NORSAR

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1 January – 30 June 1976

Prepared by
K. A. Berteussen

Kjeller, 23 July 1976

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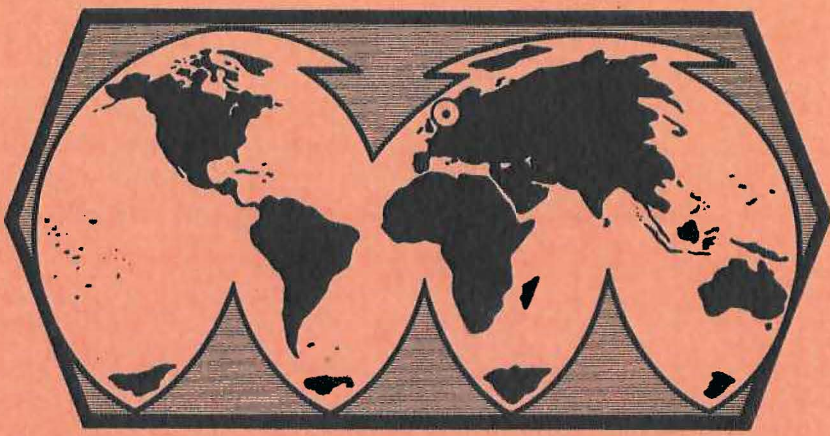

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This report covers research and operation activities at the Norwegian Seismic Array (NORSAR) for the period 1 January - 30 June 1976.

In this reporting period the operation of the Detection Processor System (DP) have been interrupted by a number of stops that are larger than usual, while the Event Processor

has performed satisfactorily. Project personnel have increased their participation in maintenance on some of the special equipment. From the beginning of the period the NORSAR DP on-line system has exchanged 2.4K bit/sec of real data over the ARPANET. The total number of events reported is higher than usual, with a daily average of 22.2. There are no changes in the monitoring schedule, but towards the end of the period the array monitoring was hampered by EOC (Experimental Operations Console) faults and a DP fault restricting the use of the EOC. Seven reports/papers and one program have been finished in the period. Altogether 8 topics are covered in the summary of research activities. In the first study it is shown how the discrimination problem may be solved by a pattern recognition approach. Then comes a section about inversion of large apperature array travel time data for mapping of seismic anomalies in the lithosphere-asthenosphere. A study of lateral variations in the structure of the upper mantle beneath Eurasia as well as a direct measurement of the crustal P-velocity in the NORSAR area, using the angle of incidence of long period P-waves has been finished. A detailed investigation of the precursors to the ScS-phase has been initiated, and the seismicity of the area around the presently active part of the Jan-Mayen fracture zone has been re-examined. Finally is presented a seismic risk analysis, and a study of the noise level variation at NORSAR and its effect on detectability.

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I SUMMARY

This report covers research and operation activities at the Norwegian Seismic Array (NORSAR) for the period 1 January - 30 June 1976.

In this reporting period the operation of the Detection Processor System (DP) have been interrupted by a number of stops that are larger than usual, while the Event Processor has performed satisfactorily. Project personnel have increased their participation in maintenance on some of the special equipment. From the beginning of the period the NORSAR DP on-line system has exchanged 2.4K bit/sec of real data over the ARPANET. The total number of events reported is higher than usual, with a daily average of 22.2. There are no changes in the monitoring schedule, but towards the end of the period the array monitoring was hampered by EOC (Experimental Operations Console) faults and a DP fault restricting the use of the EOC. Seven reports/papers and one program have been finished in the period. Altogether 8 topics are covered in the summary of research activities. In the first study it is shown how the discrimination problem may be solved by a pattern recognition approach. Then comes a section about inversion of large apperature array travel time data for mapping of seismic anomalies in the lithosphere-asthenosphere. A study of lateral variations in the structure of the upper mantle beneath Eurasia as well as a direct measurement of the crustal P-velocity in the NORSAR area, using the angle of incidence of long period P-waves has been finished. A detailed investigation of the precursors to the ScS-phase has been initiated, and the seismicity of the area around the presently active part of the Jan-Mayen fracture zone has been re-examined. Finally is presented a seismic risk analysis, and a study of the noise level variation at NORSAR and its effect on detectability.

K.A. Berteussen

II. OPERATION OF ALL SYSTEMS

II.1 Detection Processor Operation (DP)

In this reporting period, the operation of the Detection Processor System has been interrupted by a number of stops that are larger than usual. This is reflected in the up time percentage, which is 93.9%* as compared to 97.3% for the last reporting period (July to December 1975). The two overall main reasons for the drop in uptime are:

- malfunctioning hardware, and
- the adaptation of the DP system to the ARPANET environment.

Fig. II.1. and the accompanying Table II.1.1 both show the daily DP downtime in hours for the days between 1 January and 30 June 1976. The monthly recording times and up percentages are given in Table II.1.2.

The most significant break in recording occurred from January 11 to January 14, when a hardware error in the SPS (Special Processing System) Read-Only Storage (ROS) caused a down period of about 72 hours. Also, on January 17, the cable connecting the SPS Binary Synchronous Adapter to the multiplexer in the Codex Modem for the ARPANET connection was unplugged, because maintenance was being done on the TIP (Terminal Interface Processor). However, the adapter was not masked by the operator, and this caused the SPS to remain inoperable for about 47 hours before the reason was discovered.

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* The percentage of the time when ARPANET communication has been flowing is considerably less, due to the fact that the DP system may perform all its other functions even when no data can flow through the subnetwork (Subnetwork failure, Destination Dead, etc.)

The 425 breaks occurring in the reporting period can be grouped in the following categories:

a)	Software related stops	:	169
b)	SPS " "	:	116
c)	Error on the Multiplexor channel	:	68
d)	Other hardware related stops	:	21
e)	C.E. (Customs Engineering) Maintenance	:	15
f)	Tests	:	13
g)	Tape drive problems	:	8
h)	Disk " "	:	4
i)	TIP related stops	:	4
j)	EOC unit problems	:	4
k)	Unknown	:	3

In category a) are included all stops caused by the system running out of core space, all stops caused by program errors, all stops to take up a new version of the system, and all cases when the system was taken down on purpose because something evidently was wrong. Although the number of stops in this category is larger than the number for category b), it is the SPS related stops that have caused the largest time gaps in the recording, as can clearly be seen from Fig. II.1.1 and Table II.1.1.

The first version of the DP system that used APRANET for exchange of real-time seismic data with the Communications and Control Processor (CCP) at SDAC was taken up as the Primary On-line system in the middle of February, the delay being caused by the SPS hardware problems mentioned above, and an error in the communications software that made this system unstable. However, after starting to operate this system, it soon became clear that it required considerable improvements in order to be able to perform all its functions adequately. The inadequacies of the new system were felt especially in two areas:

- The (virtual) connection to the CCP was very unstable, leading to frequent situations of, say, "Destination Dead". This again caused local conflicts inside the DP system, with respect to core storage and use of the CPU.
- The Experimental Operations Console (EOC) had earlier never been actively involved when testing the new system, mainly because it had all the time been tested as the Secondary On-line system, which does not use the EOC. It now turned out that the EOC task would compete for the same core storage queue blocks as were used for ARPANET data, especially when Array Monitoring and Control (AMC) tests were initiated by the operator from the EOC.

Because of this, later improvements and modifications of the DP system have often been performed directly on the Primary On-line system, since this was the only way to test out new features in a realistic environment. This testing procedure has, of course, contributed heavily to the number of stops in category a) above.

Another problem turned up after we started to run the ARPANET-connected version of the DP system. The 360 computer goes down, on the average once a day, because of some unrecoverable error occurring on its multiplexor channel (listed as category c) above). The 2821 controller for the card reader and printer is attached to this channel, together with the 2150 controller for the 1052 printer Keyboard. In addition, the Special Host Interface Unit for linking of the 360 system to the ARPANET TIP is attached to the channel. It is evident that the error mentioned occurs because this latter unit competes in a destructive way with the other units for use of the multiplexor channel under certain circumstances, but we have not yet been able to pinpoint what the circumstances are and when they occur. This error does not occur when the interface unit is not in use, and also, the error occurs on both the interface units at NORSAR. This should give low probability to an intermittent error in an interface unit, since it occurs in both the units, and at the same time it indicates that the error has to do with the interface unit's intrusion in the 360 system. Various efforts to remedy this situation (i.e., switching channel priorities by changing the order of attachment to the channel, changing the transfer mode on the 2821 controller) have so far all failed.

The total down time for this period was 291 hours 38 minutes. The mean-time-between-failures was 0.4 days, as compared with 1.6 days for the last reporting period (July-December 75).

D. Rieber-Mohn

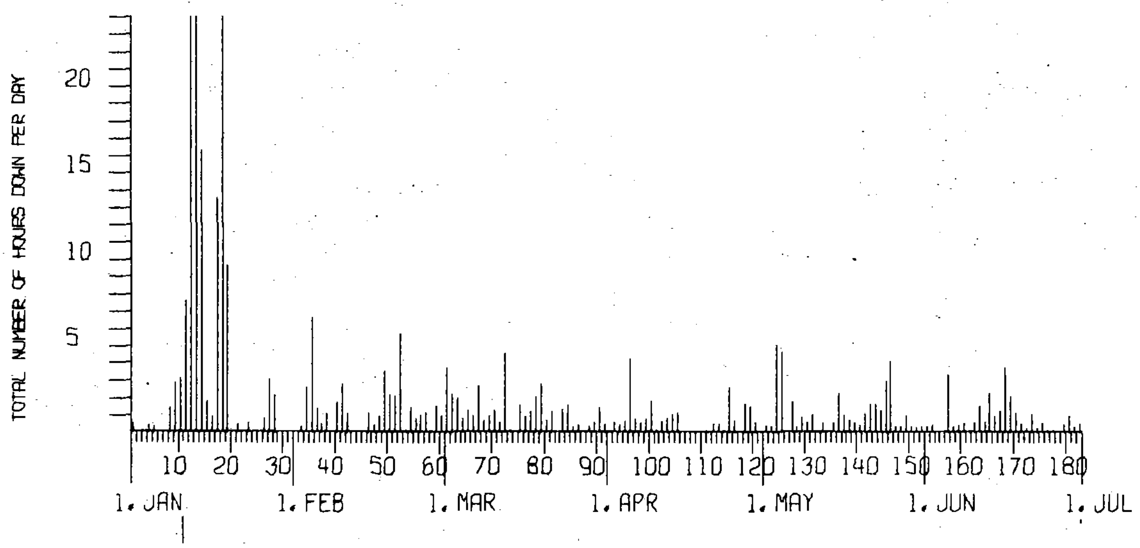

Fig. II.1.1 Detection Processor down time 1 January - 1 July 1976.

TABLE II.1.1

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
1	0	0	0	3	START NEW YEAR
1	3	15	3	20	1052 ERROR IN TIMING
1	12	3	12	17	1052 ERROR IN TIMING
1	14	36	14	41	1052 ERROR IN TIMING
4	8	51	9	10	SPS INTER NOT RECEIVED
5	10	6	10	16	SPS INTER NOT RECEIVED
8	13	16	13	22	TEST SDAC
8	13	40	13	46	TEST SDAC
8	16	53	17	27	TEST SDAC
8	18	7	18	13	TEST SDAC
8	18	22	18	28	TEST SDAC
8	21	55	22	19	TEST SDAC
8	23	59	24	0	NEW VERSION, PROBLEMS
9	0	0	0	43	NEW VERSION, PROBLEMS
9	3	4	4	4	NEW VERSION, PROBLEMS
9	8	14	8	40	NEW VERSION, PROBLEMS
9	15	3	15	11	TEST SDAC
9	16	17	16	48	TEST SDAC
9	23	59	24	0	NEW PROGRAM VERSION
10	0	0	0	47	NEW PROGRAM VERSION
10	4	58	5	14	NEW PROGRAM VERSION
10	8	21	8	41	NEW PROGRAM VERSION
10	11	25	11	49	NEW PROGRAM VERSION
10	20	3	20	46	NEW PROGRAM VERSION
10	22	42	23	15	NEW PROGRAM VERSION
11	16	26	24	0	SPS ROS HARDWARE
12	0	0	24	0	SPS ROS HARDWARE
13	0	0	24	0	SPS ROS HARDWARE
14	0	0	16	4	SPS ROS HARDWARE
14	22	52	23	4	BLOCKED CHANNEL 1 (B)
15	0	10	0	24	BLOCKED CHANNEL 1 (B)
15	0	35	1	25	BLOCKED CHANNEL 1 (B)
15	1	56	2	14	BLOCKED CHANNEL 1 (B)
15	8	25	8	37	BLOCKED CHANNEL 1 (B)
15	13	29	13	32	CHANGE OF DISK DRIVE
15	19	33	19	41	CHANGE OF DISK DRIVE
16	2	1	2	6	CHANGE OF DISK DRIVES
16	6	51	6	59	SPS
16	7	30	7	35	SPS
16	11	9	11	12	SPS
16	11	58	12	6	SPS
16	14	13	14	27	TIP MAINTENANCE
16	14	47	14	52	TIP MAINTENANCE
17	10	30	24	0	SPS BSC ADAPTER
18	0	0	24	0	SPS BSC ADAPTER
19	0	0	9	2	SPS BSC ADAPTER
19	9	10	9	25	SPS CHECKED
19	9	46	10	5	SPS BSC ADAPTER TEST

TABLE II.1.1

(cont.)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS..........
21	4	48	4	58	SPS
21	12	11	12	23	SPS
23	13	52	13	58	NEW DP VERSION
23	20	18	20	35	PROGRAM STOP
26	5	16	5	52	NO HR TAPES
26	21	18	21	27	SPS
27	4	26	6	32	CHANNEL 1 BLOCKED
27	8	15	8	36	C. E. MAINT (1052)
27	14	40	15	14	NEW DP VERSION
28	11	36	11	59	PLOTTER HARDWARE ERROR
28	12	4	12	55	PLOTTER HARDWARE ERROR
28	15	19	16	12	NEW VERSION,TEST
33	8	38	8	53	SPS STOP
34	20	23	22	56	SPS STOP
35	8	5	8	17	C. E. MAINT (POWER OFF)
35	9	7	9	14	NEW VERSION, TEST
35	9	21	9	47	PROGRAM CHANGE
35	12	24	16	57	SPS STOP
35	17	16	17	40	SPS STOP
35	18	57	19	8	SPS FALSE DETECTIONS
35	19	47	20	3	SPS FALSE DETECTIONS
35	22	1	22	16	SPS FALSE DETECTIONS
35	22	45	22	53	SPS FALSE DETECTIONS
35	23	57	24	0	FALSE DETECTIONS SPS
36	0	0	0	3	FALSE DETECTIONS SPS
36	0	35	0	46	FALSE DETECTIONS SPS
36	0	51	0	58	FALSE DETECTIONS,SPS
36	4	49	4	56	FALSE DETECTIONS,SPS
36	5	55	6	2	FALSE DETECTIONS,SPS
36	14	10	14	18	NEW VERSION,TEST
36	14	40	15	10	PROGRAM STOP
36	20	42	20	50	SPS
37	14	10	14	16	SPS
37	14	23	14	39	PROGRAM STOP
38	7	41	7	54	PLOTTER
38	9	30	10	21	C. E. MAINT
40	2	27	2	38	SPS
40	12	53	13	7	SPS
40	14	16	14	32	PROGRAM STOP
40	15	16	15	37	PROGRAM STOP
40	17	36	17	42	SPS
40	17	53	17	59	SPS
40	20	5	20	12	SPS
40	22	16	22	38	SPS
41	9	53	12	39	SPS
42	18	17	19	19	SPS
46	7	53	8	54	SPS

TABLE II.1.1

(cont.)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
47	9	43	9	48	SPS
47	23	10	23	22	PROGRAM STOP
48	9	22	9	27	NEW VERSION,TEST
48	10	7	10	20	PROGRAM STOP
48	14	49	15	5	HARDWARE (360) ERROR
48	21	28	21	46	HARDWARE (360) ERROR
49	0	0	0	6	NEW VERSION,TEST
49	7	1	9	8	SPS
49	10	42	11	24	HARDWARE (360) ERROR
49	15	9	15	26	SPS
49	15	49	16	8	SPS
50	10	21	10	55	SPS
50	14	43	15	8	1052 HARDWARE (A TO B)
50	16	25	17	8	WORK 1052 (B TO A)
50	23	30	23	59	HARDWARE (360) ERROR
51	3	49	3	58	PROGRAM STOP
51	7	28	7	32	SPS
51	8	41	8	56	PROGRAM STOP
51	13	2	13	14	PROGRAM STOP
51	14	10	14	27	PROGRAM STOP
51	14	30	15	29	SPS
51	19	49	19	56	NEW VERSION START
52	2	24	2	50	SPS
52	4	23	4	36	PROGRAM STOP
52	5	26	5	57	SPS
52	12	18	16	47	SPS
53	10	44	10	52	PROGRAM STOP
54	12	6	13	4	C. E. MAINT
54	19	37	20	2	PROGRAM STOP
55	0	30	0	43	SPS
55	7	44	7	55	HARDWARE (360) ERROR
55	19	48	20	7	PROGRAM STOP
56	12	55	13	8	PROGRAM STOP
56	14	34	14	48	PROGRAM STOP
56	15	27	15	44	PROGRAM STOP
56	19	39	19	49	PROGRAM STOP
57	1	56	2	2	PROGRAM STOP
57	9	16	9	31	PROGRAM STOP
57	18	6	18	52	1052 HARDWARE A TO B
58	13	8	13	15	B TO A
59	0	170	0	260	PROGRAM STOP
60	12	39	12	47	PROGRAM STOP
60	17	58	18	20	ROGRAM STOP
60	23	40	24	0	PROGRAM STOP

TABLE II.1.1

(cont.)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS..........
61	0	0	0	1	PROGRAM STOP
61	12	1	12	6	SPS
61	14	4	14	16	SPS
61	19	34	22	35	SPS
61	22	41	23	3	SPS
62	14	4	14	11	PROGRAM STOP
62	14	42	14	47	1052 HARDWARE ERROR
62	19	35	21	34	SPS
63	7	55	8	11	PROGRAM STOP
63	8	26	8	34	SPS
63	11	14	11	35	SPS
63	20	7	21	14	SPS
64	0	12	0	23	SPS
64	8	44	8	54	SPS
64	11	48	11	55	SPS
64	15	40	15	44	SPS
64	19	13	19	27	PROGRAM STOP
65	5	5	5	14	SPS
65	5	56	6	11	SPS
65	14	47	15	2	SPS
65	23	25	24	0	PROGRAM/SPS STOP
66	0	0	0	43	PROGRAM/SPS STOP
66	16	46	16	55	SPS
67	1	31	2	2	SPS
67	6	0	6	29	SPS
67	8	5	8	14	SPS
67	11	37	12	43	SPS
67	19	10	19	32	PROGRAM STOP
68	4	59	5	10	PROGRAM STOP
68	21	43	22	12	PROGRAM STOP
69	12	47	13	11	MPX ERROR
69	20	4	20	9	SPS
69	22	36	22	58	PROGRAM STOP
70	11	46	12	51	SPS
70	22	3	22	7	SPS
70	22	30	22	34	SPS
71	7	16	7	22	SPS
71	11	40	12	8	
72	0	46	1	1	MPX ERROR
72	8	9	12	3	C. E. MAINT SPS
72	14	46	15	0	PROGRAM STOP
72	18	5	18	11	SPS

TABLE II.1.1

(cont.)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
73	0	2	0	8	SPS
75	1	50	2	17	PROGRAM STOP
75	5	11	6	12	MPX ERROR
76	10	8	10	20	SHARED DISK DOWN
76	14	44	14	52	SPS
76	20	34	20	50	PROGRAM STOP
76	21	18	21	32	SPS
77	9	52	10	7	MPX/LATE ERROR
77	12	50	13	27	PROGRAM STOP
77	13	39	13	53	PROGRAM STOP
77	17	53	17	59	SPS
78	1	10	1	28	MPX/LATE
78	6	4	6	59	PROGRAM STOP
78	10	15	10	24	MPX/LATE ERROR
78	13	45	13	54	MPX/LATE ERROR
78	19	29	20	0	PROGRAM STOP
79	10	43	11	3	PROGRAM STOP
79	11	7	11	59	C. E. MAINT
79	14	12	15	47	PROGRAM STOP
80	7	50	8	14	MPX/LATE ERROR
80	13	32	13	47	MPX/LATE ERROR
81	0	30	1	6	PROGRAM STOP
81	2	15	2	40	MPX/LATE ERROR
81	22	28	22	38	MPX/LATE ERROR
83	2	16	2	46	MPX/LATE ERROR
83	12	45	13	3	PROGRAM STOP
83	14	9	14	38	SPS
84	9	23	10	43	C. E. MAINT
84	11	10	11	24	SPS
85	14	28	14	42	PROGRAM STOP
86	7	47	8	3	PROGRAM STOP
86	23	50	23	54	SPS
87	12	59	13	3	PROGRAM STOP
88	20	52	21	6	SPS (CB8 FRAME 1)
89	5	12	5	19	PROGRAM STOP
89	5	21	5	33	MPX/LATE ERROR
89	11	48	12	4	PROGRAM STOP
90	0	33	0	42	EOC HANGUP
90	16	42	17	8	PROGRAM STOP
90	22	4	22	12	SPS
90	22	28	22	35	SPS
90	23	19	23	49	PROGRAM STOP
91	11	32	11	43	PROGRAM STOP
91	13	2	13	10	PROGRAM STOP
91	14	15	14	20	SPS
92	14	3	14	6	PROGRAM CHANGE
93	7	26	7	48	MPX/LATE ERROR

TABLE II.1.1

(cont.)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS............
93	18	39	18	51	PROGRAM STOP
94	15	35	15	53	PROGRAM STOP
95	14	39	14	43	PROGRAM CHANGE
95	22	2	22	32	MPX/LATE ERROR
95	22	37	22	40	PROGRAM STOP
96	0	17	0	24	MPX/LATE ERROR
96	0	42	0	47	PROGRAM STOP
96	4	58	5	12	MPX/LATE ERROR
96	9	55	11	4	INTERFACE TESTS
96	12	17	14	36	INTERFACE TESTS
96	21	26	21	43	PROGRAM STOP
97	10	29	10	42	PROGRAM STOP
97	10	53	11	4	PROGRAM STOP
97	13	9	13	28	SPS C. E. MAINT
98	6	47	7	6	PROGRAM STOP
98	19	10	19	22	PROGRAM STOP
99	3	9	3	13	PROGRAM STOP
99	7	43	7	51	PROGRAM STOP
99	15	35	16	7	PROGRAM STOP
100	1	46	2	4	MPX/LATE ERROR
100	3	57	4	25	MPX/LATE ERROR
100	12	42	12	48	A TO B
100	12	56	13	4	MPX LATE ERROR
100	21	8	21	52	MPX LATE ERROR
101	12	23	12	29	PROGRAM STOP
102	10	44	11	8	MPX/LATE ERROR
102	20	15	20	29	MPX/LATE ERROR
103	12	9	12	27	MPX/LATE ERROR
103	21	47	22	15	PROGRAM STOP
104	14	11	14	31	PROGRAM STOP
104	14	53	15	3	MPX/LATE ERROR
104	15	51	16	15	PROGRAM STOP
105	1	25	1	29	PROGRAM STOP
105	2	54	3	9	PROGRAM STOP
105	6	15	6	38	PROGRAM STOP
105	8	29	8	41	PROGRAM STOP
105	14	52	15	5	PROGRAM STOP
105	20	28	20	36	IMP DOWN PROBLEMS
105	23	9	23	18	IMP DOWN PROBLEMS
111	17	37	17	41	PROGRAM STOP
112	13	16	13	28	SPS
112	14	28	14	32	PROGRAM STOP
112	21	9	21	16	PROGRAM STOP
113	1	16	1	21	PROGRAM STOP
113	13	9	13	13	PROGRAM STOP
113	17	10	17	28	PROGRAM STOP
114	14	59	15	5	PROGRAM STOP

TABLE II.1.1

(cont.)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS..........
115	1	45	2	10	SPS
115	11	9	11	15	SPS
115	13	3	15	2	SPS
116	3	19	3	47	SPS
116	12	12	12	22	SPS
118	6	20	7	7	1052 HARDWARE ERROR
118	13	24	13	26	PROGRAM STOP
118	19	36	20	0	PROGRAM STOP
118	20	56	21	11	SPS
118	23	53	24	0	PROGRAM STOP
119	0	0	0	10	PROGRAM STOP
119	10	7	10	46	MPX REARRANGEMENT
119	14	39	14	45	SPS
119	21	2	21	14	SPS
119	22	39	22	56	MPX/LATE ERROR
120	8	20	8	24	C. E. MAINT (1052)
120	8	40	8	53	C. E. MAINT (1052)
120	11	38	11	51	MPX/LATE ERROR
121	0	25	0	30	PROGRAM STOP
122	3	48	4	7	PROGRAM STOP
123	23	44	23	59	SPS
124	12	28	12	42	SPS
124	13	21	13	40	MPX LATE
124	15	2	19	30	FAULTY SPS CARD
125	2	30	2	54	MPX/LATE
125	9	3	13	9	SPS REPAIR
125	15	25	15	31	SPS
127	4	49	6	24	TAPE DRIVE ERROR
128	10	34	10	47	MPX/LATE ERROR
129	7	25	7	37	PROGRAM STOP
129	12	50	13	25	PROGRAM STOP
130	23	16	23	50	MPX LATE ERROR
131	5	0	5	42	MPX/LATE ERROR
131	14	23	14	37	PROGRAM STOP
131	17	18	17	22	PROGRAM STOP
132	7	49	7	55	PROGRAM STOP
133	13	41	13	49	SPS (THERM FRAME 1)
133	13	55	14	2	SPS (THERM FRAME 1)
133	17	33	17	49	MPX/LATE ERROR
134	15	9	15	14	EOC TEST,A TO B
135	8	45	9	0	B TO A
135	10	34	10	45	PROGRAM CHANGE
135	17	50	17	57	SPS (THERM FRAME 1)
136	12	11	12	38	PROGRAM STOP
136	20	12	20	19	SPS
136	20	42	20	51	SPS
136	20	55	22	24	SPS

TABLE II.1.1

(cont.)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
137	20	54	21	48	PROGRAM STOP
138	8	52	9	32	PROGRAM STOP
139	4	11	4	24	PROGRAM STOP
139	12	6	12	12	PROGRAM STOP
139	16	54	17	5	PROGRAM STOP
140	16	27	16	46	MPX/LATE ERROR
141	7	48	8	19	PROGRAM STOP,A TO B
141	11	57	12	1	B TO A
141	13	4	13	9	EOC PROBLEMS
141	15	24	15	31	EOC PROBLEMS
141	18	59	19	12	PUNCH HARDWARE ERROR
142	1	6	1	10	C. E. WORK ,PUNCH
142	5	1	5	37	MPX/LATE ERROR
142	7	0	7	29	MPX/LATE ERROR
142	12	20	12	33	PROGRAM STOP
142	21	17	21	27	PROGRAM STOP
143	4	0	4	21	MPX/LATE ERROR
143	9	9	9	19	MPX/LATE ERROR
143	12	[illegible]	12	18	PROGRAM STOP
143	20	20	20	26	PROGRAM STOP
143	22	[illegible]	22	15	MPX LATE
143	22	30	23	4	MPX LATE
144	0	50	0	58	PROGRAM STOP
144	8	29	8	42	EOC PROBLEMS
144	11	32	11	37	PROGRAM STOP
144	21	5	21	11	PROGRAM STOP
144	22	15	22	42	MPX/LATE
144	23	45	24	0	MPX/LATE
145	0	0	0	14	MPX/LATE
145	2	16	2	22	PROGRAM STOP
145	10	24	10	33	PROGRAM STOP
145	11	57	12	53	MPX/LATE ERROR
145	21	31	21	59	MPX/LATE ERROR
145	22	3	23	6	MPX/LATE ERROR
146	0	26	1	25	MPX/LATE ERROR
146	2	41	3	31	MPX/LATE ERROR
146	3	42	4	48	MPX/LATE ERROR
146	9	41	9	55	MPX/LATE ERROR
146	13	49	14	3	PROGRAM STOP
146	22	[illegible]	23	32	MPX/LATE
147	2	55	3	2	PROGRAM STOP
147	22	54	23	2	PROGRAM STOP
148	11	32	11	38	PROGRAM STOP
148	16	44	16	51	PROGRAM STOP

TABLE II.1.1

(cont.)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
149	5	13	5	34	MPX/LATE ERROR
149	8	28	8	34	PROGRAM STOP
149	13	53	14	10	PROGRAM STOP
149	15	30	15	42	MPX/LATE ERROR
150	0	40	0	47	PROGRAM STOP
150	10	37	10	45	SPS
151	10	40	10	44	PROGRAM STOP
151	15	53	16	1	PROGRAM STOP
152	0	15	0	29	PROGRAM STOP
153	7	46	8	0	PROGRAM STOP
154	0	1	0	10	PROGRAM CHANGE
154	13	45	13	50	TAPE DRIVE ERROR
154	13	53	13	58	TAPE DRIVE ERROR
157	0	20	0	26	PROGRAM CHANGE
157	9	21	12	30	SPS
158	22	5	22	19	MPX/LATE ERROR
159	0	0	0	6	PROGRAM CHANGE
159	0	59	1	12	SPS
160	12	52	13	7	SPS
160	14	11	14	16	SPS
160	16	25	16	30	SPS
161	23	59	24	0	PROGRAM CHANGE
162	0	0	0	9	PROGRAM CHANGE
162	7	52	8	0	PROGRAM STOP
162	11	41	11	52	PROGRAM STOP
163	0	3	0	9	PROGRAM STOP
163	12	6	12	11	PROGRAM CHANGE
163	13	4	13	9	PROGRAM STOP
163	14	10	14	49	PROGRAM STOP AND CHANGE
163	19	24	19	34	MPX/LATE ERROR
163	20	59	21	18	TAPE DRIVE ERROR
164	10	52	11	27	TAPE DRIVE ERROR
165	1	24	1	42	TAPE DRIVE ERROR
165	2	0	2	29	MPX/LATE ERROR
165	8	43	9	23	PROGRAM STOP
165	15	0	15	25	PROGRAM STOP
165	21	41	22	3	MPX/LATE ERROR
166	8	11	8	16	TAPE DRIVE ERROR
166	9	21	9	35	MPX/LATE ERROR
166	13	46	13	54	PROGRAM CHANGE
166	14	58	15	21	MPX/LATE ERROR
167	9	58	10	2	PROGRAM STOP
167	12	7	12	12	PROGRAM STOP
167	15	56	16	13	
167	22	36	23	19	SPS

TABLE II.1.1

(cont.)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
168	8	23	11	46	C. E. MAINT 1052
168	12	45	12	51	C. E. MAINT 1052
168	13	2	13	34	C. E. MAINT 1052
169	11	2	11	11	MPX/LATE ERROR
169	14	27	14	35	SPS THERM
169	17	5	17	34	PROGRAM STOP
169	19	2	20	2	MPX/LATE,CARD DECK
169	21	29	21	45	SPS THERM
170	0	45	1	22	MPX/LATE ERROR
170	19	3[illegible]	19	54	MPX/LATE ERROR
171	2	47	2	59	TAPE DRIVE ERROR
171	19	11	19	22	MPX/LATE ERROR
172	11	9	11	21	SPS
173	0	4	0	10	PROGRAM STOP
173	3	15	3	32	PROGRAM STOP
173	9	18	9	34	MPX/LATE ERROR
173	11	30	11	50	MPX/LATE ERROR
174	10	23	1[illegible]	34	PROGRAM STOP
175	8	16	8	32	C. E. MAINT 1052
175	12	9	12	22	PROGRAM CHANGE
176	14	5	14	13	PROGRAM STOP
177	14	56	15	3	PROGRAM CHANGE
179	3	59	4	16	PROGRAM CHANGE
180	0	3[illegible]	0	35	PROGRAM CHANGE
180	20	11	20	45	MPX/LATE ERROR
180	21	46	22	0	PROGRAM STOP
181	1	30	1	45	
182	7	16	7	43	MPX/LATE ERROR

TABLE II.1.2

DP & EP Computer Usage January - June 1976

MONTH	DP UPTIME (HRS)	DP UPTIME (%)	NO. OF DP BREAKS	NO. OF DAYS WITH DP BREAKS	DP MTBF* (DAYS)	EP UPTIME (HRS)	EP UPTIME (%)
JAN	610.3	82.0	52	20	0.5	337	45.3
FEB	670.0	97.2	78	24	0.4	233	33.5
MAR	710.6	95.5	85	29	0.3	186	25.0
APR	698.7	97.0	67	24	0.4	165	22.9
MAY	710.0	95.4	81	31	0.4	182	24.5
JUN	701.3	97.4	62	26	0.5	189	26.3
	4100.9	93.9	425	154	0.4	1292	29.6

* MTBF = mean time between failures.

II.2 Event Processor Operation (EP)

The Event Processor system has performed satisfactorily throughout the reporting period. Its up time percentage is 29.6%, as compared to 25.5% for the last reporting period (July-December 1975).

H. Bungum

II.3 NORSAR Data Processing Center (NDPC) Operation

Data Center

A few changes in operational procedures due to changes in the Detection Processor occurred in the period.

Maintenance of equipment continued as before, mainly performed by subcontractors for the different categories of equipment. Project personnel have, however, increased their participation in maintenance on some of the special equipment (mainly EOC and SPS).

As the Detection Processor up time of 93.9% for the period shows, the performance of the DP has not been very good. For a discussion of the reason for this deteriorating performance, see Section II.1.

As far as special equipment is concerned, project personnel have been engaged in fault-finding maintenance. The equipment in question is Experimental Operations Console (EOC) including waveform displays, digital control unit, etc., partly also the SPS, as the standard contract does not cover such equipment.

Data Communication

The Terminal Interface Processor (TIP)

In January an extra 4 K memory bank and a Very Distant Host Interface were installed, the latter to interface with an

NDRE (Norwegian Defence Research Establishment) built communication interface unit. Coincident with this work the Bolt Beranek and Newman (BBN) representative had trouble with program loading, and the TIP was down for quite a time.

In February another BBN representative arrived in connection with intermittent TTY (Teletype model 33) operation when attempts were made to communicate with other institutions in the ARPANET. Mechanically the machine was found to be in perfect order, but aparently it did not read Honeywell test tapes properly. A misalignment between the TTY start/stop pulses and the CPU timing pulses was assumed to be the cause. Real Time Clock cards were replaced, but the TTY still failed to read the tapes. Several smaller errors were discovered, but the real cause was not found. By the end of March the TIP was very difficult to restart after a 'crash'. Different checks were done without finding any concrete fault. In connection with new TIP difficulties primo May a small peace of wool was found attached to the base of a card in the modem interface no. 1. Since then the TIP has performed satisfactorily.

National Communication Circuits

The last 2 years data transfer between subarrays and the Data Processing Center was hampered by frequent outages caused by instability in carrier systems, (1A-4B, 2C-6C), power system failure, rerouting, and temporary cable arrangements in connection with extensive changes with respect to equipment and cables at Lillestrøm and Gjøvik (5B-7B, 9C-14C). As most of the activities have come to an end, the outages are less frequent, which also Table II.3.1 reflects.

TABLE II. 3.1

Communications, degraded performance (> 20/outages > 200). Figures in per cent of total time. Month = 4 or 5 periods as indicated.

Sub-array	Jan (5)		Feb (4)		Mar (4)		April (5)		May (4)		June (4)		AVG 1/2 year	
	>20	>200	>20	>200	>20	>200	>20	>200	>20	>200	>20	>200	>20	>200
1A	0.1	0.1	0.4	3.1	0.3	0.9	0.3	7.3	0.4	-	0.5	-	0.4	1.9
1B	0.2	0.2	0.2	-	0.2	0.7	0.2	-	0.4	-	0.2	-	0.2	0.2
2B	0.1	0.2	0.2	-	0.1	1.0	0.1	0.1	0.4	-	0.4	-	0.2	0.2
3B	0.1	0.2	0.2	-	0.2	0.9	0.2	0.1	0.5	-	0.4	-	0.3	0.4
4B	0.2	0.2	0.2	-	0.3	1.0	0.2	0.1	0.5	-	0.5	0.1	0.3	0.2
5B	0.3	0.2	0.6	0.3	0.3	0.7	0.1	0.1	0.1	0.1	0.1	-	0.3	0.2
6B	0.3	0.3	0.5	0.2	0.5	0.9	0.4	0.5	0.3	0.5	16.2	0.4	3.0	0.5
7B	0.2	0.3	0.4	0.3	0.3	0.6	1.1	1.7	0.1	0.1	0.1	-	0.4	0.5
1C	0.2	0.3	0.6	0.2	0.3	0.7	0.4	1.5	4.6	19.6	6.1	2.1	2.1	4.1
2C	0.3	0.5	3.1	2.0	1.2	1.5	0.7	0.4	0.4	0.2	1.0	0.8	1.1	0.9
3C	0.1	2.6	0.3	-	0.2	1.0	0.2	0.1	0.5	1.1	0.4	0.5	0.3	0.9
4C	0.2	12.2	0.2	-	0.3	0.9	0.4	0.2	0.4	-	0.3	0.1	0.3	2.2
5C	0.1	0.3	0.3	-	0.3	0.9	0.2	0.1	0.3	-	0.4	0.1	0.3	0.2
6C	0.1	3.3	0.3	2.6	0.3	0.8	0.3	0.1	0.3	-	0.3	-	0.3	1.1
7C	-	14.3	-	26.2	-	2.4	0.1	-	-	0.2	0.1	4.4	-	7.9
8C	0.1	-	-	-	-	0.1	0.1	-	-	-	0.1	0.3	-	0.1
9C	0.3	0.3	0.3	0.5	0.7	0.8	0.2	0.2	0.4	0.5	0.4	0.5	0.6	0.5
10C	0.7	0.4	0.6	0.6	0.4	0.9	0.4	0.4	0.3	0.6	1.1	0.6	0.6	0.6
11C	1.0	0.2	4.4	0.2	1.2	1.5	0.9	0.2	2.3	0.4	3.6	0.4	2.2	0.5
12C	0.2	0.2	0.3	0.3	0.5	0.7	0.2	0.1	-	0.3	0.2	-	0.2	0.3
13C	0.3	0.2	0.4	0.3	0.5	0.7	0.2	0.1	0.4	0.3	0.1	1.0	0.3	0.3
14C	0.2	0.4	0.4	0.3	0.6	0.7	0.2	0.2	0.2	0.4	0.3	0.1	0.3	0.4
AVG	0.2	1.7	0.6	1.7	0.8	0.9	0.3	0.6	0.6	1.1	1.5	0.5	0.6	1.1
Less	(4C,7C)	0.5	(7C)	0.5	-		-		(1C)	0.2	(6B) 0.8	(7C) 0.3	(6B) 0.2	(1C,7C) 0.6

Single subarrays have been affected by other reasons, usually causing longer outages. The subarrays in question are:

1A	(April)	Heavy attenuation on highest frequencies.
7B	(March)	Broken communication cable.
1C	(May)	Deteriorated line, and later power failure.
2C	(Febr.)	Bad communication cable.
6C	(Jan.)	Equalizer trouble
7C	(Jan,Feb) June)	Damaged communication cable.
11C		Degraded sporadically by intermittent line quality.

Modems situated in CTV 1A, 6B, 4C, 5C and 9C failed in the period. Modem situated at NDPC, part of 3C communication circuit, failed once in the period.

Remeasuring and reconditioning of communication circuits to conform with CCITT M102 recommendations in cooperation with the Norwegian Telegraph Administration (NTA) had not the expected progress due to lack of people to do the job. Although a number of circuits are outside specifications, specially with respect to Attenuation Distortion, the equalizers/ amplifiers keep the lines within the marginal values.

International Communication Circuits (London, SDAC)

The London CCT

In January the seabed communication cable between Kristiansand and England was damaged and the path rerouted while the cable was repaired. After normal conditions were achieved, we have experienced a few cases with carrier loss and low input level to NDPC. MARGINAL CIRCUIT indicator has been on, specially some days in June.

The SDAC Circuit

We have had a few incidents with carrier loss and level changes. Apart from that this circuit has performed satisfactorily.

O. A. Hansen
J. Torstveit

II.4 ARPANET

The attachment configuration for the NORSAR TIP has not changed to any extent from the last reporting period. NORSAR-attached equipment still consists of 2 terminals and 2 Special Host Interfaces for the 360/40 computers. By the end of this reporting period 3 other terminals, used by other institutions, were also attached, and the Very Distant Host Interface attachment was used for preliminary test purposes by the neighboring Norwegian Defence Research Establishment (NDRE).

From the beginning of this reporting period, the (modified) NORSAR DP on-line system has exchanged 2.4 K bit/sec of real data over the ARPANET, with the Communications and Control Processor (CCP) located at SDAC. The problems encountered and modifications performed to the DP system throughout this period are reported elsewhere.

D. Rieber-Mohn

III ARRAY PERFORMANCE

Some basic statistics for the EP operation are given in Table III.1, which shows the analyst decisions for all the DP detections processed by EP during the reporting period. The percentages are fairly close to those from previous reporting periods, with slightly more than half of the processings being accepted as real events. The total number of events, however, is higher than usual, with a daily average of 22.2. In Fig. III.1 the statistics are broken down on a daily basis, and in Table III.2 on a monthly basis, and it is seen there that the largest numbers are found for January 1976, this being caused by earthquake swarms from Kermadec and the Kuriles. It is noteworthy, as seen from Fig. III.1, that the array was subjected to particularly long down times right in the middle of these swarms, thereby reducing significantly the number of events which otherwise would have been reported.

H. Bungum

Table III.1

Analyst decisions for detections processed by EP during the time period Jan-June 1976

Analyst Classification	No. of Processings	Percentage
Accepted as events	4459	52.7
Rejected as being		
- Poor SNR or noise	1194	14.1
- Local events	1574	18.6
- Double processings	1004	11.9
- Communications errors	228	2.7
Sum processed	8459	100.0

Table III.2

Number of teleseismic and core phase events reported during the time period Jan-June 1976

Month	Teleseismic	Core	Sum
Jan 76	639	659	1298
Feb	347	202	549
Mar	351	112	463
Apr	416	132	549
May	425	228	653
Jun	401	131	532

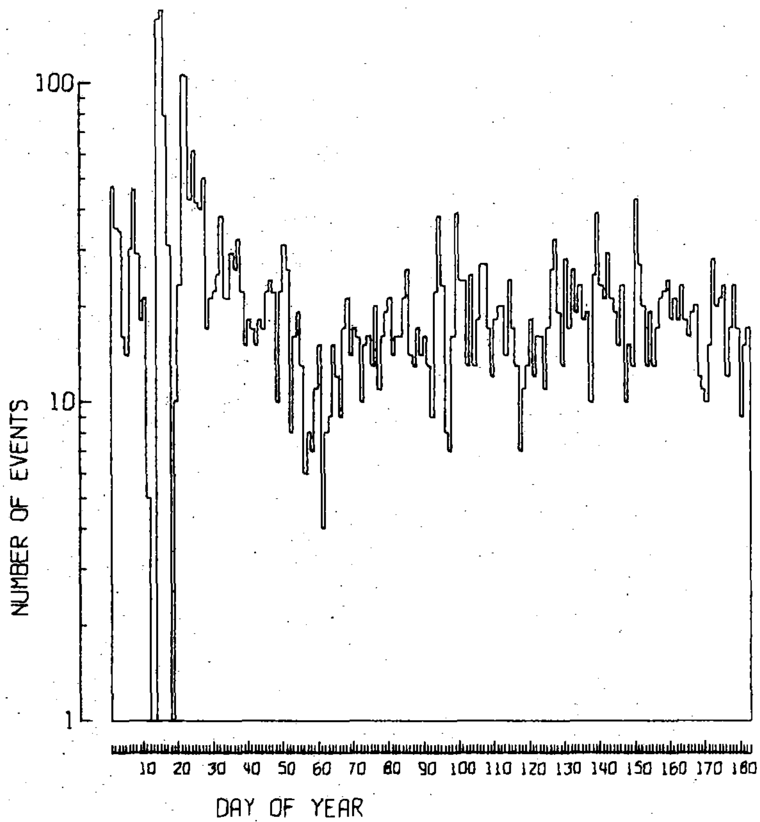

Fig. III.1 Number of Events reported as a function of day of year Jan-June 1976.

IV. IMPROVEMENTS AND MODIFICATIONS

IV.1 Detection Processor

The Detection Processor system at NORSAR has throughout this period continually been modified and improved. The main reason for this is the introduction of the exchange of seismic data with the SDAC Communications and Control Processor, using the ARPANET as a communication medium. While no further changes/modifications were done to the old (non-ARPANET) system, the following improvements were made to the new system during the reporting period:

- An algorithm for dealing with the output queue for the messages to SDAC has been worked out. The strategy is to allow the number of messages waiting in the queue to be sent to increase to a maximum (15) and then drop the oldest and keep the new message generated, until communication starts to flow again. However, if the CCP is dead (Destination Dead flag on), the complete queue is flushed after one second. Also, if the local Imp is down, no new messages will be entered in the output queue.
- The Timeout interval for messages sent out, waiting for RFNM (Ready for next message) acknowledgement (which shows that the SDAC Imp has received them) has been increased to 60 seconds. Also, the timeout algorithm has been modified so that no messages not yet written to the IMP (i.e., waiting in a queue or belonging to a CCW chain not yet executed) will be timed out and released.
- The situations arising when the CCP is not communicating (Destination Dead), and when the local Imp goes down (Imp Dead) had to be dealt with. Many alternative strategies have been tried before the present one, which seems to cope quite well with those situations, was adopted:

  If the "Destination Dead" message is received, both subtasks handling the outgoing messages are disabled. No messages will therefore be written to the Imp before another data message is received from the CCP, declaring it "alive" again.

If the "Imp Going Down" message is received, the NCP task will, after a certain time, try to reinitialize itself, by the same time trying to re-establish contact with the Imp. This will be done repeatedly, until successful contact with the Imp has been established.

- Two new operator commands have been added to the system. One (HOSTN) resets the address of the CCP in the network, the other (RESET) simulates an "Imp Going Down" situation, in that way re-initializing the Host-Imp connection.

- Various modifications in the other (older) tasks of the DP system have been done in order to adapt to the new situation:

  In the Data Acquisition task, the routines that deal with sending and receiving of trans-Atlantic messages have been modified to communicate with the NCP task instead of with the SPS front-end computer. Also, code has been inserted to activate the NCP task at every cycle (0.5 second), except when the CCP is down (every second) or when the local Imp is down (every 30 seconds). The message tasks have been modified to be able to write out messages from the NCP task.

  The disk task has been modified to send Off-line Result data in queue blocks of variable length, thus using the resources available instead of waiting for a queue block of one specific size. This modification has also been implemented in other parts of the system, thus preventing disastrous competition for one type of queue block only.

  While earlier the system willfully program-checked when no queue blocks were available for transport of data to the Experimental Operations Console (EOC), it now just gives out a message and continues its processing.

- Throughout the period continuous debugging has taken place. This is because of all the modifications done to the system after January 1. In fact, by the time of writing, modifications are still being done to the system. The overall problem has all the time been lack of core space for queue blocks, to adequately perform all the functions of the DP system at the same time. However, a reduced array and a smaller data volume is expected to greatly improve upon this situation.

D. Rieber-Mohn

IV.2 Event Processor

No modifications were performed in the EP system during this period.

D. Rieber-Mohn

IV.3 Array Instrumentation

The status of two improvement projects from previous periods is as follows:

- Depression of noise in SLEM discrete inputs (Larsen et al, 1975)	Due to a relatively small number of false alarms in the last year, this modification has been dropped for the present.
- Too low surge rating of BE protection cards (Larsen et al, 1975)	The cards have been modified on all subarrays except for three (04C, 07C, 14C).

In cooperation with the University of Copenhagen a three-axis SP seismometer, Geotech S-13, was installed in the well head vault (WHV) at 14C02 and operational as of 30 June. The seismometers are directed towards the Hunderfoss power plant with channle 01 as vertical, 02 as horizontal 90° on Hunderfoss (137°) and 06 horizontal directed towards Hunderfoss (47°). The low pass filters on the LTA cards were removed from the same day on these channels and channel 04. The instrumentation as for the rest is NORSAR standard equipment. Some of the characteristics are shown in Table IV.3.1. Channel outputs at LTA are identical to standard NORSAR SP channels (5.71 Vpp). Fig. IV.3.1 shows the installation in the 14C02 WHV. Further information is available on request.

Table IV.3.1

Damping, natural frequency and damping resistance of the three-axis SP seismometer at 14C, Geotech S-13.

Channel	Damping Ratio	Natural Frequency (Hz)	Damping Resistance (ohms)
01(Vertical)	0.705	0.958	71 100
02(Horizontal 137°)	0.687	0.968	72 100
06(Horizontal 47°)	0.688	0.986	73 900

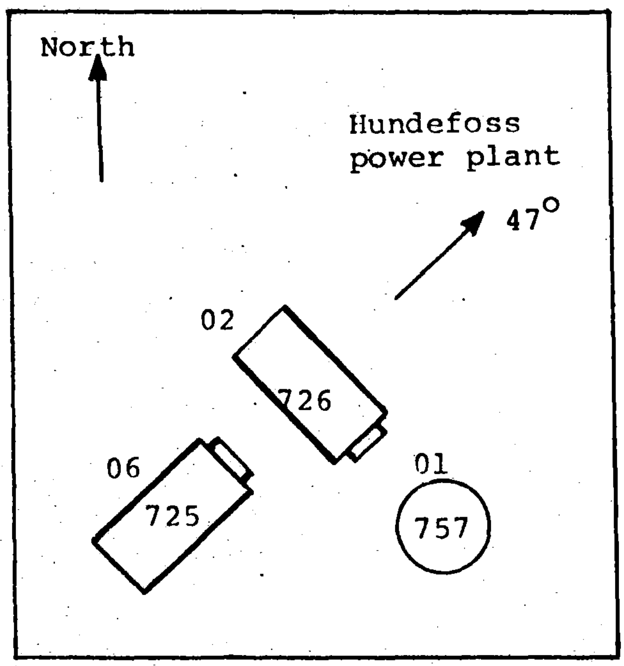

Fig. IV.3.1 Installation of the three-axis SP seismometer at 14C02, location 61°11'28.9" North and 10°22'40.8" East.

A.Kr. Nilsen

V. MAINTENANCE ACTIVITY

This section includes a review of the maintenance accomplished at the subarrays by the field technicians as a result of the remote array monitoring and visual inspections. There are no changes in the monitoring schedule this period, but towards the end of the period the array monitoring was hampered by EOC faults and a DP fault restricting the use of the EOC.

Maintenance Visits

Fig. V.1 shows the number of visits to the subarrays in the period. Excluding visits caused by troubles in the communication system, the subarrays have on the average been visited 4.1 times. Five of the vists to 14C are due to installation of the three-axis SP seismometer.

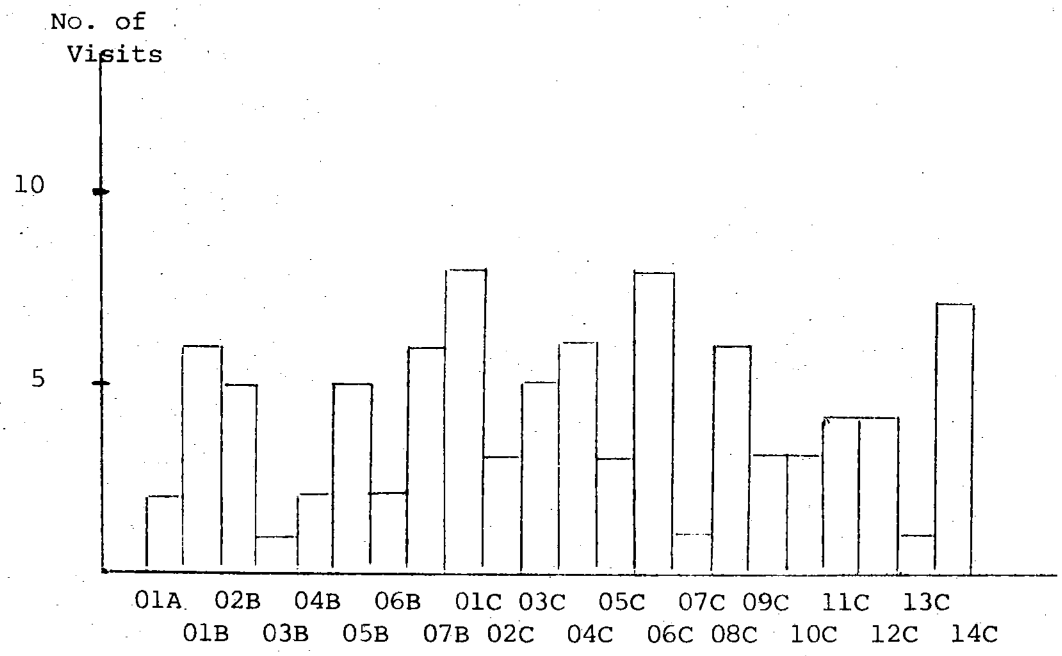

Fig. V.1 Number of maintenance visits to the NORSAR subarrays 1 January - 30 June 1976

Preventive Maintenance Projects

The preventive maintenance work in the array is described in Table V.1.

Table V.1

Unit	Action	No. of Actions		Comments
		Accomp.	Remaining	
LTA	Adjustment of SP DC offset to postive bias	46		
	Adjustment of channel gain SP	17		
	Adjustment of channel gain LP	7		
Power	Battery Maintenance	15		
LPV	Painting of LPV*	8	2 (01A, 02C)	01B,02B,07B,01C,03C 04C,06C,07C

* Reported as corrective maintenance in the monthly reports due to the great need for this work, but have preventive effects as well.

Disclosed Malfunctions on Instrumentation and Electronics

Table V.2 gives the number of accomplished adjustments and replacements of field equipment in the total array with the exception of those mentioned in Table V.1.

Table V.2

Total number of required adjustments and replacements in the NORSAR data channels and SLEM electronics 1 January - 30 June 1976.

Unit	Characteristic	SP Repl.	SP Adj.	LP Repl.	LP Adj.
Seis-mometer	Damping				3
	Sensitivity				1
	RCD			7	2
Seis-mometer Ampli-fier (RA-5)	Gain	1	1		
	Distortion	1			
	Taper pin block	1			
LTA	Ch. gain		12		1
	Filter discr.	5			
	DCO		1		
	CMR		2		
SLEM					
BB gen.		1	4		
RSA/ADC		2	1		
EPU		1			
DU		1			

Malfunction of Rectifiers, Power Loss, Cable Breakages

Malfunction of the rectifiers and power loss requiring action of the field technicians or local power company are reported in Table V.3.

Table V.3

Faults disclosed in subarray rectifiers and power loss.

Sub-array	Fault	Period of Inoperation	Comments
01C	Main AC power break		No outage due to CTV backup power (5-7 January)
04C	Rectifier continuous in high charge		Time coil burned
10C	Main AC power break	23-24 May 26-28 May	Power cable fault

Six cable breakages have been repaired in the period requiring 8 days' work of the field technicians. In addition the location of the cable trenches have been pointed out three times prior to digging work to prevent cable breakage.

Conclusion

The instrumentation performance has been stable and satisfactory in the period. Towards the end of the period the array monitoring has been insufficient due to faults in DP and EOC restricting the use of the EOC.

The modification of the BE lightning protection cards are almost completed, and so far no faults on the cards have been detected.

Due to lack of manpower and to reduce the expenses, the recording of the NORSAR analog SP station was reduced to 5 days a week from 31 January 1976.

A few projects planned completed this period should be commented. First, the reason for a slow trend towards increasing damping of the LP seismometers is not clarified. Second, the LP test generators modification to improve the period is left over. The material needed (resistors of various values) have been bought and modification of the seven generators in operation after October 1976 will soon be completed. The communication line from NDPC to the simulated subarray at NMC will not be reestablished, since the 04B line is not available after October this year.

A. Kr. Nilsen

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ABBREVIATIONS

AC	-	Alternate current
ADC	-	Analog-to-Digital converter
BB	-	Broad band
BE card	-	Lightning protection card
CMR	-	Common mode rejection
CTV	-	Central terminal vault
DC	-	Direct current
DP	-	Detection Processor
DCO	-	DC offset
DU	-	Digital unit
EPU	-	External power unit
LP	-	Long period
LTA	-	Line terminating amplifier
RA-5	-	SP seismometer amplifier
RCD	-	Remote centering device
RSA	-	Range switching amplifier
SLEM	-	Seismic short and long period electronics module
SP	-	Short period
WHV	-	Well head vault

VI. DOCUMENTATION DEVELOPED

VI.1 Reports, Papers

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L.B. Tronrud

VI.2 Program Documentation

During this period the program REGNSKAP, documented as N/PD-90, has been designed and developed at NORSAR, by Jan Fyen. It is an automatic bookkeeping system for keeping NORSAR accounts.

D. Rieber-Mohn

VII. SUMMARY OF SPECIAL TECHNICAL REPORTS/PAPERS PREPARED

VII.1 A Pattern Recognition Approach to Seismic Discrimination

The task of discriminating between earthquakes and underground nuclear explosions can be formulated as a problem in pattern recognition: On the basis of an observational raw data vector $\underline{X} = [X_1,\ldots,X_N]$ which may represent the digitized short period and long period wave traces from one or more seismological stations, the task is to recognize the vector and to decide which of two populations it belongs to. As a problem in pattern recognition it may be separated into two stages, feature extraction and classification. The feature extraction stage consists of reducing the original data vector $\underline{X}$ to a feature vector $\underline{Z} = [Z(1),\ldots,Z(M)]$ where it is desirable that M is small compared to N while $\underline{Z}$ is still preserving as much information as possible from the original vector $\underline{X}$. The classification then proceeds on the vector $\underline{Z}$.

In the literature on pattern recognition a variety of techniques for feature extraction and classification have been discussed. Curiously enough these methods have not received much attention in seismic discrimination. Motivated by this fact we have initiated a two-stage pattern recognition study of seismic discrimination. Up to now the emphasis has been on feature extraction and some preliminary results are reported in Tjøstheim and Husebye (1976). From a raw data vector $\underline{X}$ with the total number of long period and short period data samples ranging between 3000 and 5000 (depending on epicenter distance) we have constructed a primary feature vector $\underline{Y}$ of dimension 37. The short period features consist of m_b and 9 autoregressive parameters characterizing the signal, coda and the preceding noise. Contrary to common usage we have extracted long period features from Love waves and horizontal Rayleigh waves as well as from vertical Rayleigh waves. Altogether we have used 3 x 9 = 27 long period power spectral estimates computed within various group velocity windows.

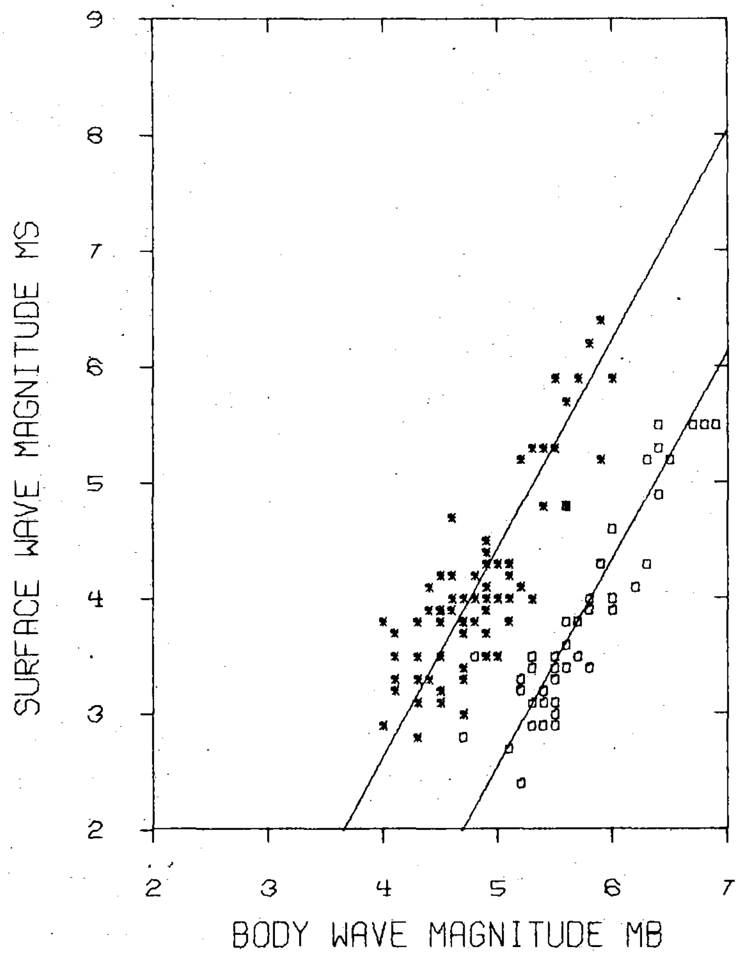

Fig. VII.1.1 m_b:M_s diagram for the Eurasian data set of 52 explosions and 73 earthquakes. PDE m_b and NORSAR M_s values have been used.

We have tested the feature extractors on a data set of Eurasian events containing 52 explosions and 73 earthquakes. An m_b:M_s diagram of the data set is shown in Fig. VII.1.1. To get a rough indication of the quality of the feature extractors, the following generalization of the X1:X2 discriminant of Tjøstheim and Husebye (1976) was studied:

$$X1(A,B) = m_b - B\,\hat{a}_1(S)$$
$$X2(A,B) = E_{20}^{(1)} + A(E_{20}^{(2)} - E_{20}^{(3)}) + B(\hat{a}_1(C) - \hat{a}_1(N)) \qquad \text{(VII.1.1)}$$

Here A and B are scaling parameters and $E_{20}^{(i)}$ are long period energy estimates as defined by Tjøstheim and Husebye (1976). We evaluated the X1(A,B):X2(A,B) discriminant separately for vertical and horizontal Rayleigh waves and Love waves. The results are shown in Fig. VII.1.2, which gives the false alarm rate for the various cases. The figure indicates that the Love wave feature extractors $E_{20}^{(i)}$ are more useful than the corresponding vertical and horizontal Rayleigh features. Also, it is seen that the combination of short period and long period features as in formula (1) is superior to the $m_b:M_s$ discriminant over a wide range of values for the scaling factors A and B, this being true for all three categories of surface waves.

We have also done some experiments to test the appropriateness of a 5th order autoregressive model when computing the E_{20} estimates. Fig. VII.1.3 shows the values of Akaike's (1970) FPE criterion for deciding the "optimal" order for an autoregressive fit to a long period time series generated by an Eastern Kazakh explosion which occurred on 30 Dec 1971. The optimal order is obtained by choosing the order corresponding to the minimum FPE. It is seen that this is close to 20 for the horizontal Rayleigh wave and close to 30 for the Love and vertical Rayleigh wave. However, most of the variation in FPE is from order 1 to 5, so using a 5th order model as an approximation should not have too large effect on discrimination.

The dimension of the vector $\underline{Y}$ is still a little too high for an efficient application of the standard multivariate statistical classification procedures. The next stage therefore consists of reducing the vector $\underline{Y}$ to a secondary feature vector $\underline{Z}$. This can be done using for example the technique of principal components. The resulting vector $\underline{Z}$ can then be

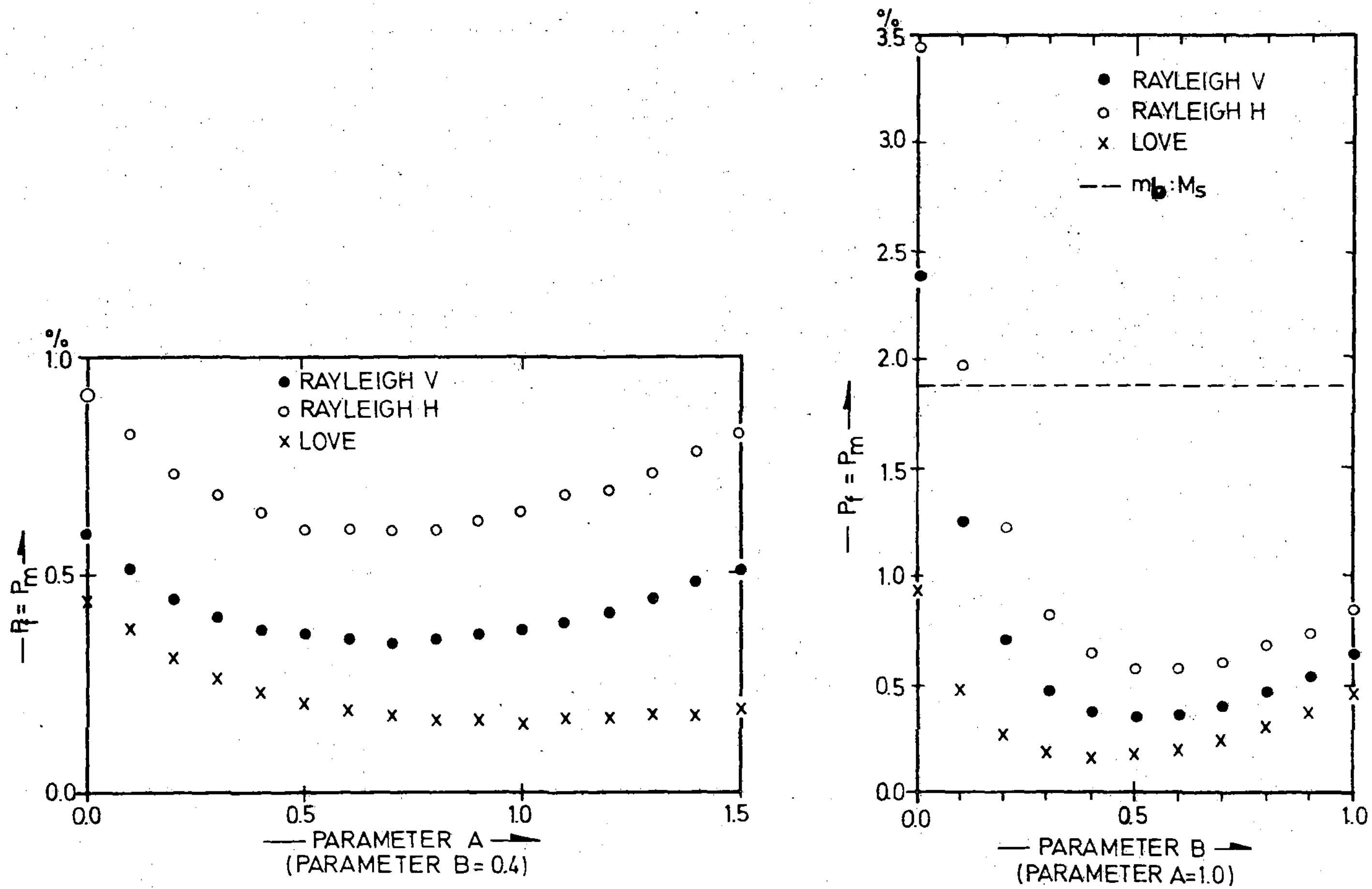

Fig. VII.1.2 (a) The false alarm rate P_f (when this equals the probability P_m of missing an explosion) as a function of the LP scaling factor A of Eq. (VII.1.1) when the SP scaling factor B equals 0.4. (b) $P_f = P_m$ as a function of the SP scaling factor B for a fixed value A=1.0 of the LP scaling factor. The dashed line represents the $m_b:M_s$ discriminant.

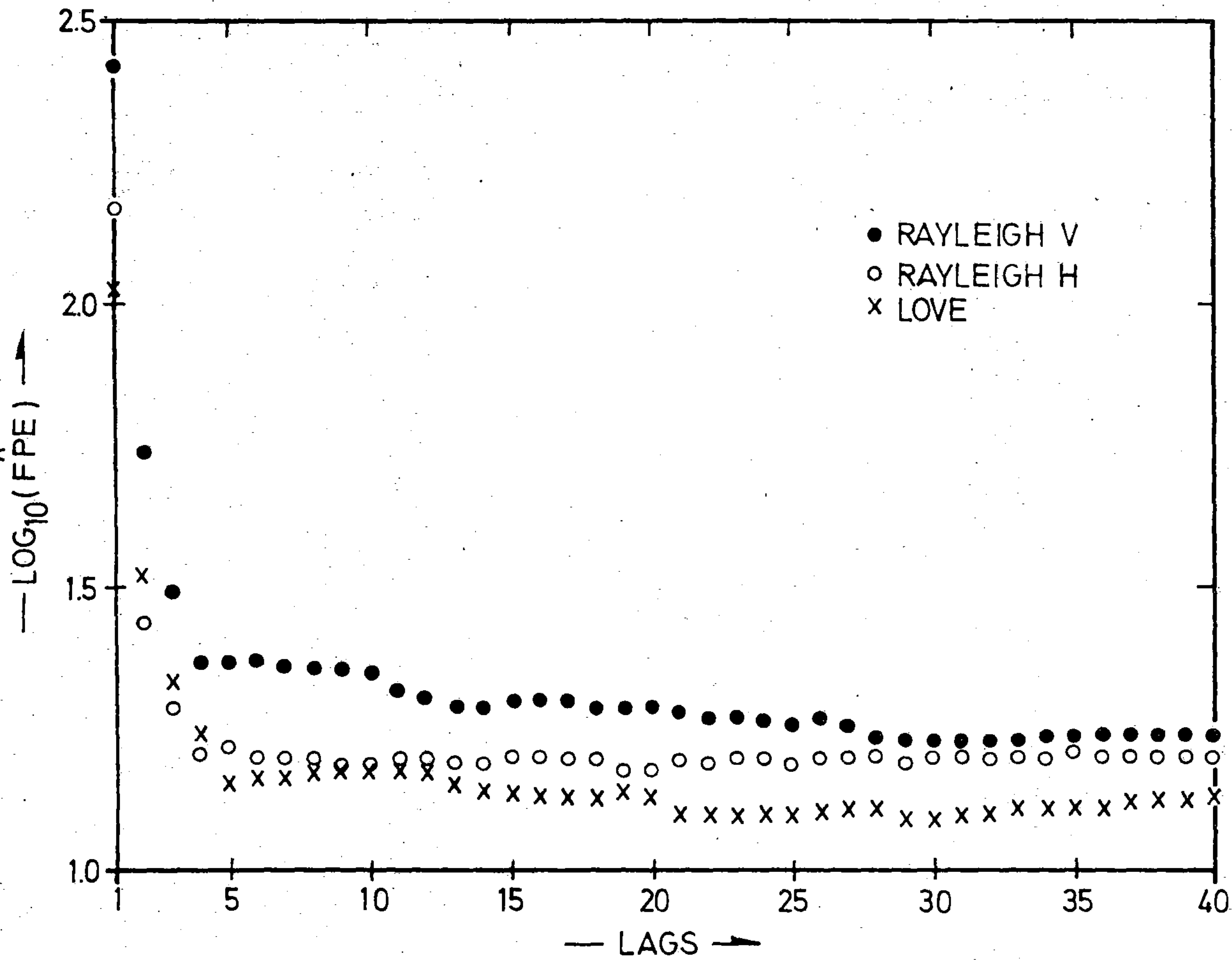

Fig. VII.1.3 Estimated values of Akaike's FPE criterion. The corresponding long period time series data are from an Eastern Kazakh explosion which occurred 06.20.57.7 on Dec 30 1971.

classified by approximating the distribution of earthquake and explosion $\underline{Z}$ vectors by multivariate normal distributions and using the nonlinear version of the so-called Fisher discriminant (see Anderson, 1968).

D. Tjøstheim

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VII.2 Inversion of Large Aperture Array Travel Time Data for Mapping of Seismic Anomalies in the Lithosphere-Asthenosphere

In a recent series of papers Aki et al (1976a,b) and Husebye et al (1976) have demonstrated the usefulness of a novel technique for inverting travel time residuals as observed at large aperture seismic arrays like NORSAR, LASA and the central Californian network. A minor drawback with this approach is that the corresponding computer program has core requirements of the order of 600-800 K bytes. In practice, this means that the program only can be run on very large computers which are not easily accessible and besides are relatively costly. In view of the many requests for copies of the program, we have spent some time on making the program more easily understandable, also more efficient and at the same time obtained a substantial reduction of the core requirements. The main program modifications are tied to splitting the program in two parts, the first one being tied to experimenting with model definitions and at the same time calculating exactly the core storage needed. In the second part of the program where the actual inversion is performed, the core storage savings are mainly obtained by replacing the eigenvalue routine with one that calculates eigenvectors one by one and utilizes intermediate tape storage. In this way only the original input matrix needs to be in single precision while the work vectors could be in double precision, thus diminishing the effect of rounding-off errors as compared to the original version.

E.S. Husebye
A. Christoffersson (Uppsala Univ.)
M. Baer (Zurich Technical Univ.)

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VII.3 Lateral Variation in the Structure of the Upper Mantle beneath Eurasia

In a previous study, King and Calcagnile (1976) constructed a detailed, extensive and exceptionally clear record section from recordings at NORSAR of presumed explosions in continental Russia. This section exhibits two distinct (T,Δ) triplications of which the more noteworthy is the extension of the first arrival branch for $\Delta \lesssim 21^{\circ}$ as a secondary arrival to a distance of about 33°.

A similar study of NORSAR records augmented by some 80 records from the Eskdalemuir array, has been completed for rays bottoming beneath southern and central Europe. The results of this study differ markedly from those of King and Calcagnile (1976) in two respects: not only is there a pronounced difference in the uppermost mantle between the two regions (down to ~ 200 km) which is reflected in the difference between first arrival travel time curves for Europe and Russia (England and Worthington, 1976), but there also exist differences in the secondary arrivals at distances $\gtrsim 21^{\circ}$ which indicate lateral heterogeneity to considerable depths below Eurasia.

In particular, there is no trace of the very clear A-B branch of King and Calcagnile in the European data and the only arrivals which could be interpreted as lying on such a branch are weak and laterally discontinuous. This result is interpreted as evidence for a lateral variation in the velocity structure at least to the depth of 500 km beneath the two regions. Figs. VII.3.1 and VII.3.2 show the difference between the model of King and Calcagnile (1976) (KCA) and the preferred model of this study (EKW), and the extremal bounds on the two models based on the first arrival travel times of England and Worthington (1976).

P. England
D.W. King (Sydney Univ.)
M. Worthington (Oxford Univ.)

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King, D.W.**, and G. Calcagnile (1976): P-wave velocities in the upper mantle beneath Fennoscandia and Western Russia, Geophys. J.R. astr. Soc., in press.

* Now at NORSAR

** Formerly at NORSAR, now at the Univ. of Sydney, Australia.

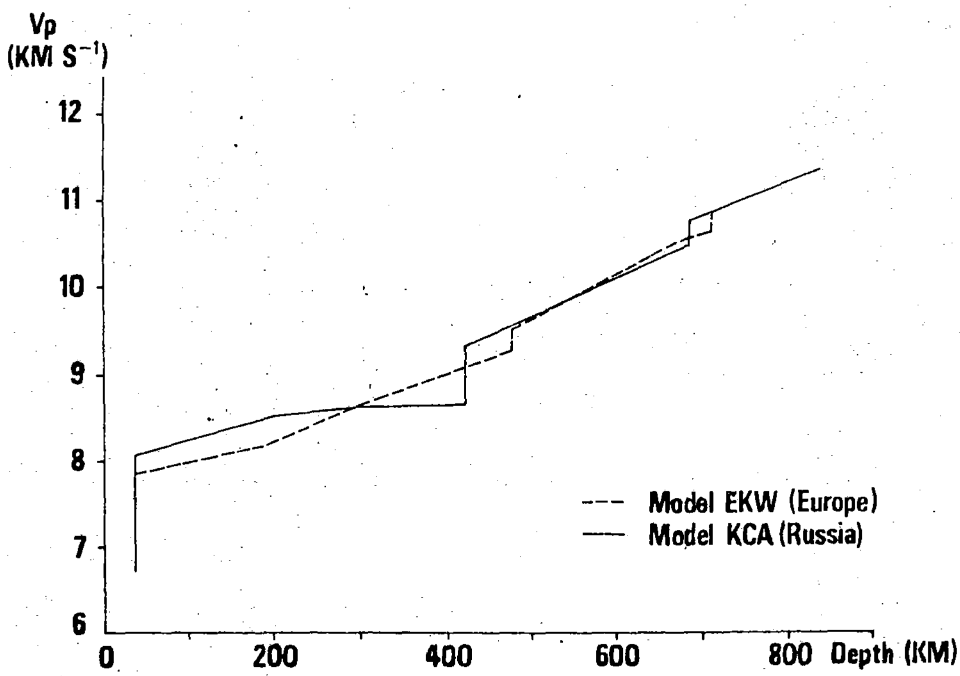

Fig. VII.3.1 Models resulting from the inversion of the travel time data of the two studies mentioned above.

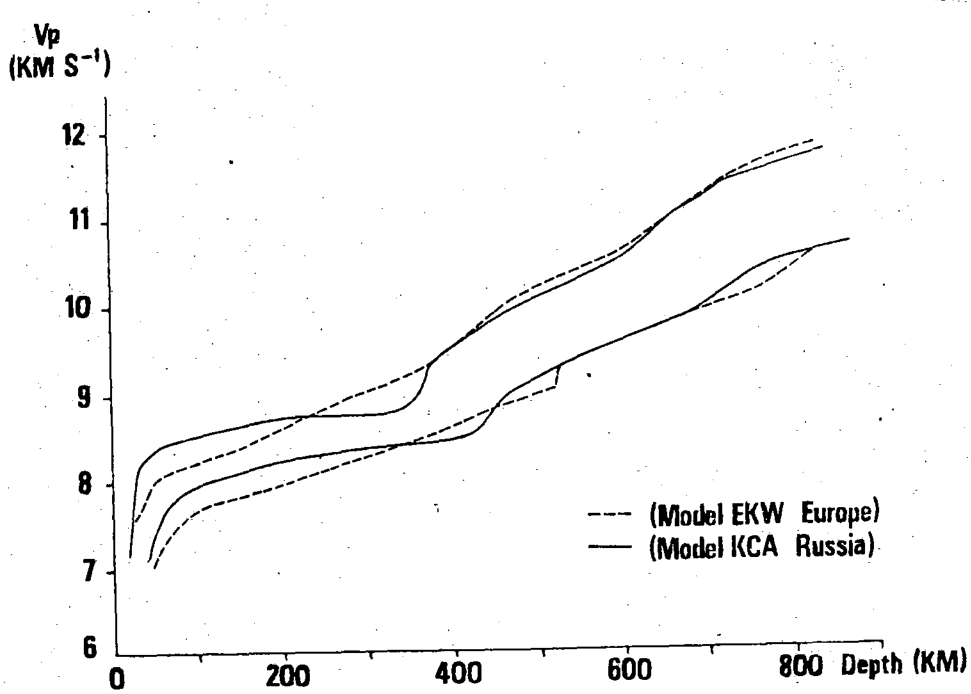

Fig. VII.3.2 Extremal bounds for the models EKW and KCA shown in Fig. VII.3.1.

VII.4 Direct Measurements of Crustal P-velocities in the NORSAR Area

Using simulated data, it is demonstrated that one may estimate the body wave velocity in the crust by measuring the angle of incidence of P-waves provided only the very first part of the signal is used. It is important to use only the very first part of the signals, because converted and/or multiple reflected phases may make the particle motion for the later part of the signal very complicated (Fig. VII.4.1).

This angle has been measured at the 22 NORSAR long period instrument sites for ten events. Combining these observations with measurements of apparent velocities, we find that the data indicates a crust velocity of 6.1 ± 0.4 km/sec. While it is somewhat uncertain to what depth the value is representative, the observations are in obvious disagreement with previous authors who concluded that long period P-waves were not affected by the earth's crust. When the observed P-wave velocities are plotted on a map of the array configuration, we find that the velocity observations tend to group themselves into relatively large areas with respectively high and low values (Fig. VII.4.2), which indicates that real velocity variations in the medium under NORSAR contribute significantly to the variations observed. To discriminate between the effect of real velocity variations and measurement errors is, however, difficult, but as a very crude estimate we found a standard deviation corresponding to 3 per cent variation in the P-wave velocity.

K.A. Berteussen

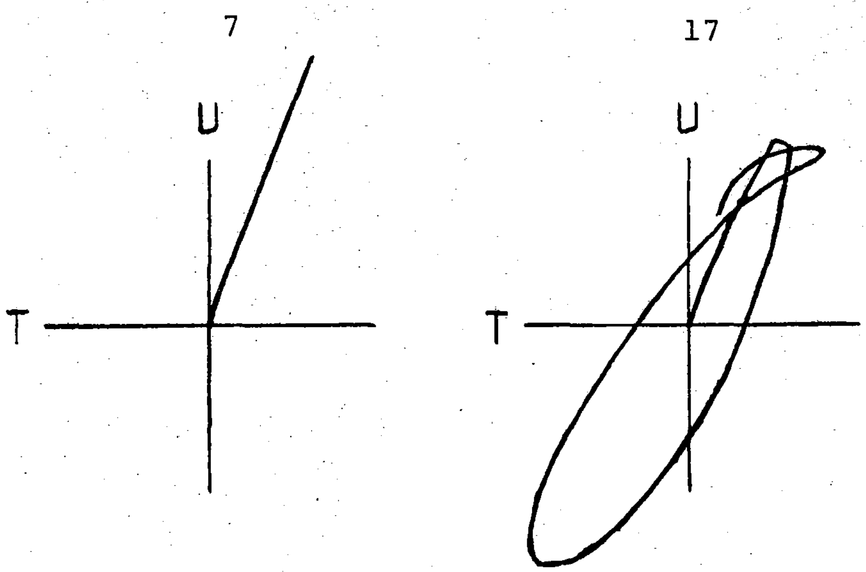

Fig. VII.4.1 Simulated particle motion diagrams for first 8 and 30 seconds of a delta-pulse P-signal having crossed a 35 km thick crust. Angle of incidence at Moho is 35 degrees. The upper 5 km of the crust has P-velocity 4.0 while the rest of the crust has a velocity of 6.2 km/sec. Mantle P-velocity is 8.2 and Poissan's ratio is 0.25. NORSAR long periodic instrument response has been included. The letter U on the figure means up, while T means towards the source. The numbers above give relative scaling.

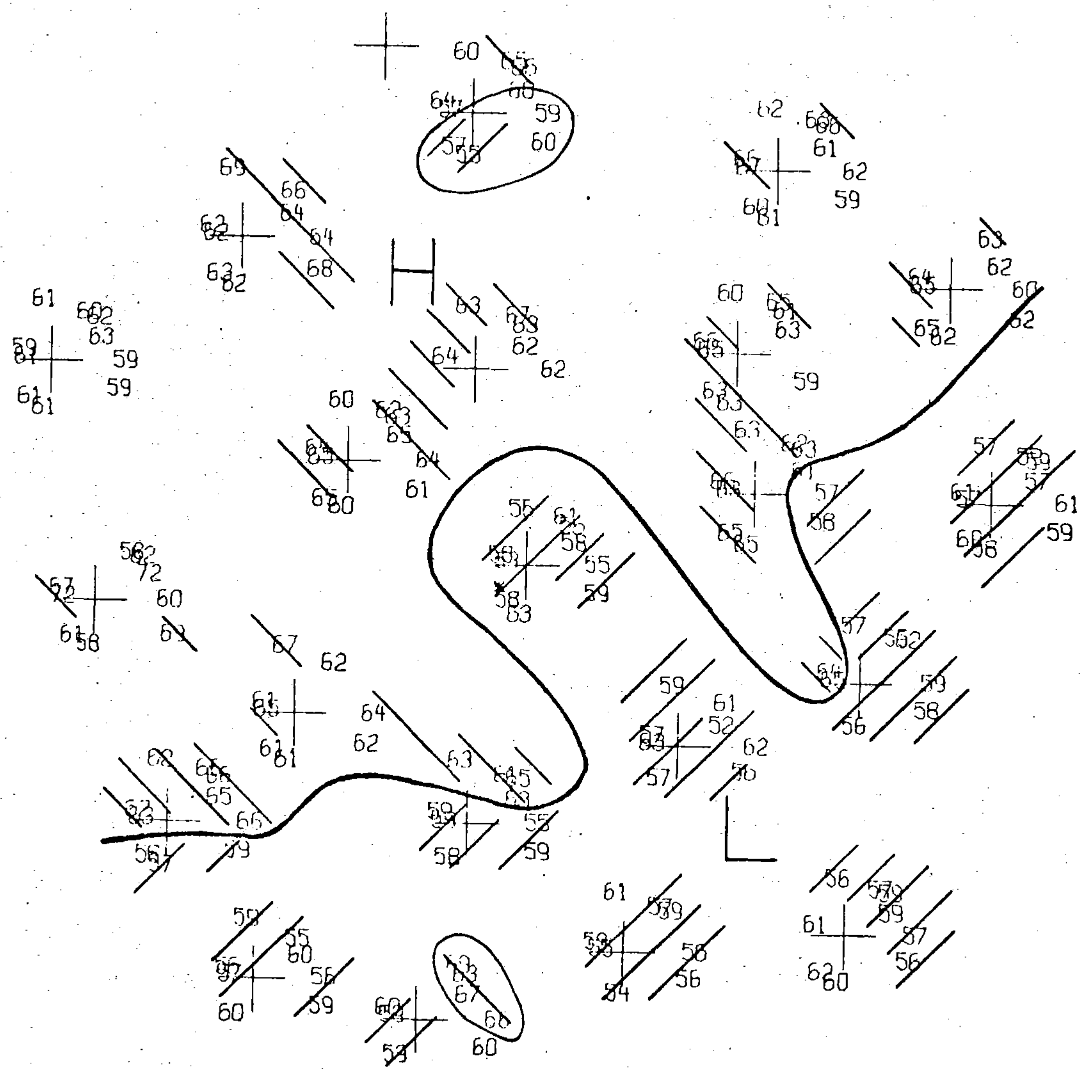

Fig. VII.4.2 Observed P-wave velocity multiplied with ten plotted directly on the array configuration. The crosses mark the location of the long period instruments. The star in the middle marks the center of the array. The values are plotted at the horizontal projection of the first 1/7 wavelength of the ray path.

VII.5 ScS Precursor Waves

In recent years, considerable interest has been focused on S and ScS travel time residuals as such observations are taken as manifestations of lateral velocity anomalies in the mantle, say, beneath continental and oceanic areas respectively. However, in a number of cases the reported ScS residuals are larger than expected from realisitc earth models and also occasionally significant energy bursts appear in the interval intermediate between S and ScS arrivals. These features have encouraged us to undertake a detailed investigation of the S-wave coda or more correctly precursors to the ScS-phase. In the distance interval 45-65^{o} we have found several NORSAR recordings exhibiting clear precursor arrivals. The lead times with respect to ScS vary considerably while the lag times with respect to S are fairly constant and amount to around 100 secs. The observed slownesses are equal to or slightly less than those of S and thus differ significantly from those of ScS. Polarization filtering and particle motion diagrams favor SV or SH as the dominant phase motions. The wave parameter observations mentioned above all favor S-wave reflections from horizons of around 200-250 km depth, and in this respect are similar to proposed generating mechanisms of long period precursors to the PP-phase (e.g., see Husebye and Madariaga, 1970, and Ward, 1976). The observations are incompatible with once-suggested generating mechanisms of leaking modes, various types of mode conversions or multipathing due to lateral inhomogeneities in the lower mantle.

R.J. Brown (Univ. of Luleå)
H. Bungum
E.S. Husebye

References

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VII.6 Seismicity of the Norwegian Sea: The Jan Mayen Fracture Zone

The seismicity of the area around the presently active part of the Jan Mayen Fracture Zone has been re-examined. The epicenters presented in Fig. VII.6.1 cover the time period 1955-1975, and consist primarily of ISC solutions. Moreover, only solutions with at least 15 reporting stations have been plotted. These restrictions have significantly reduced the scatter in the epicenter distribution previously observed when primarily PDE data have been used (Husebye et al, 1975). It is seen from Fig. VII.6.1 that the seismicity is restricted to the mid-oceanic axes and to the part of the fracture zone which is located between the two ridge ends (Wilson, 1965), the only notable exception being the seismicity area northeast of the Jan Mayen island itself.

Fault plane solutions have previously been published for four events in this area, and the nodal plane directions for the two most reliable ones are given in Fig. VII.6.1. Moreover, the solution for one more earthquake has been obtained by us; this is the westernmost of the events in Fig. VII.6.1, and the actual solution is given in Fig. VII.6.2. All the focal solutions are strike-slip with deeply dipping planes.

Fracture zones are important within the new global tectonics because they are considered to represent actual flow lines delineating the relative direction of plate movements. More specifically, the Jan Mayen Fracture Zone plays an important role in the opening of the Norwegian Sea, where a model recently has been published by Talwani and Eldholm (in press). Based on this model, synthetic flow lines have been calculated through the fault plane epicenters in Fig. VII.6.1, where it is seen that the strike of these flow lines coincides reasonably well with the orientation of the fault planes. The Jan Mayen Fracture Zone is bathymetrically characterized by a 2.2 km deep and 10-12 km wide trough where the orientation is such that the epicenters in Fig. VII.6.1 roughly follow the northeast facing escarpment. All this data (flow lines, fault planes, bathymetry, seismicity) are consistent with a model where the transform portion of the Jan Mayen Fracture Zone consists of an én-echelon system of active faults. The resulting orientation of the fracture zone differs slightly from the one previously delineated on the basis of a gravity low (Talwani and Eldholm, in press).

H. Bungum
E.S. Husebye

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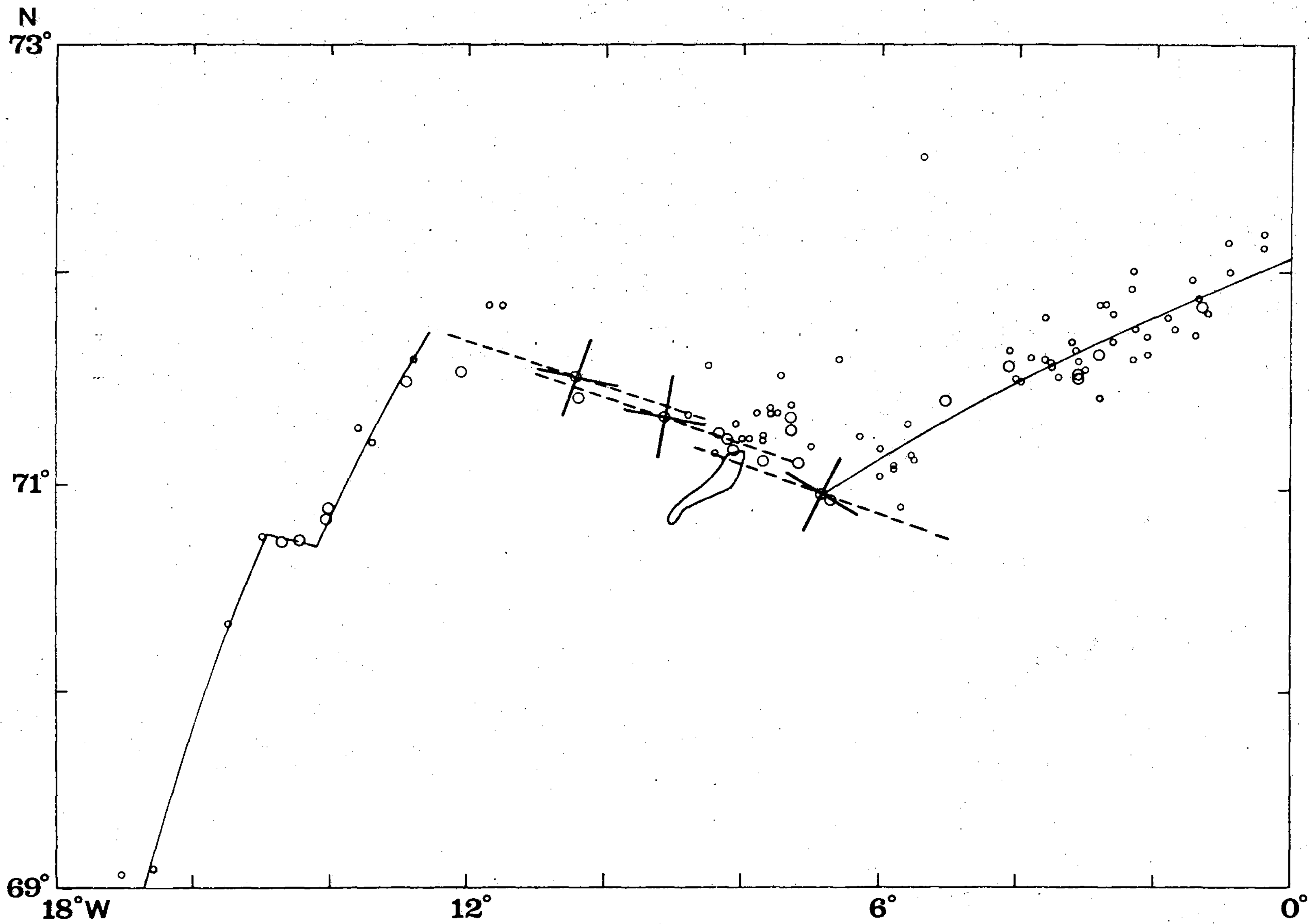

Fig. VII.6.1 The seismicity of the Jan Mayen Island Region for the time period 1955-75 where ISC-solutions have been used when available (1964-1973), and where all solutions are based on at least 15 stations. Three fault plane solutions are also included. The structural trends in this figure are our suggestions, and the dashed lines are synthetic flow lines based on the opening model of Talwani and Eldholm (in press).

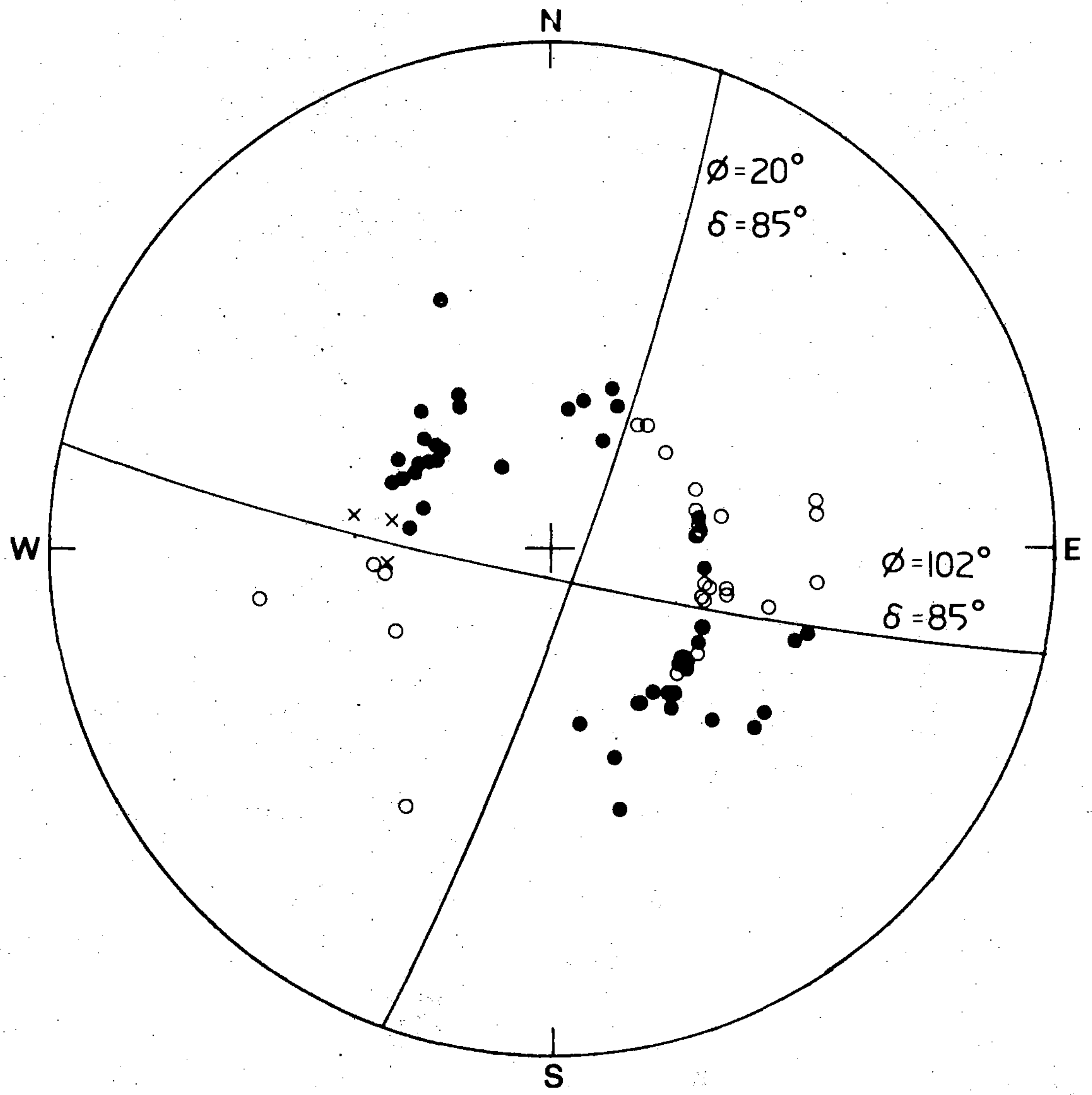

Fig. VII.6.2 Fault plane solution for the westernmost of the three events in Fig. VII.6.1. There are 80 readings of first motion from predominantly long period or broad band seismographs. Solid circles are compressions, open circles dilitations, and crosses indicate stations near the nodal plane. Stereographic projection.

VII.7 Seismic risk analysis for a nuclear power plant at Forsmark, Sweden

NTNF/NORSAR was asked in February this year to participate in a seismic risk analysis for the nuclear power plant under construction at Forsmark, Sweden. Previously, we have participated in similar investigations for the outer Oslofjord area.

In case of the Forsmark investigation (Husebye and Ringdal, 1976) we compiled a detailed seismicity map for Fennoscandia from historic times and up to present. Fig. VII.7.1 shows as an example the epicentral distribution of all reported events between 1891 and 1950, based on the catalogue of Båth (1956), while the largest known historic earthquakes in Fennoscandia are mapped in Fig. VII.7.2. Clearly, the large earthquakes are of particular importance in seismic risk analysis, and in view of the relatively low seismic activity in Fennoscandia, this is our main reason for using a data base covering several hundred years.

The extremal-value theory of Gumbel (1958) is a particularly attractive technique for analyzing recurrence times of large earthquakes. Since only knowledge of the largest events is required, a historic data base, although incomplete, will often be sufficient. In our case, we applied the Gumbel theory to earthquake intensity (rather than magnitude) as the intensity parameter is most directly related to macroseismic observations. Fig. VII.7.3 shows an extremal-probability plot of the largest earthquakes occurring within consecutive 10 year intervals for South Sweden. The straight line indicates the estimated Gumbel distribution, and the fit is seen to be quite good. Clearly, this line should not be extrapolated infinitely; in our case we imposed a maximum intensity of 10 (M.M.Scale) in the model.

Having established the seismicity in terms of intensities, it remains to incorporate intensity decay factors and conversion relations from intensity to ground acceleration. Using Trifunac and Brady's (1975) conversion relations and examining four different models of intensity decay, we found ground accelerations averaging 0,16 g at a probability level of 10^{-5} per year at Forsmark.

E.S. Husebye
F. Ringdal

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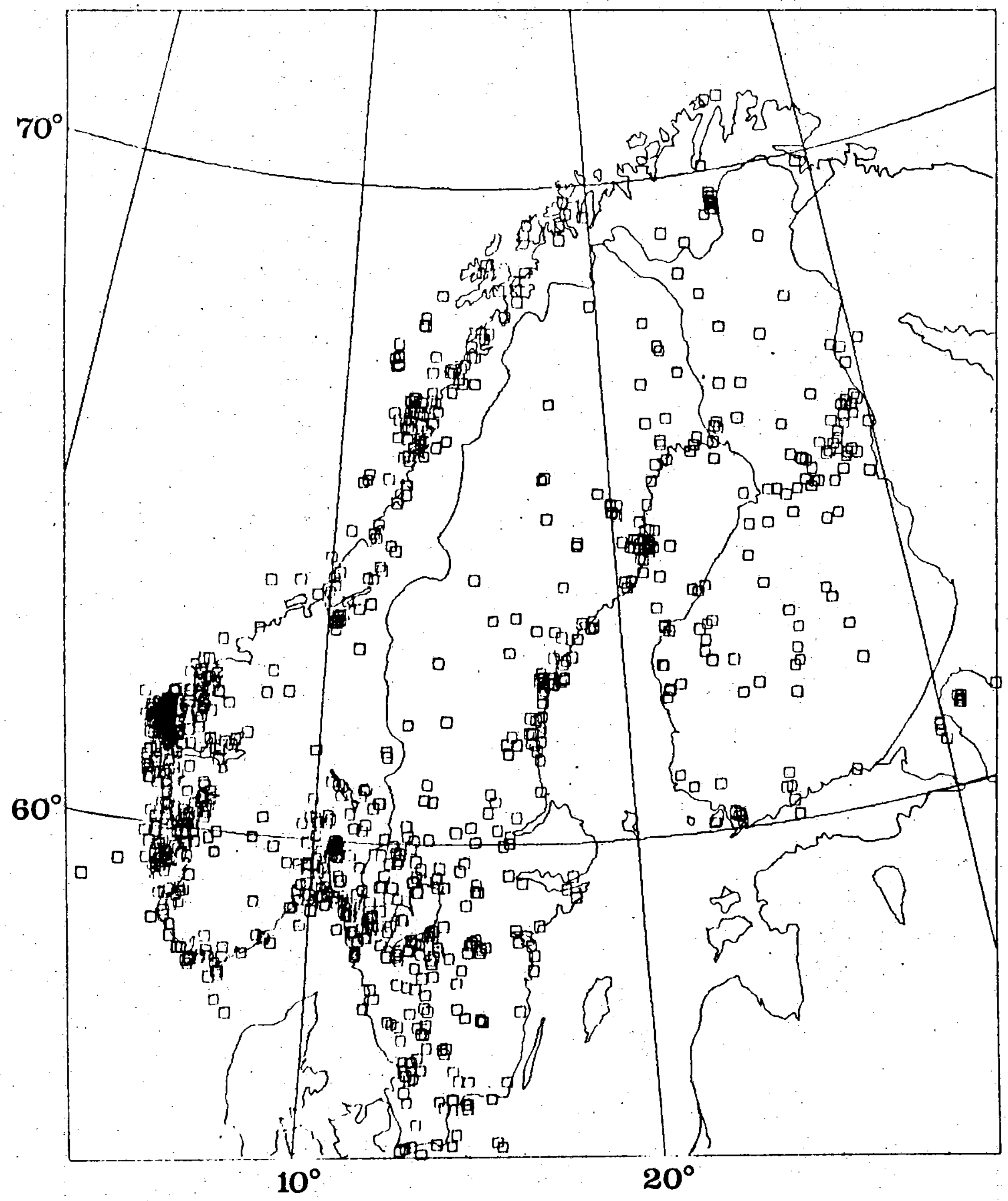

Fig. VII.7.1 Seismicity map for Fennoscandia covering the interval 1891-1950, based on mostly macroseismic data but also a few instrumental observations.

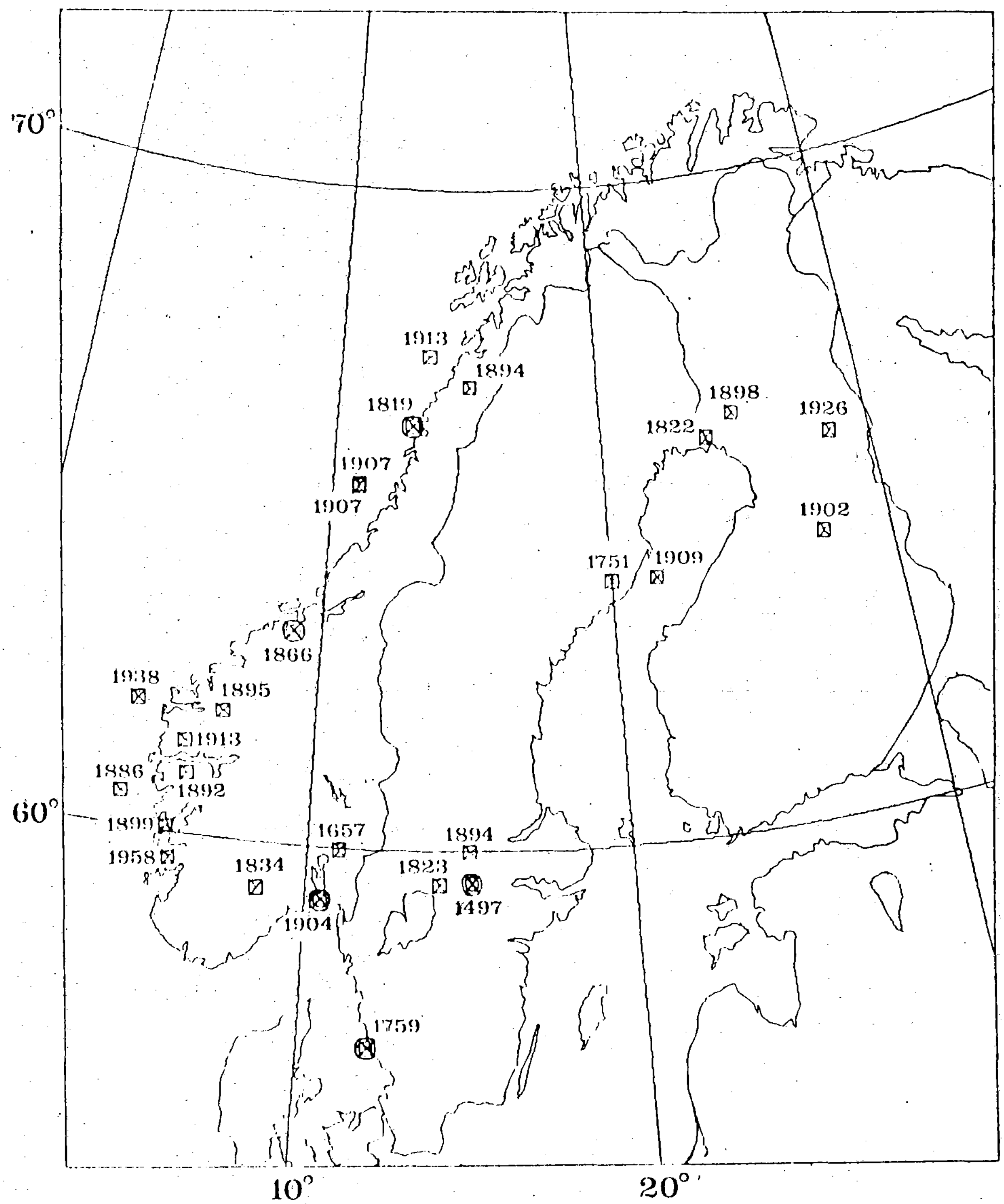

Fig.VII.7.2 Map showing epicenter and year of occurrence of Fennoscandian earthquakes presumed to have a magnitude M of at least 5.0 The double symbols indicate earthquakes presumed to have M of at least 6.0.

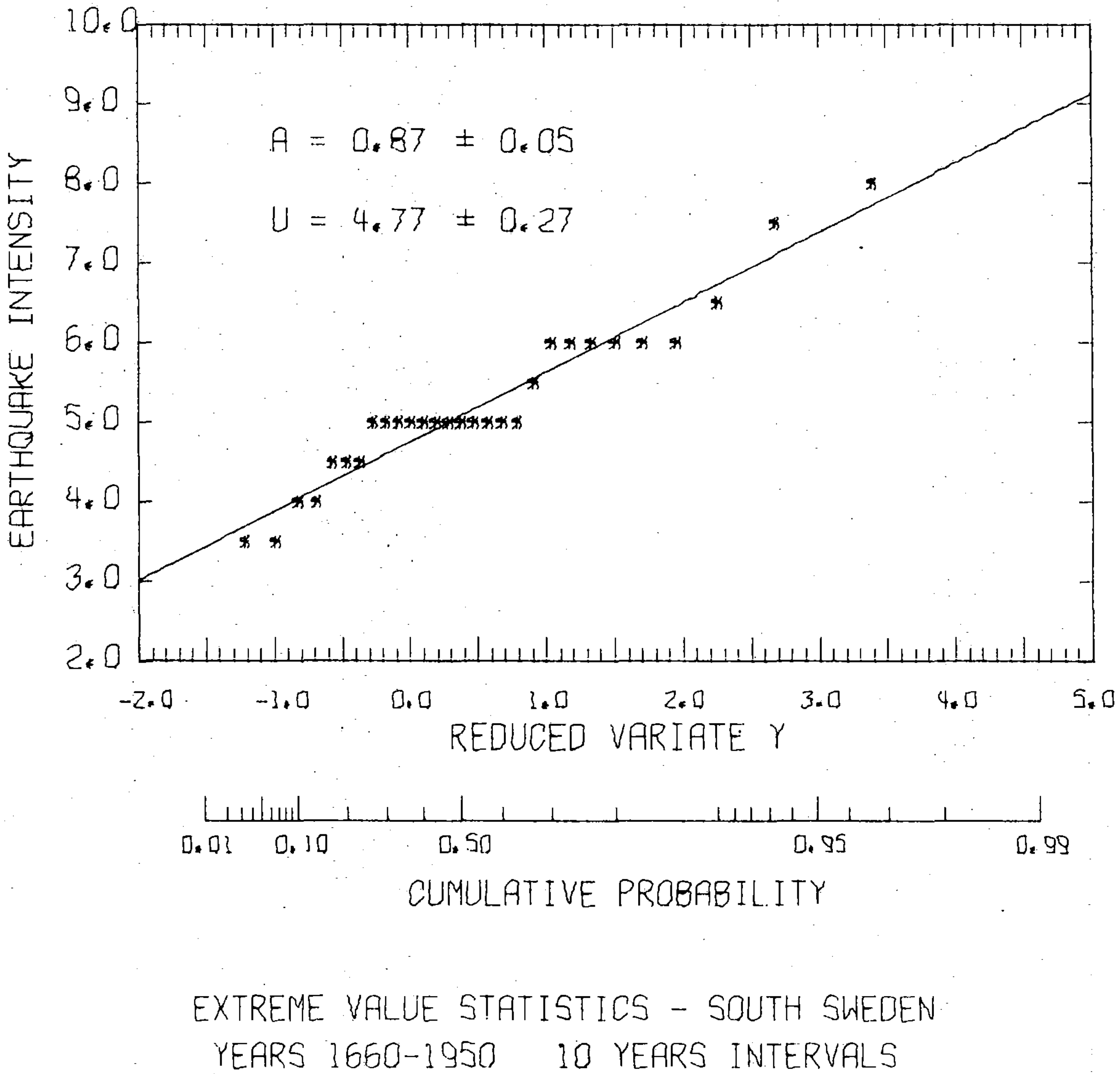

Fig. VII.7.3 Extremal value statistics for observed earthquake intensity in south Sweden and adjacent coastal areas.

VII.8 Noise level variation at NORSAR and its effect on detectability

Fluctuations in seismic noise level, both on a seasonal and a diurnal basis have a significant effect on the earthquake detectability of seismic stations and networks. Several sources contribute to these variations, such as microseisms generated by atmospherically induced oceanic conditions, local meteorological factors and cultural noise sources. For the Norwegian Seismic Array (NORSAR) several spectral studies of microseisms have been performed (e.g., Capon, 1972; Korhonen and Pirhonen, 1976), and a correlation between peak noise levels and storms in the North Atlantic Ocean has been clearly established. The purpose of the present paper is to give a detailed, quantitative analysis on the extent of seismic noise level fluctuations at NORSAR, both for short and long period data. This has been made possible by the recording of noise level estimates performed on-line at the array; a total of three years of densely sampled noise data has been used for this study.

Fig. VII.8.1 shows the variation in noise amplitude level (averaged across the array) for the vertical LP component (unfiltered) and the SP sensors (1.2-3.2 Hz filter) during 1973-75. The seasonal fluctuation is particularly pronounced for the LP data, and we note the predominance of sharp peaks (duration typically 1-2 days) corresponding to microseismic storms during fall and winter months. The amplitude distributions for these data are shown in Fig. VII.8.2, in a logarithmic scale. We note that the distribution of short period noise amplitudes is approximately lognormal, while the LP data show a skewness that cannot be represented by a lognormal distribution. Table VII.8.1, summarizes the noise level statistics for NORSAR; we note in particular that the noise standard deviation, expressed in magnitude units, is 0.1 and 0.3 for short and long period data, respectively.

Diurnal fluctuations in noise level were found to be quite small, but definitely present both for short period and horizontal long period data (Fig. VII.8.3-4). In view of the weekly pattern observed on Fig. VII.8.3, we attribute the short period variability to cultural activity, while the long period fluctuations may be adequately explained by athmospheric pressure fluctuations (Murphy & Savino, 1975).

Event detection performance at NORSAR was found to generally follow noise level trends. Only insignificant diurnal variation was observed, while we found an increase in the number of reported events during summer of approximately 50 per cent relative to winter. (Fig. VII.8.5)

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Murphy, A.J. and J.M. Savino, 1975: A comprehensive study of long-period (20-200 sec) earth noise at the high-gain world wide seismograph stations, Bull. Seism. Soc. Am., 65, 1827-1862.

Type of Data	Reference	LOGARITHMIC SCALE					LINEAR SCALE	
		Mean Values (nm)				St. Dev. (dB)	Mean (nm)	St. Dev. (nm)
		1973	1974	1975	1973-75	1973-75	1973-75	1973-75
LP Z	Single sensor	29.2	26.7	29.4	28.4	7.26	49.6	57.3
LP N/S	Single sensor	25.7	22.9	24.5	24.3	6.00	37.7	37.0
LP E/W	Single sensor	26.8	25.0	27.0	26.3	6.24	41.6	42.1
SP 1.2-3.2 Hz	Array beam	0.083	0.080	0.083	0.082	2.42	0.087	0.023
SP 1.6-3.2 Hz	Subarray beam	0.163	0.155	0.163	0.160	1.80	0.164	0.034
SP 1.2-3.2 Hz	Single sensor*	0.95	0.92	0.95	0.94	2.42	1.00	0.25
SP 1.6-3.2 Hz	Single sensor*	0.40	0.38	0.40	0.39	1.80	0.40	0.08

* Estimated values.

Table VII.8.1

Noise level statistics (both in logarithmic and linear scales) for short and long period data at NORSAR. Note that the logarithmic mean values have been converted back to equivalent ground motion, i.e., representing the "geometric mean values" of the amplitude data.

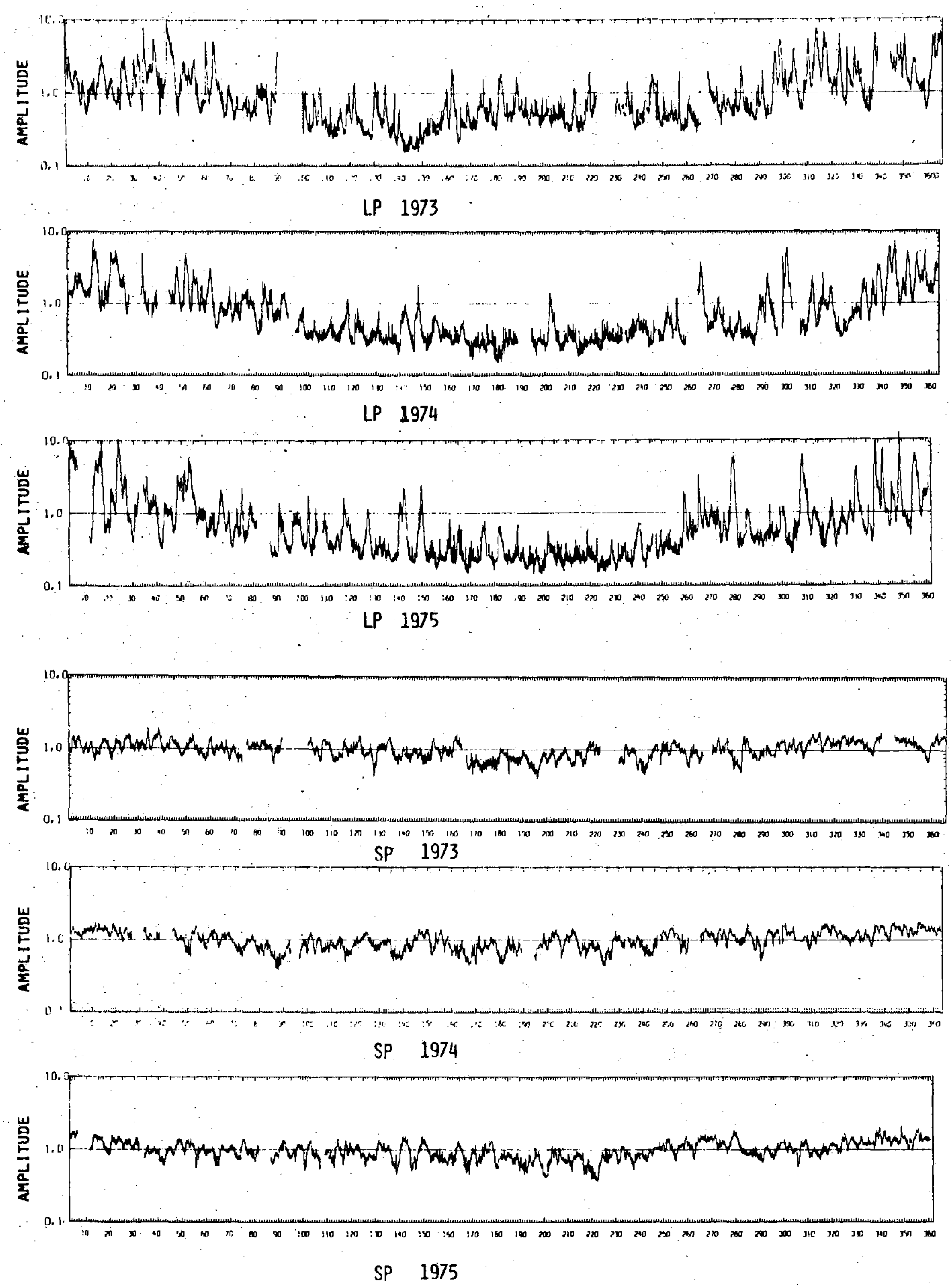

Fig. VII.8.1 For text, see next page.

Fig. VII.8.1 (previous page) Fluctuation in noise amplitudes at NORSAR for the three years 1973-75. The upper three traces represent the average of the long period vertical components, while the lower three traces are average short period noise values in the band 1.2-3.2 Hz. All amplitudes are scaled relative to the average value of each year. Gaps in the data indicate lack of recorded noise estimates for the corresponding time intervals.

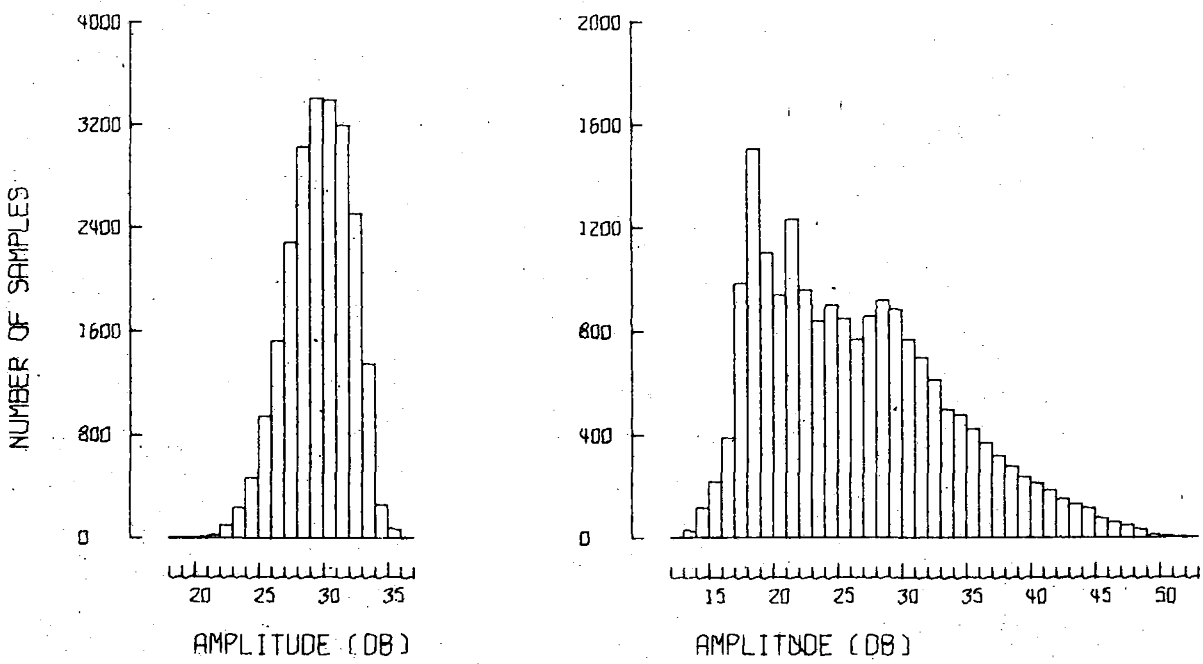

Fig. VII.8.2 Noise amplitude histogram (logarithmic scale for SP data in the band 1.2-3.2 Hz (left) and unfiltered vertical component LP data (right).

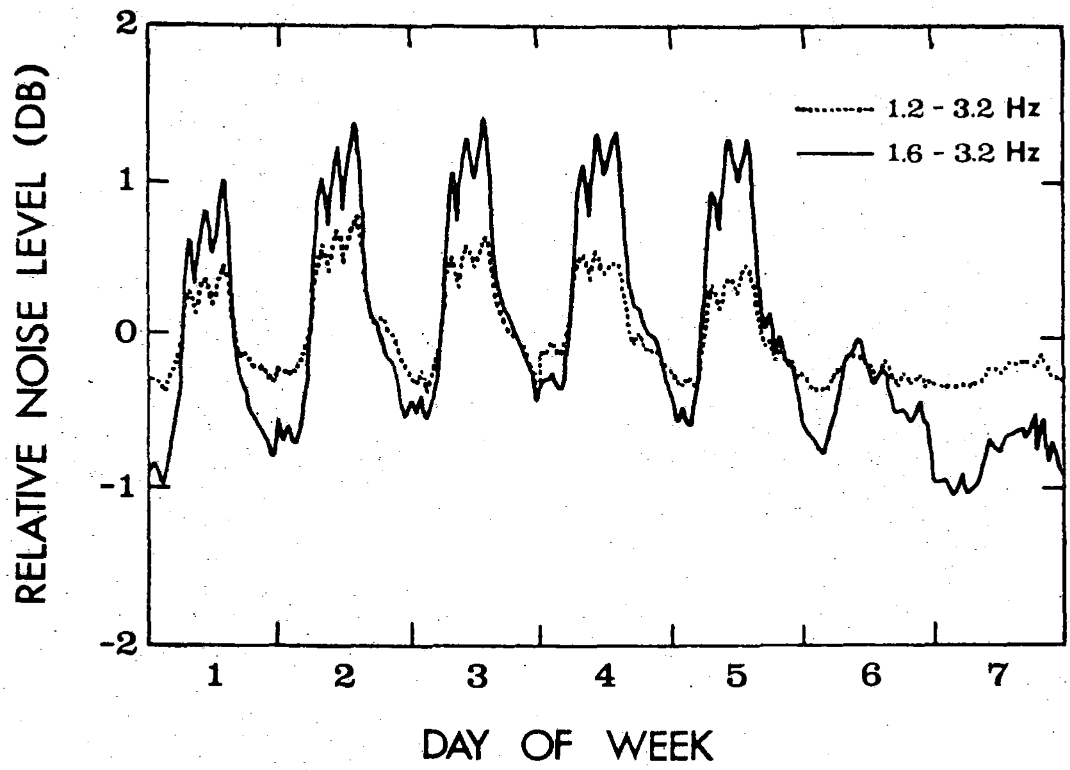

Fig. VII.8.3 Diurnal variation of short period noise level by day of week (Monday through Sunday).

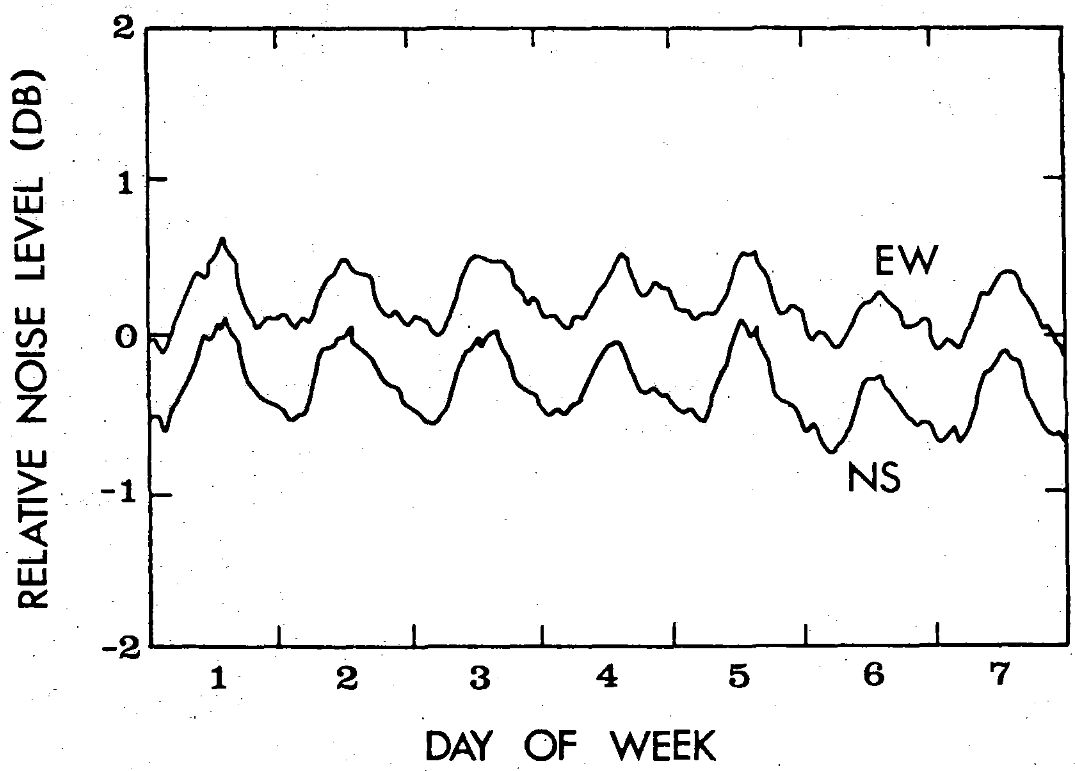

Fig. VII.8.4 Diurnal variation of horizontal component long period noise level by day of week (Monday through Sunday).

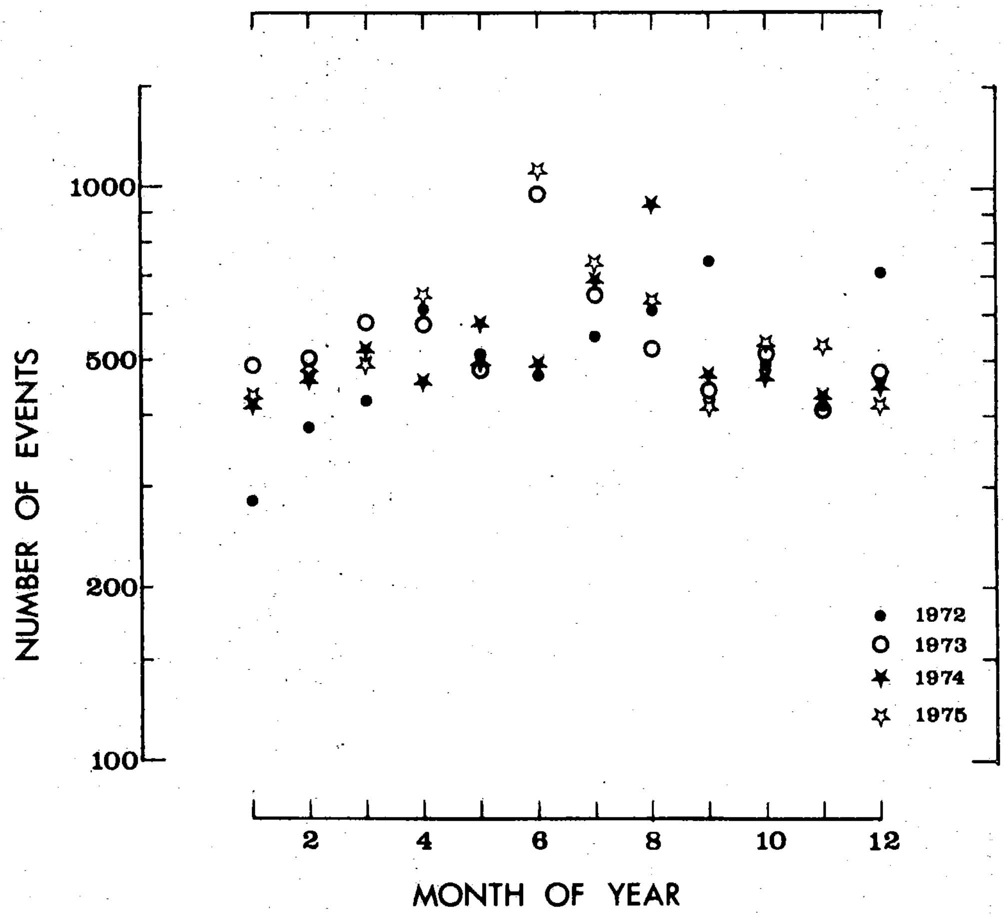

Fig. VII.8.5 Monthly number of NORSAR-reported events for the four-year period 1972-75.