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Analysis of Registration and Processing of Seismological Data in the Republic of Armenia from 1991 to 1998

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Abstract

Determining the coordinates of earthquakes is a priority task in seismically active regions, the accuracy of which is subject to ever-increasing demands. The accuracy and completeness of the data determine the correctness of solving prognostic and structural problems of modern seismology, as well as problems of geodynamics of seismic regions. The work analyzes the registration and processing of Republic Armenia (RA) seismological data. It has been shown that the accuracy of processing Republic Armenia seismological information is generally insufficient to obtain reliable results when determining the coordinates of earthquake hypocenters. From the results obtained it follows that in order to build an accurate and reliable database of seismological information, it is necessary to redefine the existing data using new processing methods, a more accurate model of the structure of the earth, and also to increase the efficiency of the existing observation system. This information is critical to informing earthquake preparedness and mitigation conditions.

Subject Areas

Environmental Sciences, Geophysics, Natural Geography

Keywords

Earthquake, Hypocenter, Observing System, Algorithm, Velocity Curve, Wadati Diagram

1. Introduction

It is well known that for the successful forecast of strong earthquakes, seismic zoning and earthquake-resistant construction, it is necessary to have an accurate

understanding of the distribution of earthquake hypocenters in the study area.

For this purpose, when processing the initial seismological information, this work uses the averaged velocity curve given by [1] [2] and the HYPOBUR algorithm.

To determine the coordinates of earthquakes, currently, mainly variations of the Geiger method are used [3] [4]. When determining the coordinates of earthquake hypo-centers, the arrival times of P- and S-waves, seismic wave hodographs, or velocity columns for the region being studied are used as initial data.

To determine the location of earthquake sources with high accuracy, it is necessary to have a fairly detailed understanding of the deep structure of the earth's crust and upper mantle, where processes associated with the preparation of an earthquake occur. Therefore, errors in determining the coordinates of earthquake hypocenters also depend on the choice of the velocity model of the region being studied.

Despite the fact that a number of works have been devoted to the structure of the earth's crust and upper mantle in the Caucasus, and in particular on the territory of Armenia, existing hodographs do not allow determining the coordinates of earthquake hypocenters with the required accuracy [5] [6] [7]. Until recently, to determine the coordinates of earthquake hypocenters, the Levitskaya hodograph [8] or the Jeffery's Bullen hodograph was used with station corrections, which should take into account the conditions under the stations [9] [10] [11].

According to the authors themselves, they are local in nature and cannot generally ensure the necessary accuracy of data processing.

The work [12] constructed a velocity curve for the crust of Armenia. For this purpose, all available data on velocities were used, obtained on the basis of materials from regional profiles of the ECWM (Earthquake Conversion Wave Method) and DSS (Deep Seismic Sounding) [12]. Each point of the studied environment is mainly selected in such a way that its location coincides with the intersection of the DSS and ECWM pro-files.

To study the deep structure of the territory of the Republic of Armenia, in addition to data obtained using the methods of converted waves and deep seismic sounding, it is advisable to use information about nearby earthquakes. Such data were accumulated in sufficient quantities in 1971-1990 when the network of seismic stations was in the RA Academy of Sciences system.

A seismological observation system that plays a decisive role in seismically active zones for the period 1971-1990. Functioned normally, providing real-time monitoring. Almost 1.500 earthquakes were recorded using 13 stations, i.e. there is an average of 75 earthquakes per year.

From 1991 to 2010, the number of seismic stations increased to 34. From 1991 to the present, bulletins and catalogs have not been published in Armenia. Data for processing was taken from the international website https://isc.ac.uk/.

2. Distribution of Epicenters

Despite the increase in the number of seismic stations during the period 1991-1998, the system recorded 209 earthquakes, of which only 65 occurred on the territory of the Republic of Armenia, i.e. in 8 years there were only 65 earthquakes.

It should be noted that out of 209 recorded earthquakes, according to the bulletins, it is impossible to determine the coordinates of 85, but they are indicated in the catalogs. It is not clear how they were determined. A study of the catalogs showed that for 1991, 1992, 1993 only one earthquake was presented. No data is available for 1994. The catalogs present basic data on earthquakes from 1995 to 1997. It should be noted that monthly data is presented only for 1995 and 1996, and 1997 is represented by only two months (January and February), and in 1998 there were no earthquakes. It is obvious that the observation system did not function fully. Seismic events were recorded by only 3 - 4 stations out of 34.

Figure 1 shows the distribution of epicenters of 124 earthquakes, according to the National Seismic Protection Service of the Republic of Armenia (NSPS), data were taken from the international website https://isc.ac.uk/, the results are shown in Table 1.

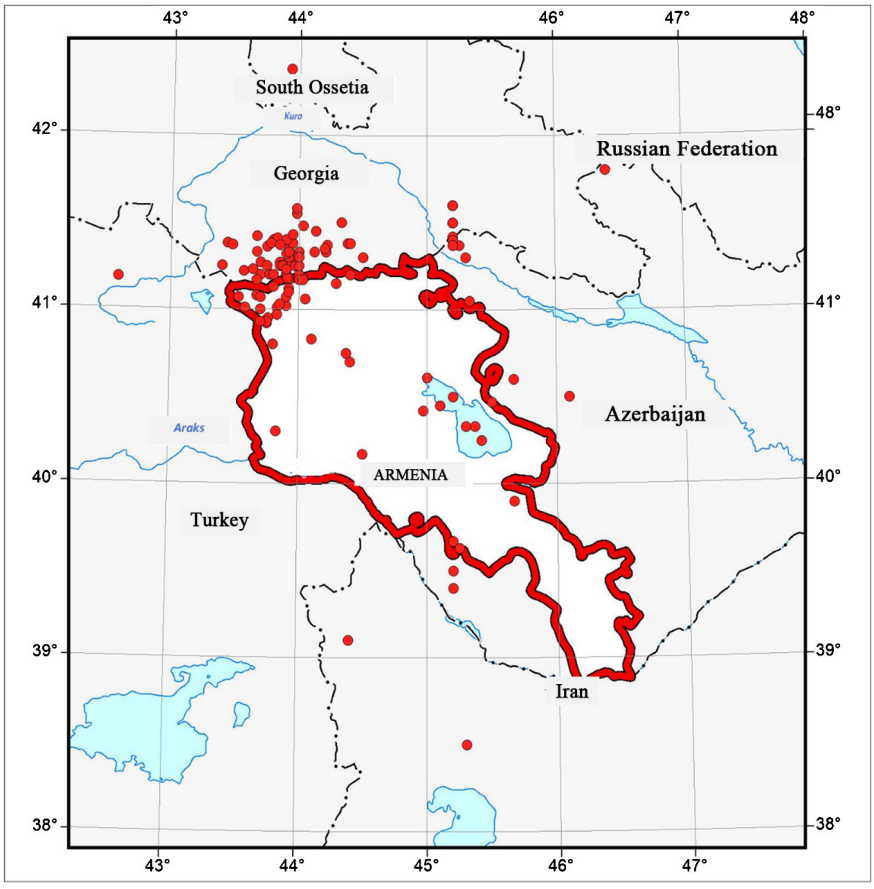


Figure 1. Distribution of epicenters of 124 earthquakes according to catalog data.

As can be seen from Figure 1, the epicenters of earthquakes have a wide-spread, a significant part of which is located outside the territory of the Republic of Armenia, particularly, in Georgia, Iran, Azerbaijan, Turkey, South Ossetia, and Russia.

Table 1 presents a consolidated catalog of 124 earthquakes according to the NSPS data. The indicated 124 earthquakes are characterized by M ≤ 4.5.

Table 1. Consolidated catalog of 124 earthquakes based on data NSPS.

N	Date	φ	λ	H	N	Date	φ	λ	H
1	10.10.1991	41.38	43.44	5	63	05.03.1996	40.8	43.8	3
2	18.02.1992	41.22	43.57	5	64	06.03.1996	41.25	43.87	3
3	08.12.1992	40.25	45.42	10	65	06.03.1996	41.25	43.87	3
4	21.03.1993	41.37	44.22	5	66	06.03.1996	41.25	43.87	3
5	02.01.1995	41.2	43.7	10	67	16.03.1996	40.45	45.1	3
6	02.01.1995	41.27	43.85	10	68	24.03.1996	41.2	43.9	3
7	06.01.1995	41.33	43.92	10	69	26.03.1996	41.17	44	3
8	06.01.1995	41.08	43.67	3	70	27.03.1996	41.3	43.95	3
9	07.01.1995	41.33	43.92	10	71	30.03.1996	40.33	45.37	3
10	07.01.1995	41.33	43.92	10	72	31.03.1996	41.27	43.7	3
11	05.03.1995	41.01	43.58	5	73	04.04.1996	41.17	44.03	5
12	16.03.1995	41.17	43.92	5	74	10.04.1996	41	43.7	5
13	25.03.1995	41.02	43.9	5	75	11.04.1996	41.03	43.85	5
14	28.03.1995	41.07	43.7	5	76	13.04.1996	40.61	45	5
15	28.03.1995	40.7	44.4	5	77	27.04.1996	40.83	44.1	3
16	01.04.1995	41.01	43.83	0	78	27.04.1996	41.23	43.64	5
17	01.04.1995	41.2	43.77	0	79	30.04.1996	41.2	43.9	3
18	01.04.1995	39.4	45.2	0	80	01.05.1996	41.2	43.9	3
19	02.04.1995	41.2	43.77	5	81	02.06.1996	40.95	43.76	5
20	05.04.1995	41.07	43.53	3	82	02.06.1996	40.93	43.75	3
21	10.04.1995	41.38	44.38	5	83	09.06.1996	40.93	43.7	10
22	10.04.1995	41.33	44	5	84	21.08.1996	41.2	43.8	5
23	10.04.1995	41.48	44.03	5	85	15.10.1996	41.3	43.98	5
24	24.04.1995	41.12	43.92	5	86	20.10.1996	41.33	43.67	5
25	24.04.1995	40.6	45.67	5	87	21.10.1996	41.2	43.9	5
26	07.05.1995	38.5	45.3	10	88	23.10.1996	41.1	43.92	5
27	10.05.1995	39.1	44.4	10	89	03.11.1996	39.67	45.2	3
28	15.05.1995	41.5	44.33	10	90	04.11.1996	40.17	44.5	5
29	20.05.1995	40.92	43.75	10	91	04.11.1996	41.2	44.4	5
30	20.05.1995	39.9	45.67	10	92	08.11.1996	41.25	43.75	3
31	26.05.1995	41.25	43.92	10	93	08.11.1996	41.45	44.13	5
32	29.05.1995	41.8	46.4	25	94	15.11.1996	41.3	43.92	3
33	29.05.1995	41.25	43.85	5	95	19.11.1996	41.25	43.97	3
34	03.06.1995	41.36	43.75	5	96	20.11.1996	41.33	44.12	3
35	03.06.1995	41.18	44.03	5	97	12.12.1996	39.5	45.2	5
36	03.06.1995	41.33	44.21	5	98	03.01.1997	41.55	43.98	0
37	03.06.1995	40.5	45.2	10	99	03.01.1997	41.58	43.98	0
38	04.06.1995	40.3	43.83	20	100	04.01.1997	41.35	44.2	0
39	05.06.1995	41.18	42.59	0	101	04.01.1997	41.2	43.9	5
40	10.06.1995	41.15	44.29	5	102	06.01.1997	42.38	43.93	0
41	05.01.1996	41.2	44	3	103	06.01.1997	41.18	43.91	5

Continued

42	06.01.1996	40.42	44.97	0	104	15.01.1997	39.63	45.25	10
43	11.01.1996	41.37	43.92	3	105	15.01.1997	41.3	45.3	5
44	11.01.1996	41.37	43.92	3	106	20.01.1997	41.06	44.05	5
45	16.01.1996	41.25	43.87	3	107	21.01.1997	41.41	43.83	5
46	17.01.1996	41.4	43.8	0	108	22.01.1997	41.38	43.95	4
47	18.01.1996	40.5	46.1	0	109	23.01.1997	41.32	43.9	5
48	21.01.1996	40.47	45.5	2	110	25.01.1997	41.17	43.67	5
49	22.01.1996	41.07	43.9	4	111	29.01.1997	41.38	44.4	5
50	22.01.1996	41.42	43.67	2	112	29.01.1997	41.38	43.78	5
51	23.01.1996	40.33	45.3	2	113	04.02.1997	41.37	45.2	10
52	25.01.1996	41.42	45.2	5	114	07.02.1997	41.37	43.48	5
53	26.01.1996	41.13	43.8	5	115	10.02.1997	40.97	43.83	5
54	29.01.1996	41.6	45.2	0	116	10.02.1997	41.4	43.9	5
55	29.01.1996	41.6	45.2	0	117	12.02.1997	41.37	43.85	5
56	30.01.1996	41.5	45.2	5	118	14.02.1997	41.3	44.5	5
57	30.01.1996	41.5	45.2	5	119	16.02.1997	41.33	43.92	5
58	04.02.1996	41.05	45.33	3	120	16.02.1997	41.43	43.95	5
59	15.02.1996	41.37	45.25	5	121	23.02.1997	41.25	43.4	5
60	17.02.1996	43.62	43.17	4	122	24.02.1997	41.23	43.9	3
61	20.02.1996	40.75	44.37	5	123	26.02.1997	41.25	44	5
62	20.02.1996	41.4	45.2	5	124	26.02.1997	41.3	44	5

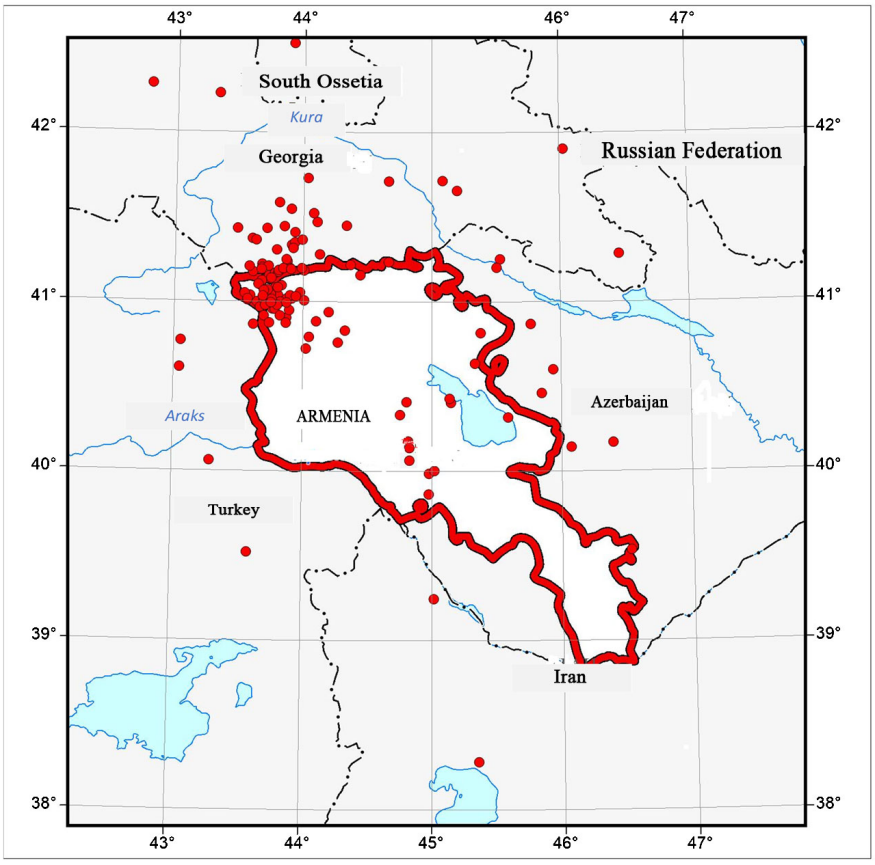


Figure 2. Distribution of epicenters of 124 earthquakes after recalculation.

Figure 2 shows the distribution of epicenters of 124 earthquakes after recalculation. The results were obtained using a new averaged velocity curve [12].

Table 2. Results of 124 earthquakes after recalculation using the velocity curve.

N	Date	φ	λ	H	N	Date	φ	λ	H
1	10.10.1991	40.5982	43.043	0	63	05.03.1996	40.8983	43.863	16.38
2	18.02.1992	40.7568	43.0483	0	64	06.03.1996	41.0381	43.705	0.8
3	08.12.1992	39.865	44.9795	61.4	65	06.03.1996	41.0318	43.6901	0
4	21.03.1993	40.9915	43.6317	0	66	06.03.1996	41.0069	43.6842	4.7
5	02.01.1995	41.2134	43.6688	3	67	16.03.1996	40.6384	45.3295	50.2
6	02.01.1995	41.1691	43.5988	0.8	68	24.03.1996	40.972	43.6977	1.2
7	06.01.1995	41.3286	43.8974	2.3	69	26.03.1996	41.2145	44.3573	23.36
8	06.01.1995	40.9645	43.7327	27.24	70	27.03.1996	41.0301	43.8894	19.47
9	07.01.1995	41.1459	43.7222	21.07	71	30.03.1996	40.3217	45.5865	31.02
10	07.01.1995	41.161	43.7702	26.54	72	31.03.1996	41.0348	43.739	9.19
11	05.03.1995	41.0014	43.5583	8.09	73	04.04.1996	41.0487	43.9665	1.2
12	16.03.1995	41.2302	43.8651	7	74	10.04.1996	40.9492	43.7719	0
13	25.03.1995	40.9343	44.1922	11.49	75	11.04.1996	41.0624	43.715	18.77
14	28.03.1995	41.0863	43.6647	6	76	13.04.1996	40.0037	45.0219	3.1
15	28.03.1995	42.2188	43.3089	120.45	77	27.04.1996	40.8266	44.3203	0
16	01.04.1995	41.1941	43.6685	20.47	78	27.04.1996	41.3097	43.9095	0.5
17	01.04.1995	41.1163	43.6687	12.09	79	30.04.1996	41.0884	43.8222	13.29
18	01.04.1995	39.5425	46.5298	0	80	01.05.1996	41.7101	44.6497	35.5
19	02.04.1995	40.9983	43.7204	1.2	81	02.06.1996	40.9918	43.8149	5.9
20	05.04.1995	41.1681	43.7961	39.68	82	02.06.1996	40.9724	43.7903	4.4
21	10.04.1995	41.155	44.4346	46.93	83	09.06.1996	40.9104	43.8131	10.19
22	10.04.1995	41.1781	43.7984	25.05	84	21.08.1996	41.0284	43.5792	21.16
23	10.04.1995	41.1906	43.8866	29.73	85	15.10.1996	41.0414	43.5363	17.38
24	24.04.1995	41.4653	44.0942	25.15	86	20.10.1996	41.3561	43.6196	19.37
25	24.04.1995	40.8739	45.7608	14.88	87	21.10.1996	41.0061	43.7463	5.6
26	07.05.1995	38.2852	45.3734	12.79	88	23.10.1996	41.0765	43.7934	8.39
27	10.05.1995	41.2921	46.4493	15.58	89	03.11.1996	39.5124	43.5918	18.87
28	15.05.1995	41.423	43.4723	30.93	90	04.11.1996	40.8188	45.3731	38.88
29	20.05.1995	40.9496	43.7536	5.2	91	04.11.1996	41.2334	44.6551	16.18
30	20.05.1995	39.9868	44.9808	41.37	92	08.11.1996	41.7238	44.0168	27.44
31	26.05.1995	41.0732	43.7709	13.19	93	08.11.1996	40.9426	43.8846	0
32	29.05.1995	41.9086	46.0137	114.46	94	15.11.1996	41.4033	43.9216	12.79
33	29.05.1995	41.2002	43.5699	16.08	95	19.11.1996	41.1851	43.8941	0
34	03.06.1995	41.4248	43.7026	10.49	96	20.11.1996	41.0581	43.6849	10.59
35	03.06.1995	40.9601	43.6567	19.17	97	12.12.1996	39.2467	45.0239	0
36	03.06.1995	40.858	43.6076	12.69	98	03.01.1997	41.5782	43.7966	17.78
37	03.06.1995	40.0513	43.2897	0	99	03.01.1997	41.5171	44.0655	2.3
38	04.06.1995	41.0305	43.7959	0	100	04.01.1997	41.5406	43.8907	8.09
39	05.06.1995	42.5195	43.8928	89.96	101	04.01.1997	41.1782	43.9966	36.99
40	10.06.1995	40.879	44.0955	0	102	06.01.1997	42.2697	42.7754	38.28

Continued

41	05.01.1996	41.0109	43.8642	2.6	103	06.01.1997	41.1915	43.9781	0.5
42	06.01.1996	40.4084	44.8034	8.59	104	15.01.1997	40.177	46.3957	0
43	11.01.1996	41.0953	43.6414	29.93	105	15.01.1997	41.2054	45.4953	17.68
44	11.01.1996	41.3432	43.9219	46.83	06	20.01.1997	41.0015	43.9998	2
45	16.01.1996	41.2427	43.8576	0	107	21.01.1997	41.4377	43.8383	14.28
46	17.01.1996	41.1895	43.8335	21.36	108	22.01.1997	41.3596	43.9798	2.4
47	18.01.1996	40.1492	46.0742	33.51	109	23.01.1997	41.2031	43.7189	25.85
48	21.01.1996	40.4661	45.8459	24.35	110	25.01.1997	41.1836	43.6645	20.87
49	22.01.1996	41.0115	43.9042	9.49	111	29.01.1997	40.7174	44.0189	14.38
50	22.01.1996	41.3642	43.59	19.37	112	29.01.1997	41.2992	43.7811	28.54
51	23.01.1996	40.6065	45.9346	59.32	113	04.02.1997	40.332	44.7539	0
52	25.01.1996	41.2552	45.5219	34.41	114	07.02.1997	40.8676	43.8599	13.09
53	26.01.1996	41.1321	43.741	21.86	115	10.02.1997	40.9873	43.8621	15.88
54	29.01.1996	40.4064	45.1457	24.55	116	10.02.1997	41.0077	43.5594	19.17
55	29.01.1996	41.6578	45.1837	27.74	117	12.02.1997	40.9867	43.7414	1.1
56	30.01.1996	40.1766	44.8187	0	118	14.02.1997	40.7863	44.0417	0
57	30.01.1996	40.4303	45.1349	31.22	119	16.02.1997	41.0249	43.6777	7.9
58	04.02.1996	40.1562	44.8394	0	120	16.02.1997	40.9088	43.6881	17.78
59	15.02.1996	41.7155	45.0694	137.7	121	23.02.1997	41.2747	44.1167	2.8
60	17.02.1996	43.5125	42.9912	58.43	122	24.02.1997	41.4456	44.3231	0
61	20.02.1996	40.7557	44.2659	22.16	123	26.02.1997	41.0246	43.935	13.29
62	20.02.1996	40.0642	44.8275	0	124	26.02.1997	40.8677	43.7304	3.2

3. Distribution of Focal Depths

To compare the results of the focal depths, the distribution of hypocenters in the latitudinal (**Figure 3(a)**) and longitudinal planes (**Figure 3(b)**) was constructed according to the catalog data for 1991-1998.

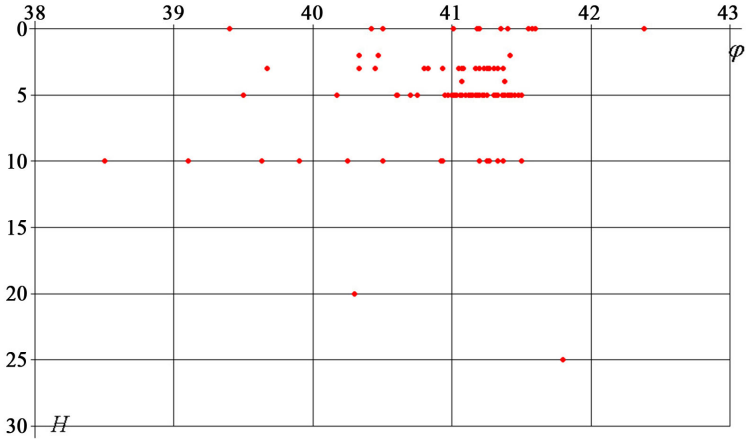
As can be seen from **Figures 3(a)-(b)**, earthquake hypocenters, as one would expect, are mainly distributed at depths with discrete values of 0, 5, 10, 15, 20, 25 km. Such a pattern in the distribution of focal depths has not been established. Consequently, the depths of the lesions were not determined accurately. The main reason for this distribution is that the location of the global minimum in this case is sought for a local minimum at the interval [0; 25] km.

In **Figures 4(a)-(b)** shows the distribution of earthquake hypocenters after recalculation for 1991-1998.

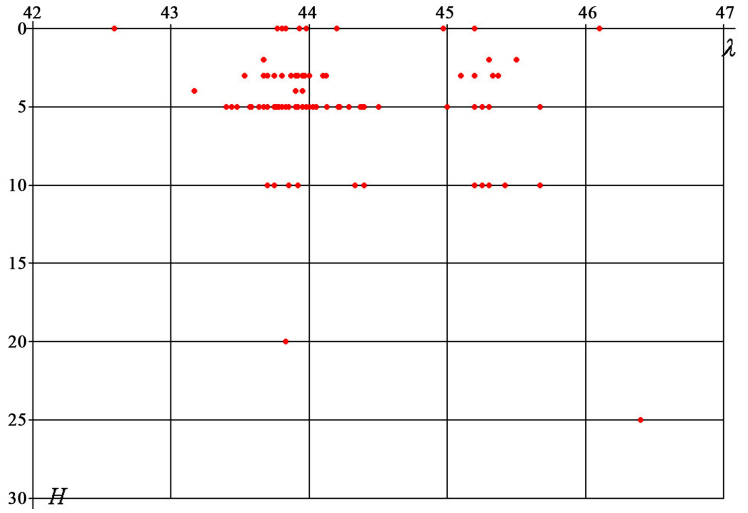
From **Figures 4(a)-(b)** it is clear that the depths of the over-determined earth-quake hypocenters are not located discretely, as presented in the NSPS results. These results indicate that the depth hotspots cover a larger area in depth, up to 140 km, rather than 25 km as indicated in the NSPS results.

Most of the earthquakes listed in **Table 1** (124 earthquakes according to the NSPS data) were recorded by 3 or 4 stations. With such data, it is difficult to guarantee high accuracy of processing results.

Wadati plot for 124 earthquakes for the period 1991-1998 according to the NSPS data and the results after recalculation are given in **Figures 5(a)-5(b)**.

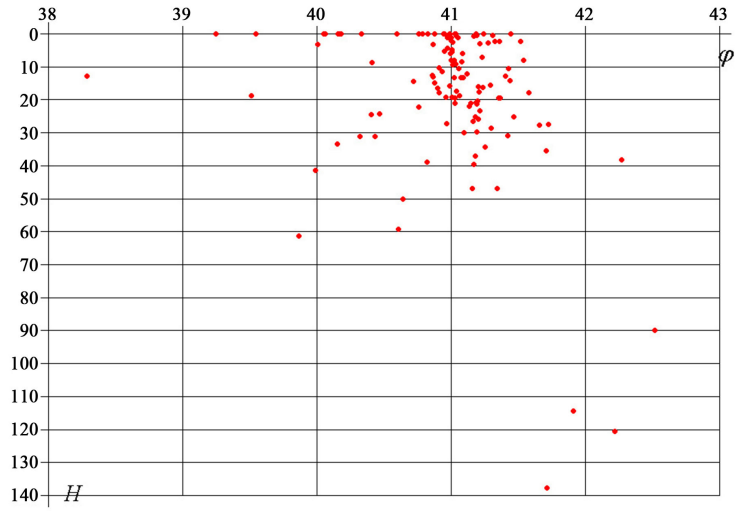


(a)

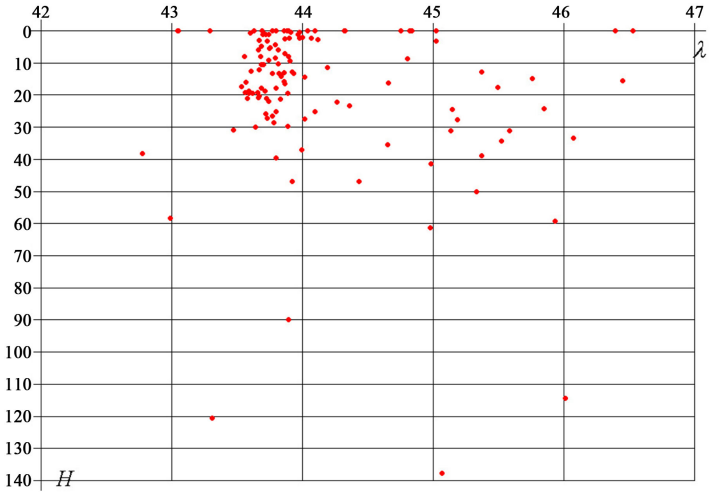


(b)

Figure 3. (a) Distribution of hypocenters in the latitudinal plane for 1991-1998 according to catalog data; (b) Distribution of hypocenters in the longitudinal plane for 1991-1998 according to catalog data.

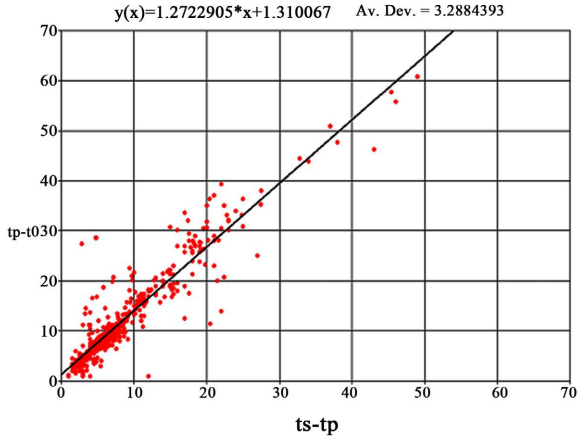


(a)

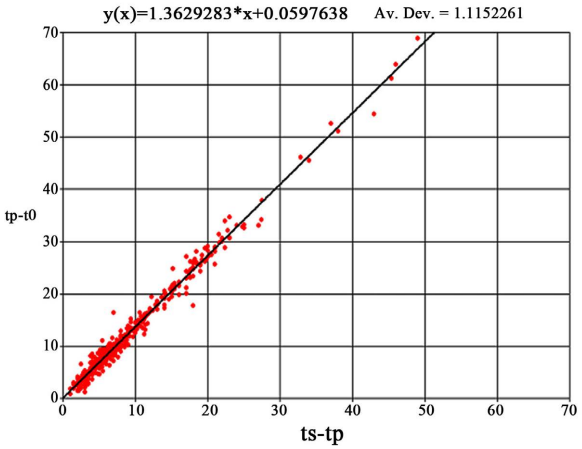


(b)

Figure 4. (a) Distribution of epicenters in the latitudinal plane after recalculation for 1991-1998; (b) Distribution of hypocenters in the longitudinal plane after recalculation for 1991-1998.



(a)



(b)

Figure 5. (a) Wadati plot for 124 earthquakes for the period 1991-1998 according to the NSPS; (b) Wadati plot for 124 earthquakes for the period 1991-1998 after recalculation.

In Figure 5(a) there is a large scatter, which indicates that the times at the source were obtained inaccurately. Comparing Figure 5(b) with Figure 5(a) it is clear that after recalculation more reliable results were obtained, i.e. the environmental model was chosen more accurately.

4. Conclusions

The results of processing for 1991-1998 indicate that the registration and processing of source data was not carried out properly. When determining the main parameters of earthquake hypocenters, in addition to random errors, systematic errors caused by an inaccurate choice of the velocity structure of the studied region have a great influence.

The use of the average velocity curve, as shown by the results obtained, makes it possible to determine the coordinates of earthquake hypocenters, including the depth of the hypocenter, which can reach 60 km. It is shown that during the study period, the distribution of hypocenters obtained using the averaged velocity curve turns out to be less compact, and earthquake epicenters have a smaller scatter in the study area than those obtained from the catalog of the Armenian seismic service. Finally, to create an accurate and reliable seismological information base, it is necessary to redefine existing data using new methods for processing a more accurate model of the structure of the earth, as well as improve the efficiency of the existing observing system.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Burmin, V.Y. (2019) Some Inverse Kinematic Problems of Seismology. The Science, Moscow.

[2] Burmin, V.Y., Avetisyan, A.M., Karapetyan, D.K. and Oganesyan, A.O. (2021) Construction of the Average Velocity Curve of the Earth's Crust on the Territory of Armenia Based on Profile Seismic Observations. *Seismic Instruments*, **57**, 29-41.

[3] Geiger, L. (1910) Herdbestimmung bei Erdbeben aus den Ankunftszeiten. *K. Gesell, Wiss Goett*, **4**, 331-349.

[4] Geiger, L. (1912) Probability Method for Determination of Earthquake Epicenters from Arrival Time Only. *Saint Louis University*, **8**, 60-71.

[5] Avetisyan, A.M., Burmin, V.Y., Oganesyan, A.O. and Kazaryan, K.S. (2015) Analysis of Initial Data and Results of Processing Seismological Information on the Territory of Armenia Izvestiya NAS RA. *Earth Sciences*, **68**, 31-43.

[6] Burmin, V.Y., Avetisyan, A.M. and Gevorkyan, K.V. (2006) Analysis of the Initial Data of the Regional Seismological Network of the Caucasus and Construction of an Averaged Velocity Curve Based on Them. *Volcanology and Seismology*, **1**, 67-68.

[7] Burmin, V.Y., Shemeleva, I.B., Fleifel, L.D., Avetisyan, A.M. and Kazaryan, K.S. (2016) Results of Processing Seismological Data for the Territory of Armenia. *Issues in Engineering Seismology*, **43**, 29-38.

[8] Levitskaya, A.Y. and Lebedeva, T.M. (1953) Hodograph of Seismic Waves of the

Caucasus. Quarterly Seismological Bulletin, Tbilisi, 51-59.

[9] Sahakyan, A.A. (1981) Epicentral Corrections to the Standard Jeffreys-Bullen Hodograph for the Armenian Highlands. SSR Earth Sciences, Yerevan.

[10] Karapetyan, N.K. (1974) Hodographs of Seismic Waves for Earthquakes in the Armenian Highlands, SSR, Yerevan, 142 p.

[11] Slavina, L.B., Bagramyan, A.K. and Mkrtchyan, M.B. (1983) Application of an Area Hodograph to Clarify the Parameters of Earthquake Epicenters in the Armenian Highlands. *Izvestia of the Academy of Sciences of the Arm SSR Earth Science*, **3**, 56-61.

[12] Burmin, V.Y., Avetisyan, A.M., Karapetyan, D.K. and Oganesyan A.O. (2022) Construction of the Average Curve of the Seismic Velocity of the Crust in the Territory of Armenia from Profile Seismic Observation Data. *Seismic Instruments*, **58**, 26-31 https://doi.org/10.3103/S0747923922010042