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Joint Epicentre Determination of Soviet Underground Nuclear Explosions 1973-89 at the Semipalatinsk Test Site

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SUMMARY

This report gives estimated epicentres for underground nuclear tests at the Soviet Semipalatinsk test site for the period 1973-1989 inclusive. These estimates are obtained using the Joint Epicentre Determination technique on tests in the Shagan, Degelen and Konystan areas of the test site restrained using data released on the locations of some tests all of which took place before 1973. The estimated epicentres should therefore be free from bias which can result from incorrect assumptions regarding the restrained epicentres required to fix the overall location of each group.

1. INTRODUCTION

Locations of underground nuclear tests are important to seismologists investigating the structure of the earth as well as those researching into the size and nature of the explosion sources using the generated seismic signals. The release in 1989 in the paper by Bocharov, Zelentsoz & Mikhailov, (1) of epicentre, depth and yield information for many Soviet tests at the Semipalatinsk test site for the period 1961-72 is thus to be welcomed. Clearly knowledge of the true epicentres of tests since 1972 would also be useful but until they are released it is important to have reliable estimated values. To satisfy this need, this report gives estimates of epicentres obtained by a joint epicentre determination (JED) technique, of many explosions not included in the paper of Bocharov et al (1).

2. JOINT EPICENTRE DETERMINATION

The Joint Epicentre Determination (JED) method described by Douglas 1967 (2) was used to relocate the explosions. Data used are the P wave arrival time data taken from the International Seismological Centre (ISC) bulletin tapes for the period 1964-87. For the more recent period 1988-89 the data were taken from the Earthquake Data reports (EDR's) published by the US Department of the Interior, Geological Survey. JED is most effective when all the events are from a small area so that deviations from the assumed travel time curve can be corrected by a single term for each station. The explosions for the Shagan, Degelen and Konystan sites were therefore relocated as three separate groups. To obtain stable solutions the epicentre and origin time of at least one explosion from each group must be restrained. The data given by Bocharov et al (1) were used for this purpose thus giving unbiased absolute locations for all 3 groups. The number of restrained epicentres and origin times were 7 for Shagan, 68 for Degelen and 14 for Konystan.

A system of weighting the arrival time readings was used to remove gross errors and to allow for variations in the quality of the arrival time measurements between stations. Gross errors were removed by the method of uniform reduction (Jeffreys (3)). The standard deviation (SD) of the residuals for all sites are small (0.20 for Shagan, 0.24 for Degelen and Konystan). Arrival times with residuals in excess of about 2 SD are effectively given zero weight. With the Shagan and Degelen data the large number of readings enable the SD of the residuals to individual stations to be estimated and each station's data were weighted to allow for variation in this.

3. RESULTS

The epicentres for Shagan, Degelen and Konystan are given in tables 1-3 and plotted in figures 1-3 respectively. The restrained epicentres are also included and are plotted as stars in the figures. The 95% confidence limits and areas for the Shagan epicentres suggest that the most location errors should be no more than 1 km. The smaller number of arrival readings available for most Degelen and Konystan relocations result in somewhat larger limits but most should be within 2 km of true.

It is interesting to compare results presented here with those published in Marshall, Bache & Lilwall(4). Marshall et al (4) located many of the epicentres in the Semipalatinsk site for the period up to 1982 using the same technique used here but did not have the large number of epicentres given in Bocharov et al (1) to restrain the groups. Instead the overall positions of all three sites were restrained using a single explosion (650115) in the Shagan test site whose location was inferred from the crater visible on satellite photographs. Considering only the events common to both reports we find that for Shagan the mean epicentre of the group in this report is only 0.75 km N of that in Marshall et al (4). For the Degelen and Konystan sites the differences are 3.0 km N 250 E and 3.1 km N 240 E respectively. As might be expected the cratering shot (650115) is appropriate for constraining the Shagan tests but results in a slight bias for the other more distant sites.

REFERENCES

1. V S Bocharov, S A Zelentsoz, V N Mikhailov: "Characteristics of 96 Underground Nuclear Explosions at the Semipalatinsk Test Site". Atomic Energy (Atomnaya Energiya) 67(3), 1989.

2. A Douglas: "Joint Epicentre Determination". Nature 215, 47-48, 1967.

3. H Jeffreys: "The Theory of Probability". 3rd Ed Oxford University Press, 1961.

4. P D Marshall, T C Bache, R C Lilwall: "Body Wave Magnitudes and Locations of Soviet Underground Explosions at the Semipalatinsk Test Site". AWRE Report No. O 16/84, HMSO London, 1985.

N	DATE	ORIGIN H	M	TIME SEC	DOT SEC	LAT	DLAT km	LON	DLON km	DEPTH km	AREA sqkm
1	650115	6	0	0.80		49.935N		79.009E		0.178	
2	680619	5	5	59.80		49.980N		78.986E		0.316	
3	691130	3	32	59.70		49.924N		78.956E		0.472	
4	710630	3	56	59.80		49.946N		78.980E		0.217	
5	720210	5	3	0.00		50.024N		78.878E		0.295	
6	721102	1	27	0.20		49.927N		78.817E		0.521	
7	721210	4	27	10.00		50.027N		78.996E		0.478	
8	730723	1	23	0.11	0.04	49.966N	0.9	78.810E	0.5	0.000	2.1
9	731214	7	46	59.65	0.04	50.054N	1.0	78.987E	0.5	0.000	2.3
10	740416	5	52	59.82	0.13	50.039N	2.2	78.946E	1.4	0.000	15.3
11	740531	3	26	59.95	0.04	49.953N	0.9	78.846E	0.5	0.000	2.2
12	741016	6	33	0.06	0.05	49.985N	1.1	78.896E	0.6	0.000	3.0
13	741227	5	46	59.35	0.05	49.949N	1.1	79.011E	0.5	0.000	2.9
14	750427	5	36	59.73	0.05	49.955N	1.1	78.926E	0.5	0.000	2.6
15	750630	3	26	59.86	0.15	50.001N	2.0	78.996E	1.8	0.000	17.0
16	751029	4	46	59.82	0.05	49.955N	1.1	78.877E	0.5	0.000	2.8
17	751225	5	16	59.65	0.04	50.051N	0.9	78.813E	0.5	0.000	2.2
18	760421	5	2	59.72	0.07	49.906N	1.2	78.827E	0.7	0.000	4.1
19	760609	3	2	59.75	0.05	50.002N	1.1	79.025E	0.6	0.000	3.2
20	760704	2	56	59.94	0.04	49.912N	0.9	78.908E	0.5	0.000	2.3
21	760828	2	56	59.99	0.05	49.979N	1.0	78.928E	0.5	0.000	2.3
22	761123	5	2	59.75	0.04	50.013N	0.9	78.962E	0.5	0.000	2.2
23	761207	4	56	59.85	0.04	49.927N	0.9	78.847E	0.5	0.000	2.1
24	770529	2	57	0.01	0.04	49.932N	0.9	78.774E	0.5	0.000	2.0
25	770629	3	7	0.35	0.07	50.033N	1.3	78.861E	0.6	0.000	3.6
26	770905	3	2	59.86	0.04	50.048N	0.9	78.923E	0.5	0.000	2.1
27	771029	3	7	4.92	0.07	50.068N	1.5	78.977E	0.7	0.000	5.0
28	771130	4	6	59.85	0.04	49.966N	0.9	78.890E	0.5	0.000	2.1
29	780611	2	57	0.08	0.04	49.903N	0.9	78.791E	0.5	0.000	2.0
30	780705	2	46	59.97	0.04	49.896N	0.8	78.868E	0.5	0.000	1.8
31	780829	2	37	8.75	0.04	50.011N	1.0	78.976E	0.5	0.000	2.2
32	780915	2	36	59.90	0.04	49.922N	0.9	78.876E	0.5	0.000	1.9
33	781104	5	5	59.81	0.04	50.040N	0.9	78.941E	0.5	0.000	2.0
34	781129	4	33	4.99	0.05	49.959N	1.0	78.801E	0.5	0.000	2.7
35	790201	4	13	0.17	0.05	50.101N	1.0	78.863E	0.5	0.000	2.5
36	790623	2	57	0.02	0.04	49.913N	0.8	78.857E	0.4	0.000	1.7
37	790707	3	46	59.81	0.04	50.032N	0.9	78.989E	0.4	0.000	1.9
38	790804	3	56	59.57	0.03	49.900N	0.8	78.900E	0.4	0.000	1.6
39	790818	2	51	59.61	0.03	49.949N	0.8	78.937E	0.4	0.000	1.5
40	791028	3	16	59.45	0.04	49.982N	0.8	78.996E	0.4	0.000	1.7
41	791202	4	36	59.95	0.04	49.900N	0.9	78.793E	0.4	0.000	1.9
42	791223	4	56	59.93	0.04	49.920N	0.8	78.753E	0.4	0.000	1.7
43	800425	3	57	0.03	0.04	49.981N	0.9	78.756E	0.5	0.000	2.2
44	800612	3	27	0.11	0.04	49.986N	0.9	78.998E	0.5	0.000	2.1
45	800629	2	33	0.19	0.04	49.951N	0.9	78.815E	0.5	0.000	2.2
46	800914	2	42	41.63	0.03	49.930N	0.8	78.801E	0.4	0.000	1.6
47	801012	3	34	16.58	0.03	49.967N	0.8	79.026E	0.4	0.000	1.6
48	801214	3	47	8.91	0.04	49.909N	0.8	78.932E	0.4	0.000	1.7
49	801227	4	9	10.56	0.04	50.063N	0.9	78.982E	0.5	0.000	2.0
50	810329	4	3	52.51	0.04	50.011N	0.9	78.978E	0.4	0.000	1.8
51	810422	1	17	13.82	0.03	49.891N	0.8	78.811E	0.4	0.000	1.6
52	810527	3	58	14.82	0.05	49.992N	1.0	78.979E	0.5	0.000	2.6
53	810913	2	17	20.76	0.03	49.920N	0.8	78.911E	0.4	0.000	1.6
54	811018	3	57	5.14	0.03	49.927N	0.9	78.854E	0.4	0.000	1.7
55	811129	3	35	11.11	0.04	49.898N	1.0	78.857E	0.5	0.000	2.1
56	811227	3	43	16.62	0.03	49.930N	0.8	78.792E	0.4	0.000	1.6
57	820425	3	23	7.88	0.03	49.912N	0.8	78.906E	0.4	0.000	1.6
58	820704	1	17	16.65	0.04	49.958N	0.9	78.800E	0.5	0.000	2.0

Table 1 Shagan test site epicentres. Nos 1-7 are those given by Bocharov et al (1) with coordinates rounded to nearest 0.001 degrees. Columns headed DOT,DLAT,DLON and AREA refer to 95% confidence limits

N	DATE	ORIGIN H	M	TIME SEC	DOT SEC	LAT	DLAT km	LON	DLON km	DEPTH km	AREA sqkm
59	820831	1	31	3.17	0.05	49.926N	1.0	78.760E	0.5	0.000	2.5
60	821205	3	37	15.04	0.03	49.924N	0.8	78.812E	0.4	0.000	1.6
61	821226	3	35	16.68	0.04	50.078N	0.9	78.986E	0.4	0.000	1.8
62	830612	2	36	46.01	0.03	49.920N	0.8	78.914E	0.4	0.000	1.5
63	831006	1	47	9.08	0.03	49.924N	0.8	78.761E	0.4	0.000	1.5
64	831026	1	55	7.33	0.03	49.912N	0.8	78.828E	0.4	0.000	1.6
65	831120	3	27	6.86	0.04	50.055N	0.9	78.997E	0.5	0.000	1.9
66	840219	3	57	5.85	0.04	49.894N	0.8	78.745E	0.4	0.000	1.6
67	840307	2	39	8.80	0.04	50.049N	0.8	78.950E	0.4	0.000	1.6
68	840329	5	19	10.66	0.03	49.922N	0.8	78.949E	0.4	0.000	1.5
69	840425	1	9	5.99	0.03	49.935N	0.7	78.867E	0.4	0.000	1.4
70	840526	3	13	14.85	0.03	49.973N	0.7	79.000E	0.4	0.000	1.3
71	840714	1	9	12.99	0.03	49.901N	0.7	78.879E	0.4	0.000	1.4
72	840915	6	15	9.69	0.16	49.992N	3.2	78.881E	3.6	0.000	28.3
73	841027	1	50	12.93	0.03	49.925N	0.7	78.776E	0.4	0.000	1.2
74	841202	3	19	8.85	0.03	49.993N	0.8	79.009E	0.4	0.000	1.5
75	841216	3	55	5.07	0.03	49.930N	0.7	78.816E	0.4	0.000	1.3
76	841228	3	50	13.09	0.03	49.875N	0.7	78.700E	0.4	0.000	1.3
77	850210	3	27	9.98	0.03	49.893N	0.7	78.783E	0.4	0.000	1.5
78	850425	0	57	8.97	0.03	49.921N	0.7	78.899E	0.4	0.000	1.4
79	850615	0	57	3.14	0.03	49.903N	0.7	78.839E	0.4	0.000	1.2
80	850630	2	39	5.07	0.03	49.857N	0.7	78.659E	0.4	0.000	1.3
81	850720	0	53	16.91	0.03	49.943N	0.7	78.783E	0.4	0.000	1.3
82	870312	1	57	19.57	0.04	49.929N	0.8	78.824E	0.5	0.000	1.8
83	870403	1	17	10.28	0.03	49.910N	0.7	78.786E	0.4	0.000	1.1
84	870417	1	3	7.09	0.03	49.874N	0.7	78.663E	0.4	0.000	1.2
85	870620	0	53	7.09	0.03	49.927N	0.7	78.740E	0.4	0.000	1.2
86	870802	0	58	9.21	0.03	49.877N	0.7	78.873E	0.4	0.000	1.2
87	871115	3	31	9.08	0.03	49.881N	0.7	78.753E	0.4	0.000	1.3
88	871213	3	21	7.17	0.03	49.957N	0.7	78.792E	0.4	0.000	1.3
89	871227	3	5	7.15	0.03	49.867N	0.7	78.718E	0.4	0.000	1.2
90	880213	3	5	8.17	0.03	49.932N	0.7	78.878E	0.4	0.000	1.3
91	880403	1	33	8.12	0.03	49.909N	0.8	78.918E	0.4	0.000	1.4
92	880504	0	57	9.08	0.03	49.931N	0.8	78.741E	0.4	0.000	1.4
93	880614	2	27	8.98	0.05	50.034N	1.2	78.964E	0.5	0.000	2.9
94	880914	3	59	59.69	0.03	49.869N	0.8	78.825E	0.4	0.000	1.4
95	881112	3	30	6.26	0.04	50.048N	1.0	78.960E	0.5	0.000	2.2
96	881217	4	18	9.17	0.03	49.879N	0.8	78.924E	0.4	0.000	1.5
97	890122	3	57	9.02	0.03	49.934N	0.8	78.815E	0.4	0.000	1.4
98	890212	4	15	9.19	0.03	49.911N	0.8	78.704E	0.4	0.000	1.5
99	890708	3	47	0.03	0.04	49.869N	0.9	78.775E	0.4	0.000	1.7
100	890902	4	16	59.85	0.05	50.019N	1.2	78.988E	0.6	0.000	3.0
101	891019	9	49	59.81	0.03	49.927N	0.8	78.927E	0.4	0.000	1.6

Table 1 cont Shagan test site epicentres. Nos 1-7 are those given by Bocharov et al (1) with coordinates rounded to nearest 0.001 degrees. Columns headed DOT,DLAT,DLON and AREA refer to 95% confidence limits

N	DATE	ORIGIN H	M	TIME SEC	DOT SEC	LAT	DLAT km	LON	DLON km	DEPTH km	AREA sqkm
1	640315	8	0	0.40		49.816N		78.075E		0.220	
2	640516	6	0	59.80		49.808N		78.102E		0.253	
3	640719	6	0	0.60		49.809N		78.093E		0.168	
4	641116	6	0	0.20		49.809N		78.133E		0.194	
5	650303	6	14	59.40		49.825N		78.053E		0.196	
6	650511	6	40	0.20		49.770N		77.994E		0.103	
7	650617	3	45	0.00		49.828N		78.067E		0.152	
8	650729	3	5	0.20		49.780N		77.998E		0.126	
9	650917	4	0	0.10		49.812N		78.147E		0.156	
10	651008	6	0	0.40		49.826N		78.111E		0.204	
11	651121	4	58	0.00		49.819N		78.064E		0.278	
12	651224	5	0	0.20		49.805N		78.107E		0.213	
13	660213	4	58	0.10		49.809N		78.121E		0.297	
14	660320	5	50	0.30		49.762N		78.024E		0.294	
15	660421	3	58	57.50		49.810N		78.100E		0.178	
16	660507	3	58	0.20		49.743N		78.105E		0.274	
17	660629	6	58	0.50		49.834N		78.073E		0.187	
18	660721	3	58	0.00		49.737N		78.097E		0.176	
19	660805	3	57	59.60		49.764N		78.042E		0.171	
20	660819	3	52	59.90		49.827N		78.109E		0.134	
21	660907	3	51	59.70		49.829N		78.064E		0.117	
22	661019	3	57	59.90		49.747N		78.021E		0.185	
23	661203	5	2	0.20		49.747N		78.033E		0.153	
24	670130	4	1	59.50		49.767N		77.991E		0.131	
25	670226	3	57	59.80		49.746N		78.082E		0.241	
26	670325	5	58	1.10		49.754N		78.063E		0.152	
27	670420	4	8	1.00		49.742N		78.105E		0.225	
28	670528	4	7	59.60		49.756N		78.017E		0.262	
29	670629	2	56	59.90		49.817N		78.049E		0.195	
30	670715	3	26	59.90		49.836N		78.118E		0.161	
31	670804	6	58	0.30		49.760N		78.056E		0.160	
32	671017	5	4	0.20		49.781N		78.004E		0.181	
33	671030	6	4	0.00		49.794N		78.008E		0.173	
34	671208	6	3	59.80		49.817N		78.164E		0.150	
35	680107	3	46	59.90		49.754N		78.031E		0.237	
36	680424	10	35	59.70		49.845N		78.103E		0.127	
37	680611	3	5	59.70		49.793N		78.145E		0.149	
38	680712	12	8	0.00		49.755N		78.090E		0.172	
39	680820	4	5	59.60		49.823N		78.074E		0.208	
40	680905	4	5	59.60		49.742N		78.076E		0.162	
41	680929	3	43	0.00		49.812N		78.122E		0.290	
42	681109	2	54	0.10		49.801N		78.139E		0.125	
43	681218	5	1	59.70		49.746N		78.092E		0.194	
44	690307	8	26	59.80		49.821N		78.063E		0.214	
45	690516	4	2	59.70		49.759N		78.076E		0.184	
46	690704	2	46	59.60		49.746N		78.111E		0.219	
47	690723	2	47	0.20		49.816N		78.130E		0.175	
48	690911	4	2	0.00		49.776N		77.997E		0.190	
49	691001	4	2	59.90		49.783N		78.098E		0.144	
50	691229	4	2	0.00		49.734N		78.102E		0.086	
51	700129	7	3	0.00		49.796N		78.124E		0.214	
52	700327	5	2	59.60		49.748N		77.999E		0.138	
53	700628	1	58	0.00		49.802N		78.107E		0.332	
54	700724	3	57	0.00		49.810N		78.128E		0.154	
55	700906	4	2	59.90		49.760N		78.005E		0.212	
56	701217	7	1	0.00		49.746N		78.099E		0.193	
57	710322	4	33	0.30		49.798N		78.109E		0.283	
58	710425	3	32	59.90		49.769N		78.034E		0.296	

Table 2 Degelen test site epicentres. Nos 1-68 are those given by Bocharov et al (1) with coordinates rounded to nearest 0.001 degrees. Columns headed DOT,DLAT,DLON and AREA refer to 95% confidence limits

N	DATE	ORIGIN H	ORIGIN M	TIME SEC	DOT SEC	LAT	DLAT km	LON	DLON km	DEPTH km	AREA sqkm
59	710525	4	3	0.40		49.802N		78.139E		0.132	
60	711129	6	2	59.90		49.743N		78.079E		0.203	
61	711215	7	52	59.80		49.826N		77.997E		0.115	
62	711230	6	21	0.20		49.760N		78.037E		0.249	
63	720310	4	56	59.80		49.745N		78.120E		0.171	
64	720328	4	22	0.10		49.733N		78.076E		0.124	
65	720607	1	28	0.00		49.827N		78.115E		0.208	
66	720706	1	3	0.00		49.738N		78.110E		0.081	
67	720816	3	16	59.80		49.765N		78.059E		0.139	
68	721210	4	27	0.00		49.819N		78.058E		0.264	
69	730216	5	3	0.00	0.06	49.816N	1.2	78.116E	0.7	0.000	3.9
70	730710	1	27	0.15	0.07	49.792N	1.3	78.042E	0.7	0.000	4.4
71	731026	4	27	0.14	0.07	49.753N	1.3	78.122E	0.7	0.000	4.7
72	740130	4	57	0.18	0.12	49.829N	2.0	78.012E	1.3	0.000	12.2
73	740130	4	57	4.60	0.08	49.845N	1.6	78.051E	0.8	0.000	6.4
74	740516	3	3	0.05	0.07	49.745N	1.3	78.053E	0.7	0.000	4.5
75	740625	3	57	0.21	0.40	49.844N	5.9	78.111E	2.6	0.000	66.9
76	740710	2	56	59.98	0.09	49.772N	1.6	78.088E	0.8	0.000	6.6
77	740913	3	3	0.04	0.09	49.775N	1.6	78.036E	0.9	0.000	6.8
78	741216	6	23	0.14	0.10	49.787N	1.7	78.092E	1.1	0.000	8.7
79	741216	6	41	0.34	0.11	49.858N	1.6	78.053E	1.1	0.000	8.7
80	750220	5	33	0.02	0.06	49.781N	1.2	78.019E	0.6	0.000	3.6
81	750311	5	43	0.05	0.06	49.740N	1.2	78.102E	0.7	0.000	4.0
82	750608	3	26	59.96	0.07	49.757N	1.2	78.008E	0.7	0.000	4.1
83	750807	3	57	0.07	0.07	49.808N	1.3	78.120E	0.8	0.000	4.9
84	751213	4	56	59.99	0.09	49.806N	1.3	78.121E	1.0	0.000	6.6
85	760115	4	46	59.97	0.08	49.817N	1.2	78.161E	0.9	0.000	5.4
86	760421	4	58	0.16	0.10	49.773N	1.7	78.109E	1.0	0.000	8.3
87	760519	2	57	0.20	0.13	49.789N	2.5	78.019E	1.5	0.000	17.4
88	760723	2	33	0.19	0.08	49.774N	1.5	78.046E	0.9	0.000	6.3
89	761030	4	57	0.21	0.15	49.825N	3.1	78.022E	1.9	0.000	25.1
90	761230	3	57	0.31	0.10	49.795N	1.7	78.030E	1.0	0.000	7.8
91	770329	3	56	59.95	0.06	49.781N	1.3	78.042E	0.7	0.000	4.6
92	770425	4	7	0.16	0.10	49.811N	1.7	78.107E	1.0	0.000	7.9
93	770730	1	57	0.11	0.08	49.754N	1.7	78.057E	0.8	0.000	6.4
94	770817	4	26	59.97	0.09	49.817N	1.6	78.128E	1.0	0.000	7.9
95	771029	3	6	59.97	0.05	49.827N	1.1	78.091E	0.6	0.000	3.3
96	771226	4	3	0.24	0.14	49.843N	2.2	78.070E	1.4	0.000	15.3
97	780326	3	56	59.96	0.05	49.766N	1.0	78.008E	0.6	0.000	3.0
98	780422	3	7	0.01	0.06	49.756N	1.2	78.140E	0.7	0.000	4.1
99	780529	4	56	59.85	0.17	49.762N	3.3	78.092E	1.4	0.000	23.2
100	780728	2	46	59.89	0.06	49.752N	1.1	78.100E	0.6	0.000	3.2
101	780829	2	36	59.95	0.08	49.807N	1.4	78.107E	0.8	0.000	5.9
102	780920	5	3	0.00	**	49.848N	4.4	78.212E	1.8	0.000	22.2
103	781015	5	37	0.14	0.08	49.746N	1.2	78.121E	0.9	0.000	5.3
104	781031	4	17	0.19	0.06	49.803N	1.1	78.099E	0.7	0.000	4.0
105	781129	4	33	0.17	0.06	49.808N	1.3	77.999E	0.6	0.000	4.2
106	781214	4	43	0.03	0.17	49.805N	3.5	78.103E	1.6	0.000	27.1
107	781220	4	33	0.04	0.12	49.850N	2.1	78.047E	1.5	0.000	13.9
108	790506	3	17	0.07	0.07	49.770N	1.3	78.008E	0.8	0.000	4.8
109	790531	5	55	0.05	0.07	49.830N	1.4	78.087E	0.8	0.000	5.4
110	790927	4	13	0.00	0.16	49.757N	2.7	78.097E	1.9	0.000	24.9
111	791018	4	17	0.11	0.08	49.829N	1.6	78.104E	1.0	0.000	7.3
112	791130	4	53	0.58	0.12	49.781N	2.2	78.104E	1.6	0.000	15.4
113	791221	4	42	0.09	0.14	49.795N	2.5	78.127E	1.7	0.000	18.9
114	800410	4	7	0.19	0.09	49.796N	1.6	78.068E	1.0	0.000	7.7
115	800522	3	57	0.14	0.05	49.780N	1.2	78.037E	0.6	0.000	3.5
116	800731	3	33	0.07	0.06	49.803N	1.3	78.105E	0.7	0.000	4.2

Table 2 cont Degelen test site epicentres. Nos 1-68 are those given by Bocharov et al (1) with coordinates rounded to nearest 0.001 degrees. Columns headed DOT,DLAT,DLON and AREA refer to 95% confidence limits

N	DATE	ORIGIN TIME H	M	SEC	DOT SEC	LAT	DLAT km	LON	DLON km	DEPTH km	AREA sqkm
117	800925	6	21	13.06	0.12	49.826N	2.6	78.071E	1.7	0.000	17.7
118	801226	4	7	9.26	0.20	49.863N	4.1	78.119E	2.1	0.000	40.0
119	810630	1	57	15.34	0.07	49.761N	1.5	78.071E	0.9	0.000	5.9
120	810717	2	37	18.12	0.06	49.800N	1.4	78.126E	0.7	0.000	4.7
121	810814	2	27	15.24	0.07	49.781N	1.7	78.077E	1.0	0.000	6.7
122	811120	4	57	5.07	0.08	49.746N	1.6	78.120E	1.0	0.000	7.1
123	811222	4	31	5.27	0.11	49.821N	2.0	78.107E	1.2	0.000	11.4
124	820219	3	56	13.42	0.07	49.806N	1.5	78.029E	0.9	0.000	6.0
125	820625	2	3	7.16	0.11	49.801N	1.8	78.089E	1.2	0.000	10.6
126	820823	2	43	6.70	0.15	49.758N	2.4	78.044E	1.8	0.000	19.8
127	820921	2	57	3.17	0.06	49.785N	1.4	78.121E	0.7	0.000	4.5
128	821225	4	23	8.38	0.19	49.799N	3.0	78.037E	2.4	0.000	31.4
129	830330	4	17	10.22	0.13	49.792N	2.2	78.029E	1.7	0.000	15.7
130	830412	3	41	8.26	0.11	49.815N	1.9	78.076E	1.5	0.000	12.1
131	830530	3	33	47.04	0.06	49.736N	1.1	78.120E	0.7	0.000	3.8
132	830624	2	56	13.85	0.09	49.757N	1.8	78.039E	1.4	0.000	10.1
133	830911	6	33	13.10	0.11	49.820N	2.1	78.118E	1.7	0.000	13.6
134	831129	2	19	8.80	0.06	49.739N	1.2	78.105E	0.7	0.000	3.7
135	831226	4	29	9.25	0.07	49.804N	1.2	78.098E	0.8	0.000	4.2
136	840415	3	17	11.46	0.06	49.749N	1.2	78.101E	0.6	0.000	3.5
137	840909	2	59	8.85	0.08	49.809N	1.8	78.072E	1.1	0.000	7.4
138	841018	4	57	8.32	0.12	49.775N	2.4	78.133E	1.9	0.000	18.0
139	841123	3	55	7.48	0.12	49.830N	2.3	78.073E	1.8	0.000	16.5
140	850725	3	11	9.23	0.08	49.836N	1.8	77.998E	1.1	0.000	7.7
141	870226	4	58	24.32	0.05	49.844N	1.1	78.088E	0.7	0.000	3.5
142	870506	4	2	8.11	0.06	49.777N	1.2	77.984E	0.9	0.000	4.6
143	870606	2	37	9.25	0.05	49.837N	1.3	78.065E	0.7	0.000	3.9
144	870717	1	17	9.18	0.05	49.769N	1.1	78.035E	0.6	0.000	3.2
145	870918	2	32	10.01	0.48	49.976N	5.1	78.024E	4.7	0.000	115.6
146	871016	6	6	6.99	0.20	49.802N	3.5	78.140E	3.2	0.000	35.0
147	871220	2	55	9.14	0.09	49.774N	1.8	77.975E	1.2	0.000	10.0
148	880206	4	19	9.13	0.10	49.787N	2.6	77.975E	1.5	0.000	14.0
149	880422	9	30	9.44	0.07	49.824N	1.8	78.102E	0.9	0.000	7.3
150	881018	3	40	9.16	0.08	49.802N	2.1	78.002E	1.1	0.000	9.2
151	881123	3	57	8.99	0.07	49.765N	1.5	78.029E	0.7	0.000	5.2
152	890217	4	1	9.22	0.07	49.849N	1.5	78.064E	0.8	0.000	5.5
153	891004	11	30	0.16	0.10	49.751N	2.7	78.005E	1.3	0.000	14.3

**Note that origin time of event 102 restrained to exact minute to obtain more stable solution

Table 2 cont Degelen test site epicentres. Nos 1-68 are those given by Bocharov et al (1) with coordinates rounded to nearest 0.001 degrees. Columns headed DOT,DLAT,DLON and AREA refer to 95% confidence limits

N	DATE	ORIGIN H	M	TIME SEC	DOT SEC	LAT	DLAT km	LON	DLON km	DEPTH km	AREA sqkm
1	661218	4	58	0.00		49.925N		77.747E		0.427	
2	670916	4	4	0.30		49.937N		77.728E		0.230	
3	670922	5	4	0.00		49.960N		77.691E		0.229	
4	671122	4	3	59.90		49.942N		77.687E		0.227	
5	690531	5	1	59.40		49.950N		77.694E		0.258	
6	691228	3	47	0.20		49.937N		77.714E		0.388	
7	700721	3	2	59.70		49.952N		77.673E		0.225	
8	701104	6	2	59.80		49.989N		77.762E		0.249	
9	710606	4	2	59.70		49.975N		77.660E		0.299	
10	710619	4	4	0.10		49.969N		77.641E		0.290	
11	711009	6	2	59.70		49.978N		77.641E		0.237	
12	711021	6	2	59.70		49.974N		77.597E		0.324	
13	720826	3	46	59.70		49.982N		77.717E		0.285	
14	720902	8	56	59.90		49.959N		77.641E		0.185	
15	730419	4	32	59.92	0.07	49.984N	1.4	77.614E	0.8	0.000	5.3
16	741207	6	0	0.03	0.22	49.916N	2.5	77.605E	2.6	0.000	31.6
17	780319	3	46	59.82	0.06	49.945N	1.3	77.704E	0.8	0.000	5.0
18	790216	4	4	0.50	0.07	49.974N	1.4	77.668E	0.8	0.000	5.1
19	790718	3	17	4.92	0.07	49.919N	1.4	77.812E	0.9	0.000	6.1
20	800404	5	32	59.83	0.12	50.000N	2.2	77.823E	1.7	0.000	15.7

Table 3 Konystan test site epicentres. Nos 1-14 are those given by Bocharov et al (1) with coordinates rounded to nearest 0.001 degrees. Columns headed DOT,DLAT,DLON and AREA refer to 95% confidence limits

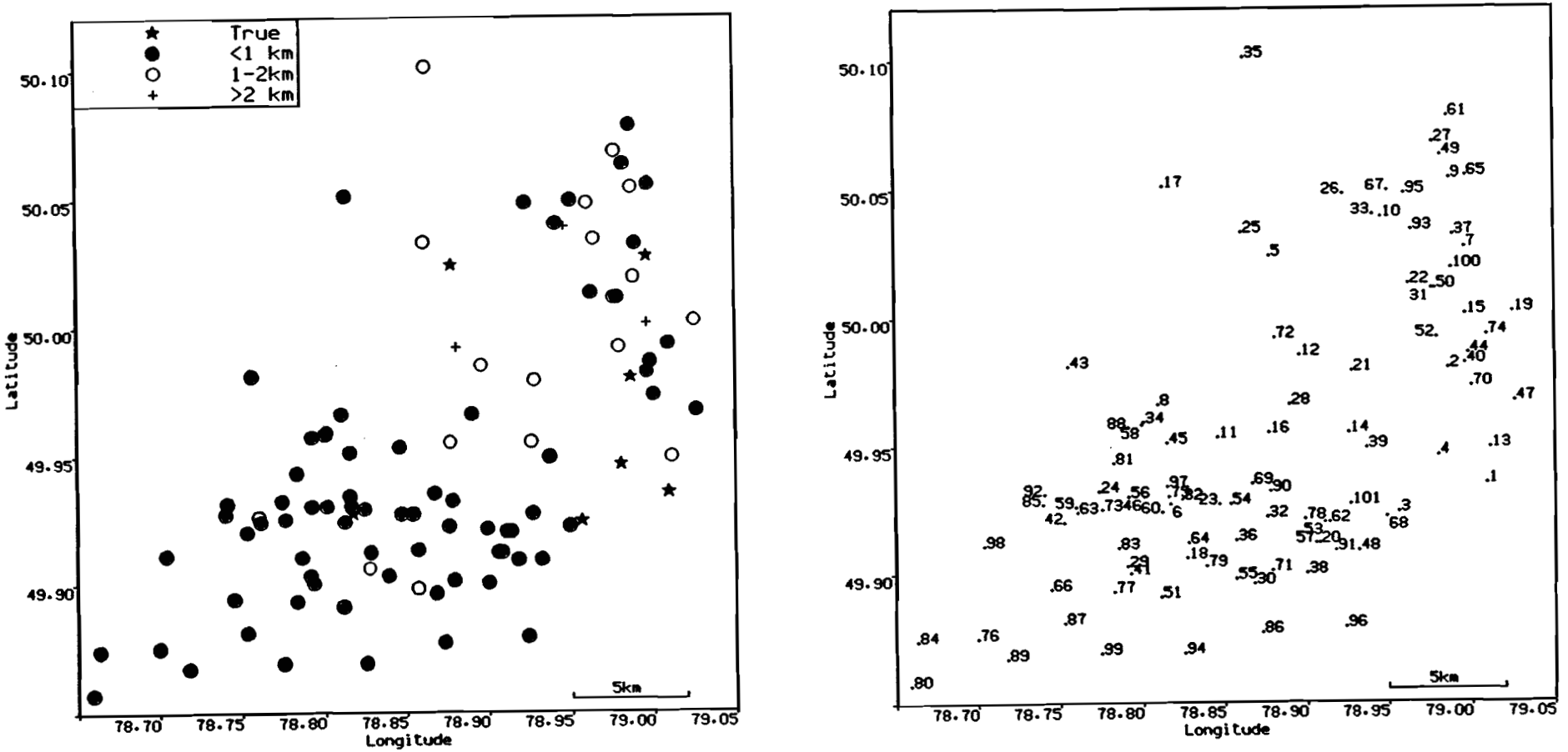

Fig 1. Epicentres of Explosions at the Shagan test site 1964-89. Numbers in key box refer to location accuracy based on 95% confidence limits and areas. Numbers in right plot correspond to those in Table 1.

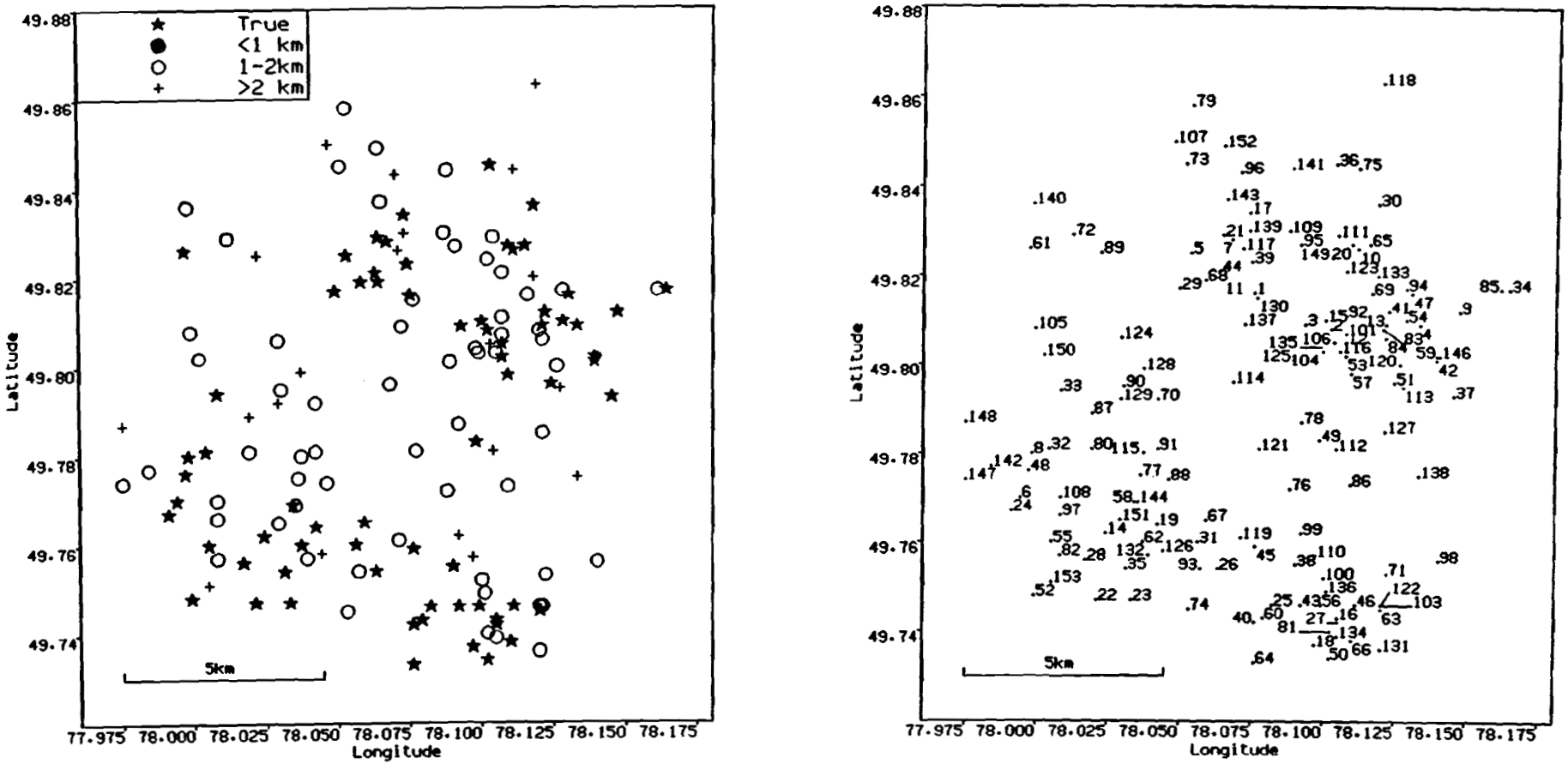

Fig 2. Epicentres of Explosions at the Degelen test site 1964-89. Numbers in key box refer to location accuracy based on 95% confidence limits and areas. Numbers in right plot correspond to those in Table 2. Note that explosions numbered 102 and 145 plot outside this area.

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