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7.5 Establishment of a mining explosion data base

On a daily basis, numerous local and regional events are detected and located by the signal analysis procedures applied to the high-frequency arrays NORESS and ARCESS. The majority of these events are related to mining activity in the area monitored by these arrays. Specific knowledge pertaining to mining explosions such as mine locations, charge sizes, firing practices, etc., will aid in the regular analysis of the array data. In addition, such information will be the basis for adequately addressing a range of interesting and important topics within seismological verification research.

With the purpose of obtaining such information, a survey of mining activity in the areas monitored by NORESS and ARCESS was initiated during the reporting period. The work consists of four steps including gathering of back ground material, acquiring information from the mines, defining relational tables and selecting time series from our data archives.

Collection of background information

The authorization of mining activity in Scandinavia is decentralized to local police; however, there is no official regulation requiring recording of blasting parameters, etc. The initial work towards establishing a mining explosion data base therefore was aimed at obtaining an overview of activities from branch organizations and companies relating to mining activity. The survey of activity resulted in a list of 24 Swedish and 43 Norwegian companies some of which may operate at several locations. These companies represent presumably continuous operation of mining activity underground or at the surface, or simply rock quarries for the purpose of producing building materials. At present, no effort has been made to map temporary mining activity relating to various construction projects or military activity. However, data regarding larger naval detonations are available via a reporting schedule to the University of Bergen. A list of explosions from the largest open pit mine in southern Norway (Titania) was also obtained as a part of a reporting program to the University of Bergen.

Submission of a questionnaire to actual mines and quarries

Common practice regarding filing of information about past explosions varies considerably from one mine to another, as the mining companies are not required to provide reports on their explosions. A questionnaire was submitted to the 67 companies identified, asking for a number of details about blasting practice and explosions detonated since 1984. Out of the 67 companies approached, answers were obtained from 16, corresponding to an answering per cent of about 25. The quality of the responses varied greatly, apparently due to the lack of details in their files. The sparse response may also be attributed to the fact that the workload on the part of the companies was not associated with any compensation by NORSAR. A map showing the location of mines presently contributing to the explosion data base is given in Fig. 7.5.1. The mines from which data are acquired include four of the main open pit mining sites in Norway, located in southern Norway, western Norway, mid Norway and northern Norway, respectively.

Details of explosion locations at the mine in mid-Norway (Rana Gruber) are shown in Fig 7.5.2, and for the mine in northern Norway (Sydvaranger) located close to the Russian border in Fig. 7.5.3. The latter mine performs blasting at five different locations within an area of about 10 km across. The distances to ARCESS and NORESS from these four mines are shown in Fig. 7.5.4. The amounts of explosives detonated vary from less than 10,000 kg to more than 200,000 kg, thus providing a good range of charge sizes and distances for consideration in future research.

Establishing mining explosion relations according to CSS data base structure

The mines responding to the questionnaire do provide a basis for defining elements of a mining explosion data base for future research and master event selections. Two relations are proposed in conformance with the 2.8 CSS data base structure for the mining explosions. The relational table MINFO contains information specific for one particular mine location, but common to many explosions in that mine. The description of individual explosions is contained in the relation MINEX. Details of the proposed relations are provided in Appendix A.

The information contained in the returned questionnaires has been edited to a computer file and subsequently processed and rewritten to a file in conformance with CSS external file format. The processing includes conversion from local time to EPOC-time and conversion from local coordinates provided by the Norwegian Mapping Authority (NGO) to geodetic latitude and longitude. Subroutines needed for this transformation were acquired and implemented at NORSAR as part of this project.

Examples of the external files of the relational tables MINFO and MINEX are presented in Tables 7.5.1 and 7.5.2. The description of ripple firing is given in terms of one tuple for each individual detonation in the ripple. For many ripple-fired explosions reported by the mines, detailed descriptions of the cap delay times and charge distribution were not provided. In cases where the charge configuration parameter 'chacon' is set to 'obtainable', details of ripples may be obtained upon specific request and entered into the tables at a later time.

Selection of master recordings of mine explosions

The work towards entering typical mine explosion recordings at our arrays into master files is at a preliminary stage, and must await the consideration of a large number of recordings supported by data processing results in terms of energy distribution in time, frequency and space. Crucial issues for further consideration ar the attenuation of the seismic waves from various types of mining explosions and the characteristics of ripple firing in time-frequency estimates (spectograms) of such recordings; see, e.g., Baumgardt and Ziegler (1988), Hedlin *et al* (1989), Richards *et al* (1989). Some examples of mine recordings are shown in Figs. 7.5.5 to 7.5.7.

Plans for further work

From the information gathered from the mining industry so far, we are in a good position to judge which of the mines that have not yet returned the questionnaire are of interest to us. We will make an effort to contact these mines again. Many of the mines in this category are located in Sweden, and we expect to obtain some help and advice from Swedish seismologists in establishing contact with the mines in question. After this second round of information gathering, we hope to be able to compile a fairly comprehensive data base of mining explosions in Norway and Sweden.

The network of regional arrays providing real time data to the NORSAR Data Processing Center is currently being expanded. Very soon, data from the FINESA array in Finland and the GERESS array in the Federal Republic of Germany will become available. It will then be necessary to expand the survey of mining activity described in this report to new regions, in particular Finland, the western USSR, Poland, Czechoslovakia and the FRG. Again, we expect to be able to obtain help and information from colleagues in these countries.

A. Dahle
A. Alsaker
S. Mykkeltveit

References

Baumgardt, D.R., and K.A. Ziegler, Spectral evidence for source multiplicity in explosions: application to regional discrimination of earthquakes and explosions, *Bull. Seis. Soc. Am.*, 78, 1773-1795, 1988

Hedlin, M.A.H., J.B. Minster, and J.A. Orcutt (1989): The time-frequency characteristics of quarry blasts and calibration explosions recorded in Kazakhstan U.S.S.R., *Geophys. J. Int.*, 99, 109-121, 1989.

Richards, P.G., A. Lerner-Lam, R. Such and D. Simpson (1989): Chemical explosions and the discrimination problem, Contract No F19628-8-K-0041.

Mine No.	Name	Lat, deg	Lon, deg	Mine Type
1	Olivin	62.04000	5.52333	open pit
3	Rana Gruber	66.42063	4.67853	open pit
4	Sydvaranger	69.65189	30.02533	open pit
5	Sulitjelma	67.14769	16.07007	shaft
6	Fz.f,Bryggja	61.93000	5.45000	shaft
7	Grong	64.87000	13.88000	shaft
8	Bleikvassli	65.93000	13.88000	shaft
9	Fosdalen	64.07000	11.20000	shaft
13	Steens Kalkverk	60.74000	11.02000	open pit
14	Fz.f,Sandvika	59.90000	10.50000	shaft/pit
15	Titania	58.30000	6.40000	open pit
16	Fz.f,Vinterbro	59.75000	10.77000	open pit
101	Vammala	61.33000	23.03000	
102	Enonkoski	62.04000	28.77000	
103	Taipalsaari	61.18000	28.04000	
104	Pyhaesalmi	63.66000	26.05000	
105	Hitura	63.85000	25.05000	
106	Vihanti	64.41000	25.15000	
107	Elijaervi	65.78000	24.70000	
108	Saattopora	67.78999	24.43000	
109	Faarby	60.10000	22.88000	
110	Mustio	60.17000	23.84000	
111	Sipoo	60.25000	25.39000	
112	Tytyri	60.27000	24.07000	
113	Parainen	60.30000	22.29000	
114	Ihalainen	61.03000	28.18000	
115	Vampula	61.05000	22.64000	
116	Otama	61.81000	21.74000	
117	Ruokojaervi	61.94000	29.03000	
118	Ankele	62.07000	27.41000	
119	Ryytimaa	63.15000	24.02000	
120	Kalkkimaa	65.90000	24.47000	
121	Kemiaa	60.14000	22.59000	
122	Horsmanaho	62.82000	29.25000	
123	Lipasvaara	63.02000	29.23000	
124	Siilinjaervi	63.12000	27.74000	
125	Nilsiae	63.16000	27.99000	
126	Lahnaslampi	64.12000	28.06000	

Mine No.	Name	Lat, deg	Lon, deg	Mine Type
201	Dala Kalk AB	60.62000	15.10000	open pit
202	Dannemora	60.12000	17.52000	
203	Garpenberg Nord	60.20000	16.13000	
204	Garpenberg	60.18500	16.11500	
205	Zinkgruvan	58.80000	15.10000	
206	Glanshammar	59.30000	15.40000	
207	Grängesberg	60.10000	15.00000	
208	Yxsjöberg	60.00000	14.80000	
209	Gåsgruvan	59.70000	14.10000	
210	Svärdsjö	60.70000	15.90000	

Table 7.5.1 Example of attributes contained in the MINFO relation. Mines 1–100 are Norwegian, mines 101–200 Finnish, and mines 201–300 are Swedish.

Epoch	Mine No.	Charges	Charge No.	Delay,ms	Configur.
610812300.000	1	9	1	0.000	ripple
610812300.000	1	9	2	45.000	ripple
610812300.000	1	9	3	90.000	ripple
610812300.000	1	9	4	135.000	ripple
610812300.000	1	9	5	180.000	ripple
610812300.000	1	9	6	225.000	ripple
610812300.000	1	9	7	270.000	ripple
610812300.000	1	9	8	315.000	ripple
610812300.000	1	9	9	360.000	ripple
612021900.000	1	8	1	0.000	ripple
612021900.000	1	8	2	45.000	ripple
612021900.000	1	8	3	90.000	ripple
612021900.000	1	8	4	135.000	ripple
612021900.000	1	8	5	180.000	ripple
612021900.000	1	8	6	225.000	ripple
612021900.000	1	8	7	270.000	ripple
612021900.000	1	8	8	315.000	ripple
507291300.000	3	22	0	0.000	obtainable
508768800.000	3	24	0	0.000	obtainable
509991000.000	3	21	0	0.000	obtainable
516042900.000	3	26	0	0.000	obtainable
518026200.000	3	27	0	0.000	obtainable
526588200.000	3	21	0	0.000	obtainable
578831400.000	3	14	0	0.000	obtainable
581738400.000	3	20	0	0.000	obtainable
584957700.000	3	34	0	0.000	obtainable
592677600.000	3	10	0	0.000	obtainable
595688100.000	3	16	0	0.000	obtainable
604710000.000	3	17	0	0.000	obtainable
609668100.000	3	26	0	0.000	obtainable
532384500.000	4	103	0	0.000	obtainable
613826100.000	5	0	0	0.000	obtainable
602370000.000	6	17	1	0.000	ripple
602370000.000	6	17	2	100.000	ripple
602370000.000	6	17	3	200.000	ripple
602370000.000	6	17	4	300.000	ripple
602370000.000	6	17	5	400.000	ripple
602370000.000	6	17	6	450.000	ripple
602370000.000	6	17	7	950.000	ripple
602370000.000	6	17	8	1450.000	ripple

Epoch	Mine No.	Charges	Charge No.	Delay,ms	Configur.
602370000.000	6	17	9	1950.000	ripple
602370000.000	6	17	10	2450.000	ripple
602370000.000	6	17	11	2950.000	ripple
602370000.000	6	17	12	3450.000	ripple
602370000.000	6	17	13	3950.000	ripple
602370000.000	6	17	14	4450.000	ripple
602370000.000	6	17	15	4950.000	ripple
602370000.000	6	17	16	5450.000	ripple
602370000.000	6	17	17	5950.000	ripple
599612400.000	9	1	1	0.000	single

Table 7.5.2 Example showing some of the attributes of the MINEX relation. The middle section of the table contains data of ripple fired charges where the details of ripple firing is not specified, however, the data may be obtainable from the mining company.

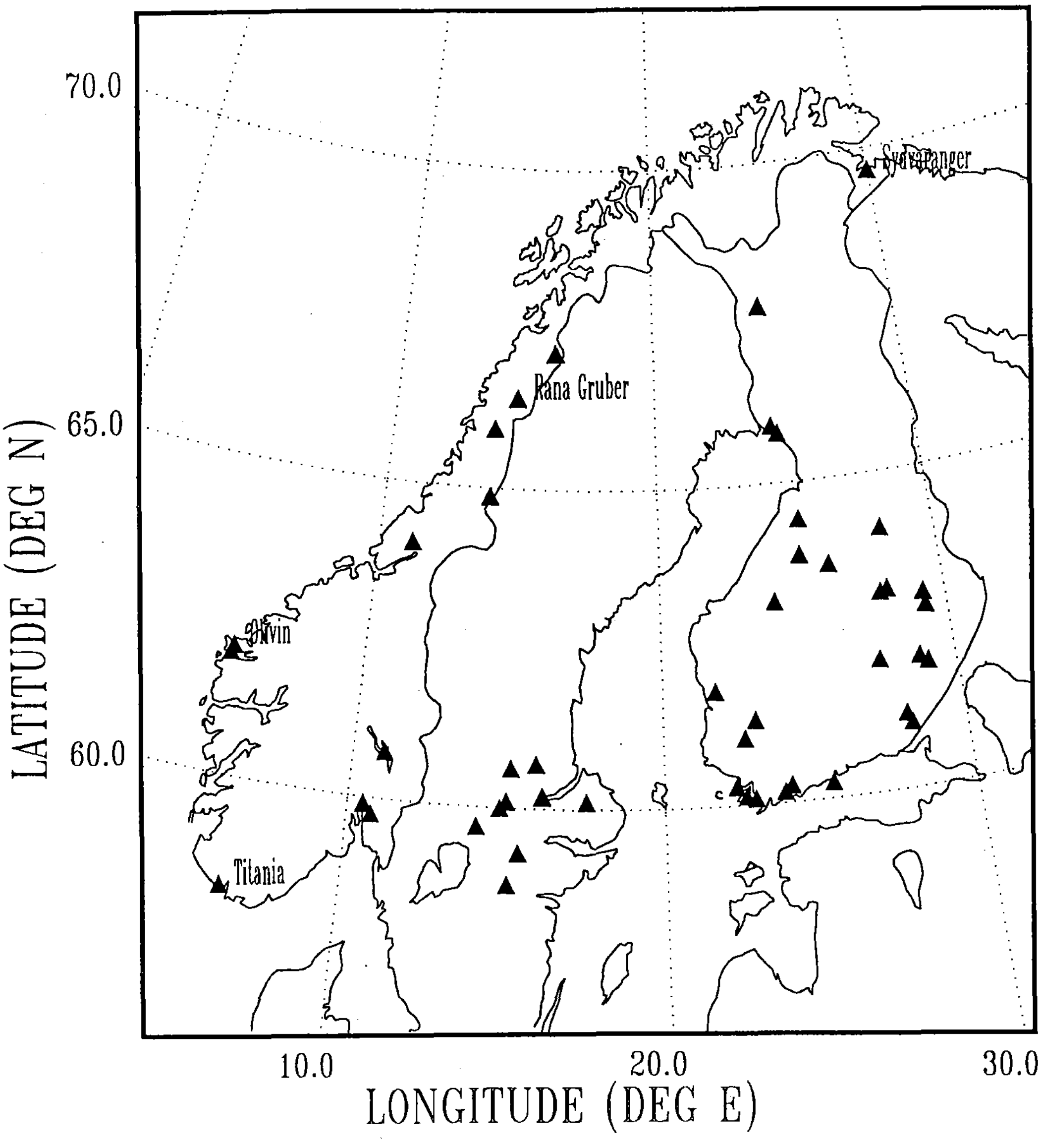

Fig. 7.5.1 Mines and quarries in Scandinavia presently registered in the mining explosion data base. The most important mines in Norway are shown as Titania, Olivin, Rana Gruber and Sydvaranger.

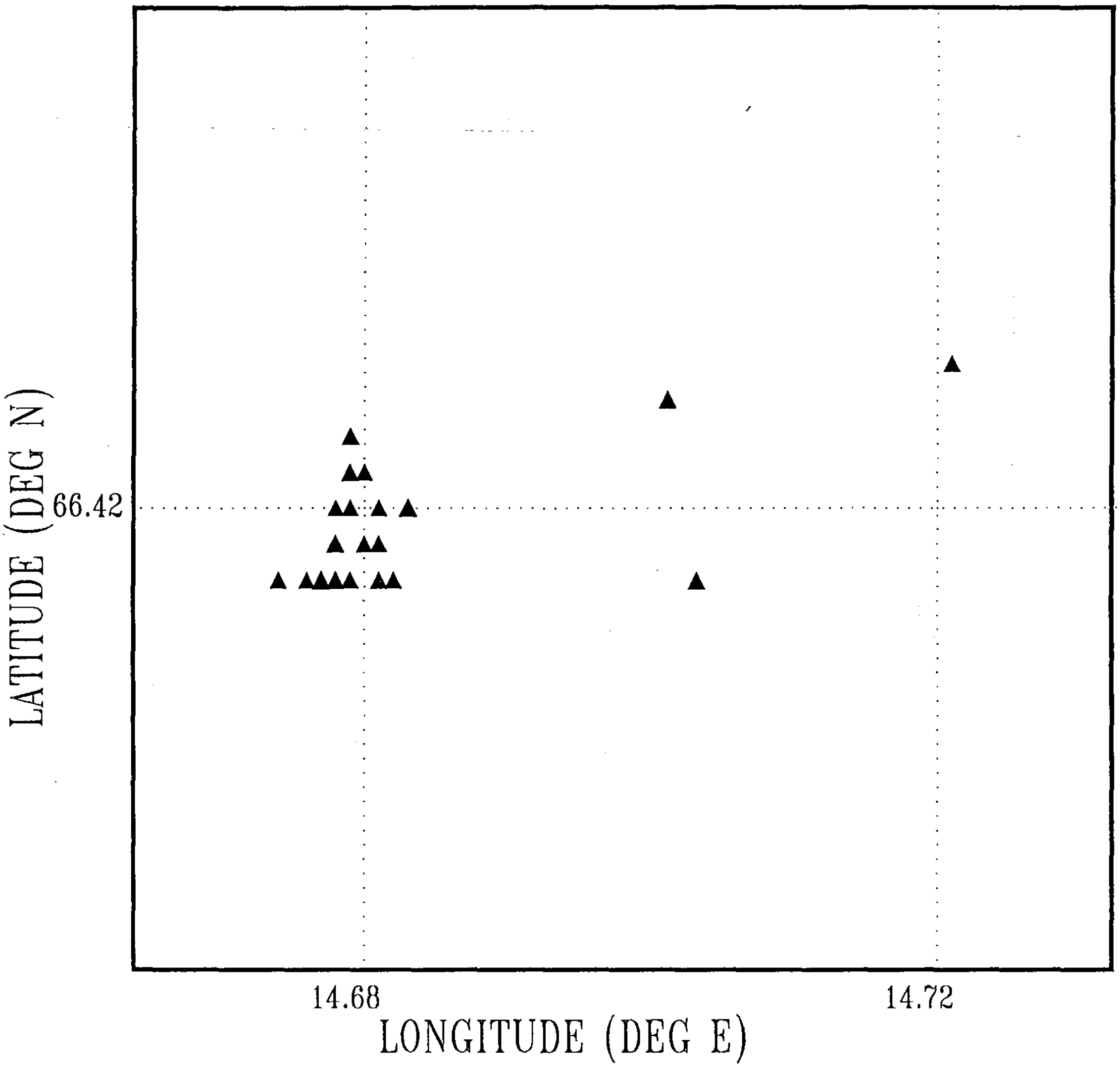

Fig. 7.5.2 Location of explosions in the open pit mine Rana Gruber, mid-Norway.

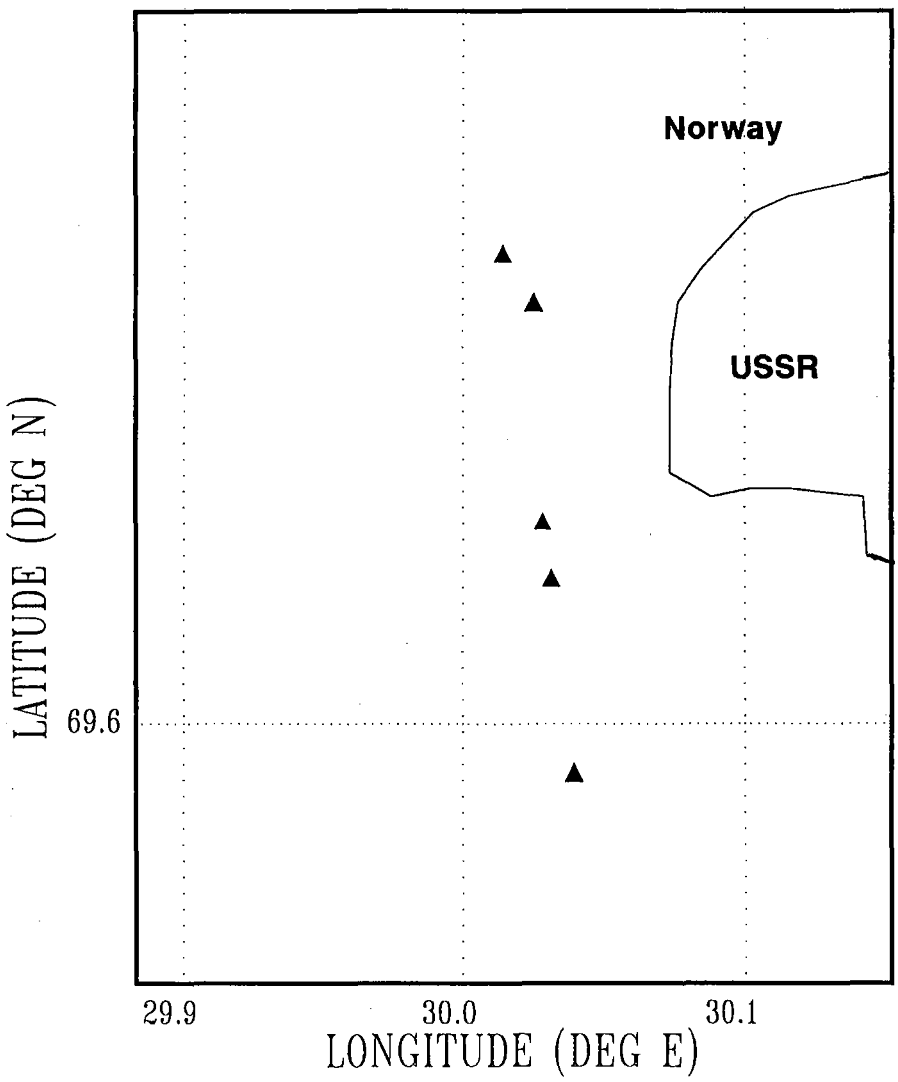

Fig. 7.5.3 Main explosion sites of the open pit mine Sydvaranger close to the Russian border in northern Norway.

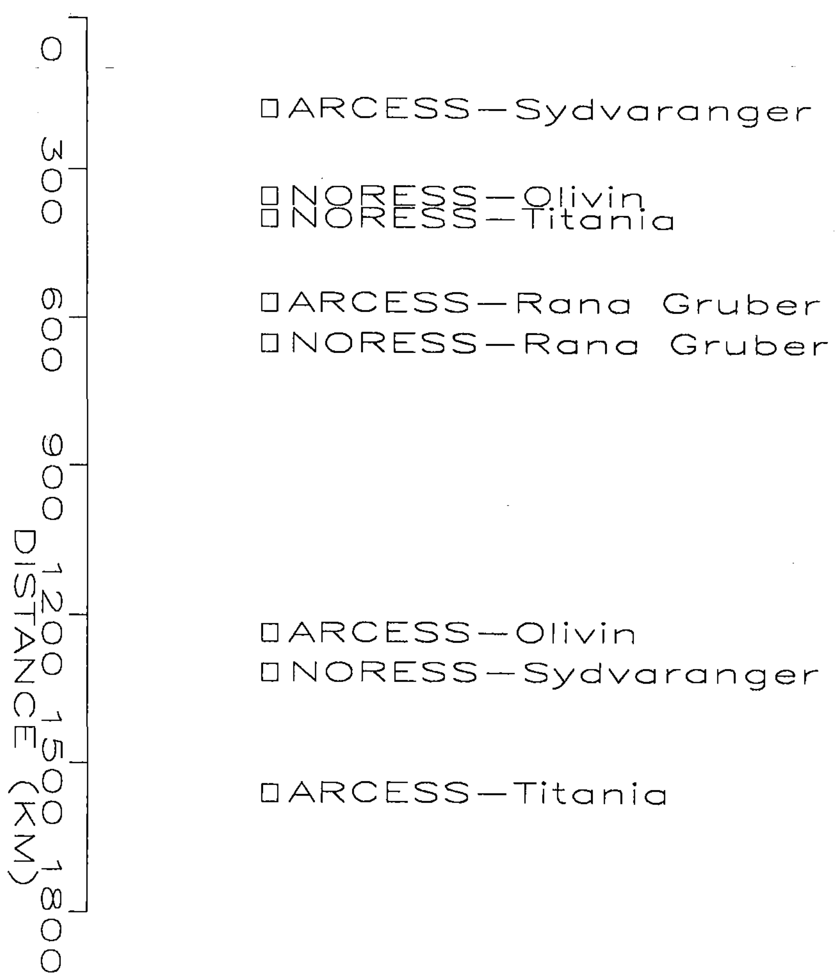

Fig. 7.5.4 Distance from ARCESS/NORESS to four of the main mines in Norway. Location of the mines is shown in Fig. 7.5.1

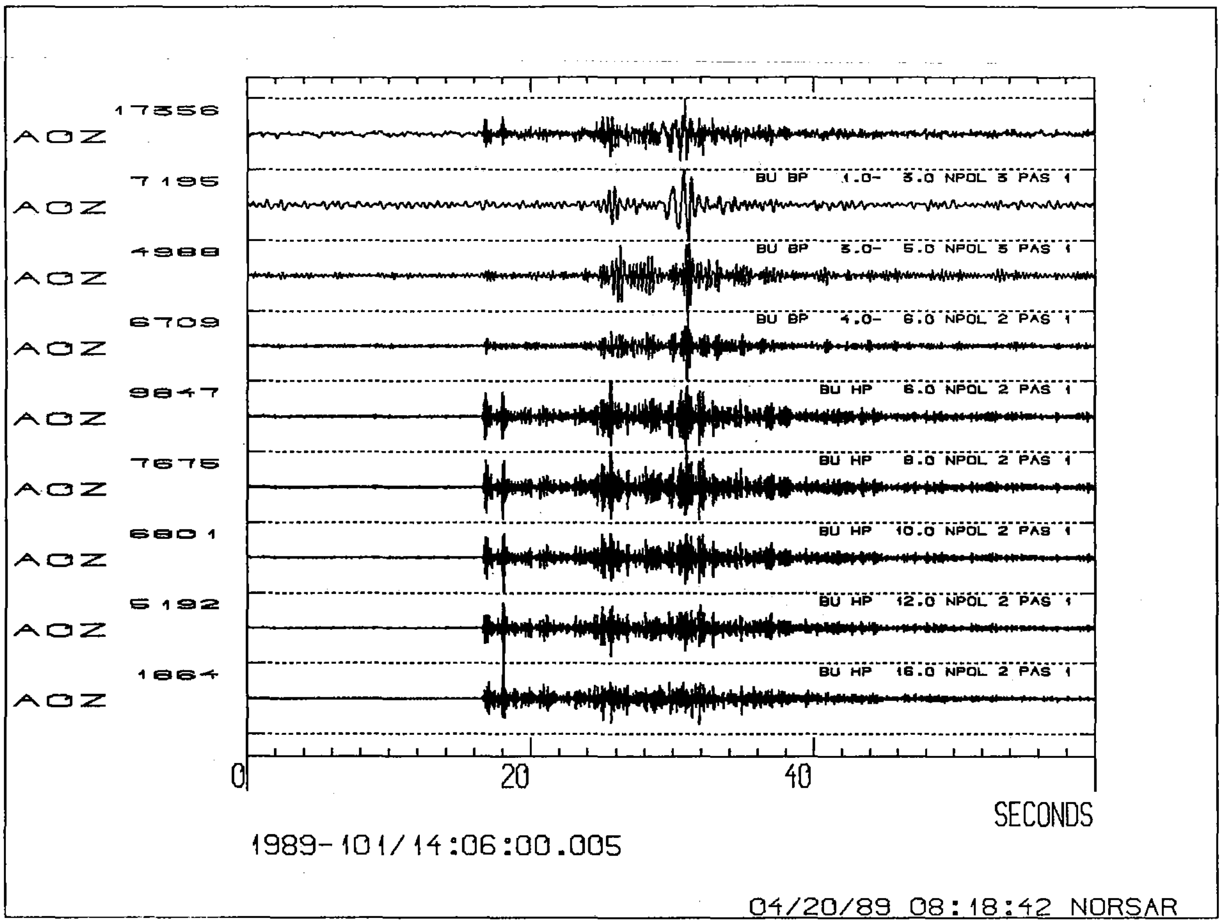

Fig. 7.5.5 NORESS single channel recording of ripple fired explosion at Sandvika (near Oslo), shown in nine filter bands. Charge was 1.615 tons over 68 delays in the time interval 0–578 ms.

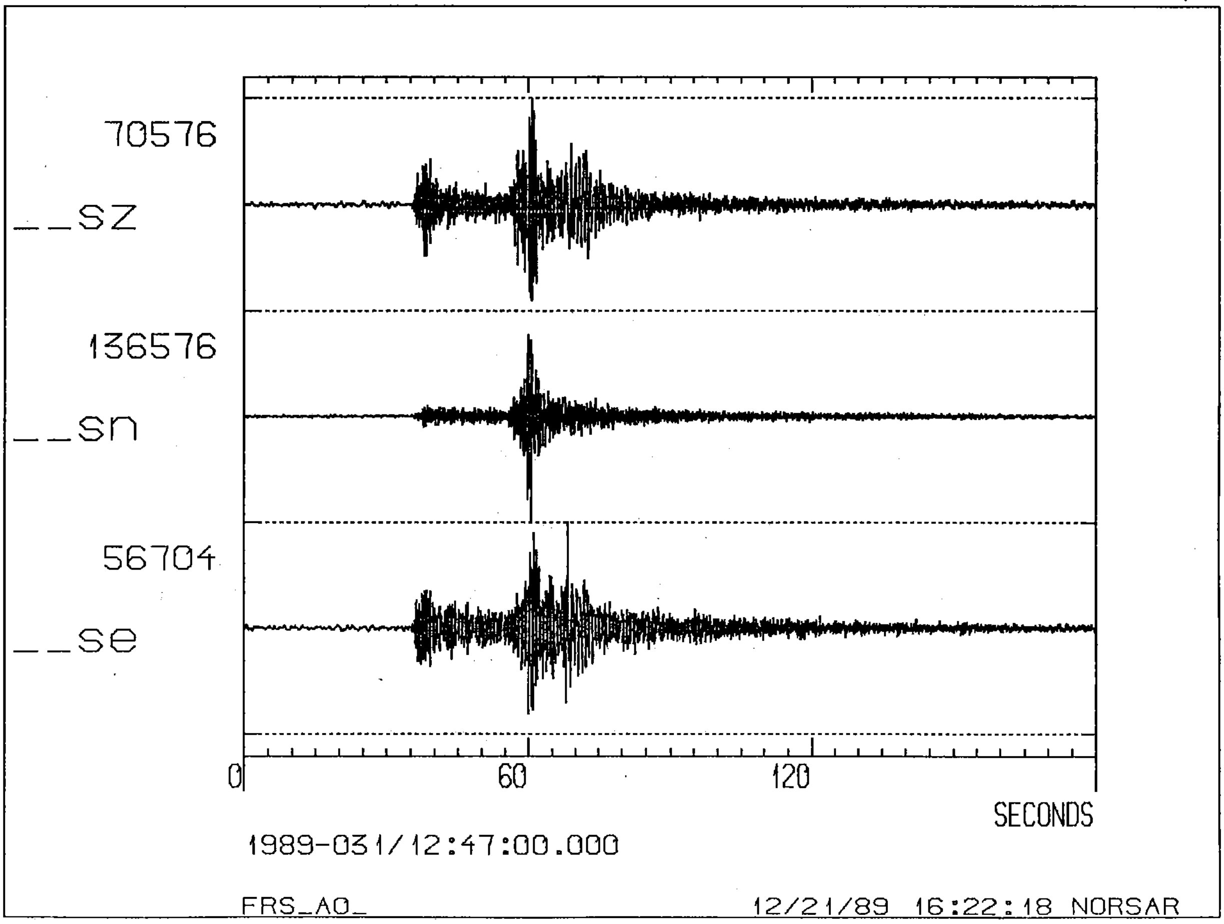

Fig. 7.5.6 ARCESS recording of ripple fired explosion at Sydvaranger, shown for a three-component station. Charge size over 200 tons.

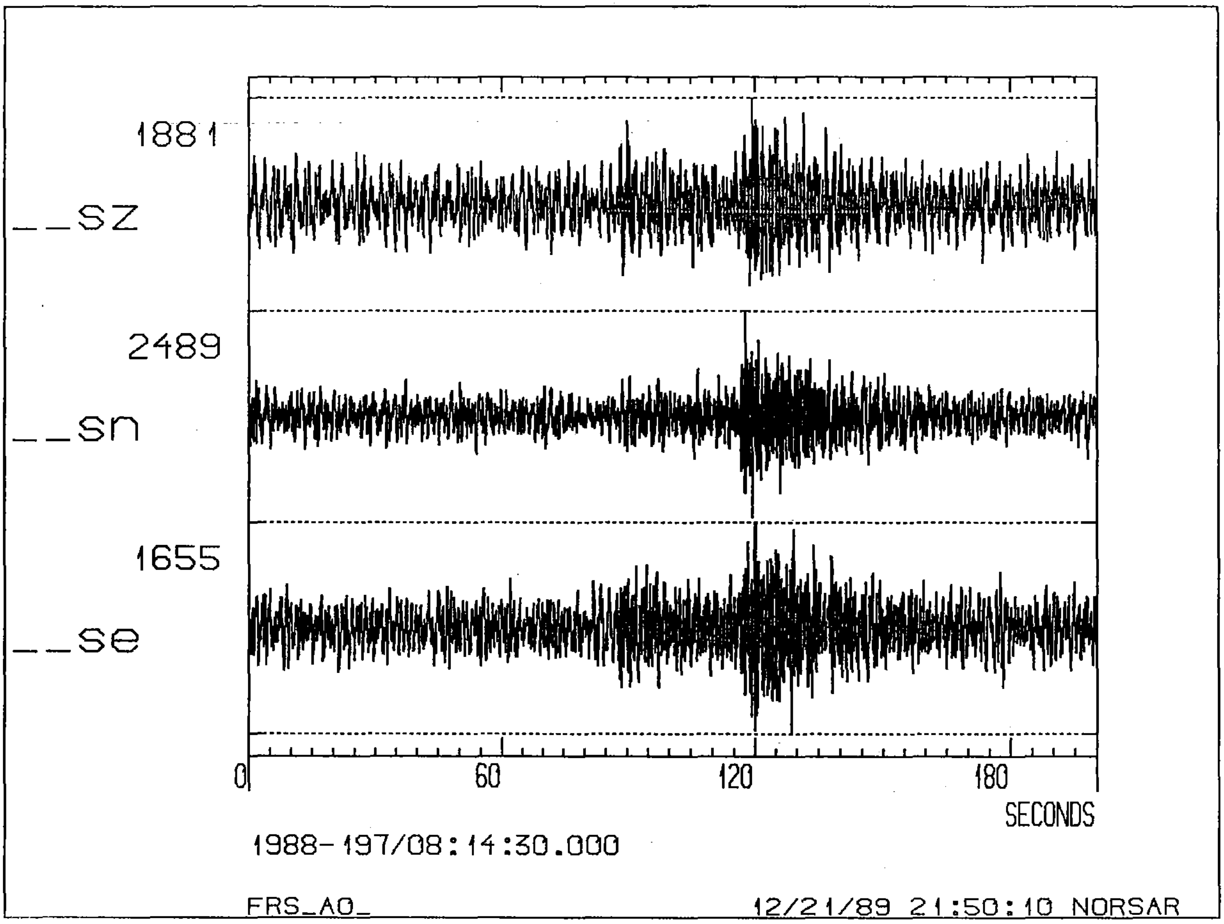

Fig. 7.5.7 ARCESS recording of ripple fired explosion at Rana Gruber. Charge was 180 tons over 34 delays in the time interval 0–1530 ms.

APPENDIX A

Note on Data Base Structure Proposal for Mine Explosion Relations

The present note proposes two relations in conformance with CSS Database Structure, Version 2.8. The relations and attributes are those proposed by NORSAR based on a sparse return of questionnaires submitted to 67 mines and quarries. The answering per cent is around 25, and it may prove necessary to include more attributes during future research and contact with the mining companies.

The relations proposed are denoted minex and minfo. Minfo contains the basic information about each mine not pertaining to specific explosions. The relation with minex is secured via the relational key minid, the unique identification number of each mine. Further attributes contained in minfo are defined below.

The minex relation contains the relational evid key and other attributes proposed for mine explosions (see below). The minex relation describes each detonated charge in ripple firing by one tuple. The number of tuples pertaining to a ripple fired explosion thus equals the number of charges in the ripple. The charge configuration attribute chacon characterizes the charge as being 'single', 'ripple', 'unknown' or 'obtainable'. In the case of 'unknown', and rdur given, the charge is a ripple but the details of the ripple configuration is only known as the time from first to last subcharge in the ripple. In the case of 'obtainable', the ripple description may be requested from the mining company.

minex

attribute name	field no.	storage type	external format	character positions	attribute description
evid	1	i4	i8	1-8	event id
time	2	f8	f15.3	10-24	epoch time of explosion
date	3	i4	i8	26-33	shot date (julian)
minid	4	i4	i8	35-42	mine id
depth	5	f4	f9.4	44-52	shot depth (km)
elev	6	f4	f9.4	54-62	surface elevation (km)
lat	7	f4	f10.5	64-73	latitude (geodetic)
lon	8	f4	f10.5	75-84	longitude (geodetic)
extyp	9	c15	a15	86-100	type of explosive
grade	10	f4	f9.4	102-110	strength relative tnt
nex	11	i4	i8	112-119	tot no. charges in ripple
subnex	12	i4	i8	121-128	actual charge number
delt	13	f4	f9.3	130-138	delay rel. first charge (ms)
rdur	14	f4	f9.3	140-148	ripple duration (ms)
totcha	15	f4	f9.1	150-158	total charge (kg)
charge	16	f4	f9.1	160-168	indiv. ripple charge (kg)
chacon	17	c10	a10	170-179	charge config. description
auth	18	c15	a15	181-195	author

minfo

attribute name	field no.	storage type	external format	character positions	attribute description
minid	1	i4	i8	1-8	mine id
minam	2	c15	a15	10-24	name of mine
lat	3	f4	f10.5	26-35	latitude (geodetic)
lon	4	f4	f10.5	37-46	longitude(geodetic)
elev	5	f4	f9.5	48-56	surface elev. (km)
prodpt	6	f4	f9.5	58-66	production depth (km)
mintyp	7	c15	a15	68-82	mine type
prodct	8	c20	a20	84-103	product
geolog	9	c30	a30	105-134	bedrock geology
firprc	10	c40	a40	136-145	firing practice
auth	11	c15	a15	177-191	author

Glossary of attributes

minid   Relations : minex minfo
Mine id; each mine is assigned a positive unique number which identifies it in the data base. (i4) No null.

extyp   Relation : minex
Explosive type; type of explosive used in a charge.(c15) Mixed case.

grade   Relation : minex
Explosive strength; messured relative to TNT=1. Slurry may be of grade 0.9, the unit weight of slurry is equivalent to 0.4 units of TNT. used to normalize charge strength to common reference strength. (f4) Null = -1.

nex   Relation : minex
Total number of charges in a ripple firing.   (i4) Null = -1.

subnex   Relation : minex
Charge number in ripple firing; sequencial unique number identifying the acctual charge for the current entry. values 1 - nex. subnex=0 means obtainable charge distribution in a ripple firing. (i4) Null = -1.

delt   Relation : minex
Delay time in ripple firing; delay for current charge (entry) relative to first charge measured in miliseconds. (f4) Null = -1.

rdur   Relation : minex
Duration of ripple firing when chacon is 'unqnown';
relative to first charge measured in miliseconds. (f4) Null = -1.

totcha Relation : minex
Total charge; sum of nex individual charges (charge) measured in kg. For single charges totcha=charge. (f4) Null = -1.

charge Relation : minex
Individual charge size in a ripple firing measured in kg. (f4) Null = -1.

chacon Relation : minex
Charge configuration attaining values 'single', 'ripple', 'unknown', 'obtainable' (c10) lower case

minam Relation : minfo
Name of mine; (c15) Mixed case

prodpt Relation : minfo
Production depth below surface in km. (f4) Null = -1.

mintyp Relation : minfo
Type of mine ; Pit or shaft (c15) Case = lower

prodct Relation : minfo
Type of product of the mine; Ore (type), rock etc. (c20)

geolog Relation : minfo
Type of geological environment; sedimentary, crystalline, metamorphic, specific rock types etc. (c30)

firprc Relation : minfo
Firing practice information; Time of day, regularity, etc. (c40)