NORSAR

ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Scientific Report No. 1-79/80

SEMIANNUAL
TECHNICAL SUMMARY
1 April—30 September 1979

By
H. Gjøystdal (ed.)

Kjeller, 15 November 1979

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER F08606-79-C-0001	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SEMIANNUAL TECHNICAL SUMMARY 1 April - 30 September 1979		5. TYPE OF REPORT & PERIOD COVERED 1 Apr - 30 Sep 1979
		6. PERFORMING ORG. REPORT NUMBER Scientific Rep. No. 1-79/80
7. AUTHOR(s) H. Gjøystdal (ed.)		8. CONTRACT OR GRANT NUMBER(s) F 08606-79-C-0001
9. PERFORMING ORGANIZATION NAME AND ADDRESS NTNF/NORSAR P.O. Box 51 N-2007 Kjeller, Norway		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NORSAR Phase 3
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 15 November 1979
		13. NUMBER OF PAGES 52
14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office) VELA Seismological Center 312 Montgomery Street Alexandria, VA 22314 USA		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the operation and research activities at the Norwegian Seismic Array (NORSAR) for the period from 1 April to 30 September 1979.

The performance of the NORSAR online DP system has improved relative to the previous reporting period; the uptime has been 95.5%, which is an increase by 1.4%. The number of SPS stops has decreased drastically

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There has been an ever increasing load on the off-line computer, forcing research personnel to run their own jobs during nights and weekends. In spite of these extra efforts, a number of jobs are getting further and further behind.

There have been some problems with the array communications. In the period May-July some of the subarrays were affected by serious cable errors, and consequently, a number of data channels were masked in this period. As to the ARPA network, the operations have been satisfactory apart from minor irregularities with the SDAC cmmunication circuit.

A seismic amplifier with high and low gain outputs has been constructed for the new Southern Norway Seismic Network. A close clustered experimental subarray was put into operation at the end of September, especially designed for analysis of high frequency noise coherence. The work with the SPS substitution, that is, the installation and programming of the MODCOMP computer, is in progress. By the end of this reporting period, transmitting ICW's and receiving ODW's from the SLEM's had been achieved. IBM interfacing will be started as soon as NORSAR has the relevant equipment available.

During the present period a considerable amount of work has been conducted on the design of a future NORSAR processing center, including both a new off-line research computer and an upgrade of the on-line DP system. A brief summary of the suggestions and conclusions obtained is given in this report.

The research activities are summarized in five separate subsections of the last chapter of this report. The first subsection discusses P and Lg wave attenuation within 15 degrees using NORSAR short period records, and the second one is an analysis of global P-wave attenuation characteristics based on ISC data. Then follows a work on classification of regional events, all within the distance range 10 to 40 degrees. The fourth subsection describes an experimental small subarray within the NORSAR array and the last one deals with the NORSAR short period recording of explosions during the 'Fennoscandia Long Range Profile 1979' seismic experiment.

AFTAC Project Authorization No.	:	VELA VT/9702/B/PMP
ARPA Order No.	:	2551
Program Code No.	:	9F10
Name of Contractor	:	Royal Norwegian Council for Scientific and Industrial Research
Effective Date of Contract	:	1 October 1978
Contract Expiration Date	:	30 September 1980
Contract No.	:	F08606-79-C-0001
Project Manager	:	Frode Ringdal (02) 71 69 15
Title of Work	:	The Norwegian Seismic Array (NORSAR) Phase 3
Amount of Contract	:	$1,233,000.-
Contract Period Covered by the Report	:	1 April - 30 September 1979

This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by AFTAC, Patrick AFB FL 32925, under contract no. F08606-79-C-0001.

NORSAR Contribution No. 269

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I. SUMMARY

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H. Gjøystdal

II. OPERATION OF ALL SYSTEMS

II.1 Detection Processor (DP) Operation

There have been 84 breaks in the otherwise continuous operation of the NORSAR Online DP system within the current 6-month reporting interval. Even though this is just half the number of stops compared to the previous period (Oct 78 - Mar 79), the uptime percentage has just increased with 1.4% to 95.5%. This is due to five stops that occurred during nights and weekends without setting off the alarm. These five stops stand for 1.5% of the downtime. 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 1979. The monthly recording times and percentages are given in Table II.1.2.

The breaks can be grouped as follows:

a)	SPS malfunction	:	45
b)	Error on the Multiplexor Channel	:	2
c)	Stops related to possible program errors	:	10
d)	Maintenance stops	:	4
e)	Power jumps and breaks	:	3
f)	Hardware problems	:	3
g)	Magnetic tape and disk drive problems	:	14
h)	Stops related to system operation	:	1
i)	TOD error stops	:	2

This shows that the SPS is still the main reason for the downtime even though there has been a decrease from 115 to 45 in the number of stops compared to the previous interval (Oct 78 - Mar 79).

The total downtime for this period was 195 hours and 53 minutes. The mean-time-between-failures (MTBF) was 2.5 days, as compared with 1.0 days for the previous reporting period.

J. Torstveit

Month	DP Uptime (hrs)	DP Uptime (%)	No. of DP Breaks	No. of Days with Breaks	DP MTBF* (days)
Apr	686.12	95.3	22	12	1.2
May	711.96	95.7	11	9	2.5
Jun	680.31	94.5	9	8	2.8
Jul	729.57	98.1	15	11	1.9
Aug	732.25	98.4	5	5	5.1
Sep	656.47	91.2	22	13	1.2
Total Period	4196.68	95.5	84	58	2.5

* Mean-time-between-failures = (Total uptime/No. of Up Intervals)

Table II.1.2

Online System Performance

April 1979 - September 1979

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS..........
91	23	7	23	53	SPS ERROR
93	9	29	10	25	MPX/LATE
93	19	7	20	3	SPS ERROR
94	6	49	6	58	SPS ERROR
94	16	21	18	49	SPS ERROR
94	19	8	23	7	SPS ERROR
96	10	26	10	40	SPS ERROR
96	19	1	21	8	SPS ERROR
96	21	42	22	37	SPS ERROR
97	1	30	11	28	SPS ERROR
98	10	21	11	23	SPS ERROR
98	14	8	14	48	SPS ERROR
98	16	29	17	17	SPS ERROR
98	22	16	23	1	SPS ERROR
99	5	8	6	16	SPS ERROR
99	10	2	10	21	SPS ERROR
99	16	54	19	18	SPS ERROR
105	7	53	9	16	SPS ERROR
108	9	47	10	28	SPS ERROR
109	17	40	19	40	POWER BREAK
114	20	54	21	1	PROGRAM ERROR
116	12	18	12	25	SPS ERROR
124	0	21	1	21	SPS ERROR
124	1	32	7	35	SPS ERROR
124	7	52	8	18	SPS ERROR
125	7	41	9	55	SPS ERROR
125	18	7	18	13	PROGRAM ERROR
126	12	52	13	54	SPS ERROR
142	4	31	7	50	POWER BREAK
143	21	37	23	32	TESTOUT OF MODCOMP
144	6	57	11	20	TESTOUT OF MODCOMP
145	12	17	13	51	WORK ON DC POWER
148	0	49	7	27	MT STATION FAILURE
149	8	39	12	2	TOD FAILURE
152	21	29	24	0	DISK DRIVE FAILURE
153	0	0	12	40	DISK DRIVE FAILURE
154	7	39	8	23	DISK DRIVE FAILURE
154	16	33	17	14	CPU FAILURE
154	17	34	18	32	CPU FAILURE
165	8	13	8	20	PROGRAM ERROR
166	22	45	24	0	OPERATOR ERROR
167	0	0	16	19	OPERATOR ERROR
179	2	40	6	46	MT STATION FAILURE
179	22	12	22	21	EOC FAILURE
180	13	47	13	58	PROGRAM ERROR
182	11	40	12	6	PROGRAM ERROR
182	16	12	20	43	DISK DRIVE FAILURE

Table II.1.1

(Sheet 1 of 2)

LIST OF BREAKS IN DP PROCESSING THE LAST HALF-YEAR

DAY	START		STOP		COMMENTS...........
183	8	43	10	21	DISK DRIVE FAILURE
186	7	35	7	48	PROGRAM ERROR
187	7	39	8	50	MT STATION FAILURE
190	9	58	10	15	SPS ERROR
191	11	19	11	41	POWER BREAK
191	12	21	12	32	POWER BREAK
196	11	17	11	29	CE WORK
204	10	10	10	29	MT STATION FAILURE
205	13	3	13	16	PROGRAM ERROR
206	12	29	12	54	MT STATION FAILURE
206	13	19	15	4	SPS ERROR
206	22	41	23	1	MT STATION FAILURE
211	20	58	23	21	MT STATION FAILURE
215	13	40	14	9	PROGRAM ERROR
218	11	58	12	6	MT STATION FAILURE
221	6	23	7	1	SPS ERROR
221	9	23	12	23	SPS ERROR
229	23	37	24	0	SPS ERROR
230	0	0	7	8	SPS ERROR
248	17	54	24	0	MT CONTROLLER FAILURE
249	0	0	6	27	MT CONTROLLER FAILURE
253	6	38	6	54	MPX/LATE
256	8	31	8	41	PROGRAM ERROR
257	13	26	13	29	MT CONTROLLER FAILURE
261	12	15	12	20	PROGRAM ERROR
265	1	14	8	52	SPS ERROR
265	10	11	10	20	SPS ERROR
265	16	56	17	2	SPS ERROR
265	18	27	19	16	SPS ERROR
265	20	58	24	0	SPS ERROR
266	0	0	8	50	SPS ERROR
267	5	2	7	30	SPS ERROR
267	7	49	8	50	SPS ERROR
267	11	3	11	7	SPS ERROR
267	14	51	16	20	TOD FAILURE
267	17	0	18	24	SPS ERROR
268	6	14	11	45	SPS ERROR
268	16	34	17	9	SPS ERROR
269	3	0	14	58	SPS ERROR
270	2	9	2	51	SPS ERROR
270	9	8	9	42	SPS ERROR
270	10	2	11	24	SPS ERROR
271	9	0	11	43	SPS ERROR

Table II.1.1

(Sheet 2 of 2)

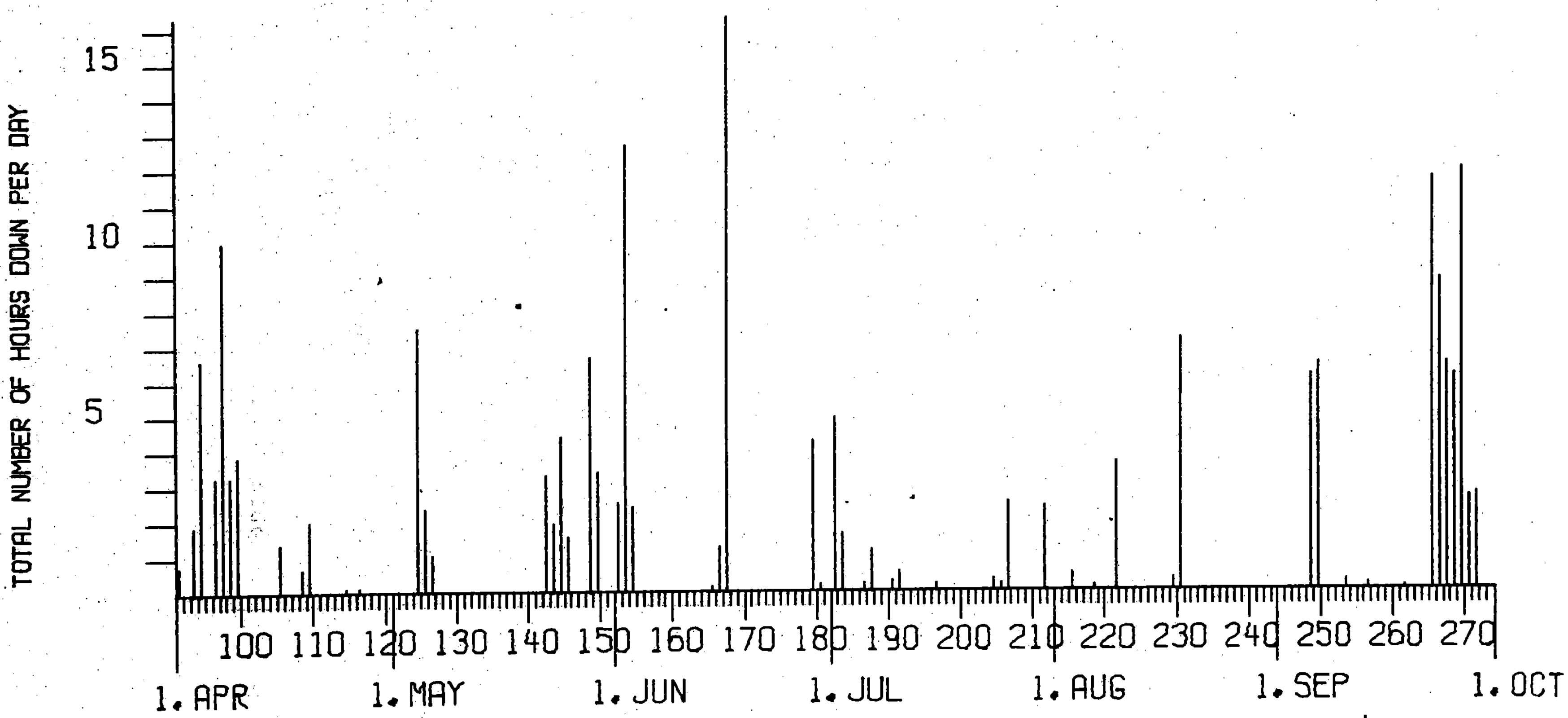

Fig. II.1.1 Detection Processor Down Time Apr-Sep 1979.

II.2 Event Processor Operation

The operation of the Event Processor has continued as before, including the production of a monthly seismic bulletin which now is distributed to 66 recipients around the world. ARPANET is used for sending the bulletins to NEIS/USGS and to AFTAC/VSC. Hardware problems have caused some delay in the editing of the bulletins for August and September 1979, so that bulletins for three months (Aug-Oct) were issued simultaneously in the beginning of November.

Some statistics for the present reporting period are given in Table II.2.1. An average of 10 events per day seems to be typical 'summer performance' since the array was reduced in size.

H. Bungum
B. Hokland
T. Hoff

	Teleseismic	Core Phases	Sum	Daily
April 1979	307	69	376	12.5
May 1979	250	54	304	9.8
June 1979	227	52	279	9.3
July 1979	240	80	320	10.3
August 1979	244	77	321	10.4
September 1979	187	36	223	7.4
	1455	368	1823	10.0

Table II.2.1

II.3 NORSAR Data Processing Center (NDPC) Operation

Data Center

The heavy load of work on the B-computer continued throughout this period. Most users have now learned to run the computer so they can run their own jobs outside office hours. Also a couple of students have been hired to run jobs during nights and weekends. However, there are jobs that are getting more and more behind.

J. Torstveit

Array Communications

In May, June and July the subarrays 02B, 02C, 04C and 06C were affected due to serious cable problems. The problems started already in April (7-10) when 02C com. cable caused problems. 18 May 02B was masked and remained so until 12 June. Due to spikes in the 06C data this subarray was taken out of operation 29 May (masked). NTA discovered serious problems on the cable toward the Central Terminal Vault (CTV). 5 July the subarray was back in operation.

16 June 04C was taken out of the system and remained so until 3 July. The subarray was also masked for periods between 3 and 10 July. As for 06C lightning was the cause of the difficulties, and the same was true for 04C. A number of pupin coils were damaged in the buried cables. The repair work was time-consuming, as the coils had to be exactly located, thereafter exposed and replaced.

17 June NTA found the cable toward the 02C CTV uncovered in a sand pit, damaged by an open fire. After repair the subarray resumed operation 3 July. Although reported mended, errors appeared in the input words (ICW's) toward the CTV, up to and sometimes more than 200 (per 16 2/3 min.) were observed. In spite of the errors, the data seems to be unaffected, according to the Chief Data Analyst.

Week/ Year	Subarray/Per Cent Outage (approx.)						
	01A	01B	02B	02C	03C	04C	06C
15/79				20.5			
17/79					3.5		
20/79			36.0				
21/79			100.0				
22/79			100.0				62.0
23/79			100.0				100.0
24/79			19.5	29.0		29.0	18.0
25/79				100.0		100.0	92.0
26/79				100.0		100.0	100.0
27/79				36.0		33.0	30.0
28/79				6.0		1.0	3.0
29/79							
30/79			10.0				
31/79			13.5				
32/79							
33/79				1.0			
34/79				2.5			
35/79							
36/79				21.0			
37/79			2.0	0.4			
38/79				14.5			
39/79		7.5		9.0	4.0		2.5

Table II.3.1

Individual subarray outages (incl. error rates exceeding 200). Figures in per cent of total time.

Outages where all subarray circuits have been involved simultaneously are as follows:

April	3 outages
May	4 outages
June	3 outages
July	0 outages
August	4 outages
September	4 outages.

Table II.3.2 shows outages/degraded performance related to communications circuits.

II.4 The ARPA Subnetwork

The London Communication Circuit

Apart from one 'Carrier Loss' in May, most reliable.

The SDAC Communication Circuit

Apart from one 'Carrier Loss' in June, and minor short irregularities, mostly 'Marginal Circuit' indications, this circuit has also been reliable during the period.

The Terminal Interface Message Processor (TIP)

Preventive Maintenance (PM) was carried out according to schedule. Apart from a few restarts, the machine has also during this period been runnigg continuously.

12, 29 June and 6 July the TIP was restarted. 30 August Mr. C. Kelley of Bolt, Beranek and Newman visited Tanum and NORSAR. Here at NORSAR he tested different TIP interfaces. In this connection the machine was down approximately 1 h 15 min.

TIP Connections

Sentralinstituttet (Central Institute for Industrial Research, contact man Renskaug) will most likely within the foreseeable future be connected to one of the TIP ports, provided that permission is given.

O.A. Hansen

SA	APRIL (4) (2-29)		MAY (5) (30.4-3.6)		JUNE (4) (4.6-1.7)		JULY (4) (2-29)		AUG (5) (30.7-2.9)		SEP (4) (3-30)		AVERAGE ½ YEAR	
	>20	>200	>20	>200	>20	>200	>20	>200	>20	>200	>20	>200	>20	>200
01A	-	0.1	0.2	0.2	-	0.3	-	-	0.2	-	0.2	0.2	0.1	0.1
01B	-	0.1	0.2	0.3	-	0.4	0.1	-	0.2	0.2	0.2	2.0	0.1	0.5
02B	0.2	0.1	0.1	47.2	-	29.9	-	2.5	0.2	2.7	0.2	0.6	0.1	13.8
02C	2.4	5.2	0.1	0.3	-	57.2	7.8	10.7	7.4	0.8	10.3	11.3	4.7	14.3
03C	-	0.8	0.2	0.7	0.2	-	-	0.1	0.1	0.2	0.1	1.2	0.1	0.5
04C	0.1	0.3	0.2	0.2	0.1	57.1	0.4	8.6	0.1	0.1	0.4	0.2	0.2	11.1
06C	0.1	0.1	0.8	12.4	4.8	77.6	0.8	8.2	0.1	0.2	0.2	0.7	1.1	16.5
AVER	0.4	1.0	0.3	8.8	0.8	31.8	1.3	4.3	1.2	0.6	1.6	2.3	0.9	8.1
LESS	02C 0.1	02C 0.3		02C/06C 1.3	06C 0.1	02B/02C 04C/06C 0.1	02C 0.2	02B/02C 04C/06C 0.1	02C 0.1	02B 0.2	02C 0.1	02C 0.9	02C 0.2	02B/02C 04C/06C 0.1

Table II.3.2

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

III. IMPROVEMENTS AND MODIFICATIONS

III.1 The On-line System

There have been no major changes in the On-line System during this reporting period.

III.2 Event Processor

A new Fortran program has been developed on the CDC Cyber computer to produce the NORSAR telex messages and ARPA messages on paper tape.

Jan Fyen

III.3 Array Instrumentation and Facilities

Array surplus material, 87 HS-10 short period seismometers, 44 Geotech long period seismometers, 68 RA-5 and 12 Ithaco seismometer amplifiers and 10 SLEM's were sent to the Defense Property Disposal Office in Germany and to Columbia University, New York, as of 3 May 1979.

A seismic amplifier with high and low gain outputs intended for the Southern Norway Seismic Network has been constructed. All the sites have been surveyed and all equipment has been acquired except for the central computer.

The NORSAR Analog SP station recording device, the Helicorder, was replaced with a Sprengnether MEQ-800-B recorder as of 15 August 1979. The frequency response is shown in Fig. III.3.1 with the corresponding number in Table III.3.1. Analog filter is NORSAR standard (upper 3 dB point at 4.75 Hz).

The cable drum storage at Løten was closed down in August, and all the cable drums have been transported to the NORSAR Maintenance Center.

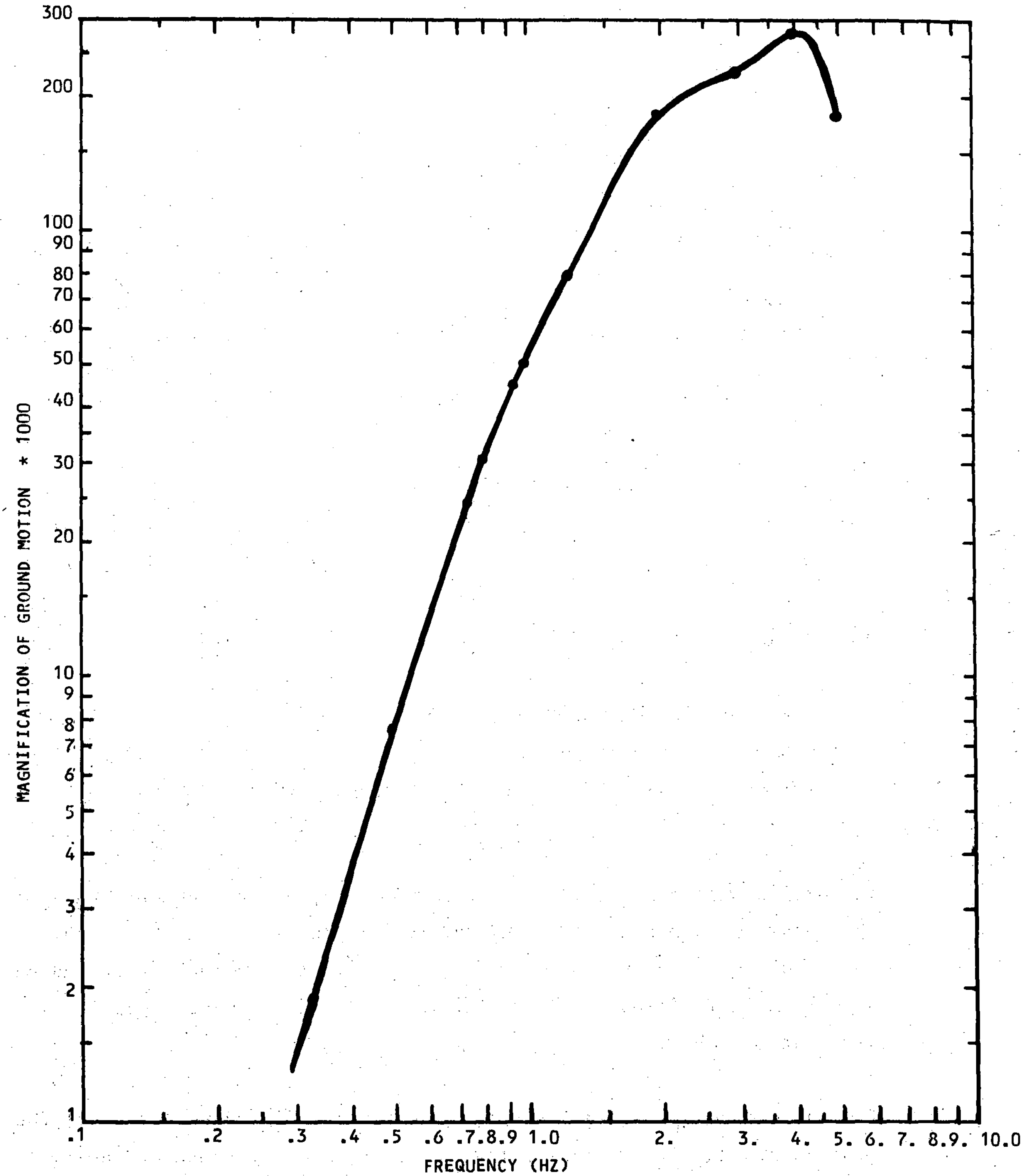

Fig. III.3.1 Frequency response of the NORSAR Analog SP station as of 15 August 1979.

Frequency (Hz)	Recorder Deflection (mm)	Magnification
0.2	3.0	300
0.33	6.9	1877
0.5	12.2	7618
0.625	15.3	14928
0.80	19.0	30372
0.95	20.0	45083
1.0	20.2	50453
1.25	20.4	79613
1.6	18.2	116372
2.0	15.3	185282
3.0	10.0	224791
4.0	7.0	279739
5.0	2.9	181082

Table III.3.1

Magnification of NORSAR Analog SP Station

as of 15 August 1979 after the following equation:

$$M = a/y, \quad y = \frac{G \cdot I \cdot 10^3}{4\pi^2 \cdot f^2 \cdot m}$$

where

a - pen peak-to-peak deflection in mm on the seismogram

y - equivalent ground motion in microns

G - Cal. coil motor constant 0.0325 N/A

I - Calibration current in amps (400 μA)

f - Calibration frequency in Hz

m - seismometer mass, .825 Kgs.

An experiment for monitoring seismic noise coherence for high frequencies in a close clustered subarray in the 06C area has been initiated and was nearly ready for operation at the end of September.

A.Kr. Nilsen

III.4 SPS Substitution

The main contributor to the lowering of the Detection Processor uptime is the malfunctioning of the SPS. It had earlier been decided to resolve this problem by replacing the SPS by a programmable minicomputer with high reliability. However, the interfacing of today's technology with IBM System 360 is by no means easy. The minicomputer which most closely can emulate the SPS functions is the MODCOMP II communication processor. Modcomp has the necessary equipment to communicate both with the SLEM's and the System 360 hardware. A contract for the purchase of relevant equipment was signed in June 1978. Since then, the local dealer of Modcomp has had a number of problems, but the equipment was delivered at last in October/November 1978. During the installation we were faced with the problem that Modcomp has all the hardware needed, but the software operating system did not support both the line communication and the IBM interface simultaneously. In other words, the ordered system could not fulfill its task without extensive software developments.

Concurrently, Modcomp came up with suggestions on how to circumvent the problems and NORSAR analyzed other minicomputer systems (including IBM). It turns out that Modcomp is still the most appropriate computer to replace the SPS in view of its flexible handling of the SLEM communication task. The Modcomp MAX III operating system, which supports the SLEM communication, can in addition interface System 360 by wideband synchronous communication through an IBM 2701 Synchronous Data Adapter Type II. This would solve the interface problems but would of course require the acquisition of such a unit.

After these initial considerations, programming of the computer was started and by the end of this reporting period transmitting ICW's and receiving ODW's from the SLEM's had been achieved. The problems of synchronization have been overcome, and the TOD task is fulfilled. IBM-interfacing will be started when NORSAR has the relevant equipment available.

Preparations for direct satellite communications to the SDAC hve been initiated, and the programs currently being developed on the Modcomp are designed to handle this application as well.

In detail the status of the SPS substitution is as follows:

A. Time-of-Day task is finished

B. SLEM-task is tested for one subarray. The simultaneous transmission and receiving of data for 7 subarrays and definition of data buffers are in progress.

C. Filtering and subarray beamforming will be implemented by NORSAR personnel. This task is in progress.

D. Interfacing with IBM 360/40 will be tested when 2701 SDA II is available. (Presently a 2701 Parallel Data Adapter is used for SPS interfacing, but this type of interface cannot be used by MODCOMP.)

Jan Fyen

III.5 Future NORSAR Data Processing Center

The IBM System 360 equipment at NORSAR represents the computer technology of 15-20 years ago, and we are now starting to feel some problems in getting qualified service personnel and parts whenever external expertise is required. In practice we have been reasonably successful in keeping the Detection Processor running (except for SPS stops), since there are enough backup units for tape drives and disks. However, there is little flexibility in the system and wanted changes like interfacing new communication systems, testing new detectors and increasing on-line disk capacity are extremely difficult to achieve.

For the research group the change in 1977 to operator service during working hours only has efficiently removed almost all computer capacity available. Most of the available time on the off-line computer is used for routine event processing, reruns for EPX transmissions to the SDAC, data copying and retention and array monitoring functions. However, research results are still obtained due to the staff members' willingness to work during nighttime and weekends, operating the computers on their own.

New Computer System for Research at NORSAR

NORSAR has recently applied to NTNF for $400,000 to purchase an IBM 4331 processing system. We have reason to expect that the necessary funds will be made available to NORSAR, and we will then have a modern mainframe computer available for the research staff. Among the features of the planned configuration we mention 1 megabyte memory, 2000 megabyte disk storage (expandable to 9000 megabytes) and several interactive terminals which should increase research productivity significantly.

We expect to have the new computer installed during the first half of 1980. It will then for most purposes replace our IBM S/360 Mod 40 Event Processor. With the on-going substitution of the Modcomp Communications Processor for the SPS interface, it seems an opportune time to also consider the future status of the NORSAR IBM S/360 Mod 40 Detection Processor.

Suggested Detection Processor Upgrade

We consider that a reasonable approach would be to upgrade the Modcomp computer in such a way that this processor can accommodate all the current functions of the NOSAR DP, plus a number of functions, specified below, that could be implemented on an experimental basis as found required.

The upgrade could most easily be performed by expanding the current Modcomp II processor, e.g., to a Modcomp Classic 7860 computer, in order to take advantage of current software developments. The DP upgrade could then as an example consist of:

- CPU 512 K bytes, approximately 1 mill. instr. pr. second.
- On-line disk storage of 500 megabytes
- Two tape drives 6250 bpi
- A graphic display station (to replace the EOC)
- Interface equipment + console typewriter.

The cost of such an upgrade has been estimated at $250,000. The software development would be conducted by NORSAR personnel. The time frame for complete software development should be on the order of 2 years. The current NORSAR system would run without significant extra downtime during the software development period. The new communication protocol to SDAC could be implemented without being affected significantly by these developments.

Benefits of Suggested Upgrade

- Computer maintenance costs for the DP system, currently about $40,000 a year, would be reduced to about $15,000. Utility bills (electricity) would also be reduced.
- Reliability of the DP system would be greatly enhanced.
- Sufficient on-line disk storage would exist to retain an on-line buffer at any point in time covering
  (i) The last recorded 24 hours of raw data (~ 250 megabytes)
  (ii) The last 6 months of EPX files (about 5000 EPX executions) (~ 40 megabytes)
  (iii) The last 1 year of detection files (~ 2 megabytes)
  (iv) Complete raw data for the last 500 EPX executions (approximately 14 days) (~ 140 megabytes).

  Any of these data could be requested by SDAC on-line without any operator intervention required at NORSAR.
- With the above dimensioning, only about half of the memory and 30 per cent of the CPU time would be required for the current on-line functions. The spare capacity could be used in either of the following ways:
  (i) Deploying additional beams, possibly with new filters, steered to areas of special interest
  (ii) Implementing experimental on-line three-component detection processing
  (iii) Testing other new detection algorithms in an on-line environment
  (iv) Expanding and refining the on-line Event Processor (OEP) algorithms.
- Employing a recording density of 6250 bpi would make possible 16 hours of raw data per magnetic tape. Thus, only about 500 magnetic tapes per year would be generated, and permanent retention of <u>all</u> recorded data would then be feasible.
- The new DP system would be interfaced to the off-line computer by a communication link. Tape copying (and conversion from 6250 to 1600 bpi) would be performed off-line.

<u>Time Frame</u>

We consider that the initial steps toward a DP upgrade should be taken as soon as possible, and we will continue to study this problem in detail.

F. Ringdal
J. Fyen

IV. FIELD MAINTENANCE ACTIVITY

The maintenance activity at the subarrays by the field technicians has been fairly low in the period, indicating stable operation, and there have been no major corrective or preventive projects during this summer. The array instrumentation characteristics are close to normal, a few examples are given in Figs. IV.1 to IV.3. Due to limited computer time, the array monitoring off-line analysis has at times been somewhat less than scheduled.

Maintenance Visits

Table IV.1 shows the number of visits to the subarrays in the period, with an average of 3.6 visits per subarray. This is a low number compared with the same period last year (9.3 times). The visits include five visits for communications maintenance.

Subarrays	01A	01B	02B	02C	03C	04C	06C	Total
No. of Visits	4	5	3	4	0	3	6	25

Table IV.1

Number of visits to the NORSAR subarrays
in the period 1 April to 30 September 1979

Preventive Maintenance Projects

The preventive maintenance work in the array is described in Table IV.2. The adjustments are corrections of characteristics within the tolerance limits.

Unit	Action		No. of Actions
Seismometer	MP adjust (in field)		10
Line Terminator Amplifier	Adjustment of DC offset	SP	43
		LP	1
	Adjustment of channel gain	SP	13
		LP	8
SLEM	BB adjust		1
Emergency Power	Battery and charger check		7

Table IV.2

Preventive maintenance work in the period
1 April to 30 September 1979

Disclosed Malfunctions on Instrumentation and Electronics

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

Unit	Characteristics	SP Repl.	SP Adj.	LP Repl.	LP Adj.
Seismometer	MP (in field)				9
	FP (-"-)				
	MP/FP (At NDPC)				58
	RCD			1	
Seism. Ampl. RA-5/Ithaco	Distortion	2	1		
	Cal. amp circuit	1			
Line Termination Amplifier	Channel gain		8		2
	DCO		2		
	CMR		3		2
	TC	1			
SLEM	Test generator	2	1		
	RSA/ADC		3		
	BE protection card	4			
External Power Unit	Voltages		1		

Table IV.3

Total number of required adjustments and replacements in the NORSAR data channels and SLEM electronics period 1 April to 30 September 1979

Array Status

The status of the array instrumentation characteristics is close to normal with little change from previous periods. As of 30 September there is only one channel with out-of-tolerance conditions (02B LPZ). A few examples of the SP characteristics are given in Figs. IV.1 - IV.3.

A.Kr. Nilsen

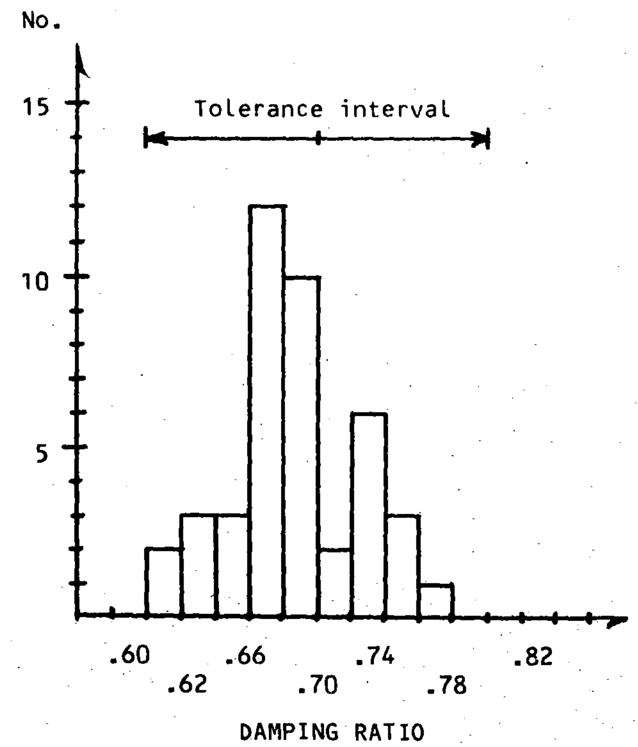

Fig. IV.1 The spread of the damping ratio values of the NORSAR SP seismometers as of 30 September 1979.

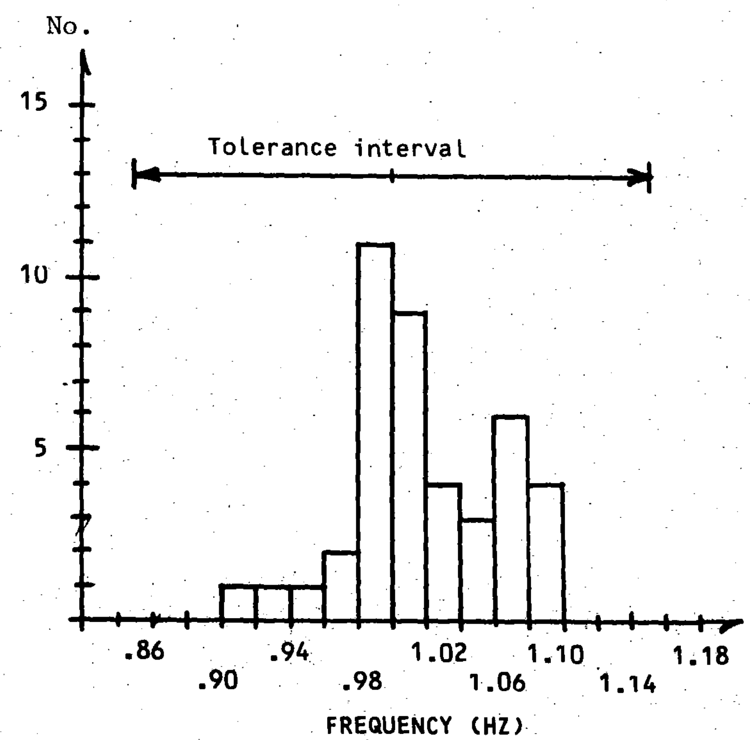

Fig. IV.2 The spread of the natural frequency values of the NORSAR SP seismometers as of 30 September 1979.

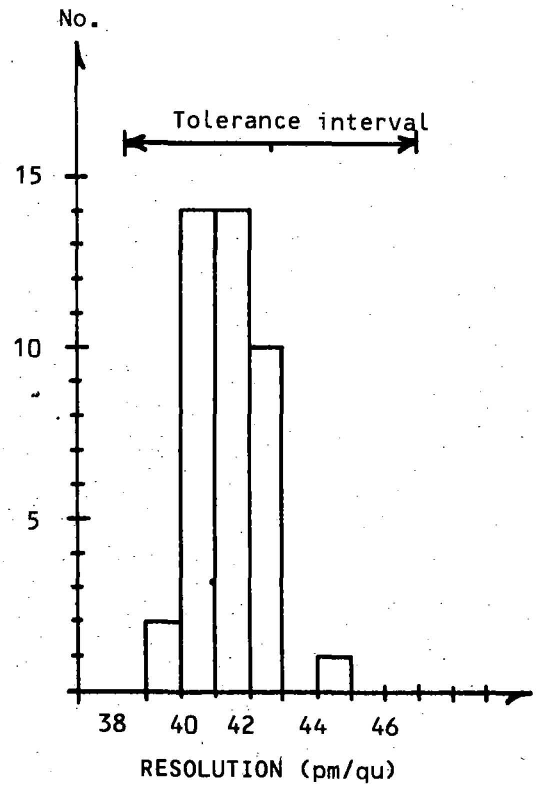

Fig. IV.3 The spread of the channel resolution values of the NORSAR SP channels as of 30 September 1979.

ABBREVIATIONS

ADC	-	Analog-to-digital converter
BB	-	Broad band
CMR	-	Common mode rejection
DC	-	Direct current
DCO	-	Direct current offset
FP	-	Free period
LP	-	Long period
MP	-	Mass position
RCD	-	Remote centering device
RSA	-	Range switching amplifier
SLEM	-	Seismic short and long period electronics module
SP	-	Short period
TC	-	Time constant

V. DOCUMENTATION DEVELOPED

V.1 Reports, Papers

Bungum, H., and J. Fyen, 1979: Hypocentral distribution, focal mechanisms and tectonic implications of Fennoscandian seismicity 1954-1978, Geol. Fören. Stockholm Förh., in press.

Gjøystdal, H., 1979: Semiannual Technical Summary, 1 Oct 78 - 31 Mar 79, NORSAR Sci. Rep. No. 2-78/79, NTNF/NORSAR, Kjeller.

L.B. Tronrud

VI. SUMMARY OF SPECIAL TECHNICAL REPORTS/PAPERS PREPARED

VI.1 P and Lg Wave Attenuation within 15 Degrees in Selected Frequency Bands in the 1-5 Hz Range using NORSAR Short Period Records

NORSAR short period data from 7 subarrays for explosions and earthquakes within 15 degrees (Fig. VI.1.1) have been analyzed to determine attenuation characteristics and signal-to-noise ratios for P and Lg waves at various frequencies. The earthquakes are either felt or classified as earthquakes by various reporting agencies, and the explosions are associated with refraction profiling investigations or reported mining/hydroelectrical power plant activity.

Fig. VI.1.2 shows the logarithm of the Lg to P ratio for subarray average amplitude values as a function of epicentral distance for five frequency windows. It is found that Lg is generally larger than P up to about 10 degrees. However, the assessment of the full detection potential of the Lg phase is left for further study. Dominant frequency of P is almost always higher than that of Lg, the differences being most pronounced beyond 10 degrees. Typical dominant frequencies are 3-5 Hz or higher for P and 1-3 Hz for Lg. These points are illustrated in Fig. VI.1.3, where records for two subarrays are shown for an explosion at a distance of 11.7 degrees.

Discrimination on the basis of Lg to P amplitude ratio seems difficult. The explosions in our data base generate surprisingly large Lg waves, and no clear separation between P to Lg amplitude ratios for earthquakes on one side and explosions on the other can be found in any of the five frequency bands.

The data base is presently being extended and also events in or near the U.K. are considered. This allows a study of Lg propagation characteristics also outside Fennoscandia, and the conclusion so far is that propagation efficiency is far less for paths including substantial parts of the North Sea. This observation is related to the existence of sediments exhibiting strong lateral heterogeneity, which is known to cause large attenuation of Lg phases.

S. Mykkeltveit
F. Ringdal

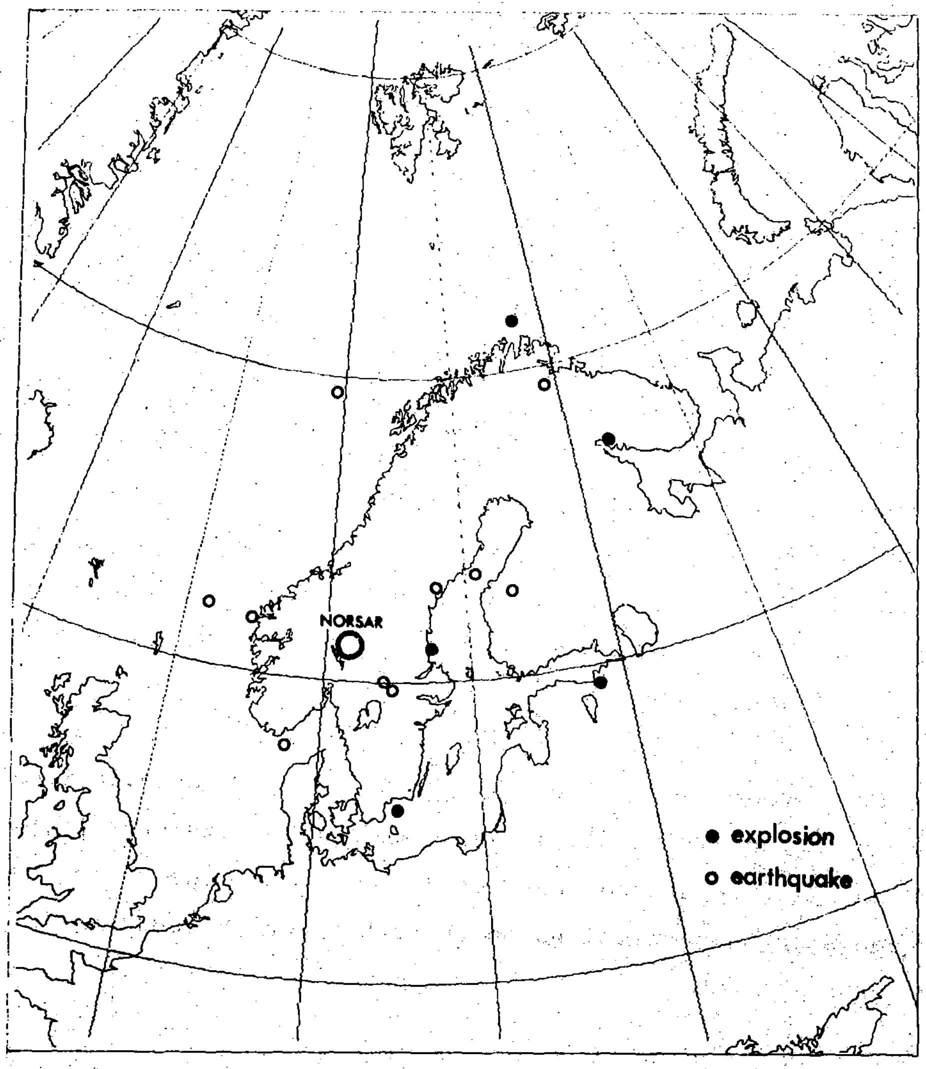

Fig. VI.1.1 Earthquake and explosion locations for events analyzed.

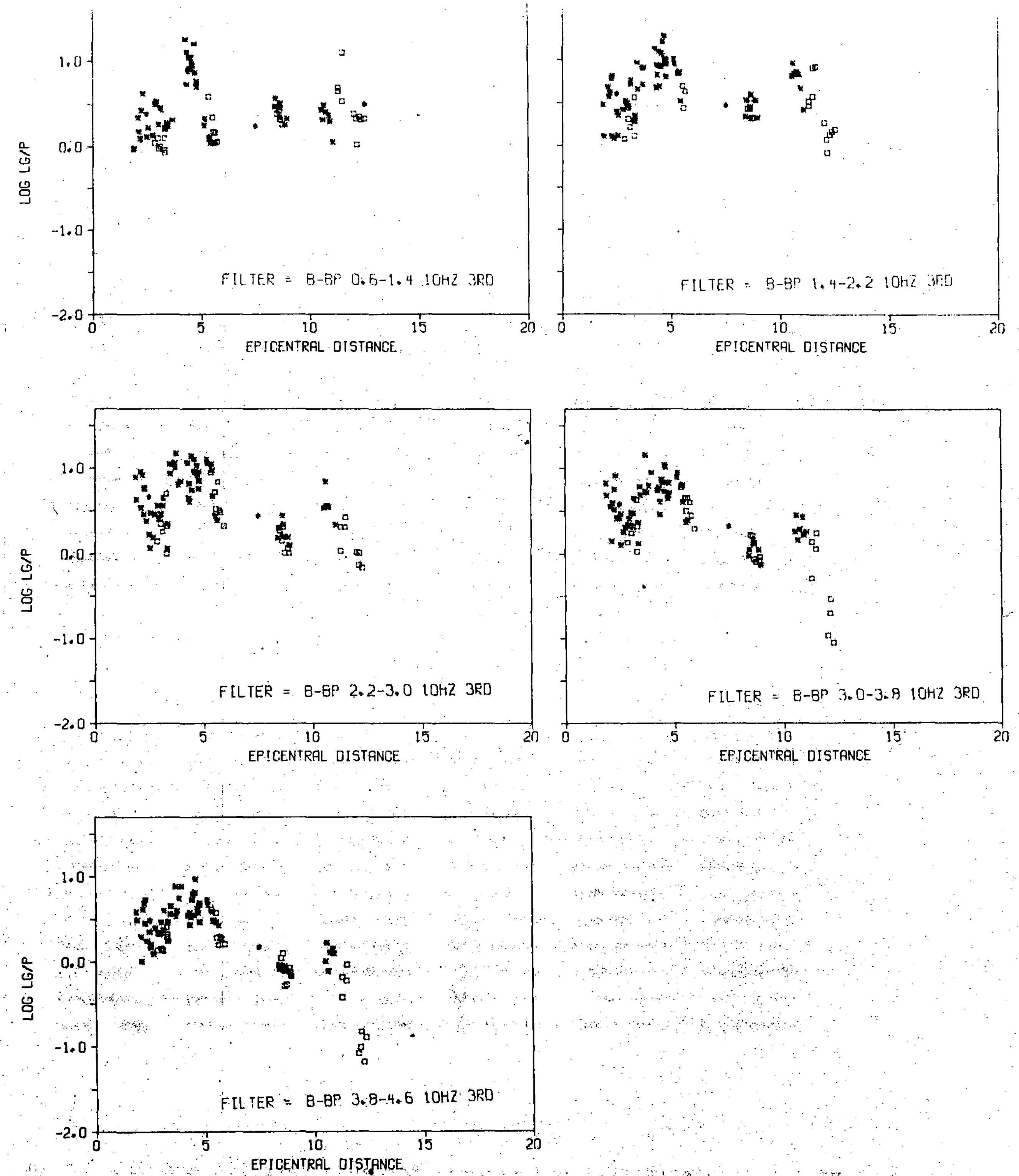

Fig. VI.1.2 Lg to P amplitude ratios for five frequency intervals as a function of epicentral distance. Squares indicate explosions, stars denote earthquakes. Each symbol represents an average subarray value.

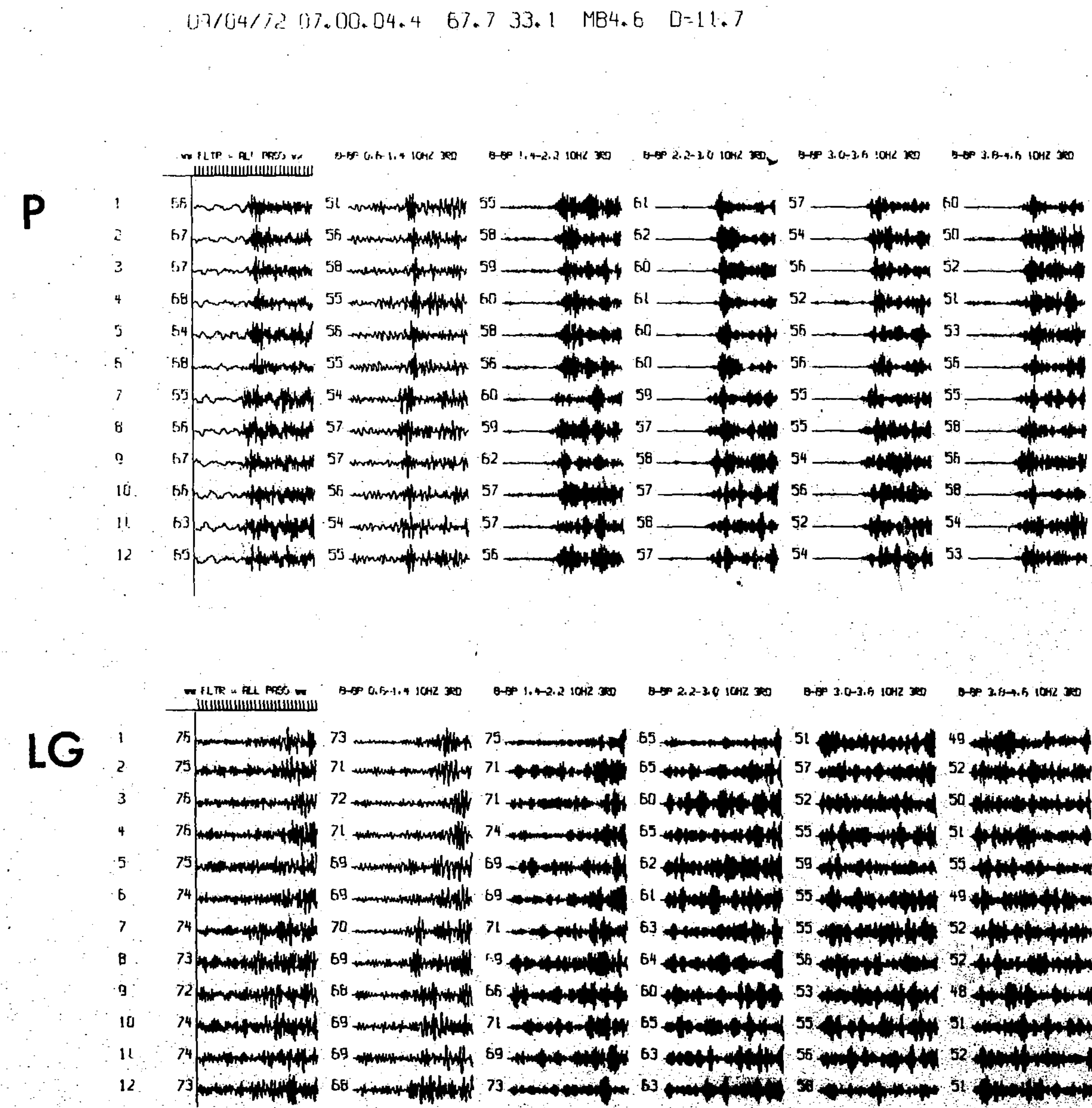

Fig. VI.1.3 NORSAR filtered records for subarrays 01A and 01B for an explosion in the Kola peninsula; distance 11.7 degrees from NORSAR. A 30 s interval is covered for both P and Lg wave main arrivals, and the number in front of each trace represents its maximum amplitude in dB relative to 1 quantum unit. Note the rapid falloff of signal-to-noise ratio with increasing frequency for the LG phase, as compared to P.

VI.2 Analysis of Global P-wave Attenuation Characteristics using ISC Data Files

A study has been undertaken to derive the global attenuation characteristics of P-waves based upon data files from the International Seismological Centre (ISC). The main motivation behind the study has been the failure of commonly accepted attenuation relations to provide good magnitude estimates at epicentral distances below 20 degrees. In fact, using the Gutenberg and Richter (1956) or Veith and Clawson (1972) amplitude-distance curves at close distances usually leads to an overestimation of earthquake magnitudes (m_b), sometimes by a full magnitude unit or more, relative to teleseismically derived m_b estimates.

For the study presented here, 136 globally distributed seismograph stations were selected. Most of these were WWSSN stations, and all of them are stations with fairly consistent reporting of amplitudes and periods of P-phases of detected seismic events. Altogether 6 years of data (1971-76) were included in the data base, giving a total of about 214,000 log A/T observations in the distance range 0-90^o.

The observed values of log A/T - m_b(ISC) are plotted versus epicentral distance in Fig. VI.2.1, and compared to the Veith-Clawson (1972) and Gutenberg and Richter (1956) relationships. In the plot all data within each 1 degree interval have been averaged to obtain a fairly smooth curve, The following major points may be noted:

a) Below 20 degrees the observed averages generally lie at least 0.5 m_b units higher than the conventional correction factors, thus confirming the bias effects mentioned earlier.

b) Although there is a local maximum between 15 and 20 degrees, this is not by far as pronounced as indicated in the conventional attenuation relations.

We also did some studies to investigate the effects of possible error sources in the data base, and preliminary conclusions are as follows:

1. Possible ISC m_b bias at low or high magnitudes. We first note that all ISC m_b values are based on stations only at epicentral distances at least 20 degrees, so that the bias effects at closer distances

should be relatively small. Nonetheless, we compared, for one year, the attenuation curves obtained using ISC and NORSAR reference m_b, respectively. As shown in Fig. VI.2.2, the resulting effect is only a baseline shift (independent of distance), thus this problem would not cause a change in the shape of the attenuation relationship.

2. Effects of instrument saturation and 'clipping'. This is potentially a serious problem, since, for large events, it may result in close-in stations reporting too low magnitudes. To investigate this, we subdivided all reference events into magnitude bins of 0.5 m_b units, and plotted the resulting curves separately as shown in Fig. VI.2.3. It is seen that there are indeed significant differences, although the main conclusions a) and b) remain unaltered. However, this problem will be subjected to further investigation.

There may also be other sources of bias effects, such as the lack of consistency in station reports and possible effects of frequency-dependent attenuation, but we have at this stage little possibility to investigate these further. Our main conclusion is that the conventionally used P-wave attenuation relationships should be revised for short distances, and we believe that this study will provide a useful first step for such a revision.

F. Ringdal
J. Fyen

References

Gutenberg, B., and C.F. Richter, 1956: Magnitude and energy of earthquakes, Ann. Geofisica 9, 1-15.

Veith, K.F., and G.E. Clawson, 1972: Magnitude from short-period P-wave data, Bull. Seism. Soc. Amer. 62, 435-452.

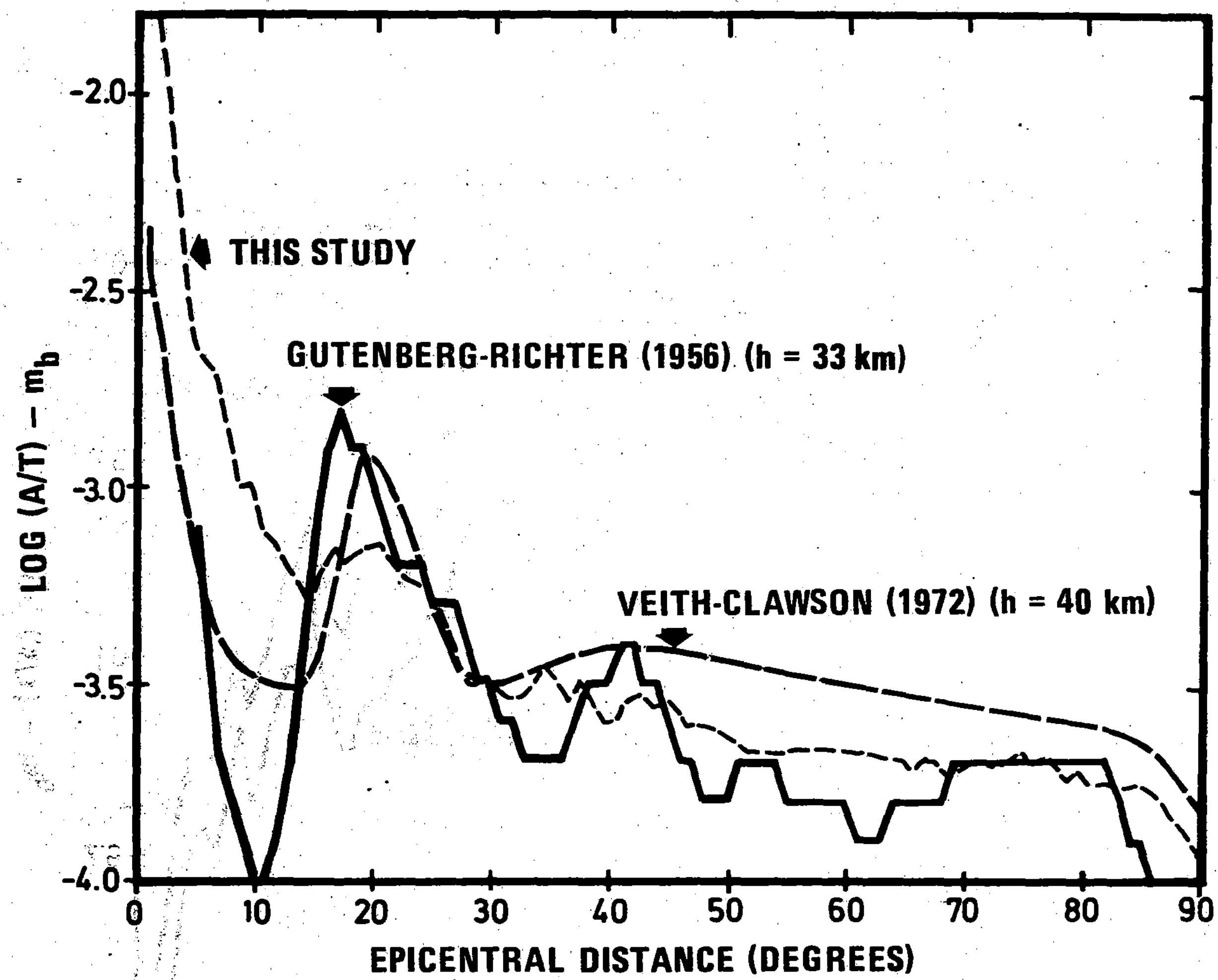

Fig. VI.2.1 Average observed magnitude correction factors based on ISC data for 23,198 events and 136 stations. Averages have been computed and plotted within each 1 degree distance interval. Note the considerable deviations from 'standard' curves at distances below 20 degrees.

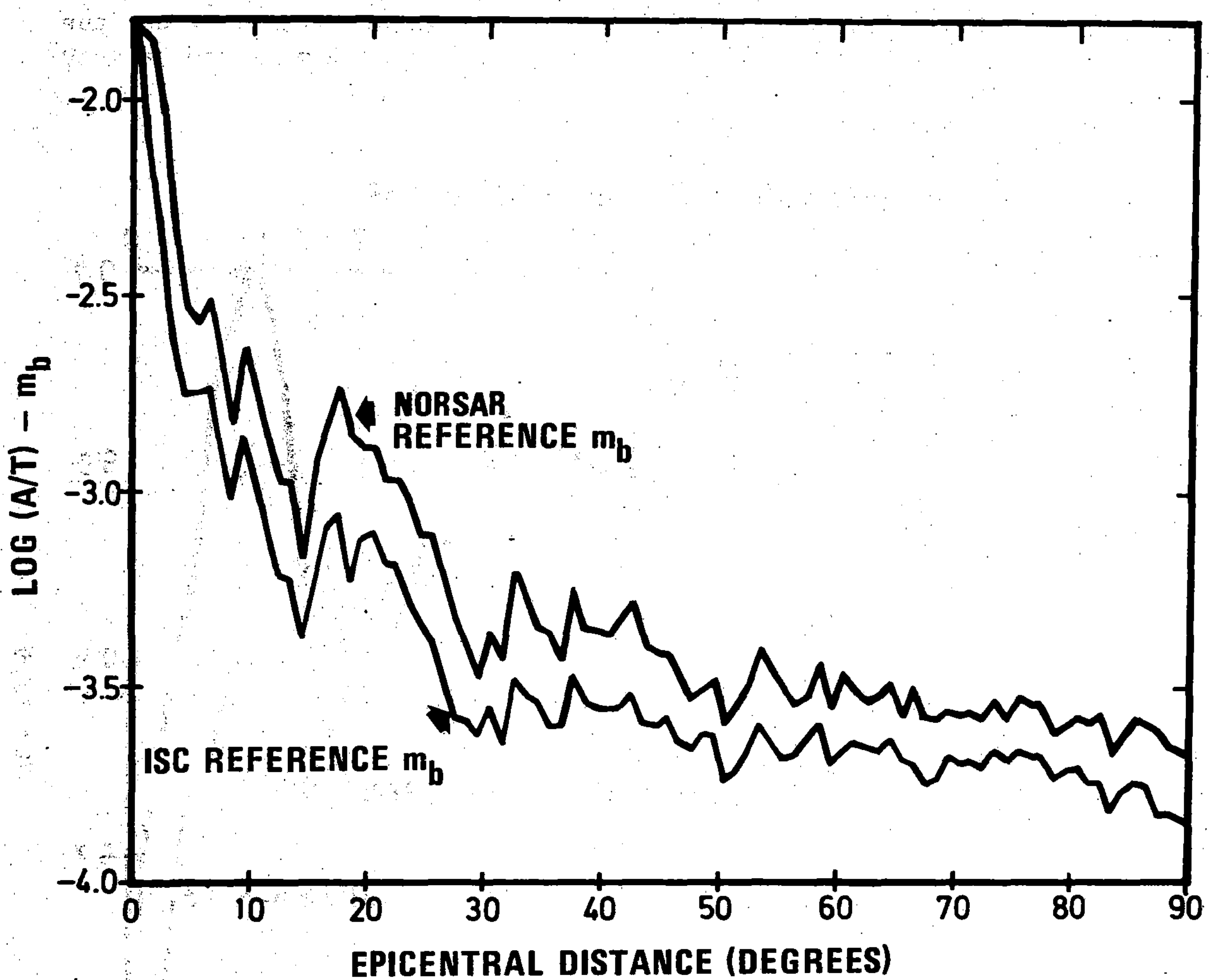

Fig. VI.2.2 Comparison of observed magnitude correction factors using NORSAR and ISC m_b values as a reference. The bias effect of about 0.2 m_b units is independent of distance.

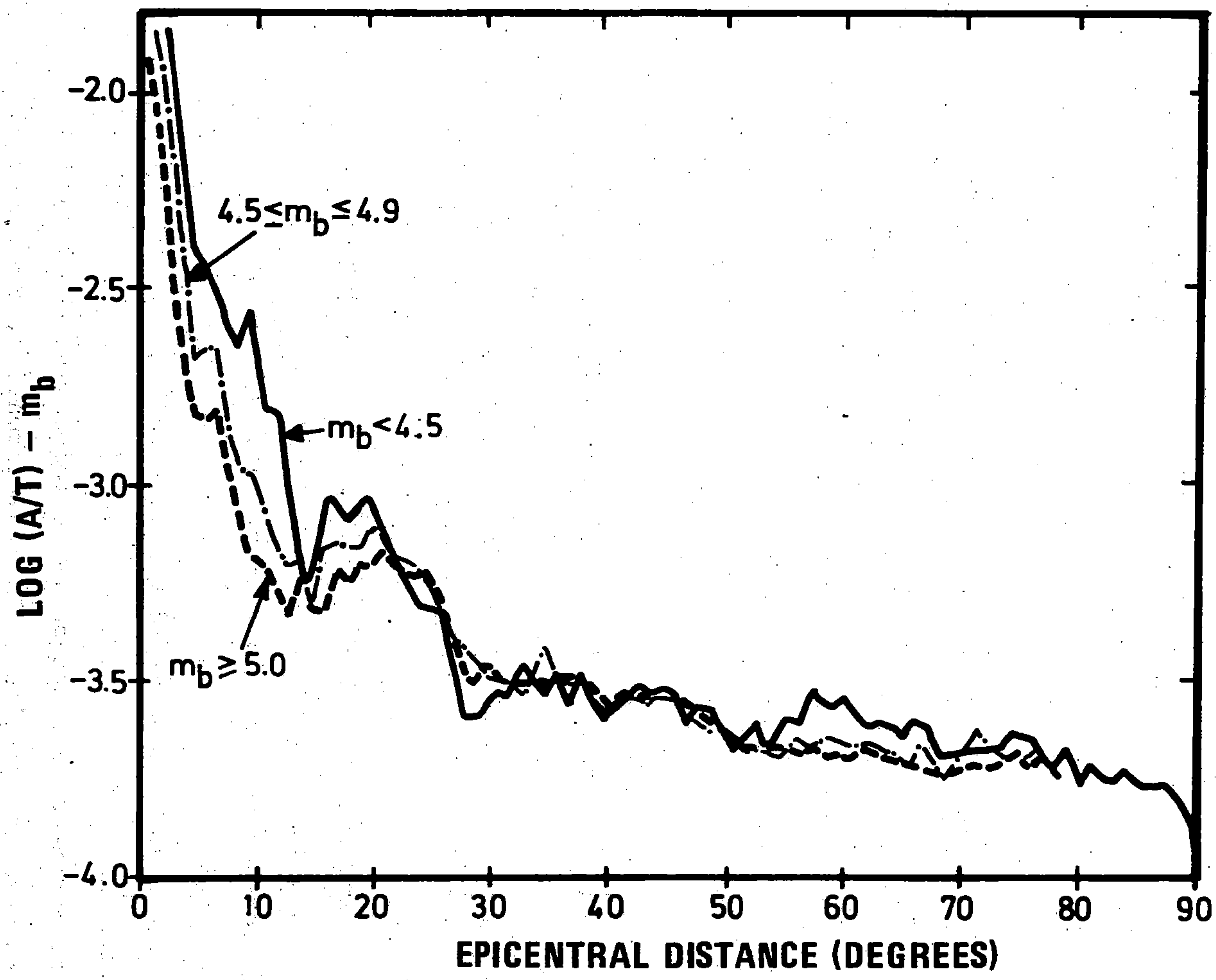

Fig. VI.2.3 Comparison of observed magnitude correction factors using as a data base events of different magnitudes. Using small reference events (m_b<4.5) results in higher correction factors within 20 degrees distance than using larger events.

VI.3 Classification of Regional Events

Special interest has in this period been focused on the problem related to the discrimination potential of the near-field observations of seismic events. The capabilities of the NORSAR array to detect and locate events at distances smaller than the conventional teleseismic distances has been undertaken and intensive work is now going on upgrading the detection capabilities at regional distances. In this context a preliminary analysis has been initiated to consider the array's capabilities of discriminating between earthquakes and explosions based on events reported at distances smaller than the teleseismic boundaries. A data base of 90 events of which 43 were presumed explosions and the remaining 47 were presumed earthquakes, all with a distance range covering from 10 to 40 degrees, were selected from the data library at NORSAR. The presumed explosions population was mainly located in western or southwestern Russia, while the presumed earthquakes were dominantly restricted to the Mediterranean area and eastwards towards Pakistan. Though it has recently become more popular to include additional near-field phases like the Lg into the discrimination scheme, we have exclusively restricted ourselves to the P-phase observations for our discriminant. The basis for the discriminant is found in the power spectrum of the P phase observations at the different instruments in the array and the energy distribution as a function of time after initial onset. The idea is to assemble optimally all available information in the spectrum in a restricted number of parameters and subsequently design a discriminant which will in an optimal way separate out the major difference in the information contained in the two populations (earthquake or explosion), if there is any significant difference at all. The discriminant to be considered here is identical to the one introduced by Sandvin and Tjøstheim (1978), except that the first step where the initial parameter extraction is performed is technically different but essentially contains the same information, i.e., the reproduction of the power spectrum. The philosophy of the discriminator is based on statistical classification where each data vector which is input to the discriminant is treated within a statistical framework and a distribution is fitted to the data vector belonging to each of the populations. (For references, see Sandvin and Tjøstheim, 1978).

It is surprising that even at frequencies close to the low-pass cut-off frequency installed at the seismometers a considerable portion of energy is observed at some NORSAR registrations from Russian explosions even as far away as Eastern Kazakhstan. It is consequently desirable to have an estimate of the energy distribution over a wide frequency range. The techniques we have adopted for estimating the energy-distribution is simply to apply a series of bandpass filtering with increasing center-frequencies. In this study five bandpass filters were applied with increasing center-frequency. A constant bandwith of 0.8 Hz was selected, starting with the frequency band 0.6-1.4 Hz and ending with the frequency band 3.8-4.6 Hz. A filtered section of the complete 42 traces is demonstrated for an explosion from Western Russia with a distance of $\Delta=15.6^{o}$ in Fig. VI.3.1. The single traces are divided into three subsections; one section contains the noise preceding the signal for an instant indication of the varying noise level; one subsection consists of the P phase itself; and finally the last subsection consists of the coda observations. The coda traces were included due to previous indications that the coda observations contain valuable information for discrimination purposes.

As demonstrated by King & Calcagnile (1976) a rapid change in velocity occurs at a depth of about 420 km in continental Russia resulting in a pronounced later arrival in the approximate distance range $21^{o}\leq\Delta\leq33^{o}$. This feature causes additional complications into the complexity of the P arrivals and the P phase subsection was consequently divided into two sections; one containing the first P onset and the second the later arrival. This leaves us with four subsections. For each frequency band and each subsection a parameter A was estimated, given by

$$A = 20 \log \text{(max. amplitude)}$$

which represents an estimate of the energy restricted to that subsection and that frequency band. The energy estimate of the noise section was subtracted from the remaining three subsections to compensate for the noise level variation.

From the trace with the maximum signal-to-noise ratio, the parameters from the three signal subsections were selected for each frequency band resulting in 3 x 6 = 18 parameters. In addition the average value (averaged over all 42 instruments) of the same parameters were added resulting in a total of 18 + 18 = 36 parameters from each event. These parameters finally enter the discriminant and from this point on the procedure is identical to the one described by Sandvin and Tjøstheim (1978). The number of parameters is significantly reduced by a principal-component analysis and the classification rule is finally based on the reduced data vector. Each event is tested against the remaining events and assigned to the population with the highest classification score.

A histogram presentation of the final discrimination score is depicted in Fig. VI.3.2. From this figure it may be inferred that of the total data base of 90 events included, 4 earthquakes and 2 explosions were misclassified. This is a result that is comparable with discrimination performed on a data base consisting of teleseismic events.

O.A. Sandvin

References

King, D.W., and G. Calcagnile, 1976: P-wave velocities in the upper mantle beneath Fennoscandia and western Russia, Geophys. J.R.Astr. Soc., 46, 407-432.

Sandvin, O.A., and D. Tjøstheim, 1978: Mutlivariate autoregressive presentation of seismic P-wave signals with application to short period discrimination. Bull. Seism. Soc. Amer., 68, 735-756.

09/19/71 11.00.06.8 57.8 41.1

** FLTR = ALL PASS ** TAPE 13132

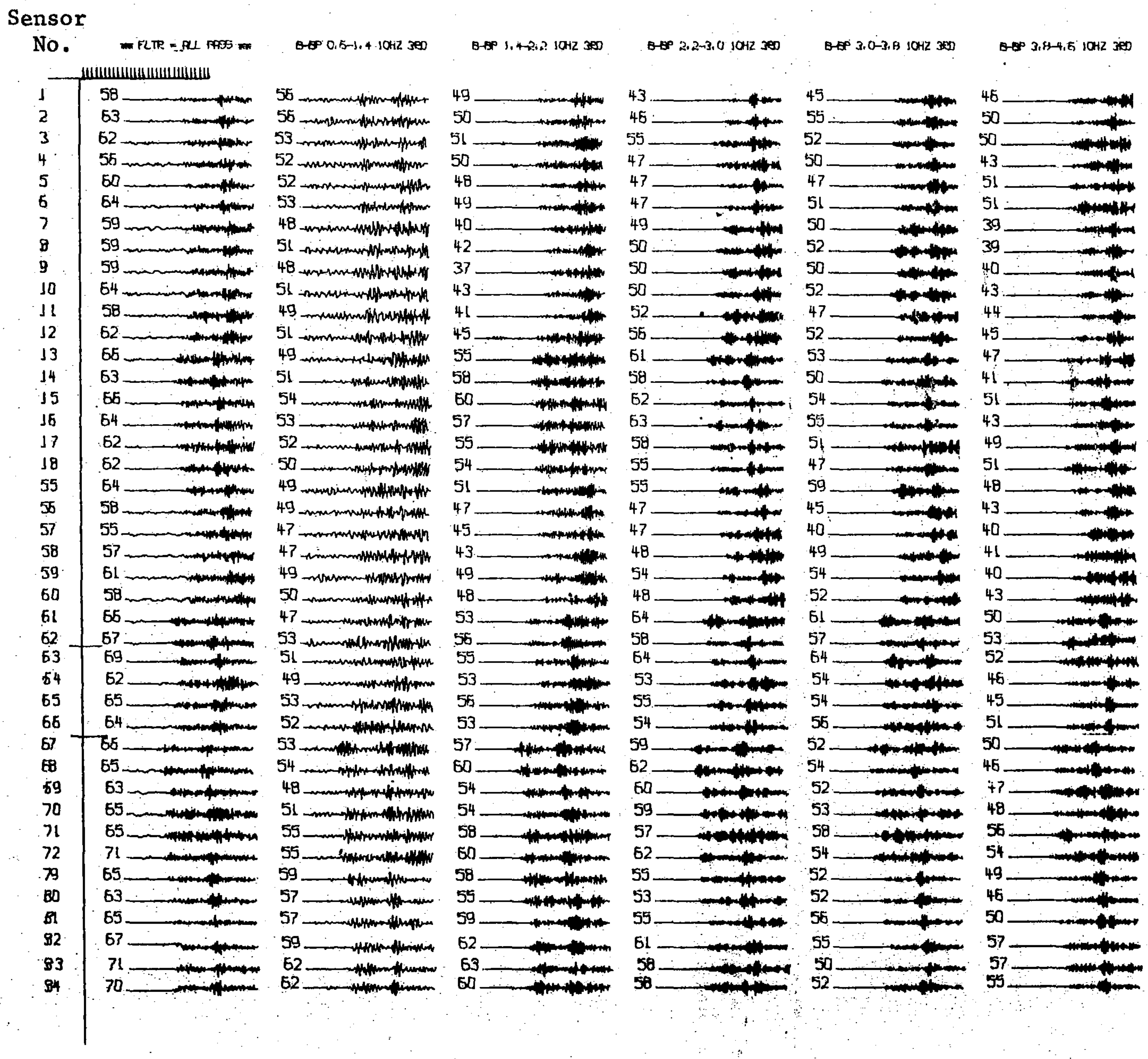

Fig. VI.3.1 Energy distribution as function of frequency for presumed explosion from western Russia with m_b=4.5 and epicentral distance Δ=15.6°. For each NORSAR SP instrument, the figure displays an unfiltered trace and five bandpass filtered traces. The number in front of each trace represents amplitudes in dB relative to 1 quantum unit.

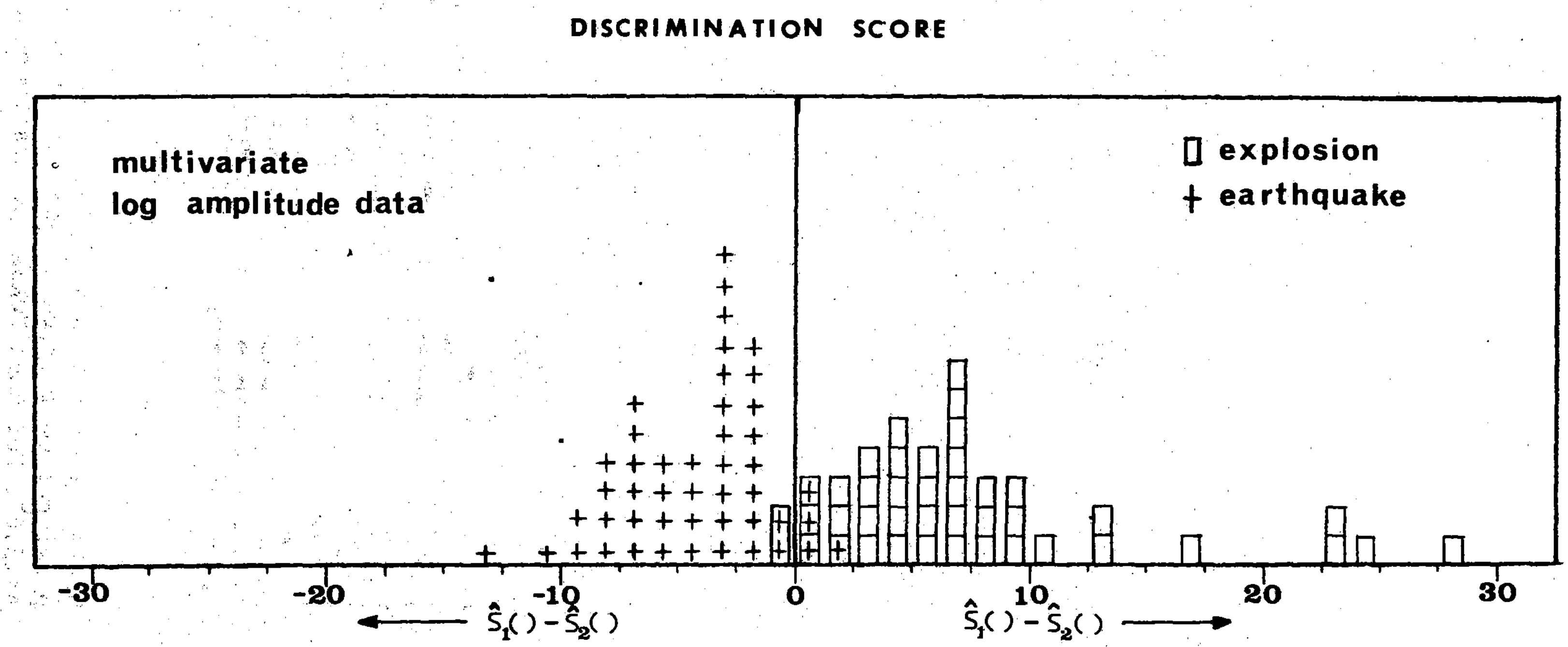

Fig. VI.3.2 Histogram of discrimination score obtained for our data base consisting of 43 explosions and 47 earthquakes.

VI.4 An Experimental Small Subarray within the NORSAR Array

One of the principles governing the design of the NORSAR array was that distances between instruments should be so that ordinary beamforming should give near to optimum gain in SNR for teleseismic events, which means that the distances should be large enough to give a low noise coherency (at around 1 Hz) and small enough to maintain a high signal coherency. This resulted in distances within each subarray of about 3 km, and it was soon discovered that this gave very low signal coherencies for regional and local events. An interesting consequence of this is that the 'incoherent' or envelope beamforming principle, which has been developed and implemented in the NORSAR online processing system as a means to overcome the incoherency between subarrays (Ringdal et al, 1974), might be applied with favorable results also within subarrays.

With the recent increased interest for regional and local events in a discrimination context, it was decided to implement, for experimental purposes and for a limited time period, a test subarray with very small station distances. The subarray became operational on 12 October 1979, and it consists of 6 seismometers as shown in Fig. VI.4.1, with station distances from 125 to 2051 meters. A change from 5 to 8 Hz lowpass filters was implemented on 23 October 1979.

Using these new data, we have started an analyzing program both on noise and signal characteristics. In Table VI.4.1 we give noise coherency values for four frequencies at one octave difference (0.5, 1.0, 2.0 and 4.0 Hz), and in order of increasing station distances. The results for the two middle frequencies are also plotted in Fig. VI.4.2, and coherency and phase vs. frequency for one particular combination is shown in Fig. VI.4.3. The block-averaging method of direct spectral estimation has been used, with 20 blocks each of 512 samples of 20 Hz data, amounting to a total of 8.53 minutes. With that much data the bias is relatively small, so that we expect 90% of the uncorrelated values (observed coherence for true zero coherence) to fall in the range 0.05 to 0.35 (Amos & Koopmans, 1963). Moreover, a frequency smoothing has also been applied, by averaging the output values into three estimates per octave.

The noise results show that the coherency (note that we use the so-called 'root coherence') for 0.5 Hz is maintained above the random level out to distances of about 2.3 km, for 1.0 Hz to 1.3 km, for 2.0 Hz to 0.7 km and for 4.0 Hz to about 0.4 km. Those values follow quite closely the regression

$$\log \Delta = 0.11 - 0.83 \log f$$

where Δ is distance in km and f is frequency in Hz. Of course, it is not known to which extent this formula will apply for frequencies outside the range 0.5-4.0 Hz, but it is known that the derived coefficients will not necessarily be valid at other times. The latter point is an effect of the large time variations expected in the level, propagating characteristics, and coherency of the seismic noise (cf. Bungum et al, 1971). A preliminary frequency-wavenumber analysis of our new data indicates that there is a significant amount of propagating noise at frequencies at least up to 1.0 Hz, with phase velocities in the order of 4-5 km/s.

We have also started investigations of signal characteristics across the new subarray, and Fig. VI.4.4 shows the Lg waves from an event about 200 km away (17 October 1979, 09.58 GMT, 60.3°N, 7.5°E). While signal coherencies for Lg waves previously have been very low for the distances in the ordinary NORSAR geometry, we see now that the signal similarities in the first few cycles are quite high, and especially so for the two closest channels, 2 and 6. For the Lg coda the coherence seems to be maintained at a reasonably high level only out to distances of about 400-600 m. The signal frequency is around 3 Hz, and at this frequency the noise coherency is close to random also at 500 m, which indicates that this may be a critical distance for 'coherent' processing of Lg waves. Computed coherencies for the waves in Fig. VI.4.4 are shown in Fig. VI.4.5, where the average coherence between all channel combinations is plotted. With the present large variation of distances (cf. Table VI.4.1) the standard deviation is also quite large, and it is only in the frequency range from about 1.5 to 3.0 Hz that the coherency is kept well above the random level, which in this case is much higher than for the noise analysis.

This work will now proceed with more detailed and thorough investigations of both signal and noise characteristics. It is possible that the array will be extended from 6 to 11 seismometers, all within the old subarray 06C.

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S. Mykkeltveit
O.A. Sandvin

References

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Bungum, H., E. Rygg and L. Bruland, 1971: Short-period seismic noise structure at the Norwegian Seismic Array, Bull. Seism. Soc. Amer., 61, 357-373.

Ringdal, F., E.S. Husebye and A. Dahle, 1974: P-wave envelope representation in event detection using array data, in: Exploitation of Seismograph Networks (ed. K.G. Beauchamp), Nordhoff-Leiden, 353-372.

Pair	Distance (m)	Noise Coherency 0.5 Hz	1.0 Hz	2.0 Hz	4.0 Hz
2-6	125	1.00	.99	.96	.86
1-2	303	.98	.96	.72	.54
1-6	408	.95	.91	.54	.41
3-4	603	.88	.86	.32	.26
1-4	724	.92	.77	.35	.25
2-3	750	.88	.74	.38	.32
3-6	809	.89	.71	.34	.30
2-4	827	.90	.70	.25	.27
1-3	875	.80	.71	.30	.25
4-6	945	.87	.64	.27	.30
1-5	1180	.79	.41	.29	.32
2-5	1400	.68	.36	.29	.25
5-6	1432	.64	.35	.29	.27
4-5	1730	.59	.25	.27	.23
3-5	2051	.36	.25	.27	.24

Table VI.4.1

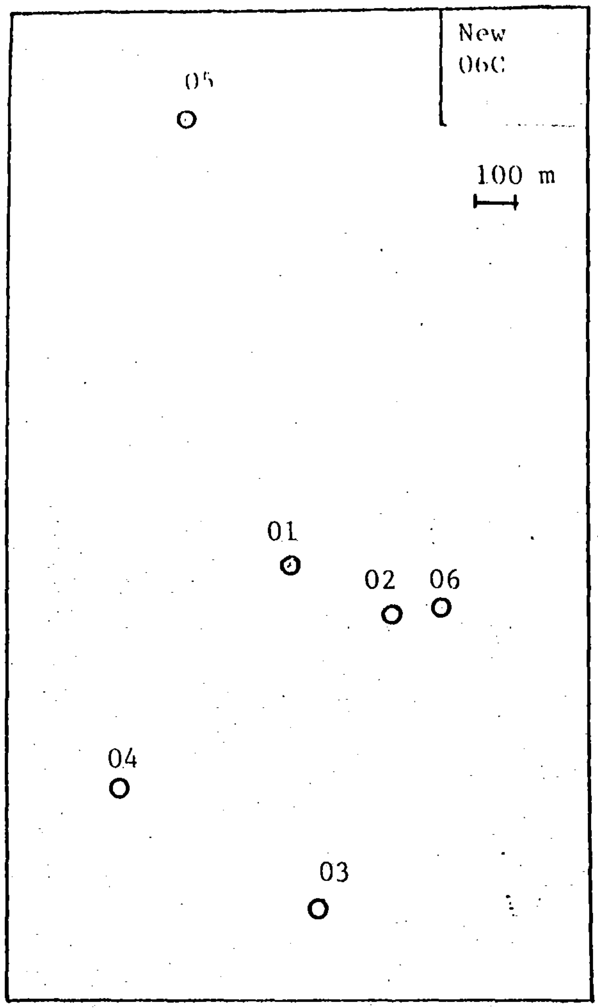

Fig. VI.4.1 Geometry of the new experimental small subarray inside the old subarray 06C. The data are transmitted over the old lines from 06C, with station 2 being unchanged. The old stations 1, 3, 4, 5 and 6 are for the time being not giving data.

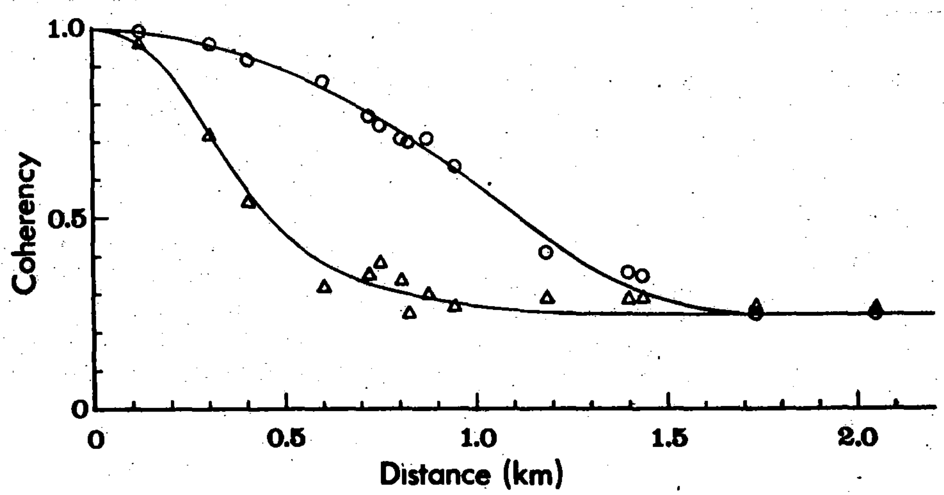

Fig. VI.4.2 Noise coherency vs distance for 1.0 Hz (circles) and 2.0 Hz (triangles). The estimates are obtained from 8.5 minutes of 20 Hz data, with 40 degrees of freedom, and an additional frequency smoothing has been applied by averaging over a frequency band of $\pm$ 0.17 octaves.

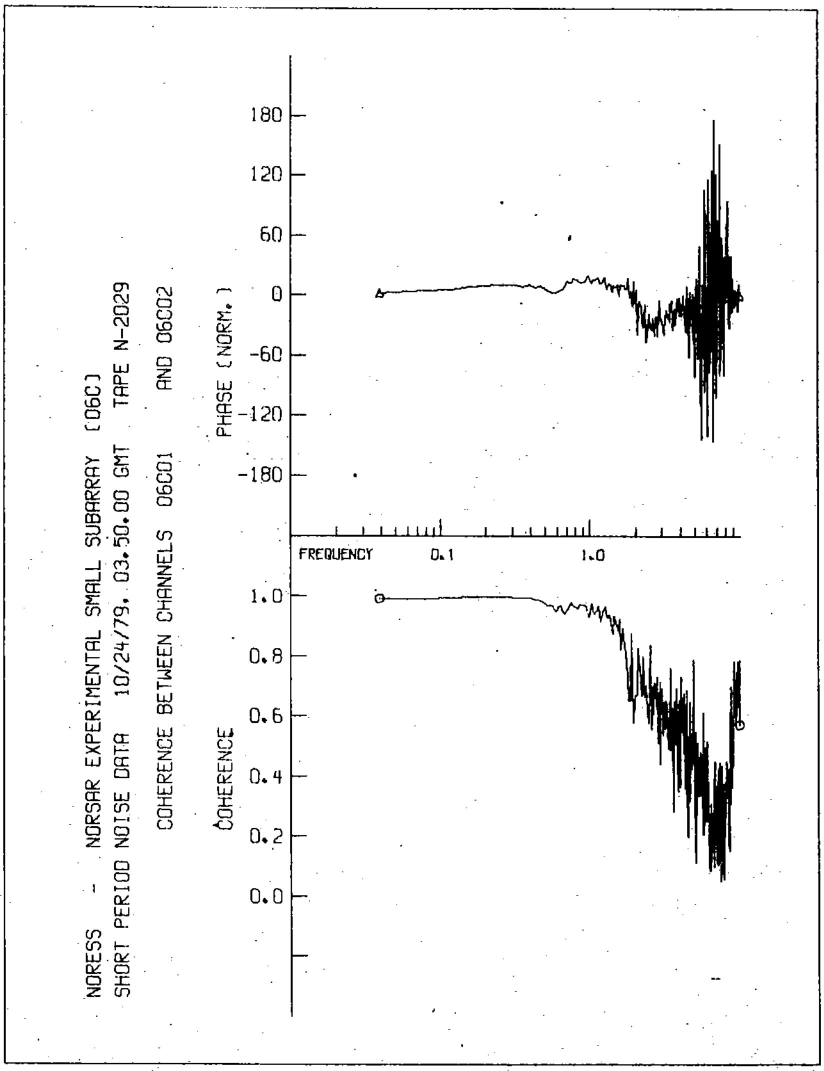

Fig. VI.4.3 Noise coherencies and phase lags vs frequency for channel combinations 1-2, with 303 m separation. The results in Table VI.4.1 and in Fig. VI.4.2 are taken from such calculations for all possible channel combinations, only with an extra frequency smoothing.

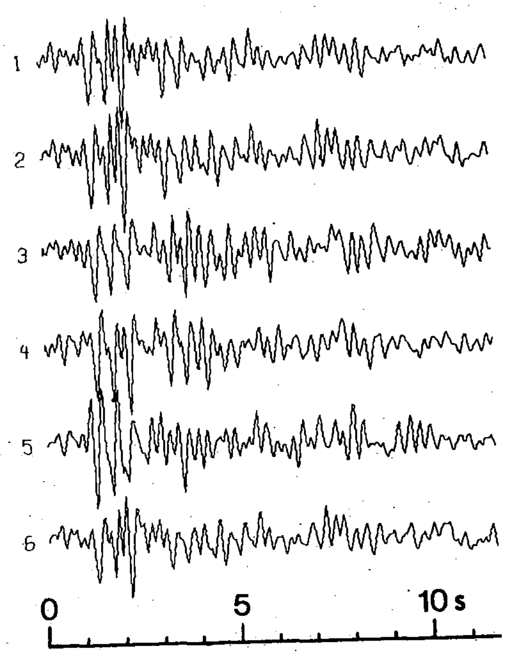

Fig. VI.4.4 Lg waves from a local event 200 km away (see main text).

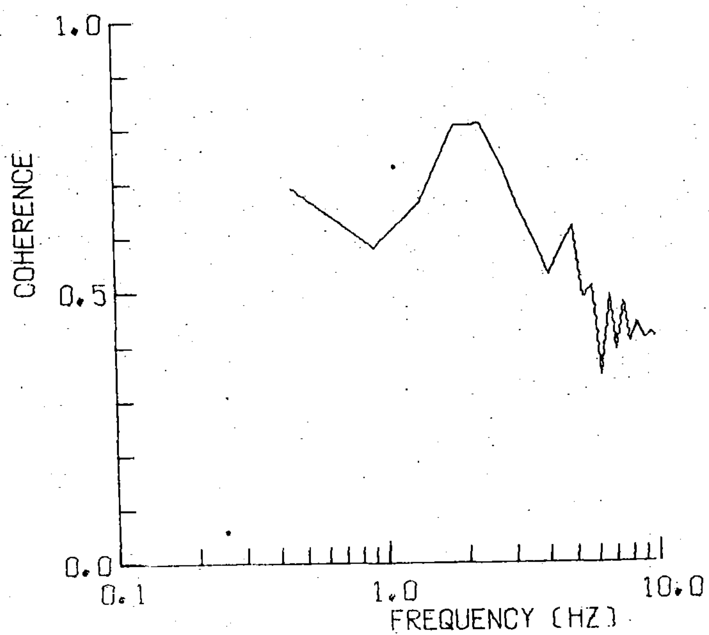

Fig. VI.4.5 Signal coherency for the data in Fig. VI.4.4. The length of the time window was 10 sec and the maximum lag in cross-correlation 15%, corresponding to about 6 degrees of freedom.

VI.5 NORSAR Short Period Recording of Explosions during the 'Fennoscandia Long Range Profile 1979' ('Fennolora') Seismic Experiment

During the Fennolora experiment in August 1979 charges ranging from 700 to 8000 kg of TNT were fired at the locations indicated in Fig. VI.5.1. This figure also shows the main profile line for deployment of mobile seismic stations. Information on shotpoint coordinates, charge sizes and actual shottimes has been provided by the Fennolora operations group. NORSAR records including all short period data for a 20 min interval following the communicated origin time for each shot are available on separate stack tapes.

A screening of the records shows that shots at points b, c, d, e, f and i in Scandinavia, PU1 in Poland and PU3 in the USSR are well recorded at NORSAR. Shots at position h (up to 1800 kg) are marginal, while even a 3-ton shot at g is nondetectable at NORSAR. No signal is found from shots at W (700 kg), BW (700 kg), S (800 kg), PU2 (2500 kg) and PU4 (4000 kg).

Fig. VI.5.2 shows the NORSAR records for a 2-ton shot at location c. The individual seismograms are arranged according to the actual shot-point-sensor distance, so that nearby seismograms do not necessarily represent records at nearby stations. Still, a reasonable station-to-station correlation seems to be maintained for two distinct phases. Altogether, the NORSAR records cover the distance intervals 315-375 km (shotpoint d), 360-420 km (shotpoint e), 415-485 km (shotpoint c), 585-650 km (shotpoint b), 630-695 km (shotpoint f), 855-930 km (shotpoint PU1), 1335-1395 km (shotpoint i) and 1415-1490 km (shotpoint PU3).

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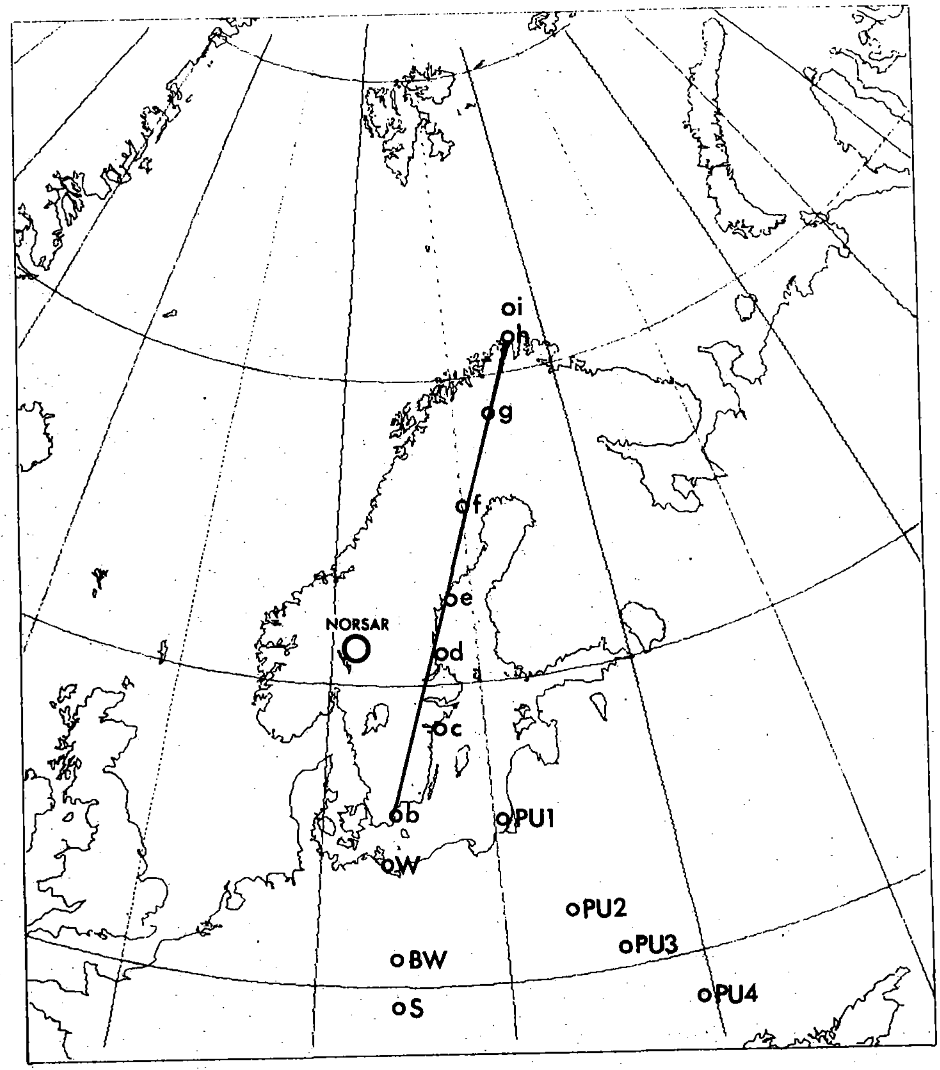

Fig. VI.5.1 Shotpoint locations for the 'Fennoscandia Long Range Profile 1979'. The profile line for deployment of mobile seismic stations is indicated.

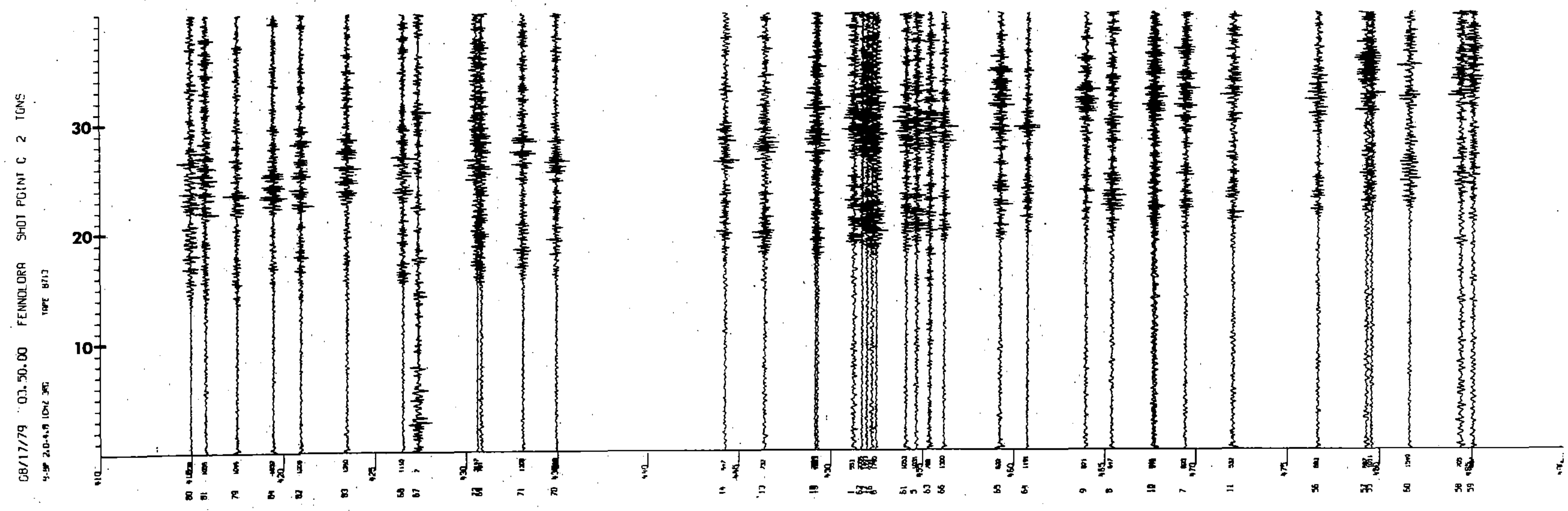

Fig. VI.5.2 A normalized seismic 'section' for a 2-ton shot at point c. The distance interval covered runs from 415 to 485 km. Plotting start time is 46 secs after shot time for each trace. A bandpass filter 2.0-4.8 Hz is applied. The numbers in front of each trace represent sensor number (bottom) and maximum amplitude.