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USSR PEACEFUL NUCLEAR TESTS, GEOPHYSICAL OBSERVATORY "BOROVOYE"

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The paper presents a summary of corrected data on the Soviet Peaceful Nuclear Explosions (abbreviated as PNEs) with the author's corrections, taking into account the information on the updated coordinates of the works of the authors Makei, Fujita, etc. As a result, the article presents the calculated epicentral distances for PNEs, travel-time curves and azimuths from the Geophysical Observatory "Borovoe" to the geographical coordinates of the PNEs, which were registered in digital format during the monitoring conducted by Expedition № 4 of the Special Sector of the Institute of Physics of the Earth of the USSR Academy of Sciences since 1966.

Refined coordinates of Soviet PNEs are given in [1, 2]. Using this, we recalculate and acquire new epicentral distances and azimuths from the "Borovoye" Geophysical Observatory for the PNEs, which were digitally recorded during earthquakes' monitoring since 1966 [3].

At the "Borovoye" Geophysical Observatory (BRVK), out of 122 national USSR underground PNEs [4], 98 were registered in digital format (according to the archive of Expedition No. 4 of the Special Sector of the Institute of Physics of the Earth (IPE) USSR Academy of Sciences). However, when reformatting the archive of digital seismograms BRVK at the end of the last century, only 79 seismograms were saved [5]. The table presents the data of the 79 PNEs database from the Institute of Geosphere Dynamics (IDG RAS).

Figures 1, 2 show fragments of BRVK three axial seismograms along the closest and furthest PNEs from "Borovoye" Observatory: Meridian-1 and Kraton-4 (see table). Records from digital stations KOD and STsR are shown here [5].

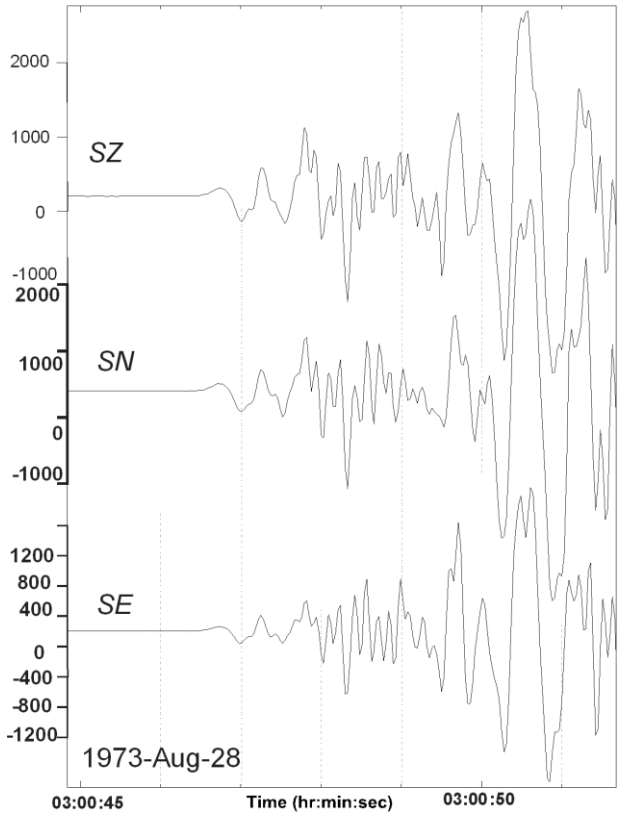

Figure 1. KODm, 28 August 1973, Meridian-1. δT = +0.217 sec [6]. The channels are from top to bottom with channel number: 1 – SZ, 3 – SN, 4 – SE

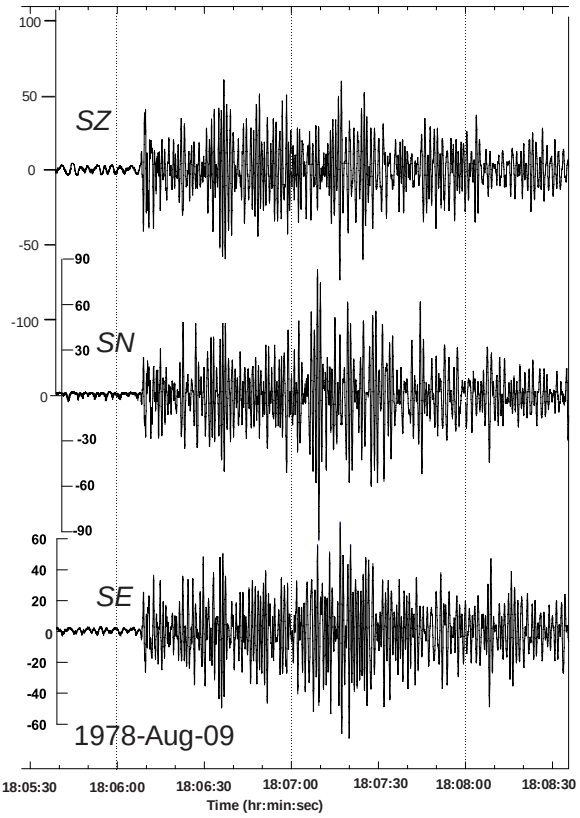

Figure 2. STsR-SS, 09 August 1978, Kraton-4. δT = +0.226 sec [6]. The channels are from top to bottom with channel number: 7 – SZ, 8 – SN, 9 – SE

The table shows the travel time of P-wave (t_{p0}) to the BRVK Observatory from [3], taking into account the time corrections (δT) of the digital registration stations [6]. An error was found in [3] in the travel time of the 22nd August 1988 test named Ruby-2 (corrected in the table by the underlined bold).

*Table. USSR Peaceful Nuclear Explosions, registered by "Borovoye" Geophysical Observatory (BRVK: φ ° N = 53.05806, λ ° E = 70.28278)**

Test No.	Test name	m_b (P)	Date Year-Mo-Da	Time hr:mn:sec	Coordinates		Δ° from BRVK	Az° from BRVK	t_{p0} BRVK sec	Inst. Type [7]
					Lat. φ° (N)	Long. λ° (E)				
1	**Tawda**	**4.7**	**1967-10-06**	**06:59:57.50**	**57.70**	**65.20**	**5.4797**	**330.12**	84.26	KODb
2	Pamuk	**5.4**	1968-05-21	**03:59:11.98**	38.918	63.032	14.5991	196.45	202.70	KODb
3	**Grifon-1**	**4.8**	**1969-09-02**	**04:59:58.61**	**57.220**	**55.393**	**9.4861**	**301.99**	135.68	KODb
4	**Grifon-2**	**4.8**	**1969-09-08**	**04:59:58.70**	**57.220**	**55.417**	**9.4738**	**302.02**	135.28	KODb, KODm
5	**Stavropol**	**5.6**	**1969-09-26**	**06:59:58.14**	**45.848**	**42.600**	**19.3028**	**259.22**	263.83	KODb, KODm
6	Mangyshlak-1	**5.8**	1969-12-06	**07:02:59.85**	43.8625	54.7727	13.7771	234.31	192.71	KODb, KODm
7	Magistral	**4.9**	1970-06-25	**04:59:55.50**	52.3265	55.7238	8.8765	271.09	129.25	KODb
8	Mangyshlak-2	**6.0**	1970-12-12	**07:00:59.83**	43.9096	54.7937	13.7322	234.40	192.01	KODb, KODm
9	Mangyshlak-3	**6.0**	1970-12-23	**07:00:59.76**	43.8858	54.8973	13.6990	234.10	191.58	KODb, KODm
10	Taiga	**5.5**	1971-03-23	**06:59:58.38**	61.306	56.599	11.0884	323.58	157.57	KODb, KODm
11	**Globe-4**	**4.7**	**1971-07-02**	**17:00:01.13**	**67.283**	**63.467**	**14.6526**	**349.50**	202.91	KODb
12	**Globe-1**	**4.5**	**1971-09-19**	**11:00:01.08**	**57.508**	**42.643**	**16.3024**	**296.87**	225.87	KODb
13	**Globe-2**	**4.6**	**1971-10-04**	**10:00:00.14**	**61.358**	**48.092**	**14.5502**	**313.58**	203.719	KODb
14	Azgir A-3-1	**6.0**	1971-12-22	**06:59:59.00**	47.8980	48.1298	14.9938	258.76	207.405	KODb, KODm
15	Crater	**4.9**	1972-04-11	**06:00:01.92**	37.4158	62.0508	16.6626	203.43	230.459	KODb
16	Fakel	**4.8**	1972-07-09	**07:00:01.25**	49.552	35.471	21.9101	274.87	293.034	KODb
17	Region-3	**5.7**	1972-08-20	**03:00:00.01**	49.4169	48.16155	14.3130	264.13	199.142	KODb, KODm
17	Region-3	**5.7**	1972-08-20	**03:00:00.01**	49.4169	48.1615	14.3130	264.13	199.142	KODb, KODm
18	Dnepr-1	**4.6**	1972-09-04	**07:00:00.00**	67.782	33.618	22.8505	324.21	308.013	KODb
19	Region-1	**5.0**	1972-09-21	**09:00:00.31**	52.1404	52.0929	11.1031	272.53	158.143	KODb
20	**Region-4**	**5.6**	**1972-10-03**	**09:00:00.18**	**46.853**	**44.938**	**17.3970**	**259.29**	238.325	KODb
21	Region-2	**4.5**	1972-11-24	**09:00:00.04**	51.9933	51.8826	11.2614	271.93	161.012	KODb
22	Meridian-3	**5.3**	1973-08-15	**02:00:00.02**	42.7740	67.40695	10.4688	191.73	149.359	KODb, KODm, SS
23	Meridian-1	**5.2**	1973-08-28	**03:00:00.04**	50.5279	68.32127	**2.8114 min**	206.45	46.643	KODb, KODm, SS
24	Meridian-2	**5.1**	1973-09-19	**03:00:00.18**	45.7588	67.82289	7.4800	193.35	109.022	KODb, KODm, SS
25	Sapphire-2	**5.2**	1973-09-30	**05:00:00.35**	51.6052	54.5991	9.7138	267.66	139.674	KODb
26	Kama-2	**4.8**	1973-10-26	**05:59:59.50**	53.5615	55.51436	8.8605	279.16	127.611	KODb
27	**Horizon-1**	**5.0**	**1974-08-29**	**15:00:00.39**	**67.085**	**62.625**	**14.5620**	**348.02**	203.400	SS
28	**Horizon-3**	**4.8**	**1975-09-29**	**11:00:00.43**	**69.578**	**90.337**	**18.9886**	**21.71**	259.782	SS
29	Azgir A-3-2	4.3	1976-03-29	07:00:00.23	47.8980	48.1298	14.9938	258.76	**207.43 ??**	SS, TSG
30	Azgir A-4	**5.9**	1976-07-29	**05:00:00.50**	47.871	48.138	15.0018	258.65	207.158	SS, TSG
31	Oka	**5.3**	1976-11-05	**03:59:59.98**	61.4608	112.8592	24.1061	52.71	314.878	SS
32	**Meteorite-2**	**5.0**	**1977-07-26**	**17:00:00.22**	**69.575**	**90.375**	**18.9948**	**21.75**	258.899	SS, TSG
33	**Meteorite-3**	**5.0**	**1977-08-20**	**22:00:00.78**	**64.108**	**99.558**	**18.6478**	**42.18**	255.899	TSG
34	Meteorite-4	**4.8**	1977-09-10	**16:00:00.18**	57.2583	106.5565	20.9753	63.92	283.447	SS, TSG
35	Azgir A-5	**5.0**	1977-09-30	**06:59:58.43**	47.888	48.153	14.9848	258.69	207.838	SS
36	Kraton-4	**5.6**	1978-08-09	**18:00:00.79**	63.6773	125.5266	**29.8783 max**	47.33	367.406	SS
37	Kraton-3	**5.1**	1978-08-24	**18:00:00.35**	65.9254	112.3330	24.3581	41.77	317.681	SS, TSG
38	**Kraton-2**	**5.2**	**1978-09-21**	**15:00:00.19**	**66.598**	**86.210**	**15.6834**	**23.92**	215.752	SS, TSG
39	Vyatka	**5.2**	1978-10-08	**00:00:00.00**	61.5565	112.9922	24.1716	52.47	315.919	SS
40	Azgir A-7	**5.8**	1978-10-17	**04:59:59.06**	47.847	48.120	15.0239	258.60	207.710	SS
41	**Kraton-1**	**5.5**	**1978-10-17**	**14:00:00.16**	**63.185**	**63.432**	**10.7732**	**343.18**	152.487	SS
42	Azgir A-9	**5.9**	1978-12-18	**07:59:58.50**	47.857	48.161	14.9949	258.58	207.855	SS, TSG
43	Azgir A-8	**6.0**	1979-01-17	**07:59:58.50**	47.919	48.124	14.9872	258.83	207.860	SS, TSG
44	Azgir A-11	**5.6**	1979-07-14	**04:59:58.00**	47.882	48.120	15.0072	258.71	207.254	SS, TSG
45	Kimberlite-4	**4.9**	1979-08-12	**18:00:00.21**	61.7997	122.4161	28.6462	51.47	355.658	SS, TSG

Test No.	Test name	m_b (P)	Date Year-Mo-Da	Time hr:mn:sec	Coordinates		Δ° from BRVK	Az° from BRVK	t_{p0} BRVK sec	Inst. Type [7]
					Lat. φ° (N)	Long. λ° (E)				
46	**Kimberlite-3**	**4.9**	**1979-09-06**	**18:00:00.31**	**64.110**	**99.562**	**18.6502**	**42.18**	257.024	SS, TSG
47	**Kimberlite-1**	**5.4**	**1979-10-04**	**16:00:00.03**	**60.675**	**71.455**	**7.6641**	**4.33**	107.615	SS, TSG
48	Sheksna	**5.0**	1979-10-07	**21:00:00.22**	61.7679	113.1554	24.2540	51.96	316.473	SS, TSG
49	Azgir A-10	**5.8**	1979-10-24	**05:59:59.00**	48.852	48.143	15.0079	258.58	208.281	SS, TSG
50	Vega-1	**5.2**	1980-10-08	**06:00:00.29**	46.7565	48.2738	15.4846	254.81	213.473	SS
51	**Batholith-1**	**5.2**	**1980-11-01**	**13:00:00.42**	**60.80**	**97.55**	**16.6751**	**51.53**	231.578	TSG
52	**Pyrite**	**5.5**	**1981-05-25**	**05:00:00.32**	**68.20**	**53.50**	**17.1684**	**338.57**	236.342	SS
53	Helium-1	**4.4**	1981-09-02	**03:59:59.99**	60.2751	57.2991	10.1514	320.56	145.379	TSG
54	Vega 2-1	**5.2**	1981-09-26	**05:00:00.28**	46.7936	48.3088	15.4445	254.88	212.732	TSG
55	Vega 2-2	**5.3**	1981-09-26	**05:03:59.94**	46.7760	48.3012	15.4583	254.84	214.682	TSG
56	**Shpat-2**	**5.1**	**1981-10-22**	**14:00:00.36**	**63.80**	**97.55**	**17.7117**	**41.95**	244.801	TSG
57	**Rift-3**	**5.0**	**1982-07-30**	**21:00:00.00**	**53.80**	**104.15**	**20.0877**	**74.25**	273.192	TSG
58	**Rift-4**	**5.2**	**1982-09-25**	**18:00:00.18**	**64.35**	**91.80**	**15.8005**	**35.89**	218.070	TSG
59	Lira 1-1	**5.3**	1983-07-10	**03:59:59.99**	51.3627	53.306	10.5577	267.54	150.648	SS
60	Lira 1-2	**5.3**	1983-07-10	**04:04:59.94**	51.3660	53.3258	10.5449	267.54	151.245	SS
61	Lira 1-3	**5.3**	1983-07-10	**04:09:59.85**	51.3802	53.3388	10.5332	267.61	149.695	SS
62	Vega 4-1	**5.2**	1983-09-24	**05:00:00.03**	46.7812	48.3197	15.4447	254.83	212.555	SS
63	Vega 4-2	**5.1**	1983-09-24	**05:05:00.03**	46.7872	48.2966	15.4550	254.88	212.964	SS
64	Vega 4-3	**5.0**	1983-09-24	**05:10:00.08**	46.7671	48.3079	15.4591	254.80	212.417	SS
65	Vega 4-4	**5.2**	1983-09-24	**05:15:00.14**	46.7500	48.3006	15.4724	254.76	213.059	SS
66	Vega 4-5	**5.4**	1983-09-24	**05:19:59.93**	46.7538	48.2877	15.4779	254.79	213.677	SS
67	Vega 4-6	**5.3**	1983-09-24	**05:25:00.00**	46.7657	48.2740	15.4796	254.84	213.489	SS
68	Lira 2-1	**5.4**	1984-07-21	**02:59:59.81**	51.3584	53.3198	10.5506	267.51	150.022	SS
69	Lira 2-2	**5.3**	1984-07-21	**03:04:59.71**	51.3717	53.3357	10.5374	267.56	149.769	SS
70	Lira 2-3	**5.4**	1984-07-21	**03:09:59.85**	51.3916	53.3497	10.5235	267.66	151.319	SS
71	**Quartz-3**	**5.3**	**1984-08-25**	**19:00:00.33**	**61.90**	**72.10**	**8.9200**	**5.56**	123.723	SS
72	**Quartz-4**	**5.0**	**1984-09-17**	**21:00:00.03**	**55.834**	**87.526**	**10.4174**	**67.65**	149.494	TSG
73	**Vega 5-1**	**5.0**	**1984-10-27**	**06:00:00.10**	**46.90**	**48.15**	**15.4811**	**255.44**	213.594	SS, TSG
74	**Vega 5-2**	**5.0**	**1984-10-27**	**06:05:00.00**	**46.95**	**48.10**	**15.4842**	**255.67**	214.404	SS, TSG
75	Neva 2-2	**5.1**	1987-07-24	**02:00:00.00**	61.4172	112.8927	24.1215	52.81	314.981	SS
76	Neva 2-3	**5.0**	1987-08-12	**01:30:00.50**	61.4266	112.8879	24.1193	52.79	315.097	SS
77	**Batholith-2**	**5.3**	**1987-10-03**	**15:15:00.03**	**47.60**	**56.20**	**10.5241**	**244.37**	149.077	SS, TSG
78	**Ruby-2**	**5.3**	**1988-08-22**	**16:20:00.07**	**66.280**	**78.491**	**13.8757**	**13.94**	**192.197**	SS, TSG
79	**Ruby-1**	**4.8**	**1988-09-06**	**16:19:59.94**	**61.361**	**48.092**	**14.5515**	**313.60**	202.637	SS, TSG

*In the table, the parameters according to [4] are marked in bold, according to [1, 2] – ordinary, according to Institute of Geosphere Dynamics (IDG RAS) - underlined.

Three different sets of recording systems were operated at Borovoye, each using several different seismometers and different gain levels. Digital data were recorded by three different Russian registration systems, called KOD, STsR-SS, and STsR-TSG; Inst. Type = instrument used; KODb = three-component high-gain and a vertical-component low-gain; KODm = three-component low-gain and a vertical-component high-gain system; seismic station SS = STsR-SS system; typical seismic station TSG=STsR-TSG system [5].

The regional travel-time curve $t_{p0} = F(\Delta°)$ up to on the traces USSR PNEs – BRVK is presented in Figure 3. It was built under data from the table. Axis X shows the distance between PNE and BRVK, axis Y–P-wave travel time. Note, that the points well fit with a linear function both for regional (Figure 3) either for local distances (Figures 4-6). However, the gradient of the line at the close areas (2–12° shown in Figure 4) is greater than at the further intervals (as 13–18° in Figure 5 and 18-30° in Figure 6 with the same slope of the travel-time curve).

The Azgir A-3-1 and Azgir A-3-2 explosions were performed in the same well. The first is 1971-12-22 with a capacity of 64 kT at a depth of 986 meters with m_b = 6.0, the second is 1976-03-29 with a capacity of 10 kT with m_b = 4.3 [4, 8]. The P-wave travel time of the second explosion according to the archive of Expedition No. 4 of the Special Sector of the IPE of the USSR Academy of Sciences was determined with a small accuracy due to the high level of microseisms.

When reformatting digital seismograms, sometimes there was a failure in the date and time. In this case, a time lapse of –1 min was detected in the record of the explosion of 27th October 1984 named Vega 5-1 at the STsR-SS. At STsR-TSG time is correct.

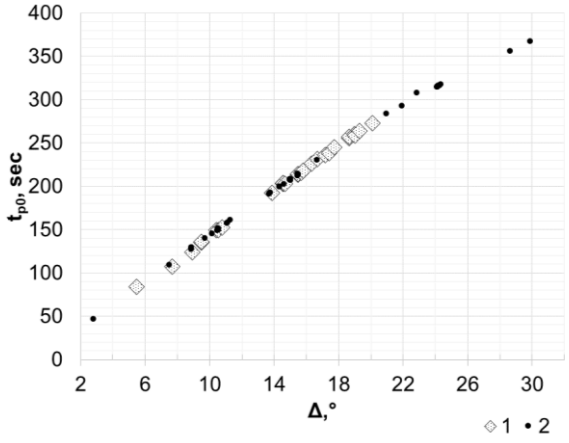

Figure 3. Travel-time curve $t_{p0} = F(\Delta°)$ P-wave for «USSR Peaceful Nuclear Explosions – observatory «Borovoye» (symbols 1 – after [4], 2 – after [1, 2])

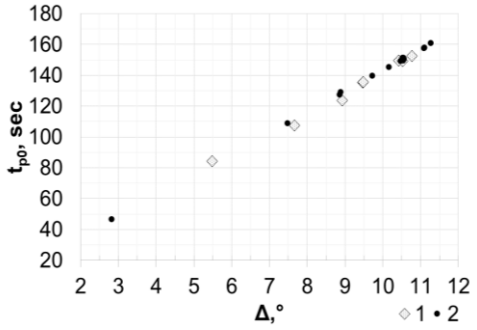

Figure 4. Local travel-time curve $t_{p0} = F(\Delta°)$ P-wave for «USSR Peaceful Nuclear Explosions – observatory «Borovoye», Δ° = 2 – 12 (symbols 1 – after [4], 2 – after [1, 2])

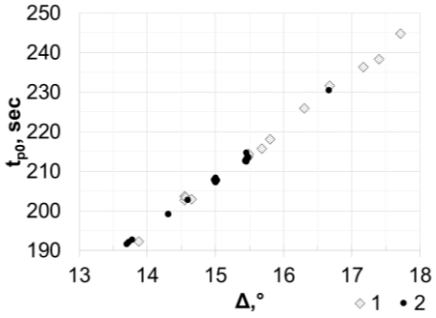

Figure 5. Local travel-time curve $t_{p0} = F(\Delta°)$ P-wave for «USSR Peaceful Nuclear Explosions – observatory «Borovoye», Δ° = 13–18 (symbols 1 – after [4], 2 – after [1, 2])

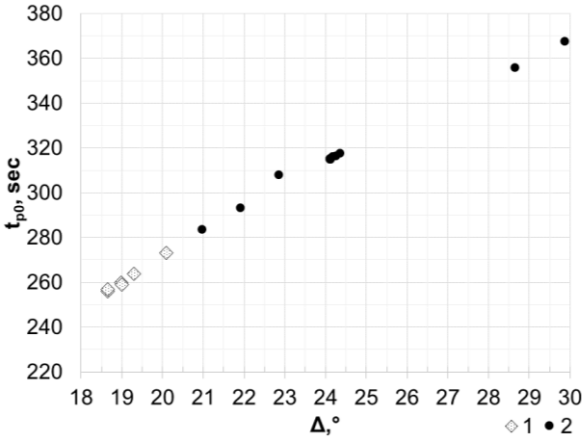

Figure 6. Local travel-time curve $t_{p0} = F(\Delta°)$ P-wave for «Peaceful Nuclear Explosions USSR – observatory «Borovoye», Δ° = 18–30 (symbols 1 – after [4], 2 – after [1, 2])

It is possible to document the time of occurrence of failures: in the process of registration or reformatting. According to the regulations of registration of underground nuclear explosions established by Expedition No. 4 of the Special Sector of the IPE of the USSR Academy of Sciences (now Geophysical Observatory "Borovoye"), magnetic digital recording was duplicated in three copies for storage. But, most importantly, the entry of a signal on the vertical component of each short-period set of equipment was necessarily decoded at a high sweep speed: up to 28 mm/s for STsR-TSG and 9 mm/s for KOD and STsR-SS. At the same time, it was bound to real-time and the uniformity of the decoding speed control within 0.2 sec on the STsR-TSG and 0.6 sec on the records of the KOD and STsR-SS. These decoded records are stored in the archive "Borovoye". Due to modern technology, it is sufficient to simply digitize, measure, and make corrections to the records of the modern PNEs database.

The coordinates of 82 Peaceful Underground Explosions as a result of the analysis of satellite images, regional seismic data, and visits to the epicenters are specified in [1, 2]. Figures 4–6 show that, according to [4], the parameters of the USSR PNEs epicenters practically do not misfire from the refined local travel-time curves according to [1, 2]. Unfortunately, there are still quite a lot of USSR PNEs epicenters require the refinement of coordinates.

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REFERENCES

1. Mackey, K.G. Improvement of GT classification of Soviet PNEs / K.G. Mackey, K. Fujita // J. NNC RK Bulletin, 2014. – No 2. – P. 62–64.
2. Mackey, K.G. Improvement of GT classification of Soviet PNEs / K.G. Mackey, K. Fujita, A. Abishev, E. Bergman // J. NNC RK Bulletin, 2016. – No. 2. – P. 123–127.

3. An, V.A. The travel-time curves of “Borovoye” Geophysical Observatory constructed using underground nuclear tests / V.A. An, P.B. Kaazik, T. V. Chelyubeyeva // J. NNC RK Bulletin, 2016. – No. 2. – P. 90–95.
4. Sultanov, D.D. A Seismic Source Summary for Soviet Peaceful Nuclear Explosions / D.D. Sultanov, J.R. Murphy, Kh.D. Rubystein // Bull. Seism. Soc. Am., 1999. – Vol. 89, No. 3, – P. 640–647.
5. An, V.A. A digital seismogram archive of nuclear explosion signals, recorded at the Borovoye Geophysical Observatory, Kazakhstan, from 1966 to 1996 / V.A. An, V.M. Ovtchinnikov, P.B. Kaazik, V.V. Adushkin, I.N. Sokolova, I.B. Aleschenko, N.N. Mikhailova, W-Y. Kim, P.G. Richards, H.J. Patton, W.S. Phillips, G. Randall, D. Baker // GeoResJ, 2015. – No. 6. – P. 141–163.
6. An, V.A. Time corrections for digital seismograms at “Borovoye” Geophysical Observatory 1966 – 1995 / V.A. An, P.B. Kaazik, T. V. Chelyubeyeva // J. NNC RK Bulletin, 2016. – No. 3. – P. 30–35.
7. An, V.A. About normals of magnet digital records from Geophysical Observatory «Borovoye» / V.A. An, I. P. Bashilov, P.B. Kaazik, V.A. Konovalov // J. NNC RK Bulletin, 2010. – No. 3. – P. 62–69.
8. Nuclear test of USSR. – M.: IzdAT, 1997. – 304 p.

КСРО БЕЙБІТ ЯДРОЛЫҚ СЫНАУЛАРЫ, «БУРАБАЙ» ГЕОФИЗИКАЛЫҚ ОБСЕРВАТОРИЯСЫ

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Жұмыста кеңестік бейбіт ядролық сынаулар (БЯС) туралы түзетілген жиынтық деректері берілген, Макей, Фуджита ж.б. авторлардың жұмыстарынан нақтыланған координаттар туралы ақпаратты есепке ала отырып. Нәтиже ретінде мақалада, БЯС үшін есептелген эпиорталықтық қашықтары келтірілген, годографтары салынған және «Бурабай» геофизикалық обсерваториясынан, 1966 жылдан КСРО Ғылым Академиясы Жер физикасы институтының Арнайы Секторының № 4 Экспедициясы жүргізген мониторингі уақытында цифрлық форматында тіркелеген БЯС географиялық координаттарына дейін азимуттары көрсетілген.

МИРНЫЕ ЯДЕРНЫЕ ИСПЫТАНИЯ СССР, ГЕОФИЗИЧЕСКАЯ ОБСЕРВАТОРИЯ «БОРОВОЕ»

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Приведены сводные выправленные данные о советских мирных ядерных взрывах (МЯВ) с авторскими поправками и с учетом информации об уточненных координатах из работ авторов Макей, Фуджита и др. В качестве результата в статье приведены рассчитанные эпицентральные расстояния для МЯВ, построены годографы и указаны азимуты от Геофизической обсерватории «Боровое» на МЯВ (с уточненными географическими координатами), которые были зарегистрированы в цифровом формате во время мониторинга, проводимого Экспедицией № 4 Специального Сектора Института физики Земли Академии Наук СССР с 1966 г.