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SEISMIC EVENTS LOCATED IN AND NEAR FINLAND

BY

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Abstract

In order to investigate the seismicity of Finland, local seismic events recorded at more than three stations in Fennoscandia during the period July 1957 to June 1962 have been studied. The work is only very provisional and depth determination has not been attempted.

Some of the concentrated epicenters appear to belong not to tectonic earthquakes but to artificial explosions. Several series of seismic events are suggested to be explosions, but the possibility that isolated events located in the same place are tectonic cannot be excluded, unless reliable information on explosions is given. For the study of seismicity it may be indispensable to have such information until seismological technique has advanced to the point at which artificial explosions can be distinguished from natural earthquakes. Exchange of information concerning the artificial explosions in Fennoscandia and neighboring territory should be recommended.

1. *Introduction*

Although the level of seismicity in Finland is very low, we have many records of seismic activity in this country (RENQVIST [14, 15], SAHLSTRÖM [19], BÅTH [1, 2]). In the last few years several earthquakes have been felt in Finland and some of these have been studied seismometrically (PORKKA and VESANEN [12], PENTTILÄ [6], KATAJA [3, 4]).

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The recent increase in the number of seismological stations in Finland and the improvements in their equipment seemed to be promising for the study of the seismicity of minor earthquakes in the territory (Porkka [11], Porkka and Vesanen [13], Vesanen *et al.* [21], Penttilä [7]).

During the past few years the seismological services of the neighboring countries have also developed very greatly and this is expected to be useful in the study.

Therefore the authors have tried to re-investigate the problem, using the data obtained by the Finnish stations during the last five years in conjunction with those given in the published bulletins of the neighboring countries.

As regards the seismometric work of locating epicenters in Fennoscandia the situation has also improved very much in recent years, as intensive work on explosion seismic experiments has been done for Finnish territory (Penttilä *et al.* [9], Penttilä and Nurmia [8], Vesanen *et al.* [22]).

2. *Data used*

Endeavors have been made to locate as many as possible of the local earthquakes occurring in and near Finland, *i.e.* in the area 59°—72° N, 15°—40° E, during the last five years from July 1957 to June 1962.

A list of the Finnish stations and their dates of operation during this period is given in Table 1. Swedish data were used till June 1961 and the

Table 1. List of the Finnish stations and their operation dates during the period under review.

Stations	Coordinates	Operation periods
Helsinki	60°10′32.3″N 24°57′25.2″E	1.7.57—30.6.62
Kajaani	64.1°N 27.7°E	21.11.59—30.6.62
Kevo	69°45′21.2″N 27°00′45.1″E	16.9.61—30.6.62
Nurmijärvi	60°30′32.3″N 24°39′18.1″E	21.11.58—30.6.62
Sodankylä	67°22′16.2″N 26°37′44.7″E	1.7.57—30.6.62

data from USSR were available till December 1960. Regrettably, no Norwegian data could be used for the present study.

All seismic events that were recorded at not less than three stations in and near Finland, and at least one record of which can supply the two fundamental crustal phases, so enabling us to calculate the origin times, have been included, except those which are known to be due to artificial explosions. Industrial explosions in the mines at Norrköping, Malmberget (Gällivare), Kiruna, Stavanger, etc., and some experimental explosions are indicated in the Swedish Bulletin and have been excluded. Series of seismic events in the Gulf of Bothnia, Baltic Sea, and Gulf of Finland, which took place successively within a couple of hours during one day or a few days are regarded as due to artificial explosions in the Swedish Bulletin and we also excluded these from our study. In Table 2 they are listed according to the Swedish Bulletin. But we included those which the Swedish Bulletin suspects to be of an artificial nature, adding remarks such as »seismic?», »explosions?», etc., provided that they fulfilled our criterion for inclusion of data described above. Probably the comments may be true, but we do not know how reliable they are. Regarding some of the events that occurred at the same places as those suspected to be explosions and excluded by us, no remarks as to the possibility of explosions are made in the Swedish Bulletin. Hence we decided that at least for the first analysis, it is safer to include than to exclude them. Readings used in the present study are listed in Table 3.

Table 2. Series of seismic events in the Gulf of Bothnia, Baltic Sea, and Gulf of Finland according to the Swedish Bulletin.

Year	Date	Epicenter	Number of events
1958	July 21–22	61.6N 20.2E	7 events*)
1958	Aug 7	59 N 19¼E	6 events
1958	Aug 8	58 N 21 E	6 events
1959	Mar 26	57.4N 21.3E	3 events
		59.4N 23.7E	3 events
		59.6N 23.8E	3 events
1959	Mar 27–28	57 N 21 E	4 events
1959	Mar 8	56 N 24 E	2 events
1959	June 1	59.8N 20.0E	3 events
1959	Oct 13–18	Near Baltic States, USSR	10 events
1959	Oct 29–30	Near Baltic States, USSR	4 events
1960	Dec 30	61.4N 19.5E	8 events

* Finnish explosions for scientific purposes.

Table 3. Readings used in the present study

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
01 July 28 1957								
SOD	iPn	06—18—05.1				44.4	295	
	iPg	08.5	34.9	47.2	06—17—21.3	47.8	290	
	iSn	38				77.3	310	
	iSb	41				80.3	290	
	iSg	43.4				82.7	290	
							295	
HEL	iSb	06—21—15				234.3	(875)	
	iSg	42				261.3	915	
							890	
KIR	iPn	06—18—36				75.3	560	
	iSn	19—36				135.3	580	
							570	
SKA	iSg	06—22—24				303.3	1060	
UPP	iSg	06—22—51				330.3	1152	
APA	iPg	06—17—23	2.0	2.7	06—17—20.3	2.3	14	
	iSg	25				4.3	16	
					06—17—20.7		15	
02 Aug. 02 1957								
SOD	iPg	09—17—05	54	73	09—15—52.0	73	470	Δ: 4.1°
	iSg	59				127	450	
							460	
HEL	iPb	09—17—03				71	460	Δ: 4.5°
	iPg	13	60	81	09—15—52.0	81	490	O: 09—15—42
	iSn	43				111	465	63¾°N 31°E
	iSb	59				127	465	
	iSg	18—13				141	490	
							475	
UPP	iSg	09—19—46				224	780	63.2°N 31.0°E
KIR	iSn	09—18—43				171	630	O: 09—15—50
	iSg	19—22				210	730	by BÅTH
SKA	eSb	09—19—43				231	860	
	eSg	20—30				278	920	
					09—15—52.0		890	
03 Dec. 12 1957								
UPP	iSg	11—57—20				262	920	O: 11—52—54
KIR	iPn	11—53—35		38.4	11—52—56.6	38	250	68.0°N 14.0°E
	iSn	54—05				68	270	by BÅTH
	iSg	14				77	270	
	i	42					265	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
SKA	eSn	11—54—51				114	480	
	eSg	55—18				138	485	
					11—52—56.6		482	
04 Jan. 19 1958								
SOD	iPg	19—45—40	24	32.4	19—45—07.6	32	195	Δ: 19°
	iSg	46—04				56	195	O: 19—45—01
							195	
KIR	iPg	19—45—22			19—45—07.6	12	70	Felt at Nilivara
	iSg	34				24	70	and
SKA	eSb	19—47—47				159	585	SE of Kiruna
	iSg	48—01				171	595	O: 19—45—01
							590	by BÅTH
APA	ePn	19—46—26				76	490	
	eSb	47—24				134	490	
					19—45—07.6			
05 Feb. 24 1958								
SOD	ePn	14—42—04				80	590	
	iPb	14				90	580	
	iPg	25	70	98	14—40—50.0	101	590	
	iSn	43—07				140	600	
	iSb	20				153	570	
	iSg	35			14—40—48.5	168	590	
							585	
HEL	iPn	14—42—42				115	880	
	iSn	44—15				208	915	
	i	33						
	iSg	45—05				258	900	
							897	
UPP	iSg	14—44—17				212	740	
KIR	ePn	14—41—38				51	355	
	iSg	42—28				101	355	
SKA	iPn	14—41—29				42	285	66½°N 13°E
	iPg	41—37	37	50	14—40—47.0	50	305	O: 14—40—41
	iSb	42—08				81	295	by BÅTH
	iSg	14				87	305	
							297	
06 March 15 1958								
SOD	iPb	04—51—50				41.5	261	
	iPg	53	33	44.5	04—51—08.5	44.5	270	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
	iSn	52—19				70.5	278	
	iSb	23				74.5	268	
	iSg	26				77.5	270	
							269	
KIR	ePn	04—52—19	56	66	04—51—13.0	70.5	515	
	eSn	53—15				126.5	538	
	iSg	37				148.5	518	
							524	
SKA	e(Sg)	04—56—08				299.5	1045	
					04—51—10.7			
07 March 30 1958								
SOD	iPg	06—41—07	32	43	06—40—24.0	43	260	
	i	12				48		
	iSg	39				75	262	
							261	
HEL	i	06—44—35				251		
	iSg	42				258	901	
UPP	i(Sg)	06—45—50				326	1137	
KIR	eSn	06—42—30				126	535	
	i(Sg)	54				150	525	
							530	
SKA	i(Sg)	06—45—20				296	1032	
					06—40—24.0			
08 April 30 1958								
SOD	iPb	21—03—25				41.5	260	
	iPg	28	33	44.5	21—02—43.4	44.5	264	
	eSn	54				70.5	278	
	iSb	57				73.5	264	
	iSg	04—01				77.5	271	
							267	
KIR	i(Sg)	21—04—50				126.5	442	
SKA	e	21—07—50				306.5	1070	
					21—02—43.5			
09 June 18 1958								
UPP	iSg	14—09—19				192	670	
							670	
KIR	iPg	14—06—54	45	60.6	14—05—53.4	61	370	
	iSg	07—39				106	370	
SKA	iPg	14—06—37	33	44.5	14—05—52.5	44	300	
	iSg	07—10				77	270	
					14—05—53.0		285	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
10 Sep. 15 1958								
SOD	eSn	17—32—41				206	905	
	iSg	33—19				244	855	
							880	
HEL	iPg	17—29—30	11	14.9	17—29—15.1	15	85	
	iSb	38				23	80	
	iSg	41				26	85	
	iL	43				28		
							83	
UPP	iSg	17—30—53				98	345	59.9°N 23.2°E
KIR	eSn	17—32—51				216	915	O: 17—29—16
	eSg	33—43				268	935	by BÅTH
SKA	iSg	17—32—49				214	750	
					17—29—15.1			
11 Dec. 19 1958								
SOD	iPn	00—51—48	60	76.7	00—50—31.3	77	565	Δ: 5.1°
	iSn	52—48				137	585	O: 00—50—27
	iSg	53—13				162	565	
					00—50—31.0		572	
NUR	iPn	00—52—18	85	109		107	815	Δ: 7.4°
	iPb	33				122	790	
	i	37				126		
	iPg	51	92	128		140	855	
	iSn	53—43				192	835	
	iSg	54—23				232	855	
							830	
UPP	iPn	00—52—07	73	93.4		96	625	65.8°N 14.4°E
	iPb	18				107	690	O: 00—50—32
	i	58				147		by BÅTH
	iSn	53—20				171	740	
	iSb	38				187	690	
	iSg	52				201	705	
							700	
KIR	iPn	00—51—19				47	325	
	iPg	27	42	56.7	00—50—30.3	56	340	
	iSg	52—09				97	340	
							335	
SKA	iPn	00—51—12				41	280	
	iSg	46				75	265	
					00—50—31.0		272	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
GOT	iPn	00−52−33				122	935	
	iSn	54−07				216	945	
	i	51						
	iSg	55				264	920	
							940	
APA	iPn	00−52−22				111	725	
	iSb	53−49				198	725	
					00−50−31.0			
12 Dec. 19 1958								
SOD	iPn	07−57−36	60	76.7	07−56−19.3	77	570	Δ: 5.1°
	i	52				93		O: 07−56−15
	i	55				96		
	iSn	58−36				137	585	
	iSg	59−01				162	570	
							575	
NUR	iPn	07−58−06	85	109	07−56−17.0	107	810	Δ: 7.4°
	i	25				126		
	iSn	59−31				192	835	
	iSg	08−00−11				232	810	
							818	
UPP	iPn	07−57−56	72	92	07−56−24.0	97	730	65.8°N 14.4°E
	iPg	58−15				116	705	O: 07−56−22
	i	47				148		Felt
	iSn	59−08				169	730	by BÅTH
	iSb	25				186	690	
	iSg	42				203	710	
							713	
KIR	ePn	07−57−08				49	340	
	iPb	14	38	49	07−56−25.0	55	350	
	iSb	52				93	335	
	eSg	58−00				101	355	
							345	
SKA	iPn	07−57−00				41	270	
	iSg	35				76	265	
							267	
GOT	iPn	07−58−26	89	114		127	975	
	iPg	44				145	950	
	iSg	59−55				216	950	
	iSg	08−00−22				243	910	
	iSg	44				265	925	
							942	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
APA	Pn	07—58—11	88	113	07—56—18.0	112	850	
	eSn	59—39				200	870	
					07—56—19.0		860	
13 Dec. 23 1958								
SOD	iPn	21—52—24	31	39.6	21—51—44.4	39.5	265	Δ: 2.5°
	iSn	55				70.5	280	O: 21—51—42
	iSb	53—00				75.5	277	
	iSg	05				80.5	280	
					21—51—44.5		275	
KIR	iPg	21—51—56	9	12.1	21—51—43.9	11.5	65	Possibly explo-
	iSg	52—05				20.5	70	sion at Gällivare
	i(Rg)	07				22.5		O: 21—51—41
SKA	iSg	21—54—20				155.5	540	by BÅTH
14 March 11 1959								
SOD	ePn	07—19—11				69	502	
	ePg	32				90	545	
	iSn	20—01				119	502	
	iSg	39				157	(548)	
							525	
NUR	ePn	07—19—51				109	835	
	iSn	21—18			07—17—55.0	196	857	
							846	
UPP	i	07—21—43				228		
	iSg	47				232	810	
KIR	iPg	07—18—48	35	54	07—17—54.0	53	320	
	iSg	19—23				88	310	
							315	
SKA	ePn	07—18—47				52	365	
	ePg	59	41	65	07—17—53.0	64	390	
	iSg	19—40				105	370	
					07—17—54.0		375	
15 March 26 1959								
NUR	iPb	17—16—05.5				19.9	115	O: 17—15—44
	iPg	08.5	16.5	22.1	17—15—46.4	22.9	125	
	i	19.0				33.9		
	iSg	25.0				39.4	135	
	i	28.0				42.4		
							125	
UPP	iPg	17—16—40	41	55.3	17—15—44 7	54.4	330	59.4°N 23.7°E
	iSg	17—21				95.4	335	O: 17—15—35

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
KIR	e(Sb)	17—19—54				248.4		Seismic?
	iSg	20—25				279.4	965	by BÅTH
SKA	eSg	17—19—19				213.4	745	
GOT	iSg	17—19—05				199.4	695	
16 March 26 1959								
SOD	e	17—29—40				43.4		
	iSg	56				59.4	207	
NUR	iPb	17—29—22				25.4	(154)	If i-47 is Sg,
	iPg	25	18	24.3	(17—29—00.7)	28.4	172	O: 19—29—55.3
	i	39.5	22	29.7	17—28—55.3	42.9		which is closer to
	i	43				46.4	(163)	Helsinki's data
	iSg	47				50.4	176	
HEL	i	17—29—16.3				19.7		
	iPg	18.7	16.3	22.0	17—28—56.7	21.1	113	
	i	28.8				32.2		
	i	29.8				33.2		
	iSg	34.9				38.4	130	
	i	40.2				43.6		
							122	
UPP	iPg	17—29—53	41	55.3	17—28—57.7	56.4	342	
	iSg	30—34				97.4	342	
							342	
KIR	iSb	17—32—58				241.4	(892)	
	iSg	33—24				267.4	933	
SKA	e	17—32—03				186.4		
	iSg	36				219.4	767	
					17—28—56.6			
17 April 02 1959								
SOD	iPn	08—33—25				80.9	599	
	iPg	42	73.0	98.5	08—32—03.5	97.9	596	
	iSn	34—28				143.9	616	
	iSg	55				170.9	597	
							602	
NUR	ePn	08—33—58				113.9	868	
	eSn	35—21				196.9	861	
	iSg	36—04				239.9	837	
							855	
UPP	i(Sn)	08—34—55				170.9	741	
	iSb	35—27				202.9	755	
							748	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
KIR	iPg	08—33—04	44.0	59.4	08—32—04.6	59.9	362	
	iSg	48				103.9	362	
					08—32—04.1		362	
18 April 08 1959								
SOD	ePn	14—08—15				58.8	417	
	ePb	20				63.8	408	
	ePg	25	51.0	68.8	14—07—16.2	68.8	417	
	e	34				77.8		
	iSn	54				97.8	403	
	eSb	59				102.8	(375)	
	i	09—03				106.8		
	iSg	16				119.8	418	
							413	
NUR	iSg	14—12—38				321.8	1123	
KIR	iSb	14—09—36				139.8	555	
	i(Sg)	55				158.8	555	
					14—07—16.2			
19 April 08 1959								
SOD	Pn	14—24—39.5				43.5	295	
	Pb	45				49.0	310	
	Pg	50	40	54	14—23—56.0	54.0	327	
	Sn	25—20				84.0	341	
	Sb	24.5				88.5	321	
	i	28				92.0		
	Sg	30				94.0	328	
							320	
NUR	iSg	14—29—01				305	1064	
KIR	i	14—26—01				125		
	i(Sg)	20				144	502	
20 May 08 1959								
NUR	iPg	15—24—25.6	17	23.0	15—24—02.6	22.0	127	
	i	29.1				25.5		
	iSg	42.6				39.0	135	
	i	45.6				42.0		
HEL	iPg	15—24—19.5	11	14.9	15—24—04.6	15.9	90	
	iSg	30.5				26.9	90	
	i	35.5				31.9		
							90	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
UPP	iPg	15—25—04	40	54	(15—24—10)	60.4	367	
	iSg	45				101.4	355	
							361	
KIR	eSg	15—28—25				267.4	933	
SKA	e(Sn)	15—27—05				181.4	(785)	
	iSb	24				200.4	743	
	iSg	41				217.4	759	
					15—24—03.6		751	
21 May 30 1959								
SOD	ePg	03—16—25	73	90.5	03—14—53.0	90.5	555	
	iSn	17—04				129.5	550	
	iSb	26				151.5	555	
	iSg	38				163.5	570	
							557	
NUR	ePn	03—16—57				122.5	(940)	
	iSn	18—25				210.5	925	
	iSb	19—10				255.5	950	
							940	
UPP	e	03—18—52				237.5		
	iSg	55				240.5	840	
KIR	iPn	03—15—40	36	48.6	03—14—51.4	45.5	310	
	iSn	16—11				76.5	308	
	eSb	16				81.5	295	
							304	
SKA	ePg	03—16—01	47	63.4	03—14—57.6	66.5	405	
	iSg	48				113.5	397	
					03—14—54.5		401	
22 July 22 1959								
NUR	iPn	07—44—58	28	35.8	07—44—22.2	36.4	237	
	i	45—16				54.4		
	iSn	26				64.4	251	
	i	37				75.4		
	i	42				80.4		
							244	
HEL	iPn	07—45—02				40.4	270	O is too big
								Underwater
	i	17				55.4		explosion?
	i	21				59.4		61.1°N 20.3°E
	iSn	30				68.4	270	by BÅTH
	iSb	38				76.4	275	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
	iSg	45				83.4	280	
	i	48				86.4		
							274	
UPP	iPg	07—44—54	24	32.4	07—44—21.6	32.4	200	
	iSb	45—17				55.4	197	
	iSg	18				56.4	197	
							198	
SKA	iSg	07—46—48				146.4	512	
					07—44—21.6			
23 July 30 1959								
NUR	iPn	18—33—41.0	36.8	47.1	18—32—53.9	46.2	(317)	If 1—28.8 is Sg,
	iPb	44.4				49.6	(317)	the origin time
	i	47.3				52.5		becomes near to
	iPg	48.8	44.5	60.0	(18—32—48.8)	54.0	(317)	that obtained at
	iSn	34—17.8	40.0	54.0	18—32—54.8	83.0	337	Helsinki
	i	22.3				87.5		
	iSb	24.6				89.8	326	
	i	26.6				91.8		
	i	28.8				94.0		Probably Sg
	iSg	33.3				98.5	344	
	i	38.8				104.0		
	iLg	45.0				110.2		
							336	
HEL	iPn	18—33—41.6	36.3	46.5	18—32—55.3	47.0	(323)	
	iPb	44.7				49.9	(316)	
	iPg	50.7	40.2	54.3	(18—32—56.4)	55.9	340	
	iSn	34—18.1				83.3	337	
	iSb	24.8				90.0	327	
	iSg	30.9				96.1	337	
							335	
UPP	eSn	18—35—42				167.2	725	
	iSg	36—18				203.2	710	
							718	
KIR	e	18—36—13				198.2		
	eSg	45				230.2	804	
SKA	iPn	18—35—01				125.2	963	
	iSg	37—22				267.2	932	
					18—32—54.8		948	
24 July 31 1959								
NUR	iPn	10—04—54.2	36.8	47.1	10—04—07.1	47.2	(325)	
	iPb	57.5				50.5	(320)	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
	i	59.3				52.3		if i-43.1 is Sg,
	iPg	05−02.2	44.4	59.8	(10−04−02.2)	55.2	335	origin time is
	i	04.5	40.9	55.1	10−04−07.1	57.5		consistent
	i	10.0				63.0		
	iSn	31.0				84.0	341	
	i	34.8				87.8		
	iSb	39.0				92.0	334	
	iSg	43.1				96.1	336	Probably Sg
	i	46.6				99.6	(347)	
	iLg	51.6				104.6		
							337	
HEL	iPn	10−04−55.0	37.3	47.6	10−04−07.4	48	(331)	
	iPb	58.6				51.6	(328)	
	iPg	05−03.0	40.4	54.5	(10−04−10.5)	58	341	
	iSn	32.3				85.3	347	
	iSb	39.2				92.2	342	
	iSg	45.4				98.4	343	
							346	
UPP	iSn	10−06−56				169	733	
	iSb	07−15				188	696	
	iSg	31				204	712	
							714	
KIR	ePn	10−06−00	87	113	10−04−07.0	113	861	
	eSn	07−27				200	875	
	i	40				213		
							868	
SKA	iPn	10−06−13				126	968	
	iSg	08−35				268	(935)	
					10−04−07.0		952	
25 Aug. 01 1959								
NUR	iPn	09−25−34.0	38.1	48.6	09−24−45.4	49.3	343	
	i	37.3				52.6		
	iPb	38.9				54.2	345	
	i	40.6	40.9	55.3	09−24−45.3	55.9		Probably Pg
	iPg	41.7	39.8	53.7	(09−24−48.0)	57.0	346	
	i	42.8				58.1		
	ten i-phases here							
	i	26−08.0				83.3		
	iSn	09.6				84.9	345	
	i	12.1				87.4		
	i	12.7				88.0		
	i	14.0				89.3		

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
	i	15.4				90.7		
	iSb	21.5				96.8	350	
	iSg	26.9				102.2	355	
	i	31.9				107.2		
	i	33.4				108.7		
							350	
HEL	iPn	09—25—32.7	35.9	45.9	09—24—46.8	48.0	(330)	
	i	34.5				49.8		
	i	35.0				50.3		
	iPb	37.0	39.3	53.0	09—24—44.0	52.3	330	
	iPg	39.6				54.9	330	
	i	41.1				56.4		
	i	26—03.6				78.9		
	iSn	08.6				83.9	(340)	
	i	12.9				88.2		
	iSb	16.3				91.6	335	
	iSg	22.0				97.3	340	
							334	
UPP	iPn	09—26—20	61	98	(09—25—12)	95.3	718	
	iSn	27—31				166.3	723	
	iSb	51				186.3	690	
	iSg	28—05				200.3	700	
							704	
KIR	eSn	09—28—00				195.3	855	
	iLg	33				228.3		
SKA	iSg	09—29—12				266.3	930	
					09—24—44.7			

26 Aug. 01 1959

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
NUR	iPn	12—14—57.6	36.0	56.1	(12—14—01.5)	47.6	328	
	i	15—00.9				50.9		
	iPb	04.0				54.0	340	
	iPg	05.1	39.9	53.9	12—14—11.2	55.1	335	
	iSn	33.6				83.6	338	
	i	33.8				83.8		
	i	35.8				85.8		
	i	39.2				89.2		
	iSb	41.0				91.0	330	
	i	42.9				92.9		
	iSg	45.0				95.0	332	
							334	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
HEL	iPn	12—14—58.0	37.6	58.2	(12—13—59.8)	48	330	
	iPb	15—00.8				50.8	323	
	iPg	02.7	39.9	53.9	12—14—08.8	52.7	318	
	i	06.0				56.0	330	
	iSn	31.2				81.2	330	
	i	35.6				85.6		
	i	38.3				88.3		
	iSb	39.6				89.6	325	
	iSg	42.6				92.6	323	
	iLg	48.6				98.6		
							325	
UPP	iPn	12—15—45				95	710	
	iSn	16—58				158	685	
	iSb	17—17				187	690	
	iSg	31				201	700	
							696	
KIR	iPn	12—16—03				113	865	
	eSn	17—27				197	865	
	iLg	59				229		
					12—14—10.0		865	
27 Aug. 21 1959								
NUR	iPg	13—24—15.0	11.7	15.8	13—23—59.2	15.3	85	Δ: 100 km
	iPb	16.0				16.3	90	O: 13—23—58.0
	iPn	19.0				19.3	95	
	i	22.5				22.8		
	iSg	26.7				27.0	90	
	iSb	28.7				29.0	95	
	iSn	31.7				32.0	100	
	i	34.7				35.0		
							93	
HEL	iPg	13—24—08.7	6.3	8.5	13—24—00.2	9	45	
	iPb	09.3				9.6	45	Δ: 60 km
	i	10.2				10.5		O: 13—23—58.3
	iPn	11.3				11.6	35	
	i	12.2				12.5		
	iSg	15.0				15.3	50	
	iSb	16.8				17.1	55	
	i	18.4				18.7		
	iSn	19.4				19.7	45	
	i	20.2				20.5		
							47	

Stat.	Phase	Arrival time GMT	Sg–Pg	Pg–O	Origin time	Travel time	Δ	Remarks
UPP	iPg	13–24–52	51	69		52.3	325	59.6°N 25.0°E
	iSb	25–35				95.3	350	O: 13–23–34
	iSg	43				103.3	360	seismic?
							345	by Båth
KIR	eSb	13–27–52				232		
	iSg	28–23				263.3	920	
SKA	e	13–26–59						
	iSg	27–35				215.3	755	
					13–23–59.7			
28 Sep. 29 1959								
UPP	iPg	13–25–30	16	21.6	13–25–08.4	21.6	125	59¾°N 20°E
	iSg	46				37.6	130	O: 13–25–06
							127	Explosion?
KIR	eSg	13–29–19				240.6	540	
SKA	eSn	13–28–03				174.6	770	
					13–25–08.4			
29 Oct. 09 1959								
NUR	iPn	08–24–08.5	48	61.4	08–23–07.1	60.5	430	
	iSn	56.5				108.5	455	
							442	
HEL	iPn	08–24–01.5	43	55	08–23–06.5	53.5	380	
	iSn	44.5				96.5	400	
							390	
UPP	iPg	08–24–01	46	62	08–22–59.0	53	320	Explosion?
	i	04	(41)	52.5	08–23–08.5	56		by Båth
	iSg	42				94	330	
	i	47				99		
							325	
KIR	i(Sg)	08–28–27				319	1120	
SKA	eSg	08–27–00				232	810	
					08–23–08.0			
30 Oct. 09 1959								
NUR	iPn	13–51–24	47	60.1		68	490	
	iSn	52–11				115	482	
	iLg	21						
							486	
HEL	iPn	13–51–16.0	45.5	68.2		60	430	
	iSn	52–01.5				105	436	
	iLg	12.5						
							433	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
UPP	iPg	13−51−17	45	60.7	13−50−16.3	61	370	Explosion?
	i	19				63		by BÅTH
	iSg	52−02				106	370	
SKA	eSg	13−54−17				241	840	
31 Oct. 11 1959								
NUR	iPn	10−29−09.0				50	350	
	iPb	13.9				55	350	Δ: 337 km
	iPg	17.9	41.5	56	10−28−22.0	59	356	O: 10−28−19
	i	43.9						
	iSn	45.4				86	350	
	iSb	51.6				92	335	
	i	54.9						
	iSg	59.4				100	350	
		30−00.4						
		04.9						
							348	
HEL	iPn	10−29−09				50	350	
	i	10.5						Δ: 337 km
	iPb	11.8				53	340	O: 10−28−19
	i	12.8						
	i	14.0						
	ePg	16.0	43.7	59	10−28−15.0	57	345	
	iSn	45.3				86	350	
	iSb	51.5				92	335	
	i	57.0						
	iSg	59.7				100	350	
	i	30−04.3					345	
							344	
UPP	iSn	10−31−07				168	730	61½°N 29½°E
	iSg	44				205	718	O: 10−28−19
							724	by BÅTH
KIR	eSn	10−31−41				202	885	
	e(Sb)	32−15				238	885	
	iSg	32				253	885	
SKA	eSg	10−32−50				271	945	
					10−28−19.0			
32 Oct. 13 1959								
NUR	iPn	11−24−25	36	46	11−23−39.0	45	310	Δ: 325 km
	iSn	25−01				81	325	O: 11−23−37
							316	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
HEL	iPn	11−24−26.5	35.5	45.5	11−23−41.0	46	315	Δ: 325 km
	iSn	25−02.0				82	330	O: 11−23−38
							322	
UPP	i(Sb)	11−26−42				182	675	62.3°N 27.6°E
	iSg	27−01				201	700	O: 11−24−01
KIR	iSn	11−26−55				194	845	by Båth
	iSg	27−33				232	845	
							845	
SKA	eSg	11−28−00				259	905	
					11−23−40.0			
33 Oct. 13 1959								
NUR	iPn	13−32−27	56	71.7		62	440	
	iSn	33−23				118	495	
							468	
HEL	iPn	13−32−22.5	44	56.4	13−31−26.1	58	415	
	i	28.0						
	iSn	33−06.5				101	418	
	i	11.0				106		
	iSb	16.5				111	405	
	iSg	20.5				115	405	
							411	
UPP	iPg	13−32−27	46	62	13−31−25.0	62	375	Explosion?
	iSb	33−07				102	370	by Båth
	iSg	13				108	378	
							374	
SKA	iSg	13−35−30				245	820	
					13−31−25.0			
34 Oct. 23 1959								
SOD	iPn	03−56−29.5				96	725	Δ: 4.2°
	ePb	46.0				112	730	O: 03−55−32.7
	ePg	56.5	65.5	88.4		123	745	
	iSn	57−26.5				153	665	
	iSb	42.5				179	665	
	iSg	58−02.0				199	695	
							708	
UPP	iSn	03−57−08			03−54−53.5	134	570	64½°N 13¾°E
	i	31						O: 03−54−46
	iSg	34				160	560	by Båth
KIR	ePn	03−55−59				65	470	
	iSb	57−06				132	485	
							477	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
SKA	iPg	03−55−11	13	17.5	03−54−53.5	17	105	
	iSg	26				32	112	
							109	
GOT	eSg	03−58−29				216	755	
					03−54−54.0			
35 Oct. 29 1959								
HEL	ePn	12−52−05.5	47.0	60	12−51−05.5	60	430	
	iPb	10.5				65	420	
	iPg	14.5				70	425	
	iSn	52.5				108	445	
	iSb	59.0				114	420	
	iSg	53−03.5				119	417	
							427	
NUR	ePn	12−52−08.0	42	53.7		63	455	
	iPb	15.0				70	453	
	iSn	50.0				105	440	
	iSb	53−02.0				117	430	
							444	
UPP	iPb	12−52−01				56	360	
	iPg	08	47	63.4	12−51−04.6	63	385	
	i	11				66		Explosion
	iSb	45				100	365	by BÅTH
	iSg	55				110	385	
							375	
KIR	eSg	12−56−27				322	1120	
					12−51−05.0			
35 Oct. 30 1959								
NUR	ePn	07−55−38				59	420	
	iPb	43				64	410	
	ePg	50	52	70	07−54−40	71	428	
	eSn	56−26				107	445	
	iSb	36				117	430	
	iSg	42				123	430	
							427	
HEL	ePn	07−55−38				59	420	
	iPb	42				63	405	
	ePg	45	54	73	07−54−32	66	405	
	eSn	56−27	49	66	07−54−39	108	453	
	iSb	34				115	422	
	iSg	39				120	420	
							421	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
UPP	iPn	07—55—37				58	415	Explosion
	iPg	42	47	63.4	07—54—38.6	63	405	by BÅTH
	i	44				65	398	
	iSn	56—24				105	383	
	iSg	29				110	385	
					07—54—39		397	
37 Oct. 11 1959								
NUR	iPg	09—08—55.0	15.0	20.3	09—08—34.7	20	117	
						16	90	
	iPb	57.0				22	119	
						18	105	
	iPn	59.0	16.0	20.5	09—08—38.5	24	(135)	
						20	(102)	
	iSg	09—10.0				35	120	
						31	105	
	iSb	12.5				37.5	127	
						33.5	114	
	iSn	15.0				40.0	(137)	
						36.0	(118)	
	iLg	16.5				41.5		
						37.5		
							121	
HEL	iPg	09—08—54.5	11.4	15.4	09—08—39.1	19.5	113	
						15.5		
	iPn	58.1	17.7	23.9	09—08—36.6	23.1	90	
						19.1		
	i	09—02.2				27.2		
						23.2		
	iSg	05.9				30.9	104	
						26.9	89	
	i(Sg)	12.2				37.2	(127)	
						33.2	(115)	
							109	
							90	
UPP	i	09—09—54				79		
						75		
	iSg	10—14				99	345	
						95	333	
KIR	iSg	09—12—59				264	922	
						260	908	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
SKA	i	09−12−02				207		
						203		
	iSg	10				215	751	Two origin time
					09−08−35.0	211	733	must be tried
					09−08−39.0			
38 Dec. 25 1959								
NUR	Pg	09−34−22.0	13.0	17.5	09−34−04.5	18.4	107	
		25.5	20.5	37.6	(09−34−44.4)	21.9		
	Sg	35.0				31.4	108	
		42.5				38.9		
							108	
HEL	Pg	09−34−19.5	7.0	9.5	(09−34−10.0)	15.9	90	Explosion?
	Sg	26.5	12.5	16.9	09−34−02.6	22.9	(78)	by BÅTH
		32.0				28.4	97	Probably Sg
							94	
UPP	iPg	09−34−55	46.0	62.0		51.4	312	
	iSg	35−41				97.4	342	
							327	
KIR	eSn	09−37−40				216.4	(950)	
	iSb	58				234.4	(872)	
	iSg	38−31				267.4	932	
SKA	i(Sn)	09−37−01				177.4	(772)	
	i	28				204.4		
	iSg	37				213.4	745	
GOT	eSb	09−37−08				184.4	(683)	
	iSg	27				203.4	710	
					09−34−03.6			
39 Feb. 02 1960								
SOD	iPg	12−33−01.0	21.4	28.9	12−32−31.0	30.0	185	Tolvantijärvi
	i	04.0				33.0		Earthquake
	i	06.5						PENTTILÄ (1960)
	iSg	22.4				51.4	185	and PANASENKO
							185	(1961)
OUL	iPn	12−33−18.6	37.8	55.3		48.1	332	
	iPb	22.6				52.1	332	
	iPg	25.8				55.3	335	
	i	29.2						
	iSn	52.2				81.7	330	
	i	55.7						
	iSb	59.3				88.8	322	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
	iSg	34—03.6				93.1	328	
							330	
KIR	iPn	12—33—32.5				62.0	445	
	i	38.5						
	iPb	41.6				71.1	457	
	i	44.0						
	iPg	48.0	57	76.9	12—32—31.1	77.5	470	
	i	50.5						
	iSn	34—19.0				108.5	455	
	i	22.0						
	i	27.5						
	i	29.0						
	i	32.1						
	iSb	35.3				124.8	457	
	i	39.3						
	iSg	45.0				135.5	470	
							458	
KOT	iPn	12—34—10.0				100.5	760	
	ipPn	15.7				106.2		
	isPn	19.2				109.7		
	i	22.7						
	iPb	26.2				116.7	755	
	i	31.2						
	isPb	34.5				125		
	iPg	37.0			12—32—34.5	126.5	770	
	i	42.0						
	iSn	35—22.5				173	750	
	i	24.0						
	i	28.0						
	isSn	32.5				183		
	i	40.2						
	i	44.5						
	i	46.0						
	iSb	49.5				199	740	
	i	54.5						
	i	56.0						
	i	36—04.0						
	iSg	12.0				222.5	780	
							760	
NUR	iPn	12—34—13.0				103.5	785	
	ipPn	18.5				109.0		
	iPb	29.5				120.0	785	
	ipPb	34.2				124.7		

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
	isPb	39.5				130.0		
	iSn	35−29.0				179.5	780	
	i	35.0						
	isSn	39.0				189.5		
	i	48.6						
	i	52.0						
	iSb	57.0				207.5	770	
	i	36−03.0						
	iSg	14.0				224.5	785	
	i	22.0						
	i	31.0						
							780	
HEL	iPn	12−34−17.6				108.1	822	
	ipPn	22.7				113.2		
	isPn	27.1				117.6		
		30.6						
	iPb	35.6				126.1	822	
	ipPb	39.6				130.1		
	iPg	42.2	97.8		12−32−30.2	132.7	822	
	i	46.2						
	i	52.1						
	iSn	35−35.6				186.1	815	
	i	46.6						
	i	48.5						
	i	53.5						
	iSb	36−00.4				219.9	817	
	i	10.0						
	i	12.0						
	iSg	20.0				239.5	835	
	i	30.0						
							820	
APA	iP	12−32−51.0	12.6	20.5	12−32−33.0	20.5	115	
	iP	53.0						
	e	57.0						
	eS	33−03.6				33.1	115	
	eS	07.0						
							115	
PUL	eP	12−34−14.0			12−32−31.0	103	785	
	e	20.0				109		
	i	35−29.0				118		
	iS	33.0				182.5	795	
	iSb	36−09.0				218	810	
	i	41.0				250		
					12−32−30.5		795	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
40 Feb. 20 1960								
SOD	iPn	00−53−12.9	14.0	20.0	00−52−50.5	22.4	122	
	iPg	10.5				20.0	122	
	iSn	26.7				36.2	120	
	iSg	24.5				34.0	120	
	i	32.0				41.5		
							121	
OUL	iPn	00−53−24.5	26.8	37.7	00−52−50.0	34.0	220	
	i	26.2				35.7		
	iPg	27.7				37.2	225	
	i	30.5				40.0		
	iSn	47.5				57.0	218	
	i	49.5				59.0		
	i	50.5				60.0		
	i	53.0				62.5		
	iSg	54.5				64.0	223	
	iRg	54−00.0				69.5	215	
							220	
APA	iPn	00−53−24.9	28.9	40.6	00−52−51.0	34.4	223	
	iPg	28.5				38.0	228	
	i	31.1				40.6		
	i	34.4				43.9		
	iSn	50.8				60.3	232	
	iSb	53.3				62.8	225	
	iSg	57.6				67.1	235	
	i	54−00.0				69.5		
							230	
KIR	ePn	00−53−45.3	47.0		00−52−54.0	54.8	384	
	iPb	52.1				61.6	392	
	iPg	55.0				64.5	392	
	i	58.0				67.5		
	eSn	54−23.3				94.8	390	
	i	33.5				103.0		
	iSb	35.0				104.5	380	
	i	37.8				107.3		
	iSg	42				111.5	390	
	i	45.5				115.0		
	i	49.5				119.0		
	iRg	54.0				123.5	383	
							388	
KOT	iPn	00−54−22.0	83.5		00−52−51.0	91.5	687	
	i	23.6				93.1		
	ipPn	27.5				97.0		

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
	isPn	31.0				100.5		
	iPb	38.5				108.0	702	
	iPg	45.5				114.0	695	
	i	48.0				117.5		
	i	53.0				122.5		
	iSn	55−30.2				159.7	687	
	i	33.0				162.5		
	i	36.0				165.5		
	iSb	50.8				180.3	672	
	i	52.3				181.8		
	i	59.5				189.0		
	iSg	56−06.5				196.0	685	
	i	16.5				206.0		
	iRg	29.3				218.8	678	
							690	
NUR	eSn	00−55−28.8				168.3	730	
	i	52.0				181.5		
	iSb	55.0				184.5	682	
	i	56−02.5				192.0		
		05.0				194.5		
	iSg	11.0				200.5	700	
							700	
HEL	iPn	00−54−28.8	86.3	63.8	00−52.0	98.3	745	
	i	30.3				99.8		
	i	33.4				102.9		
	iPb	43.8				113.3		
	i	48.8				118.5	740	
	i	50.5				120.0		
	iPg	54.2				123.7	755	
	i	59.2				128.7		
	i	55−04.0				133.5		
	i	39.5				169.0		
	iSn	41.4				170.9	740	
	isSn	49.5				179.0		
	i	57.6				187.1		
	i	59.0				188.5		
	iSb	56−02.1				191.6	710	
	i	10.5				200.0		
	iSg	20.5				210.0	735	
	i	29.5				219.0		
	iRg	42.5				232.0	719	
							735	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
SKA	ePb	00−54−57.0				126.5	825	
		55−58				187.5		
	eSn	56−03				192.5	835	
		11.0				200.5		
	eSb	28.0				217.5	805	
	Sg	45.0				234.5	820	
							820	
UPP	ePn	00−54−51.0				120.5	925	
	ePb	55−10.0				139.5	910	
		16.0				145.5		
	eSn	56−21.0				210.5	925	
		40.0				229.5		
	eSb	52.0				241.5	897	
	iSg	57−08.5				258	900	
					00−52−50.5		910	

41 May 19 1960

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
SOD	iPn	18−54−56	40	51.2	18−54−04.8	50	350	
	iPb	59.5				53.5	343	
	iPg	55−08.0	46	62	18−54−06.0	62	380	
	iSn	36.0				90	370	
	iSb	40.0				94	345	
	iSg	55.0				109	380	
							361	
UPP	iSn	18−57−00				176	765	
	iSb	42				212	785	
	iSg	48				218	765	
							772	
KIR	iP	18−54−14						
	i(Sg)	41				35	120	
SKA	ePn	18−55−00				54	385	
	iSn	33				87	355	
	iSg	47				101	355	
							365	
APA	eSn	18−56−36				150	645	
	e	40						
	eSb	57−13				187	690	
	eSg	16				190	660	
					18−54−06.0		665	

42 July 21 1960

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
SOD	iPn	07−32−31				53	375	
	iPb	38				60	380	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
	iPg	44	48	64.8	07−31−39.2	66	400	
	iSn	33−15				97	400	
	iSb	23				105	385	
	iSg	32				114	400	
	iRg	48				130		
							390	
KIR	iP	07−32−53				75	550	
APA	iP	07−32−14				36	235	i at
	iPg	16				38	240	07−32−24
	iP	22	33	44.5	07−31−37.5	44	265	26
	iS	(44)				66	260	28
	iSg	46				68	245	31
	iS	55				77	270	32.5
	i	57						35
	i	33−00						
					07−31−38.0		253	

43 Oct. 15 1960

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
SOD	ePn	06−20−57				80.8	(598)	
	ePb	21−03				86.8	(560)	Derived origin
	ePg	05	51	68.8	(06−19−56.2)	88.8	(540)	time, differs so
	iSn	41				124.8	527	much from that
	iSb	52				135.8	499	of the nearest
	iSg	56				139.8	488	station Umeå.
							505	
KJN	iSg	06−21−41				124.8	430	
	i	22−29				172.8		
NUR	iSg	06−21−49				132.8	463	
	iRg	22−00				143.8	438	
							451	
HEL	Sn	06−21−40				123.8	523	
	Sb	57				140.8	518	
	Sg	22−01				144.8	506	
							516	
UPP	iPn	06−20−51				74.8	550	
	iPb	21−01				84.8	548	
	iSn	44				127.8	543	
	iSb	53				136.8	(503)	
							547	
UME	iPg	06−19−47	8	10.8	06−19−36.2	10.8	62	
	iSg	55				18.8	67	
							65	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
SKA	iPn	06—20—31				54.8	386	
	iSn	21—13				96.8	399	
					06—19—36.2		393	
44 Dec. 05 1960								
SOD	iPn	03—19—49				45	307	
	iSn	20—22				77	308	
KJN	iPg	03—19—33	16	28	03—19—05.0	28	170	
	iSg	49				44	155	
							163	
NUR	ePn	03—20—30				85	632	
	eSn	21—30				145	622	
							627	
HEL	Pn	03—20—28				83	615	
UPP	i	03—22—08				183		
	i	23—08				243		
	i(Sg)	21				256	894	
KIR	iPn	03—20—19				74	545	
	i	24				79		
	i(Sg)	21—15				130	(455)	
UME	i	03—21—01				116	500	
		07				122		
APA	iPn	03—19—52				47	320	
	iPg	58				53	320	
	iSn	20—26				81	325	
	iSg	28				83	300	
							316	
45 Jan. 31 1961								
SOD	iPn	09—00—36.0				19	95	
	iSn	01—04.3				47.3	(172)	
							(134)	
KIR	iPn	09—00—59				42	275	
	iPg	01—07	37	50	09—00—17.0	50	304	
	iSg	44				87	315	
							298	
SKA	e(Sb)	09—03—50				213	765	
	e	04—43				266		
UME	eSg or Sn	09—02—45				148	517 or 636	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
46 Feb. 17 1961								
SOD	iPn	03−22−35				44.8	305	
	iSn	23−07				76.8	307	
							306	
KJN	iPn	03−22−26				35.8	230	
	iSn	50				59.8	228	
							229	
NUR	iPn	03−23−03				72.8	532	
	iSn	55				124.8	533	
							533	
HEL	iPn	03−23−09				78.8	590	
	iSn	24−06				135.8	579	
							585	
UPP	iPb	03−23−31				100.8	653	
	iSn	24−28				157.8	680	
	iLg1	58				187.8	667	
							667	
KIR	iPn	03−22−38				47.8	328	
	iSg	23−25				94.8	330	
							329	
SKA	ePn	03−23−10				79.8	590	
	eSn	24−07				136.8	584	
	iSg	37				166.8	580	
							585	
UME	iPg	03−22−28	28	37.8	03−21−50.2	37.8	228	
	iSn	47				56.8	239	
	i	54				63.8		
	iSg	56				65.8	229	
							232	
47 Feb. 23 1961								
SOD	ePn	04−47−39				97.5	(735)	
	ePb	49				107.5	699	
	ePg	56	72	92.2	(04−46−23.8)	114.5	697	
	eSn	48−37				155.5	672	
	eSb	55				173.5	642	
	eSg	49−08				186.5	652	
							672	
KJN	iPn	04−47−54				112.5	857	
		49−04				182.5		
NUR	iPn	04−48−15				133.5	1029	
	iSn	49−41				219.5	965	
							997	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
UPP	i(Sn)	04—49—20				198.5	(868)	
	iSg	59				237.5	829	
KIR	iPg	04—47—09	50	67.5	04—46—01.5	67.5	380	
	i	16				74.5		
	iSn	44				102.5	425	
	iSg	59				117.5	410	
							405	
UME	iPg	04—47—36	58	78.3	(04—46—17.7)	94.5	575	
	iSn	48—09				127.5	540	
	iSb	19				137.5	503	
	eSg	34				152.5	533	
							538	
SKA	ePg	04—47—09	46	62.0	(04—46—07.0)	67.5	410	
	iSg	55				113.5	392	
							401	
GOT	i	04—50—24				262.5		
	iSg	59				297.5	1037	
					04—46—01.5			
48 April 29 1961								
SOD	iPn	09—00—35	28	34.3	09—00—00.7	36	235	
	iSn	01—03				64	250	
							242	
UPP	iSg	09—05—29				330	1150	NW Russia
	i	53						68.2°N 30.5°E
KIR	iPn	09—00—58	46	58.9	08—59—59.1	59	420	O: 09—00—01
	iPg	01—07				68	440	Explosion
	iSn	44				105	440	by BÅTH
							433	
SKA	iPn	09—02—09	104	133	08—59—56.0	130	1000	
	iSn	03—53				234	1030	
	iSg	04—44				285	1000	
							1010	
UME	e(Sn)	09—02—52				173	755	
	iSb	03—19				200	750	
					08—59—59.0		752	
49 May 17 1961								
SOD	iPn	08—12—37			08—11—56.3	41	275	
	iPb	40				44	275	
	iPg	44.5				48.5	285	
	iSn	13—08.5				72	285	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
	i	12.5				76		
	iSb	16.5				80	285	
	iSg	19.0				82.5	285	
	i	21.0				84.5		
	i	28.5				92		
	iRg	33.5				97		
							282	
KIR	iPn	08—13—06	56	75.5	08—11—50.5	70	510	68¾°N 32°E
	iSn	14—02				126	530	O: 08—11—40
							520	Possibly
SKA	eSg	08—16—48				292	1020	explosion
UME	iSn	08—14—49				173	750	by BÅTH
					08—11—56.0			
50 May 28 1961								
SOD	ePn	02—12—32.5			02—11—44.0	46.5	320	
	iSn	13—07.5				81.5	330	
							325	
KJN	ePn	02—12—54.0			02—11—48.0	68.0	495	
	ePg	13—11.0	52	83.0		85.0	510	
	iSn	42.5				113.5	480	
	iSb	57.5				128.5	470	
	iSg	14—03.0				134.0	470	
							485	
UME	iSb	02—15—22				214.0	790	
					02—11—46.0			
51 June 24 1961								
SOD	ePn	10—40—36.0				36.4	237	68.2°N 30.2°E
	iPb	37.0				37.4	237	O: 10—40—00
	ePg	39.5	30.0	40.5	10—39—59.0	39.9	240	Probably
	iSn	41—02.0				62.4	243	explosion
	iSb	04.0				64.4	233	by BÅTH
	eSg	09.5				69.9	245	
	iRg	19.0				79.4	242	
							240	
KJN	iPn	10—41—17.0				77.4	570	
	iPb	28.5				88.9	574	
	i	32.0	68	91.8	10—40—00.2	92.4		According to the
	iPg	34.0	66	89.0	(10—40—05.0)	94.4	575	calculated origin
	iSn	42—13.0				133.4	570	time this phase
	iSb	31.0				151.4	560	seems to be Pg,
	iSg	40.0				160.4	562	giving less dif-
	i	46.5				166.9		ference to So-
	iRg	53.0				173.4	(530)	dankylä's data
							569	

Stat.	Phase	Arrival time GMT	Sg−Pg	Pg−O	Origin time	Travel time	Δ	Remarks
KIR	iPn	10−40−58				58.4	415	
	iPb	41−07				67.4	437	
	iSn	44				104.4	434	
	iSg	42−00				120.4	420	
							427	
SKA	i	10−44−27				267.4		
	iSg	43				283.4	982	
UME	iSg	10−43−15				195.4	692	If it is Sb,
					10−39−59.6			Δ: 730
52 March 24 1962								
KEV	iPg	10−02−51	18	24.3	10−02−26.7	24.3	147	
	iSg	03−09				42.3	147	
SOD	iPn	10−03−04	26	33.3	(10−02−30.7)	37.3	245	
	iSn	30	28	35.8		63.3	247	
		32				65.3	255	
							249	
KJN	iPn	10−03−44	59	75.5	(10−02−28.5)	77.3	570	
	i					89.3		
	iSn	04−43				136.3	589	
					10−02−26.7		576	
53 March 24 1962								
KEV	iPg	11−37−00	14	18.9	11−36−41.1	18.9	110	
	iSg	14				32.9	110	
							110	
SOD	ePn	11−37−26	31	39.8	(11−36−46.2)	44.9	305	
	iSn	57				75.9	303	
							304	
KJN	iPn	11−39−10				148.9	1155	
	i	40				178.9		
	i	46				184.9		
					11−36−41.1			
54 March 24 1962								
KEV	ePn	23−19−58	37	47.3	(23−19−10.7)	44.3	300	
	iSn	20−35				81.3	327	
	i	42				88.3		
							314	
SOD	iPn	23−19−54	31	39.7	23−19−14.3	40.3	270	
	iSn	20−25				71.3	259	
							265	

Stat.	Phase	Arrival time GMT	Sg—Pg	Pg—O	Origin time	Travel time	Δ	Remarks
KJN	iPn	23—20—16	48	61.5	23—19—14.5	62.3	450	
	i	24				70.3		
	iSn	21—04				110.3	463	
					23—19—13.7		456	
55 March 24 1962								
KEV	ePn	23—27—01	39	50	(23—26—11)	43.8	346	
	eSn	40				82.8	335	
	i	45				87.8		
							341	
SOD	iPn	23—26—58	31	39.7	23—26—18.3	40.8	272	
	iSn	27—29				71.8		
							278	
KJN	iPn	23—27—19	48	61.5	23—26—17.5	61.8	443	
		27				69.8		
	iSn	28—07				109.8	460	
		12				114.8		
		22				124.8		
		36				138.2		
					23—26—17.2		452	
56 March 24 1962								
KEV	ePn	23—29—32	39	50	(23—28—42)	42.7	(287)	
	eSn	30—11				81.7	335	
SOD	iPn	23—29—29	31	39.7	23—28—49.3	39.7	263	
	iSn	30—00				70.7	277	
							270	
KJN	iSn	23—30—39				109.7	460	
	i	44				114.7		
	e	31—01				131.7		
	i	03				133.7		
57 March 26 1962								
KEV	iPg	06—46—45	17	23	06—46—22	23	130	
	iSg	47—02				40	134	
		05				43		
SOD	iPn	06—47—01	31	39.7	06—46—21.3	39	260	
	iSn	32				70	275	
	iSb	38				76	275	
							270	

Stat.	Phase	Arrival time GMT	Sg – Pg	Pg – O	Origin time	Travel time	Δ	Remarks
KJN	iPn	06—47—43	62	79.4	06—46—23.6	81	605	
	i	48—03				101		
	iSn	45				143	615	
	i	49—03				161		
	Sb	08				166	615	
	iSg	17				175	615	
							613	
					06—46—22			
58 March 27 1962								
KEV	iPg	18—46—40	15	20.3	18—46—19.7	20.2	118	
	iSg	55				35.2	120	
							119	
SOD	iPn	18—46—59	30	38.4	18—46—20.6	39.2	260	
	iSn	47—29				69.2	272	
							266	
KJN	iPn	18—47—40	62	79.4	18—46—20.6	80.2	595	
	iSn	48—42				142.2	610	
	i	49—02				162.2		
					18—46—19.8		603	

3. *Method of analysis*

For interpretation work the Institute of Seismology, University of Helsinki, has been using the local travel time tables based on the crustal structure determined from near-earthquake data in Northern Fennoscandia (PORKKA, [10]). Recently, the results of the explosion seismic investigations in Finland have been compiled and a provisional average structure for southern Finland is proposed, as given in Table 4 (VESANEN *et al.* [22]), for which the travel times of possible crustal phases are calculated (SAASTAMOINEN [18], VESANEN *et al.* [22]). It seemed appropriate to use the latter travel times for our analysis.

Table 4. An average crustal model for southern Finland.

Thickness of the layers		Velocities of seismic waves	
H_1	= 20 km	V_{Pg} = 6.10 km/sec	V_{Sg} = 3.5 km/sec
H_2	= 13 »	V_{Pb} = 6.65 »	V_{Sb} = 3.75 »
$H_1 + H_2$	= 33 »	V_{Pn} = 8.20 »	V_{Sn} = 4.6 »

The travel times of the fundamental crustal phases are given as follows:

$$Pg\text{—}0 = \Delta/6.10 \qquad Sg\text{—}0 = \Delta/3.5$$
$$Pb\text{—}0 = \tau b + \Delta/6.65 \qquad Sb\text{—}0 = \tau b' + \Delta/3.75$$
$$Pn\text{—}0 = \tau b + \Delta/8.20 \qquad Sn\text{—}0 = \tau n' + \Delta/4.6$$

where Pg, Sg, Pb, etc., are the arrival times of these fundamental crustal phases and 0 the origin time. The intercept times τb, $\tau b'$, τn, $\tau n'$, are constants varying in focal depth as shown in Table 5.

Table 5. Intercept times for different waves.

h km	τb sec	$\tau' b$ sec	τn sec	$\tau' n$ sec
0	2.61	4.10	6.66	11.43
5	2.28	3.59	6.12	10.50
10	1.95	3.07	5.57	9.58
15	1.63	2.56	5.02	8.65
19	1.37	2.15	4.59	7.88
20	1.30	2.05	4.48	7.70

Actual explosion data show intercept times of a few tenths of a second for Pg and Sg travel times, suggesting the existence of a thin weathered surface layer, but it can be neglected for the near earthquake interpretations.

From the travel time formulas given above we get the following formulas which enable us to find the origin time 0 from the seven respective combinations of crustal phases:

1) $Pg - 0 = \alpha_g(Sg - Pg)$, $\qquad \alpha_g = \dfrac{1}{(V_{Pg}/V_{Sg}) - 1}$

2) $Pb - 0 = \alpha_b(Sb - Pb) + \gamma_b$, $\qquad \alpha_b = \dfrac{1}{(V_{Pb}/V_{Sb}) - 1}$

$$\gamma_b = (1 + \alpha_b)\tau_b - \alpha_b \tau'_b$$

3) $Pn - 0 = \alpha_n(Sn - Pn) + \gamma_n$, $\qquad \alpha_n = \dfrac{1}{(V_{Pn}/V_{Sn}) - 1}$

$$\gamma_n = (1 + \alpha_n)\tau_n - \alpha_n\tau'_n$$

4) $Pn - 0 = \alpha_{bn}(Pb - Pn) + \gamma_{bn}$, $\qquad \alpha_{bn} = \dfrac{1}{(V_{Pn}/V_{Pb}) - 1}$

$$\gamma_{bn} = (1 + \alpha_{bn})\tau_n - \alpha_{bn}\tau_n$$

5) $Sn - 0 = \alpha'_{bn}(Sb - Sn) + \gamma'_{bn}$, $\qquad \alpha'_{bn} = \dfrac{1}{(V_{Sn}/V_{Sb}) - 1}$

$$\gamma'_{bn} = (1 + \alpha'_{bn})\tau'_n - \alpha'_{bn}\tau'_b ,$$

6) $Pb - 0 = \alpha''_{bn}(Sn - Pb) + \gamma''_{bn}$, $\qquad \alpha''_{bn} = \dfrac{1}{(V_{Pb}/V_{Sn}) - 1}$

$$\gamma''_{bn} = (1 + \alpha''_{bn})\tau_b - \alpha''_{bn}\tau'_n$$

7) $Pn - 0 = \alpha'''_{bn}(Sb - Pn) + \gamma'''_{bn}$, $\alpha'''_{bn} = \dfrac{1}{(V_{Pn}/V_{Sb}) - 1}$

$$\gamma'''_{bn} = (1 + \alpha'''_{bn})\tau_n - \alpha'''_{bn}\tau'_b$$

The formula for the combination of *Pn* and *Sn* was first proposed by WADATI [20], and, as is well known, it has been widely used (RICHTER [16], SAVARENSKY, and KIRNOS [17]).

The coefficients α_g, α_b, α_n, α_{bn}, α'_{bn}, α''_{bn}, and α'''_{bn} calculated for our model obtain the following values:

$\alpha_g = 1.35$ sec, $\alpha_b = 1.29$ sec, $\alpha_n = 1.28$ sec,

$\alpha_{bn} = 4.29$ sec, $\alpha'_{bn} = 4.40_5$ sec, $\alpha''_{bn} = 2.25$ sec,

and $\alpha'''_{bn} = 0.84$ sec.

Correction terms for the origin times γ_b, γ_n, γ_{bn}, γ'_{bn}, γ_{bn}'', γ'''_{bn} for different focal depths are calculated as in Table 6, which may be used to determine the focal depths of crustal earthquakes.

Among the above seven possibilities for calculating the origin time, the *Pg* and *Sg* combination may be the best and the *Pn* and *Sn* combinationthe next best, for the phase identification of *Pb* and *Sb* waves seems less reliable. We therefore calculated the origin times of the adopted seismic events by *Pg* and *Sg* combination, when this was possible at one station at least. If origin times were available from more than one station, the mean value was adopted. When different stations gave very inconsistent origin times we used other combinations as a check and also tried changing the possible phase nomination given in the station reports. But the original seismograms were not generally re-examined. When no reliable *Pg* and *Sg* were reported, a *Pn* and *Sn* combination was preferred and other combinations were only exceptionally used.

Table 6. Correction terms for calculation of the origin time from combinations of crustal phases.

h (km)	γ_b (sec)	γ_n (sec)	γ_{bn} (sec)	γ'_{bn} (sec)	γ''_{bn} (sec)	γ'''_{bn} (sec)
0	0.68	0.56	24.04	43.72	−11.21	8.82
5	0.58	0.52	22.60	40.94	−16.19	8.26
10	0.50	0.44	21.10	38.26	−15.19	9.68
15	0.43	0.38	19.57	35.48	−14.14	7.10
19	0.36	0.38	18.41	33.12	−13.26	6.65
20	0.33	0.36	18.12	32.59	−13.08	6.53

The accuracy of the origin times derived from different stations and different combinations for the same events seemed to be insufficient to allow us to estimate the focal depths, using the depth corrections given in Table 6. Accordingly, the authors postponed the problem to the future and all seismic events were treated as though the focus were located in the surface. Thus the epicentral distances were calculated for all identified phases reported at one station and the mean value adopted as the distance of the station from the epicenter, excepting in the case of strongly biased values, which may be due to mis-identification of the phase names.

Then circles with radii equal to the epicentral distances were drawn round the respective stations and the most probable point of intersection of these circles was taken as the epicenter. When the equi-epicentral distance circle of a station did not give a good intersection, an attempt was made to change the epicentral distance of the station by altering the phase identification given by the station.

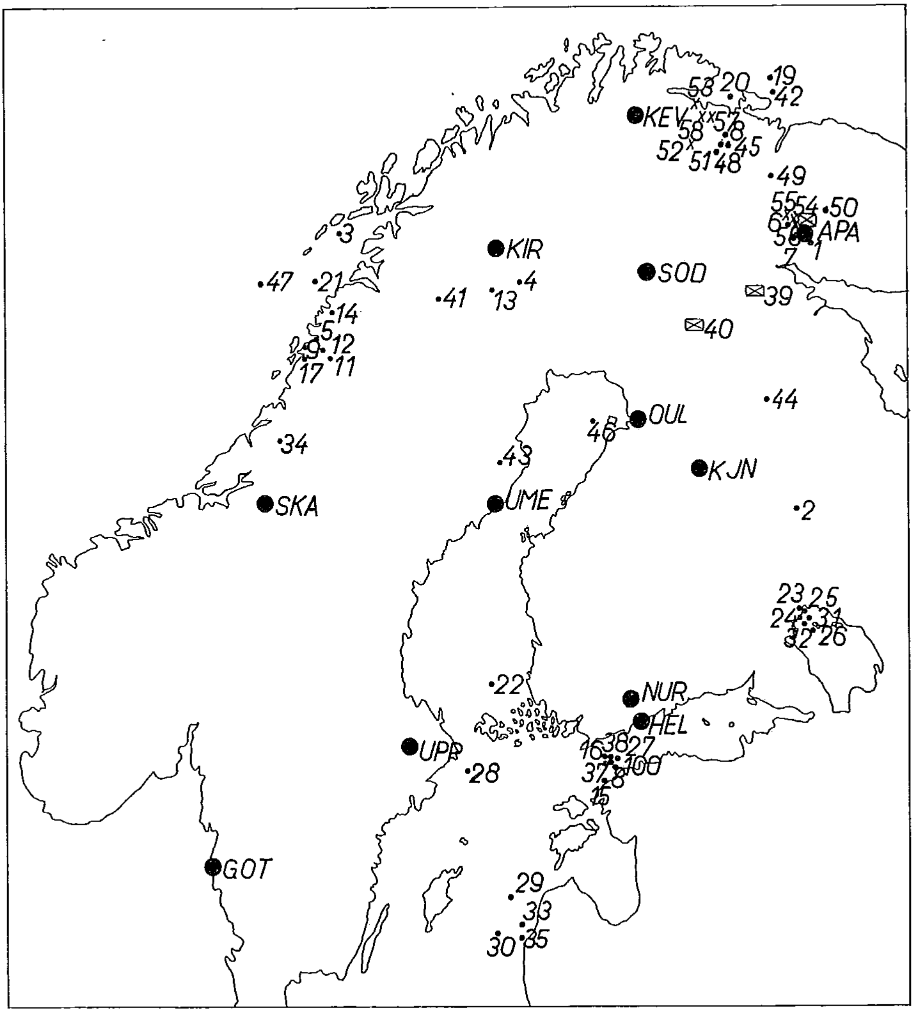

Fig. 1. Epicenters of located seismic events
(July 1957-June 1962). Epicenters of the shocks investigated:
⊠ I (1960 II 2) II (1960 II 9) by G. D. Panasenko 1961
III (1960 II 20) by E. Penttilä 1960
● July 1957-June 1961 (Finnish, Swedish and USSR data)
July 1961-June 1962 (Finnish data)

4. *Results*

Epicenters of the seismic events located are plotted in the map given in Fig. 1. The epicenters of the earthquakes on Feb. 2, 1960, Tolvantijärvi Earthquake and Feb. 9, 1960, studied by PANASENKO [5], and Kuusamo—Salla Earthquake, Feb. 20, 1960, studied by one of the present authors (PENTTILÄ [6]), are indicated respectively according to the published investigations. Series of seismic events suspected in the Swedish Bulletin to be artificial explosions are also shown in the map, with the epicenters given in the Bulletin.

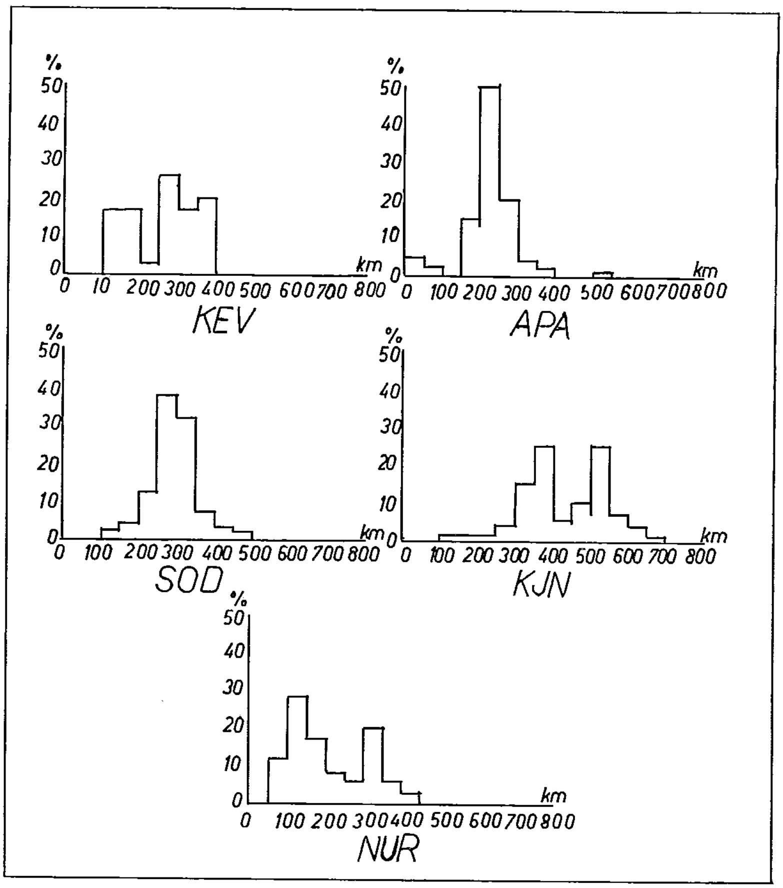

Fig. 2. Frequency distributions of epicentral distances of events recorded at the several Fennoscandian stations. July 1957-June 1962.

5. *Discussion and remarks*

Although during the last five years the seismological service in the territory has developed very much compared with previous years, the network has not yet provided sufficient data for the study of local seismicity, as too few epicenters have been located. An individual station, *e.g.* Sodankylä, Apatity or Kiruna, records many local seismic events which are not recorded at the other stations. The epicentral distances computed from the $S-P$ times from each station suggest that most (or some) of the shocks recorded at a single station belong either to the epicenter group near Apatity or to that around Kirkenes. Frequency distributions of epicentral distances of seismic events recorded at the several Fennoscandian stations are given in Fig. 2. It suggests to us that the most frequent events are expected at epicentral distances of about 0—100 km and 200—250 km from Apatity, 250—350 km from Sodankylä, 100—200 km and 250—300 km from Kevo and 350—400 km and 500—550 km from Kajaani in Northern Fennoscandia, which coincide with the areas around Kirkenes and Apatity. Frequency maxima at epicentral distances of 100—150 km and 300—350 km from Nurmijärvi may correspond to the epicenter groups in the western part of the Gulf of Finland and in Lake Ladoga respectively.

The times of occurrence of the shocks observed at Apatity with epicentral distances between 200 and 250 km, the epicenters possibly being near Kirkenes, show a peculiar concentration and this suggests that the shocks may possibly have been due to artificial explosions. But, since we have no reliable information on the matter, we cannot easily draw any conclusions. There is a high possibility of tectonic activity, as has already been stated by PANASENKO [5].

The situation may also be similar for a group of epicenters situated near Lake Ladoga, where several shocks were reported in the years 1902, 1914, 1921, 1926 and 1927 (BÅTH [2]). Recent activity in the Lake Ladoga area may also be artificial in nature, but nevertheless we cannot exclude the possibility of its tectonic origin, if we recall the existence of seismic activity during the first quarter of this century (RENQVIST [14, 15]). Considering the accuracy of epicenter location, some of the Lake Ladoga epicenters must lie in Finnish territory, but there were no artificial explosions there at the corresponding dates.

If we assume that the shocks in the Lake Ladoga area were not artificial explosions, it is quite interesting that the seismicity of the area should have become active again since 1957, after 30 years' quiescence. Whether the tectonic fault responsible for the origin of Lake Ladoga is still active at present or not would merit investigation and the study of minor shocks must be intensified by cooperative work between the seismologists of Finland and neighboring countries.

By contrast, the epicenter group in the western part of the Gulf of Finland is quite new, although a little to the north of the located site, *i.e.* near Hanko, five earthquakes of $4.5 > M > 3.7$ occurred in 1934—35 and smaller ones in 1901 and 1927 (BÅTH [2]). Near Hanko and Porkkala several explosions were made in 1960—1961 by a salvage company and by the Finnish Army respectively, but we were informed of all of them by the companies and authorities concerned. Accordingly, we could exclude them without doubt. At the corresponding dates of these events in the Gulf of Finland we can thus be sure that no explosions took place on the Finnish side. There were several series of events, located in almost the same place, which were suspected in the Swedish Bulletin to be explosions. This strongly suggests to us the artificial nature of these events located in the western part of the Gulf of Finland. Moreover, the events located there were followed by series of similar shocks of smaller magnitude at regular time intervals, which are recorded at only one or two Finnish stations, and this is also strong evidence for suspecting them to be due to artificial explosions. Nevertheless, in the interests of science it is highly desirable to have reliable information concerning the explosions even in this case. If even some of them were tectonic, it would be quite a new finding in seismology. Although it seems quite improbable that they are tectonic, we cannot exclude the possibility, since we have no reliable evidence of the artificial nature of the events. Otherwise we must undertake an unnecessary and disagreeable study to enable us to distinguish natural seismic events from artificial ones, before we can study the frequency of local earthquakes.

Epicenters in the middle of the Gulf of Bothnia are also subject to the same doubts. In the Swedish Bulletin many shocks consisting of serial events are suspected to be due to explosions in that location. The authors assume that the Swedish seismologists were not given any information about the events and only guessed their artificial nature from their too regular serial occurrence in time. Thus the few single or double events in that location cannot be assumed to be artificial while series of several shocks are thought likely to be explosions. Considering the circumstances, the possibility cannot be excuded that the seismic events located in the middle of the Gulf of Bothnia are artificial.

In conclusion, it may be said that several epicenter groups of seismic events cannot be considered undoubtedly tectonic, and this constitutes a serious problem in studying seismicity in Fennoscandia at the present time.

Seismogram characteristics at Sodankylä were examined tentatively (for the purpose of finding a method to distinguish the natural earthquakes from artificial ones) and it was noticed that they may be classified into several types as given in Fig. 3. There are also some pictures from Nurmijärvi. The results are not conclusive but it seems worthwhile to continue study along these lines.

Type *A* is represented by the shock with an epicentral distance of 250 km west of Sodankylä. The *P* group is very weak, but the *S* group strong. The surface wave is clear and strong (Fig. 3, A. Presumably an earthquake).

Type *B* comprises the shocks with epicentral distances between 195 km and 270 km from Sodankylä to the west and north and between 340 and 350 km east of Nurmijärvi. The *P* group is strong and so is the *S* group, but the surface wave is weak or absent (Fig. 3. *B*1, *B*2, *B*3, *B*4, and *B*5. Presumably explosions).

Type *C* is represented by shocks with an epicentral distance of between 280 km and 295 km northeast of Sodankylä. The first impulse in the *P* group is very weak, but the second *P* impulse is much stronger and the *S* group is strong. The surface wave is clear or weak. (Fig. 3. *C*1, *C*2, *C*3. Presumably earthquakes).

Type *D* includes the shocks with epicentral distances between 360 km and 670 km from Sodankylä to the west and southeast and 720 km northnortheast of Nurmijärvi. The *P* group is very weak, the *S* group strong and the surface waves in these seismograms are very weak or absent (Fig.: 3. *D*, *D*2, *D*3, *D*4, *D*5, and *D*6. These events are presumed to be earthquakes).

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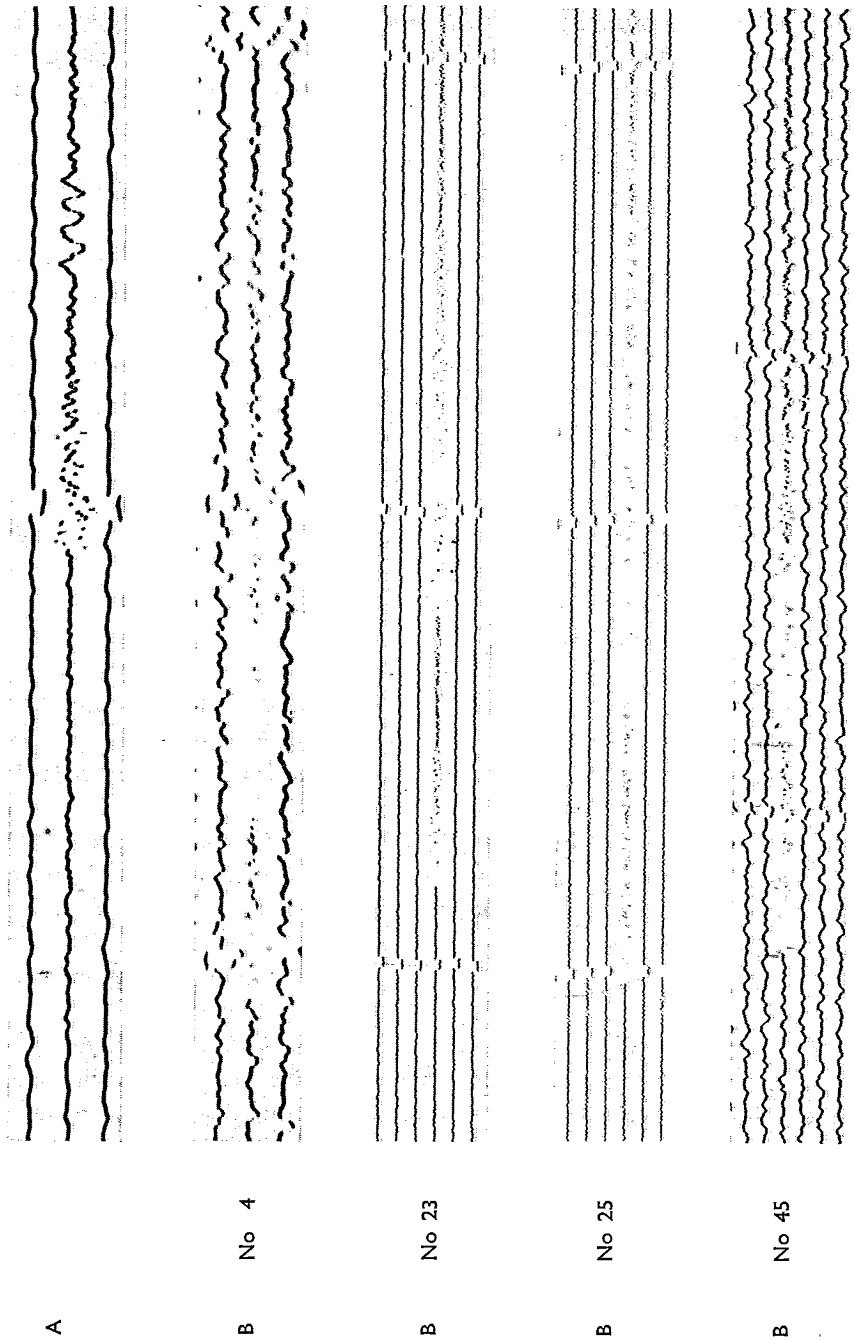

Fig. 3. Seismogram characteristics at Sodankylä and at Nurmijärvi.

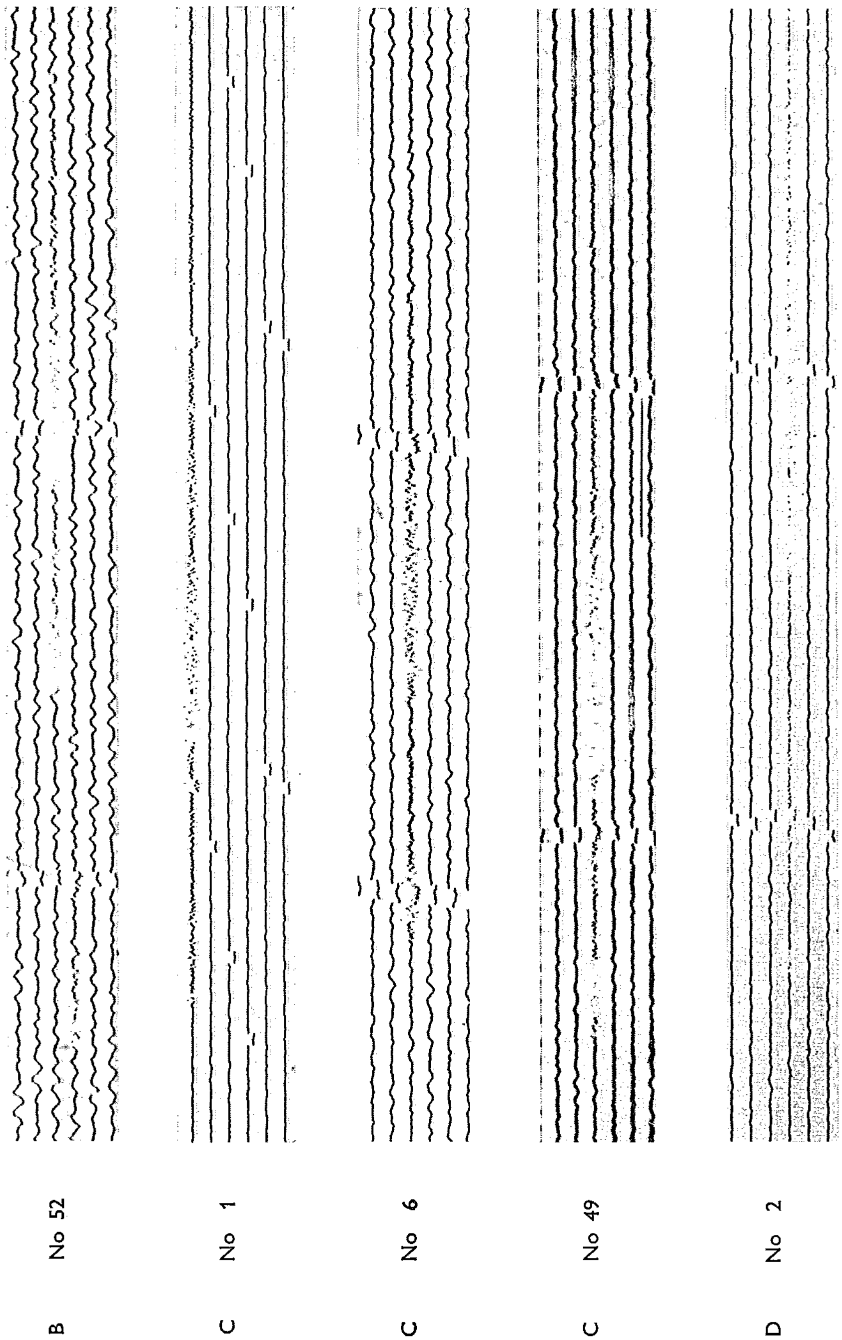

Fig. 3. Cont.

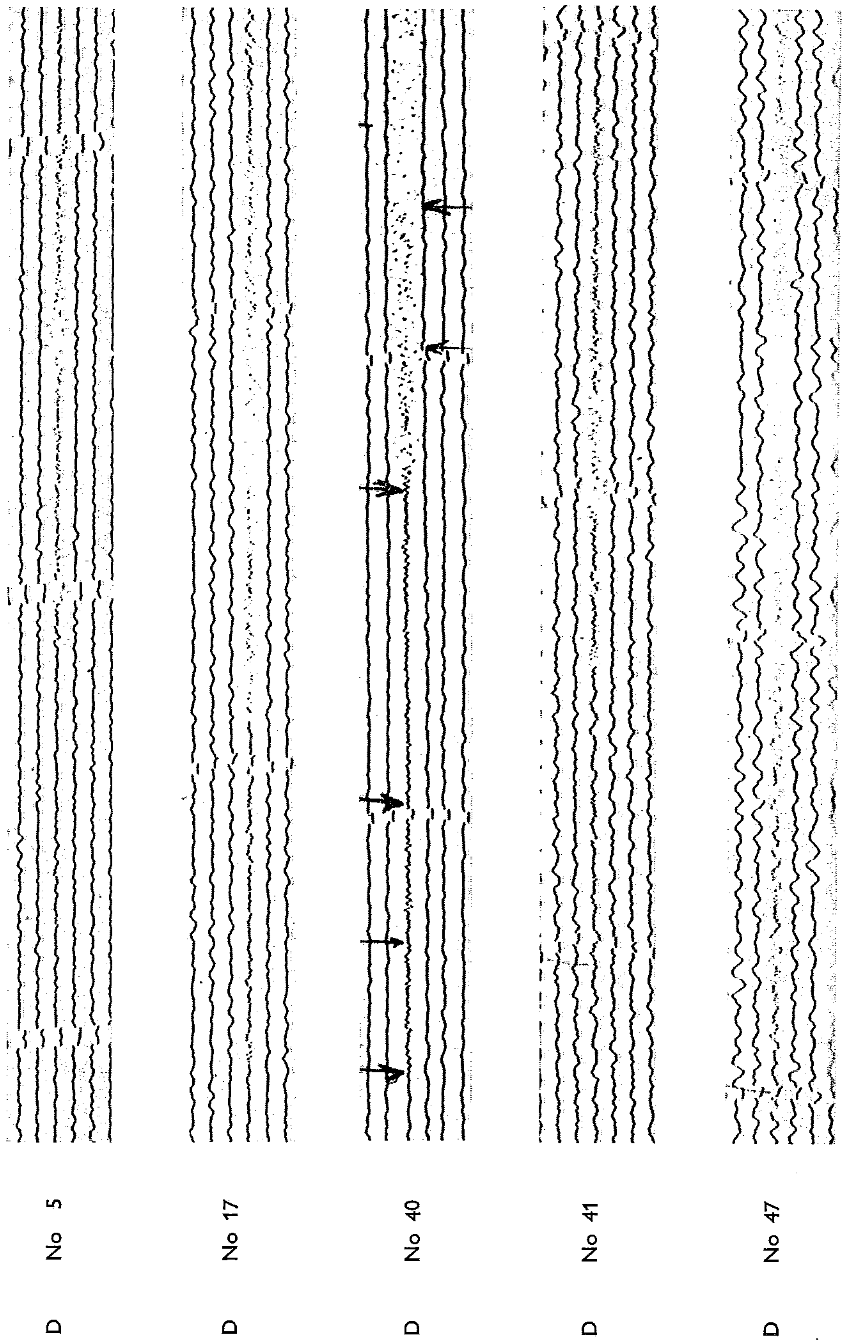

Fig. 3. Cont.

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