No ISSN : 1607-1980

Centre Sismologique Euro-Méditerranéen
European-Mediterranean Seismological Centre
www.emsc-csem.org

Newsletter

N° 19 APRIL 2003

EDITORIAL

As we approach our next Assembly on 9 April in Nice, we can report that six new members will be joining the EMSC community: Seismological Institute (Albania), CRAAG (Algeria), University of Zagreb (Croatia), Institute of Geophysics (Georgia), DEUC (Monaco) and Montenegro Seismological Observatory (Yugoslavia), So, our membership continues to expand both in our number of institutions, and through our geographical coverage. We are now 56 organisations in 36 countries spread throughout our region of focus. As an agreed policy, we have continued to maintain a modest subscription fee to encourage even wider participation in order to gain from the increased communal benefits which this brings to the service we provide, both to our science and to the populations of our member countries. More affluent members continue to be encouraged to contribute more than one unit of subscription to compensate for this strategy of maintaining the basic fee without indexation for inflation.

In two further initiatives, EMSC is seeking to raise its profile whilst earning revenue to support the co-ordination centre in Bruyeres. A consortium bid to the European Space Agency, with partners from both the public and private sectors, has been successful. It is within ESA's GMES programme (Global Monitoring For the Environment and Security), and covers initial phases through 2003/04. A strong delivery against project goals in this period will place us in a position to bid into a very substantial second phase covering a further 3 years. Members are encouraged to help the core group, when requested, to support its mission of engaging with city authorities concerned with ground movement impacts from all sources; tectonic, geological and man-made. The approach is to map and monitor such movements at millimetric resolution utilising new processing techniques (PSINSAR) on the ten years' of satellite radar data which now exists in the archives.

Guenter Bock

In its second new initiative, EMSC is partnering ORFEUS in leading an FP6 bid to build a stronger network infrastructure for European seismology, supported by new research projects. The proposal will be completed and submitted in April (for more details, see the News section below).

Against the above positive moves, I bring to you the sad news of the loss of one of our strongest supporters who has provided our rapid moment tensor service through our Key Nodal Member, GFZ. Guenter Bock was tragically killed when the plane he was travelling in crashed-landed in Luxembourg on 6 November. Our condolences and thoughts continue to be with his family, friends and colleagues, in Germany and across the World. In addition to the considerable impact he has had in our science and in his unstinting service to the EMSC, its Executive and its members, Guenter was a true gentleman, liked and respected everywhere. We shall miss him in Nice and in the future.

Chris Browitt
President

CONTENT

The ESC-SESAME Unified Hazard Model for the European-Mediterranean region

M-J. Jimenez1,2, D. Giardini1, G. Grunthal3
1. Swiss Seismological Service, ETHZ, Zurich, Switzerland,
2. Institute of Earth Sciences-CSIC, Barcelona, Spain,
3. GeoForsschungsZentrum, Potsdam, Germany

1. Projects on seismic hazard assessment in Europe and the Mediterranean: objectives, strategies and results

During the last ten years several projects on seismic hazard assessment were active at global and regional scales. Within the European-Mediterranean region a number of multinational programs were set up to produce earthquake catalogues, seismic source zoning and hazard assessment, through the following three main project frameworks: (1) GSHAP, (2) IGCP-382 project SESAME, and (3) the ESC Working Group on Seismic Hazard Assessment.

Within the framework of GSHAP (Global Seismic Hazard Assessment Program, 1992-1999), a UN/IDNDR demonstration program, which completed in 1999 the first global map of seismic hazard in terms of peak ground acceleration (Giardini, 1999); IGCP-382 SESAME (Seismotectonics and Seismic Hazard Assessment of the Mediterranean Basin, 1996-2000), which provided the first unified seismic source model and homogeneous assessment of seismic hazard for the whole Mediterranean region (e.g. Jiménez et al., 2001); and the European Seismological Commission Working Group on Seismic Hazard Assessment (ESC/WG-SHA, 1996-2002), aiming at the development of a homogeneous probabilistic seismic hazard assessment procedure for Europe and the Mediterranean, the whole European-Mediterranean region has been unified.

GSHAP produced in 1999 the first seismic hazard map for the European-Mediterranean region in terms of peak ground acceleration, as part of the GSHAP global hazard map, and was based on the compilation and assemblage of hazard results as obtained independently in different test areas and national and multinational programs. As was pointed out in Grünthal et al. (1999), although all of these independent hazard maps were produced following the same basic seismotectonic approach, the harmonization of the hazards in the assemblage of the final GSHAP map required several iterations of smoothing and border matching between the different regions. The greatest difficulties were met in the Mediterranean, owing to the large number of independent areas.

IGCP-382 SESAME developed and completed a more detailed, integrated seismic source model and homogeneous hazard mapping for the Mediterranean region. Main efforts focused in the development of a unified source model throughout the region to allow for a homogeneous hazard assessment procedure. The strategy was based on the integration of regional and national models to avoid ambiguities coming from different approaches, and also to avoid gaps in the geographical coverage through the development of new source models in areas where these were not yet available. Preliminary SESAME results were presented in September 2000 on occasion of the XXVII General Assembly of the European Seismological Commission, in Lisbon, Portugal. Improved results incorporating updates to source model and hazard computation can be found in Jiménez et al. (2001).

ESC/WG on SHA has completed in 2002 a unified seismic hazard modeling for Europe and the Mediterranean. Our approach to obtain a reference seismic hazard model for Europe and the Mediterranean has been entirely based on the integration of regional models and the adoption of a homogeneous hazard assessment procedure. The strategy was based on integrating GSHAP Central Northern Europe results with those from SESAME for the Mediterranean to allow for the first ever homogeneous seismic hazard computational procedure which for the first time is based upon a unified source model throughout the whole European-Mediterranean region. This comprehensive model for seismic hazard assessment allows, for the first time, the generation of hazard maps, expressing ground motion in different parameters, for different soil conditions and probability levels.

2. Development of a unified seismic hazard model for the European-Mediterranean region

The European-Mediterranean ESC-SESAME unified seismic hazard model is based on the Seismotectonic Probabilistic approach and thus based on a regional model of seismic source zones (established according to tectonic, geophysical, geological and seismological data) with associated parameters (magnitude-frequency parameters, maximum expected

Figure 1: *Unified seismogenic source model for the European-Mediterranean region (463 source zones).*

magnitude), through which expected ground motion is computed based on an appropriate attenuation relationship.

The unified source model consists of a total of 463 seismic sources (455 shallow and 8 intermediate-depth). Figure 1 shows the final source model. Each source is characterized by the corresponding seismicity parameters in terms of minimum and maximum magnitude, and earthquake occurrence rates with an associated sub-catalogue which stems from the corresponding regional catalogue. Source models developed in regional and multi-national programs within GSHAP have been compiled and then complemented with existing models in the literature to avoid gaps in the geographical coverage. Original background sources, established in the individual models to account for seismicity in neighbouring regions, have been eliminated; and new zones at overlapping border areas were redesigned to harmonize geometries where differences existed. These areas mostly correspond to the Pyrenees, the Alps, the Carpathians, Northern Greece and the Aegean, among others. In the Mediterranean, a new regional model for the Eastern Mediterranean region has been developed in cooperation with GII (Geophysical Institute of Israel), within SESAME and RELEMR (Reducing Earthquake Losses in the Eastern Mediterranean Region) programmes. At different stages during the development of the work, regional source models and associated parameters have gone through improvements and updates according to any new information made available.

Ground motion attenuation models developed by Ambraseys et al. (1996) in terms of peak ground acceleration, PGA, and absolute spectral acceleration, SA, are considered to be adequate for the unified computations for shallow sources, since these relationships were obtained on the basis of a wide European strong motion data set with magnitudes between 4.0 and 7.9 and four categories of soil condition (rock, stiff, soft and very soft soil). Specific attenuation relationships are considered for the eight sources of intermediate-depth seismic activity through the specific attenuation relationships derived in Musson (1999) for Vrancea intermediate source, and in Papaioannou and Papazachos (2000) for intermediate-depth seismic activity sources in the Helenic Arc.

Homogeneous Hazard computation is carried out inside the area stretching from 10ºW-30ºE and 27ºN-72ºN and 30ºE-40ºE and 27ºN-47ºN at a grid interval of 0.15 degrees and is performed through SEISRISK III (Bender and Perkins, 1987). Non-isotropic attenuation for intermediate-depth earthquakes originating in Vrancea (Romania) is handled and computed independently by applying the procedure and code used for the regional hazard mapping of North Balkan region (Musson, 1999). Ground motion variability is incorporated in the computations assuming a lognormal distribution of the ground-motion parameter with standard deviation sa. The number of computation nodes is over 70,000. To ensure that the computation through the established unified procedure gave fully compatible results with the original regional hazards, individual tests were performed for all regions to detect possible misfits and therefore identify the causative reasons. The resulting differences in the hazard results through the unified procedure should arise solely in relation to the harmonization of the basic input data (e.g., source geometries at border areas, attenuation relationship) or specific to the computations for a large geographical region (e.g. larger grid spacing).

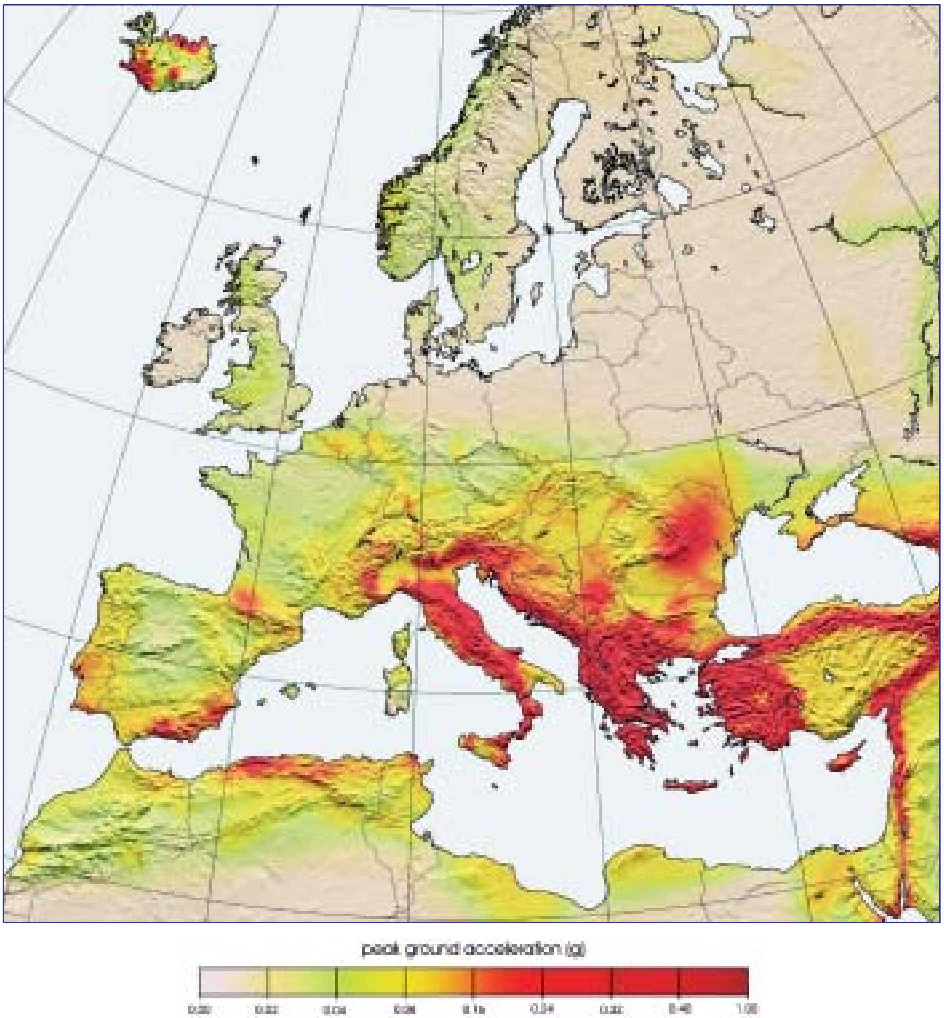


Figure 2: *ESC-SESAME European-Mediterranean seismic hazard map for peak ground acceleration [g] with 10% probability of exceedance in 50 years for stiff soil condition.*

Generation of regional probabilistic hazard maps on the basis of the developed unified seismogenic source model, and the adopted regional and specific ground-motion attenuation relationships, is carried out through a homogeneous probabilistic seismic hazard assessment (PSHA) procedure. It allows for the first time to obtain homogeneously computed regional hazard maps for the European-Mediterranean region in terms of different ground motion parameters (e.g. PGA, 0.3s SA, 1.0s SA), different soil conditions (e.g. rock, stiff soil) and different probability levels (e.g. 1%, 10% and 65% of exceedance in 50 years). The map in Figure 2 depicts the results of homogeneous seismic hazard computation of peak ground acceleration at a 10% probability of exceedance in 50 years for stiff soil; areas in the map not covered by the ESC-SESAME seismic source model (Iceland and Russia) are taken from the GSHAP Global Seismic Hazard map.

3. ESC-SESAME main results for PSHA in Europe and the Mediterranean

Main results achieved through the European-Mediterranean final unified model for PSHA can be summarized as follows:

- First ever common model of seismic sources for Europe and the Mediterranean
- Hazard computations are now based on a unified source model of 463 seismic sources (455 shallow and 8 intermediate-depth)
- Homogeneous computational procedure for PSHA
- Generation of hazard maps: ground motion expressed in different parameters, for different soil conditions and probability levels

- Establishment of databases incorporating for each seismic source: seismicity parameters (minimum and maximum magnitude), earthquake occurrence rates, and associated subcatalogue (from regional catalogue)

Publications, reports, procedures, maps and results will be loaded on the web and the final seismic hazard map for Europe and the Mediterranean (peak ground acceleration at a 10% probability of exceedance in 50 years for stiff soil) is now published under the auspices of the European Seismological Commission in 5000 copies by the *Institut Cartogràfic de Catalunya* in March 2003.

4. Outlook

The ESC-SESAME is the first ever unified model for PSHA for Europe and the Mediterranean. It was developed within the framework of several recent projects on global and regional seismic hazard assessment and allows for homogeneous hazard computation throughout the whole European-Mediterranean domain. Still some aspects in its realization have remained unavoidably heterogeneous. Future developments to harmonize and improve models and data can be achieved in the framework of future initiatives at European level through regional close-cooperation and efforts in reasonable periods of time, but these cannot go beyond the limits posed by the differences in the status on background knowledge and quality of the basic data. These differences, if existing, will remain unsolved and will reflect unavoidably in any final regional hazard map.

Nevertheless, this final unified hazard modeling for Europe and the Mediterranean will contribute to the establishment of a regional seismic hazard framework for the region in terms of peak ground and spectral acceleration from which seismologists, geologists and earthquake engineers can profit as a general guideline.

The compiled data bases (e.g. source zoning, attenuation, seismic activity parameters) for the whole European Mediterranean domain and the homogeneous hazard computation scheme constitute a unique tool which opens new possibilities for future research of interest to the seismological and engineering communities. The ESC-SESAME background hazard model for PSHA can serve for re-evaluation of hazard according to different criteria or for improved source models incorporating mixed areal/fault sources, for improved ground motion models (both for sub-regions or for the whole European-Mediterranean region), as the basis for comparative regional studies dealing with both methodological and assessment issues, also as an aid to model seismicity in neighbouring regions for national hazard maps, to establish the basis for a European-Mediterranean seismic hazard server, and for educational projects, among many other applications.

5. Events where the different stages in the development and results were presented

At different stages on the development of the ESC-SESAME unified seismic hazard model, results where presented on occasion of :

- *XXVII General Assembly of the European Seismological Commission, Lisbon, Portugal, 10-15 September 2000.*
- *Mitigation of Seismic Risk. Support to Recently Affected European Countries, EC-Joint Research Centre, Belgirate, Italy, 27-28 November 2000.*
- *XXVI General Assembly of the European Geophysical Society (EGS). Nice, France, 26–30 March 2001.*
- *American Geophysical Union Fall Meeting, San Francisco, 10-14 December 2001.*
- *3ª Asamblea Hispano-Portuguesa de Geodesia y Geofísica, Valencia, 4-8 February 2002.*
- *12th European Conference on Earthquake Engineering, Londres, UK, 9-13 September 2002*
- *XXVIII General Assembly of the European Seismological Commission, Genoa , Italy, 1-6 September 2002.*
- *Primer Centenario del Observatorio de Cartuja: 100 años de Sismología en Granada, Granada, Spain, 8-11 October 2002*

a number of invited conferences where given at :

- *European Seismological Commission Workshop on "Seismicity Modeling in Seismic Hazard Mapping", Poljce, Slovenia,22-24 May 2000*
- *XXV General Assembly of the European Geophysical Society Nice, France, 26 April 2000.*
- *UNESCO Workshop on Earthquake Hazard Assessment Practice and Velocity Models and Reference Events in the Mediterranean Region, Santa Susanna, Barcelona, Spain, 20 May 2001.*
- *PILAR (Program For Increasing Technical Capacity on Natural Disaster Reduction in the Mediterranean Region) planing Meeting, UNESCO, Paris, 24 June 2002.*

and a special session on:

- "*European Seismology Projects for Hazard and Risk: Sesame, EC8 and the Way Ahead*" at the 12ECEE meeting in London, September 2002, was convened by R. Musson as an open discussion to provide a forum to discuss the results achieved, actual status and future direction of earthquake hazard research, and supporting projects, in Europe.

6. What made it possible?

The contributions on data and efforts of many years of work of many individuals and institutions which were active in different projects related to hazard in Europe and the Mediterranean, specially all those groups and individuals active within GSHAP, SESAME and the ESC/SCF WG on SHA, have made it possible. In particular, Mustafa Erdik, Mariano García-Fernández, Roger Musson, Christos Papaioannou, Avi Shapira, Dario Slejko, for your patience and support - thank you!

We are also grateful to every contributor at the different stages of development of the different programs and projects as referenced in the published ESC-SESAME seismic hazard map, but to name all of them here would be impractical.

Propietary software for hazard computation was made available for ESC-SESAME by R. Musson (BGS,UK). Figures were prepared using GMT software (Wessel and Smith , 1998).

7. References

Ambraseys N.N., K.A. Simpson and J.J. Bommer.1996. *Prediction of horizontal response spectra in Europe.* Earthq. Eng. Struct. Dyn., **25**, 371-400.

Giardini, D. Editor.1999. *The Global Seismic Hazard Assessment Program 1992-1999.* Special Issue. Annali Geofis., **42** (6).

Grünthal G., C. Bosse, S. Sellami, D. Mayer-Rosa and D. Giardini. 1999. *Compilation of the GSHAP regional seismic hazard for Europe, Africa and the Middle East.* Annali Geofis., **42**, 1215-1223.

Jiménez M.J., D. Giardini, G. Grünthal, and SESAME Working Group. 2001. *Unified Seismic Hazard Modelling throughout The Mediterranean Region.* Boll. Geof. Teor. Appl., **42**, 3-18.

Musson R. 1999. *Probabilistic seismic hazard maps for the North Balkan region.* Annali Geofis., **42**, 1109-1124.

Papaioannou C. and C. Papazachos. 2000. Time-Independent and *Time-Dependent Seismic Hazard in Greece based on Seismogenic Sources.* Bull. Seism. Soc. Am., **90**, 22-33.

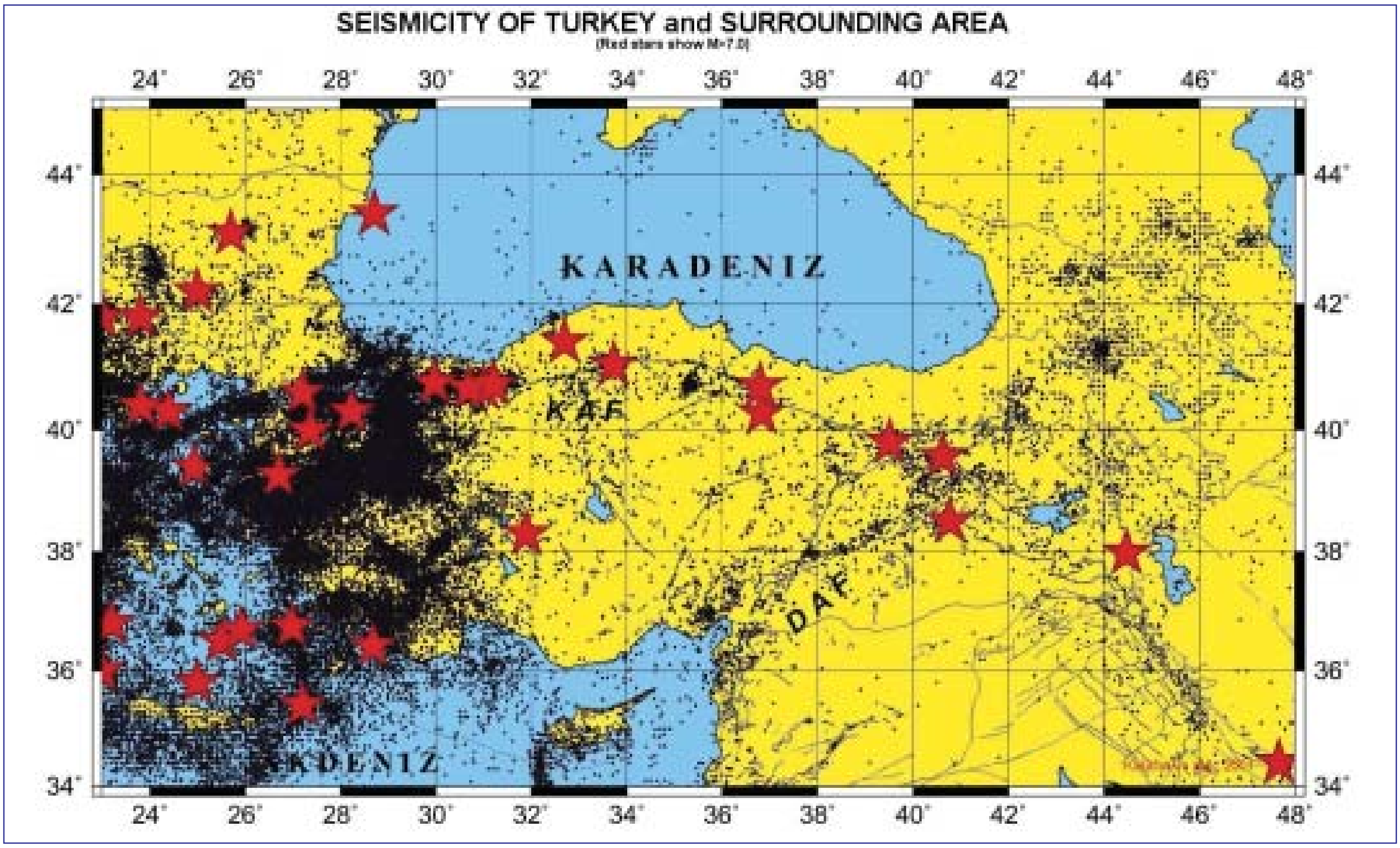
Wessel P., W. Smith. 1998. *New, improved version of Generic Mapping Tools released.* EOS Trans. Am. Geophys. U. 1998; 79(47): 579.

B.U. KANDILLI OBSERVATORY and EARTHQUAKE RESEARCH INSTITUTE SEISMOLOGY LABORATORY

Doğan Kalafat
Kandilli Observatory, Seismology Lab., 34680 Çengelköy- ISTANBUL, TURKEY

Mission of Seismology laboratory

The seismological laboratory of the KOERI is consisting 67 seismic stations is the center for data analysis and it determines the parameters of earthquakes (origin time, epicenter coordinates, depth, magnitude, intensity) that occur in Turkey.



Events are collected continuously at the center from all of the stations in Turkey by real time. At the same time, those earthquake information are disseminated as rapidly as possible to government agencies, to government public information centers and to news media.

The Seismology laboratory provides a twenty-four hour information service continuously and it also monitors the seismic activity throughout Turkey even on holidays. All of the historical information and parametric data are collected at the center as a databank thus, that plays a very important role for institutions and researchers. After a destructive earthquake, the earthquake information is also disseminated to emergency and civil centers in order to mitigate the seismic risk and panic.

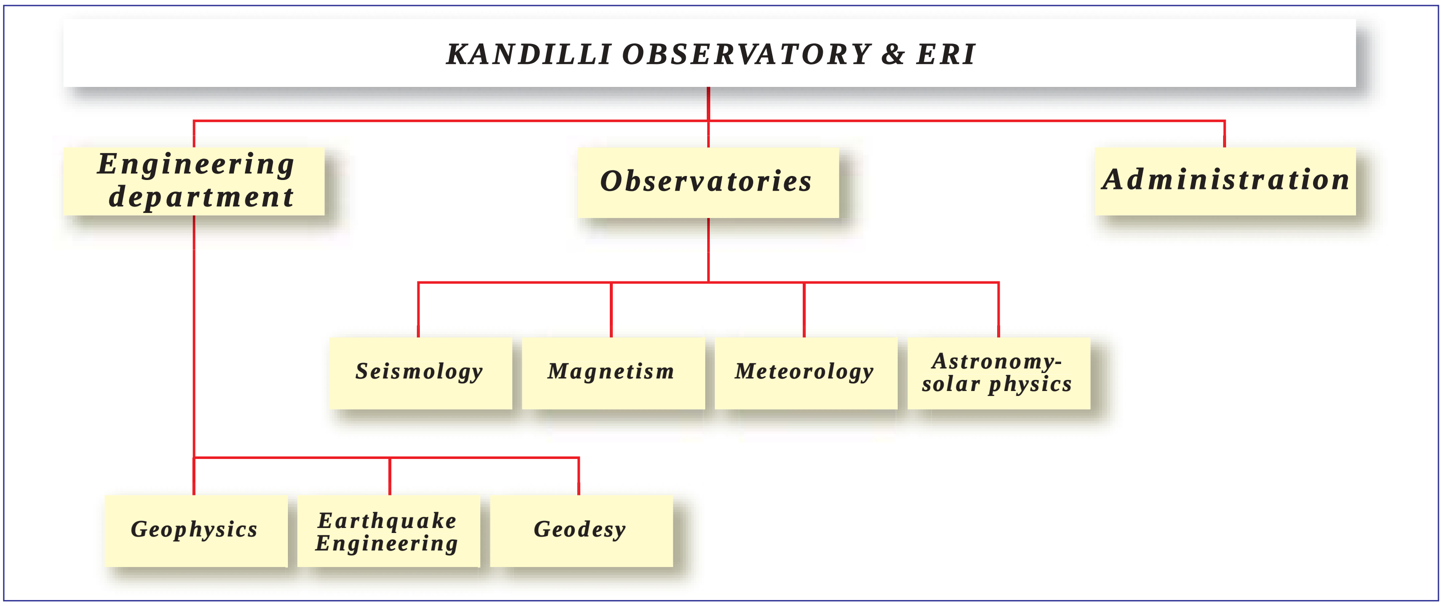
Our laboratory provides the important seismic information for preparing of the seismotectonic and seismic risk maps of the country. Today it is unique organization that gives continuously data to international seismological centers such as NEIC, ISC and EMSC through internet.

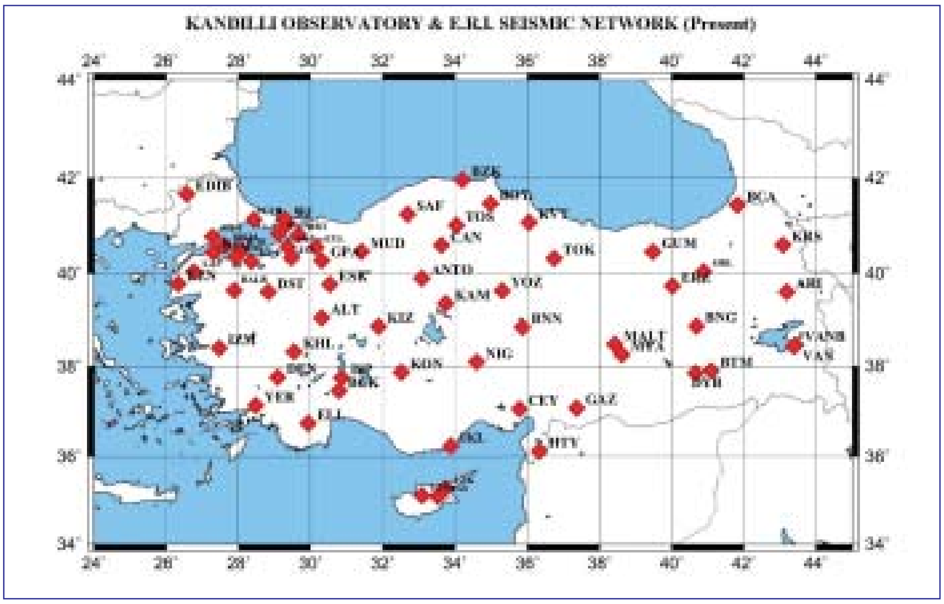
KOERI continues to provide Seismological Observation services with its continuously expanding network throughout Turkey.

Organization

The Kandilli Observatory and Earthquake Research Institute (KOERI) is Turkey's unique organization encompassing earthquakes observation, research, education and application services within a single, integrated body. Established 135 years ago in 1868 as The imperial Meteorological Observatory, Kandilli Observatory extended its activities in the 20 th century into various observational fields such as astronomy, astrophysics, geophysics, geomagnetism and seismology. In 1982 the Kandilli Observatory was joined to Bogazici University. A new Earthquake Research Institute was founded to merge with the Observatory. The new body, named KOERI, was reorganized with its main emphasis oriented towards earthquake, research, education and relevant service actives.

Through the 1980's KOERI has evolved into a multidisciplinary research organization providing graduate education to M. Sc. and Ph.D. levels in three departments, namely Earthquake Engineering, Geophysics and Geodesy, with full-time and part-time faculty members.

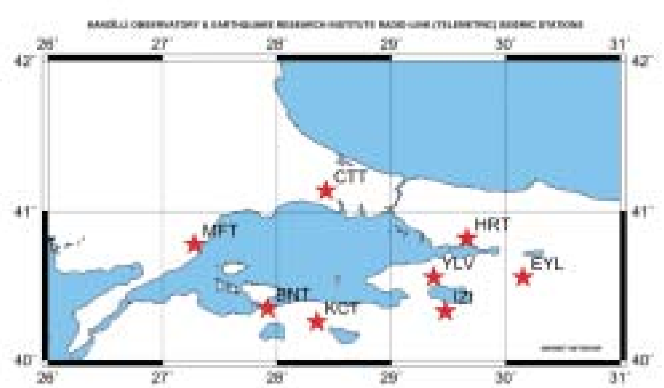


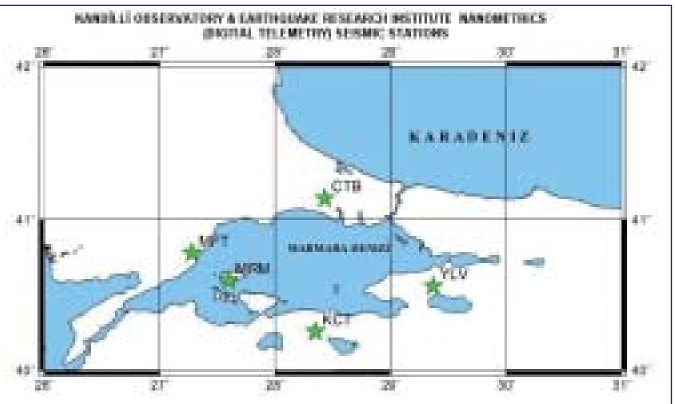


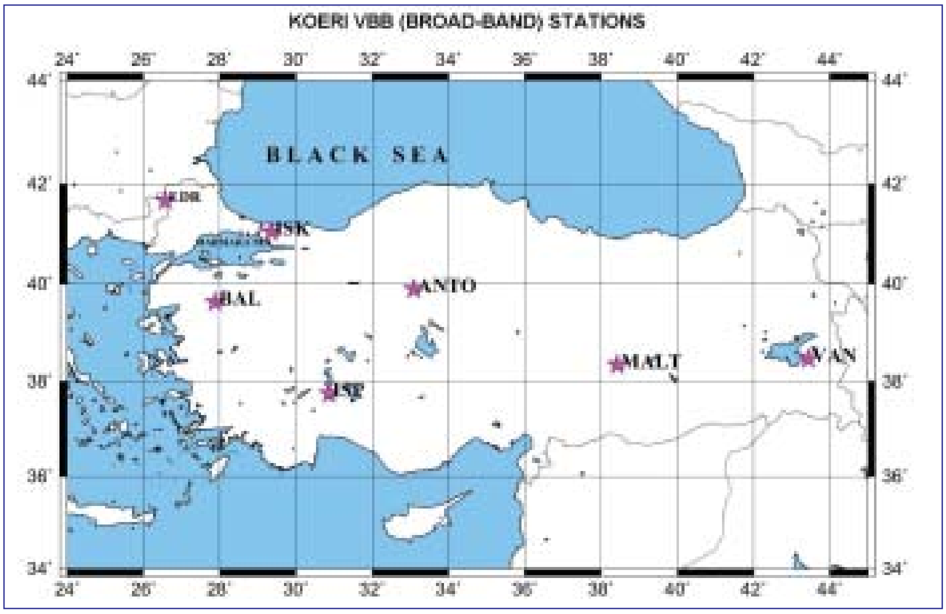
Seismic Network and Instruments

The Kandilli Observatory and Earthquake Research Institute (KOERI), being the oldest institution on seismological studies, have observation networks having seismological and engineering purposes. Since 1926, The Kandilli Seismological Division, an integral arm of KOERI, continues to provide seismological observation services with its continuously expanding network distributed throughout Turkey. The first station was a mechanical Mainka seismograph installed at Kandilli in Istanbul abbreviated as ISK. The KOERI's seismic stations started to be a network in the early 1970's with the installation of conventional seismic stations in Western Turkey. First real-time data recording has been started in Marmara Region, TURKEY by the commencement of MARNET sub-network which is consisting 9 radio-link stations. The KOERI has started to expand its network throughout Turkey in 1993 by the installation of on-line and digital seismic stations. Today, there are three kind of stations according to the signal transmission; radio-link, on-line, broad-band seismic stations.

Radio-Link Seismic Stations: MARNET and IZINET are the earthquake monitoring system covering the populous Marmara region and Lake Iznik in Northwestern Turkey. Seismometers placed at remote sites transmit signals continuously by radio to the center in Istanbul. Nanometrics telemetric system is located in the Marmara Sea region and it has five digital seismic stations. Real time data are recorded in digital forms at the center. In addition, all of them have very sensitive seismic sensors (BB) and Nanometrics network can make automatic detection of earthquakes with magnitude larger than 3.0.







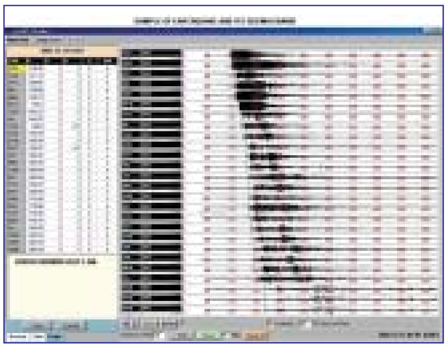
On-Line Seismic Stations provide continuous analog data to the seismological center at the KOERI, Istanbul by leased lines. Real time data are recorded in analog and digital forms at the center.

Broad-Band Seismometer System is widely being utilized in the world. Their extremely high dynamic range and stable transfer characteristics make them ideal for a wide-range of applications. The KOERI started to run a broad-band seismic station at Isparta (ISP) according to the memorandum of understanding between the KOERI, Geo Forschungs Zentrum (GFZ) and the Instituto Nazionale di Geofisica (ING) in the mid of October,1996. The KOERI has a dial-up connection with the ANTO (Ankara-Turkey, Observatory)- IRIS (Incorporated Research Institutions For Seismology) broad-band seismic station located in the Middle East Technical University, Ankara. Also, the central station ISK was being replaced by a broad-band station. In addition, a new broad-band station so called VAN and MALT stations located in the Eastern part of Turkey. BAL and EDR stations installed in the Western part of Turkey.

The number of broad-band stations will be increased to 30 in near future.

Data Analysis and data distribution

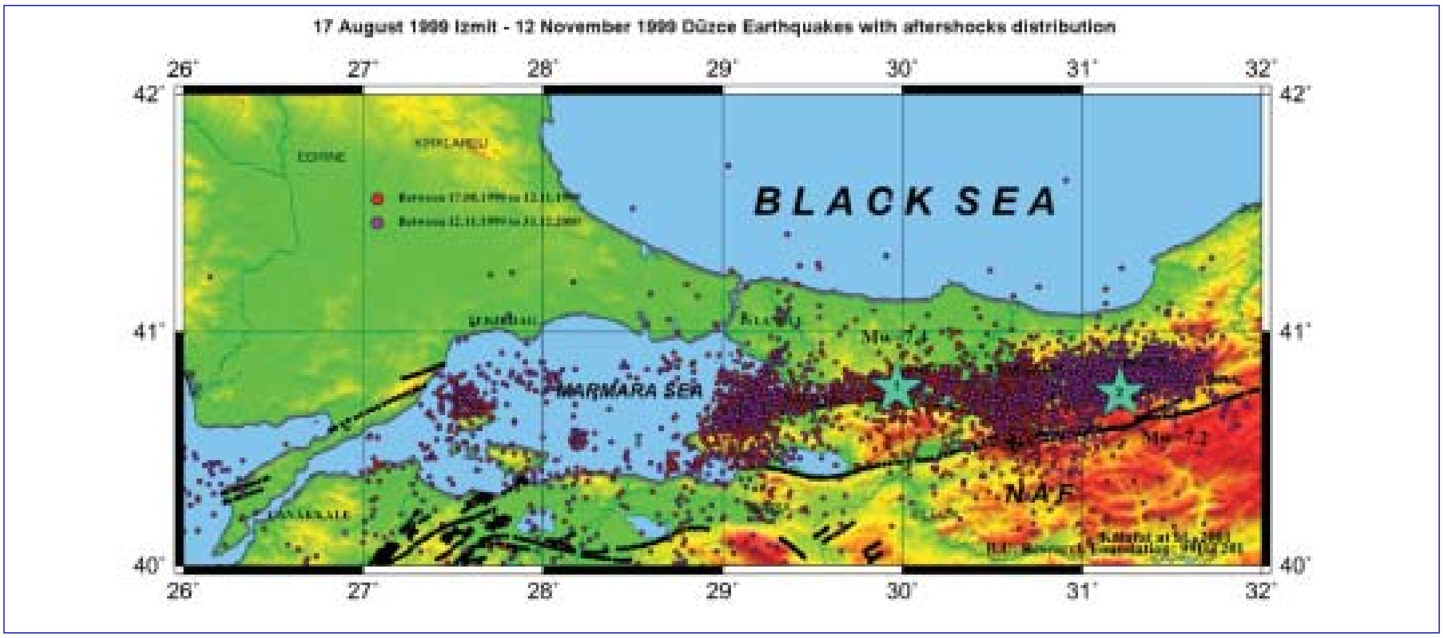
Events are recorded at the center both in analog and digital forms obtained from telemetred, broad-band and on-line seismic stations. These are processed using HYPO71 for the hypocenter determination. The seismological division of KOERI determines, as rapidly and accurate as possible, location and size of all earthquakes of magnitude larger than 3.0 that occur in the country. It provides twenty-four hour information service to government agencies, to government public information centers and to news media. This information is also disseminated immediately to the relevant international seismological centers by fax and by internet channels. Observatory has been supplying mainly 3 kind of seismological data: phase readings, waveform and catalogue to the earth scientists in Turkey and all over the world through internet facilities. The data are also disseminated to the relevant international seismological centers such as NEIC, ISC, and CSEM through fax and internet.



Future plan

Nowadays, several earthquakes in Turkey have occurred more frequently. In particular, the epicentre of these earthquakes are located in northwestern part of Turkey . Izmit and Düzce earthquakes caused the deaths of more than 18.000 people, injured 49.000 people and over 108.000 buildings either collapsed or heavily damaged especially at Yalova-Gölcük-Izmit-Adapazarı-Gölyaka-Düzce- Kaynaşlı areas.

The earthquake was felt in the Marmara region, Central Anatolia and the Aegean Sea in an approximately 480.000km^2 area. To mitigate the seismic risk and prevent seismic panic, the Kandilli Observatory and Earthquake Research Institute have draft the future plan for improving the seismic monitoring system by establishment the broadband digital seismic network in Turkey. Such monitoring system should permit rapid acquisition of seismic wave form data, automatic detection of earthquake event and hypocenter determination. The system should also provide high quality data appropriate to study on seismology and tectonic as well as earthquake prediction.



Observations and monitoring of the seismicity in Bulgaria

R. Glavcheva, E. Botev, B. Rangelov
Geophysical Institute,
Bulgarian Academy of Sciences

The observations and monitoring of the seismicity in Bulgaria are carried out by the Seismological Department of the Geophysical Institute, Bulgarian Academy of Sciences.

The Geophysical Institute was established in 1961 and it incorporated the academic research (staff and equipment) of Seismology, Earth Magnetism and Gravimetry, Physics of the Ionosphere and Atmosphere. The main part of the Seismological Department is the National Seismological Survey, which is responsible for the maintenance and regular operation of the National Seismic Network consisting of 14 permanent seismic stations and two local networks with 7 stations.

The observed earthquakes in Bulgaria are generated as a result of the collision between the African and the European plates. The subduction zone is clearly expressed along the Hellenic arc-trench system. Not so far – less than 600-800 km, the strong Bulgarian earthquakes show more or less typical intercontinental behavior with a dominant extensional regime. The complicated recent tectonic environment needs special attention in connection with the seismicity observations on the territory of Bulgaria. Strong seismic events and local increased seismicity are the clear expression of the seismogenesis of Bulgaria.

The strongest seismic events in Bulgaria

Bulgaria is interested by moderate to high seismicity: since 347 it experienced at least 30 events of magnitude M ≥ 6 (at least 12 of them with magnitude M ≥ 7). The strongest event in the country is the earthquake of April 4, 1904 with a magnitude Ms 7.8, which occurred in the SW, near the border with Macedonia. Since 1700 there have been at least 3 events with magnitude greater than 7 in each century, with a burst of activity in the period 1858-1928, when about 20 events with magnitude greater than 6 (six of which with magnitude M ≥ 7) occurred.

13th September 1858

Sofia region has been destroyed, estimated magnitude over 6.5, observed intensity - IX MSK (Fig.1), coseismic normal fault, boiled sands, a mineral spring appeared, large destruction of the buildings, some casualties and many injured reported, long lasted aftershock activity - more than 5 months.

14th October 1892

northern part of northeast Bulgaria, maximum intensity 8 according to MSK is reported for region of Dulovo, magnitude around 7.

31st March, 1901

Shabla-Kaliakra region, epicenter in the aquatory of the Black sea (NE coast of Bulgaria), estimated magnitude - 7.1, observed intensity - up to X MSK, a foreshock (M~4) reported several hours prior to the main shock, many coseismic and post-seismic events reported (landslides, stonefalls, liquefaction, tsunami effects - up to 3 meters, about 5 years aftershock activity). A large destruction of houses, deaths and injured reported.

4th April 1904

Kresna-Kroupnik region in southwest Bulgaria, two very strong shocks in the time domain of about 20 minutes occurred (M=7.2 and M=7.8). Intensities up to X MSK reported. All coseismic and post-seismic events observed and reported - landslides, stonefalls, surface normal faulting (a river has been barraged and a lake observed), liquefaction, springs appearance, etc. Many deaths and injured reported. Large destruction of the houses. Long lasted aftershock sequence - more than 7 years. This is the most active part of Bulgaria up to now.

16th June 1913

Gorna Oriahovitza region in central part of north Bulgaria. Magnitude 7.0, intensity - up to IX degree MSK. Large destruction, many deaths and injured reported. Landslides, sand boils, liquefaction and aftershocks reported. 7th December 1986 a magnitude 5.7 earthquake occurred in the same region. Large destruction and a few deaths and injured have been reported.

14 and 18th April 1928

again two shocks (M=6.8 and 7.0) with IX and X degree MSK reported for central part of south Bulgaria. Large liquefaction area, sand boils, landslides, surface normal faulting reported and geodetically measured (mentioned in the Richter's "Elementary seismology"). More than 120 deaths and several hundreds injured. More than three years aftershock activity.

It is remarkable that there are no events with M>6.0 within the Bulgarian territory (and only 9 with M > 5.0) after 1928 (with the exception of 2 events with M≥6 which occurred in 1931 in the closed vicinity of neighbouring Macedonia). After the frequent moderate events until 1940, seismicity is lower during the recent years, when especially high magnitude events are missing. Only two earthquakes with magnitude Ms=5.2 and Ms=5.7 (Io=VIII), with long aftershock sequences, occurred in 1986 near by the Strazhitza town (Gorna Oriahovitza region in central northern Bulgaria).

The history of observations

The first network of correspondents for observations of felt earthquakes was organized and it has collected macroseismic data since 1891. It was initiated by Spas Watzof, the director of the Central Meteorological Station, Sofia. In 1903, the Bulgarian seismology survey became a member of the International Seismological Association. The annual reports of earthquake impacts in Bulgaria (published in French and Bulgarian) go on more than 75 years. After 1965, many studies of the

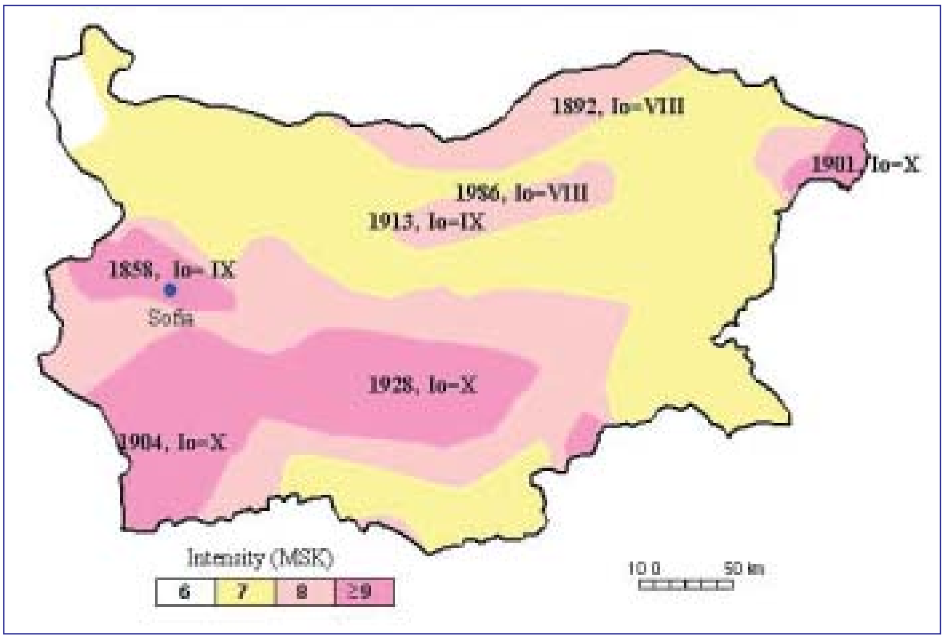


Figure 1: *1000 years shakeability map of Bulgaria and the last strongest events*

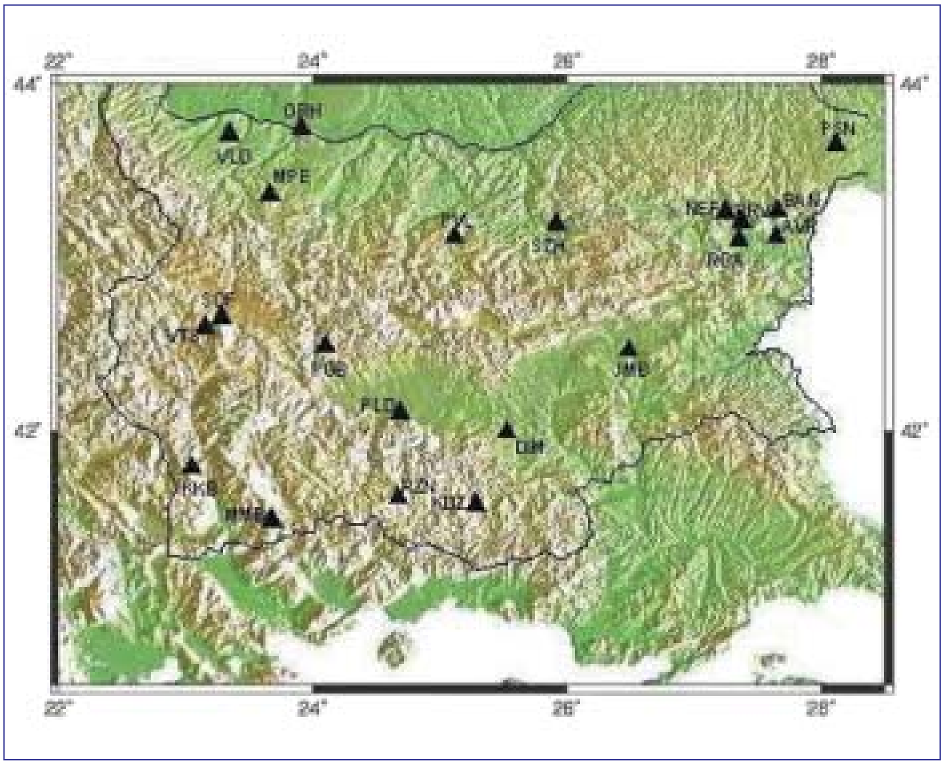


Figure 2: *Seismological network of NOTSSI*

moderate size earthquakes and the atlases of isoseismal maps have been published. The contributions of the Bulgarian specialists to the long-term seismicity investigation of the Balkan region have been done during the execution of many recently completed European projects (Glavcheva and Radu, 1994; Albini and Stucchi, 1997, Ranguelov et al, 2000).

The instrumental seismology started in 1905, when a Bosch-Omori seismograph was installed in Sofia. This action was motivated by the occurrence of several violent earthquakes, some of them followed by long-lasting aftershock sequences: the 1892 earthquake in northeast Bulgaria (maximum intensity VIII MSK); the Black Sea earthquake in 1901 (observed intensity X MSK in northeast Bulgaria); and two transborder Bulgarian-Macedonian earthquakes (maximum intensity in Bulgaria up to X MSK).

Two facts concerning the earliest stage of Bulgarian instrumental seismology are notable:

- the first bulletins, which systematized the registrations during 1905 and 1906, appeared soon after the instrument installation (Watzof, 1907); and
- selected Bulgarian registrations used by A. Mohorovicic and H.F. Reid in their world-recognized works published in 1910 (s. References).

The Sofia station remained the only well instrumented site up to 1961 (in 1905 Agamennone seismoscopes were installed too at several localities in Bulgaria), although its equipment was modernized at the end of 1934 by two horizontal Wiechert seismographs (To = 9-11 sec, magnification ca. 200). The first Bulgarian catalogue (Kirov et al., 1960) covers all seismic events affected Bulgaria by intensity of minimum V MSK occurring both inside and outside the country during the time-period 1892-1958. In this catalogue, beside the earthquake occurrence time, epicentral or maximum intensity together with the corresponding area, the most likely epicenter location for foreign events has been presented; there are not any magnitude determinations therein.

Grigorova and Rizhikova (1966) compile the first parametric catalogue in Bulgaria. An instrumental magnitude, based on Wiechert records, appears as energy characteristics of the earthquakes. Later on, an enriched national catalogue, together with some isoseismal maps of the strongest Bulgarian earthquakes, prepared by Grigorova in the framework of a UNESCO project, has taken place in the first Balkan earthquake catalogue (Shebalin et al., 1974) and in the isoseismal atlas (Shebalin, 1974). This catalogue covers most of the seismic events with a lower magnitude threshold 4 occurring since the antiquity till 1970. With the aim to make the seismic zonation updating, a revised catalogue is compiled in the end of the 70's (Grigorova et al., 1978) using the systematization already produced and techniques performed during the Balkan catalogue creation. The new catalogue presents more than 1400 entries within the territory outlined by geographical coordinates 40 - 46oN, 20 - 30oE. This catalogue has been used as input data for the seismic zonation maps of Bulgaria (Boncev et al., 1982). The shakeability map of 1000 years has been accepted as a basic map (Fig.1) for the seismic rules and code in Bulgaria (Bulgarian seismic rules and code, 1987). The corresponding design coefficients have been attached to the intensities on the 1000 years shakeability map. At present the seismic code of Bulgaria is in the process of modification according to the EUROCODE 8.

In the early 60's one two component mechanical seismograph "Krumbach" was installed in South Bulgaria (Dimitrovgrad station). In the 1960's and 1970's the seismic network was expanded to cover the seismogenic areas of Bulgaria by the high-sensitive 3-component seismographs SKD, SKM, VEGIK with galvanometric registration. The instrumental registrations of that time have been stored on a smoked paper (for the old instruments), pen ink records and photo paper.

After the 1977 Vrancea earthquake a modern seismological network was established in Bulgaria starting its operation on 1 August 1980.

Recent observational network

In 1980 the new National Operative Telemetric System for Seismological Information (NOTSSI) started operating. Initially it consisted of 6 short period vertical seismographs (S-13 / Teledyne Geotech) which were situated to monitor the most active seismic zones of Bulgaria. During the next several years the telemeter network has been expanded up to 14 registration sites. At present all the 21 analog stations in Bulgaria (Fig.2) are equipped with the same one-component velocitygraphs (vertical S-13). Most of the stations have a visual recorder unit of the type "Helikorder" where the record of the signals is performed by ink pens on a paper. NOTSSI is with a near real time signal transmission, by telephone connections mainly, to the main building of the Geophysical Institute, Sofia. Here the recorded signals are collected and processed in the Operative Center (Fig.3). Two local networks have started operation in the mid-90's in connection with the seismicity observation around a Nuclear Power Plant "Kozloduy" site (3 local network stations in northwest Bulgaria) and a salt deposit exploitation site near the Provadia town (4 local network stations around the Provadia(PRV) permanent station in northeast Bulgaria).

All the analog records of the local network around NPP "Kozloduy" are digitized by a Nanometrics acquisition system in Geophysical institute according to a contract with the corresponding authorities of NPP. According to this contract Geophysical institute is responsible for the entire seismic monitoring and analysis of the seismicity around the NPP site. One 3-component digital station "Quantera" and broad-band STS1 seismometer are in operation at the moment in Vitosha

Figure 3: *Operative center in Geophysical Institute*

Geophysical Observatory (near the city of Sofia), according to the contract with MEDNET international project. In the Operative Center of Geophysical institute the seismological data from all 21 stations are manually interpreted (P- and S- arrivals identification, first onsets, signal duration) and processed by computer. For the focal parameters determination an adaptation of the widespread software HYPO'71 and the “four layers” regional velocity model are used (Solakov, 1992). In the earthquake file the duration magnitude Md is computed according to the regional formula by Christoskov and Samardzieva (1983). Two persons on duty (a seismologist and a technician) are available 24 hours each day. These two specialists belong to a qualified team of seismologists and technicians, which are in charge to ensure:

- permanent high-quality recording and analysis of the seismic signals,
- determination of the earthquake parameters,
- relevant assessment of the potential dangerous impact on the people or buildings and to inform the responsible governmental bodies if this impact becomes dangerous. In a case of a strong earthquake on the Balkans, the seismologist on duty sends Bulgarian seismic data to the neighboring and international seismological centers. At the same time the seismological team is responsible for the processing, analyzing and classification the daily seismological data.

The regular international data exchange is based on the later compiled weekly seismological bulletin. The information and analysis of the bulletins of the neighbor and international seismological centers are accepted as a natural and necessary condition for the preparation of the final earthquake catalogue in NOTSSI.

The location accuracy in the seismic catalog depends on the instrumental sensitivity at the different location sites and on the spatial position of the seismic source within the frame of the recording network. The high sensitivity of the seismographs in Southwest Bulgaria allows records and data processing of a great number of earthquakes with a minimum magnitude M less than 1.0. The different magnitude levels of the well-solved local, regional and long distance earthquakes are established as follows: M=2.0 for the territory of Bulgaria, M=3.0 for the Balkans, M=5.0 for the long distance events. About 12000 events recorded during the operation of the National network are located on the territory of Bulgaria and its close vicinity (Fig.4). Most of them are micro earthquakes – more than 95% with a magnitude M<3.0. The strongest recorded by the NOTSSI event is the 1986 magnitude M5.7 Strazhitza earthquake in the central North Bulgaria.

The earthquake monitoring in Bulgaria ensures the necessary base for permanent investigations of space, time and energy distribution of seismicity, the deep Earth's structure and the stress field in the earth crust and leads to better understanding of the earthquake genesis nature. Detailed information and analysis of the realized seismic energy (Botev et al., 1991, 1992...2001, 2002) are also periodically proposed as a generalization and supplementation of the monthly publications of the preliminary seismological bulletin of NOTSSI. These studies help the sought for correlation between seismicity and some geophysical parameters aiming to find out eventual precursor anomalies.

The strong motion network also exists (equipped with SMA1, and other analogue or digital instruments) to support the practical application in the construction of buildings and facilities. The Central Laboratory of Seismic Mechanics and Earthquake Engineering manages this.

The earthquake monitoring promotes many scientific and practical challenges of contemporary Bulgarian seismology such as:

- monitoring of natural, artificial and induced seismic events in Bulgaria and its surroundings;
- earthquake statistics (general, aftershocks, etc);
- seismic zonation of the Central Balkans;
- long-term seismicity investigations;
- earthquake source mechanisms, kinematic and dynamic specification of the large sources,
- seismic energy attenuation;
- tsunami modeling (Black Sea);
- seismic hazard assessment;
- seismic waves propagation (kinematic and dynamic aspects);
- seismic monitoring and site-effects studies in areas of state important sites (nuclear power plants, dams, lifelines, etc);
- delineating earth structures and dynamic processes in tectonically active regions by seismological data;
- searching for earthquake's precursors of seismic, electro-magnetic, or of other geophysical nature.

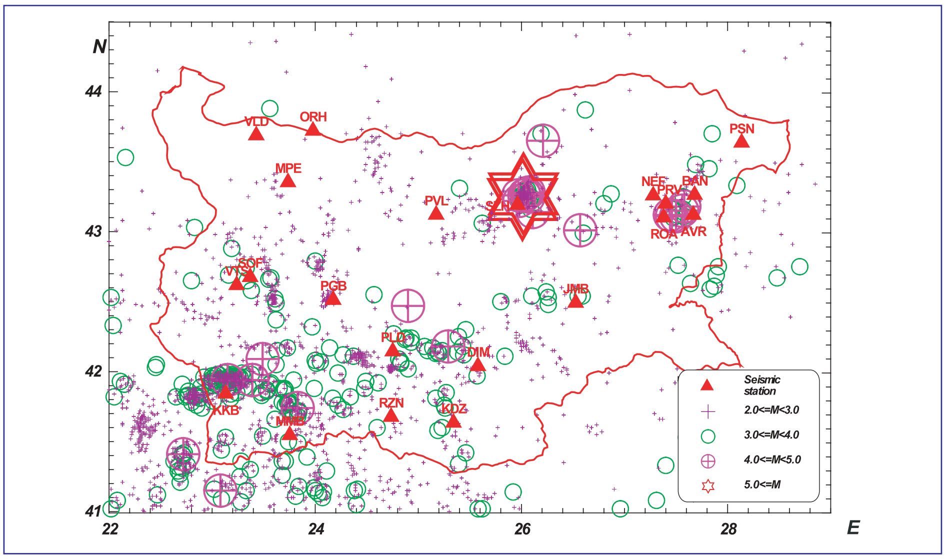


Figure 4: *Seismicity of Bulgaria (after 1980, M>=2.0)*

Near future activities.

To improve the quality of the monitoring of the seismicity the establishment of a digital network (with minimum three broad band 3-component seismographs) is planned to start operating in the very near future. One more network near the future second NPP site "Belene" (under construction) is intended to be deployed around the site. The establishment of a mobile group for the field investigations after the strong event is also an important task for the post earthquake activity research and data collection. The detailed study of the well-expressed earthquake sources of the strong earthquakes observed on the territory of Bulgaria is an essential task for the better understanding of the seismic process using the monitoring information.

It is important to recommend, in the framework of the different European programs and projects, a wide co-operation among the scientists of Central and Southeast Europe regions for the seismological, building's structural and prevention research. The area is under the strong influence of earthquakes and other geodynamic disasters. The improvement of the instrumental networks connected by the modern communication networks is the necessary condition for the successful development of the region and the seismic protection measures. We consider that the aims of seismology, earthquake engineering and the people's protection and prevention are a governmental task and each country as well as the EU community must give their support by funding from different sources.

References:

Albini, P. and M. Stucchi (1997): A Basic European Earthquake and a Catalogue for the evaluation of long-term seismicity and seismic hazard (BEECD), in Seismic risk in the European Union, edited by A. Ghazi A. and M. Yeroyanni, (Brussels-Luxembourg) vol. I, pp. 53-77.

Boncev E., V.I.Bune, L.Christoskov et al.(1982). A method for compilation of seismic zoning prognostic maps for the territory of Bulgaria. Geologica Balcanica, v.12 N2, 3-48.

Botev E., B.Babachkova, B.Dimitrov, S.Velichkova, I.Tzoncheva, K.Donkova, S.Dimitrova .(1991,1991,1992,1992, . . .2002, 2002). Preliminary data on the seismic events recorded by NOTSSI in January - June 1991 (July – December 1991), .. ., (July – December 2001). Bulg. Geophys. J., 18,18,. . . 28,28 (1,2,3,4).

Bulgarian seismic rules and code (1987). CTSU – BAS, Sofia, 67 pp. (in Bulgarian).

Christoskov L. and E.Samardjieva, (1983). Investigation on the duration of the seismic signals like an energetic characteristic of the earthquakes. BGJ, vol.IX, N1, , Bulg. Geophys. J. 9 (1), 28-37. (in Bulgarian)

Glavcheva, R. and C. Radu (1994): The earthquake of October 14th, 1892 in Central Balkans: a transfrontier case. In: Albini P. and Moroni A. (eds.), Materials of the CEC project "Review of Historical Seismicity in Europe", 2, CNR - Istituto di Ricerca sul Rischio Sismico, Milano, 215-223.

Grigorova, E., S.Rizhikova (1966): Tremblements de terre en Bulgarie au cours de 1961 a 1964. NN 62-65, Editions de l'Acad. Bulg. Sci., Sofia, 105.

Kirov, K. (1931, 1945): The earthquakes in Bulgaria. Report on the felt earthquakes during 1917-1927, 1928-1930 (Sofia), NN18-28, 29-31 (in Bulg.).

Mohorovicic, A. (1910): Das Beben vom 8.X.1908. Jahrbuch Meteor. Obs. in Zagreb (Agram) fur das Jahr 1909, Jahrg. IX, IV Teil, Zagreb, 63 S.

Ranguelov B. et al., (2000): The earthquake (M 7.8) source zone (SW Bulgaria)., Acad. Publ. House "M.Drinov", Sofia, 279 pp.

Reid, H.F. (1910): The California earthquake of April 18, 1906. Report of S.E.I. Comm., V. II - The mechanics of the Earthquake. Carnegie Inst., Washington D.C., 195 p.

Shebalin, N.V., V. Karnik, D. Hadzievski (Eds.) (1974): Catalogue of Balkan Earthquakes, UNDP/UNESCO Surv. Seism. Balk. Reg., Skopje.

Sokerova, D., S.Rizhikova, R.Glavcheva (1982): Catalogue of Earthquakes in Bulgaria during the period 1970-1980. In: National Report of Bulgaria, UNDP/UNESCO and UNDRO Project RER/79/014 "Earthquake Risk Reduction in the Balkan Region, W.Gr. A: Seismology, Seismotectonics, Seismic Hazard and Earthquake Prediction, Final Report, Athens, Dec. 1982, A47 - A49.

Solakov, D. (1993): An algorithm for hypocenter determination of near earthquakes. Bulg. Geophys. J. 19 (1), 56-69.

Watzof, S. (1902, 1903, ..., 1923): The earthquakes in Bulgaria. Report on the earthquakes felt in XIXc., and during 1901, 1902,..., 1913-1916. (Centr. Meteorol. Inst., Sofia), NN 1-17 (in Bulgarian, in French).

Watzof S. (1907) Bulletin seismographique de l'Institute meteorologique central de Bulgarie de 1905, 1906, NN1, 2 (Sofia) 1907.

NEWS OF THE EMSC

Euro.-Med. bulletin

The main objective of the EPSI project was the production of the Euro.-Med. seismological bulletin. This EU-funded project lead by EMSC ended last December and first results of the Euro.-Med. bulletin are already available on our web site. Olivier Piedfroid, who has been involved for more than 2 years in this project, has recently left EMSC. Stéphanie Godey who defended her PhD thesis last year at Utrecht University, has just taken over his position.

Stéphanie is now in charge of the production of the bulletin from 01/01/1998 up to now. We expect to have a complete 6-year bulletin by the end of this year and then start detailed performance analysis of the results.

The Euro.-Med. bulletin is based on data contributions from network operators. EMSC has set up procedures to help data operator in the registration of stations to the World Data Centre. Nearly 200 stations have been registered following these procedures. So far, about 70 networks and 1500 stations have contributed to the bulletin. A description of the database content is available by month and by network at www.emsc-csem.org/Html/DATA_main.html If your network does not appear on this page or if you could help filling some reported gaps, please contact Gilles Mazet (mazet@emsc-csem.org) as soon as possible, otherwise we may not be able to include your data in the Euro.-Med. bulletin!

EMSC-ORFEUS Infrastructure proposal

EMSC and ORFEUS are co-ordinating the preparation of an Infrastructure proposal for the EU Sixth Framework Program. This five-year project is based on our common Expression of Interest named NERIES and it aims at improving the integration of the seismological community and at improving the services provided by our organisations. Details of this proposal to be submitted on April 15, are available on both EMSC and ORFEUS web site. An information meeting will be held during the EGS meeting on April 8, from 19:30 to 21:00 in lecture room R7

New prototype service for active members

Following requests from active members, EMSC has developed a tool to automatically disseminate by email the result of automatic relocations. Every thirty minutes, all available data concerning very recent seismic events are merged, relocations (names MIX) are computed for new events and they are updated for events for which new data has been made available. The results are automatically displayed on the Real Time Seismicity Page (for more details on this web page, see Newsletter n°17).

The prototype service automatically sends a single email by seismic event. In order to avoid the dissemination of poorly constrained location, the message is sent for events which occurred at least 3 hours before, a delay which is large enough to ensure that the majority of data has already reached EMSC. As an average, these relocations have proved to be more reliable that individual automatic locations.

Today, EMSC is looking for active members interested in receiving these messages, helping us to finalise this tool and make it operational by providing feedback on the reliability of the provided locations. If you are interested, please let us know!

Next Newsletter issue

The next issue is planned for September 2003. We would like to have a special part on earthquake monitoring in Northern Africa. A number of authors have already been identified and new propositions are welcome and should be addressed to Rémy Bossu (bossu@emsc-csem.org).

Seismic Hazard Assessment for Nuclear Power Plants Safety Laboratory (BERSSIN), Radioprotection and Safety Nuclear Institute (IRSN, France).

Catherine Berge-Thierry, Stéphane Baize, David Baumont, Fabian Bonilla, Marc-Edward Cushing, Pierre Dervin, Francis Lemeille, Stéphane Nechtschein, Gérard Peyridieu, Oona Scotti and Philippe Volant.

IRSN

IRSN is a governmental organization recently created by a law (28th of February 2002). IRSN is the association of two entities, the Nuclear Protection and Safety Institute and the Protection against the Ionizing Radiations Office. IPSN was originally part of the Atomic Energy Commission, which is a nuclear operator. In order to clearly distinguish between a safety organization and a nuclear operator the French Government decided to separate IPSN from CEA. Approximately 1,500 experts and researchers work at IRSN, on radiation protection and nuclear safety. The main issue for IRSN is to provide advices for the French Nuclear Safety Authority (called DGSNR). IRSN is its main technical support.

Scientific research is carried out in the areas associated with the use of nuclear energy, ionizing radiation and natural radioactivity. Actual tasks consist in risk assessment, expertise and consulting for public authorities, public opinion information, environmental monitoring and radiation-dose follow-up for employees and training of medical personnel.

THE BERSSIN

The Seismic Hazard Assessment for the Nuclear Power Plants Safety Laboratory (hereafter BERSSIN), whose activities and missions are presented in this paper is one of the four laboratories that composed the Waste Elimination and Geosphere service. The main assignment of the BERSSIN consists in the expertise of the safety demonstration of the nuclear operators from the seismic point of view, for new and old power plants. According to this task, the BERSSIN conducts research studies to improve seismic hazard assessment in France. Finally the division has to maintain the regulation for the nuclear power plant safety in coherence with the «state of the art». The team is composed of three geologists, a seismotectonical specialist, five seismologists, a technical engineer and a technical assistant. At this time, three PhD and three postdoctoral students work in the team.

SEISMIC HAZARD ASSESSMENT

In all the countries, seismic hazard assessment requires three main steps: the first one consists in the seismic sources definition, i.e. the cartography of active faults. The second one is to evaluate the seismic potential of these sources. The last point is the seismic motion prediction, in term of response spectrum or acceleration time series or any other pertinent indicator, at the site of interest. This motion is the input data for the structural engineers for the power plant design or for the resistance tests.

The definition of active faults in France is still a controversial scientific debate. Different methodologies allow improving our knowledge on active faults. Classical geological approaches such as field and geomorphic studies are completed with Digital Elevation Model (hereafter D.E.M.) and aerial photography analyses. Several main faults are already known in France. The study of neotectonical indices, indicators of seismic ruptures in recent (i.e. quaternary) sedimentary formations is also a way to study the active faults. Whatever the location and the geometry of a fault, a question still remains: can the fault produce an earthquake ?

Geologists of BERSSIN published this year a synthesis of the quaternary deformation indices for the French territory (Baize et al., 2003). The BERSSIN collaborated with academic teams and others specialists, and contributed for the publication of the 1993 French sismotectonic map (Grellet et al., 1993). This publication presented the state of the art in the 1993, using a very broad source of data (from geology to geophysical interpretations, seismic profiles, magnetic anomalies…).

Historical Seismicity

In addition to these geological investigations the seismic history of the country provides important information on seismic sources. The instrumental seismicity, which covers a 40 years period considering the installation of the national network in the 1960's. This short period has been complemented with a project started 25 years ago, whose aim is the study of the historical seismicity. The BERSSIN with the Electrical French Operator (EDF) and the Geological and Mines Research Division (BRGM) constructed the French historical database (http://www.sisfrance.net). This database is today a reference with all the earthquakes and the associated archives describing the effects of the event. Using SisFrance, one can find the location of any event and a map of observation points. An evaluation of all the intensity points is given, with the epicentral intensity (MSK scale). Because the confidence or the descriptions themselves are very scattered, quality factors for the location and the intensity values are given. SisFrance database has more than 80 000 observations and 9000 archives describing 6000 earthquakes. The time period covered by SisFrance is around ten centuries. The interpretation of historical document, such as damage summaries after earthquakes, or description of the event in ancient newspapers or church archives is not common for seismologists. That is the reason why collaboration with historians is very important. They are able to interpret these old documents, taken into account the historical social and economical context (Quenet et al., 2002).

A sensible point in seismic hazard assessment is the estimation of magnitude from macroseismic observations for historical events. Levret et al. (1994), using a set of 73 earthquakes simultaneously documented by macroseismic intensities and recorded by the French National Seismic Network (LDG) have proposed an attenuation relation. Levret et al., computing 238 isoseismals proposed a relation between the instrumental magnitude, the focal distance and the epicentral intensity of the event. Using this relation, any historical event with sufficient intensity observations can be associated with a magnitude value. The BERSSIN still continues to improve this relation (Scotti et al., 1998).

Archeosismicity and Paleoseismology

The last sources of data that contribute to improve our knowledge on the seismicity of the country, for a period longer than the historical period described before, are the archeo and the paleoseismological studies. Archeoseismicity consists in the study of deformation on old Roman or Middle Age structures that could be related to a seismic event. In France, several studies have been carried out in this field, and the BERSSIN conducted several of these projects. At present, the BERSSIN is compiling a ten years long project in archeoseismicity performed on the Pont du Gard (Southern France). Architects, archeologists, geologists and seismologists discovered structural reinforcements on this bridge that could be associated to past earthquake damages. Numerical simulations confirmed the possibility of seismic effects (Volant et al., 2003). But all these observations and computations do not allow to describe precisely the position and the magnitude of the seismic event.

As in other countries, several paleoseismic indicators have been discovered in France since the 1990's. This recent research field allows to define another tool to characterize the seismic activity of faults, in addition with the instrumental and historical activities. In France, several reliable indicators have been

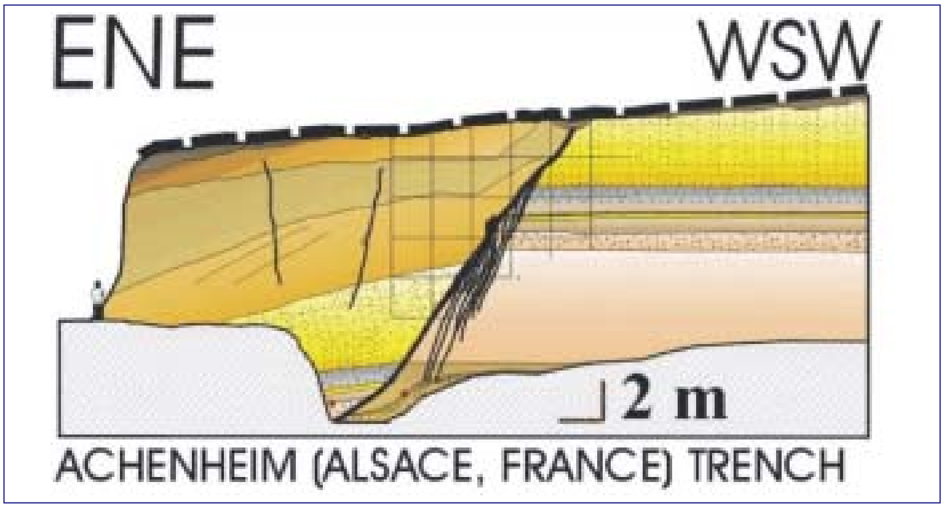


Figure 1: *Paleoseismological study in east of France (Lemeille et al., 1999)*

published (Lemeille et al., 1999, Figure 1). The difficulty of such kind of data remains the dating of the event (with a large time uncertainty) and the estimation of the size of the event, in terms of magnitude. The BERSSIN was involved in the European Project PaleoSis (ENV4-CT97-0578 EC).

The BERSSIN uses all these approaches to assess the location of active faults and to define their seismic potential. But all these data do not allow answering precisely key questions such as what is the maximal size of an earthquake on a segmented fault. This kind of questions still remains unanswered today. Numerical simulations based on dynamic rupture propagation could help to progress on this question.

Ground Motion Prediction and Site Effects

In addition to the geological source characterization and the assessment of seismic potential, the BERSSIN works on ground motion prediction, to propose to civil engineers, the ground motion that can be considered as an input for the structure design. Empirical approaches with attenuation relations are currently used in the French Basic Safety Rule (methodology to assess the seismic hazard for a French Nuclear Power Plant). This rule has been recently modified, introducing new topics, such as paleoseismicity and site effects. The attenuation law developed for the rule (Berge-Thierry et al., 2003), with mainly European strong motion records (Ambraseys et al., 2000), allows the calculation of the ground motion for rock (Vs>800m/s) or sedimentary (300m/s<Vs<800m/s) sites. Specific site effects, due to very soft soil, or 2D-3D geometrical effects are not taken into account in the empirical law. For such cases, a specific study is required to evaluate the linear and nonlinear soil response. Such complex effects are sometimes cumulative, such as in the Grenoble basin (France), which is a deep valley filled with thick soft sediments (Figure 2).

The BERSSIN collaborated during more than ten years with the University of Santa Barbara (California) on the Garner valley experiment, to study the 1D linear and non-linear effects, using instrumented deep boreholes. Now, the BERSSIN continues on site effects studies in the active seismic zone of the Corinth Gulf. In the framework of CORSEIS European Program, IRSN collaborates with ENS-Paris, IPG-Paris, AUTH (Greece) and NKUA (Greece) to install an array of accelerometers and pore pressure probes at different depths dedicated to the study of liquefaction in the Aigion harbor. This experiment would allow to collect ground motion data to improve seismic motion modeling. In addition, BERSSIN is also involved in the study of site effects, and particularly, nonlinear soil behavior. Such phenomena occurred during the Aigion earthquake on June 15, 1995 (M 6.2). Geotechnical measurements and geophysical experiments improved the knowledge of the site providing basic physical parameters. The main objectives for the BERSSIN in this experiment are (1) to increase the strong motion database with a good knowledge of site conditions (including static and dynamic soil parameters), and (2) to improve the strong motion modeling considering linear and nonlinear soil response (Bonilla et al., 2002). We expect that the results could be applied on weak seismicity and low deformation rate areas such as France.

A good strong motion assessment using empirical relationships requires the collection of numerous and reliable data. The BERSSIN collaborates with academic teams since several years to collect and disseminate strong motion data. For example BERSSIN participated to the development and to the production of the European Strong Motion Database (Ambraseys et al., 2000): this

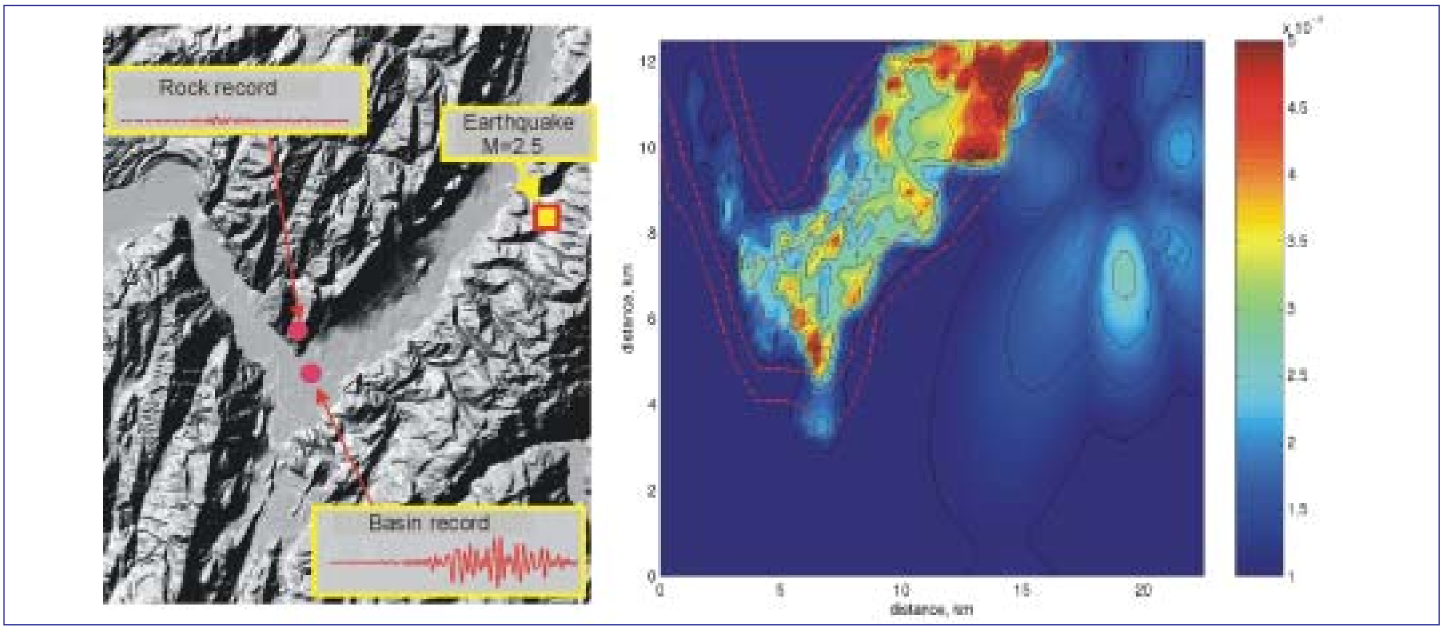


Figure 2: *Two seismological records in the Grenoble area, one on the rock and one on the sediments (left). 3D seismic simulation of the horizontal peak velocity (right).*

database can be obtained by simple request at BERSSIN (request addressed to Catherine.berge@irsn.fr). In France, the strong motion data are centralized by the French Accelerometric Network (RAP: http://www-rap.obs.ujf-grenoble.fr/) .The BERSSIN is associated to the RAP. The improvement of strong motion assessment is strictly related to the increase of reliable data, with accurate site conditions.

Empirical relationships use simple physical models to describe the seismic energy attenuation with few parameters, such as the source to site distance, the event magnitude and sometimes the geological site condition. Source complexity, such as the geometrical extension of the fault, which has a strong effect close to the fault (directivity) is not taken into account in this empirical description, neither hanging wall effects, or focal mechanism. These parameters can only be estimated in areas with high seismic level activity. Nevertheless, synthetic simulation allows to take into account realistic complexities of the source. The BERSSIN develops numerical approaches, especially using a kinematic description of the source. Directivity is then modeled, and peak ground acceleration maps and broadband accelerograms can be calculated (Baumont and Berge-Thierry, 2002). This code has been used in the European Project, dedicated to the Predictability of the Aftershocks after a Main Event (PRESAP EVG1-CT-1999-0001). In this project, the BERSSIN was leader of WP2 related to the Coulomb stress change method, as a tool of predictability for the aftershock location (Baumont et al., 2002).

The Durance Multidisciplinary Research Program

Considering all these research fields, seismic hazard assessment in moderate seismic countries appears to be a real challenge. In order to improve the knowledge of the seismic behavior of an active fault in a low deformation rate area, IPSN decided in 1990's to conduct a multidisciplinary study on the Moyenne Durance Fault, located in South Eastern France. Historical earthquakes characterize this fault system (4 events with magnitude 5 and 5.5 since 1509). This is the only fault in France with such a periodic historical seismic activity. A complete geological study of the region has been done, combining field investigations, with aerial photography interpretations, in collaboration with academic teams (Paris XI and Cerège). Seismic profiles released by private or public companies were re-interpreted. The resulting 3D model constrained by borehole data shows the complex 3D geometry of the fault (Cushing et al., in prep.). In 1992 IRSN decided to install a permanent seismological network surrounding the fault area (Figure 3). It is the first time in France that a permanent seismic network is completely devoted to one specific fault zone. Although major historical earthquakes are clearly associated with this structure, few earthquakes have been recorded since 1962 with the national seismic network. Our network shows a small seismic activity, with epicenters well aligned along the fault direction (Volant et al., 2000). Focal mechanisms computed for two events agree with the regional microstructural studies (Cushing et al, 1997). The Moyenne Durance Fault is characterized by a complex 3D geological structure. The fault of the Moyenne Durance is segmented. Standardized location procedures with 1D velocity models using linear algorithms are not adapted for such areas and do not constrain the event location especially in depth (Lomax et al., 1998). A 3D non-linear location program has been developped (Lomax et al.,2000). To complete the seismic potential assessment of this fault, IRSN installed three years ago two permanent GPS stations on each side of the fault, which will allow to constrain the deformation rate in the fault area within the next five or ten years. These sensors will be completed by semi-permanent network in order to identify strain along a cross section through the fault.

Deterministic and Probabilistic Approaches

Seismic hazard assessment for nuclear plants is guided by a specific regulation, which is based on a deterministic approach (RFS2001-01). Nevertheless, in the context of Probabilistic Seismic Assessment (PSA) studies, IRSN has always developed probabilistic seismic hazard codes (Bottard and Gariel, 1995). Since the beginning of 2001, the BERSSIN is involved in the revision of the French seismic zonation, to produce a map describing the different regions with their associated seismic levels. The Environment Ministry conducts this revision, and requested IRSN for technical supporting. This seismic zonation has to be evaluated following a probabilistic approach, according to the Eurocode 8, and should be the bases for the regulation on conventional structures. A private company produced the seismic hazard study, and the BERSSIN did the expertise of their work. The objective was to give to the French Government and the expert group, recommendations to evaluate the results. During this experience the BERSSIN developed a probabilistic seismic hazard code using a logic tree approach. Furthermore a Ph.D Thesis (Beauval et al., 2002) is dedicated to the probabilistic seismic hazard feasibility in moderate seismicity countries. In the same time, IRSN itself proposed to realize a whole Probabilistic Safety Assessment for Nuclear Power Plants. This type of approach is currently being developed for the Tricastin NPP site (south of France). Comparison of deterministic and probabilistic approaches enables the BERSSIN to define and compute uncertainties and margins that should be included or explicited in all assessments.

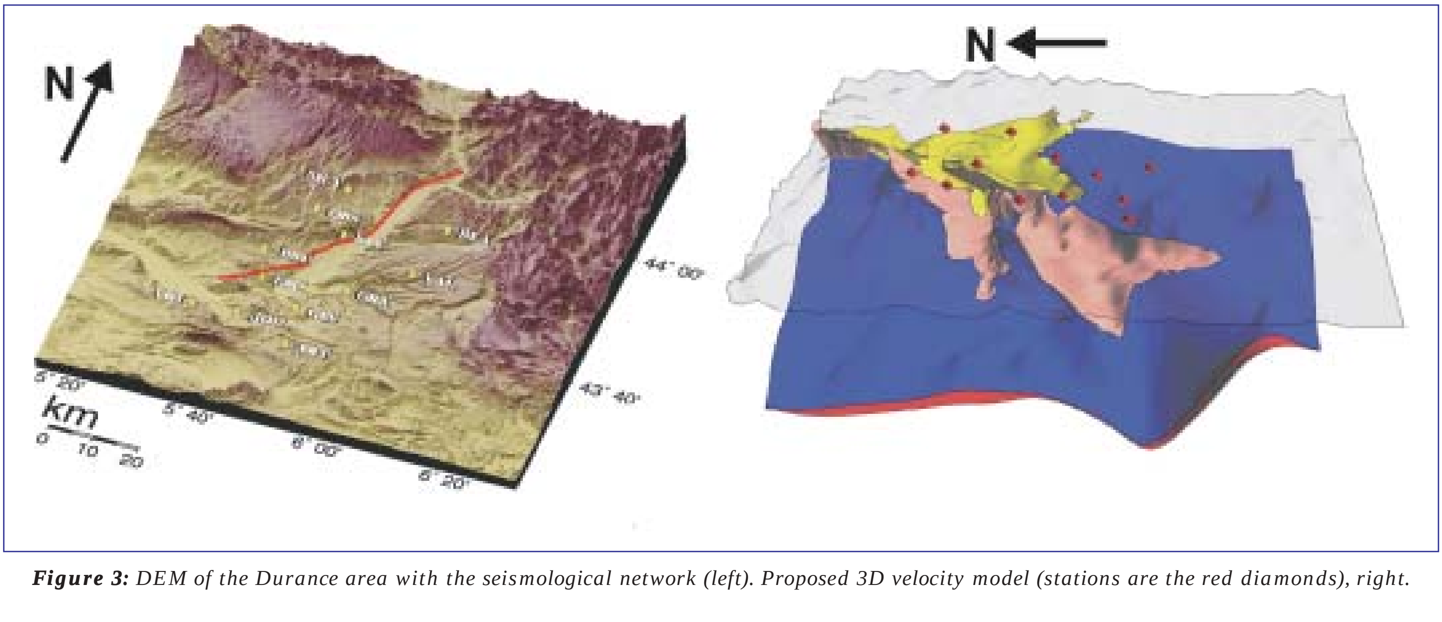


Figure 3: *DEM of the Durance area with the seismological network (left). Proposed 3D velocity model (stations are the red diamonds), right.*

Underground Waste Storage

IRSN is especially involved on seismic hazard assessment related to surface nuclear power plants. Nevertheless, the possibility to store nuclear wastes in deep geological formations appeared in the 1990's. This possibility developed new research fields. The French Government decided to conduct research in France in order to define the conditions where a reversible or irreversible disposal site could be achieved and operated in deep geological formations. The underground research laboratories give the opportunity to answer important questions on this topic. The program is conducted by a governmental agency –ANDRA- (agency responsible for the nuclear wastes management). Since the beginning, IRSN expertises all the research results of ANDRA, for the safety authority. The BERSSIN is often requested to give answer on specific seismological and geological questions. The BERSSIN conducts several research projects devoted to this deep storage concept. For example, through postdoctoral research the BERSSIN works on the growth of fault networks, using numerical approaches, or on the use of the calcite macles to construct the deformation history of a region (Rocher et al., 2003). Geophysical methodologies are tested in the IRSN underground natural laboratory, (an ancient one-century years old tunnel), especially to characterize the fracturation of the argillite due to a rock excavation (Excavation Damaged Zone). The old tunnel is the reference and new galleries have been excavated. A network of 20 high frequency accelerometers has been cemented in boreholes before the excavation of a new gallery. The study of the microseismicity will allow to characterize and to image the damaged zone evolution. The main advantage of this method is that it is a non-destructive method which has been used in several places all over the world. But it is the first time that this method is used in argillite. The BERSSIN is also involved in the seismic motion prediction in depth, the BERSSIN proposed two Ph.D thesis subjects on this topic: using the KikNet Japanese accelerometric network, which offer thousands of stations (a surface reference and a station in a borehole) where geological conditions are known (Lussou et al., 2001), we hope to improve the linear and non-linear strong motion prediction from depth to surface

The wide range of fields covered by the IRSN/BERSSIN contributes to improve the seismic hazard assessment for both nuclear and conventional structure safety.

Références:

Ambraseys, N., P. Smit, R. Beradi, D. Rinaldis, F. Cotton et C. Berge-Thierry, Dissemination of European Strong Motion Data. CDROM-collection, European Commission, Environment and Climate Research Program, 2000.

Baize S., E. M. Cushing, F. Lemeille, T. Granier, B. Grellet, D. Carbon, P. Combes, C. Hibsch, Sismotectonique de la France métropolitaine - volume 3 : Inventaire des indices de rupture affectant le Quaternaire en relation avec les grandes structures connues, Mémoire Soc. Géol. Fr, in press, 2003.

Baumont D. et C. Berge-Thierry, Contribution IRSN to the final report for WP4, PRESAP project, 2002.

Baumont D., F. Courboulex, O. Scotti, N. Melis, G. Stavrakakis, Slip distribution of the Mw 5.9, 1999 Athens earthquake inverted from regional seismological data., Geophys. Res. Lett, 29, No 15, 2002.

C. Beauval, D. Bertil, F. Bonilla and O. Scotti, Logic tree approach for PSHA for nuclear power plants in France, ESC, Gènes, 2002.

Berge-Thierry C., D. Griot-Pommera, F. Cotton and F. Fukushima, New empirical response spectral attenuation laws for moderate European earthquakes, Jour. of Earthquake Eng., in press, 2003.

Bonilla L. F. Computation of Linear and Non-linear Site Response for Near Field Ground Motion, Ph.D. dissertation, University of California, Santa Barbara, 2000.

Bottard S., Gariel J.C, Une méthodologie probabiliste pour l'évaluation de l'aléa sismique en France. Seventh International Conference on Applications of Statistics and Probability in Civil Engineering, Paris, 1995.

Cushing M., Ph. Volant, O. Bellier, M. Sebrier, E. Baroux , B. Grellet, Ph. Combes and Th. Rosique. 1997. A multidisciplinary experiment to characterize an active fault system in moderate seismic activity area : the example of the Durance fault (south eastern France). European Geophysical Society ; Annales Geophysicae, supplement I to vol. 15, p. C233. Vienne, April 1997.

Cushing M. , F. Lemeille. B. Grellet and D. Carbon IPSN/BERSSIN, 1998 : Paloseismological studies in the upper rhine graben area. XXVI General assembly of the European Seismological commission. 23-28 August 1998, Tel Aviv, Israel.

Grellet B., Ph. Combes, Th. Granier and H. Philip, Sismotectonique de la France métropolitaine dans son cadre géologique et géophysique, Mémoires de la société géologique de France, Vol. 1, N 164, Vol 2, 1993.

Quenet G. , A. Levret, O. Scotti and D. Baumont, The Study of Poorly Documented Historical Earthquakes in France through a multidisciplinary approach, Americcan Geophysical Union Meeting, 2002.

Lemeille F., M.Cushing , F. Cotton, B. Grellet, F. Ménillet, J.C. Audru, F. Renardy and C. Fléhoc. Evidences for Middle to Late Pleistocene faulting within the Northern Upper Rhine Graben (Alsace Plain, France). Traces d'activité pléistocène de failles dans le nord du Fossé du Rhin supérieur (Plaine d'Alsace, France. Comptes Rendus de l'Académie des Sciences, t.328, série II, n°12, Juin 1999, p. 839-846, 1999.

Levret A., J.C. Backe and M. Cushing, Atlas of macroseismic maps for French earthquakes with their principal characteristics. Natural Hazard, p. 19-46, 1994.

Lomax, A., P. Volant, C. Berge and J. Virieux, Probabilistic, grid-search earthquake location in three-dimensional media: Application to the Durance Network in the South of France, Shalheveth Freier 1st Intl. Workshop on Advanced Methods in Seismic Analysis, Israel, 1998.

Lomax, A., J. Virieux, Ph. Volant and C. Berge-Thierry, probabilistic earthquake location in 3D and layered models – Introduction of a Metropolis-Gibbs method and comparison with linear locations, in Advances in Seismic Event Location, p. 101-134, eds. C.H. Thurber and N. Rabinowitz, 2000.

Lussou P., P.Y. Bard, F. Cotton, and Y. Fukushima, Seismic design regulation codes : contribution of K-NET data to site effect evaluation, Journal of Earthquake Engineering, Vol. 5 (1), p. 13-33, 2001.

Rocher M., S. Baize, S. Jaillet, M. Cushing, Y. Lozac'h. and F. Lemeille. Quaternary stresses revealed by calcite twinning inversion: Insights from observations in the Savonnières underground quarry (eastern France), submitted, 2003.

Scotti O, Levret A.,.and Hernandez B.. Verification of macroseismic methods on five M > 5 instrumental earthquakes in France. Physics and Chemistry of the Earth (A), 24, 6, p. 495-499, 1998.

Volant, P., C. Berge, P. Dervin, M. Cushing, G. Mohammadioun and F. Mathieu. The southeastern Durance fault permanent network: preliminary results, Journal of Seismology, 4(2), p. 175-189, 2000.

Volant P., A. Levret, D.Carbon, D. Combescure, T. Verdel, Archeosismicity : a multidisciplinary case study on the Roman aqueduct of Nîmes (France), in preparation, 2003.

EMSC information

EMSC/CSEM - c/o LDG, Bât. Sables - BP 12 91680 Bruyères-le-Châtel, France

Chris Browitt		**Véronique Guerdet**	
President	president@emsc-csem.org	Administration	+33-1-69267808
Rémy Bossu	+33-1-69267814	**Fax**	+33-1-69267000
Secretary General	bossu@emsc-csem.org	**Alert messages**	alert@emsc-csem.org
Gilles Mazet-Roux	+33-1-69267813		urg@ing.es
Alert system / Data Exchange	mazet@emsc-csem.org	**Bulletins**	csem@emsc-csem.org
Stéphanie Godey	+33-1-69267813	**JSOP data**	jsop@emsc-csem.org
Euro.-Med. Bulletin	godey@emsc-csem.org	**Other matters**	csem@emsc-csem.org

EMSC members

Institute	Country	Correspondant
Active Members		
National Seismological Centre (NSC)	Armenia	**Dr. A. Arakelyan**
Central Institute for Meteorology and Geodynamics (ZAMG)	Austria	**Dr. Edmund Fiegweil**
Centre of Geophysical Monitoring of NAS of Belarus (CGM)	Belarus	**Dr. A. Aronov**
Observatoire Royal de Belgique (ORB)	Belgium	**Dr. Roland Verbeiren**
Bulgarian National Operating Telemetric System for Seismological Information (NOTSSI)	Bulgaria	**Dr. B. Ranguelov**
Geological Survey Department (GSD)	Cyprus	**Dr. George Petrides**
Geophysical Institute of the Academy of Sciences (GFU)	Czech Republic	**Dr. Jan Zednik**
Institute of Physics of the Earth, Brno (IPE)	Czech Republic	**Dr. Jan Svancara**
National Survey and Cadastre, Copenhagen (KMS)	Denmark	**Dr. Soren Gregersen**
National Research Inst. for Astr. and Geophysics (NRIAG)	Egypt	**Prof. Ali Tealeb**
Institute of Seismology (ISUH)	Finland	**Dr. Pekka Heikkinen**
Seismic Risk Evaluation for the Safety of Nuclear Facilities (BERSSIN)	France	**Dr. Catherine Berge-Thierry**
Bureau Central de Sismologie Français (BSCF)	France	**Dr. Michel Cara**
Bureau de Recherches Géologiques et Minières (BRGM)	France	**Dr. Pascal Dominique**
Laboratoire Central des Ponts et Chaussées (LCPC)	France	**Dr. Pierre-Yves Bard**
BGR Seismologisches Zentralobs. Gräfenberg (BGR)	Germany	**Dr. Klaus Klinge**
National Observatory of Athens (NOA)	Greece	**Dr. George Stavrakakis**
University of Thessaloniki (AUTH)	Greece	**Dr. Manolis Scordilis**
Institute of Engineering, Seismol., and Earthq. Engineering (ITSAK)	Greece	**Dr. Christos Papaioannou**
Icelandic Meteorological Office (IMO)	Iceland	**Dr. Ragnar Stefansson**
Dublin Institute for Advanced Studies (DIAS)	Ireland	**Dr. Peter Readman**
Geophysical Institute of Israel (GII)	Israel	**Dr. Yefim Gitterman**
Osservatorio Geofisico Sperimentale (OGS)	Italy	**Dr. Marino Russi**
Storia Geofisica Ambiente srl (SGA)	Italy	**Dr. Emanuela Guidoboni**
Geophysics Centre at Bhannes (SGB)	Lebanon	**Dr. Alexandre Sursock**
Centre National de la Recherche (CNR)	Morocco	**Prof. Aomar Iben Brahim**
Norwegian Seismic Array (NORSAR)	Norway	**Dr. Jan Fyen**
University of Bergen (BER)	Norway	**Dr. Jens Havskov**
Instituto de Meteorologia (IMP)	Portugal	**Dr. Maria-Luisa Senos**
Instituto Superior Tecnico (IST)	Portugal	**Dr. Joao Fonseca**
National Institute for Earth Physics (NIEP)	Romania	**Dr. Gheorghe Mărmureanu**
King Abdulaziz City for Sciences and Technology (KACST)	Saudi Arabia	**Dr. Tariq Al-Khalifah**
Agencija Republike Slovenije za Okolje (ARSO)	Slovenia	**Dr. Ina Cecić**
Universidad Politecnica de Madrid (UPM)	Spain	**Dr. Sonia Alvarez Rubio**
Institut Cartografic de Catalunya (ICC)	Spain	**Dr. Antoni Roca**
Schweizerischer Erdbebendienst (SED)	Switzerland	**Dr. Manfred Baer**
Royal Netherlands Meteorological Institute (KNMI)	The Netherlands	**Mr. Reynoud Sleeman**
Kandilli Observatory and Earthquake Research Institute (KOERI)	Turkey	**Prof. A. Mete Isikara**
Earthquake Research Institute (ERD)	Turkey	**Dr. Ferhat Tasçi**
British Geological Survey (BGS)	United Kingdom	**Dr. Chris Browitt**
Key Nodal Members		
Laboratoire de Détection et de Géophysique (LDG)	France	**Dr. Bruno Feignier**
GeoForschungsZentrum (GFZ)	Germany	**Dr. W. Hanka**
Istituto Nazionale di Geofisica (INGV, Roma)	Italy	**Dr. M. Oliveiri**
Istituto Nazionale di Geofisica (INGV, Milano)	Italy	**Dr. Massimiliano Stucchi**
Center of Geophysical Computer Data Studies (CGDS)	Russia	**Dr. Alexei Gvishiani**
Instituto Geografico Nacional (IGN)	Spain	**Dr. E. Carreno**
Corporate Members		
Mediterranean Re	Ireland	**Mr. Tim Hennessy**
Members by Right		
European Seismological Commission (ESC)	-	**Ms. Alice Walker**
Observatories and Research Facilities for European Seismology (ORFEUS)	-	**Dr. Bernard Dost**
International Seismological Centre (ISC)	-	**Dr. Ray Willemann**

Applications for EMSC membership

Seismological Institute, (ASN)	Albania	**Dr. E. Dushi**
Centre de Recherche en Astronomie, Astrophysique et Géophysique (CRAAG)	Algeria	**Dr. A. K. Y. Chaouche**
Department of Geophysics, University of Zagreb (IRB)	Croatia	**Prof. M. Herak**
Institute of Geophysics (TIF)	Georgia	**Prof. T. Chelidze**
Direction Environnement Urbanisme et Construction (DEUC)	Monaco	**Dr. P. Mondielli**
Montenegro Seismological Observatory (MSO)	Yugoslavia	**Dr. B. Glavatovic**

EMSC, coordinator of an E.C. funded project

50

COUNCIL OF EUROPE CONSEIL DE L'EUROPE

EMSC, specialized European Centre for the Open Partial Agreement