UNIVERSITY OF HELSINKI

The 38th Nordic Seismology Seminar

Institute of Seismology
June 13-15, 2007
Helsinki, Finland

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University of Helsinki

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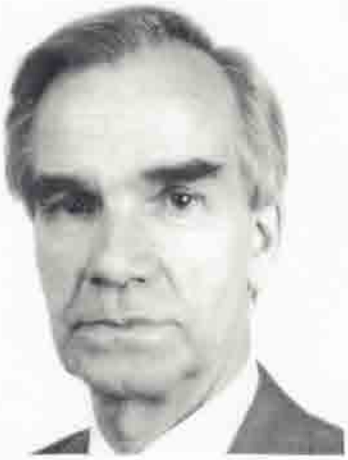
Heikki Korhonen – in memoriam
Programme
Abstracts
List of participants
Maps

Heikki Korhonen in Memoriam 1924-2007



The former director of the Institute of Seismology of the University of Helsinki, professor Heikki Korhonen died in Helsinki on March 25 2007 at the age of 82. He was born 1924 in Karelia in Kuokkala, today a part of Russia.

After graduating in high school in 1942 he worked as a high school teacher in mathematics and physics for ten years in 1947-1957. While working he also studied at the Helsinki university, obtaining MSc degree in geophysics 1960. He got his PhD in 1971. Heikki started his career as a researcher in 1963 at the Oulu University, getting a position as a seismologist in 1968. In 1977 Heikki became the director of the Institute of Seismology. He retired in 1992

Heikki's own research area was microseism, which was also topic of his PhD thesis. His publication list contains over 100 publications. As the director of the institute his contribution was of great importance when the deep seismic soundings were started in late 70's. Our understanding on the structure of the Earth's crust in Finland is still largely based on these studies. Heikki was also active in monitoring seismology. Since 1979 he represented Finland as a scientific expert in Geneva disarmament talks. One should also mention his efforts in building up the Sambian seismic network and in further education of Sambian seismologists.

Heikki was very active both in national and international scientific organisations. He was the chairman of the Geophysical Society of Finland in 1978 and the president of the EMSC in 1982-1988. In 1982 he was elected as a member of the Finnish Academy of Sciences and Letters. He was also the Honorary Member of the Geophysical Society of Finland.

Heikki was an inspiring leader. He had the skill to organise large research efforts, find funding for them and, using his wide network, find people and institutions to work together. Especially the Nordic co-operation was very close to his heart. All of us in this Nordic Seismology Seminar will miss him.

PROGRAMME

Wednesday 13th June 2007

12:00	Registration
13:00	Pekka Heikkinen: Opening address

Session I: Seismograph stations, monitoring seismology and monitoring technologies

Chair: Matti Tarvainen

13:10	Moring, M.: CTBT Radionuclide monitoring and the Finnish NDC
13:30	Nedgård, I.: Discrimination of seismic events in Iran by waveforms from the International Monitoring System
13:50	Voss, P.: The Seismological Network in Denmark and in Greenland, and applied research
14:10	Kværna, T. and Ringdal, F.: The Capability for Seismic Monitoring of the North Korean Test Site
14:30	Break

Session I (Cont.)

Chair: Jens Havskov

15:10	Lindblom, P. and Kortström, J.: Seismic stations and data flow – operators' view on daily routines
15:30	Gibbons, S.J.: Lowering the Seismic Detection Threshold in the European Arctic using the Upgraded SPITS Regional Array
15:50	**Posters:**
	Mäntyniemi, P.: Town of Tornio in November 1898: a rare survey of earthquake damage in Finland
	Korja, A., Heikkinen, P., Tiira, T., Hyvönen, T. and FIRE Working Group: Seismic Images of the Svecofennian Orogen
17:00	Ice Breaking Party, Exactum, 4th floor

Thursday 14th June 2007

	Session II: Crustal structure, modelling Chair: Bela Assinovskaya
10:00	Korja, A., Heikkinen, P. and Kosunen, P.: Seismic images of Paleoproterozoic continental growth in Fennoscandia
10:20	Heikkinen, P., Koivisto, E. and Kukkonen, I.: FIRE high resolution seismic reflecetion survey in Outokumpu
10:40	Hjortenberg, E.: Fractals and Earthquakes
11:00	Break
	Session III: Earthquakes, seismicity Chair: Ragnar Slunga
11:20	Soosalu, H., White, R.S., Knox, C., Jakobsdóttir, S.S. and Einarsson, P.: Discovery of lower-crustal earthquakes down to ~30 km depth near the Askja volcano in north Iceland
11:40	Uski, M.: Hypocenter distribution of earthquakes in north-western Finnish Lapland: Preliminary investigation
12:00	Ottemöller, L.: Moment tensor solutions calculated for two M>4 UK earthquakes in 2007
12:20	Lunch hosted by the Institute of Seismology at Dynamicum, Erik Palménin aukio 1, top floor
	Session III (Cont.) Chair: Pekka Heikkinen
13:30	Heinloo, O.: On Finnish travel-times lines based analysis of local seismic events on territory of Estonia
13:50	Assinovskaya, B. and Karpinsky, V.: Ladoga seismic observations
14:10	Sveinbjörnsson, H.: Mapping quakes with Google Earth
14:30	Bödvarsson, R.: SNSN developments
14:50	Mäntyniemi, P., Eystein S. Husebye, E.S. and Gregersen, S.: Research Initiative for a Northern European Intensity Databank (short communication)
15:00	**General discussion**: Hot spots in seismology in Nordic countries (data exchange ? education ? etc.)
18:00-22:00	Dinner Cruise on the boat m/s Merisaraste, starting from the Helsinki Market place, Pier nro 4, beside the Old Market Hall, Eteläranta 1

Friday 15th June 2007

Session IV: Seismic risk and seismic hazard assessment
Chair: Tormod Kværna

10:00	Havskov, J. and Eltahir, N.B.: Is Sudan dangerous?
10:20	Slunga, R.: How microearthquake monitoring of the absolute crustal stress field can be used for improved earthquake warnings
10:40	Roth, M. and Blikra, L.H.: Passive seismic monitoring of the Åknes rock slope, Møre og Romsdal, Norway
11:00	Saari, J. and Lakio, A.: Seismic Monitoring of Nuclear Waste Repository-Four Basic Applications
11:20	Closing Remarks

Presentations

Assinovskaya, B. and Karpinsky, V.: Ladoga seismic observations

Bödvarsson, R.: SNSN developments

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Korja, A., Heikkinen, P., Tiira, T., Hyvönen, T. and FIRE Working Group: Seismic Images of the Svecofennian Orogen (poster)

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Ladoga seismic observations

Bela Assinovskaya[1] and Vladimir Karpinsky[2]

1) Central Astronomical observatory at Pulkovo RAS (bassin@mail.wplus.net)
2) Seismic station Pulkovo Geophysical Service RAS

The Saint-Petersburg region and surrounding is characterized by very high level of man-caused seismic activity. According to Helsinki bulletins about 700 seismic events occur here annually. Up to 2006 only Finnish seismic network has operated in this border region but now permanent digital seismic registration is organized in the region including the Valamo archipelago (central part of the northern Ladoga). The station is situated on the south-west of the Valamo Island; it is equipped by short period three component seismometers Teledyne Geotech GS-13. Numerous Ladoga historical seismic events with magnitudes M = 2- 3 were revealed in the result of Valamo Cloister archive data research. Their macroseismic effect looked like sounds – strokes but sometimes there were ground shakings. Epicentral zones of these events were situated on the western part of the Ladoga at a distance of about 20 km from Valamo. The long-term seismic registration coincidentally with macroseismic observations should to confirm or to disprove tectonic origin of mentioned above historical events. We have obtained first results. During half a year seismic station registered about 300 events probably quarry explosions from a distance of 40-150 km with magnitude ML 0.5 – 2.7. About 30 occurrences were felt with intensity 3 around the station. Some of them are strong quarry explosions with magnitude ML ~ 2.5 located at a distance of 40-50 km from the station. Other group of felt events occurred in water area at a distance not more 5 km from the station on a very shallow depth. Digital data processing in particular spectra evolution, polarization analysis, wavelet transformation were applied to reveal these events origin.

SNSN developments

Reynir Bödvarsson

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Over the last few years, 60 new, permanent, digital, broadband seismological stations have been deployed in Sweden, from Lannavara in Lappland in the North to Skåne in the South. The network operates largely automatically, and is now essentially complete. The network will be further developed during the coming years for real-time monitoring of local, regional and global events. Good number of stations will be made available to the seismological community in real-time.

Lowering the Seismic Detection Threshold in the European Arctic using the Upgraded SPITS Regional Array

Steven J. Gibbons

NORSAR (steven@norsar.no)

The small aperture SPITS array underwent a major upgrade in August 2004, implementing three major changes. The short-period instruments were replaced with broadband sensors, the sampling rate was increased from 40 Hz to 80 Hz and, thirdly, 3-component seismometers were installed at six of the nine sites. Three small seismic events close to Novaya Zemlya in the eastern Barents Sea, during March 2006, illustrate some of the advantages to signal detection and parameter estimation which have resulted from the upgrade.

Signals from the Novaya Zemlya events, at distances exceeding 1000 km, are demonstrated to contain significant energy well in excess of 20 Hz - the Nyquist frequency of the old system. The most important improvement to the detection capability for regional events in the European Arctic is the ability to form beams using the rotated horizontal components which provides a large improvement in SNR for the Sn-arrivals.

With six three-component sites, it is possible to estimate apparent velocity and backazimuth using f-k analysis on the horizontal components. The transverse components are significantly more coherent than the vertical components for Sn phases and are significantly less coherent for P-arrivals. This provides a useful criterion for discriminating between the important and sought-after Sn phases from events at regional distances and the crustal P-phases from very local events which arrive with similar apparent velocities.

Is Sudan dangerous?

Jens Havskov[1] and Nada Bushra Eltahir[2]

1) Department of Earth Science, University of Bergen (jens@geo.uib.no)
2) Geological Research Authority of Sudan (GRAS)

Though Sudan is characterized by low seismic activity, several big earthquakes have been recorded, which resulted in loss of life and damage to properties. The largest of these was probably the largest earthquake in Africa in the 20th century. It occurred on 20 may 1990 (Ms=7.1-7.4) near Juba in the southern part of Sudan. There have been other earthquakes whose effects caused major damage and even deaths in the interior of Sudan and the latest was the Khartoum event (Ms=5.5) of August 1993. This prompted the Sudan Geological Research Authority (GRAS) to establish a three station seismic network around Khartoum in 2001. The University of Bergen, has, for the last year established contacts with several research institutions in Sudan and seismology is part of this collaboration.

The local network around Khartoum has, for various reasons, and despite a good signal to noise ratio, recorded few events. It is of particularly interest to investigate the local seismicity around Kharthoum to better establish the potential for large events since a magnitude 5.5 event in Khartoum could be a disaster. Apparently the area has a very low seismicty level with only a few local events per year and there has not been any known events larger than Ml=4 since 1993. The long term seismicity rate is similar to the New Madrid area and there are potentially large geological structures which could support a large earthquake. Some of these structures apparently are seismically active. However there is no evidence of historical large events. More data will have to be collected to evaluate the true seismic hazard potential around Khartoum.

The Juba area in southern Sudan is regularly experiencing larger earthquakes and the seismic hazard is significant. However the risk is low since there are few vulnerable buildings. Due to the distance to Juba, the local network record few events from the area and no other seismic stations are located near Juba so all information about Juba seismicity comes from the Global Seismic Network.

FIRE high resolution seismic reflecetion survey in Outokumpu

Pekka Heikkinen[1], Emilia Koivisto[2] and Ilmo Kukkonen[3]

1) Institute of Seismology, University of Helsinki (pekka.j.heikkinen@helsinki.fi)
2) Department of Earth Science, Rice University
3) Geological Survey of Finland

As a part of the FIRE (FInnish Reflection Experiment) project, 30 km of high resolution seismic reflection data along three lines were acquired in Outokumpu in 2002. The Palaeoproterozoic Outokumpu formation is a classical ophiolite-derived ore-belt in eastern Finland. Two of the lines (OKU-1 and OKU-2) transect the Outokumpu formation perpendicularly and the third (OKU-3) runs along it connecting the lines OKU-1 and OKU-2. Subsequently, a deep drilling project was initiated in Outokumpu by the Geological Survey of Finland, and a 2.5 km deep hole was drilled in 2004-2005 into one of the deep reflectors in the area.

The acquisition was done using three 15-ton vibrators. Along OKU-1 and OKU-3 the roads were paved asphalt roads, the acquisition on OKU-2 was done on a gravel road. The shooting geometry was split-spread, excluding the ends of lines where asymmetric shooting was applied. The geophone group interval was 25 m and the source point interval 50 m giving the nominal fold from 78 to 119. In practice, this number was slightly reduced, because some shooting points could not be used due to vicinity of buildings or other structures. The frequency range of the signal was 30-130 Hz corresponding wavelengths from 40 to 200 m. The recording length was 6 seconds, giving the depth range of 18 km. The basic processing of the data was done by the contractor, Spetsgeofyzika. Final processing steps including migration were done at the Institute of Seismology.

The dominating features in all three sections are 400-500 m thick layers of strong reflectors in the depth range of 1-3 km (Fig. 2). The velocity analysis gives P-velocity values between 6400-6600 m/s in this layer. Beneath OKU-1 and OKU-2 the layer can be seen in the SE end of the profiles at the depths of 1300-1750 m and in the NW end slightly deeper, at 2000-2500 m. Beneath OKU-3 the layer is apparently horizontal and can be followed along the entire line between OKU-1 and OKU-2. Outokumpu deep hole, which is located at about 400 m W from the OKU-1 line, cut through the Outokumpu association rocks at the depths 1317-1550. The layer is an assemblage of serpentinite, skarn rock, quartz rock and black schist in a mica schist environment. This ophiolite-derived rock type assemblage also hosts the sulphide deposits in the Outokumpu area. The top of this layer is very close to the upper boundary of the seismic reflector and thus the strongly reflecting layer can be interpreted to consist of Outokumpu association rocks. The base of the reflecting zone in the seismic sections is about 200 m deeper than the layer in the hole, but this is most probably a geometrical 3D effect, as indicated also by the change in the dips of the reflectors beneath 1600 m. The uppermost kilometre in the seismic sections in Outokumpu is less reflective. The short reflecting segments are generally nearly horizontal or dip south and can be correlated structures observed on the surface. The deep-hole results further suggest that some of the seismically transparent areas represent pegmatitic granite.

Analysis of local travel times of P and S waves in Estonian territory

Olga Heinloo

Geological Survey of Estonia (olga@obs.ee)

The presentation contains an analysis of the seismic events in the Baltic Sea and in the quarries of North-East Estonia, based on data of two seismic stations VSU and SRPE of Estonia in years 2004 - 2006. The local travel-time curves of P and S waves for Estonian territory are composed.

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Fractals and Earthquakes

Erik Hjortenberg

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At the 37th Nordic Seminar on Detection Seismology held in Nesjavellir,Iceland in August 2006, a field trip through the South Iceland Lowland was made on day three. The effect of a M=6.5 earthquake that occurred in year 2000 was examined by the group of seismologists. Páll Einarson pointed out the similarity between the appearance of the faulting of the big earthquake and the appearance of that of the smaller ones in the same area (e.g. similar en echelon structures). This self-similarity suggests a fractal description of earthquakes.

Mandelbrot (1983, p461) has a chapter on Scaling, Fractals and Earthquakes, with reference to Kagan & Knopoff (1978, 1980, 1981) and to Andrews 1980-1981. The chapter states that earthquakes are self-similar, i.e., no particular scale is connected with their time-distance-magnitude pattern, and their geometry is fractal.

Bak and Chen(1995) states: "Earthquakes have a variety of fractal aspects. The distribution of energy released during earthquakes is given by the Gutenberg-Richter(1956) power law. The distribution of epicenters appear to be fractal with dimension D ~ 1-1.3 (Kagan and Knopoff, 1980). The number of aftershocks decay as a function of time according to the Omori(1894) power law."

Fractals sets are characterized by a dimension, usually non-integer, and Turcotte(1992) defines fractal dimension to be the exponent of the power law distribution describing the scaling properties of the set. An ordinary fractal set has one dimension only, but multifractal sets are characterized by having a spectrum of dimensions (Halsey, 1986), and the elements of the set need not all have the same scaling exponents. Multifractal measures have been found to describe the geometrical properties of faults, fractures, and earthquakes (Main, 1996), one example is the seismicity in Pamir, the Caucasus, and California (Geilikman et al., 1990). Another example of a multifractal analysis examins the self-similarity of the spatial distribution of microearthquakes in the Kanto area (Hirata and Imoto, 1991). Power laws are an abundant source of self-similarity because they represent phenomena that have the same characteristics or features at very small and at very large scales (Rodriguez-Iturbe and Rinaldo, 1997, p109).

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Seismic images of Paleoproterozoic continental growth in Fennoscandia

Annakaisa Korja, Pekka Heikkinen and Paula Kosunen

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The deep seismic reflection data from *BABEL* and *FIRE* profiles indicate that the Karelian margin was a long live margin (2.0-1.8 Ga) on to which island arcs and microcontinents accreted to - causing temporary changes in the arc geometries, accretionary episodes and westward growth of the continent during Svecofennian Orogeny. After isostatic balance was achieved in gravitational collapse the structures froze and thus they have been protected from subsequent deformation. The paleoplate boundaries are marked by thicker crust, lower velocities, lower vp/vs ratios, deep conductors and massive sulphide deposits. Some of the oblique collisions were taken up by near vertical shear zones of the continental wrench faults.

Seismic Images of the Svecofennian Orogen
(poster)

Annakaisa Korja, Pekka Heikkinen, Timo Tiira Tellervo Hyvönen and FIRE Working Group

Institute of Seismology, University of Helsinki (annakaisa.korja@helsinki.fi)

The Capability for Seismic Monitoring of the North Korean Test Site

Tormod Kværna and Frode Ringdal

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On 9 October 2006 the Democratic People's Republic of Korea (DPRK) conducted an underground nuclear explosion at a test site near Kimchaek. The explosion was detected by several seismic stations in the International Monitoring System (IMS), and the event magnitude as reported in the REB was 4.1. In this paper we analyze the recorded waveforms in order to investigate the capability of the IMS to monitor the DPRK test site for possible future explosions. Our analysis is based upon the so-called Site-Specific Threshold Monitoring (SSTM) approach. Using actual seismic data recorded by a given network, SSTM calculates a continuous "threshold trace", which provides, at any instance in time, an upper magnitude bound on any seismic event that could have occurred at the target site at that time.

We find that the IMS primary network has a typical "threshold monitoring capability" of between mb 2.3 and 2.5 for the DPRK test site. Not unexpectedly, it turns out that the Korean array (KSRS) is of essential importance in obtaining such low thresholds. We have also experimentally investigated how the capability could be improved by adding non-IMS stations to the network. We find that by adding the nearby station MDJ in China, the threshold monitoring capability is improved to between magnitude 2.1 and 2.3.

A different perspective is to investigate the actual network detection capability for events at the test site, requiring at least 3 IMS stations to detect the event. This is the traditional way of looking at network capability, and the resulting threshold will always be considerably higher than that obtained by the SSTM approach. A global capability map, which is published by the IDC for each hour, shows that at the time of the event, the IMS 3-station detection capability was approximately 3.5. This is an order of magnitude higher than the threshold obtained by SSTM.

We conclude that the SSTM approach allows the analyst to identify times when there is a possibility of occurrence of events too small to be detected by the usual 3-primary station requirement, and to subject such occasions to extensive analysis in order to determine whether an event in fact occurred. Thus, the SSTM approach constitutes a valuable supplement to the traditional network processing carried out at the IDC.

Seismic stations and data flow – operators' view on daily routines

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CTBT Radionuclide monitoring and the Finnish NDC

Mikael Moring

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Research Initiative for a Northern European Intensity Databank (short communication)

Päivi Mäntyniemi[1], Eystein S. Husebye[2], Sören Gregersen[3]

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2) Center for Computational Science, University of Bergen
3) Geological Survey of Denmark and Greenland

An online macroseismic database is proposed for Northern Europe. Currently, the original macroseismic observations are seldom available even for basic inspection. Advanced research efforts can be advocated, because existing studies on the largest earthquakes in the region can mainly be found in printed national publications, often in different languages and based on different intensity scales and data analysis practices, which do not necessarily meet modern research standards.

An online databank is a convenient means to store, display and disseminate macroseismic data. Several intensity databanks were released over the Internet in the late 1990s for various countries around the world, but Northern Europe still lacks such a facility.

The concept of Intensity Data Point (IDP) has been introduced for displaying macroseismic observations online. An IDP is essentially a triplet (x,y,I) giving the intensity value I assigned to locality (x,y). The triplet can be followed by the respective place name. The IDPs originating from the same earthquake are basically identified by the time of observation. IDP maps constitute the core of a macroseismic databank: at least an IDP map and a list of available literature should be given for each earthquake.

Re-examination of the original data sources remains important and cannot be overlooked when preparing reliable IDP collections. Some preliminary studies conducted so far have shown that the IDP lists based on existing descriptive earthquake catalogues can be improved. A list of all the sources utilised to retrieve primary data should be made available in order to avoid repeating the same data collection efforts later.

Illustrations of original written documents such as macroseismic questionnaires and possible contemporary background material such as information about population distribution and density at the time of the earthquake can be included in the databank as well. Such information helps the user of the database to capture a comprehensive view of each earthquake and assess the macroseismic data independently.

An expert databank can be used for scientific studies on the largest earthquakes in the region and other topics. It can easily be converted into more popular websites in various languages for larger audiences in Northern Europe.

Town of Tornio in November 1898: a rare survey of earthquake damage in Finland (poster)

Päivi Mäntyniemi

Institute of Seismology, University of Helsinki (paivi.mantyniemi@helsinki.fi)

This contribution focuses on the effects of the Fennoscandian earthquake of 4 November 1898 (GMT) on the town of Tornio (Torneå) located on the Finnish-Swedish border in Northern Finland. It constitutes a special case of macroseismic analysis in Finland, because damage resulting from the earthquake of macroseismic magnitude around 4.4 was reported in the town and the available data are quite plentiful in comparison with the conditions of the country on average. Ten useful reports were extracted from contemporary newspapers, and archives were searched for further information.

The Tornio town administration ordered an extra fire inspection to be conducted to survey the failures. It was carried out on 21, 22 and 23 November 1898 by three men. The inspection revealed that more than 30 heating units made of masonry stone had been harmed in the town. The damage consisted mainly of severe cracks and fractures in the smoke conduits. At one site, the oven had become totally separated from the chimney structure. The total number of heating units in Tornio at the time of the earthquake can be counted using the discovered documents such as the Chimneysweeps' books for 1898 and Lists of fireplaces, ovens and chimneys to be swept in the town. With the given number of failures the proportion of damaged chimneys is about 11 per cent, which fulfils the EMS definition of quantity as "few". The severity of the failures is considered to be of grade 2, because the town authorities forbade the use of the damaged heating units until repaired. The vulnerability class of the heating units is described as B, meaning either unreinforced, with manufactured stone or simple stone structures. The overall damage can thus be summarised as a few class B structures suffering grade 2 failures.

No macroseismic questionnaires were returned from Tornio, but information about the transient consequences caused by the earthquake can be found in the press. Many people awoke, even from a sound sleep. In three reports, doors are said to have opened. China clattered in many places. Lamps and clocks fell from tables and ceilings, but the quantity remains unknown. The extracted indices suggest an intensity level of 5 or higher. If only the transient consequences were available, a critical analysis could reveal a value of I = 5 – 6, meaning by definition that the intensity was 5 in the town and partly 6, but the observations are insufficient to determine whether level 6 was reached in the area. The effect of the earthquake on dwellings is considered more decisive, because the proportion of failures can be estimated; indeed, the quantification of damage provides a perfect match with an index of intensity 6 on the EMS. In conclusion, an intensity of I = 6 (EMS) is assigned to Tornio, a value that stands for slightly damaging.

Reference

Mäntyniemi, P., 2007. Town of Tornio in November 1898: a rare survey of earthquake damage in Finland, *J. Seismology*, 11, 177-185.

Discrimination of seismic events in Iran by waveforms from the International Monitoring System

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October 9, 2006 the Democratic People's Republic of Korea (North Korea) carried out its first nuclear explosion in the P'unggye area. This was the first confirmed nuclear test since the Pakistan test on May 30, 1998 and a new nation entered the scene of testing a nuclear device. The occurrence of earthquakes is not particularly high in North Korea and the event was easily detected by regional seismic stations in South Korea and located by 22 stations in the International Monitoring System (IMS). A reference event occurred April 16, 2002 in a place about 75 km apart from the nuclear test site. The difference in relative sizes of the seismic P, Sn and Lg phases between the two events was clearly observed. The waveform of the reference event was typical for an earthquake with a longer duration and a later maximum than the nuclear explosion. The seismic measurements were also later confirmed by noble gas measurements.

The monitoring situation is quite different in Iran. The occurrence of earthquakes is rather high with an average of 264 ± 27 events located by the IMS per year (2000-2006). The International Data Centre (IDC) provide post-location automatic processing that screens out events that are considered to be consistent with natural phenomena or non-nuclear, man-made phenomena. The screening criteria are based on estimates made from seismic records of source depth, difference of body and surface wave magnitudes and regional P/S amplitude ratios. A hydro acoustic criterion is used for off shore events. An event is screened out if one SCORE is greater than zero. At present, the standard event-screening criteria are not applied to events below m_b 3.5. If should Iran decide to carry out a nuclear test, the explosion would probably have a yield around or below 20kt TNT with an estimated seismic magnitude in the interval m_b=4.0 to m_b=5.5 (REB). During year 2006 there were 376 events located to Iran and border areas by the IDC in the Reviewed Event Bulletin. The number of events with magnitude 4.0-5.5 were 96 and 27 events were not screened out and thus presented in the SSEB-bulletin. These events can be further studied by waveform inspection, time-frequency characteristics and complexity. During year 2007 up to May 2 there were 97 events located to Iran and border areas in the REB. The number of events with magnitude 4.0-5.5 were 31 and 11 events were not screened out.

Moment tensor solutions calculated for two M>4 UK earthquakes in 2007

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The UK seismic network is undergoing an upgrade to broadband instrumentation. At present, 14 broadband stations are operated by the BGS, and one by AWE Blacknest. All stations have a natural period of more than 100s and data is available in real-time. One application of the broadband data is calculating the moment tensor (MT) of moderate size earthquakes through full waveform inversion. Two earthquakes in 2007, the first on 7 January in the northern Viking Graben with 4.7MW and the second on 28 April on the SE coast of England with 4.0MW, were good test cases for the MT inversion and to evaluate the performance of recently installed stations. MT solutions could be obtained in both cases using regional data, including data from the UK, Denmark, Norway and others. The solutions are oblique-reverse for the Viking Graben and oblique-normal for the SE England event. The axis of maximum compression, in both cases, is NW-SE in agreement with the regional compression. The broadband real-time data is exchanged between Denmark, Norway and the UK for improved detection of events in the North Sea as well as in the larger region for the purpose of detection of large earthquakes for tsunami warning.

Passive seismic monitoring of the Åknes rock slope, Møre og Romsdal, Norway

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The instable rock slope at Åknes, Norway is a threat to close by villages and ships in the fjord system. The site is remote, but a sudden failure of the slope can possibly generate a local tsunami endangering large parts of the fjord and its shores. The estimated volume of the instability lies between 40 and 70 million cubic meters and the movement rate within the slope varies between 4 and 15 cm/year.

Several continuous monitoring systems have been installed and presently are operational. Amongst these there is a seismic monitoring system consisting of 8 three-component geophones with the purpose to record microseismic events related to the movement of the slope. The network has been installed October 2005 and is running without major interruption since then. It covers an area of about 250 x 150 meters in the upper part of the unstable slope, where the mass movements can directly be observed by means of extensometers and a laser ranging system. The local acquisition system is connect through a 13 km radio link and the internet to NORSAR. Thereby we can download the data in real-time using an automatic file transfer to NORSAR. In the first year we collected the data in continuous mode in order to gain an overview on the ambient noise conditions and the different types of seismic events. From August 2006 onwards we record the data in an event-triggered mode with higher sampling rates. Usually we observe 1-10 local microseismic events per week that we consider to be related with the movement. These signals have a duration of about 2-3 s and can be observed on all geophones simultaneously with a good signal-to-noise ratio. So far the events could not be localized, because of lack of a realistic velocity model for the subsurface. The site is very heterogeneous having a rough topography and strong variations of the seismic velocities. In October 2006 we conducted a first calibration experiment consisting of 11 blasts located in and around the seismic network. It turned out that the velocities vary significantly (by a factor of 2-3) within the network, which is partly on solid rock and partly on the moving part of the slope.

Seismic Monitoring of Nuclear Waste Repository- Four Basic Applications

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The island of Olkiluoto, in the western coast of Finland, has been selected as the site for the final disposal facility of spent nuclear fuel. A Finnish expert organisation, Posiva started to construct an underground characterisation facility in Olkiluoto, in 2004. This facility will be used to acquire detailed information about the bedrock in Olkiluoto, to be utilised in the planning of the final disposal facility. The construction of the actual final disposal facility is scheduled to start in 2015, and the final disposal of spent nuclear fuel can be started in 2020.

In February 2002, Posiva Oy established a local seismic network of six stations on the island of Olkiluoto. At the end of 2006 the number of seismic stations was 14. In this presentation, four basic applications of seismic monitoring are introduced. The applications are related to 1) quality analysis of excavation rounds, 2) safeguards of nuclear material, 3) tectonic seismicity and 4) excavation induced seismicity.

How microearthquake monitoring of the absolute crustal stress field can be used for improved earthquake warnings

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It has been shown that the complete and absolute crustal stress tensor field can be estimated by use of microearthquakes recorded by local seismic networks (Slunga 2007). This means that deterministic intermediate term earthquake predictions are possible. The degree of stability on crustal faults can be computed from the stress field (the Coulomb failure stress, CFS). The loading rates from plate tectonic processes can be computed and when added to the known absolute CFS it is possible to get an estimate of the time when CFS reaches zero (instability) and an EQ occur. In practice geodetic methods will be used to monitore the changes in the crustal stress. These will continously be compared to the observed stress given by the microearthquakes. The effects of larger earthquakes must of course also be included as well as known stable slip in the deep crust. In the Marmara area in Turkey the yearly changes in CFS due to tectonic loading and stable creep in deeper crust have been nicely modelled (Lorenzo-Martin et al, 2007). If microearthquakes within that region were analyzed giving the present absolute CFS it will be straightforward to give a predicted time for instability (earthquake). As the Istanbul area is very densely populated and, as not all buildings are safe during strong earthquakes, it is surprising that the microearthquake method is not used to improve the earthquake warnings in Turkey! Examples of how the microearthquakes can be used in this sense will be shown for the June 17 and 21, 2000, earthquakes in south Iceland.

References:

Lorenzo-Martin, Wang, Pohl, and Roth, 2007, Time-dependent Coulomb stress changes in the Marmara Sea region, EGU2007 -A-11536.

Slunga, 2007, Use of stress tensor field for earthquake warnings, EGU2007-A-07147.

Discovery of lower-crustal earthquakes down to ~30 km depth near the Askja volcano in north Iceland

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The volcanic system of Askja is located on the mid-Atlantic divergent plate boundary in north Iceland. Askja with its surroundings is an area of persistent small-scale seismicity (typically well below magnitude 3). We deployed and operated a network of 20 broadband seismometers in the area during July–August 2006 and combined with the data of the Icelandic national seismic network, SIL, detected over 1800 local earthquakes during this period.

As anticipated, the majority of the earthquakes were located 10–20 km to the NE of the volcano massif of Askja, beneath the mountains of Herðubreið and Herðubreiðartögl, at depths of 2–7 km. These events favour the deeper end of this range, marking the thickness of the brittle upper crust, with a slight deepening towards the north-east, away from the Askja volcano. Another conspicuous cluster of earthquakes is in the south-eastern part of the nested caldera system of Askja, at depths of 2–5 km. This activity is considered to be related to geothermal activity.

Unexpectedly, we discovered a fascinating new type of earthquake in the Askja area: lower-crustal events concentrated at depths of 13–27 km, with one event as deep as 34 km. This is near the base of the crust, as the crustal thickness in the Askja area has been estimated to be approximately 30 km.

The lower-crustal events are distinctly different in appearance to the upper-crustal earthquakes, with emergent P- and S-phases and low frequency content with a peak around 3 Hz. They typically occur in swarms of short duration, up to a few minutes, with several subsequent events sometimes merging into continuous tremor. They appear to be a persistent feature, as during the short measuring period of two months, we detected over 100 such events. As they are difficult to locate and are small in magnitude, only the two largest (M_L 1.4 and 1.0) were detected by the more distant SIL network.

However, the confirmation of the great depth of the lower-crustal earthquakes has enabled us to conduct a retrospective examination of observations of deep earthquakes by the SIL network. They have indeed also been detected earlier, since the year 2005, when a seismic net of several stations was installed within 15–50 km of Askja.
We propose that the newly discovered lower-crustal seismicity is related to magmatic movements within the north Iceland plate boundary. The events at Askja cluster in the north part of the volcano, immediately north of the suggested deeper Askja magma chamber at 16 km depth, and they extend towards the north-east. There is a gap between these events and another cluster of deep events to the north-west of

Herðubreið. In Iceland there are known occurrences of magma transport occurring alternately seismically and aseismically, and this may be an example of such a case. The deep events show that even though the Icelandic lower crust is hot and ductile, earthquakes can and do occur there.

Mapping quakes with Google Earth

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Hypocenter distribution of earthquakes in north-western Finnish Lapland: Preliminary investigation

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The Seismological Network in Denmark and in Greenland, and applied research

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The Geological Survey of Denmark and Greenland (GEUS) operates the national seismological network in Denmark and in Greenland. In Denmark the network consists of 3 broad band and 2 short period seismometers, all permanent. In Greenland the network consists of 17 broad band seismometers, 4 are permanent and 13 are temporary. The data from the stations in Denmark are collected through the Internet. Data from two stations in Greenland are collected through the Internet, from the rest of the stations data are either mailed weekly on tapes or flash cards or collected at a yearly inspection. The data is stored and processed in SEISAN databases, which also contain the GEUS earthquake catalogues for Denmark and Greenland.

The seismological networks are currently part of four research projects: (1) A UN article 76 based study of crustal structures in North Greenland. (2) A study of lithospheric structures in West Greenland initiated by the diamond exploration. (3) A study of Glacial earthquakes in East Greenland. (4) PASSEQ - a teleseismic tomographic study of the lithospheric structures in Germany, Poland and Lithuania.

The status of the seismological network in Denmark and in Greenland, and the current research projects are presented.

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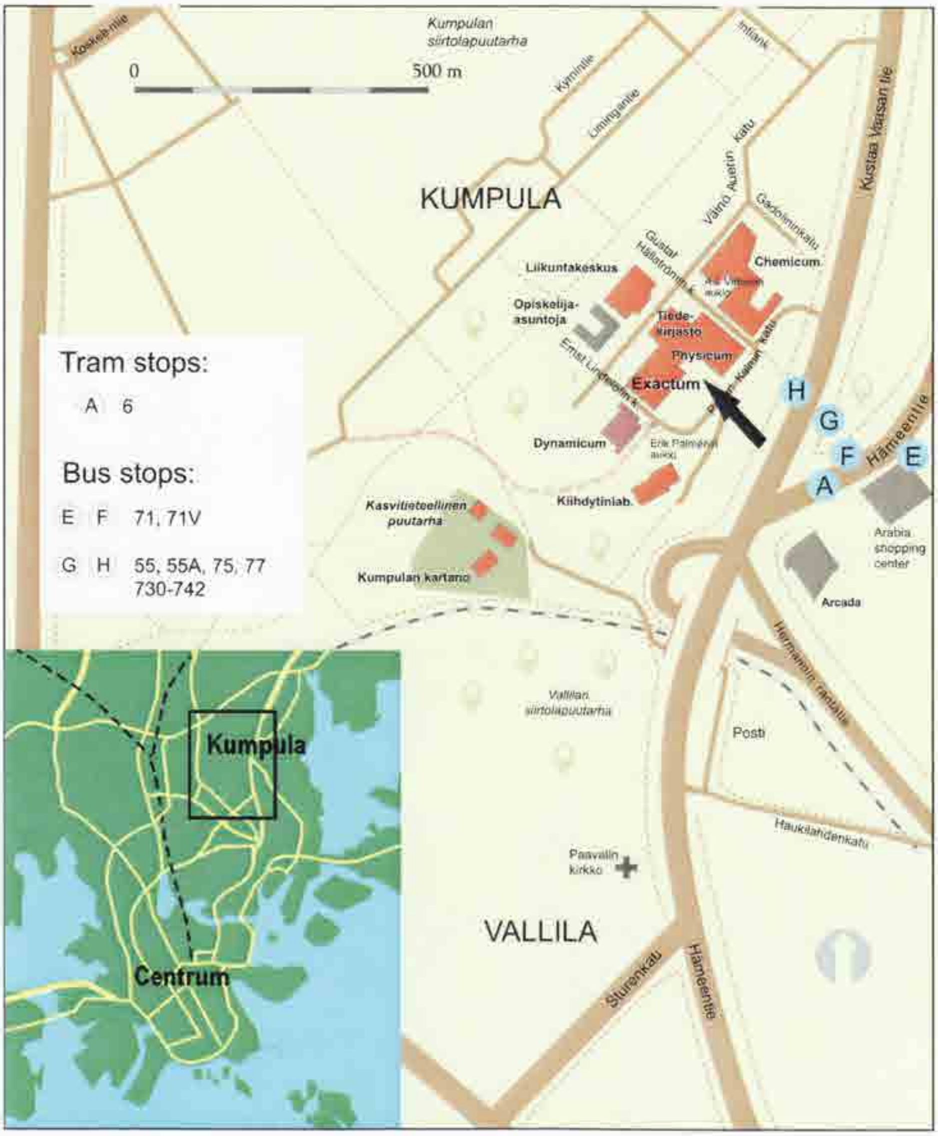

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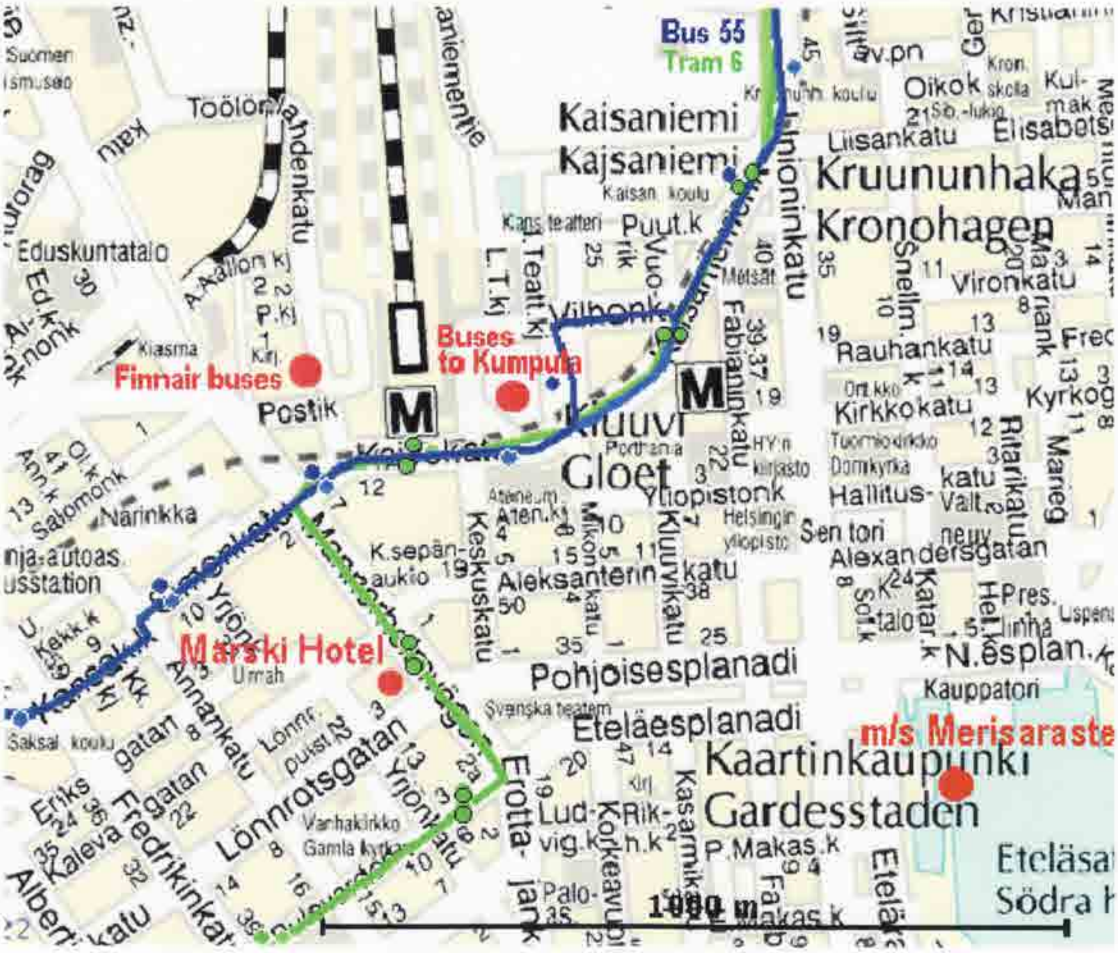

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