NORSAR

ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

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SEMIANNUAL TECHNICAL SUMMARY 1 April—30 September 1980

By
Alf Kr. Nilsen (ed.)

Kjeller, November 1980

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The operation and some of the research activities at the Norwegian Seismic Array (NORSAR) are described in this report, covering the period 1 April to 30 September 1980.

Compared with the previous reporting period a decrease in the operation performance of the NORSAR online DP system is observed, from 83.7% uptime to 71.1% this period, with the SPS as the main source of trouble, accounting for

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90% of the downtime. The mean-time-between-failures was 0.6 day as compared with 0.9 day for the previous period. The operation of the Event Processor has continued unchanged with an average daily number of events of 6.7.

A new IBM 4331 computer was installed in the beginning of the period, and the load of the old 360 B-computer has gradually decreased as programs have been implemented on the new computer.

Apart from communication faults caused by thunderstorms the communication system performance has been satisfactory. A new line in the ARPA network, via Germany to SDAC, was established in July but was not considered quite reliable as of the end of this reporting period.

Enlargement of NORSAR Experimental Small-Aperture Subarray (NORESS) up to twelve seismometer sites was initiated (completed 31 October 1980). An experiment undertaken by Teledyne-Geotech testing an event detector based on the Walsh theory utilizing a North Star microprocessor and three of the NORSAR SP channels was started. The test period is planned to last out this calendar year. Digital recording of five stations from the Southern Norway Seismic Network (SNSN) was initiated in August.

The three last subsections of the last chapter of this report summarize some of the research activities. The first subsection describes results from NORESS. Incresing the subarray from 6 to 12 channels eliminated the aliasing problem previously encountered, and gives more stable estimates of phase velocity.

The second subsection gives a few preliminary results from a refraction seismic profile in the North Sea/Southern Norway shot this summer. The last subsection deals with the effect of a second-order velocity discontinuity on elastic waves near their turning point, in this study about the long-wavelength effect. Nine additional research contributions from NORSAR have been published in the report AFTAC-TR-80-37.

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Compared with the previous reporting period a decrease in the operation performance of the NORSAR online DP system is observed, from 83.7% uptime to 71.1% this period, with the SPS as the main source of trouble, accounting for 90% of the downtime. The mean-time-between-failures was 0.6 day as compared with 0.9 day for the previous period. The operation of the Event Processor has continued unchanged with an average daily number of events of 6.7.

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A.Kr. Nilsen

II. OPERATION OF ALL SYSTEMS

II.1 Detection Processor (DP) Operation

There have been 285 breaks in the otherwise continuous operation of the NORSAR online system within the current 6-month reporting interval. This is the highest number of stops ever reported; 247 of them are due to SPS malfunction. Both the number of SPS stops and the downtime due to these stops have shown a significant increase the last year. The uptime percentage is 71.1 as compared to 83.7 for the previous period (October 1979-March 1980). Of the downtime of 28.9% the SPS failure covers 26%, the rest is due to other causes.

Fig. II.1.1 and the accompanying Table II.1.1 both show the daily DP downtime for the days between 1 April and 30 September 1980. The monthly recording times and percentages are given in Table II.1.2.

The breaks can be grouped as follows:

a)	SPS malfunction	247
b)	Error on the multiplexor channel	0
c)	Stops related to possible program errors	0
d)	Maintenance stops	7
e)	Power jumps and breaks	11
f)	Hardware problems	17
g)	Magnetic tape and disk drive problems	3
h)	Stops related to system operation	0
i)	TOD error stops	0

The total downtime for this period was 1268 hours and 9 minutes. The mean-time-between-failures (MTBF) was 0.6 days as compared with 0.9 days for the previous period.

J. Torstveit

LIST CF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS..........
92	4	34	6	49	SPS ERROR
95	1	29	2	17	MT ERROR
95	23	30	24	0	SPS ERROR
96	0	0	0	9	SPS ERROR
96	2	15	8	43	SPS ERROR
96	9	8	9	41	SPS ERROR
96	11	35	13	27	SPS ERROR
96	19	2	19	46	SPS ERROR
96	21	32	24	0	SPS ERROR
97	0	0	9	39	SPS ERROR
97	21	33	22	8	SPS ERROR
99	8	42	9	7	SPS ERROR
99	10	31	12	16	SPS ERROR
99	12	39	12	51	SPS ERROR
99	16	25	21	59	SPS ERROR
100	2	15	7	50	SPS ERROR
100	8	43	12	34	SPS ERROR
100	12	57	13	48	SPS ERROR
101	2	31	5	5	SPS ERROR
101	7	5	7	32	SPS ERROR
102	0	37	1	46	SPS ERROR
102	9	23	9	28	SPS ERROR
102	14	8	24	0	SPS ERROR
103	0	0	7	57	SPS ERROR
104	0	46	2	8	SPS ERROR
104	12	37	14	1	SPS ERROR
104	20	48	22	10	SPS ERROR
105	21	34	22	40	SPS ERROR
106	11	2	11	32	SPS ERROR
106	22	57	23	38	SPS ERROR
109	14	18	14	25	SPS ERROR
109	21	50	22	51	SPS ERROR
110	3	12	11	13	SPS ERROR
111	20	21	21	6	SPS ERROR
112	9	55	11	16	POWER INST. FOR IBM 4331
112	13	12	13	28	POWER BREAK
112	13	50	18	8	POWER BREAK
112	18	36	22	11	CPU ERROR

TABLE II.1.1
(Sheet 1 of 9)

LIST CF BREAKS IN CP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS..........
112	22	31	24	0	CPU ERROR
113	0	0	6	15	CPU ERROR
113	6	43	8	10	CPU ERROR
113	13	1	13	10	CPU ERROR
113	13	52	14	3	CPU ERROR
113	14	18	14	26	CPU ERROR
113	18	14	18	32	CPU ERROR
114	1	6	2	18	CPU ERROR
114	3	34	3	41	SPS ERROR
114	5	39	14	50	CPU ERROR
115	5	20	5	30	SPS ERROR
115	22	8	22	44	SPS ERROR
116	1	12	6	11	SPS ERROR
118	15	33	16	50	SPS ERROR
118	19	12	20	36	SPS ERROR
120	14	3	14	12	SPS ERROR
120	14	25	14	54	SPS ERROR
120	16	25	17	26	SPS ERROR
120	17	45	19	33	SPS ERROR
120	22	15	24	0	SPS ERROR
121	0	0	6	28	SPS ERROR
121	7	17	16	49	INST. OF IBM 4331
122	3	6	3	47	SPS ERROR
122	5	51	6	45	SPS ERROR
122	7	5	10	38	SPS ERROR
122	11	4	11	13	CPU ERROR
122	12	22	13	0	SPS ERROR
122	15	20	16	31	SPS ERROR
122	19	14	20	1	SPS ERROR
122	20	39	21	54	SPS ERROR
122	23	47	24	0	SPS ERROR
123	0	0	11	56	SPS ERROR
124	12	53	13	56	SPS ERROR
125	2	1	6	13	SPS ERROR
126	1	38	3	11	SPS ERROR
126	8	16	8	50	SPS ERROR
127	8	21	8	42	SPS ERROR
127	9	39	11	19	SPS ERROR

TABLE II.1.1
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LIST CF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS..........
128	16	5	17	50	SPS ERROR
129	8	7	8	19	SPS ERROR
129	11	15	12	27	SPS ERROR
130	7	6	9	40	SPS ERROR
130	14	37	15	19	SPS ERROR
131	11	50	12	58	CE MAINTENANCE
136	16	43	17	58	SPS ERROR
137	11	24	11	32	CE MAINTENANCE
139	23	33	24	0	SPS ERROR
140	0	0	0	18	SPS ERROR
140	2	55	6	24	SPS ERROR
140	14	49	17	28	CPU ERROR
141	2	20	4	55	SPS ERROR
141	10	31	10	44	POWER BREAK
144	17	11	17	59	SPS ERROR
145	22	20	23	8	SPS ERROR
146	11	47	16	22	SPS ERROR
146	23	27	24	0	SPS ERROR
147	0	0	6	25	SPS ERROR
147	15	42	16	42	SPS ERROR
147	23	32	24	0	SPS ERROR
148	0	0	0	20	SPS ERROR
148	3	29	5	41	SPS ERROR
148	23	37	24	0	SPS ERROR
149	0	0	3	17	SPS ERROR
149	6	53	7	19	SPS ERROR
149	8	7	8	18	SPS ERROR
149	8	31	8	51	SPS ERROR
149	16	1	16	45	SPS ERROR
149	22	38	24	0	SPS ERROR
150	0	0	5	56	SPS ERROR
150	15	19	16	0	SPS ERROR
151	0	11	0	47	SPS ERROR
151	1	41	6	33	SPS ERROR
151	6	53	7	25	SPS ERROR
151	7	36	7	48	SPS ERROR
151	8	13	8	20	SPS ERROR
151	10	15	10	32	SPS ERROR

TABLE II.1.1
(Sheet 3 of 9)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS..........
151	11	12	11	28	SPS ERROR
151	12	1	12	56	SPS ERROR
151	15	55	16	11	SPS ERROR
151	16	36	16	49	SPS ERROR
151	18	25	18	35	SPS ERROR
151	22	20	24	0	SPS ERROR
152	0	0	24	0	SPS ERROR
153	0	0	24	0	SPS ERROR
154	0	0	24	0	SPS ERROR
155	0	0	24	0	SPS ERROR
156	0	0	24	0	SPS ERROR
157	0	0	24	0	SPS ERROR
158	0	0	24	0	SPS ERROR
159	0	0	24	0	SPS ERROR
160	0	0	24	0	SPS ERROR
161	0	0	24	0	SPS ERROR
162	0	0	24	0	SPS ERROR
163	0	0	24	0	SPS ERROR
164	0	0	24	0	SPS ERROR
165	0	0	24	0	SPS ERROR
166	0	0	24	0	SPS ERROR
167	0	0	24	0	SPS ERROR
168	0	0	24	0	SPS ERROR
169	0	0	13	42	SPS ERROR
169	17	41	20	26	SPS ERROR
169	23	38	24	0	SPS ERROR
170	0	0	6	16	SPS ERROR
170	13	29	13	47	SPS ERROR
171	7	9	8	1	SPS ERROR
172	7	44	8	35	SPS ERROR
173	12	46	16	34	POWER BREAK
174	4	46	9	2	SPS ERROR
174	17	21	19	18	SPS ERROR
175	1	29	15	49	CPU ERROR
175	20	17	21	3	SPS ERROR
176	10	55	11	5	SPS ERROR
177	6	30	10	57	SPS ERROR
177	11	27	11	38	SPS ERROR

TABLE II.1.1
(Sheet 4 of 9)

LIST CF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
178	10	56	11	36	SPS ERROR
179	6	34	7	13	SPS ERROR
179	12	24	12	31	SPS ERROR
181	8	53	9	24	SPS ERROR
181	22	21	22	58	SPS ERROR
183	18	11	20	28	SPS ERROR
184	0	21	6	10	SPS ERROR
184	9	11	9	47	SPS ERROR
184	15	47	17	18	SPS ERROR
185	4	51	5	59	SPS ERROR
185	12	22	12	27	SPS ERROR
186	9	21	9	27	SPS ERROR
186	14	18	15	38	SPS ERROR
186	22	3	24	0	SPS ERROR
187	0	0	0	19	SPS ERROR
187	2	30	9	24	SPS ERROR
188	6	0	7	46	SPS ERROR
190	1	45	6	17	SPS ERROR
190	12	14	12	45	SPS ERROR
190	13	49	14	52	SPS ERROR
190	16	11	19	48	POWER BREAK
191	11	4	11	14	SPS ERROR
191	16	4	17	22	SPS ERROR
191	20	40	21	31	SPS ERROR
192	1	25	6	47	SPS ERROR
192	7	50	8	26	SPS ERROR
192	22	25	23	10	SPS ERROR
193	1	21	7	0	SPS ERROR
193	13	4	14	23	POWER BREAK
193	15	2	18	47	SPS ERROR
194	0	19	9	46	SPS ERROR
194	10	27	15	58	SPS ERROR
194	17	23	24	0	SPS ERROR
195	0	0	24	0	SPS ERROR
196	0	0	10	19	SPS ERROR
196	12	18	13	11	SPS ERROR
196	17	22	20	6	SPS ERROR
197	22	19	23	29	SPS ERROR

TABLE II.1.1
(Sheet 5 of 9)

LIST CF BREAKS IN CP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS..........
198	10	34	13	28	SPS ERROR
198	16	55	19	7	SPS ERROR
199	0	1	24	0	SPS ERROR
200	0	0	24	0	SPS ERROR
201	0	0	24	0	SPS ERROR
202	0	0	24	0	SPS ERROR
203	0	0	12	46	SPS ERROR
203	13	15	13	23	SPS ERROR
203	14	55	15	12	SPS ERROR
203	23	52	24	0	SPS ERROR
204	0	0	7	36	SPS ERROR
204	8	4	8	42	POWER BREAK
204	9	40	11	35	CPU ERROR
204	14	23	16	50	SPS ERROR
205	0	46	6	17	SPS ERROR
205	8	2	8	15	SPS ERROR
205	9	0	9	17	SPS ERROR
205	13	40	17	49	SPS ERROR
206	3	40	6	44	SPS ERROR
206	9	53	10	8	SPS ERROR
207	1	0	6	39	SPS ERROR
207	15	33	21	26	SPS ERROR
208	6	38	6	49	SPS ERROR
208	9	9	9	19	SPS ERROR
209	5	22	8	5	SPS ERROR
209	8	43	8	51	SPS ERROR
210	4	5	5	5	SPS ERROR
210	6	19	6	29	SPS ERROR
210	11	43	12	1	SPS ERROR
210	15	16	18	58	SPS ERROR
210	22	28	24	0	SPS ERROR
211	0	0	5	15	SPS ERROR
211	6	59	7	6	SPS ERROR
211	10	17	10	27	SPS ERROR
211	22	3	24	0	SPS ERROR
212	0	0	5	29	SPS ERROR
212	9	37	10	2	SPS ERROR
212	11	52	12	29	SPS ERROR

TABLE II.1.1
(Sheet 6 of 9)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS............
212	16	22	19	23	SPS ERROR
213	14	14	15	38	SPS ERROR
213	20	46	21	27	SPS ERROR
214	4	36	5	55	SPS ERROR
214	6	27	6	36	SPS ERROR
214	10	22	10	31	SPS ERROR
214	11	45	11	52	SPS ERROR
214	13	11	13	35	SPS ERROR
214	13	53	14	1	EOC ERROR
214	20	38	24	0	SPS ERROR
215	0	0	9	36	SPS ERROR
215	9	57	24	0	SPS ERROR
216	0	0	18	38	SPS ERROR
216	19	8	24	0	SPS ERROR
217	0	0	6	56	SPS ERROR
217	7	23	7	37	SPS ERROR
217	12	14	12	42	SPS ERROR
217	13	2	13	13	SPS ERROR
217	19	8	19	29	SPS ERROR
217	22	48	23	23	SPS ERROR
218	1	5	6	17	SPS ERROR
218	7	35	7	43	SPS ERROR
218	13	8	13	16	SPS ERROR
218	15	18	15	54	SPS ERROR
218	16	57	19	19	SPS ERROR
218	20	48	21	18	SPS ERROR
218	21	29	24	0	SPS ERROR
219	0	0	9	37	SPS ERROR
220	1	11	12	5	SPS ERROR
220	16	22	17	3	SPS ERROR
220	19	56	21	40	SPS ERROR
220	22	44	24	0	SPS ERROR
221	0	0	6	14	SPS ERROR
221	10	19	12	55	SPS ERROR
222	1	27	2	5	SPS ERROR
222	12	7	12	17	SPS ERROR
222	12	46	13	47	SPS ERROR
222	16	28	16	57	SPS ERROR

TABLE II.1.1
(Sheet 7 of 9)

LIST CF BREAKS IN CP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
222	21	46	22	19	SPS ERROR
223	22	15	22	50	SPS ERROR
224	1	38	8	58	POWER BREAK
224	10	44	13	11	CE MAINTENANE
225	5	18	8	47	SPS ERROR
225	10	49	12	54	SPS ERROR
226	6	47	9	34	SPS ERROR
227	6	23	18	57	CE MAINTENANCE
227	19	57	20	13	DISK ERROR
228	11	7	11	27	CE MAINTENANCE
230	13	55	14	38	SPS ERROR
230	18	25	19	50	SPS ERROR
231	7	40	7	51	SPS ERROR
235	7	13	7	22	MT ERROR
236	2	6	4	13	SPS ERROR
240	6	32	6	43	SPS ERROR
243	16	24	16	42	SPS ERROR
244	20	54	21	38	SPS ERROR
246	5	32	6	30	SPS ERROR
246	9	17	9	37	SPS ERROR
246	16	19	20	4	SPS ERROR
247	5	30	6	38	POWER FAILURE
247	8	55	9	6	SPS ERROR
247	9	52	10	2	SPS ERROR
247	12	5	12	15	SPS ERROR
247	17	12	20	26	SPS ERROR
248	0	2	8	42	SPS ERROR
248	19	20	21	35	SPS ERROR
250	11	27	20	35	SPS ERROR
251	21	0	24	0	SPS ERROR
252	0	0	6	35	SPS ERROR
254	4	47	6	58	SPS ERROR
256	7	39	7	49	SPS ERROR
256	9	21	9	50	CPU ERROR
256	10	49	12	18	CPU ERROR
258	3	54	6	0	SPS ERROR
258	7	52	9	58	SPS ERROR
259	7	29	15	35	CPU ERROR

TABLE II.1.1
(Sheet 8 of 9)

LIST CF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
259	16	51	17	35	SPS ERROR
259	17	52	20	8	SPS ERROR
259	20	45	24	0	POWER FAILURE
260	0	0	10	28	POWER FAILURE
260	10	44	11	8	CPU ERROR
260	11	45	13	18	SPS ERROR
261	12	34	12	43	SPS ERROR
262	2	29	6	13	SPS ERROR
263	12	25	12	34	SPS ERROR
263	12	38	12	44	SPS ERROR
264	2	1	2	14	SPS ERROR
264	2	27	3	11	SPS ERROR
265	3	38	4	39	SPS ERROR
265	10	43	11	18	SPS ERROR
265	12	31	16	27	SPS ERROR
265	16	39	17	56	SPS ERROR
265	18	24	19	3	SPS ERROR
265	20	45	24	0	SPS ERROR
266	0	0	12	55	SPS ERROR
267	0	10	11	12	SPS ERROR
267	14	9	14	22	SPS ERROR
269	2	22	6	12	SPS ERROR
269	8	13	8	21	SPS ERROR
270	20	21	21	25	SPS ERROR
271	0	12	4	54	SPS ERROR
271	21	56	22	56	SPS ERROR
273	4	50	7	21	SPS ERROR
273	12	15	12	57	SPS ERROR
273	15	2	15	17	SPS ERROR

TABLE II.1.1
(Sheet 9 of 9)

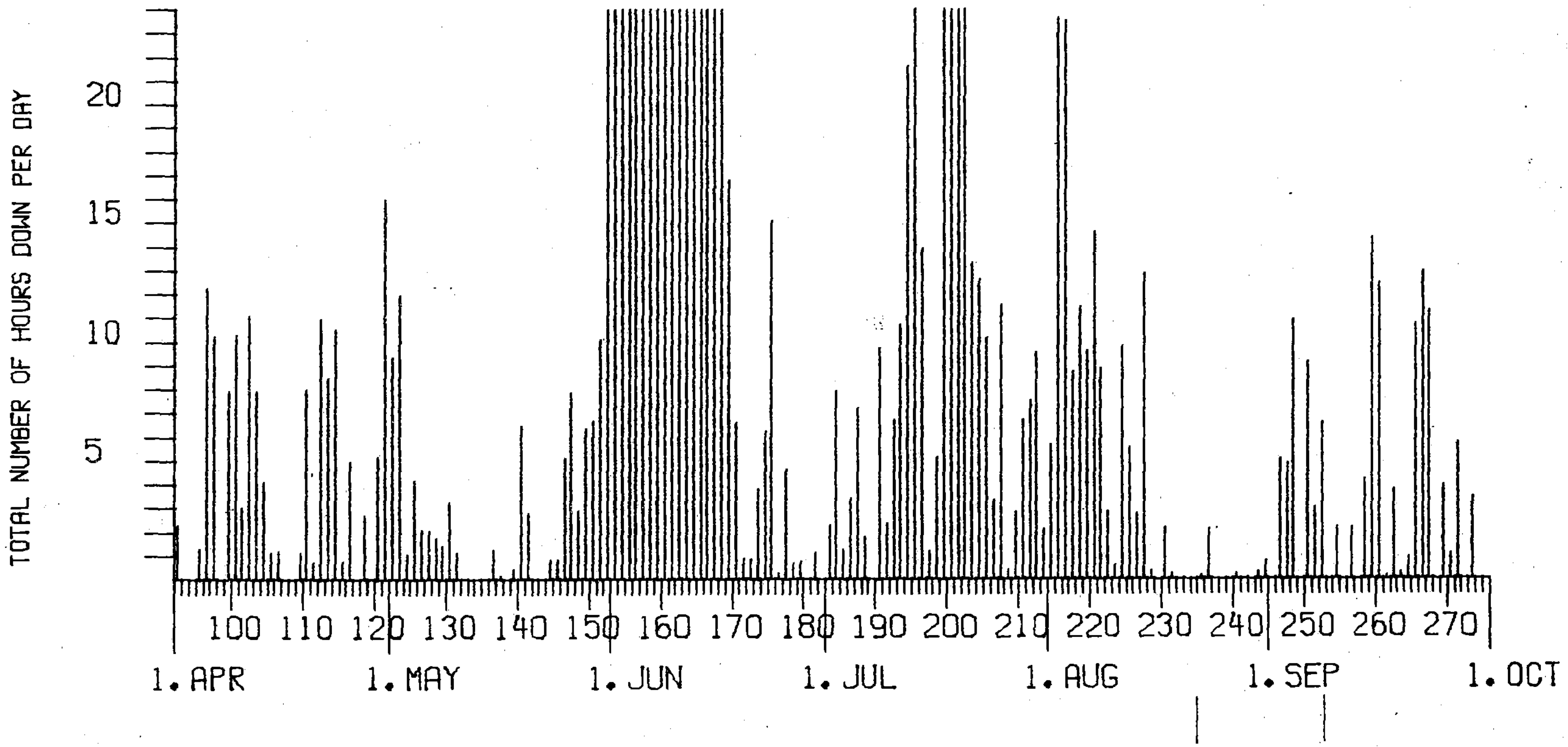


Fig. II.1.1 Detection Processor Downtime in the period April - September 1980.

Month	DP Uptime (hrs)	DP Uptime (%)	No. of DP Breaks	No. of Days with Breaks	DP MTBF* (days)
Apr	577.82	80.3	54	16	0.4
May	630.14	84.7	54	24	0.5
Jun	278.40	38.7	19	28	0.6
Jul	449.03	60.4	64	30	0.3
Aug	597.48	80.3	48	22	0.5
Sep	590.98	82.1	46	22	1.1
	3123.85	71.1	285	142	0.6

*Mean-time-between-failures = Total uptime/No. of up intervals)

TABLE II.1.2

Online System Performance
April-September 1980

II.2 Event Processor Operation

The Event Processor has been operated as before. Some monthly statistics are presented in Table II.2.1.

	Teleseismic	Core Phases	Sum	Daily
Apr 80	193	60	253	8.4
May 80	211	45	256	8.3
Jun 80	95	41	136	4.5
Jul 80	147	58	205	6.6
Aug 80	149	26	175	5.6
Sep 80	163	44	207	6.9
	958	274	1232	6.7

TABLE II.2.1

B. Kr. Hokland

II.3 NORSAR Data Processing Center (NDPC) Operation

Data Center

The installation of the new computer, the IBM 4331, which took place in the beginning of this period has gradually eased the load of jobs on the B-computer as programs are brought to run on the 4331. This has also eased the working situation for the operators, as the computer users load and run their jobs themselves from remote terminals. Though most routine jobs now are run in the daytime, we still occasionally have students running jobs in the evenings, to keep up with the varying work load.

J. Torstveit

II.4 Array Communication

Table II.4.1 reflects the communications system performance throughout the reporting period. It does not only reflect conditions caused by elements directly related to the communications channels themselves, but also other sources and incidents which may have generated errors in the communications channels. Such 'sources' and 'incidents' included:

- CTV power failues
- SLEM failures
- Switching of lines between the SPS com. adapters and the MODCOMP processor.

As indicated by the table we have statistics only for the two last weeks in June, as our SPS was down most of the time weeks 23 and 24.

15 April most systems were affected due to reorganization of cable trenches in the Løten area. On 22 April all line levels were too low, between -24.0 and -31.0 dB (nominal -21.0 dB). Adjustments were carried out by the Norwegian Telegraph Administration (NTA).

On 5 May 01A affected by a broken cable near Brumunddal.

In June there was a power loss at 02B week 26. 01A and 01B were frequently switched to the MODCOMP communications processor. There was an intermittent cable fault

Sub-Array	APR (5)		MAY (4) (5.5-1.6)		JUN (2) (16-29.6)		JUL (5) (30.6-3.8)		AUG (4) (4-31.8)		SEP (4) (1-28.9)		AVERAGE ½ YEAR	
	>20	>200	>20	>200	>20	>200	>20	>200	>20	>200	>20	>200	>20	>200
01A	0.1	0.3	1.0	-	0.4	25.6	0.2	5.8	0.3	0.8	0.1	0.3	0.3	5.5
01B	-	17.8	-	4.7	-	9.1	-	32.7	-	32.5	-	30.1	-	21.1
02B	0.2	3.7	0.3	0.5	0.1	2.6	2.6	92.4	10.2	58.5	20.7	1.3	5.7	26.5
02C	3.8	2.1	3.5	0.5	13.0	10.5	32.0	25.8	15.6	48.0	0.3	4.2	11.4	15.2
03C	0.2	1.0	-	-	0.5	0.2	0.7	0.5	0.5	0.2	0.1	-	0.3	0.3
04C	1.3	0.5	0.1	0.8	1.2	0.7	0.3	0.3	0.3	0.1	0.1	0.2	0.5	0.4
06C	0.2	5.6	-	0.1	0.4	2.0	0.2	3.0	0.1	14.2	0.2	1.1	0.2	4.3
AVER	0.8	4.5	0.7	0.9	2.2	7.2	5.1	32.4	3.8	22.0	3.1	5.3	2.6	10.4
		06C,01B				01A,01B		01B,02B	02B	01A,01B			02B	01B,02B
LESS		02B			02C	02C	02C	02C	02C	02C,06C	02B	01B	02C	02C
		1.0			0.4	1.4	0.7	2.3	0.2	0.4	0.1	1.2	0.2	2.6

TABLE II.4.1

Communications (degraded performance >20/outages >200)
Figures in per cent of total time. Month four or five weeks (June 2, as indicated).

between Lillehammer and Hornsjø causing high error rate on 02C. NTA have been involved, but the main fault was not located. Errors are all in the ICW's toward the subarray.

In July 02B remained down due to lack of power. 02C error rate increased and NTA was informed.

In August cables and modems at 01B/NORESS and 06C were damaged by thunderstorms, causing high error figures that month and on 01B/NORESS also in September. At 02B the power problem was solved week 35. At 02C the communications system was still impaired in spite of NTA involvement, but error-free operation after repair of the communication cable September 11.

Table II.4.2 indicates distribution of outages on a weekly basis throughout the reporting period pertaining to the individual subarrays. The table also indicates (by asterisks) group outages, i.e., when some or all subarrays have been down simulataneously.

The ARPA Subnetwork

The new line via Germany to SDAC has since it was measured by the telegraph agencies in Norway and Germany (16, 22 April) been subject to several additional tests and measurements. In May the first unsuccessful attempt was made to use the line under normal operating conditions, and therefore the original line via Tanum was reconnected. In the beginning of July attempts were made to improve the new line, and finally, 8 July, it was hooked up permanently. Based on observations and engagements initiated by the Network Control Center (NCC) we can still not characterize the circuit as reliable.

Week/	Subarray/Per cent outage						
Year	01A	01B	02B	02C	03C	04C	06C
14/80		1.8					
*15		5.9	0.5	0.7			0.2
*16	0.7	68.0	17.4	3.6	4.8	1.9	27.3
17		8.3		2.5			
*18	0.4	5.3	0.7	3.9	0.4	0.4	0.4
*19		1.5	0.4			0.4	
20		8.3	1.5	0.8			0.2
21		7.0	0.2	1.3			
22		1.8					0.5
*25	0.5	10.4	0.4	1.5	0.4	0.5	3.3
*26	50.7	7.9	4.8	19.5		0.9	0.7
27	28.6	1.6	66.0	65.2			1.8
28		9.5	88.2	26.0	2.1		
29		78.0	100.0	11.1			12.9
30		71.4	85.7	10.5			
31	0.2	3.1	100.0	16.0	0.4		0.4
*32	1.7	4.3	100.0	18.6	0.9	0.5	0.4
33		5.8	100.0	38.5			
34	1.2	22.9	34.2	58.3			20.8
35	0.4	96.4	0.9	76.6			35.6
36	0.2	79.9	2.8	15.8			2.5
37		3.2		0.2			0.5
38		20.4	1.8				0.4
*39	0.9	17.0	0.8	0.7	0.2	0.8	1.1

TABLE II.4.2

The Terminal Interface Message Processor (TIP)
This period the processor has been less reliable than usual. It started 6 May when the machine stopped due to lack of +15 Volt to memory. Restart was necessary 21 May and finally the CPU stopped 22 May due to a faulty cooling fan. After replacing the fan the machine would still not start. Memory and modem I/F tests were run to test their condition; further attempts to start failed. A BBN representative arrived 24 May and replaced items in the ID card in the CPU.

In June we again had problems with the +15 Volt to memory, but after power OFF/ON we restarted the machine. On 5, 6, 9, 12, 19 and 21 June the machine had to be restarted. 21 June the TIP did not recover after a power outage. Upon BBN request we removed TIP power 23 June and swapped the +15 Volt power cards in the two lower power units (as the card in the lowest drawer is not used).

In July we had some problems, and restart was necessary on 9 July. After the machine had failed to recover after a couple of power outages, a BBN representative adjusted the sensing level in the power units 14 July.

In August a BBN representative again arrived in order to improve data transfer from/to the ARPANET via the TIP, mainly based on claims forwarded by NDRE. In addition to the known line problem (most certainly the main cause), a VDH-interface card was replaced in the TIP.

In September the performance was reliable.

During the NATO seminar arranged at Voksenåsen Hotel in Oslo in September, a printer terminal was hooked up to the TIP port 60 via two asynchronous modems and a rented telephone line. Otherwise no changes to the port connections quoted in the last report.

O.A. Hansen

III. IMPROVEMENTS AND MODIFICATIONS

III.1 NORSAR On-Line System

Fig. III.1.1 gives a schematic overview of the current NORSAR on-line computer configuration. No changes have been effected in the on-line system in the reporting period.

III.2 NORSAR Event Processor

Implementation of event processing on the new IBM 4331 research computer system, which has been funded by NTNF, is in progress. A major problem in the conversion of programs is the jump over 2 generations of software and hardware developments. However, we are not tempted to make old assembler programs run on a new system, and therefore the converted programs will be mainly Fortran coded, up-to-date and easy to service. We put weight on interactive use for both bulletin and seismogram work.

J. Fyen

III.3 Array Instrumentation and Facilities

In this period no modifications or improvements in the NORSAR array were accomplished, except that the work with enlargement of NORESS up to twelve closely clustered seismometer sites in the subarray 06C area was initiated. Refer to Table III.3.1 for changes of NORSAR SP instruments recorded on data tape in the reporting period (and out October). The horizontal SP seismometers on 06C02 and 04 were removed 18 June and replaced with standard vertical HS-10A seismometers.

At NDPC Teledyne-Geotech installed this summer a Northstar microcomputer and a Helicorder analog recorder for testout of an event detector based on the Walsh theory utilizing three of the SP channels from 03C after digital-to-analog conversion in the EOC. Comparisons are then made between this detector's capability and NORSAR array beam detector. The test period is planned to last out this calendar year.

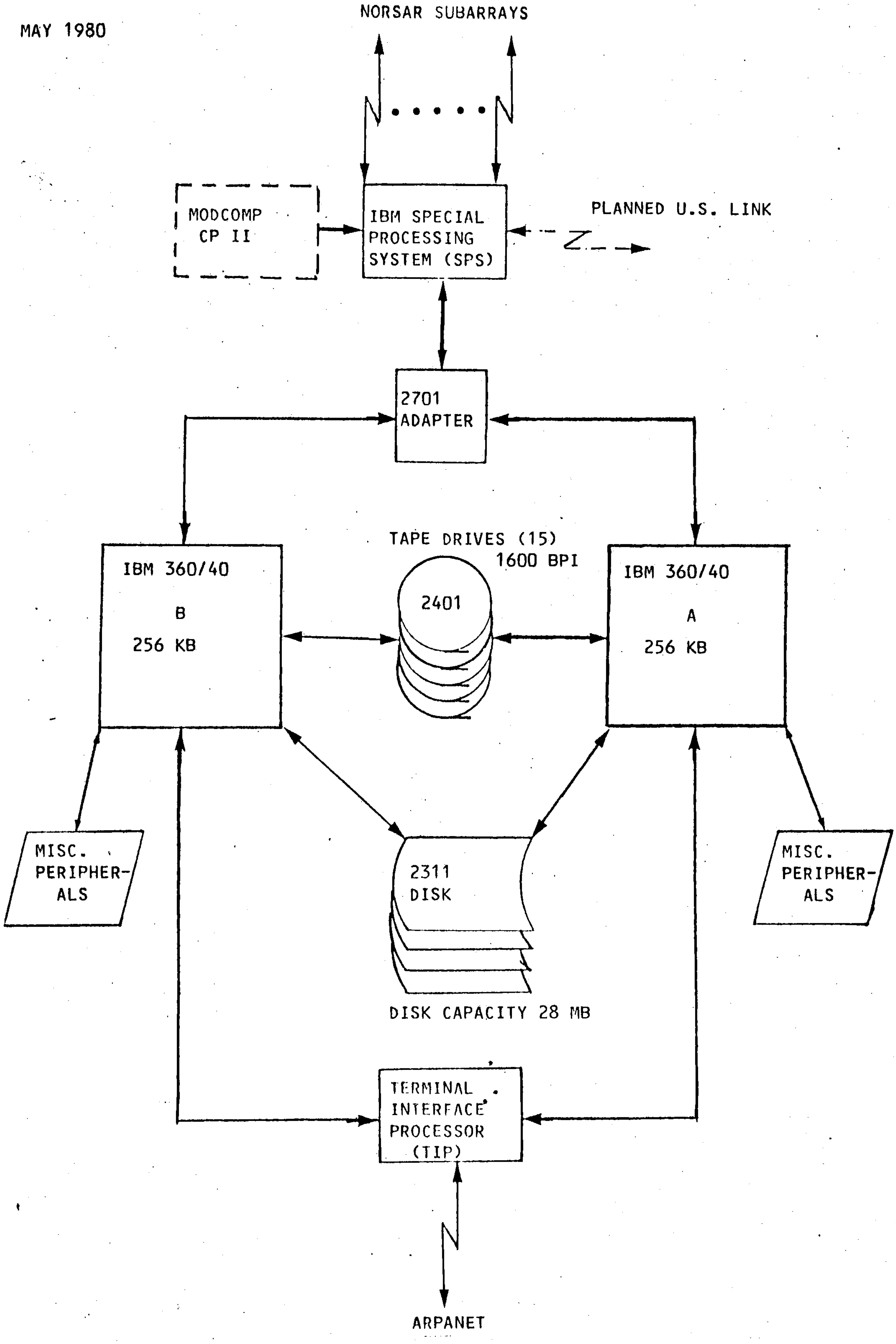


Fig. III.1.1 Current NORSAR on-line computer configuration.

All sites for the Southern Norway Seismic Network (SNSN) were completed in the end of July, and data was recorded from the first station (Sørum) in the period 3-9 July. Though data was recorded digitally on the PDP 11/34 computer from some of the stations in the beginning of August, official opening dates were mostly in the second half of August (ref. Table III.3.2). The analog data is transmitted on telephone lines from the sites to NORSAR. Otherwise the instrumentation used in the SNSN is as follows:

Field Stations

Seismometer	Teledyne/Geotech S-13 - 102 with Gc of 629 Volts/m/sec.
Seismometer amplifier	Constructed at NORSAR Field Maintenance Center with two amplifier channels, one on 40 dB and the high one on 80 dB. Filter lowpass with upper 3 dB point at 25 Hz, 18 dB/oct roll off.
VCO	Teledyne/Geotech type 46.22 and 46.22-1.

Subarray Normally	Instr. No. within SA	Ch. No. on NORSAR Data Tape	Time of Change			
			80/06/19	80/09/04	80/10/28	80/10/31
01A	1	1				
(1)	2	2				
	3	3				
	4	4				
	5	5				
	6	6				
01B	1	7	NORESS(1) 8 Hz	NORESS(1) 4.75 Hz	'New' NORESS(1)	'Old' NORESS(1)
(2)	2	8	" (2) 8 Hz	" (2) "	" (2)	" (2)
	3	9	" (3) 4.75 Hz	" (3) "	" (3)	" (3)
	4	10	" (4) 4.75 Hz	" (4) "	" (4)	" (4)
	5	11	" (5) 8 Hz	" (5) "	" (5)	" (5)
	6	12	" (6) 8 Hz	" (6) "	" (6)	" (6)
02B	1	13				
(3)	2	14				
	3	15				
	4	16				
	5	17				
	6	18				
02C	1	19				
(4)	2	20				
	3	21				
	4	22				
	5	23				
	6	24				

TABLE III.3.1

Status of NORSAR SP instruments recorded on data tape.
(Page 1)

Subarray Normally	Instr. No. within SA	Ch. No. on NORSAR Data Tape	Time of Change 80/06/19	80/09/04	80/10/28	80/10/31
03C	1	25				
(5)	2	26				
	3	27				
	4	28				
	5	29				
	6	30				
04C	1	31				
(6)	2	32				
	3	33				
	4	34				
	5	35				
	6	36				
06C	1	37			'Old' NORESS (1)	'New' NORESS (1)
(7)	2	38	Normal HS-10A SP		" (2)	'Old' NORESS (2)
	3	39			" (3)	'New' NORESS (3)
	4	40	Normal HS-10A SP		" (4)	" (4)
	5	41			" (5)	" (5)
	6	42			" (6)	" (6)

TABLE III.3.1
(Page 2)

Station	Telephone lines operational dates	Comments
Sørum	3 July	Down 9 July, restored 21 August
Sarpsborg	20 August	
Drangedal	2 September	Operational from 30 September due to lightning damage on field power supply
Evje		The line is still not operational
Seljord	19 August	
Norefjell	28 August	
Blåsjø		Ready for installation

TABLE III.3.2

Operational status for the stations in the Southern Norway Seismic Network

Automatic Pulse Calibrator	PC-100, set to one pulse pr day
Power	HP-6217A powers DC/DC converter with output ±12V.

<u>NDPC</u>

FM Discriminator	Teledyne/Geotech type 46.12, filter possibilities, 5, 12.5 and 25 Hz low pass, 18 dB/oct roll off
Analog recorder	Teledyne/Geotech Helicorder Type RV-301
Computer	PDP 11/34 with 12 bit analog-to-digital converter type AD11-K and one tape drive (TS11). The sample frequencies are flexible, as for now on 40 Hz. Least significant bit (1 quantum unit) is 2.44 mv, maximum ±5.0 volts.

Timing

Sprengnether TS-400 supports timing for both digital and analog recording. Digital timing system TS-250 will be installed later.

Alf Kr. Nilsen

III.4 SPS Substitution

By the end of the reporting period, status on the MODCOMP interface was as follows:

- The previously reported problems with the two-way communication between MODCOMP and IBM 360/40 were due to an error in a PROM in the MODCOMP interface. A new PROM has now been acquired and communication appears satisfactory.
- The MODCOMP programming devleopments are proceeding.

III.5 Future NORSAR Data Processing Center

The computer upgrade at NORSAR as outlined in the former reporting period is in progress and the dual 4300 system will be acquired in the next reporting period.

J. Fyen

IV. FIELD MAINTENANCE ACTIVITY

The operation performance of the array instrumentation continues to be stable and satisfactory, and except for two of the subarrays which had faults caused by lightning, the maintenance activity is lower than in previous summer seasons. The main task besides normal maintenance has been the installation and starting up of the Southern Norway Seismic Network (SNSN).

Maintenance Visits

Table IV.1 shows the number of visits to the NORSAR subarrays in the period which in average is 4.4 to each subarray; excluding 02B and 06C/NORESS the average number of visits is 1.4 times. The large number of visits to 02B and 06C/NORESS is due to cable breakages, power faults and communication faults, all caused by thunderstorms.

Subarrays	01A	01B	02B	02C	03C	04C	06C/NORESS	Total
No. of Visits	1	2	11	2	1	1	17	35

TABLE IV.1

Number of visits to the NORSAR subarrays including NORESS
in the period 1 April-30 September 1980

Preventive Maintenance Projects

The preventive maintenance work in the array is listed in Table IV.2. There have been no major preventive projects during the period. The adjustments are corrections of characteristics within tolerance limits.

Unit	Action	No. of Actions
Seismometer	MP adjust (in field)	4
Line Termination Amplifier	Adjustment of channel gain (SP)	3
	-"- DC Offset (SP)	2
	-"- CMR (SP)	1
Emergency Power	Battery and charger check	7
CTV	Cleaning	3

TABLE IV.2

Preventive maintenance work in the period 1 April - 30 September 1980

Corrections of Disclosed Malfunctions on Instrumentation and Electronics

Table IV.3 gives the number of required adjustments and replacements of field equipment in the array with the exception of those listed in Table IV.2.

Unit	Characteristics	SP Repl.	SP Adj.	LP Repl.	LP Adj.
Seismometer	Damping				1
	MP/FP (At NDPC)				37
	MP (in field)				7
	FP (in field)				4
Seismometer Ampl.	Input card	1			
RA/5, Ithaco	Gain low	1			
JA-,JB-,JC-box	Taper pin block	2			
	Short due to water seepage	1			
Line Termination	Ripple	1			
Amplifier	Filter fault	1			
	Channel gain		3		
	Calibration relay	1			
	Other	1			
Charger/rectifier	U3 card	1			
	'low battery limit'		1		
SLEM	Test generator	1			
	Analog Unit	1			
	BB		1		
	Gas fuses all SP ch	1			
	RSA/ADC	3			
	Digital Unit	2			
Constructions	LPV light			2	

TABLE IV.3

Total number of required adjustments and replacements of NORSAR field equipment in the period 1 April-30 September 1980

Power Breaks, Cable Breakages, Communication Faults

There have been two power breaks requiring action of the field crew, four signal cable breakages and three communication faults.

Array Status

Threre is little change from previous periods. As of 30 September 1980 four channels have out-of-tolerance conditions (01A EWLP, 02B 04SP, 04C EWLP and 06C EWLP). Channels with nonstandard conditions are:

01A	04	Attenuated 30 dB, 01A 06 data
01B	01-06	NORESS
	LP	Disconnected.

Alf Kr. Nilsen

ABBREVIATIONS

ADC	-	Analog-to-digital converter
BB	-	Broad band
CMR	-	Common mode rejection
CTV	-	Central Terminal Vault
DC	-	Direct current
EW	-	East-West (LP)
EOC	-	Experimental Operations Console
FM	-	Frequency modulation
FP	-	Free period
JA, JB, JC	-	Junction boxes
LP	-	Long period
LPV	-	Long period vault
MP	-	Mass position
NDPC	-	NORSAR Data Processing Center
NORESS	-	NORSAR Experimental Small-Aperture Subarray
RSA	-	Range switching amplifier
SA	-	Subarray
SLEM	-	Seismic short and long period electronics module
SNSN	-	Southern Norway Seismic Network
SP	-	Short period
VCO	-	Voltage controlled oscillator

V. DOCUMENTATION DEVELOPED

Doornbos, D.J., 1981: The effect of a second-order velocity discontinuity on elastic waves near their turning point, Geophys. J.R. astr. Soc. 64, 499-511.

Gjøystdal, H., 1980: Ray-tracing in complex 3-D geological models, Report prepared for GECO A/S, NORSAR Technical Rep. 2/80.

Gjøystdal, H., 1980: Computation of seismic ray paths between given source and receiver line in a complex 3-D model, Report prepared for GECO A/S, NORSAR Technical Rep. 3/80.

Gjøystdal, H., 1980: A general computer algorithm for calculating zero-value contours of a bivariate scalar function, with special application to seismic ray-tracing in complex 3-D models, Report prepared for GECO A/S, NORSAR Technical Rep. 4/80.

Hovland, J., D. Gubbins and E.S. Husebye, 1981: Upper mantle heterogeneities beneath central Europe, Geophys. J.R. astr. Soc., in press.

Mykkeltveit, S., E.S. Husebye and Ch. Oftedahl, 1980: Remnants of the Iapetus Ocean beneath the Møre Gneiss Region of southern Norway - Seismic evidence, Nature, 288, 473-475.

Nilsen, A.K., 1980: Semiannual technical summary, 1 October 1979 - 31 March 1980, NORSAR Sci. Rep. 2-79/80, NTNF/NORSAR, Kjeller, Norway.

VI. SUMMARY OF TECHNICAL REPORTS/PAPERS PREPARED

VI.1 Further Development of the NORESS Small-Aperture Array

From 31 October 1980 the NORESS small-aperture array has been operated with 12 vertical seismometers, all within the 2 km diameter 'old' NORESS 6-channel array. Fig. VI.1.1 shows the new NORESS geometry, with the location of the 6 new stations fed into the central part of the array. Positions relative to the center seismometer are given in Table VI.1.1.

Implementation of the new NORESS geometry was partly motivated by spatial aliasing problems previously encountered in preparing f-k plots, especially in case of high-frequency slow phases (mainly Sn and Lg). The single frequency response pattern for the new NORESS array is given in Fig. VI.1.2, in comparison with the response of the 'old' NORESS array. As is seen in that figure, the new geometry should overcome the problems arising from serious side lobes, as these side lobes are removed from the part of the k-space corresponding to wave numbers $\underline{k}$ ($|\underline{k}|$ = f/c, f = frequency, c = phase velocity) that apply in propagation of regional phases. In fact, processing of regional events that have occurred after the change in the NORESS geometry shows that the aliasing problem has been eliminated.

In addition, the new geometry seems capable of giving more stable estimates of phase velocity. Using the technique of computation of frequency-wavenumber spectra, phases independently identified as Pn now exhibit rather consistent phase velocities of 8 km/s, rather than values fluctuating between 7 and 9-10 km/s.

The NORESS evaluation program now continues with processing of data from various subgroups of the 12 channels in order to find an optimal configuration for the final version of our small-aperture array.

S. Mykkeltveit
F. Ringdal

Channel	NS(m)	EW(m)
01B01	132	-253
01B02	136	-101
01B03	-690	-176
01B04	-407	-660
01B05	1232	-502
01B00	5	119
06C01	271	-62
06C02	0	0
06C03	-180	109
06C04	-348	-219
06C05	-33	-365
06C00	-83	-129

TABLE VI.1.1

Positions for the 12 NORESS sensors relative to the center seismometer (06C02)

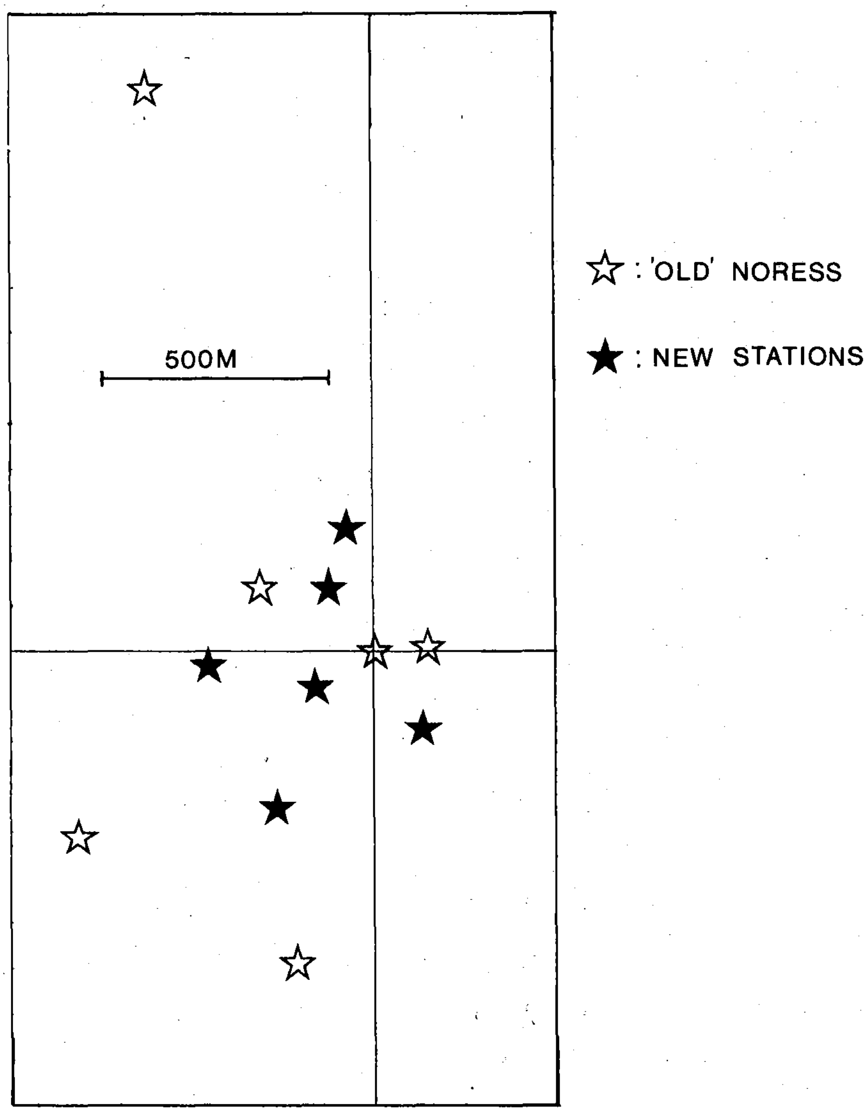


Fig. VI.1.1 Geometry of the new NORESS small-aperture array. All sensors are now equipped with 4.75 Hz low-pass filters.

RESPONSE PATTERNS

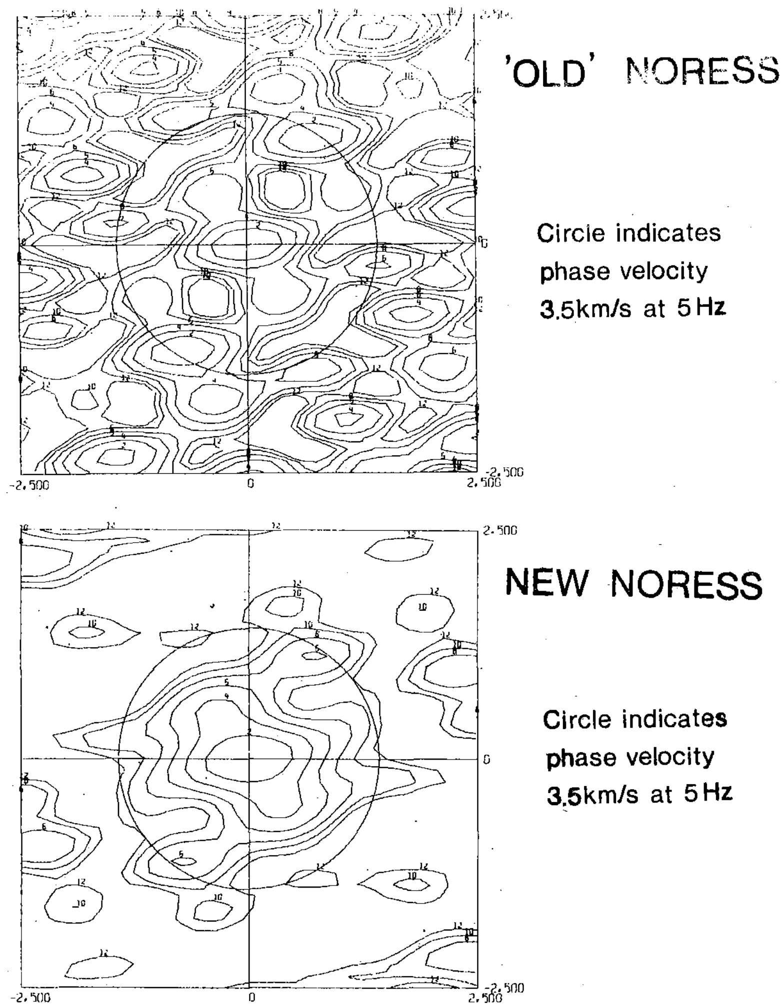


Fig. VI.1.2 Single frequency response patterns for 'old' and 'new' geometries of the NORESS array.

VI.2 A New Refraction Seismic Profile in the North Sea/Southern Norway

The field work of a seismic refraction profiling investigation in the North Sea/southern Norway was carried out in the time period 26 July - 4 August 1980 as a joint undertaking between NORSAR and the Universities of Cambridge and Bergen. Ten shots were fired in Norwegian waters and recorded on land in Norway by a total of 13 field stations. Data for shots arranged by Cambridge and NORSAR are given in Tables VI.2.1 and VI.2.2, respectively.

Recording lines and the location of the NORSAR array as well as shot points are given in Fig. VI.2.1. During shots at N2, N3, N4 and N5, the 13 field stations occupied permanent positions along leg 1 (Fig. VI.2.1). During subsequent shots H1-H6 at the same position, the stations were moved along the profile, covering one leg for each shot. The presence of the Oslo Graben at the far end of the profile motivated recording along two different lines in this area.

As of today, all station locations have been read and shot-to-station distances calculated. Stacking of all data onto digital tapes is under way. Preliminary travel times have been computed on the basis of records from Cambridge stations (prepared by Bruce Cassell) and are shown in Fig. VI.2.2 for both the N and H shot series. Data from shots N2-N5 indicate a dipping Moho in the transition area between the North Sea and southern Norway, while the Pn velocity along the land profile seems to attain 'normal' values of slightly more than 8 km/s. The Pn arrivals within the Oslo Graben tend to be earlier than outside.

Data from the permanent NORSAR array for shot H1 are shown in Fig. VI.2.3, where all traces are arranged according to the distance to the shot point. Two clear P-arrivals are seen in this section, the early one corresponding to Pn, the later one probably being the slower (~6.5 km/s) crustal Pg phase.

S. Mykkeltveit

SHOT	SIZE kg	DATE	TIME BST HRS:MINS:SECS	POSITION LATITUDE	POSITION LONGTITUDE	SHOT DEPTH m	WATER DEPTH m
S1	125	18.7.80	20:02:19.910	56°49'59.219"N	00°54'11.394"E	92	92
F2	1000	19.7.80	17:03:35.905	56°14'33.226"N	02°11'26.792"W	47.5	53
F7	500	21.7.80	16:03:24.364	56°42'28.843"N	00°20'38.848"E	96.5	176
S2	75	26.7.80	13:02:07.043	56°53'52.424"N	01°15'38.683"E	94.6	94.6
S3	75	26.7.80	15:02:08.364	56°57'56.878"N	01°35'46.265"E	100.3	100.3
S4	75	26.7.80	18:02:10.706	57°02'13.893"N	01°56'59.928"E	92.4	92.4
S5	125	26.7.80	20:02:18.188	57°04'39.369"N	02°11'28.942"E	90.0	90.0
N2	500	27.7.80	06:03:12.262	57°21'26.944"N	03°41'43.647"E	58	65.2
N3	500	27.7.80	12:03:11.490	57°29'44.472"N	04°26'12.679"E	73	80.6
N4	500	27.7.80	19:03:12.038	57°38'38.648"N	05°17'40.619"E	83	101.5
N5	750	28.7.80	06:03:16.623	57°35'51.680"N	06°00'40.613"E	102	145

Table VI.2.1. Shots in the North Sea arranged by Cambridge University.

SHOT	SIZE Kg	DATE	TIME GMT Hrs:Mins:Secs	POSITION LATITUDE	POSITION LONGITUDE	SHOT DEPTH (= Water Depth) m
H1	825	31.7.80	06:00:00.37	57°36'24"N	05°58'18"E	140
H2	825	31.7.80	18:00:00.40	57°36'00"N	05°59'30"E	136.5
H3	825	1.8.80	18:00:00.20	57°36'24"N	05°59'06"E	139
H4	825	2.8.80	18:00:00.09	57°36'30"N	06°00'12"E	138
H5	825	3.8.80	18:00:00.06	57°36'12"N	05°59'00"E	142
H6	825	4.8.80	18:00:00.20	57°36'06"N	06°00'06"E	138

Table VI.2.2. Shots in the North Sea arranged by NORSAR.

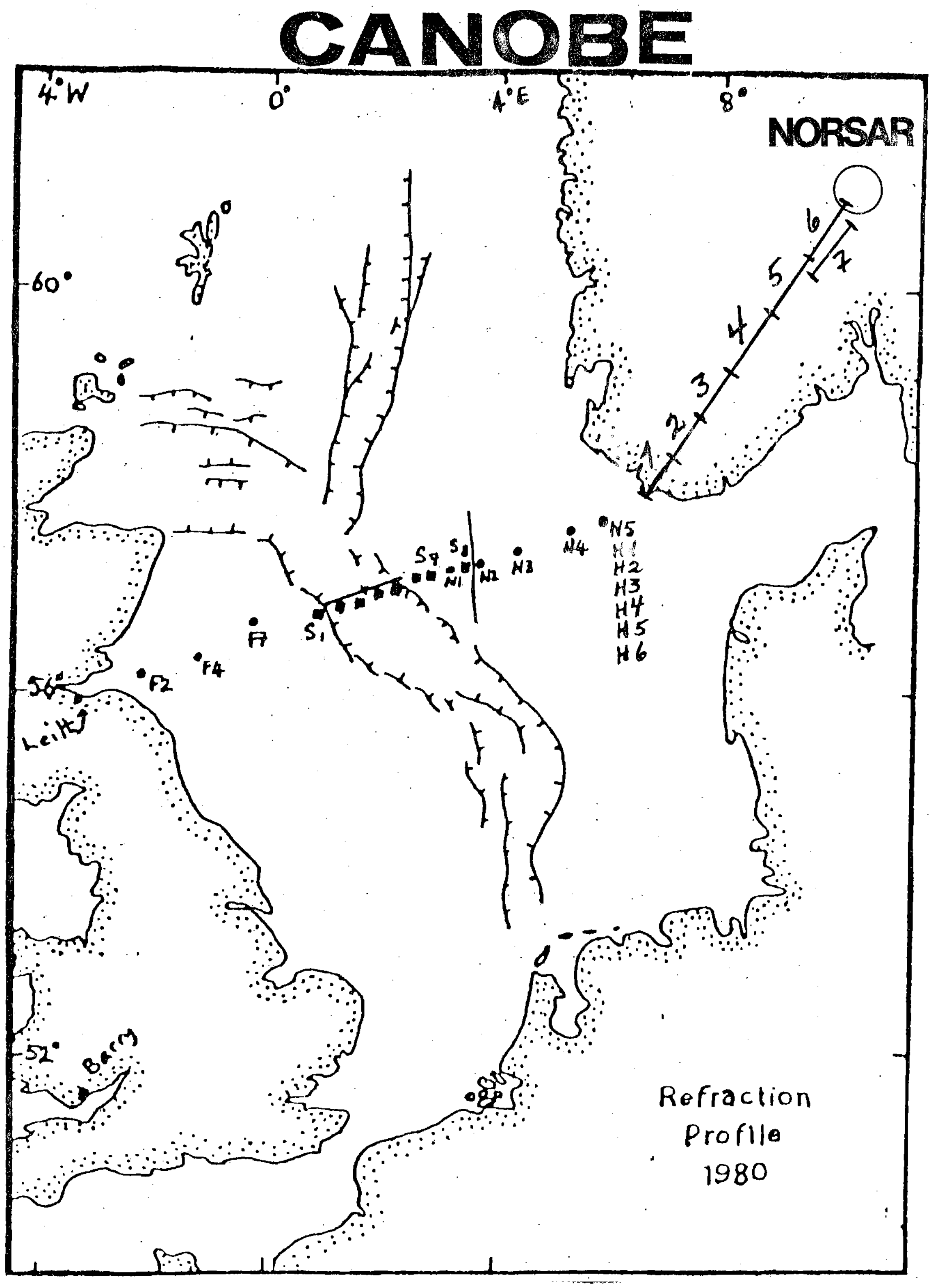
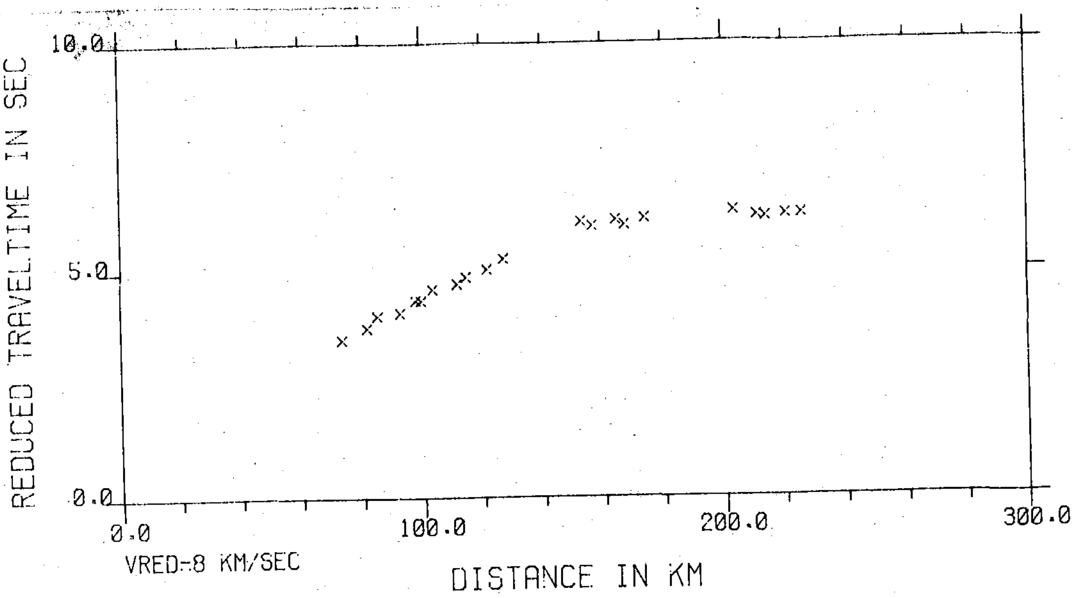


Fig. VI.2.1. Shot points and profile locations for the Cambridge-NORSAR-Bergen (CANOBE) refraction profile 1980. The location of the NORSAR seismic array is also given.



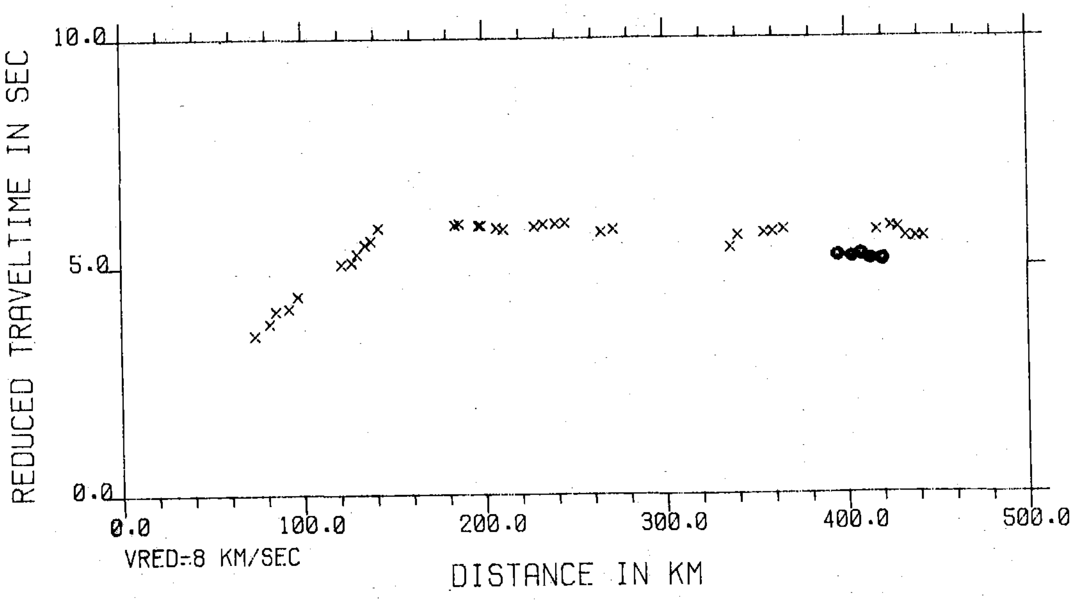


Fig. VI.2.2. Preliminary travel time curves as derived from Cambridge stations participating in the experiment. The upper frame shows travel times for the shot series N2-N5, with the stations permanently situated along leg 1 (Fig. 1). Travel times denoted by x in the lower frame refer to shots N5, H1-H5 and recording along leg 1 leg 6, while leg 7 (Oslo Graben) travel times for shot H6 are given by rings.

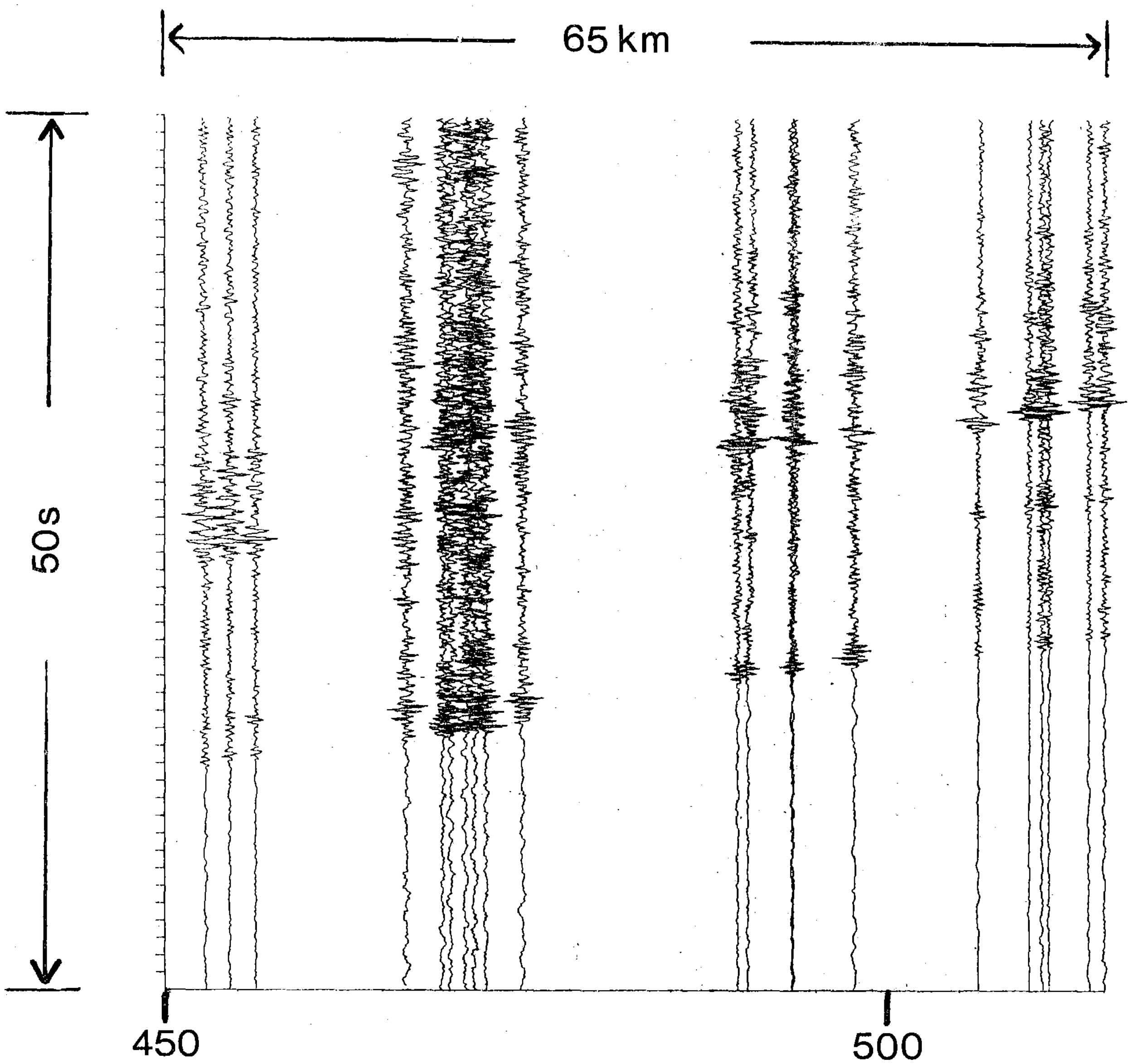


Fig. VI.2.3. NORSAR record section for shot H1, covering the distance interval 455-515 km.

VI.3 The Effect of a Second-Order Velocity Discontinuity on Elastic Waves Near their Turning Point

For various purposes (i.e., in both studies of the velocity structure and of the seismic source), it is important to understand the effects that certain features of a velocity model have on the elastic wave field. Thus, the effects of a velocity discontinuity and of a velocity gradient have been widely discussed; the effect of a change in the velocity gradient appears to be less understood. In an earth model, second-order velocity discontinuities (i.e., discontinuities in the velocity gradient) may arise due to model parameterization, and their high-frequency effect has been demonstrated in applying geometrical ray theory. It is desirable to smooth this effect since it is an artefact of the model, and this is conveniently done in a WKBJ approximation (Chapman, 1978). However, for some regions of the earth, notably the upper mantle and the base of the mantle, it has sometimes been proposed that rather abrupt changes in velocity gradient occur in a relatively short depth interval. In these cases, the model of one or more second-order discontinuities would still be a simplification but, in analogy to approximating rapid velocity changes by one or more first-order discontinuities, it would be a sensible approximation at relatively long wavelengths. It is the long-wavelength effect that has been studied here. The effect is associated with a change in the curvature of a wavefront across a second-order discontinuity. This change is ignored in the classical WKBJ approximation, but it is described by the extended WKBJ method (the Langer approximation). Following Richards (1976), it is now widely appreciated that the extension of the WKBJ method is most important for long waves near their turning point, consequently the second-order discontinuity is expected to be most effective in the same circumstances. To demonstrate this, generalized wave functions will be used to compute reflection/transmission coefficients. At a second-order discontinuity, the continuity condition for the stress-displacement field reduces to a continuity condition for the wavefield and its vertical derivative. This requires, at least in principle, coupling of up- and down-going waves, but no coupling between P and SV. The reflection/transmission coefficients for P, SV and SH are therefore given by similar expressions

(Upward reflection) $$\frac{A_u^+}{A_d^+} = \frac{U_d^+}{U_u^+} \frac{C_d^+ - C_d^-}{C_u^+ + D_d^-}$$

(Downward transmission) $$\frac{A_d^-}{A_d^+} = \frac{U_d^+}{U_d^-} \left(1 - \frac{C_d^- - C_d^+}{C_u^+ + D_d^-}\right)$$

where superscript + and - denote the top and bottom side of the discontinuity, $U_{u/d}$ are up/downgoing wave functions, $A_{u/d}$ the up/downgoing wave coefficients, and $C_{u/d}$ the so-called generalized cosines which are related to vertical derivatives of the waves functions (Richards, 1976). Similar expressions for downward reflection and upward transmission follow from symmetry considerations; for real angle of incidence, downward reflection equals upward reflection in absolute value. In the WKBJ approximation of the wave functions: $C_u^+ = C_d^+ = C_u^- = C_d^- = \cos i$, where i is the angle of incidence, so in this approximation the second-order discontinuity has no effect. However, near a turning point the WKBJ solution is invalid and it has now become almost common practice (Richards, 1976) to extend the approximation by Langer's solution which, among other things, takes into account the difference in curvature of the wavefront on opposite sides of the interface. Fig. VI.3.1 gives an illustration of the effect, in terms of reflection coefficients; obviously, these reflection coefficients can be perhaps surprisingly large for long-period waves near their turning point.

Of course, the model of a single reflector is often an oversimplificatied concept; multiple reflection must be taken into account especially for waves near their turning point. Calculations in a layered model (e.g., reflectivity type of methods) would then account for the effects although these would not be explicitly identified. In fact, one of the motivations for the present study was to explain certain differences between results with the 'classical' reflectivity method (Fuchs and Müller, 1971) and a version of the so-called full wave method which ignores layering. Indeed, introducing layering in the last method, with interfaces coinciding with the second-order discontinuities, satisfactorily removes the discrepancy (Doornbos, 1980). It demonstrates the usefulness of uniformly asymptotic solutions in a piecewise smooth layered model.

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Richards, P.G., 1976: On the adequacy of plane-wave reflection/transmission coefficients in the analysis of seismic body waves, Bull. Seism. Soc. Am., 66, 701-717.

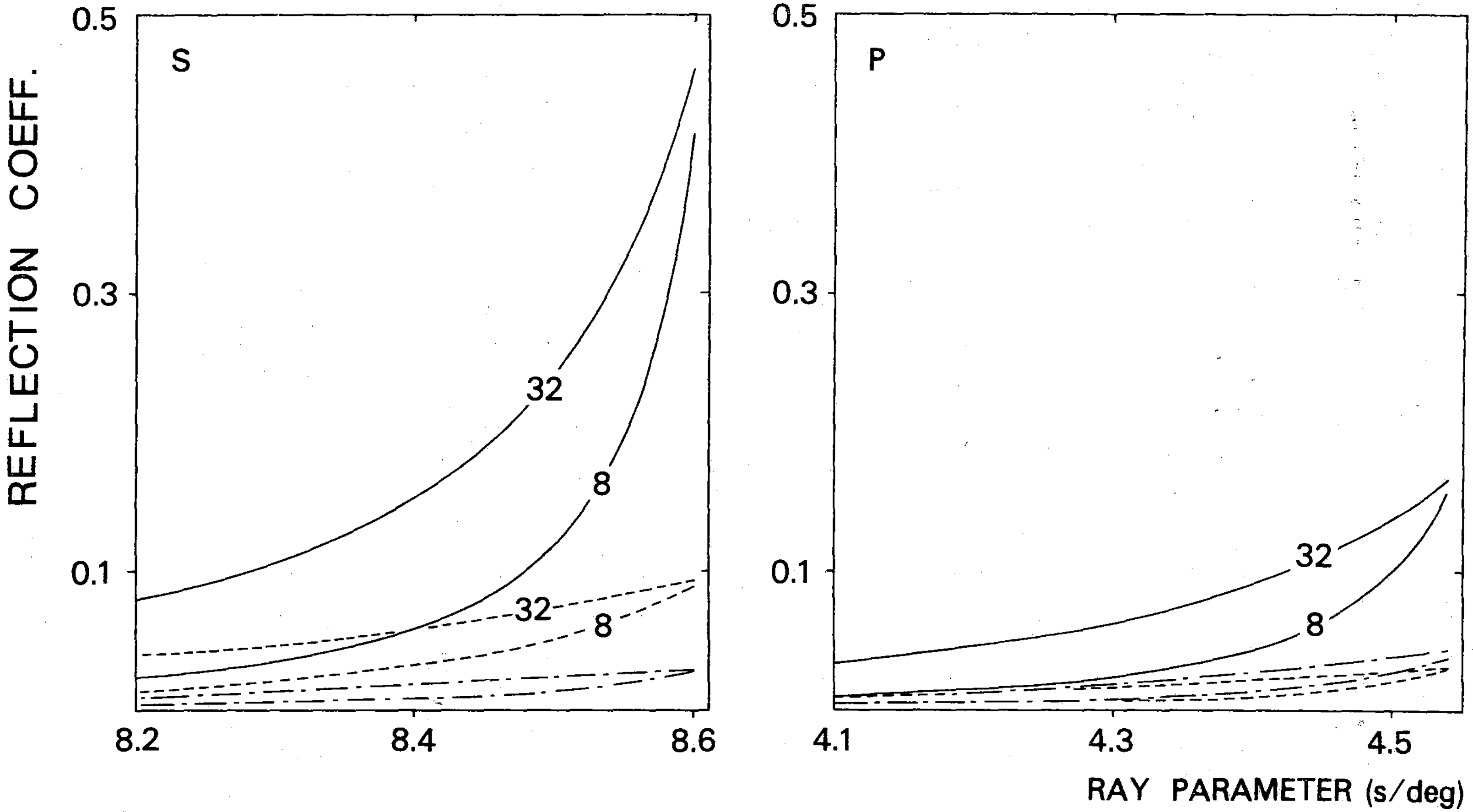

Fig. VI.3.1 Reflection coefficients as a function of ray parameter for P and S waves at a period of 32 and δ s. The interface is a second-order velocity discontinuity at radius 3560.7 km, u_p = 13.661 km·s^{-1}, u_s = 7.218 km·s^{-1}.

______ = du_p^+/dr = -0.001, du_p^-/dr = 0.001g, du_s^+/dr = -0.0004, du_s^-/dr = 0.001 g

-------- = du_p^+/dr = -0.001, du_p^-/dr = -0.001g, du_s^+/dr = -0.0004, du_s^-/dr = -0.001 g

_ - _ - = du_p^+/dr = -0.001, du_p^-/dr = 0 , du_s^+/dr = -0.0004, du_s^-/dr = 0

+ and - refer to the top and bottom side of the interface.