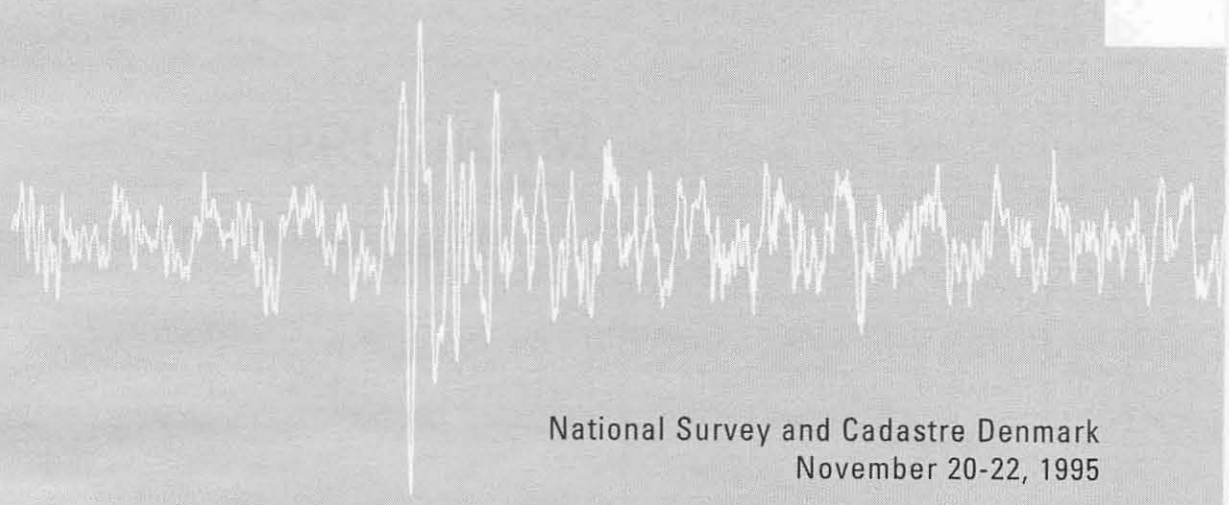
26th Nordic Seminar
on Detection Seismology

including sessions on
Nordic Engineering Seismology



National Survey and Cadastre Denmark
November 20-22, 1995

Kort & Matrikelstyrelsen

26 NORDIC SEMINAR ON DETECTION SEISMOLOGY

INCLUDING SESSIONS ON NORDIC ENGINEERING SEISMOLOGY

November 20-22, 1995
Kort & Matrikelstyrelsen
Rentemestervej 8
Copenhagen, Denmark

PROGRAM

Monday 20 November, 1995 (Meeting room 1)

1230-1245 Registration

1245-1300 Opening

1300-1440 SESSION I
SEISMIC DETECTION AND VERIFICATION
Presiding: Peder Johansen

1300 Status and plans for the GSETT-3 experiment
Frode Ringdal

1325 Experiments on detection and location capability using IRIS stations and spectral techniques for yield estimation
Roger A. Hansen

1350 Automatic estimation of phase arrival times at the GSETT-3 IDC
Tormod Kvaerna

1415 Location accuracy of Swedish events in GSETT-3
Nils-Olov Bergkvist

1440-1500 Coffee break

1500-1640 SESSION II
ARCTIC SEISMOLOGY
Presiding: Frode Ringdal

1500 Mapping active faults in the Tjörnes Fracture Zone, Iceland
Sigurdur Th. Rögnvaldsson, Ragnar Slunga, Páll Einarsson and Ragnar Stefánsson

1525 Monitoring the Mid-Atlantic ridge north of Iceland
Ragnar Stefansson

1550 Mining activity and seismic events in Khibiny (Kola Peninsula)
Elena O. Kremenetskaya, V. E. Asming and F.Ringdal

1615 Estimation of Lg wave attenuation and magnitude relations for earthquakes recorded in Finland.
Marja Uski and Antero Tuppurainen

Tuesday 21 November, 1995 (Meeting room 1, 4th floor)

0900 - 1015 SESSION III
REGIONAL SEISMICITY, ICELAND AND NORWAY
Presiding: Ragnar Slunga

0900 The SIL system, present status, ongoing development and the future.
Reynir Bodvarsson, Sigurdur Th. Rögnvaldsson, Steinunn S. Jakobsdottir, Ragnar Stefánsson.

0925 The SIL earthquake prediction project, main results, or Microearthquakes as a tool for earthquake prediction.
Ragnar Stefánsson, Reinir Bödvarsson, Steinunn Jakobsdóttir, Ragnar Slunga and Sigurdur Rögnvaldsson.

0950 New focal mechanisms and hypocentre depth for earthquakes in offshore and onshore Norway.
Erik Hicks.

1015 - 1035 Coffee break

1035 - 1125 SESSION IV
DIGITAL PROCEDURES
Presiding: Reynir Bödvarsson

1035 Slowness vector correction of teleseismic events with artificial neural network.
Timo Tiira.

1100 Effects of the acausal response of zero phase FIR filters on the onset time determination of P waves for intermediate and big earthquakes.
Steinunn S. Jakobsdóttir.

1125 - 1155 SESSION V
PRESENTATION OF POSTERS
Presiding: Erik Hjortenberg

1155 - 1245 Lunch break.
Lunch may be bought in the cafeteria, which is on the same floor.

1245 - 1400 SESSION VI
SEISMOTECTONICS ETC., DENMARK, SWEDEN, FINLAND
Presiding: Bo Holm Jacobsen

1245 Earthquakes in Denmark.
Søren Gregersen, Jørgen Hjelme and Erik Hjortenberg.

1310 Seismotectonics and lithospheric stresses in the northern Fennoscandian shield.
Rutger Wahlström and Bela Assinovskaya.

1335 Seismic anisotropy in Olkiluoto, SW Finland.
Pekka Heikkinen

1400 - 1425 Coffee break.

1425 -1555 SESSION VII
INVERSIONS TECHNIQUES
Presiding: Søren Gregersen

1425 A synthetic study of the influence of lower crustal complexity on the character of Pg and PMP phases.
Thomas Hansen, Bo Holm Jacobsen, Egon Nørmark and Niels Balling

1455 Two- and three-dimensional inverse modelling in the ray approximation.
Lars Nielsen and Bo Holm Jacobsen

1525 A rapid method for the computation of zero offset reflection profiles over complex 3-D lithospheric structure.
Morten Wendell Pedersen and Bo Holm Jacobsen.

1600 Meeting of the steering committees for SIL and COASP

1900 Dinner in the same cafeteria as used for lunch

Program for Wednesday 22 November, 1995

0900 - 1040 SESSION VIII
SEISMIC HAZARD ASSESSMENT
Presiding:Claes Dyrbye

0900 Seismic hazard assessment
Pall Haldorsson

0920 Seismic Hazard Analysis of the Rio Viejo Area, Nicaragua
Lars Maersk Hansen

0940 Excavation induced seismicity in Loviisa
Jouni Saari

1000 New spectral strong motion attenuation models for central America
Anders Dahle, Alvaro Climent, Waldo Taylor, Hilmar Bungum, Pedro Santos, Mauricio Ciudad Real, Conrad Lindholm, Wilfried Strauch and Fabio Segura.

1020 A new regional seismic zonation for Central America
C. Lindholm, W. Rojas, H. Bungum, A. Dahle, E. Camacho, H. Cowan and M. Laporte

1040 - 1100 Coffee break

1100 - 1220 SESSION IX
SEISMIC ZONATION/DESIGN PROVISIONS/EUROCODE 8
Presiding: Conrad Lindholm

1120 EUROCODE 8 - DESIGN PROVISIONS FOR EARTHQUAKE RE SISTANCE OF STRUCTURES.
Claes Dyrbye

1140 Comparative study for methods to determine the seismic response of structures.
Pentti Varpasuo

1200 Machine foundation with small allowable vibrations
Jari Puttonen, Olli Majamaki and Jouni Saari

POSTERS

Earthquake-generating hypotheses for Fennoscandia.
Rutger Wahlström.

Status of the teleseismic tomography project Tor.
Soren Gregersen.

Local tilt noise compensation on broad-band seismometers.
Alexander P. Iakovlev and V.A. Komotskiy.

Strain-inertial hybrid system for seismic signal detection.
Alexander P. Iakovlev, A.N. Gashin, A.F. Kushnir, L.G. Holcom and C.R. Hutt.

ABSTRACTS

ONGOING WORK IN EARTHQUAKE ENGINEERING AT KTH, STOCKHOLM

Anders Bodare, Department of Soil and Rock Mechanics
KTH, Stockholm

Since 1985 earthquake engineering problems in Central America have been studied at the Department of Soil and Rock Mechanics at Royal Institute of Technology (KTH), Stockholm. The work has been performed as diploma theses and has mainly concerned hazard analysis, liquefaction, soil amplification and a dam analysis. The countries visited were El Salvador, Nicaragua and Costa Rica.Below follows a list of the titles of the theses.

Diploma Theses from the Department of Soil and Rock Mechanics, KTH.

Larsson, Torleif and Mattson, Christina, (1987), "Seismic hazard analysis in Nicaragua", Examensarbete No. 3:87 JoB, KTH, Stockholm.

Johansson, Lars, O, (1988), "Seismic Hazard Analysis of Managua - Nicaragua", Examensarbete No. 3:88 JoB, KTH, Stockholm.

Toivanen, Minna and Wagenius, Johan, (1989), "Seismic aspects on building in Managua - Nicaragua", Examensarbete No. 8:89 JoB, KTH, Stockholm.

Alexanderson, Mats and Wænglund, Carina (1990), "Leon City, Nicaragua: Investigations of the consequences of strong ground motion", Examensarbete No. 5:90 JoB, KTH, Stockholm.

Hafstrøm, Per and Skogsberg, Jan, (1994), "Liquefaction during the Limon-Telire Earthquake, 22 April 1991", Examensarbete, Trita - JOB, Rapport nr 94/7, JoB, KTH, Stockholm.

Sjøgren, Stina and Søderstrøm, Catrine, (1995), "Dynamical analysis of the San Miguel Dam, Costa Rica". (in preparation)

Ingvarsson, Magnus and Johansson, Jørgen, (1995), "Amplification of earthquake induced ground movements in San Salvador, El Salvador". (in preparation)

Stål, Fredrik and Westberg, Gunnar, (1996), "Amplification of earthquake induced ground movements in Managua, Nicaragua". (in preparation)

THE SIL SYSTEM, PRESENT STATUS, ONGOING DEVELOPMENT AND THE FUTURE.

Authors: Reynir Böðvarsson (rb@geofys.uu.se), Sigurður Th. Rögnvaldsson (sr@vedur.is), Steinunn S. Jakobsdóttir (ssj@vedur.is), Ragnar Stef ánsson (ragnar@vedur.is).

The SIL (South Iceland Lowland) data acquisition system consists of 18 remote seismic stations connected through an X.25 link to a common data center. Each station is equipped with a 3-component short period or broadband seismometer, a 16-bit gain-ranging digitizer with an Omega synchronized clock and a 32-bit computer (PC) running the Unix operating system.

The automatic earthquake analysis performed by the SIL network can be divided into three categories. These are:

1) Single-station analysis performed at the site stations producing extensive information about all incoming phases, including onset time, duration, reference to previous and following phases, signal and noise averages, maximum amplitude, type of wave (P and S), P-wave azimuth and coherency and spectral parameters including DC-level and corner frequency.

2) Multi-station analysis done at the center, using the phase reports from the stations and producing information about all detected events including estimates of location, magnitude, fault-plane solutions, peak slip, slipped area and static stress drop.

3) Alert reporting to notify the operators of the network in case of a priori defined changes in parameters derived from the single- and multi-station analysis.

The main advantage of the single-station phase detection and multi-station event selection is to reduce the amount of waveform data transmitted to the center, without loosing significant data. Routine interactive analysis consists mostly of fine tuning results of the automatic analysis, such as making minor corrections to arrival time readings, and removing false events. With the current settings of operation parameters the detection threshold is about ML=0 in south Iceland and about ML=0.5 in northern Iceland. For the inner part of the country (the highland) the detection threshold is about ML = 2.0 - 2.5. Approximately 30% of the events automatically classified as earthquakes are later rejected in the interactive analysis. These false detections could easily be avoided if higher detectability threshold would be accepted. During 1994 the SIL network recorded and analyzed more than 15000 earthquakes. More than 1000 earthquakes have been recorded in a single day.

In addition to the seismic data, the system also collects data from seven volumetric strainmeters and two gravimeters.

NEW SPECTRAL STRONG MOTION ATTENUATION MODELS FOR CENTRAL AMERICA

Anders DAHLE, Alvaro CLIMENT, Waldo TAYLOR, Hilmar BUNGUM, Pedro SANTOS, Mauricio CIUDAD REAL, Conrad LINDHOLM, Wilfried STRAUCH and Fabio SEGURA.

Abstract: Cooperation between six Central American countries (Guatemala, El Salvador, Hon-duras, Nicaragua, Costa Rica and Panama) and Norway, within the frame of the CEPREDENAC organization, has made it possible to collect and analyze a data base of 280 sets of three-component strong motion recordings from Central America, including some recordings from the Guerrero array in Mexico in order to obtain a better coverage in magnitude and distance. Response spectral attenuation relations are developed for several frequencies of the response spectrum, not only the conventional Peak Ground Acceleration (PGA). The role of the PGA parameter in hazard and risk estimation will be discussed.

EUROCODE 8 - DESIGN PROVISIONS FOR EARTHQUAKE RESISTANCE OF STRUCTURES. DISCUSSION OF POSSIBLE NORDIC COOPERATION ON FORMULATION OF NATIONAL APPLICATION DOCUMENTS.

Claes Dyrbye
Department of Structural Engineering
The Technical University of Denmark

This eurocode is divided into 5 main parts, and part 1 is further subdivided in 4 parts as described below:

Part 1 : General and buildings,
- 1-1: General rules - Seismic actions and general requirements for structures (Pr may 94)
- 1-2: General rules - general rules for buildings (Pr may 94)
- 1-3: General rules - Specific rules for various materials and elements (Pr nov 94)
- 1-4: Strengthening and repair of buildings (Approved as prestandard at subcommittee meeting june 95)

Part 2 : Bridges (Pr october 94)

Part 3 : Towers, masts and chimneys (Draft ENV disapproved june 95)

Part 4 : Tanks, silos and pipelines (No progress during the last 2 years)

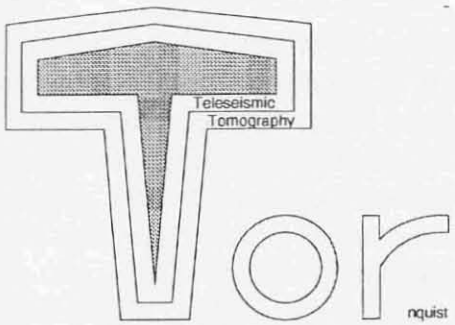
Part 5 : Foundations, retaining structures and geotechnical aspects (Pr june 94)

The seismic actions, given in part 1-1 will be discussed. The concept of response spectrum is fundamental in the formulation, for this reason it will be explained.

Like the other Eurocodes, EC8 leaves a number of decisions to the national authorities. Such decisions should be given as a National Application Document (NAD). As all the nordic countries are characteristic in having low seismicity, it may be reasonable to cooperate in the preparation of NADs for these countries.

Status of the teleseismic tomography project Tor.

Soren Gregersen, KMS, Rentemestervej 8, DK-2400 Copenhagen NV, Denmark.



Teleseismic Tomography experiment across the Tornquist Zone, for short called Tor like the Nordic God. The project is carried out by a working group with scientists from 10 European countries. It is part of the Trans-European Suture Zone project of the Europrobe program. In a preliminary experiment 24 broad band seismographs have been placed in the winter of 1994/1995 on a line crossing the Tornquist Zone in southern Sweden and Denmark. This zone is the transition between Proterozoic and Paleozoic Europe. It runs through Denmark, Sweden, Poland, Ukraine and Romania and is expected to show large lithospheric differences. The seismograms of this winters campaign show differences as well as similarities in seismic P and S wave signals across the zone. The plans for teleseismic tomography studies with 200 seismographs in the coming winters have been prepared through a feasibility study showing that the expected lower lithosphere differences can be resolved. Unfortunately we still have to wait for some months for a German decision on participation.

Earthquakes in Denmark.

by Soren Gregersen, Joergen Hjelme and Erik Hjortenberg. Office of Seismology, Geodetic Division, Kort- og Matrikelstyrelsen, Rentemestervej 8, DK-2400 Copenhagen NV, Denmark.

Abstract.

Within the last two decades the sensitivity to small earthquakes has been much improved in Denmark. Two to ten earthquakes are recorded each year of magnitudes 1½ to 4½. The seismicity pattern seen in recent data basically confirms the patterns developed from instrumental locations as well as felt areas of older dates, and this means earthquake activity in the northwest and in the northeast cutting off southwards the earthquake zones in western Norway and in southern Sweden. In north-western Jylland, and in the Skagerrak Sea the earthquake zone cuts off a zone of earthquakes along the western coast of Norway. At least some of these earthquakes in Jylland and Skagerrak occur at depths 30-40 km, close to Moho. In north-eastern Sjaelland and in Kattegat the earthquake activity occurs in the upper crust, at depths shallower than 15 km. This appears as the south-western cut-off of the scattered activity in south-western Sweden.

In general terms this can be seen as the south-western edge of the Fennoscandian Shield. The first-mentioned zone is along the middle axis of the Norwegian-Danish Basin, and the latter-mentioned zone is in the Tornquist Zone. The two earthquake zones are not connected, and this can not be ascribed to lack of sensitivity, so the Fennoscandian Border Zone can not be termed active as such, the central part of Denmark is aseismic; and the same is true for the south-western part of Denmark, just like northern Germany. In the North Sea only the graben area is active. The Viking Graben in the north has a significant earthquake activity, and the Central Graben, which goes through the Danish sector of the North Sea has small, but noticeable activity. On the British side of the graben there are additional activity areas.

The stress field responsible for these earthquakes is rather homogeneous across the Fennoscandian Border Zone, with many scattered exceptions. It reflects the general NW-SE compression of northern Europe between the North Atlantic spreading ridge and the Alpine collision.

Seismic Hazard Assessment

Pall Haldorsson, The Icelandic Meteorological Office.

Iceland is situated on the mid-Atlantic Ridge and the seismic activity there is mainly related to the plate motions across the ridge. Most of the destructive earthquakes in Iceland occur in the South Iceland Lowland and off the north coast.

Methods to estimate seismic hazard fall into two general categories: historic and deductive
methods. Until recently we have only used historical methods. It means that statistical analysis on historical and measured data have been used to estimate the seismic hazard in Iceland. We are constantly improving earthquake catalogues both for historical and measured events.

The attenuation of earthquake intensities in Iceland has been calculated and converted in the term of acceleration. The next step is to use strong motion data, for example from the SIL system, to specify the strong ground motion (acceleration and velocity) as a function of earthquake magnitude and hypo-central distance. Microzonation studies of the responcse of soils have been carried out at some sites in South Iceland.

Even though the earthquake catalogues are constantly improved, it is not probable that a hazard assessment based on them will change considerably. For some regions historical data cover a relative short period. Therefore it is also necessary to apply deductive methods, which are based on geological and geophysical research of faults, known seismic sorces, land deformation, etc.

Experiments On Detection and Location Capability Using IRIS Stations and Spectral Techniques for Yield Estimation

by

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USA

We have completed studies aimed at quantifying the performance of IRIS networks and arrays in terms of the detection and location capabilities. We have also made assessments of relative detection and location capabilities of the networks vs. the USGS PDE catalog, and the networks vs. the capabilities of the IRIS GSN stations in the region (including the CDSN and Geoscope stations). Our intent was to quantify the detection capabilities in order to predict detection and location magnitude threshold contours based upon direct observations of signal propagation characteristics in the study region. We have determined that local/regional networks and arrays can greatly enhance the detection and location capabilities of a global network of single stations. In the course of these studies we uncovered a number of practical considerations that can have a strong effect on the relevance of IRIS open station data on nuclear monitoring including general data availability, instrumentation and data acquisition characteri stics. As a result of these studies, to provide the best data for nuclear monitoring purposes we think that some mix of permanent networks and arrays is a logical and critical adjunct to the global network single station deployments. We also recommend a number of operational criteria for all IRIS open stations that will maximize their contributions to nuclear monitoring.

Seismic waves propagating from large nuclear explosions have been studied in an attempt to characterize the attenuating properties of the crust and upper mantle in the source and receiver regions. Various smoothing techniques have been applied to teleseismic P-wave spectral estimation procedures to assess relative changes in attenuation between different test sites. Attenuation changes represented by the parameter delta t* are investigated between Lop Nor and Shagan River though the techniques of direct spectral ratios, Network Averaged Spectra, and Normalized Block Averaged Spectra. Conclusions show no significant difference in attenuation characteristics between the two test sites.

A synthetic study of the influence of lower crustal complexity on the character of Pg and PMP phases.

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Bo Holm Jacobsen (geofbhj@aau.dk)
Egon Noermark (geofegn@aau.dk)
Niels Balling (geofnba@aau.dk)

Department of Earth Sciences, University of Aarhus.

Quantitative interpretation of wide angle deep seismic data is primarily based on the fitting of traveltime of the prominent P-wave phases that travel through the crust and upper mantle.

Using inversion methods (e.g. Noermark, 1993) this approach can give smooth velocity model sections where also the uncertainty of velocity values can be estimated (cf. Nielsen and Jacobsen, 1995).

However, the relatively smooth velocity distributions resulting from inverse modelling cannot explain the observed amplitude variations of the primary phases nor the additional complexity in the wave field following the prominent phases.

We show some examples of the implied seismograms for full elastic wave field propagation in models with localized complexity in the lower crust, and we discuss how such modelling can be linked to the idea of "Interpretation in Statu Nascendi" advocated by Gregersen, Thybo, and Perchuc (1995).

References

Gregersen, S., Thybo, H., and Perchuc, E., 1995, Interpretation in Statu Nascendi of inhomogenities in seismic wide angle reflection seismograms, (manuscript in preparation).

Nielsen, L., and Jacobsen, B.H., 1995, Presentation at this seminar.

Noermark, 1993, Processing and modelling of seismic data: Residual static corrections and interpretation of deep seismic wide-angle observations. PhD Thesis, Dept. Earth Sciences, University of Aarhus, 167 pp.

New Focal Mechanisms and Hypocentre Depths for Earthquakes in Offshore and Onshore Norway

Erik Hicks

A total of 13 new earthquake focal mechanisms have been compiled in Norway and it's offshore areas. Four of the focal mechanisms were determined using first motion data only, while the remainder were found using a combination of first motion data and waveform modelling. The focal depths were estimated using both waveform modelling and the RMS travel time residual criterion. In addition, a pure depth analysis by means of waveform modelling was done for six selected events on the Halten Terrace off central Norway.

Primarily, data from the Norwegian National Seismic Network (NNSN) was used, supplemented with data from the NORSAR and NORESS arrays when possible. Data from the Finesa and Hagfors arrays, and the Uppsala station have also been used when available.

The depth determination was done using the WKBJ modelling method, providing arrival times for selected phases, and by comparing synthetic to observed arrival times, a depth resolution of 2.5 to 5 km was obtainable, ignoring the model uncertainty. For focal mechanism determination, the Herrmann modelling code was used, and the relative amplitudes of the P and S phases were compared and used in addition to first motion polarities to determine the most likely solution.

Four of the analysed earthquakes were located in the Oslo rift area. All of these were relatively shallow, with three normal faulting and one reverse faulting focal mechanism. Four events occurred in western Norway, indicating deep reverse faulting in offshore areas, and a shallow tensional regime onshore. The remaining five events occured on the Mid Norwegian margin, and consist of three normal faulting and two reverse faulting focal mechanisms with depths ranging from 10 to 20 km.

Strain-Inertial Hybrid System for Seismic Signal Detection

A.P.,Iakovlev, A.N.,Gashin and A.F.,Kushnir (Joint Institute of Physics of the Earth, B. Gruzinskaya 10, Moscow,123810, Russia; 095-254-9072; e-mail: sasha@synapse.ru)
L.G.,Holcomb and C.R.,Hutt (Albuquerque Seismological Laboratory USGS, Kirtlang AFB East, Albuquerque, 87115, NM; 505-846-6973; e-mail:hutt@asl.cr.usgs.gov

The report reflects some preliminary results of investigation of Strain-Inertial Micro-Array (SIMA) concept which has been performed at Albuquerque Seismological Station by the joint efforts of ASL and JIPE representative. SIMA is a new approach to registration of seismic waves using combination of two types of instruments: 3-component broadband seismometer STS-1 and 2-comp. horizontal broadband portable strainmeter with measuring base of 2m located at the same place on the ground. The special data processing algorithms applied to 5-comp. records provides the opportunity to get SNR enhancement over single 3-comp. seismic station and to measure seismic wave apparent velocity regardless information concerning crustal structure beneath the site. These advantages of proposed method are due to simultaneous recording of distinct features of seismic field: ground surface displacement (by seismometer) and spatial derivative of this displacement (by strainmeter). Comparizon of seismometer and strainmeter data gives one the information about seismic wave apparent velocity and provides the possibility to suppress transient seismic noise propagating as a surface wave and long-period local tilt caused by local atmosphere disturbances. It is especially important for any observational coastal site where predominantly surface noise generated by the waves at sea and ocean shores. The SIMA hybrid system could be considered as the cheapest instrument able to cover the gap between a small aperture array and a single 3-comp. digital station. The adaptive statistical multichannel data processing technique was implemented. As a strain gauge we used high-resolution portable broadband strainmeter with opto-electronic displacement transducer.

Local Tilt Noise Compensation on Broad-Band Seismometers

A P Iakovlev and V A Komotskiy (Joint Institute of Physics of the Earth, B. Gruzinskaya 10, Moscow, 123810, Russia, FAX: +7-095-254-9072; e-mail:sasha@synapse.ru

In spite of great advances in seismology over the past decade brought by wide band digital seismometers, the main remaining limitation for waveform detection and analysis is interfering ground tilt noise due to atmospheric disturbances such as the direct influence of the wind on the ground surface or the indirect action of the wind manifested as tree motion or building swaying etc., especially within LP range. Our goal is to reduce such ground tilt in near-surface installed horizontal VBB seismometers using a new instrument developed at JIPE.
The Tilt Compensator Prototype is capable to record the local tilts within frequency range up to 0.003Hz with a resolution at least 10E-10rad/Hz-1/2. We used a symmetrical-balanced horizontal pendulum to exclude any component of seismic acceleration and a precise impulse opto-electronic displacement sensor to measure the pendulum position. Since tilt distribution depends strongly on the site topography therefore, it should be installed within common base with the broad-band seismometers. It is expected that the implementation of the adaptive optimal multichannel filtering procedure to suppress local tilt will be the most efficient one. The results of joint testing with Streckeisen seismometers are discussed.

EFFECTS OF THE ACAUSAL RESPONSE OF ZERO PHASE FIR FILTERS ON THE ONSET TIME DETERMINATION OF P WAVES FOR INTERMEDIATE AND BIG EARTHQUAKES.

Steinunn S. Jakobsdóttir, The Icelandic Meteorological Office, Geophysical Division.
Frank Scherbaum, University of Muenchen.

The SIL-system has now been running in automatic mode with phase-detection for four years.For strong signals we have noticed, that the automatically determined onset often was determined about 5-7 samples too early. On close inspection, we found that the phase-detector was triggered by some kind of precursory signal which showed up only for high frequency signals. In order to find out whether this precursory signal was produced as an effect of digital anti-alias filtering using a zero-phase FIR filter, we tested different procedures to correct for it.

Correcting for the acausal impulse response with a time domain recursive filter (Scherbaum 1994, Scherbaum 1994), we noticed that the precursory signal was reduced considerably. Depending on the phase properties of the decimator employed, even slight overcorrections were observed sometimes. From tests with synthetic data we found that the best results were obtained if the decimation of the original FIR filter response was performed in the frequency domain.

To improve the performance of the automatic phase picker, the acausal response of the FIR filter must be taken into account.

Scherbaum,F.: Basic Concepts in Digital Signal Processing for Seismologist, Springer-Verlag, 1994.

Scherbaum,F.: Removal of the noncausal FIR filter responce from digital seismic records. Abstract from the ESC XXIV General Assembly 1994, Athens, Greece.

Mining Activity and Seismic Events in Khibiny (Kola Peninsula)

*Kremenetskaya E.O., V.E.Asming and F.Ringdal**
Kola Regional Seismological Centre, Apatity, Russia
**NORSAR, Norway*

Seismic activity in the Khibiny massif has significantly increased since 1980. During the same time period the annual ore excavation at the six Khibiny mines has increased from 19.1 to 46.5 million tons. A geometrical correspondence between the mine configuration and the coordinates of Khibiny earthquake epicentres has been detected.

A rockburst triggering effect started to manifest itself when the depth of underground mining work had exceeded 100 m. Currently about 30% of all underground explosions induce rockbursts of significant magnitudes (i.e., rockbursts which are detectable at a distance of at least 50 km). No similar effect have been found for open-pit mining explosions in Khibiny.

Magnitude-yield correlation is demonstrated for underground explosions. The overall correlation (using all underground explosions) is about 0.72, but it is as high as 0.89 when considering explosions from Mine 3 only. This mine has a deep underground part and well recorded underground explosions.

Some of the increased seismicity of the Khibiny massif is possibly connected with the open-pit mining and could be associated with the removal of large volumes of rock. In particular, this manifest itself in a gradual displacement of lines of equal seismic energy release in the direction of the 4th mine.

THE INTEGRATED SEISMIC AND ACOUSTIC ARRAY IN APATITY

*I.A.Kuzmin, Ju.V.Fedorenko, V.I.Bondarenko and O.M.Raspopov**
Kola Regional Seismological Centre, Apatity, Russia.
** S.Petersburg Filial IZMIRAN, Russia.*

During the summer of 1994 a new type of sensors was incorporated in the existing data acquisition system of the Kola regional Seismological Centre (KRSC) of the Russian Academy of Science (RAS). Three liquid microbarographs were installed at the Apatity Seismic Array site making up a triangle with the vertices beside seismic sensors.

The main aim of the Acoustic and Seismological Equipment Complex (ASEC) is the simultanious registration of atmospheric and Earth crust oscillations generated by the same sources. The first program for ASEC was to use microbaroms and microseisms, generated simultaniously in Atlantic Ocean region during ciclonic and storm activity, for investigations of short period (dT=1-12 h) changes of the themperature and wind velocities into stratosphere (H=30-50 km) and termosphere (H=90-120 km). The microseisms will be use for a determination of the position of the oscillation sources and the changes of the parametrs of the microbaroms will characterize the thermodynamic regime of the stratosphere and the termosphere.

The ASEC creation was supported by Russian Foundation for Fundamental Invistgations (RFFI).

Seismic Hazard Analysis of the Rio Viejo Area, Nicaragua

Lars Mærsk Hansen,

VATTENFALL HYDROPOWER AB

The analysis is part of a Master Plan and Feasibility Studies of potential hydroelectric power stations. It includes probabilistic models and deterministic methods including compilations of structural geologic maps with microseismic data, and attenuation curves based on worldwide data. The study has resulted in recommended site specific peak acceleration values, and recommendations on further site specific studies including determination of spectral acceleration values.

Two- and three-dimensional inverse modelling in the ray approximation

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Finlandsgade 8, DK-8200 Aarhus N, Denmark

Abstract

Several two-dimensional (2D) and three-dimensional (3D) inversion schemes have been proposed for the determination of the seismic velocity structure in the subsurface (e.g. Lutter et al., 1990, Zelt and Smith, 1992, Nørmark, 1993, Spakman, 1986 and Hole, 1992). The inversion schemes used in this study are all based on some kind of raytracing.

2D inversion algorithms are normally based upon some simple damped least squares scheme, which assumes that the data have normally distributed uncorrelated errors. However, data errors have different sources, and some data errors may not realistically be described as uncorrelated Gaussian noise. We show that the way one accounts for correlated errors may have influence on the quality of the inverse estimate.

This study is partly motivated by the wide-angle part of the MONA LISA Project (cf. First Break, vol. 12, No. 3, March 1994/117-118), which was carried out during two surveys in 1993 and 1995 in the North Sea area. This wide-angle data set includes classical recordings along line segments, but a substantial amount of the wide-angle data were recorded at stations situated at off-line positions thus recording refracted and reflected arrivals at different azimuths. A simple 2D (pseudo 3D) approach is proposed for the investigation of the lateral resolution of this geometry. Travel time anomalies are calculated by 2D ray-tracing in vertical sections between the source-receiver pairs. These travel time anomalies are used for inversion. The 2D lateral inversion is based on the straight ray assumption, which makes the problem linear. Modelling the crust as a horizontal grid of coarse cells reduces the total number of model parameters compared to a real 3D inversion. This reduces non-uniqueness and makes the inversion fast and stable. A main drawback of the method is that anomalies can not be placed vertically correct within the crust.

The performance of a 3D inversion scheme (Hole, 1992) on the MONA LISA wide-angle geometry is investigated. The presented results indicate that large scale crustal anomalies may be imaged in a substantial part of the geometry.

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Machine Foundation with Small Allowable Vibrations

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Abstract:
In the paper the design of a machine foundation, whose allowable vibrations are smaller than about 10 (m/s within a frequency range of 0-100 Hz, has been presented. The machines will be on the second floor in the building where the vibration criterion has also been set. The equipment on the foundation will not produce any significant vibrations and all the process lines will be separated from the foundation. The main problem is the background vibration caused by natural and man-made sources such as sea waves, wind or traffic.

The measured background vibrations, their magnitude and frequency content, were principal information for the design.The ground on the site consists of several earth layers. The Bedrock lies at a depth of 10 m.The upper layers are of backfill soil and clay and the layer resting on the bedrock is of hard glacial till. Measurements utilized in structural analyses were made on the till and clay layers at the site by using velocity transducers. A city bus was found to be the most severe source of vibration. Its main excitation ranged from 5 to 15 Hz and the amplitude exceeded several times the allowable level. Similarly, the allowable level was also exceeded on the surface of the bedrock at frequencies below 2 Hz, which was concluded to be caused by sea waves striking against a nearby shore.

The problem was to design a foundation fulfilling the set criterion. Three main variants were studied: a thick concrete plate embedded on the ground, a thick plate supported by cast-in-situ concrete piles and a rigid concrete structure resting directly on the bedrock. These alternatives were analysed for the measured ground acceleration induced by the bus and including all three orthogonal acceleration components.The duration of the excitation used was 4 s. The structural analyses were made by the FEM taking account of the soil-structure interaction. Based on the analyses an alternative where the foundation rests directly on the bedrock has been selected.

A NEW REGIONAL SEISMIC ZONATION FOR CENTRAL AMERICA

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During the last two decades a number of seismic hazard evaluations have been conducted in different Central American countries, but were generally concerned with selected sites or countries, and often applied strong motion attenuation relations that were originally developed for the western United States.

As part of a wider natural disaster mitigation program, six countries in Central America have cooperated within a regional organization (CEPREDENAC) to coordinate research in seismic hazard, and develop a more unified regional approach to seismic hazard assessment. The countries involved in this work are Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama.

The results of this cooperation include the compilation of a regional earthquake catalog for which all magnitudes were converted to a homogeneous Mw scale. A new attenuation relation has been developed, and results used to make Peak Ground Acceleration (PGA) maps for annual exceedence probabilities of 0.02 and 0.002.

A new phase of regional cooperation is pending, in which the new hazard relations will be integrated with data on secondary seismic hazards at the major population centres, and the results communicated to emergency planning committees and political forums.

Automatic estimation of phase arrival times at the GSETT-3 IDC.

by

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We have investigated the problem of automatic arrival time estimation in the data processing flow at the GSETT-3 IDC. We illustrate that the current procedure provides biased estimates, and improvements are clearly needed. A new signal processing package (DFX) is now tested at the GSETT-3 IDC, and this software will hopefully remedy some of the problems.

For the purpose of contributing to improving the IDC signal processing, we have at NORSAR been experimenting with automatic implementation of an autoregressive onset time estimator provided by the Japanese NDC. We will present results from this study, as well as describing the implementation and a new metric that enable us to automatically distingush between "good" and "bad" onset estimates.

Status and plans for the GSETT-3 experiment

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The Conference on Disarmament's Group of Scientific Experts (GSE) has since 1 January 1995 been conducting a large-scale global test of an experimental International Seismic Monitoring System (ISMS), designed to assist in the verification of a Comprehensive Nuclear Test Ban Treaty (CTBT). This experiment, which is denoted
GSETT-3, has the following principal components:

-- A global monitoring network of seismic stations meeting agreed rigorous technical specifications. The stations of this network are specifically designed and located to provide detection of seismic events throughout the world. The operation of the stations are designed to ensure uninterrupted streams of reliable data, even from stations located in remote areas.

-- An International Data Center (IDC) which receives the data from the monitoring network, applies standard analytic processing techniques to these data, and provides this information, along with other "standard services," to the National Data Centers of participating States. The IDC also collects other seismological information from the NDCs. All data received at the IDC and the data products created at the IDC are archived and provided for open access by any participating State.

-- National Data Centers (NDC) established in participating States. The NDC's receive all of the data collected at the IDC and the standard service products supplied by the IDC. The NDCs also compile supplementary national data on seismic activity and may submit this information to the IDC.

The global seismic monitoring network is a two-tiered network of Alpha and Beta stations. The first tier of stations, or Alpha stations, is composed primarily of arrays of sensors, with some three-component stations, which would provide for the main detection of seismic events on a global basis for the ISMS. The second tier of stations, or Beta stations, would provide supplementary data so that events detected by the Alpha stations could be located with improved accuracy.

Participating States may also make available supplementary data from national and regional networks that are not formally part of the ISMS. This national information is referred to as Gamma data.

In this presentation, a brief overview will be given of the current status of GSETT-3 operations, as well as the plans for the future. It is expected that GSETT-3 will gradually evolve into the seismic component of the eventual monitoring system which will be established after a CTBT is signed.

Mapping active faults in the Tjörnes Fracture Zone, Iceland.

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The Tjörnes Fracture Zone (TFZ) is a broad transform zone connecting the rift zone in northern Iceland to the Kolbeinsey ridge. It is a zone of complicated structure, strike-slip faulting, crustal dilation and recent volcanism. The transform motion takes place in three zones, the Grímsey zone, the Flatey-Húsavík fault, and the Dalvík zone. They are marked by a concentration of microseismicity, and earthquakes larger than magnitude 6 are known to have occurred in all three zones. The seismic lineaments trend 120°E, i.e. at an angle of about 20 degrees to the local spreading vector. The Flatey-Húsavík fault is a well defined dextral strike slip fault that became active four M.y. ago in response to an eastward shift of the rift zone. The fault is partly exposed on land. The accumulated slip on the fault is 10–60 km horizontally and 200–1400 m vertically. The Grímsey zone is not exposed on land. It is marked by a magnetic anomaly, earthquake swarms are frequent and evidence of recent volcanism has been found. A permanent network of six digital seismic stations that was installed around the TFZ in 1993 has recorded numerous earthquakes and earthquake sequences within the zone. We study the mode of faulting along the principal seismic zones by determining relative location of hypocenters within earthquake clusters and studying their focal mechanisms. We selected 28 earthquake clusters consisting of 686 earthquakes from the data set. We relocated each cluster seperately, determining both absolute and relative locations for each event in the group. The estimated relative location uncertainty is 1–20 m for most of the relocated earthquakes. To estimate the orientation of the fault planes, we determine the best fitting plane through each cluster and assume this to coincide with the fault plane of the group of earthquakes. Fault planes estimated in this manner for clusters near the Flatey–Húsavík fault have

strikes between 115°E and 134°E and dip 80–90 degrees to the south, comparable to the strike and dip of the fault zone itself. The slip is right–lateral strike–slip, in agreement with field observations. The earthquake clusters in the Grímsey zone, on the other hand, define steeply dipping (71–90 degrees) planes, striking roughly north–south, i.e. at an angle of 40–90 degrees to the overall trend of the seismic lineament. Faulting on the N–S planes is mostly left–lateral strike–slip with a considerable dip–slip component. The two zones thus have a totally different way of accomodating the transform movements. The Flatey–Húsavík fault is a simple strike–slip feature, whereas the Grímsey zone is characterized by bookshelf faulting, i.e. by strike–slip faulting on a series of transverse faults and the rotation of the blocks between them. The difference in the mechanics of the two zones may be related to the different age of the zones. The Flatey–Húsavík zone is a mature fault that has been active for 4 M. y. The Grímsey zone is presumed to be about 1 M. y. old, and the bookshelf faulting presently observed suggests an even lower age.

EXCAVATION INDUCED SEISMICITY IN LOVIISA

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ABSTRACT: The Loviisa nuclear power plant is located on the island of Hästholmen, in south-eastern Finland. The low- and medium-level waste from the power plant will be disposed in bedrock of Hästholmen. The structure of the rock mass is dominated by three gently dipping fracture zones called the upper, lower and intermediate fracture zones. The repository is located between the upper fracture zone and the intermediate fracture zone.

The stability and the fault geometry of the surrounding rock mass was evaluated by observing microearthquakes induced by the excavation repository. The first experiment was performed from the middle of November 1993 to the end of February 1994. During this period excavation proceeded about 200 meters and went trough the upper fracture zone. The second period of measurements were performed from the middle of March to the middle of June 1995, when two 100 meters long caverns for maintenance waste were excavated.

Altogether 40 microearthquakes were observed. As expected, most of the events occurred within the distance of 10 meters from the structure excavated. The furthermost event occurred 50 meters away from the tunnel, before the excavation reached the fracture zone. The event extended the modelled geometry of the upper fracture zone.

Three earthquake sequences were observed. They illustrated quite clearly the fracture geometry as well as the mechanism of the strain release. In the first sequence, four earthquakes proceeded 28 meters along the upper surface of the upper fracture zone. The second one consisted of six events, which proceeded 42 meters in 12 second following the tunnel orientation. Based on this sequence and the visual observations in the access tunnel, the former geometry of the intermediate fracture zone was reinterpreted. During the third sequence of six events, the seismic emission proceeded in five second 38 meters towards Northeast along a vertical set of fractures.

The events induced by the excavation of the access tunnel were related to horizontal fractures. According to the interpretation, the excavation of the cavern induced right lateral strike-slip movement in vertical set of fractures running in the direction SW-NE.

THE SIL EARTHQUAKE PREDICTION PROJECT, MAIN RESULTS, OR MICROEARTHQUAKES AS A TOOL FOR EARTHQUAKE PREDICTION.

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The SIL project is a cooperation of the Nordic countries in earthquake prediction research in Southern Iceland. It started in 1988. A central concept in SIL project has been to understand the physical processes leading to earthquakes. Therefore it was of central importance to study the information carried almost continuously with microearthquakes from the focal regions of the future large earthqual The objective of the project was to construct a data-acquisition and evaluation system which could in semireal time perform high level evaluation of data carried by microearthquakes. Of course it should also contain the slower data.

The main results of the project can be summarized along two lines. First the alerting qualities of the SIL system, secondly its achievements in making use of microearthquakes.

An automatic alerting system is now operated on basis of the SIL system. It gives alerts in a few minutes, if seismic rate or strain release rate is above predefined levels in different locations. Such alerts give rise to manual inspection. These alerts have already for three years been of practical use for volcanic eruption warning. Station alert is under testing. It will give within seconds alerts of large events or changes in noise properties, say from volcanic or earthquake sources. Alerts from slow monitoring f.ex. from strainmeters are included in the station alert system.

It has been shown that that automatically calculated fault plane solutions of earthquakes down to magnitude zero give results which are internally consistent and consistent with tectonic features. It has been shown that active minicracks at 2-10 km depth within the seismic zone can be traced with the accuracy of a few tens of meters by combining the use of joint hypocenter evaluation procedure and fault plane solutions. It can be foreseen that it will be possible to get information about stress and stress changes in real time from microearthquakes, both resulting stress changes within the region caused by external forces as well as features of stress concentrations in the close focal region of an impending earthquake.

The SIL system concept and evaluation properties has a wide range of applicability to other fields than earthquake prediction. The ability to trace active cracks below the surface is significant for monitoring changes caused by water or thermal heat extraction. The information on cracks as well as on crustal structure in general is significant for hazard assessment. The wide range of applicability is significant for the earthquake prediction research project making it less vulnerable for lack of immediate prediction success.

Slowness vector correction of teleseismic events with artificial neural network

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Abstract:
The slowness anomalies cause serious location errors. In this paper the problem is tackled using artificial neural network (ANN). One way to describe ANNs is that they are a tools which map one space to another space. They perform a transformation from input space to output space. In this work input space consists of observed slowness vectors and output space of corrected values. The ANNs are trained to perform the tasks presented to them. The training is done using a training database, which consists of known previous examples of the problem. The inputs in the training database are observed azimuth and velocity and the target outputs azimuth and velocity computed using the locations of the stations and epicenters. After training the ANN will do a transformation, which simulates the transformation from inputs to target outputs of the training database.

The training data set consisted of 2218 events from years 1988-1992, that were found both in PDE lists and bulletin resulting from interactive analysis at the Institute of Seismology, University of Helsinki. An independent test data base consisted of 1091 events from year 1993 and first half of 1994. In order to make the problem easier and to get more accurate results the task was divided in two by training separate nets for azimuth and velocity values. Another division into 2 was made to avoid the discontinuity from 0 to 360 degrees in azimuth values. Separate nets were trained for 2 hemispheres. To help the mapping at inactive areas, a set of grid points with theoretical azimuth and velocity computed using travel time tables in both input and output were added to the training data base.

The type of ANN that was used is multilayer perceptron (MLP). The ordinary configuration of MLP was slightly changed to improve the mapping. Extra bias values dedicated to each geographical region were added to the hidden layer. The MLP could use these extra biases as a lookup table of area dependent parameters, which were given optimal values during training. Several MLPs of different size were tested.

The uncorrected locations showed clear systematic error compared to PDE locations. Use of ANN correction removed most of the systematic error. The median of error dropped from 4.96 degrees to 1.48 degrees. Areal density of events in the training data base had only small influence on the results.

ESTIMATION OF Lg WAVE ATTENUATION AND MAGNITUDE RELATIONS FOR EARTHQUAKES RECORDED IN FINLAND

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We have computed a total of 1259 synthesized Wood-Anderson seismograms from 216 local and regional earthquakes recorded by the Finnish seismic network between February 1979 and June 1994. The magnitudes of the events range from 1 to 4, and the hypocentral distances from 25 to 1940 km, with the best amplitude control being from 400 to 1200 km. Maximum Sg/Lg amplitudes and periods measured from those recordings have been inverted to determine time-domain Sg/Lg wave attenuation characteristics, M_L magnitudes, and station corrections for the 11 stations used in this study.

Two different models have been used to parametrize the decay of Sg/Lg wave amplitudes versus distance. First, we have tried a "bilinear" function, $-\log A_0(f)$, in which the amplitude decay is described in terms of a frequency-dependent anelastic attenuation and a geometrical spreading with separate rates for Sg and Lg domains. Best fit to the data has been obtained by using 350 km as the transition distance from dominantly Sg type to Lg type propagation. The second function, $-\log A_0$, comprises a frequency-independent anelastic attenuation term and a single geometrical spreading term for the whole regional distance range. The results are as follows:

$-\log A_0(f) = 1.27 \log R + 0.00041\, f^{0.36} R + 0.36 + S$ for $R \leq 350$ km

$-\log A_0(f) = 0.83 \log R + 0.00041\, f^{0.36} R + 1.48 + S$ for $350 \text{ km} < R \leq 1900$ km

and

$-\log A_0 = 1.42 \log R + 0.00008\, R + 0.15 + S$ for $R \leq 1900$ km

where R is hypocentral distance in kilometers, f is frequency (Hz), and S is station correction. Calibration to the Richter's original definition of M_L has been achieved by constraining the $-\log A_0$ and $-\log A_0$(10 Hz) curves to equal the $-\log A_0$ for southern California at R = 60 km.

In addition, we have determined a correction to accommodate the use of vertical seismograms in the new M_L formulae. The logarithm of the horizontal (H) to vertical (Z) shear wave amplitude ratio is distance-dependent : $\log(H/Z) = 0.00009\, R$.

The difference in magnitudes computed from the above distance correction functions is less than 0.1 units. The frequency-independent form is preferred as it is simple to apply in routine bulletin work.

The frequency-independent M_L formula reads as:

$M_L = \log A + 1.42 \log R + 0.00017 R + 0.15 + S$ for $R \leq 1900$ km

where A is synthesized Wood-Anderson amplitude (mm) measured from vertical component seismogram.

SEISMOTECTONICS AND LITHOSPHERIC STRESSES IN THE NORTHERN FENNOSCANDIAN SHIELD

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The seismicity, fault distribution and stress pattern of northern Fennoscandia were investigated. The discrimination of many mine explosions in NW Russia and northern Fennoscandia have usually been made in a reliable way in Finnish catalogues. Some active fault zones are suggested, e.g., several faults exposed to large displacement at the late-glacial phase about 9,000 years ago. Stress orientations, derived from crack distribution and earthquake focal-mechanism solutions, are different in different areas; in some areas there is a good agreement with expectations from ridge-push generated and propagated compressive stress. However, the mechanism solutions are few and not very well constrained. There are likely two seismogenic processes acting in the region: Isostatic land elevation and plate tectonic ridge push.

Earthquake-Generating Hypotheses for Fennoscandia

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Extensional horizontal strain is higher than compressional horizontal strain in the Fennoscandian shield. In the northern part of the shield, the seismicity is high where there is a maximum curvature of land uplift. Large boulder caves, fault scarps and landslide scars in northern Fennoscandia have been connected to large earthquakes (up to magnitue 8 or larger) in the late-glacial period. These phenomena suggest that isostatic uplift following the latest glaciation-deglaciation cycle may be a cause of current seismic activity. Differential strain along the Bothnian coast of Sweden could be a seismogenic factor related to long-term isostasy.

Temporal correlation of the seismic activity in the shield with that of segments of the North Atlantic Ridge supports the idea of ridge-push generated stresses released in zones of weakness in the shield. Short-term fluctuations in large-scale asthenospheric movements may be an alternative explanation.

Earthquake focal-mechanism solutions show a variety of faulting styles and stress orientations. Clearly not all of them can be accounted for by ridge push. However, mechanisms obtained for a majority of microearthquakes in southern Fennoscandia indicate stresses reconcilable with the plate tectonic related hypothesis.

The b value and the rate of land elevation are larger in northern than in southern Fennoscandia. The idea has been put forward that ridge push and uplift are counteracting forces in the north, preventing large stress accumulation and thus implying a large b, whereas the small or zero uplift in the south permits larger stresses to be built up and thus the share of large earthquakes is increased (small b).

It is likely that both isostasy and ridge push contribute as seismogenic processes for Fennoscandia.

A rapid method for the computation of zero offset reflection profiles over complex 3-D lithospheric structure.

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Migration and modelling of 3D data are essentially the same operation and both can easily require access to RAM recources that don't match todays workstations or supercomputers. For modelling of realistical sized zero offset deep seismic dataset we therefor use a diskbased scheme for 3D inverse Stolt migration. The inverse Stolt migration does exactly the opposite of the well known Stolt migration, and maps the reflectivity function from $(k_x\, k_y\, k_z)$ to 3D zero offset data $(k_x\, k_y\,)$ in the 3-dimensional Fourier domain.

Blockmultiplexing of the data volume ensures, that only one pass through the data for each of the spatial directions is nescesarry and with a reasonable choosen blocksize the number of diskaccesses can be strongly reduced compared to "brute force" diskbased modelling.

Our models are given as 3D acustic impedance distributions on a regular grid from which the reflectivity function can be derived.

A set of relative simple examples demonstrate how complex, but geological realistic, 3D reflector geometries show up on 2D sections. We discuss the use of this program package in the interpretation of given 2D datasets as well as in the experiment design phase of new acquisition programs.