6.4	12.1	6/11	173–272	272	1.2		
54	2011	10	11	20	4	59.4	66.45	30.68	20, 15–25	110	3	4.9	14/22	47-404	138	1.2		
55	2011	11	15	17	48	10.2	67.43	31.73	0, 0–4	140	2.5	3.4	11/20	58–345	131	1.5	1.9	
56	2012	1	3	0	1	37.9	68.14	29.3	0, 0–99	70	3.4	6	4/8	44-220	206	1.1		
57	2012	1	8	20	54	25	66.81	31.46	0, 0–6	110	3.1	5.5	19/30	99-606	145	0.7		

No.	Date			Origin time			Hypocenter parameters			Error ellipse			Calculation parameters			Magnitude		
	Year	Month	Day	Hour	Minute	Second	φ,°	λ,°	h, km	AzMajor, °	Rminor, km	Rmajkm	Nstations/ Nphases	Range of distance, km	Azimutal angle,°	ML (HE)	ML (KOGSR)	ML (AH)
58	2012	2	15	6	48	8.7	66.46	32.09	4, 0–22	110	5.2	16.4	7/10	100–428	272	1.2		
59	2012	3	27	7	13	12.5	66.11	30.36	8, 3–13	90	2.3	2.7	10/19	22-271	136	0.9		
60	2012	4	22	20	9	32.4	67.01	31.32	6, 0–13	110	2.3	3.3	12/23	97-242	107	1.3		
61	2012	4	30	8	48	27.4	65.78	30.8	0, 0–12	100	2.2	3.6	6/10	45-128	288	0.8		
62	2012	8	27	7	29	45.3	66.16	30.77	12, 7–18	100	2.9	6	7/12	36-285	236	1		
63	2012	10	7	3	43	12.9	66.21	47.84	26, 99	50	8.6	19	13/25	526-1656	170	1.6		
64	2012	10	11	15	0	48	65.82	30.35	25, 19–30	100	1.9	3.9	5/9	27-92	262	0.5		
65	2012	12	4	7	13	9	65.89	30.15	5, 1–8	100	2.7	5.8	11/19	19-263	217	1.1		
66	2013	3	28	7	2	16.5	63.97	41.5	21, 8–36	150	6.8	8.1	31/59	82–2596	83	2.9		3.4
67	2013	4	3	14	49	35	66.99	30.19	0, 0–6	100	2.3	3.6	16/28	74-383	128	1.5		
68	2013	4	26	19	51	8.2	68.04	29.37	6, 0–13	70	3.3	6.3	7/12	32-230	188	0.7		
69	2013	5	1	22	52	21.7	66.49	30.79	22, 15–29	120	2.2	4.5	10/18	54-395	172	1.3		
70	2013	11	26	20	39	7.1	66.44	30.85	15, 11–22	80	4	6.9	7/12	57-217	269	0.5		
71	2013	11	30	22	16	20.1	65.48	31.73	15, 0–59	20	6.2	9.1	6/8	105–656	142	0.8		
72	2014	2	25	18	53	6.1	66.43	32.46	1, 0–10	120	2.6	3.7	12/21	122-431	118	1.7		
73	2014	3	20	13	56	40.7	64.87	35.52	41, 29–57	50	6.3	8.2	13/23	25–543	128	1.2		
74	2014	4	8	0	45	38.6	65.98	31.39	0, 0–2	110	3.4	5.7	7/13	63-246	263	0.6		
75	2014	8	20	2	27	38	66.3	31.83	4, 0–12	120	2.9	3.6	10/17	92–337	115	1.3		
76	2014	8	29	23	37	39.2	66.6	31.56	1, 0–8	100	3.4	8.5	7/13	88-241	263	0.9		
77	2014	9	5	2	27	28.3	66.44	31.7	3, 0–10	90	3	4.1	9/15	92–320	121	0.8	1.2	
78	2014	9	8	4	15	11.7	67.96	30.17	3, 0–11	10	2.8	3.1	6/11	33-256	138	1		
79	2014	9	12	22	9	43.3	66.32	31.51	26, 15–32	110	4	8.5	5/9	71-155	273	0.6		
80	2014	10	2	12	19	23.1	66.4	32.53	0, 0–7	120	3	4.3	14/23	123-508	119	1.4		
81	2014	10	11	0	32	45.6	65.94	32.43	0, 0–4	100	5.6	10.1	6/8	114–309	243	0.9		
82	2014	11	23	23	20	11.6	66.5	31.53	9, 0–21	100	3.4	6.8	6/11	86-170	251	1.1		
83	2014	11	30	9	43	19.9	67.15	32.53	13, 2–25	140	3.6	6.4	8/12	57–393	178	0.7		
84	2014	12	13	21	10	40.1	66.28	31.18	21, 15–27	110	3.1	4.9	11/17	62-307	164	1.2		
85	2015	1	8	6	20	41.2	66.17	29.96	19, 16–25	90	1.9	3.3	5/8	15-95	227	0.1		
86	2015	2	15	3	0	35.9	65.95	30.07	9, 0–15	100	1.3	2.8	6/10	Dec-88	234	0.3		
87	2015	2	28	19	33	49.1	66.31	31.85	0, 0–14	130	2.4	6.6	6/10	92–260	233	1.1	1.5	
88	2015	3	20	14	46	38.3	60.29	43.89	0, 0–99	150	10	22.8	17/29	177-1054	235	2.7		
89	2015	4	2	8	16	56.6	68.31	29.17	0, 0–7	50	3.1	4.6	8/14	65-819	126	1		
90	2015	4	4	20	23	38.9	66.17	30.74	5, 0–12	110	4.2	10.2	5/8	39-286	263	0.6		
91	2015	4	22	2	8	54.7	66.95	31.1	0, 0–6	100	2.5	4.8	9/15	89-220	161	0.7		
92	2015	5	10	14	3	11.7	66.74	31.13	21, 15–25	130	2.2	3.6	14/25	80-334	82	1.4		
93	2015	5	31	0	40	34.5	66.68	33.21	0, 0–8	130	3.8	9.6	8/11	104–317	222	0.8		
94	2015	6	23	6	15	59.3	66.88	31.03	13, 6–21	100	2.5	4.5	10/16	84-219	153	1		
95	2015	6	26	3	45	48.9	66.57	32.03	23, 13–29	120	2.7	5.2	8/13	112–264	163	0.7	1.7	
96	2015	6	29	13	5	9.1	65.93	31.88	19, 14–23	110	2.5	3	18/31	89–512	112	1.9	2.3	
97	2015	7	6	17	31	34.8	66.39	31.83	15, 7–23	110	3.4	4	10/18	94–560	115	1.7	2	
98	2015	7	12	11	31	57.2	66.45	31.42	10, 5–15	100	3	5.8	9/17	80-237	249	0.8		
99	2015	8	1	4	31	4.4	66.21	30.55	13, 8–20	90	2	3.8	7/12	32-178	226	0.7		
100	2015	9	11	19	23	52.2	66.36	31.33	20, 16–26	110	2.4	3	27/50	74-868	59	2.4		
101	2016	1	12	19	14	50.2	66.96	29.76	14, 0–32	80	1.9	4.8	5/8	66-147	181	0.4		
102	2016	2	28	17	48	7	67	32.01	16, 8–23	110	2.7	3.9	24/43	79–771	57	1.8	2.1	
103	2016	4	3	0	4	27	67.52	32.09	0, 0–6	160	3.3	4.9	7/13	40–282	152	1	1.5	
104	2016	4	23	0	9	24.9	67.63	33.31	13, 3–19	170	3.9	8.4	10/15	16-493	106	1.4		
105	2016	5	17	11	13	19.4	66.9	30.16	1, 0–6	90	2.6	4	17/32	98-380	121	1.5		
106	2016	5	26	4	46	0.7	66.04	35.66	34, 2–99	90	5.8	12.5	10/18	197–436	242	1.1	2	
107	2016	6	13	6	16	9.2	69.58	33.78	24, 14–32	30	4	8.5	11/17	64-476	196	2.1		
108	2016	6	19	22	33	25.4	67.05	30.05	5, 0–12	90	2.7	3.7	19/32	79-388	114	1.5		
109	2016	7	9	17	38	20	67.22	32.3	10, 0–29	140	3.7	6.9	10/15	53–399	168	0.8	1.3	
110	2016	7	30	21	42	24.5	66.45	32.94	3, 0–13	120	3	5.5	17/29	113–573	167	1.5	1.9	
111	2016	8	3	15	49	55.4	66.35	30.68	14, 10–18	110	2.9	3.6	21/32	49-749	89	1.6		
112	2016	8	7	19	42	11.2	66.35	31.49	20, 10–29	130	3.8	5.1	10/15	83-726	119	1.1		
113	2016	9	15	8	13	2.6	66.88	30.94	23, 18–28	100	2.7	3.4	23/43	83-705	76	2		
114	2016	11	15	19	20	23.7	65.64	30.16	7, 1–12	80	2.5	5.6	8/12	45-236	180	0.7		
115	2016	11	19	20	47	20.3	66.75	32.47	4, 0–15	120	2.7	5.3	11/18	99–404	168	1.1	1.5	
116	2016	11	20	18	21	0.1	66.98	31.44	20, 12–24	110	2.3	3.4	13/23	96–375	135	1.6	1.7	

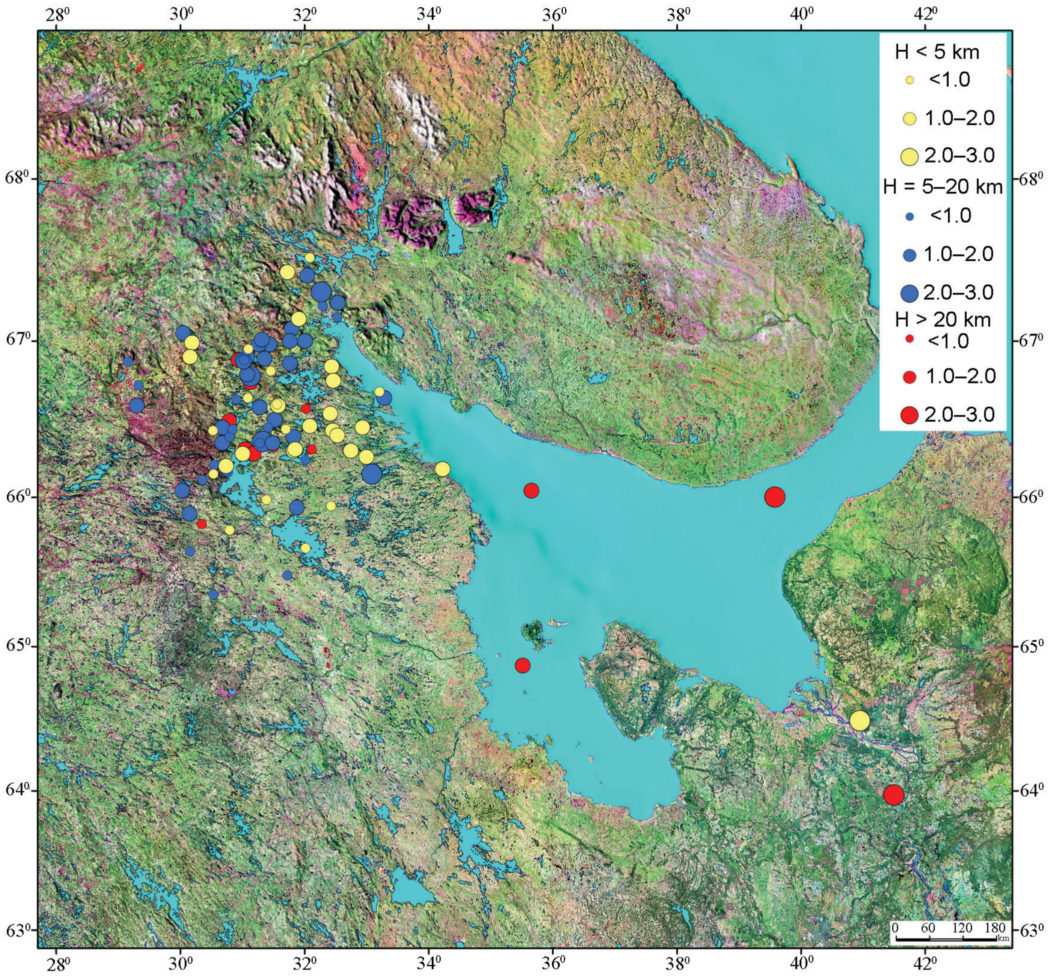

Fig. 2. A map showing revised earthquake epicenters for the White Sea region. The legend on the right shows earthquake classes arranged over depth of focus (H) and magnitude (circle size)

Map analysis Fig. 2 shows that the majority of earthquakes are concentrated in the north-western part of the defined area, in the continental part of Karelia region. The modern seismicity of the White Sea is reflected in the form of a small magnitude. The distribution of the epicenters of recorded earthquakes fully corresponds to the regularities previously revealed in the studies (Assinovskaya 2004; Nikonov and Shvarev 2013), namely, increased seismic activity in the western part of the basin and weak seismic activity in the eastern and central parts (Fig. 2).

Discussion

According to fig.2 in the eastern part of the region two earthquakes were recorded in the White-Sea-Dvina area in 2005 and 2013 years where is also an earthquake in the Gorlo Strait area in 2006 year. All earthquakes have a magnitude value of ML (HE) above 2.0, which distinguishes them from other earthquakes. The earthquake of 2005, viewed alongside the earthquake information of 1847 and 1935, as well as the earthquake in 1970 and 1975 (Nikonov 2013). may indicate seismic activity in the White Sea-Dvina region.

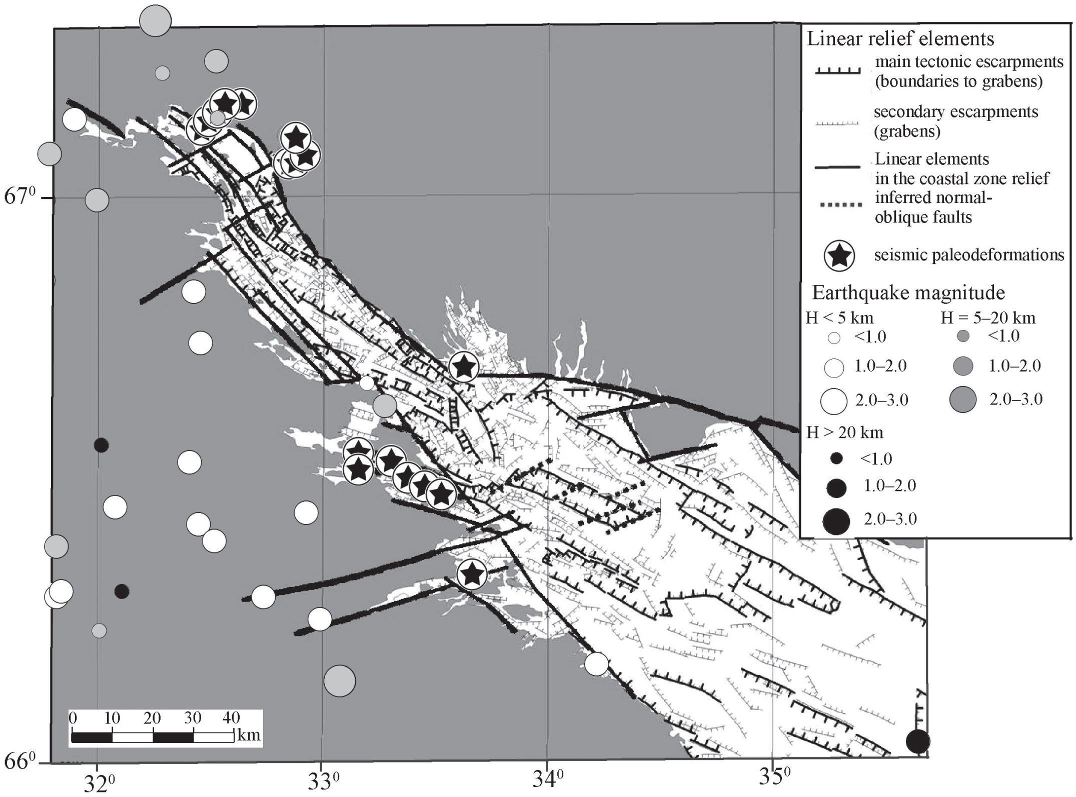

Fig. 3. A morphostructural map of the seafloor and coasts of the Kandalaksha Gulf made by S.V. Shvarev using a digital elevationmodel; seismicity is shown for comparison. The legend on the right gives a classification of the earthquakes over depth of focus (H) and magnitude (circle size)

The epicenter of the earthquake in 2013 (Fig. 2) is timed to the fault limiting Arkhangelsk scarp and the Onega-Kandalaksha ancient rift. The focal mechanism of this earthquake calculated in study (Morozov et al. 2016) is fully in line with the conclusions of L.A. Sim (Sim et al. 2011) on regional submeridional compression and sublatitudinal tension characteristic of the eastern part of the Baltic shield.

The epicenter of the 2006 earthquake in the Gorlo Strait (Fig. 2) almost coincides with the epicentre of the historic earthquake of 1912 (Nikonov 2000). In the central part of the White Sea region weak earthquakes over the past ten years are not recorded, as well as for the entire instrumental observation period (Assinovskaya 2004).

The obtained depth values indicate the presence of crustal earthquakes, and in the classification of seismic events by depth refers to a small-focus ones. Most earthquakes in the White Sea are characterized by a focal depths up to 20 km. For three earthquakes, the epicenters of which are located directly in the waters of the White Sea, and six earthquakes in Karelia, the depths are over 20 km. Earthquakes with a depth of more than 20 km were also recorded in the Arkhangelsk region in 2013.

In the western part of the White Sea region (Fig. 3), most epicenters of small events (22 events) during period 2005–2016 are located outside Kandalaksha graben, but on land to the west and south-west of it, with hypocenters are located at a depth of 5 up to 20 km., respectively. When comparing the epicenter location of the earthquake processed with the map of neotectonic and young morphostructures of Kandalaksha Gulf and its surroundings (first made based on a digital topographic model (Shvarev et al. 2015) several remarkable correlations can be found (Fig. 3). In the Gulf area, i.e. the Kandalaksha graben itself, especially on its south-west shore, only four events were recorded. The hypocenters were crustal at great distances each other. Their epicenters lie on longitudinal lines running in the direction of the North-West to South-East along the main boundary of the graben.

Conclusion

The results obtained in this article deepen our knowledge about the development of modern seismicity in the White Sea region. The use of a single speed model, a unified methodological approach and all currently available source data and bulletins of Russian and foreign seismic stations made it possible to determine earthquake parameters with the highest confidence.

The results presented in this article confirm the presence of seismicity (generally of low magnitude with ML<2.0) in the areas adjacent to the White Sea. This fact should be taken into account when carrying out the seismic monitoring of the region. The resulting updated catalog consist in essential part of the work carried out to clarify the current seismicity of the entire North of the Eastern European platform and should be included in a single seismic catalog of Eastern European platform, combining earthquakes both in historical and instrumental periods.

The research was supported by the grant RFBR «Modern seismicity of the White Sea region»(№ 18-35-00021).

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