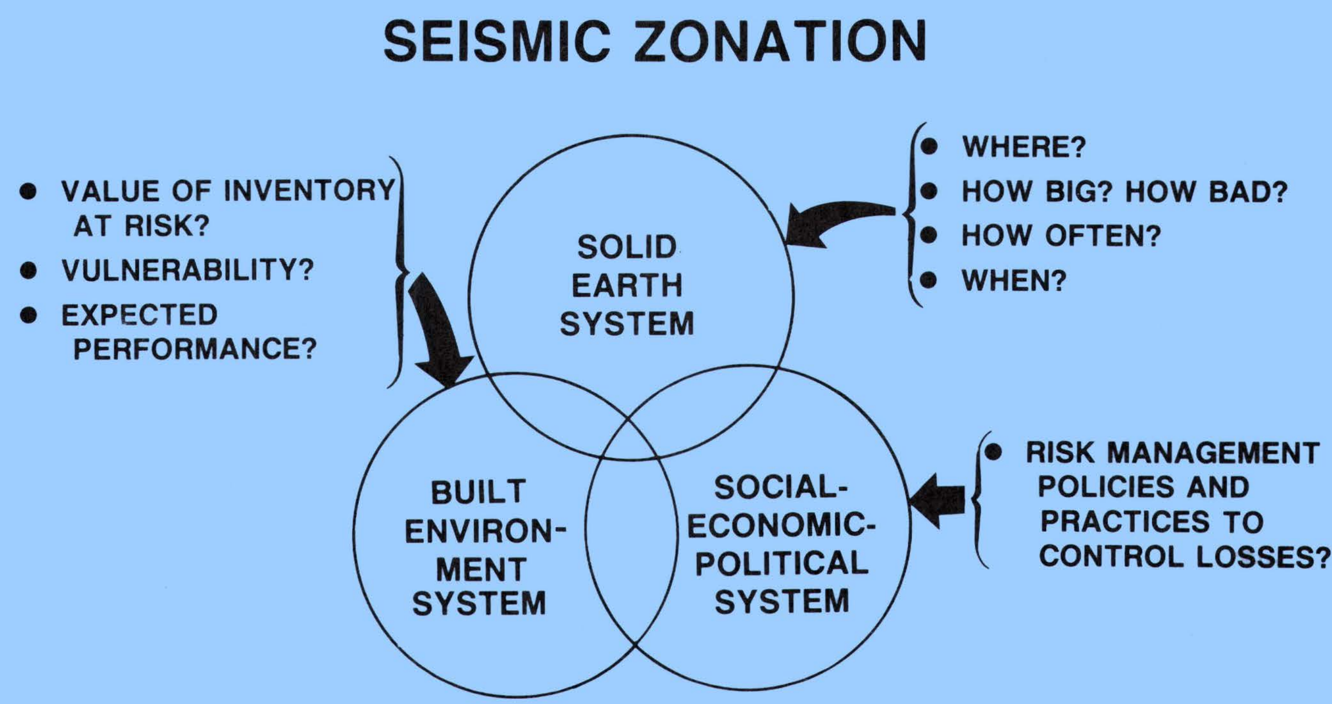
FOURTH INTERNATIONAL FORUM ON SEISMIC ZONATION

HELD IN

Chicago, Illinois--July 14, 1994
and
Vienna, Austria--August 30, 1994



Open-File Report 94-424

United States Geological Survey
Reston, Virginia

Fourth International Forum On Seismic Zonation

(An Activity Of The International Decade For Natural Disaster Reduction)

Held in

Chicago, Illinois
July 14, 1994
and
Vienna, Austria
August 30, 1994

Sponsors:

United Nations Educational, Scientific And Cultural Organization

United States Geological Survey

International Association For Seismology And Physics Of The Earth's Interior

Secretariat For The International Decade For Natural Disaster Reduction

Stanford University

Earthquake Engineering Research Institute

California Department Of Conservation--Division Of Mines And Geology

Central United States Earthquake Consortium State Geologists

Open-File Report 94-424

Editor: Walter W. Hays
Compiler: Linda R. Huey

Cover: Schematic illustration of the hazard, built, and policy environments and the critical questions professionals address in seismic zonation.

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Preface

We are pleased to provide you with information developed for the Fourth International Forum on Seismic Zonation which will be convened in two locations year in conjunction two major international meetings. The objectives are: 1) to assess the status of seismic zonation in every country of the world, 2) to evaluate the reasons for advances and new initiatives, and 3) to foster continued cooperation.

Seismic zonation is the process that leads to risk reduction and sustainability of new development. It is based on the division of a geographic region into smaller areas or zones on the basis of an integrated assessment of the hazard, built, and policy environments of the region. Seismic zonation depends on hazard mapping performed on national/regional, subregional, and urban (i.e., microzonation) scales depending on the particular application.

We gratefully acknowledge the written communications of many professionals who responded to our request for information. Also, we acknowledge the use of information contained in five valuable reports (see directories in the Appendices for information on where to obtain copies of the reports):

1. United Nations, 1990, Cooperative Project for Seismic Risk Reduction in the Mediterranean Region (SEISMED), proceedings, Office of the United Nations Disaster Relief Coordinator, Geneva, Switzerland, 3 vols. (**Franco Maranzana - Italy/Appendix D**).

2. United States Geological Survey, 1992, The Worldwide Earthquake Risk Management (WWERM) Program, Reston, Virginia, 19 p (**Paul Thenhaus or S.T. Algermissen - USA/ Appendix D**).

3. Instituto Panamericano de Geografia Historia, 1992, Revista Geofisica, Lima, Peru, No. 37, July-December, 234 p (**Alberto Giesecke - Peru/Appendix D**).

4. Annali di Geofisica, 1992, Global Seismic Hazard Assessment Program (GSHAP) (Special Issue), International Lithosphere Program, Publication 209, Bologna, Italy, 257 p (**Domenico Giardini - Italy/Appendix F**).

5. International Association of Seismology and Physics of the Earth's Interior and European Seismological Commission, 1993, The Practice of Hazard Assessment, Golden, Colorado, 284 p (**Write Bob Engdahl, U.S. Geological Survey, Denver Federal Center, Mail Stop 967, Denver, Colorado 80225, USA**).

Badaoui Rouhban
Earth Sciences Division
UNESCO

Walter Hays
Office of Earthquakes, Volcanoes, and Engineering
USGS

Fourth International Forum on Seismic Zonation

Held in

Chicago, Illinois
July 14, 1994
in conjunction with the 5th National Conference
on Earthquake Engineering

and

Vienna, Austria
August 30, 1994
in conjunction with the 10th European Conference
on Earthquake Engineering

Both Fora are activities of the International Decade for Natural Disaster Reduction

Program for Each Forum

Plenary Session: The Professional Practice of Seismic Zonation

Representatives of countries throughout the world will meet for introductions and receive information on the terms of reference for the forum.

Welcome, Introductions, Objectives, Background, and a Framework for Seismic Zonation.

Moderators: **Walter Hays, Deputy Chief for Research Applications, Office of Earthquakes, Volcanoes, and Engineering, U.S. Geological Survey, USA**

Badaoui Rouhban, Program Specialist, Earth Sciences Division, United Nations Educational, Scientific and Cultural Organization, France

Mustafa Erdik, Professor, Bogazici University, Kandilli Observatory and Earthquake Research, Institute, Istanbul, Turkey

REGISTRATION

NOTE: ALL PARTICIPANTS SHOULD SIGN IN WITH THE REGISTRAR: LINDA HUEY, U.S. GEOLOGICAL SURVEY, OR HER REPRESENTATIVE, INDICATING ANY CHANGES IN THE DIRECTORY.

DEFINITION: Seismic zonation is the process that leads to the division of any geographic region into smaller areas or zones based on an integrated assessment of the hazard, built, and policy environments of the region. Seismic zonation is performed on national/regional, subregional, and urban (i.e., microzonation) scales depending on the particular application. The elements of the built environment at risk in a given zone are expected to experience the same relative severity of characteristics of an earthquake hazard (e.g., ground shaking, liquefaction, tsunami flood wave runup, etc.) during a given exposure time. The individual risks, however, may vary widely within a zone depending on element vulnerability.

MORNING AND AFTERNOON REFRESHMENT BREAKS WILL BE TAKEN ACCORDING TO LOCAL SCHEDULE.

Plenary Session 2: Assessment of the Practice of Seismic Zonation in Each Country.

Selected representatives will contribute orally and all in writing to the assessment. The emphasis will be placed on identifying the map products, scales, methods, applications, and driving forces for progress in each country.

To provide all representatives with a comprehensive overview of the status of seismic zonation in countries having a variety of seismotectonic environments, several representatives will be asked to contribute short oral reports:

United States

- Walter Hays, U.S. Geological Survey
- Paul DuMontelle, Illinois Geological Survey
S. Cragin Knox, Mississippi Office of Geology
Buddy Schweig, U.S. Geological Survey
- Jim Davis, California Division of Mines and Geology

Other countries to be selected randomly:

Albania
Algeria
Argentina
Australia
Austria
Bangladesh
Belgium
Bolivia
Brazil
Bulgaria
Canada (British Colombia)
Caribbean (Eastern)
Chile
China

Colombia
Costa Rica
Cuba
Cyprus
Czech Republic
Ecuador
Egypt
Ethiopia
Figi
Finland
France
Germany
Greece
Hungary
Iceland
India
Iran
Ireland
Israel
Italy
Ivory Coast
Jamaica
Japan
Jordan
Lebanon
Libya
Macedonia
Malaysia
Monaco
Morocco
Nepal
Netherlands
New Zealand
Nigeria
Norway
Papua New Guinea
Poland
Romania
Russia
Saudi Arabia
Slovakia
South Africa
Spain
Switzerland
Syria
Taiwan
Thailand
Tunisia
Turkey
United Kingdom
United States
Yemen

INSTRUCTIONS: Presenters will give a brief 10 minute summary of the status in their country focusing on the following five themes:

1. **Types of Map Products**

Ground Motion:
- Intensity
- Acceleration
- Velocity
- Spectral Response

with consideration of:

Soil Amplification:
- S1
- S2
- S3
- S4

Ground Failure: Liquefaction; Landslides

Flood Waves: Tsunami; Seiche

2. **Scales**

National / Regional: 1:2,500,000; Smaller

Subregional: Larger; 1:250,000

Urban: Larger; 1:25,000 (i.e., microzonation)

3. **Methods**

Analytical Techniques: Deterministic; Probabilistic; Statistical

4. Applications

To Stop Increasing the Risk
- Building Codes
- Land Use Ordinances
- Urban / Regional Development Plans

To Start Decreasing the Risk
- Retrofit
- Non - structural Mitigation

To Continue Planning for the Inevitable
- Scenarios for Emergency Response
- Scenarios for Recovery

with consideration of the lack of consensus and gaps in knowledge on the:

Hazard Environment
- Faults
- Tectonic Structures
- Seismicity
- Attenuation
- Soil Response

Built EnvironmentVulnerability Functions
- Buildings
- Lifelines

Policy Environment
- Policies: Prevention, Mitigation, Preparedness
- Practices: Siting, Design, Construction

5. Driving Forces:

Damaging Earthquakes
- Worst Impacts
- Most Recent

Technology Transfer — Individuals / Institutions / Projects

Political Support — Decrees / Legislation

Political and Societal Concerns for Seismic Safety — Important Structures / Essential / Critical Structures

Long - Term Development of Institutional and Professional Capacity — Institutes / Monitoring / Training / Education

Formation of Working Groups

Working Groups will be formed to facilitate sharing of experiences and ideas.

Instructions To Working Groups: Each group will engage in a dialogue on two questions:

1. What were the driving forces that have advanced the practice of seismic zonation in each country?

Examples: A damaging earthquake, political/societal requirements for siting of important or critical structures or facilities, specific legislation or level government decrees, the leadership and technology transfer of individuals and institutions, within and without the country, the IDNDR, etc..

2. What can we do to advance the worldwide practice of seismic zonation (i.e., recommendations)?

Examples: Joint research and/technology transfer projects, cooperative agreements for post earthquake investigations, meetings, publications, etc.

Luncheon Break - Lunch Is On Your Own

Continuation of Working Groups

Plenary Session 3: Reports and Recommendations of Working Groups

Rapparteurs of each Working Group will present the range of views on both questions to everyone.

INTERACTIVE DIALOGUE

CLOSURE AND NEXT STEPS

- 5th International Forum on Seismic Zonation, Nice, France, October 17-19, 1994
- Regional initiatives
- Publication(s)
- Planning for the next Forum

ADJOURN

Worldwide Assessment of the Status of Seismic Zonation

(JULY 1994 DRAFT)

By
Walter W. Hays
U.S. Geological Survey
Reston, Virginia 22092
USA

Abstract

This draft paper is a summary of the practice of seismic zonation in selected countries throughout the world as of July 1994. Individually and collectively these status reports comprise an unprecedented success story which was written for most countries during the past 25 years, but whose last chapter is still being written by the scientists, engineers, planners, and policymakers in each country. The first chapter of the continuing saga started in the 1920's and 1930's for some countries (e.g., China and Russia), in the 1950's for Japan, in the 1960's for some (e.g., United States, Chile, and Mexico), and in the last decade for still others (e.g., Philippines and Saudi Arabia). Not all countries are included in this report. Those countries that were selected demonstrate four important generic factors which have value to every country. They are: 1) any country--large or small, developed or developing, characterized by high seismicity or low seismicity--can develop maximum intensity maps as a minimum to advance the practice of seismic zonation, and in fact they have; 2) the rate of advancement is highly dependent on the frequency of occurrence of damaging earthquakes, and in some cases volcanic eruptions and tsunamis; 3) international cooperation for post earthquake technical assistance, and training as typified by USGS, UNESCO, and others; and 4) technology transfer encompassing activities such as the classic publication by C.A. Cornell in 1968, the development of the computer program EQRISK for the public domain by USGS in 1976 (R.K. McGuire) with subsequent updating in 1987 (D.M. Perkins and B. Bender) and 1992 (Hanson et al), and regional projects such as the BALKANS, SEISMED, WWERM, SISRA, GSHAP, RELEMR, WWSI, CERESIS, and CENAPRED. Collectively these four factors have led to enhanced institutional and professional capacity worldwide.

Readers are invited to write the author with proposed substantive changes to the draft report.

Seismic Zonation

Seismic zonation is the process that leads to risk reduction and sustainability of new development. It is based on the division of a geographic region into smaller areas or zones on the basis of an integrated assessment of the hazard, built, and policy environments of the region. Seismic zonation depends on hazard mapping performed on national/regional, subregional, and urban (i.e., microzonation) scales depending on the particular application. The elements of the built environment at risk in a given zone are expected to experience the same relative severity of an earthquake hazard (e.g., ground shaking, liquefaction, tsunami flood wave runup, etc.) during a given exposure time. The individual risks, however, may vary widely within a zone depending upon the vulnerability of individual elements and risk management policies (i.e., prevention, mitigation, and preparedness measures) and professional practices (i.e., siting, design, and construction guidelines and standards).

Seismic zonation provides an end user with the information needed to answer the question, "Which part of the geographic area under consideration is safest for siting: a single-family dwelling, a high-rise building, a long-span bridge, a school, a hospital, a dam, or a nuclear power plant?" An alternative question is "Which part of the geographic area is best for avoiding extreme ground shaking, liquefaction, large volume landslides, or tsunami run-up?" The emergency manager can also answer the question, "What kinds of losses should be expected throughout the geographic area for a given scenario earthquake?"

Hazard maps, vulnerability functions, and risk management policies are critical in seismic zonation. The physical effects (i.e., earthquake hazards) damage or destroy buildings and lifeline systems (e.g., bridges, dams, pipelines, utility systems, tunnels, rapid transit) in urban centers and cause socioeconomic impacts over broad geographic regions. Within a minute or less economic losses can reach several tens of billions of dollars. Ground shaking can trigger liquefaction (i.e., a temporary loss of bearing strength at locations underlain by young, loosely compacted, water-saturated sand deposits) and landslides (i.e., falls, topples, slides, spreads, and flows of rock and/or soil on unstable slopes). Some earthquakes will also generate surface fault rupture where, depending on the magnitude or amount of mechanical energy released at the initial rupture zone, the fault can propagate upward, and break the surface. Surface fault rupture, liquefaction, and landsliding cause permanent displacements, which can be especially damaging to underground lifeline systems. Regional tectonic deformation (i.e., changes in elevation over a broad geographic region) is a characteristic of great-magnitude earthquakes (i.e., those having magnitudes of 8 or greater). Tsunamis (i.e., long-period ocean waves generated by the sudden vertical displacement of a submarine earthquake) can generate flood waves that can destroy ports and harbors and buildings at coastal locations far from and close to the earthquake source. Seiches (standing waves induced in lakes and harbors), dam failures, and fires can also be induced by an earthquake. Aftershocks (i.e., smaller magnitude earthquakes, following the main shock) can occur for several months to years, repeating and worsening the physical effects described above, depending on their magnitude, proximity to the urban center building or lifeline or site, and the incipient damage state of the remaining structures. Postearthquake investigations seek to understand and quantify these physical effects and to define vulnerability functions for buildings and lifelines in order to develop the best possible loss reduction measures. The knowledge gained from investigations provides a basis for constructing the best seismic zonation maps for use in building codes and land-use regulations.

Status of Individual Countries

The Annex summarizes the status of seismic zonation in each country. It contains:

1. Principal contact(s).
2. Background on the seismotectonic setting.
3. Monitoring systems (seismicity network and strong motion instruments).
4. The types of maps that have been prepared to date.
5. Some of the primary applications.
6. The driving force(s) behind the advances.

Readers should refer to the references and country contacts for more information.

All readers are encouraged to provide additional information on their country. If any part of the summary needs to be modified, submit the changes in writing to the author.

Pioneers and Entrepreneurs

Although every country has pioneers and entrepreneurs, nine individuals are well known throughout the world for their pioneering and entrepreneurial work in seismic zonation. They are:

S.T. Algermissen	G.P. Gorshkov	R.K. McGuire
C.A. Cornell	H. Kawasumi	S.V. Medvedev
L. Esteva	C. Lomnitz	Y.V. Riznichenko

Projects Referenced In the Annex

The following projects are referenced in the Annex by using their acronyms.

1. **Balkans Project** - sponsored by UNESCO during the 1970's and 1980's with technical assistance of USGS to improve earthquake hazard assessment in Greece, Bulgaria, Albania, Turkey, Yugoslavia, and Romania.

2. **SISRA Project** - sponsored by AID/OFDA with technical assistance of USGS to improve earthquake hazard assessment in the Andean region of South America during the late 1980's.

3. **SEISMED Project** - sponsored by Italian government, UNDP, and UNDRO (now DHA) with technical assistance of USGS and others to foster earthquake risk reduction in the countries adjacent to the Mediterranean Sea during the late 1980's and early 1990's. Participating countries included: Spain, France, Monaco, Malta, Albania, Italy, Macedonia (former Yugoslavia), Turkey, Israel, Egypt, Syria, Greece, Cyprus, Libya, Morocco, Tunisia, and Algeria.

4. **WWERM Program** - sponsored by AID/OFDA with technical assistance of USGS to develop seismic zonation maps and risk assessments in major cities of Peru, Chile, Morocco, Indonesia, and the Philippines with eventual expansion worldwide during the late 1980's and 1990's.

5. **RELEMR Project** - sponsored by US Department of State with technical assistance of USGS and support of UNESCO to reduce earthquake losses in the Eastern Mediterranean Region (i.e., Turkey, Lebanon, Cyprus, Syria, Jordan, West Bank, Israel, Egypt, Saudi Arabia, and Yemen) during the period 1993-2000.

6. **GSHAP Project** - proposed by the International Lithosphere Program with sponsorship by the International Council of Scientific Unions as a program of the IDNDR to promote uniform seismic hazard assessment worldwide. Regional centers have been established in Mexico, Germany, Chile, Kenya, Morocco, Russia, China, and the Philippines.

7. **WWSI Project** - an initiative of the International Association of Earthquake Engineering with support by the Japanese government and technical assistance by the United States to facilitate the development and implementation of cooperative seismic risk reduction projects worldwide during the 1990's.

8. **PAMERAR Program** - the "Programme for Assessment and Mitigation of Earthquake Risk in the Arab Region" is an initiative sponsored by the Arab fund for Economic and Social Development and the Islamic Development Bank, with technical assistance from UNESCO, during the 1980's and 1990's.

9. **CERESIS** - headquartered in Lima, the Centro Regional de Sismologia para America del Sur, was created in 1966 by agreement between the Government of Peru and UNESCO to provide international and intergovernmental coordination. Eleven nations (Argentina, Bolivia, Brazil, Ecuador, Spain, Chile, Colombia, Peru, Trinidad-Tobago, Uruguay, and Venezuela.

10. **CENAPRED** - a national disaster prevention center established in 1990 in Mexico City through a cooperative program of the governments of Japan and Mexico. Technical assistance has been provided to: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.

References for the Annex

The literature on seismic zonation is very extensive and every country has a bibliography which is beyond the scope of this report to list. Three classic references have been used throughout the world. They are:

1. Cornell, C.A., 1968, Engineering Seismic Risk Analysis, Bulletin of the Seismological Society of America, Vol. 58, pp. 1503-1606.

2. Algermissen, S.T. and Perkins, D.M., (1976), A Probabilistic Estimate of Maximum Acceleration in Rock in the Continuous United States, U.S. Geological Open-File Report, 76-416, 77 p.

3. United Nations Educational Scientific and Cultural Organizations, 1978, The Assessment and Mitigation of Earthquake Risk, Paris, France, 341 p.

The following five references were used in the compilation of status reports:

1. United Nations, 1990, Cooperative Project for Seismic Risk Reduction in the Mediterranean Region (SEISMED), proceedings, Office of the United Nations Disaster Relief Coordinator, Geneva, Switzerland, 3 vols. (**Franco Maranzana - Italy/Appendix D**).

2. United States Geological Survey, 1992, The Worldwide Earthquake Risk Management (WWERM) Program, Reston, Virginia, 19 p (**Paul Thenhaus or S.T. Algermissen - USA/ Appendix D**).

3. Instituto Panamericano de Geografia Historia, 1992, Revista Geofisica, Lima, Peru, No. 37, July-December, 234 p (**Alberto Giesecke - Peru/Appendix D**).

4. Annali di Geofisica, 1992, Global Seismic Hazard Assessment Program (GSHAP) (Special Issue), International Lithosphere Program, Publication 209, Bologna, Italy, 257 p (**Domenico Giardini - Italy/Appendix F**).

5. International Association of Seismology and Physics of the Earth's Interior and European Seismological Commission, 1993, The Practice of Hazard Assessment, Golden, Colorado, 284 p (**Write Bob Engdahl, U.S. Geological Survey, Denver Federal Center, Mail Stop 967, Denver, Colorado 80225, USA**).

ANNEX

STATUS OF SEISMIC ZONATION: JULY 1994

This is a portion of the total report being compiled for distribution at the 5th International Forum that will be convened in conjunction with the 5th International Conference on Seismic Zonation in Nice, France in October 1995.

Albania

Principal Contact: Eduard Sulstarova, Seismological Center, Academy of Sciences, Tirana, Albania

Background: The high level of seismicity is caused by the collision of the Adriatic promontory with the African and Eurasian tectonic plates.

Monitoring Systems: The first seismological station established in 1968 has become a network consisting of 13 stations. The strong motion network deployed in 1985 consists of 29 SMA-1 accelographs and 45 WM-2 seismoscopes.

Maps: The first seismic zonation map based on intensity was compiled in 1952.

- In 1979 it was replaced by a MSK intensity map with values ranging from VI to IX on a scale of 1:500,000. It represents a 100 year exposure time and a 70 percent probability of nonexceedance.

Urban scale intensity maps have been prepared for the largest towns and cities (Volora, Durres, Shkodra, Korca, and Tirana.)

Applications: In 1979, the 1979 zonation map was incorporated in the Albania Aseismic Technical Regulations.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., April 15, 1979, Montenegro earthquake)
- Technology transfer by USGS and UNESCO in conjunction with the Balkans and SEISMED projects

Algeria

Principal Contact: Dr. Mohamed Belazougui and D'Jamal El-Foul, Centre National de Recherche, Appliquee en Genie-Parasismique, Rue Kaddour Rahim Prolongee, BP 252 Hussein Dey, Algiers, Algeria

Background: Seismicity in Northern Algeria is related primarily to collision of the northward moving African and southward moving Eurasian tectonic plates.

Monitoring Systems: A telemetered network of digital seismographs and 200 accelographs were installed after the 1980 M 7.3 El Asnam earthquake.

Maps: The first national scale zonation map depicting probabilistic ground acceleration in national building codes was prepared in late 1970's with assistance from Stanford University. With support and technical assistance from UNESCO and the USGS, and investigations by a contractor, Woodward Clyde Consultants, seismic zonation maps (i.e., a maximum, historical MM intensity map and probabilistic ground acceleration, velocity, and spectral response maps) were prepared in 1984 for the Ech Chlef region (formerly El Asnam region). Urban scale (i.e., microzonation) maps were also prepared for Ech Chlef and nine other cities in the region. The zonation map for Algiers, the capitol, is underway.

Applications: Two governmental decrees of August 25, 1985 have served as a catalyst for earthquake risk management in Algeria, resulting in improved building codes, land-use planning, preparedness, and emergency response.

Driving Forces: The principal driving forces include:

- A damaging earthquake (e.g., the October 10, 1980, El Asnam earthquake which caused $2 billion of direct damage, destroyed 20,000 plus buildings, killed 1,243, and injured 8,369).
- Technology transfer by USGS, UNESCO, Woodward Clyde Consultants, and the SEISMED project.
- Acquisition of modern monitoring systems through the PAMERAR project.
- Political support through government decrees in 1985.
- Development of institutional capacity (e.g., Centre National de Recherche) and professional capability (e.g., training and participation in regional and international conferences on seismic zonation).

Argentina

Principal Contact: Juan S. Carmona, Instituto de Investigaciones Antisimica (IDIA), Universidad Nacional de San Juan, Ave. Libertador 1290-0, 5400 San Juan Argentina

Background: The seismicity of Argentina is related to complex interplate dynamics (e.g., subduction of the Nazca plate beneath the South America plate).

Monitoring: No information is available on the national seismic network or the strong motion accelographs.

Maps: Since the pioneering effort in 1965, the following national-scale seismic zonation maps have been constructed:

- Maximum MM intensity maps.

- Peak horizontal firm ground acceleration maps.

In addition, urban-scale (i.e., microzonation) maps have been prepared for the following cities: San Juan and Mendoza.

Applications: Seismic zonation maps have been incorporated in the national building code process since 1965. They have also been used for land-use regulations and urban planning. On the basis of the maps, 5 zones have been identified.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., 1861 and 1944 Mendoza and 1977 San Juan earthquakes).

- Technology transfer by USGS and others through the SISRA project and CERESIS.

- Development of long-term institutional and professional capacity.

- Political and societal concern for seismic safety of dams and hydrologic structures, nuclear power plants, offshore petroleum facilities, oil pipeline systems, and lifeline systems.

Australia

Principal Contacts: Kevin McCue and Trevor Jones, Australian Seismological Center, Australian Geological Survey Organization, Canberra ACT 2601, Australia; Jack Rynn, The Center for Earthquake Research in Australia, P.O. 276, Indooroopilly, Brisbane, Queensland, 4068 Australia.

Background: The seismicity of Australia is related to complex intraplate dynamics.

Monitoring: The national seismic network consists of 35 seismic stations and 40 strong motion accelographs.

Maps: Since the pioneering efforts in 1976 led to the publication in 1993 of national scale (1:10,000,000) seismic zonation maps which included the following:

- Maximum MM intensity maps.

- Peak horizontal bedrock ground acceleration maps.

- Peak horizontal bedrock ground velocity maps.

In addition, urban-scale (i.e., microzonation) maps have been prepared for the following cities: Brisbane, Queensland, Newcastle, Perth WA, and Sidney NSW. A liquefaction map has been prepared for an area near Rockhampton.

An effort is underway to generate a tsuanmi wave run-up map and also a landslide data base for Australia.

Applications: Seismic zonation maps have been incorporated in the national Australian building code process since 1979. The hazard map published in 1993 (having six zones) is presently incorporated in Australian Standard AS 1170.4--Minimum Design Loads on Structures: Part 4 Earthquake Loads. This standard is expected to be incorporated into the Australian building code in August 1994.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., destructive M 5.6 Newcastle earthquake of December 28, 1989 which occurred in a "zone 0" of the 1979 map, causing nearly $1 billion in damage).

- Technology transfer through the WWSI project and regional activities.

Austria

Principal Contact: Julius Drimmel, Central Institute for Meteorology and Geodynamics, Hobe Wart 38, A-1190, Vienna, Austria.

Background: Five source zones control the seismicity: 1) the Periadriatic Lineament separating the eastern and southern Alps. 2) Northern Tyrol. 3) Alpine Northern Rim fault. 4) Upper Mur Valley. 5) The Peripieninic Fault system.

Monitoring: No national network has been established.

Maps: Since the pioneering efforts in 1969 the following national-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps.

In addition, urban-scale (i.e., microzonation) maps have been started for Vienna.

Applications: Seismic zonation maps have been incorporated in the national building code process since 1979 (i.e., Austrian Standard ÖNORM B 4015 Part 1).

Driving Forces: The principal driving forces include:

- Damaging earthquakes in the region that affect Austria.

- Development of long-term institutional and professional capacity.

Bangladesh

Principal Contact: M. Muniruzzaman, Dept. of Physics, Jahangirnagar University, Savar, Dhaka, Bangladesh

Background: The seismicity of Bangladesh is related to complex interplate dynamics (e.g., subduction of the Indian plate beneath the Tibetan plate).

Monitoring: At present, no national network exists.

Maps: Since the pioneering efforts in 1979 by the Geological Survey of Bangladesh the following national-scale map has been constructed:

- Maximum MM intensity maps.

Applications: Seismic zonation maps have been incorporated in the Bangladesh national building code process since 1979. On the basis of the maps three zones have been identified: Zone 1 (most active--MM IX), Zone 2: (MM VIII), and Zone 3: (MM VII).

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., 43 events having maximum intensities of VI to IX have occurred this century).
- Development of long-term institutional and professional capacity.

Canada (British Colombia)

Principal Contact: Tim E. Little and Kim M. Meidal, British Columbia Hydro, Burnaby, British Columbia, Canada

Background: The seismicity of British Columbia, the western most province, is related to complex interplate dynamics (e.g., subduction of the Pacific plate beneath the North American plate).

Monitoring: The seismic network at present consists of more than 50 seismic stations operated by the Geological Survey of Canada, BC Hydro, and University of BC and 80 strong motion accelographs deployed by Geological Survey of Canada and BC Hydro. It can detect earthquakes of M 1 and M 2 in southwestern BC and M 3.5 over the rest of the providence.

Maps: Since the pioneering efforts in 1953, the following national-scale and regional-scale seismic zonation maps have been constructed:

- Maximum MM intensity maps.
- Peak horizontal bedrock ground acceleration maps.

- Peak horizontal bedrock velocity maps.

- Liquefaction map on a scale of 1:75,000 for Southwest British Columbia.

Applications: Seismic zonation maps have been incorporated in the National Building Code of Canada since 1953. At present the code uses probabilistic maps and adopts an annual probability of exceedance of 1/475. There are no standards governing dams or electric system facilities except those developed by BC Hydro. On the basis of the maps seven zones have been identified.

Driving Forces: The principal driving forces include:

- More than 24,000 earthquakes have occurred between 1568 and 1988).

- Development of long-term institutional and professional capacity.

- Political and societal concern for seismic safety of hydrologic structures, .

- Development of modern monitoring capability.

Caribbean (Eastern)
Trinidad, Tobago, Barbados, Grenada, St. Vincent, Grenadines, St. Lucia, Commonwealth of Dominica, St. Kitts/Nevis, Antigua, Barbuda, Auguilla

Principal Contact: John Shepherd, Environmental Science Division, Lancaster University, Lancaster, LA1-4YQ United Kingdom

Background: The seismicity of the Eastern Caribbean is related to complex interplate dynamics of the Caribbean, Cocos, North American, and South American plates.

Monitoring: Seismicity has been monitored by the University of West Indies, LaMont Doherty, and others.

Maps: Since the pioneering efforts in 1978 the following "Eastern Caribbean Scale" seismic zonation maps have been constructed marking the first time the entire region has been consistently mapped. The following maps have been constructed:

- Maximum MM intensity maps.

- Peak horizontal bedrock acceleration maps.

- Peak horizontal bedrock velocity maps.

Applications: Seismic zonation maps have been incorporated in the Caribbean Uniform building code process since 1985. All of the Islands are in zone 3 except Barbados and Tobago (zone 1) and St. Vincent and Grenada (zone 2). On the basis of the maps three zones have been identified.

Driving Forces: The principal driving forces include:

- Damaging earthquakes.
- Technology transfer through projects supported by DHA (formerly UNDRO), PAIGH, USGS, and others.

Chile

Principal Contact: Edgar Causel, Department of Geophysics, and Rodolfo Saragoni, Department of Engineering, University of Chile, Casilla 2777, Santiago, Chile

Background: The seismicity of Chile is related to complex interplate dynamics (e.g., subduction of the Nazca plate beneath the South American plate).

Monitoring: Chile has a national seismic network and strong motion arrays.

Maps: Since the pioneering efforts in 1969 the following national-scale and regional-scale seismic zonation maps have been constructed:

- Maximum MM intensity maps.
- Peak horizontal bedrock acceleration maps.
- Peak horizontal bedrock velocity maps.
- Total duration of shaking.
- Predominant Frequency.

Applications: Seismic zonation maps have been incorporated in the Chilean building code process since 1969. They have also been used for land-use regulations and urban planning. The pending new code will have three zones.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 9.5 May 1960 earthquake which caused 30,000 deaths and M 7.8 March 5, 1985, earthquake which caused losses of at least $1.8 billion and 177 deaths).
- Technology transfer by USGS, the Government of Japan, and others through such projects as WWERM and SISRA and study projects on ports and bridges. CERESIS has provided ongoing support.
- Development of long-term institutional and professional capacity.
- Political and societal concern for seismic safety of nuclear power plants.

Peoples Republic of China

Principal Contact: Yang Gunsin, Seismological Bureau of Liaoning Province, Shenyang, ll0031, Liaoning Province, P.R. China and Tao Xiaxin, Institute of Engineering Mechanics, State Seismological Bureau of China, Harbin 150080, P.R. China

Background: The seismicity of the China is related to complex intraplate and interplate dynamics. It is associated with the collision of the Indian Plate and the Eurasian Plate, uplift of the Qinghai-Xizang plateau plate, subsidence of the Talimu Plate, and the collision and underthrusting of the Pacific and Philippine Plates with the Eurasian plate.

Liaoning Province, located in northeast China, has a high level of seismicity and was the location of the 1975 Haicheng earthquake.

Monitoring: China has an extensive national seismic network consisting of several hundred seismic stations and 257 strong motion accelographs. The Liaoning Province has 20 of these seismic stations.

Maps: Since the pioneering efforts in the 1920's the following national-scale and regional-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps.

In Liaoning Province the following maps have been prepared on a scale of 1:25,000.

- Peak horizontal firm ground acceleration maps.

- Horizontal firm ground spectral response maps.

In addition, urban-scale (i.e., microzonation) maps have been prepared for cities such as: Beijing, Tangshan, Tianjin, Xian, Lanzhou, Shenyang, Dalian, Dongang, and Benxi.

Applications: Seismic zonation maps have been incorporated in the national building code process since the early 1970's. On the basis of the maps five zones have been identified. Recent editions (i.e., GBJ11-89) have considered the effect of soils, rock, and topography on ground shaking. The area encompassing intensity of VI or greater is 60 percent of the country. A 50-year exposure time and 90 percent probability of nonexceedance has been established for probabilistic maps. They have also been used for land-use regulations and urban planning, especially in Liaoning Province.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 7.3, 1975 Haicheng and M 7.8, July 28, 1976, Tangshan earthquake). Since 1900 about 2,600 damaging earthquake have occurred in China with 500 being greater than M 6.0.

- Technology transfer by USGS and others through the United States-Peoples Republic of China protocol.

- Development of long-term institutional and professional capacity.

- Political and societal concern for seismic safety of dams and hydrologic structures, nuclear power plants, and offshore petroleum facilities.

Colombia

Principal Contact: Carlos Coral-Gómez, National University of Columbia, Ingeominas, Geophysical Division, Bogota, Colombia, South America

Background: The seismicity of Colombia is related to complex interplate dynamic interaction between the South American, Caribbean, Nazca, and Cocos plates.

Monitoring: The national seismic network at present consists of 14 seismic stations. It became operational after the M 5.5 Popayan earthquake of March 31, 1983, and the eruption of Nevada del Ruiz on November 13, 1985. With help from the government of Canada and UNDP, 25 additional seismic stations and 130 accelographs will be added during the 1990's.

Maps: Since the pioneering efforts in 1977 the following national-scale seismic zonation maps have been constructed:

- Maximum MM intensity maps.

- Peak horizontal bedrock acceleration maps.

- Peak horizontal bedrock velocity maps.

Applications: Seismic zonation maps have been incorporated in the Colombian Building Code process since 1984. They have also been used for land-use regulations and urban planning. On the basis of the maps three zones (low, intermediate, and high) (high risk zone corresponding with the pacific coast above the subducting with the Nazca plate) have been identified.

Driving Forces: The principal driving forces include:

- Damaging earthquakes and volcanic eruptions (e.g., M 5.5, March 31, 1983 Popayan earthquake, M 6.8, the recent earthquake of June 6, 1994 and the eruption of Nevada del Ruiz on November 13, 1985).

- Technology transfer by USGS through the SISRA project and other activities with support of CERESIS .

- Development of long-term institutional and professional capacity.

- Political support through Presidential Decree 1400 issued in 1984 establishing the first national building code having earthquake resistant design provisions.

- Development of modern monitoring capability with support of the government of Canada and UNDP.

Costa Rica

Principal Contact: Walter Montero P., Central American School of Geology, National Seismological Network, Center for Geophysical Research, University of Costa Rica, Box 35-2060, San Pedro, Costa Rica

Background: The seismicity of Costa Rica is related to complex interplate dynamics (e.g., subduction of the Cocoa plate beneath the Caribbean plate) and the triple junction of the Cocos-Caribbean-Nazca plates.

Monitoring: Costa Rica has a national seismic network and strong motion accelographs.

Maps: Since the pioneering efforts in 1977 the following national-scale seismic zonation maps have been constructed:

- Maximum MM intensity maps.

- Peak horizontal bedrock acceleration maps.

- Landslide susceptibility maps.

Applications: Seismic zonation maps have been incorporated in the Costa Rican seismic code since 1977. They have also been used for land-use regulations and urban planning.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 7.6, April 22, 1991 earthquake).

- Technology transfer by Stanford University (Mortgat and others), USGS, US/Latin American Partnership, National Disaster Prevention Center (CENAPRED) supported by Japan and Mexico, CUSEC, and others.

- Development of long-term institutional and professional capacity.

Cyprus

Principal Contact: George Constantinou, Director, Geological Survey Department, Ministry of Agriculture and National Resources, Nicosia, Cyprus

Background: The seismicity of Cyprus which is highest along the southern coast, is associated with the interaction of the Arabian and Eurasian plates and the tectonics of the Alpo-Himalayan belt.

Monitoring: The national seismic network at present consists of four seismic stations and four strong motion accelographs.

Maps: Since the pioneering efforts in the early 1970's the following national-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps.

Applications: Seismic zonation maps have been incorporated in the national building code process since 1986. They have also been used for land-use regulations and urban planning. On the basis of these maps five zones have been identified.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 6.5, June 1, 1977 earthquake).
- Technology transfer by USGS and others through the SEISMED and RELEMR projects.
- Development of long-term institutional and professional capacity.

Czech Republic (and Slovakia)

Principal Contact: Vladimir Schenk, Geophysical Institute, Academy of Sciences of Czech Republic, Bodni II, c.p. 1411, 141 31 Praha 4-5 Pofilov, Czech Republic

Background: The seismicity is low to moderate.

Monitoring: The national seismic network at present consists of five seismic stations and two temporary arrays..

Maps: Since the pioneering efforts by Karnik and others in 1973 the following national-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps.

Applications: Seismic zonation maps have been incorporated in the national building code process since 1973. They have also been used for land-use regulations and urban planning. On the basis of the maps four zones have been identified.

Driving Forces: The principal driving forces include:

- Long-term seismicity.
- Development of long-term institutional and professional capacity.

Egypt

Principal Contacts: Ezz Eldin Ibrahim, Department of Seismology, National Research Institute of Astronomy and Geophysics, Helwan, Egypt; Amir W. Sadak, Structural Engineering Department, and Mohamed Sobaih, Department of Civil Engineering, Cairo University, Cairo, Egypt.

Background: Egypt is located in the northeast corner of the African Plate. Seismicity is controlled by movement along the following plate boundaries: the converging African and Eurasian plates on the north, the Arabian and African plates separated by the Levant Transform on the northeast, and the diverging Arabian and African plates separated by the Red Sea spreading zone on the south and southeast.

Monitoring: The national seismic network at present consists of ten seismic stations and seven strong motion accelographs. Additional seismic and accelograph stations were authorized after the 1992 Dahshour earthquake.

Maps: Since the pioneering efforts in 1982, the following national-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps.
- Peak horizontal firm ground acceleration maps.

Applications: Egypt does not yet have a building code with seismic design provisions. A draft regulation identifying four zones was proposed in 1988 by the Egyptian Society of Earthquake Engineering.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 5.9, October 13, 1992 Dahshour earthquake which killed and injured 7,000, damaged and destroyed 1,000 schools, and caused at least $4 billion in economic losses).
- Technology transfer by USGS, UNESCO, and others through the SEISMED and RELEMR projects.

- Development of long-term institutional and professional capacity through participation in national, regional, and international conferences and training.

- Political and societal concern for seismic safety of the Aswan dam and other facilities.

- Development of modern monitoring capability through the PAMERAR project following the Dahshour earthquake.

- Development of Geographic Information System capabilities.

France

Principal Contact: Pierre Mouroux, BRGM, 117 Avenue d Luminy, F-13009 Marseille, France and Bagher Mohammadioun, Institut De Protection Et De Surete Nucleaire, 60-68 Avenue du General Leclerc, BP 6, 92265 Fontenay-Auz-Roses, Cedex, France

Background: The seismicity of France is related to collision of the Eurasian and African plates.

Monitoring: France has a national seismic network.

Maps: Since the pioneering efforts in 1981 the following national-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps.

In addition, since 1982 a large number of urban-scale (i.e., microzonation) projects have been mandated by law in order to implement risk exposure plans in southeastern France. The maps from these projects are 1:5,000 to 1:10,000 and cover areas of 1000 km^2.

Applications: Seismic zonation maps are currently being incorporated into the building code process.

Driving Forces: The principal driving forces include:

- Ongoing low to moderate seismicity.

- Technology transfer by USGS, UNESCO, and others through the SEISMED project. Other activities include the cooperative US-France post earthquake investigations following the 1988 Spitak, Armenia earthquake and the 1993 United States-France Workshop on Earthquake Hazard Assessment in the Eastern United States and Europe.

- Development of long-term institutional and professional capacity.

- Political support through legislation and governmental decrees such as the law of July 22, 1987 and the decree of May 14, 1991. The law requires risk assessment for "normal risk" and "special risk" structures.

Iceland

Principal Contact: Hjörtur Thráinsson, Engineering Research Institute, Univeristy of Iceland, Hjardarhaga 2-6, 107 Reykjavik, Iceland

Background: Iceland is characterized by low to moderate seismicity and volcanic activity.

Monitoring: The national seismic network at present consists of 46 seismic stations operated by the Univeristy of Iceland and the Geophysical Division of Icelandic Meteorolgical Office and 32 strong motion accelographs operated by the Engineering Research Institute. In addtion two earthfile dams, 2 hydroelectric poower stations, one 14-story office building, and 1 base-isolated bridge have strong motion instruments.

Maps: Since the pioneering efforts in 1950's the following national-scale zonation maps have been constructed:

- Maximum MM intensity maps.

- Peak bedrock firm ground acceleration maps.

Applications: Seismic zonation maps have been incorporated in the national building code process since 1958 . They have also been used for land-use regulations and urban planning. On the basis of the maps four zones have been identified.

Driving Forces: The principal driving forces include:

- Ongoing seismicity and volcanic activity.

- Development of long-term institutional and professional capacity.

- Political and societal concern for seismic safety of dams and hydrologic structures.

Indonesia

Principal Contact: Abdul Hamid, Department of Civil Engineering, Tanjungpura University (UNTAN), Pontianak-Indonesia.

Background: The seismicity of Indonesia, which consists of 13,700 islands, is related to its location in the juxtaposition of three colliding plates: the Eurasian plate on the north, Pacific plate on the east, and the Indo-Australian plate on the south.

Monitoring: The national seismic network at present consists of 19 seismic stations, located mainly in Sumatra, Juva, Sulawesi, and other cities.

Maps: Since the pioneering efforts in 1980's the following national-scale seismic zonation maps have been constructed:

- Maximum Rossi Forel intensity maps.
- Peak horizontal bedrock acceleration maps.

Applications: Seismic zonation maps have been incorporated in the national building code process since the 1980's. They have also been used for land-use regulations and urban planning. On the basis of the maps four zones have been identified.

Driving Forces: The principal driving forces include:

- Damaging earthquakes and tsunamis (e.g., M 6.8, December 12, 1992, Flores earthquake which generated an 80 foot tsunami wave, damaged one-third of the buildings in Maumer, and killed at least 1,200). Approximately 10 percent of the world's seismicity occurs in Indonesia.
- Technology transfer by USGS (WWERM project), and Japanese Ministry of Construction, and others.
- Development of long-term institutional and professional capacity.
- Development of modern monitoring capability with the support of UNESCO and UNDP.

Israel

Principal Contact: Avi Shapira, Seismological Division, Institute for Petroleum Research and Geophysics, P.O. Box 2286, Holan, 58122 Israel

Background: The seismicity of Israel is related to complex interplate dynamics (e.g., collision of the Eurasian, African, and Arabian tectonic plates). Israel is located adjacent to the Dead Sea Rift system.

Monitoring: The national seismic network at present consists of 36 seismic stations and 44 strong motion accelographs.

Maps: Since the pioneering efforts in the late 1970's, the following national-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps.
- Peak horizontal bedrock acceleration maps.

Applications: Seismic zonation maps have been incorporated in the Israel Code 413 "Seismic Design of Structures" since the 1980's. They have also been used for land-use regulations and urban planning. On the basis of the maps seven zones have been identified.

Driving Forces: The principal driving forces include:

- Many damaging earthquakes during the past 2 centuries.
- Technology transfer by USGS, UNESCO, and others through the SEISMED and RELEMR projects.
- Development of long-term institutional and professional capacity.
- Political and societal concern for seismic safety of a proposed nuclear power plants.

Japan

Principal Contact: Takeyasu Suzuki, Technical Research and Development Institute, Kumagai Gumi Company, Ltd., 1043 Shimoyama Onigakubo Tsukuba-City, Ibaraki Pref. 300-22, Japan

Background: The very high seismicity of Japan is related tointerplate dynamics (e.g., subduction of the Pacific and North American plates). Some 2,000 active faults have been identified on land.

Monitoring: Japan has an extensive network of seismic stations and strong motion accelographs.

Maps: Since the pioneering efforts in 1951 by Kawasumi (who produced expected peak acceleration maps having return periods of 75, 100, and 200 years).the following national-scale seismic zonation maps have been constructed:

- Maximum intensity maps.
- Peak horizontal firm ground acceleration maps.
- Horizontal spectral response maps.
- Tsunami wave run-up maps.

Japan is a leader in seismic microzoning techniques based on microtremor data. This technique has been applied to microzone Kushiro City on Hokkaido Island and other cities.

Applications: Seismic zonation maps have been incorporated in the national building code process since the 1950's. They have also been used for land-use regulations and urban planning. On the basis of the maps three zones (high, medium, and low) have been identified. Peak acceleration is the primary basis for the zones at present, although the importance of spectal response has been recognized since 1982.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 7.8, July 12, 1993 Hokkaido Nansei-oki earthquake which triggered a large tsumani having a run-up of 5 to 30 m and the M 8.0, 1923, Tokyo (Kanto) earthquake).

- Technology transfer through the United States-Japan Natural Resource (UJNR) Panel on Wind and Seismic Safety.

- Development of long-term institutional and professional capacity.

- Political and societal concern for a recurrence of the great Tokyo (Kanto) earthquake.

Jordan

Principal Contact: Kays K. El-Kaysi, Department of Natural Resources Authority, P.O. Box 7, Amman, Jordan

Background: The seismicity of Jordan is related its location within the Arabian plate adjacent to the 1,000 km long Dead Sea Rift zone.

Monitoring: The national seismic network at present consists of 26 seismic stations and 12 strong motion accelographs. Both networks were deployed with technical assistance of the USGS and support of PAMERAR.

Maps: Since the pioneering efforts in the late 1980's, the following national-scale seismic zonation map have been constructed:

- Maximum MSK intensity maps.

Applications: Seismic zonation maps have been incorporated in the national building code process since 1990. At present the building code includes a chapter for seismic resistant design. They have also been used for land-use regulations and urban planning. On the basis of the map three zones have been identified.

Driving Forces: The principal driving forces include:

- Long-term historical seismicity.

- Technology transfer by USGS, UNESCO and others through the RELEMR.

- Development of long-term institutional and professional capacity.

- Development of modern monitoring capability through the PAMERAR project with technical assistance of USGS.

Mexico

Principal Contact: Luis Esteva, Coordinacion de la Investigacion Cienfifica, UNAM, Ciudad Universitaria, Mexico 04510, DF, Mexico

Background: The seismicity of Mexico is related to complex interplate dynamics (e.g., subduction of the Cocos plate beneath the North American plate).

Monitoring: The national seismic network at present consists of 40 broad band seismic instruments linked by satellite plus a number of regional networks.

Maps: Since the pioneering efforts in the 1960's by Esteva and others the following national-scale and regional-scale seismic zonation maps have been constructed:

- Maximum MM intensity maps.

- Peak horizontal bedrock acceleration maps.

- Peak horizontal bedrock velocity maps.

In addition, urban-scale (i.e., microzonation) maps have been prepared for portions of Mexico City (e.g., the Old Lake Bed zone). Extensive research to delineate and understand S_2,S_3, and S_4 soils. The Lake Bed zone, the classic S_4 soil type, was identified after a damaging earthquake in 1957.

Applications: Seismic zonation maps, including soil amplification, have been incorporated in the Mexican Building Code since the 1960's. They have also been used for land-use regulations and urban planning.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 8.1, September 19, 1985 Mexico earthquake which caused 5,728 buildings in the Old Lake Bed zone in Mexico City to collapse which included hospitals, schools, and government buildings. This earthquake killed approximately 10,000 people and caused at least $4 billion in damage.

- Technology transfer through projects such as CENAPRED.

- Development of long-term institutional and professional capacity.

Monaco

Principal Contact: Nicole Bethoux and Philippe Mondielli, Service de L'Environment, 3, Avenue de Fontvielle, Monaco.

Background: The seismicity of Monaco is related to the collision of the Eurasian and African plates.

Monitoring: The national seismic network at present consists of five seismic stations and 1 strong motion accelograph.

Maps: The following seismic zonation maps have been constructed for the Principality of Moaco:

- Maximum MM intensity maps.

- A regional tsunami wave run-up map is being developed by the University of Genoa.

Applications: These seismic zonation maps have not been incorporated in a building code for Monaco. At present architects are advised to apply French Rules PS 6982

Driving Forces: The principal driving forces include:

- Damaging earthquakes in the Mediterrean region.

- Technology transfer by USGS and others through the SEISMED project.

Philippines

Principal Contact: Raymundo Punongbayan, Director, Philippine Institute of Volcanology and Seismology, 6th Floor, Hizon Building, 2500 Quezon Avenue, Queson City, the Philippines

Background: The seismicity of the Philippines is related to its location between two colliding tectonic plates: the northeastward moving Pacific plate and the Eurasian plate which is being subducted beneath Luzon and Mindoro. The Philippine Islands are at risk from earthquakes, volcanoes, and tsunamis.

Monitoring: The national seismic network at present consists of about 15 seismic stations which are deployed to monitor active volcanoes and seismicity. In a volcano crisis additional instruments are provided by the USGS with support by AID/OFDA.

Maps: Since the pioneering efforts in 1990 the following national-scale seismic zonation maps have been constructed:

- Maximum Rossi Forel intensity maps.

- Peak horizontal bedrock acceleration maps.

Applications: Seismic zonation maps have been applied only in a general way in the national building code process and land-use planning.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 7.8, July 16, 1990 earthquake which killed 1,200 and caused at least $500 million in damage) and volcanic eruptions (e.g., June 12, 1991 eruption of Mt. Pinatubo which after 450 years of quiescence affected over 1 million people and caused at least $425 million in damage).

- Technology transfer by USGS (WWERM), and others in the USA, Japan and Europe.

- Development of long-term institutional and professional capacity.

Romania

Principal Contact: Emil-Sevier Georgescu, Building Research Institute,Sos, Panteliman 266, 79614 Bucharest, Romania; Neculai Mândrescu, Centre of Earth Physics, P.O. MG-2, Bucharest-Magurele, Romania,

Background: The seismicity of Romania is related to the Vrancea Mountains, an active seismogenic structure of the eastern Carpathians which generates large magnitude, intermediate depth earthquakes about every 35 years.

Monitoring: Romania has a national seismic network.

Maps: Since the pioneering efforts in the 1970's in conjunction with the BALKANS project the following national-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps.

- Peak horizontal firm ground acceleration maps.

A geologic hazards map on a scale of 1:1,000,000 has been constructed for the Extra-Carpathian area.

Applications: Seismic zonation maps have been incorporated in the Romanian seismic code process since the 1970's. The 1990 code is based on the maximum intensity map.

Driving Forces: The principal driving forces include:

- Damaging Vranceas zone earthquakes (1471, 1620, 1738, 1802, 1829, 1838, 1894, 1940, and 1977). These earthquakes are charcterized by long period ground motion and deep foci. The last two (M 7.4 and M 7.2) collectively damaged approximately 33,000 dwellings, schools, hospitals, and other structures and killed 2,500.

- Technology transfer by USGS, UNESCO, and others through the BALKANS project.

- Development of long-term institutional and professional capacity.

- Political and societal concern for the recurrence of the next Vrancea earthquake and seismic safety of dams and a proposed nuclear power plant.

Russia

Principal Contact: Nina J. Frolova, Scientific Research and Coordination Center for Seismology and Engineering, Russian Academy of Science, Moscow, Russia

Background: The seismicity of Russia is related to complex intraplate and interplate dynamics, the latter typified by collision of converging plates.

Monitoring: Russia has an extensive national network of seismic stations and strong motion accelographs.

Maps: Since the pioneering efforts of Gorshkov during the 1930's and others such as Medvedev and Riznichenko afterwards the following national-scale and regional-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps (scale 1:5,000,000).

In addition, urban-scale microzonation of the largest cities was begun in the 1950's and by the end of 1991 intensity maps had been prepared for the capitals of all republics of the former USSR and tens of cities. These maps were reviewed and modified every 10 to 15 years or sooner after a damaging earthquake occurred (e.g., M 7, August 31, 1986 Carpathian earthquake). An extenisve effort was made during this period to understand and delineate the effects of rock, soils, and topography on ground shaking. The comparison of the forecast values of seismic intensity and the observed ones agreed in some locations and disagreed in others and always provided a basis for revision of the maps.

Applications: Seismic zonation maps have been incorporated in the State Engineering Codes since 1957. They have also been used for land-use regulations and urban planning. These zones encompassed MSK intensities V to IX.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 7, August 31, 1986 Carpathian, M 6.8, December 7, 1988 Spitak Armenia).

- Technology transfer by USGS and others through the US-Russia (replacing the former USSR) protocol and other activities.

- Development of long-term institutional and professional capacity.

Saudi Arabia

Principal Contacts: Dr. Abdullah M. Alamri, Professor, Department Of Geology, King Saud University, P.O. Box 2455, Riyadh, 11451 Saudi Arabia and Dr. Mohammad S. Al-Haddad, Engineer, Civil Engineering Department, King Saud University, P. O. Box #800, Riyadh 11421, Saudi Arabia

Background: The seismicity of Saudi Arabia is related to its location on the Arabian plate which is drifting northward 0.5 cm per year, generating earthquakes on its extensional (Red Sea rift) and translational (Dead Sea rift) plate bountries.

Monitoring: The national seismic network at present consists of 46 seismic stations. King Abdulaziz City for Sciences and Technology (CASTS) has the responsiblity for the earthquake threat in Saudi Arabia. Three universities are involved in the montoriong program: King Saud University, King Abdulaziz University, and King Fahd University.

Maps: Since the pioneering efforts in 1989 the following national-scaleseismic zonation maps have been constructed:

- Maximum MM intensity maps.

- Peak horizontal bedrock acceleration maps (90 percent probability on nonexceedance in a 50-year period).

Applications: Saudi Arabia proposed Seismic Design Criteria in 1993 which was based on the acceleration maps and the uniform building code. Four zones are proposed.

Driving Forces: The principal driving forces include:

- Ongoing regional seismicity.

- Technology transfer by USGS, UNESCO and others through the RELEMR program.

- Development of long-term institutional and professional capacity.

Slovakia (See Czech Republic)

Switzerland

Principal Contact: Dieter Mayer-Rosa, Swiss Seismological Service, Institute of Geophysics, and Eric Rüttener, Swiss Federal Institute of Technology, CH-8093, Zürich, Switzerland.

Background: The seismicity of southern Switzerland is related to the collision zone of the African and Eurasian tectonic plates.

Monitoring: The national seismic network at present consists of 23 seismic stations and 88 strong motion accelographs. Thirty-seven accelographs are in free field locations; the others are located on five dams and four nuclear power plants.

Maps: Since the pioneering efforts in the late 1970's, the following national-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps. The 1:500,000 scale maps are based on calculated occurrence probabilities on a 10 km grid for the intensity range V to IX for exposure times of 10, 100, and 1,000 years.

Applications: Seismic zonation maps have been incorporated in the national building code process since 1989. They have also been used for land-use regulations and urban planning. On the basis of the maps four zones have been identified.

Driving Forces: The principal driving forces include:

- Large, damaging historic earthquakes (e.g., October 18, 1356 Basle earthquake).
- Development of long-term institutional and professional capacity.
- Political and societal concern for seismic safety of dams and hydrologic structures and nuclear power plants.
- Development of modern monitoring capability.

Turkey

Principal Contacts: Mustafa Erdik, Bogazici University, Kandilli Observatory and Earthquake Research Institute, Cengelköy, Istanbul, Turkey; Sinan Gencoglu, General Directorate of Disaster Affairs, Ankara, Turkey; and Atila Ansal, Istanbul Technical University, Maslek, Istanbul, Turkey

Background: The seismicity of Turkey is related to the complex interplate dynamics (e.g., collision of the Arabian and Eurasian tectonic plates). Turkey is being squeezed by the Arabain and Eurasian plates.

Monitoring: The National Seismic Network operated by Bogazici University consists of 40 seismic stations. In addition a 12-station network in central north Turkey is operated by the Earthquake Research Division of the General Directorate of Disaster Affairs.

The National Strong Motion Network operated by the Earthquake Research Division of the General Directorate of Disaster Affairs consists of 80 seismic stations. In the Istanbul area Bogazici University operates 40 stations and the Istanbul Technical University operates 10.

Maps: Since the pioneering efforts in 1945 the following national-scale and regional-scale seismic zonation maps have been constructed:

- Maximum MSK intensity maps.
- Peak horizontal firm ground acceleration maps.
- No tsunami run-up maps have been constructed to date, however, preliminary studies are underway to map the Aegean and the Marmara seashores.

In addition, one urban-scale (i.e., microzonation) map has been prepared for Istanbul and vicinity on the scale 1:10,000.

Applications: Seismic zonation maps have been incorporated in the national building code process since 1972. They have also been used for land-use regulations and urban planning. On the basis of the maps five zones have been identified having intensity ratings from V to IX. A probabilistic hazard map is used for the design of highway structures.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 8.0, 1939 and the M 6.8, 1992 Erzincan earthquakes).
- Technology transfer by USGS, UNESCO and others through the BALKANS, SEISMED and RELEMR projects.
- Development of long-term institutional and professional capacity.
- Political support through legislation and governmental decrees. The disastrous earthquake sequence of 1939-1944 in Erzincan prompted the enactment of the "Law Concerning the Pre and Post Earthquake Measures" in 1944 which required the assessment of hazardous zones, determination of appropriate building types, construction techniques and specifications in each zone, preparation of emergency response programs, and geologic studies for new settlements. The rapid development of the nation and the high rate of urbanization led to the "Law for Public Works (Urbanization)" in the 1956 and the "Law for Natural Disasters" in 1959.

- Political and societal concern for seismic safety of infrastructure to support the rapid urbanization.

United Kingdom

Principal Contact: Gordon Woo, BEQE, Ltd., 94 Sheen Park, Richmond, Surrey TW9 IUP, England.

Background: The seismicity of Britain is related to its location on the western penisula of the Eurasian plate.

Monitoring: Britains national seismic network, operated by the British Geological Survey, is capable of detecting events of M 2.5 or greater.

Maps: Neither the pioneering efforts which in 1976 nor the speical study commissioned in 1990 by the Department of the Environment which involved international experts from Greece and the United States have produced seismic zonation maps. The efforts did however provide a basis for assigning maximum values of MSK intensities and frequencies of recurrence throughout the United Kingdom.

Applications: The process of incorporating seismic zonation maps into the building code is still involving.

Driving Forces: The principal driving forces include:

- Ongoing regional seismicity.

- Technology transfer through various overseas development assistance projects and cooperative post earthquake investigations.

- Development of long-term institutional and professional capacity.

- Political and societal concern for seismic safety of proposed nuclear power plants.

United States

Principal Contacts: Art Frankel, David Perkins, Paul Thenhaus, and E.V. Leyendecker, U.S. Geological Survey, Branch Earthquake and Landslide Hazards, Mail Stop 966, Denver Federal Center, Denver, Colorado 80225, USA; James Davis, State Geologist, California Division of Mines and Geology, 801 K Street, MS-1230, Sacramento, California 95814-3531, USA; Paul DuMontelle, Illinois State Geological Survey, 615 East Peabody Drive, Champaign, Illinois 61820-6964, USA.

Background: The seismicity of the United States is related to complex intraplate and interplate dynamics which cause extensional, translational, and compressional tectonic environments. Subduction of the Pacific Plate beneath the North American Plate and the Caribbean Plate beneath the North American Plate gives rise to the highest seismicity. The west coast, Hawaii, Puerto Rico, and the U.S. Virgin Islands are at risk from tsunamis.

Monitoring: The national seismic network at present consists of more than 1,000 seismic stations, mostly in California. More than 2,100 strong motion accelographs have been deployed, also mostly in California.

Maps: Since the pioneering efforts by Algermissen in 1969 the following national-scale and regional-scale seismic zonation maps have been constructed:

- Maximum MM intensity maps.
- Peak horizontal bedrock and firm ground (S_2) acceleration maps.
- Peak horizontal bedrock and firm ground (S_2) velocity maps.
- Horizontal bedrock and firm ground (S_2) spectral response maps.
- Liquefaction maps.
- Tsunami wave run-up maps.

In addition, urban-scale (i.e., microzonation) maps have been prepared for the San Francisco Bay Region and several major cities throughout the Nation. Extensive research has been conducted to delineate and understand the characteristics of S_2, S_3, and S_4, soils in urban areas..

Algermissen and Perkins applied the deductive method of probabilistic seismic hazard assessment (Cornell, 1968) to map the conterminous United States in 1976. They incorporated a range of inputs on seismic sources, maximum magnitudes, and bedrock acceleration attenuation functions for the eastern and western United States. The product was a national scale probabilistic acceleration map for a 50 year exposure time and a 90 percent probability of nonexceedance. These acceleration maps were improved in 1982 and the process was expanded to produce velocity maps for 10-, 50-, and 250-year exposure times. Spectral response maps were produced in 1988.

USGS development of the computer program EQRISK for the public domain in 1976 (R.K. McGuire) with subsequent updating in 1987 (D.M. Perkins and B. Bender) and 1992 (Hanson et al).

California Assembly Bill 3897 was enacted in 1990 following the Loma Prieta earthquake. It required the State to delineate: the geographic areas or zones of enhanced ground shaking due to proximity to the earthquake source or soil amplification, the areas susceptible to liquefaction, and areas susceptible to large volume landslides.

Seven States in the Central Mississippi Valley area (i.e., the CUSEC States) began seismic zonation studies in 1993 with a goal of producing a 1:2,500,000 scale maximum MM intensity map. These States are at risk from recurrence of damaging earthquakes in the New Madrid seismic zone, the Wabash Valley seismic zone, or other seismic sources. Paleoseismicity studies conducted cooperatively by the Indiana Geological Survey, the USGS, and others have added significant new information on the earthquake history.

Applications: Seismic zonation maps have been incorporated in national model building codes since 1969. They have also been used for land-use regulations and urban planning. On the basis of the maps five zones have been identified. All model building codes are expected to use the same seismic risk map by the year 2000.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 7.1, October 17, 1989 Loma Prieta, California and the M 6.8, January 17, 1994 Northridge, California earthquakes causing aggregate losses of at least $35 billion and the M 8.1, August 8, 1993 Guam earthquake).

- Technology transfer by USGS, FEMA, NSF, NIST, and others through the National Earthquake Hazards Reduction Program.

- Development of long-term institutional and professional capacity through formation of regional organizations (e.g., CUSEC) and activities of professional and voluntary organizations (e.g., EERI and American Red Cross).

- Political support through legislation and governmental decrees (i.e., Presidential Executive Order 12699 issued on January 6, 1990).

- Political and societal concern for seismic safety and potential environmental impact of earthquakes on dams and hydrologic structures, nuclear power plants, offshore petroleum facilities, oil pipeline systems, and lifeline systems.

- Development of modern monitoring capability (i.e., the modernization of the National Seismic Network beginning in the 1990). When complete it will integrate local seismicity networks managed by universities with a satellite based network consisting of digital seismicity and strong motion instruments.

- Development of the Geographic Information System (GIS) to facilitate applications.

Yemen

Principal Contact: Jamal Mohamed Sholan, General Director, Seismological Observatory Center, Ministry of Oil and Mineral Resources, P.O. Box 78175, Dhamar, Republic of Yemen

Background: The seismicity of Yemen is related to the spreading of the Red Sea.

Monitoring: The national seismic network at present consists of 18 seismic stations.

Maps: At present no national scale seismic zonation maps have been prepared, however, this is a near-term goal of the Yemen Earthquake Hazards Reduction Program (YEHRP).

Applications: No building code having seismic design provisions has been adopted.

Driving Forces: The principal driving forces include:

- Damaging earthquakes (e.g., M 5.7, 1982 Yemen earthquake).
- Technology transfer by USGS, UNESCO, and others through the RELEMR.
- Development of long-term institutional and professional capacity.
- Political support through legislation and governmental decrees (e.g., creation of YEHRP).
- Development of modern monitoring capability through PAMERAR.

Post Earthquake Evaluation Program (PEEP)

Since 1990 the U.S. Geological Survey (USGS) has been responsible under Public Law 101-614 for organizing a comprehensive and integrated post earthquake investigations program after damaging US and foreign earthquakes. The primary concept of post earthquake investigations is to use a damaging earthquake as a scientific laboratory to study in cooperation with local experts in the impacted country and others the societal impact.

The Post Earthquake Evaluation Program (PEEP) was initiated in November 1992. The concept was created in a planning meeting convened in Strasbourg by the USGS, the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the Open Partial Agreement on Major Hazards of the Council of Europe (OPA/COE).

Three types of studies are involved:

1. **Pilot** - the initial study conducted within the first few days to define the scope of subsequent studies.

2. **Reconnaissance** - the multidisciplinary studies initiated and completed within the first few months to expand the pilot study. These studies document what happened, acquire perishable data, and define the need for and scope of long-term follow studies to capture opportunities during the "window of opportunity." Typically during the window of opportunity, strategies for seismic zonation and other viable mitigation measures can be tested and/or implemented.

3. **Follow Up** - the multidisciplinary focused and fundamental studies initiated several months after the earthquake and lasting for several years which explain what happened in detail. These studies seek to derive the salient lessons from the experience and to provide a basis for renewed technology transfer and a call for changes in public policies and professional practices.

It is envisioned that PEEP will: a) create a mechanism for sharing information, b) strengthen interdisciplinary and interorganizational interfaces, c) increase the worldwide capacity for post earthquake investigations, and d) foster the adoption of prevention, mitigation, and preparedness measures.

A brief summary of the investigations after the M 6.8 January 17, 1994 Northridge, California earthquake is provided in another section.

M 6.8 Northridge, California Earthquake
January 17, 1994

Although not the "Big One" a M 8.3 event expected on the San Andreas fault system in Southern California, the M 6.8 Northridge earthquake centered 30 km (18 miles) from downtown Los Angeles is the costliest U. S. earthquake disaster. Estimates of losses are approaching $25 billion with $6 billion of the total from insured losses. The magnitude of the potential loss raised four major issues:

1. Why are there too few M6 to M8 earthquakes to account for the accumulated slip on the 300 known active faults in the Los Angeles basin and what are the long-term implications for the risk to Los Angeles in a direct hit?

2. Were 3-story apartment buildings and steel frame structures unusually vulnerable to a moderate M 6.8 earthquake, and, if so, what were the geologic, seismological, engineering, and public policy reasons? Will they also affect the magnitude of the loss in the "Big One?"

3. What would have happened to the 700,000 school children and 6 million commuters if the earthquake had occurred at 9:31 a.m. on a school and work day instead of 4:31 a.m. on a holiday?

4. What will be the long-term indirect cost and the impact of the devastated freeway system on the 6 million commuters and the region's economy?

The earthquake:

- Occurred on a little known "blind" thrust fault underlying Northridge about 20 miles from the epicenter of the 1971 M 6.5 San Fernando event.

- Generated strong ground shaking throughout the major Los Angeles area with horizontal and vertical ground motions from the main shock and approximately 3,000 aftershocks during the first week reaching 1.8 g.

- Tested the design criteria for engineered buildings and lifeline systems constructed since 1971 and the recently developed retrofit technology for highway structures.

- Damaged portions of 11 major roads to downtown Los Angeles causing widespread traffic congestion due to rerouting around the damaged areas.

- Triggered local ground failure (liquefaction and landslides) causing gas and water pipelines to rupture resulting in fires, power outages, and disruption of water service during the first few days.

- Damaged more than 50,000 homes and apartments causing tens of thousands to seek temporary housing.
- Damaged 150 schools throughout the area causing students to miss classes for a week.
- Damaged hospital sprinkler systems and interiors, forcing relocation and evacuation of patients.
- Injured 6,547 and killed 63.

Within a few weeks after the earthquake, the US Congress approved Dire Emergency supplemental funding of $15 million for long-range studies. Four categories of studies were solicited:

1. Studies to contribute to immediate recovery and mitigation needs.
2. Studies to learn the lessons on the hazard, built, and policy environments of the earthquake.
3. Studies to communicate these lessons to professions in California, throughout the Nation, and the world.
4. Studies to advance mitigation in California, throughout the Nation, and the world.

All studies are expected to begin in August 1994.

Walter W. Hays
U.S. Geological Survey
June 20, 1994

World Conference on Natural Disaster Reduction
Yokohama, Japan
May 23-27, 1994

The first world conference on natural disaster reduction was convened in Yokohama, Japan by the United Nations on May 23-27, 1994, approximately the midpoint of the International Decade for Natural Disaster Reduction (IDNDR). Hosted by the Government of Japan, the conference was attended by approximately 3,000 professionals representing 145 countries and every scientific and technical discipline involved in risk assessment and risk management for earthquakes, floods, severe storms, tsunamis, landslides, wildfires, and droughts.

The conference had many highlights and succeeded in meeting the objectives set by the organizers. Five of the most notable accomplishments inherent implicity or explicity in the Yokohama declaration are noted below:

1. The conference marked the first time this premier worldwide group of experts on risk assessment and risk management had ever assembled together for dialogue on common problems related to natural disaster reduction.

2. Each country prepared and distributed a national report which gave their status of current activities and plans for the future for: a) **risk assessment**, b) **mitigation**, c) **warning systems**, and d) **international cooperation**. **This means that the whole world is thinking about these four themes.**

3. A call was made for accelerated technology transfer (i.e., transfer and enhanced utilization of information, data, and experienced people) in order to reduce the increasing toll of deaths and economic impacts worldwide, especially in developing countries.

4. All countries recognized the value of enhanced regional cooperation and called for plans to increase the number and diversity of bilateral and multilateral projects, especially with neighbors.

5. All countries acknowledged that the 1990's are not long enough to realize all of the national goals for the IDNDR and called for the establishment of an institutional mechanism and a long-term process to continue what the IDNDR has initiated.

The world is better prepared to face the challenge of natural disasters because of Yokohama.

APPENDICES

APPENDIX A

FIRST INTERNATIONAL FORUM ON SEISMIC ZONATION
STANFORD, CALIFORNIA
AUGUST 30, 1991

One hundred fifty researchers and practitioners from 25 countries joined together to share their basic information, ideas, and experiences on seismic zonation and to plan future regional activities that will advance the practice of seismic zonation worldwide. The forum was scheduled immediately after the Fourth International Conference on Seismic Zonation to take advantage of the state-of-the-art research and applications presentations during the conference. The participants of the forum were able, therefore, to spend their time becoming better acquainted and in devising creative solutions to the basic problem identified during the conference, namely:

> *an urgent need to find effective ways to understand, compare, and select the most relevant procedures and products, from the diverse set currently available, for use in their country.*

The participants of the forum requested that the sponsors: U.S. Geological Survey; United Nations Educational, Scientific, and Cultural Organization; International Association for Seismology and Physics of the Earth's Interior; the Secretariat for the IDNDR; Stanford University; Earthquake Engineering Research Institute; and the California Department of Conservation, Division of Mines and Geology consider actions to accomplish the following:

1. Improved sharing of basic scientific data (e.g., seismicity, paleoseismicity, strong ground motion, soils, vulnerability, and loss reduction measures).

2. Acceleration of the worldwide practice of seismic zonation with an emphasis on technology transfer and construction of maps.

One of the unique ideas proposed in the forum was the creation of an international "swat" team on seismic zonation. This team would operate in the post-earthquake environment on the bases of agreements and plans made in the pre-earthquake environment. They would become a resource immediately after a damaging earthquake to review the damage distribution in the stricken country and to recommend procedures for local experts to consider as they improve their seismic zonation maps and loss reduction measures. Such an activity would stimulate the development of standardized procedures and products in broad geographic regions and improve cost effectiveness.

The USGS and UNESCO agreed to begin working on establishing a steering committee which would initiate the planning for the Second International Forum on Seismic Zonation. It is tentatively scheduled for July 19-23, 1992, in conjunction with the Tenth World Conference on Earthquake Engineering.

SECOND INTERNATIONAL FORUM ON SEISMIC ZONATION
MADRID, SPAIN
JULY 23, 1992

International Fora on Seismic Zonation (IFSZ) are a joint initiative by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the U.S. Geological Survey (USGS) in the framework of their 1990 Memorandum of Understanding. The first forum was organized in August 1991 in Stanford, California, immediately after the 4th International Conference on Seismic Zonation. The second forum was organized in conjunction with the 10th World Conference on Earthquake Engineering. To date the following organizations have cosponsored the fora: USGS; UNESCO; International Association for Seismology and Physics of the Earth's Interior; the Secretariat for the International Decade for Natural Disaster Reduction; Stanford University; the Earthquake Engineering Research Institute; and the California Department of Conservation, Division of Mines and Geology. A Directory of International Resources for the Practice of Seismic Zonation has been compiled and is available from UNESCO, USGS, or any of the sponsors.
The goal of the second forum was "to develop consensus recommendations for a generic expert system on the practice of seismic zonation." An expert system is a software/hardware computer system which can help nonexperts solve a particular problem in science, engineering, or business. An expert system uses artificial intelligence concepts to ask questions, give advise, search for, and justify answers--tasks that are normally associated with human behavior and human intelligence. In addition the concept of a hypothetical International Team on Seismic Zonation (ITFZ) which could help to apply expert systems worldwide in either the postearthquake or preearthquake environment was examined as part of a long-term process to improve seismic zonation maps and earthquake risk management policies and practices."

Seismic zonation is the division of geographic region into smaller areas or zones expected to experience the same relative severity of an earthquake hazard (e.g., ground shaking, ground failure, surface faulting, tsunami wave runup, etc.). The resulting zonation maps provide community policymakers and decisionmakers with a wide range of options for ensuring sustainable development. For maximum benefit to policymakers and decisionmakers of a community, seismic zonation maps should integrate basic data on the solid earth system, the built environment, and the social-economic-political system of the community (Figure 1).

The key questions are summarized below.

1. Solid Earth System (i.e., defines the physical characteristics of the source, path, and site which control earthquake hazards (e.g., ground shaking and ground failure hazards)).

- Where have earthquakes occurred in the past?
- Where are they occurring now?

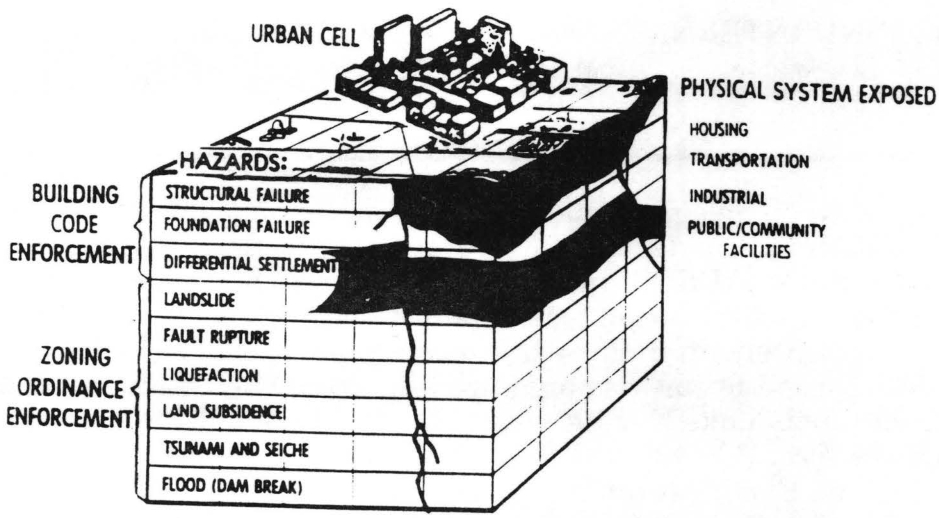

Figure 1. -- Seismic zonation requires an integrated assessment of a communities' solid earth , built environment, and social-economic-political systems.

- What is the magnitude and depth distribution of the past and present seismicity?
- How often have earthquakes of a given magnitude recurred?
- What are the dominant earthquake generating mechanisms?
- What levels of ground shaking have occurred in the past? Ground failure? Surface fault rupture? Tsunami wave runup?
- What are the maximum levels that might be expected in future earthquakes?

2. Built Environment System, (i.e., defines the temporal and spatial distribution of buildings and lifeline systems exposed to earthquake hazards).

   - What are the physical characteristics of the present inventory of buildings and lifeline systems (e.g., age, type of materials, number of stories, elevation, plan, foundations, etc.)? The future inventory?
   - How have these buildings and lifeline systems performed in past earthquakes (e.g., what are the vulnerability relations for each type of building and lifeline)?
   - ...

3. Social-Economic-Political System, (i.e., defines the community's earthquake risk management policies and practices (e.g., mitigation, preparedness, emergency response, and recovery)).

- What risk management policies and practices (i.e., building and land use regulations) have been adopted by the community in the past?
- How have they been enforced?
- How effective have they been?
- ...

Seventy scientists and engineers from twenty countries attended the second forum and participated in three working groups formed several months before the forum. In the working groups, it became clear that the first step in addressing the problem of seismic zonation and in establishing the knowledge base for an expert system is to design a system that meets the needs of policymakers, decisionmakers, and public officials. The use of an expert system was recognized and acknowledged as an efficient way to assist and enable community and national leaders to decide on the most relevant policies to enact, and to provide a scientific and technical basis for decisionmaking. The categories of questions for the expert system on seismic zonation are those which will be asked by local officials whose communities have either been impacted by or are at risk from future earthquakes. The following questions were singled out for continued study:

1. What can happen during an earthquake in a community (i.e., a scenario)?

2. Do realistic scenarios already exist for communities and countries around the World? Can they be made available?

3. To what degree should the scenario encompass the relief, recovery/rehabilitation, and the reconstruction phases?

4. What are the timelines, opportunities, and mechanisms for dispatching a special postearthquake expert-team (i.e., the ITSZ)?

5. If the scenario is incorporated as part of the expert system, how should the scenario be adjusted to represent the actual damage and disruption?

6. What kinds of guidelines and/or questionnaires should be prepared to facilitate development of a realistic scenario?

7. What is the relationship between the ITSZ and the local national experts?

8. How should the reliability of the expert system and its authors be evaluated?

The participants agreed that a three-step process should be followed in order to accomplish the expert system within the next 2-3 years. The steps are:

- determine the questions that the system should respond to;

- develop a generic software system which incorporates the questions;

- test the system by applying it in earthquake prone regions either before or after a damaging earthquake, and refine it, as necessary.

The participants also proposed that the initial development of the expert system be undertaken by a working group to be created under the leadership of Professor Haresh Shah, and that Stanford University, one of the cosponsors of the forum, serve as the institutional headquarters of the group. Interested researchers and professionals willing to participate in the work are urged to contact Professor Shah.

The development of the expert system will be undertaken, to the extent possible, in cooperation with The International Association of Earthquake Engineering's new World Seismic Safety Initiative (WSSI). Collaboration with other existing programs such as the USGS's Worldwide Earthquake Risk Management program (WWERM) and the Global Seismic Hazard Assessment Program (GSHAP), a part of the International Lithosphere Program, will be encouraged.

The Third International forum on Seismic Zonation is being planed for May 6-7, 1993. in Memphis, Tennessee in conjunction with a National Earthquake Conference. Contact Dr. B. Rouhban (UNESCO) or Dr. W. Hays (USGS) for information.

ACKNOWLEDGMENTS

We acknowledge the support and contributions of our colleagues throughout the world. We especially want to express our appreciation to Dr. Pierre Mouroux, BRGM; Dr. James Davis, CDMG; and Dr. Guillermo Santana, University of Costa Rica; who chaired the three working groups, created before the forum. Special appreciation is also extended to Dr. Charles Thiel, who first suggested the idea of an ITSZ and facilitated discussions in Madrid.

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APPENDIX C

THIRD INTERNATIONAL FORUM ON SEISMIC ZONATION
MEMPHIS, TENNESSEE
MAY 5-6, 1993

Sixty five researchers and practitioners from 17 countries came together in conjunction with the 1993 National Earthquake Conference to share information and plan future regional activities that will advance the professional practice of seismic zonation worldwide. The participants were able to build on basic principles established in the first two fora and use the information on lessons learned from past earthquakes contained in 22 expanded abstracts prepared in response to a call for papers before the forum. They continued the dialogue on the following questions whose answers underpin the practice of seismic zonation (Attachment):

1. **Hazard Environment** (i.e., defines the physical characteristics of the source, path, and site effects; that is, the ground shaking and ground failure hazards).

    - Where did the earthquake occur relative to past occurrences?
    - What was the magnitude and focal depth of this earthquake? of the past and present seismicity?
    - How often have earthquakes of this magnitude occurred?
    - What were the dominant earthquake generating mechanisms?
    - What levels of ground shaking occurred in this earthquake? in the past? Ground failure? Surface fault rupture? Tectonic deformation? Tsunami wave runup?
    - What are the maximum levels that might be expected in future earthquakes?

2. **Built Environment** (i.e., defines the temporal and spatial distribution of buildings and lifeline systems exposed to earthquake hazards).

    - What are the physical characteristics of the present inventory of buildings and lifeline systems (i.e., age, type of materials, number of stories, elevation, plan, foundations, etc.)? The future inventory?
    - How did these buildings and lifeline systems perform? How are they expected to perform in future earthquakes. What are the vulnerability relations for each type of building and lifeline?
    - ...

3. **Policy Environment** (i.e., defines the community's earthquake risk management policies and practices)

- What risk management policies and practices (i.e., building and land use regulations) had been adopted by the impacted community?
- How had they been enforced?
- How effective were they?
- ...
- Was a scenario earthquake used by the community?
- Was it realistic?
- To what degree did the scenario encompass the relief, recovery/rehabilitation, and the reconstruction phases?
- Were postearthquake investigations conducted? What are the timelines, opportunities, and mechanisms for dispatching a special postearthquake expert-team (i.e., the ITSZ)? What should be the relationship between the ITSZ and the local national experts?
- If the scenario were to be incorporated as part of an expert system on seismic zonation, how should the scenario be adjusted to represent the actual damage and disruption?
- What kinds of guidelines and/or questionnaires should be prepared to facilitate development of a realistic scenario for future applications?
- How should the reliability of an expert system on seismic zonation and its authors be evaluated?

The sponsors: U.S. Geological Survey; United Nations Educational, Scientific, and Cultural Organization; International Association for Seismology and Physics of the Earth's Interior; the Secretariat for the IDNDR; Stanford University; Earthquake Engineering Research Institute; and the California Department of Conservation, Division of Mines and Geology are considering convening the Fourth International Forum for Seismic Zonation at **multiple locations**, candidates include: Yokohama, Japan (in conjunction with the **May 23-27, 1994** World Conference on Natural Disaster Reduction) and Chicago, Illinois (in conjunction with the **July 10-14, 1994** Fifth US Conference on Earthquake Engineering), Vienna, Austria (in conjunction with the **August 28-September 2, 1994** Tenth European Conference on Earthquake Engineering.

The next steps are:

1. Continuation of efforts to a) **share** basic scientific data (e.g., seismicity, paleoseismicity, strong ground motion, soils, vulnerability, and loss reduction measures), b) **foster** technology transfer for construction of maps, c) **develop an expert system** for seismic zonation, and d) **evaluate** strategies for an international team on seismic zonation (**ITSZ**).

2. **Extension of the call for expanded abstracts** that focus on lessons from one or two selected past damaging earthquakes that have (or could have) advanced the practice of seismic zonation in your country (Due February 14, 1994).

REDUCTION OF COMMUNITY VULNERABILITY

BUILT ENVIRONMENT

- Location, value, exposure, and vulnerability of buildings and lifelines at risk from earthquake physical effects (hazards) which can cause damage, failure, loss of function, release of hazardous materials, injuries, and deaths.

HAZARD ENVIRONMENT

- Physical effects such as: ground shaking; liquefaction; landslides; surface fault rupture; tectonic deformation; fires, and flood waves from seiche, tsunami, and dam break generated in an earthquake and the aftershock sequence; each potentially impacting the built environment.

POLICY ENVIRONMENT

- Social, technical, administrative, political, legal, and economic forces which shape a community's policies and practices for: earthquake risk management (i.e., prevention, mitigation, preparedness, prediction and warning, intervention, emergency response, and recovery), public awareness, training, education, and insurance.

APPENDIX D

DIRECTORY OF INTERNATIONAL PROFESSIONALS INVOLVED IN THE PRACTICE OF SEISMIC ZONATION

(Third Edition)

Compiled as part of the First International Forum on Seismic Zonation, an activity of the International Decade for Natural Disaster Reduction

July 1994

Compiled by:
Amanda Queen
US Geological Survey
June 1993

Updated
July 194

Directory of International Resources for the Practice of Seismic Zonation

We know the directory is a dynamic document and is never fully complete or error free. Please address your correspondence with any corrections or additional listings of professionals to the attention of Dr. Walter Hays, U.S. Geological Survey (USGS), 905 National Center, Reston, Virginia 22092, USA, or Dr. Badaoui Rouhban, United Nations Educational, Scientific and Cultural Organization (UNESCO), Division of Earth Sciences, 7 Place de Fontenoy, 75700 Paris, France.

Directory of
International [illegible]
for the [illegible]
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The directory [illegible]
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correspondence [illegible]
listing professionals [illegible]
[illegible] Geological [illegible]
Center, Reston, Virginia [illegible]
Possible United Nations [illegible]
organizations [illegible]
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Directory of International Resources for the Practice of Seismic Zonation

Foreword

The purpose of this directory is to facilitate communication among professionals throughout the world who are committed to improving the worldwide practice of seismic zonation. Each one listed invites you to contact them, either to share your data, information, and experience or to request their data, information, publications, and technical assistance on seismic zonation.

We believe that this directory is complete; however, it may have unintentional errors or omissions. Please address your correspondence with any corrections or additional listings of professionals to the attention of Dr. Walter Hays, U.S. Geological Survey (USGS), or Dr. Badaoui Rouhban, United Nations Educational, Scientific and Cultural Organization (UNESCO).

The sponsoring organizations invite you to direct your inquiries for technical assistance to the following individuals who are serving on behalf of their organization:

1. International Association for Seismology and Physics of the Earth's Interior: Dr. Bruce Bolt, Seismographic Station, University of California, Berkeley, CA 94720, USA.

2. Stanford University: Dr. Haresh Shah, Chairman, Department of Civil Engineering, Stanford University, Stanford, CA 94305, USA.

3. Earthquake Engineering Research Institute: Ms. Susan Tubbesing, Executive Director, or Dr. Carl Stepp, or Mr. Lloyd Cluff, Presidents, 499 14th Street, Suite 320, Oakland, CA 94612-1902, USA.

4. California Department of Conservation, Division of Mines and Geology: Dr. James Davis, State Geologist, 1416 Ninth St., Suite 134, Sacramento, CA 95814, USA.

5. UNESCO: Dr. Badaoui Rouhban, Earth Sciences Division, 7 Place de Fontenoy, 75700 Paris, France.

6. USGS: Dr. Walter W. Hays, 905 National Center, Reston, VA 22092, USA; Dr. Walter Mooney, 345 Middlefield Rd., MS 977, Menlo Park, CA 94025, USA; Dr. John R. Filson, 922 National Center, Reston, VA 22092, USA; Dr. Randall Updike, MS 966 Denver Federal Center, Denver, CO 80225, USA; Dr. S.T. Algermissen, 917 National Center, Reston, VA 22092, USA.

We appreciate your support in our endeavor to improve the worldwide practice of seismic zonation.

Walter W. Hays
U.S. Geological Survey

Badaoui M. Rouhban
UNESCO

ALPHABETICAL LISTING

A

Abe, Katsuyuki, Earthquake Research Institute, University of Tokyo, 1-1-1 Yajoi, Abunkyo-ku, Tokyo 1134, Japan, Tel:(81-3) 3812-2111 ext. 5706, Fax:(81-3) 38469-1159

Abrams, Daniel, University of Illinois, 3148 Newmark Lab MC 250, 205 N. Mathews, Urbana, Il 61801, USA, Tel: (1-217) 333-0565, Fax: (1-217) 333-9464

Abou-Roumieh, Hassan, General Establishment of Geology, Earthquake Centre, P.O. Box 7645, Syr-Damascus, Syria, Tel: (963-11) 455 426

Adeli, Hojjat, The Ohio State University, Dept. of Civil Engineering, 470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210, USA, Tel: (1-614) 292-7929, Fax: (1-614) 292-7929

Agrawal, R.C., University of Roorkee, Roorkee-247667, India, Tel:(91-133) 22349-228 ext.722, Fax: (91-133) 23560

Agrawal, P.N., University of Roorkee, Roorkee-24667, India, Tel: (91-133) 22349, Fax: (91-133) 23560

Akour, Hasan, Royal Scientific Society, Building Research Center, P.O. Box 925819, Amman, Jordan, Tel: (962) (6) 844701, Fax: (962)(6) 844806

Al-Aqaileh, Royal Scientific Society, Building Research Center, P.O. Box 925819, Amman, Jordan, Tel: (962) (6) 844701, Fax: (962) (6) 844806

Alghafari, Ahmad, Council of Engineering, and Architects, P.O. Box 2336, SYR-Damascus, Syria, Tel: (936-11) 414 292

Al-Sáad, Nedam, Director of Planning Organizing, and Studies Dept., Civil Protection Organisation, P.O. Box 1050, Amman, Jordan, Tel: (962) (6) 661111, Fax: (962) (6) 666013

Algermissen, Ted, U.S. Geological Survey, 917 National Center, Reston, VA 22092, USA, Tel: (1-703) 648-6051

Almora, David, Instituto de Ingenieria, UNAM, Ciudad Universitaria, Mexico 04510 DF, Mexico, Tel:(52-5) 550-5215 ext. 3641, Fax: (52-5) 548-3044

Alzona, Sabina, SEISMED, Corso Dogali 18, I-16136 Genova, Italy, Tel: (39-10) 297 728

Ambraseys, Nicholas N, Civil Engr. Dept, Imperial College of Science, University of London, London SW7 2BU, England, Tel: (44-71) 589 5111 ext 4718, Fax: (44-71) 823 8525

Ammann, Walter J., Federal Institute for Snow and Avalanche Research, CH-7260 Davos, Switzerland, Tel: (41-81) 46 3264, Fax: (41-81) 46 18 97

Ang, A. H-S, University of California, Irvine, Dept. Civil Engineering, 231 ELF, Irvine, CA 92717, USA, Tel: (1-714) 856-8528, Fax: (1-714) 856-5051

Anicic, Drazen, Insititue of Civil Engineering Institute of Croatia, 1, Rakusina, P.O. Box 283, 41000 Zagreb, Croatia, Tel: 38 41 533 117, Fax: 38 41 534-737

Ansal, Atila M., Istanbul Technical University, Civil Engineering Faculty, Geotechnical Engineering Dep., Ayazaga-Istanbul, Turkey, Tel:(90-1) 2763702, Fax:(90-1) 2766587

Arabasz, Walter, Dept. of Geology and Geophysics, Univ. of Utah, 705 W C Browing Bldg, Salt Lake City, Ut 84112, USA, Tel: (1-801) 581-6274, Fax: (1-801)581-7065

Argyrakis, Kostas, Ministry of Planning and Environment, Kodron 5-Halandri, Athens 15232, Greece, Tel: (30-1) 6834812, Fax: (30-1) 6926426

Astroza, Maximiliano, University of Chile, Dept. of Civil Eng., Av Blonco Encolsde 2120-4° Piso, Santiago, Chile, Tel: (56-2) 6982071 ext: 378, Fax: (56-2) 6712799

B

Bahavar, M., IIEES, P.O. Box 19395/3913, Techran, Iran, Tel: (98-21) 275484, Fax: (98-21) 4372732

Bahrainy, Hossein, University of Tehran, Institute for Environmental Studies, #32, St. #14 Kargar Shomali Ave., Tehran, Iran, Tel: (91-21) 292054, Fax: (98-21) 299241

Bard, Pierre-Yves, LCPC/Observatoize de Grenoble, IRIGM BP 53X, F. 38041 Grenoble Cedex, France, Tel: (33-76) 51 49 37, Fax: (33-76) 51 44 22

Barghouti, Amjad, Jordan University, Dept. of Civil Eng., Amman, Jordan, Tel: (962-6) 843555, Fax: (962-6) 832318

Barrows, Allan, California Division of Mines & Geology, 1416 Ninth St., Sacramento, CA 95814, USA

Bartolo, Mario, Police Dept, Floriana, M-Valletta, Malta, Tel: (356) 224 001

Bauer, Robert, Illinois State Geological Survey, 615 East Peabody Dr., Champaign, IL 61820, USA, Tel: (1-217) 244-2394, Fax: (1-217) 244-0029

Behrouz, Gatmiri, University of Tehran, Engineering Collage, P.O. Box 4563, Teran, Iran, Tel: (98-21) 4406339

Belazougui, Mohamed, Centre National de Recherche, en Genie Sismique, Rue Kaddour Hussein-Dey, DZ-Alger, Algeria, Tel: (213) 77 68 16

Benblidia, Mohammed, ANAT/Fonds de Construction, 30 ave M. Fellah, DZ-Alger-Kouba, Algeria, Tel: (213) 74 61 73; 58 34 23

Ben Sari, Driss, Directeur National Center for Research, B.P. 1346, Rabat R.P., Morocco, Tel: (212-7) 77 28 03, Fax: (212-7) 77 12 88

Berardi, Raniero, ENEL- DDC, Viale Regina Margherita 137, 00198 ROMA, Italy, Tel: (39-6) 85098596, Fax: (39-6) 85092736

Bernal, Dionisio, Northeastern University, 360 Huntington Ave., Bostn, MA 02115, USA, Tel: (1-617) 437-4417, Fax: (1-617) 437-4419

Bertero, Vitelmo, EERC, University of Califorina at Berleley, 1301 South 46th Street, Richmond, CA 94804-4698, USA, Tel: (1-510) 231-9586, Fax: (1-510) 231-9471

Betbeder-Matibet, Jacques, Electricite De France, Tour Franklin, 92081 Paris La De Fense, CedexII, France, Tel: (33-14) 90 28 491, Fax: (33-14) 90 25 471

Bethoux, Nicole, Office Monegasque de l' Environnement, 16 bd de Suisse, 9800, Monaco, Tel: (33) 25 899 54, Fax: (33) 93 15 92 33

Bezeggoud, Mourad, Center of Research on Astronomy, Astrophysics and Geophysics, Observatoire De Bouzareah, Algiers, Algeria

Bielak, Jacobo, Carnegie Mellon Unviersity, Dept of Civil Eng., Pittsburgh, PA 15213-3890, USA, Tel: (1-412) 268-2958, Fax: (1-412) 268- 7813

Blazquez, Rafael, Instituto Eduardo Torrija (CSIC), C/ Serrano Galvache s/n, 28033-Madrid, Spain, Tel: (34-1) 7670742, Fax: (34-1) 3020700

Bolt, Bruce, University of California-Berkely, Berkely,CA 94720, USA, Tel: (1-510) 642-7030, Fax: (1-510) 643-5811

Boncheva, Haritina, Bulgarian Academy of Sciences, Central Laboratory for Seismic Mechanics, and Earthquake Engineering, BG-Sofia 1113, Bulgaria, Tel: (359-2) 71 31 33 18

Boer, Jan de, Min. Health/CVVC, P.O. Box 3008, 2280 MK RIJSWIJK, Netherlands, Tel: (070) 3 40 79 11

Bonneville, David, H.J. Degenkolb Assoc., 350 Sansome St., Suite 900, San Francisco, CA 94104, USA, Tel: (1-415) 392-6952, Fax: (1-415) 981-3157

Borja, Ronaldo I., Stanford University, Terman Engineering Center, Stanford, CA 94305-4020, USA

Boujer, K. P., Institute of Geophysics, Univ. Karlsruhe, Hertzstr. 16, W 7500 Karlsruhe, Germany, Tel: (49-7216) 084443

Bourade, Michel Salah, c/o 95 Rue Des Morillons, 75015 Paris, France, Tel: (33-1) 45315500, Fax: (33-1) 43254877

Brabb, Earl E., U.S. Geological Survey, Mail Stop 975, 345 Middlefield Road, Menlo Park, CA 84025, USA, Tel: (1-145) 329-5140, Fax: (1-415) 329-4936

Brennan, Tod, The Center for Earthquake Research, in Australia, P.O. Box 276 Indooroopilly, Brisbane, Queensland, Australia, Tel: (61-7) 2863944; 378911, Fax: (67-7) 8781252

Buen, Oscar de, Colinas de Buen Viaducto, Miguel Aleman, 190 col Atenor Salas, Mexico 30100, DF, Mexico, Tel: (52-5) 519-7240, Fax: (52-5) 530-3570

Bufe, Charles, U.S. Geological Survey, Mail Stop 966, Denver Federal Center, Denver, CO 80225, USA, Tel: (1-303) 273-8413

C

Calderón-Macras, Carlos, Centro de Investigocion Sismica, Carretera al Ajosco, 203,Col. Heroes de Dadierno, Mexico 1000 D.F., Mexico, Tel:(52-5) 652-33-01, Fax:(52-5) 652-3331

Capocecera, Paloe, ENEA, C.R.E. Casaccia, Via Anguillarese, 00100 Roma, Italy, Tel:(39-6) 30484653, Fax:(39-6) 30484927

Cara, Michel, BCSF, IPG, 5 Rue Rene Descartes, 67084 Strasbourg Codex, France, Tel: (33-88) 41 63 00, Fax: (33-88) 61 67 47

Carlo, Arrigo, Aquater Research, and Development, I-S Lorenzo in Campo, (Pesaro), Italy, Tel: (39-721) 771 372

Carreño, Emilio, Instituto Geografico Nacional, c/ General Ibanez De Ibero N° 3, 28003 Madrid, Spain, Tel: (34-1) 533 3800 ext: 303, Fax: (34-1) 533 1158

Carydis, Panayotis. G., National Technical University of Athens, Laboratory for Earthquake Engineering, 157 00 Polytechnic Campus, Athens, Greece, Tel: (30-1) 7785637, Fax:(30-1) 7706308

Casciati, Fabio, Dept. of Structural Mechanics, Via Abbiategrasso 211, 27100 Pavia, Italy, Tel: (39) 382-391458/0, Fax: (39) 382-422881

Casirati, Mario, ISMES, Dept of Structural Investigations, Via Pastrengo, I-Seriate (BG), Italy, Tel: (39-35) 307 585, Fax:
(39-35) 307 710

Celebi, Mehmet, U.S. Geological Survey, 345 Middlefield Rd., MS 977, Menlo Park, CA 94025, USA, Tel: (1-415) 329-5623, Fax: (1-415)239-5163

Chaker, Amar, Institut de Genie Civil, Universite des Sciences Et De La Technologie, Houari Boumediene, BP 32 El Alia, Bab Ezzouar, Alger, Algeria, Tel: (213) 275 94 97, Fax: (213) 2759497

Chandrasekaran, A.R., University of Roorkee, Dept. of Earthquake Engineering, Roorkee U.P. 247667, India, Tel: (91) 332 2349 ext. 124 or 272, Fax:(91) 13323560

Chatelain, Catherine, UNDRO, Palais Des Nations, CH-1211 Geneva 10, Switzerland, Tel: (41-22) 733 5623

Chen, Zhangli, State Seismological Bureau, 63 Fuxing Road, Beijing 100036, China, Fax: (86-01) 8210995

Cheng, Franklin Y., University of Missouri-Rolla, Dept. of Civil Eng., University of Missouri-Rolla, Rolla, MO 65401, USA, Tel: (1-314) 341-4469, Fax: (1-314) 341-4729

Chopra, Anil K, University of California, Dept. of Civil Engineering, Berkelay, CA 94720, USA

Cherrabi, Abdelkader, Ecole Hassania des Travaux Publics, km. 71 Route Eljedida, MA-Casablanca, Morocco, Tel: (212) 231 963

Cipollini, Attilio, National Seismic Survey, 8 Via Curtatone, 00185 Rome, Italy, Tel: 39 (6) 44 55 607, Fax: 39 (6) 44 66 745

Colozza, Riccardo,, National Seismic Survey, 8 Via Curtatone, 00185 Rome, Italy, Tel: 39 (6) 44 55 607, Fax: 39 (6) 44 66 745

Constantinou, George, Geological Survey, Ministry of Agriculture, and Natural Resources, CY-Nicosia, Cyprus, Tel: (357-2) 302 924

Cording, E.D., University of Illinois, 4 College Park CT., Savoy, IL 61874, USA, Tel:(1-217) 351-8707

Cramer, Chris H., California Division of Mines and Geology, 801 K Street, Mail Stop 13-35, Sacramento, CA 95814-3531, USA, Tel: (1-916) 322-9312, Fax: (1-916) 324-1396

Crespellani, Teresa, Universita Di Firenze, Dipartimento Di Ingegnerta Civile, Via Santa Marta 3, 50139 Firenze, Italy, Tel: (39-55) 4796313, Fax: (39-55) 404375

Crone, Anthony, U.S. Geological Survey, Box 25046, Mail Stop 966, Federal Center, Denver, CO 80225, USA, Tel: (1-303) 236-1595

Cruz, Ernesto, Depto. Ingenieria Estructural, Casilla 306, Corre 022, Santiago, Chile, Tel: (56-2) 5522375 ext. 4243, Fax: (56-2) 5524054; 5692

Cuellar, Vicente, Laboratorio De Geotecnia, Alfonso XII- 3, Madrid-28014, Spain, Tel: (34-1) 3357359, Fax: (34-1) 5277442

Czitrom, Gabor, Delegation Aux Risques Majeurs, 14 Boulevard du General Leclerc, 92524 Neuilly-Sur-Seine, Cedex, France, Fax: (33-1) 40513324

D

Davidovici, Victor, SOCOTEC, 3 Avenue du Centre, 78182 Saint Quentin, Yvelines Cedex, France, Tel: (33-13) 04 39 913, Fax: (33-13) 05 70 205

Davis, James, California Division of Mines & Geology, California State Geologist, 801 K Street Mail Stop 12-30, Sacramento, CA 95814, USA, Tel: (1-916) 445-1923, Fax: (1-916) 445-5718

de Justo, José Luis, Catedratico de mecanica De Suilos, Escuela de Arquitectura, Avda de reina Mercedes, Sevilla, Spain

De Marco, Roberto, National Seismic Survey, 8 Via Curtatone, 00185 Rome, Italy, Tel: 39 (6) 44 55 607, Fax: 39 (6) 44 66 745

Deodatis, George, Princeton University Dept. Civil Eng., & Operations Research, Princeton, NJ 08544, USA, Tel: (1-609) 258-1624, Fax: (1-609) 258-6759

Dolce, Mauro, Universita Della Basilicata, Departimento Di Strutture, Via Della Tecnica 3, 85100 Potenza, Italy, Tel: (39-971) 474 607, Fax: (39-971) 57477

Dong, Weimin, Risk Management, Software Inc., 650 Castro Street, Suite 260, Mountain View, CA 94041, USA, Tel: (1-415) 903-4848, Fax: (1-415) 940-1823

DuMontelle, Paul B., Illinois State Geological Suvery, 615 East Peabody Drive, Champaign, IL 61820, USA, Tel: (1-217) 333-5114, Fax: (1-217) 244-7004

E

Eggert, Donald, Indiana Geological Survey, 611 North Walnut Grove, Bloomington,IN 47405, USA, Tel: (1-812) 855-1366, Fax: (1-812) 855-2862

Eibl, Walter, Inst. of Bodeuurdcdiaurk in, Massivban-Univ. Karlsruke, Postfack 6980, W- 75000 Karlsrike, Germany, Tel: (49-7216) 083294, Fax: (49-7216) 93638

Elefthriou, Serghis, Geological Survey, CY-Nicosia, Cyprus, Tel: (357-2) 302 405

El-Foul, Djamal, N'Center of Research on Earthquake Engineering, (C.G.S.), Rue Kaddour Rahim, 16040 Hussein-DeyAlger, Algeria, Tel: (213-2) 59 90 81

El-Kaysi, Kays K., Natural Resources Authority, P.O. Box 7 Amman, Jordan, Tel: (962) (6) 811300, Fax: (962) (6) 811866

El-Samad, Megahed Abd, National Institut of Astronomy, and Geophysics, ET-Cairo-Helwan, Egypt, Tel: (20-2) 780 645

Englehardt, Michael D., University of Texas at Austin, Dept of Civil Eng., Austin, TX 78712-1076, USA

Erdik, Mustafa, Kanblilli Observatory, Bosphoros University, Earthquake Research Institute, 81220 Gengelkoy Istanbul, Turkey, Tel: (90-1) 3320277, Fax: (90-1) 3321711

Ergünay, Oktay, Earthquake Research Dept., Ministry of Public Works & Settlement, P.K. 763 Kizialay, Ankara, Turkey, Tel: (90-4) 2873646, Fax: (90-4) 2878924

Esteva, Luis, Coordinacion de la Investigacion Cienfifica, UNAM, Ciudad Universitaria, Mexico 04510, DF, Mexico, Tel: (525) 622 4182, Fax: (525) 550 0904

Eva, Clauedio Universita' Di Genova, Dep. Scienze Della Terra, Viale Benedetto XV 5, 16132 Genova, Italy, Tel: (39-10) 03539081, Fax: (39-10) 0352169

F

Fäh, Donat, Istituto di Geodesia Geofisica, Universita degli Studi, Via Universita 7, 34100 Trieste, Italy, Tel: (39-40) 30 14 06, Fax: (39-40) 31 17 93

Farsi, Mohamed, CGS N'Center of Research on Earthquake Engineering, Rue Kaddam Rahim, 16040 Hussein-Dey Alger, Algeria, Tel: (213) 77 66 73

Faravelli, Lucia, Dept. of Structural Mechanics, University of Pavia, Via Abbiategrasso 211, 27100 Pavia, Italy, Tel: (39-382) 391450, Fax: (39-382) 528422

Fenves, Gregory, University of California, 729 Dept. of Civil Eng, 760 Davis Hall, Berkekey, CA 94720, USA

Ferrini, Maurizio, Regione Toscana, Firenze, Italy, Tel: (39-55) 438-3991

Frankel, Arthur, U.S. Geological Survey, Mail Stop 966, Federal Center, Denver, CO 80225, USA, Tel: (1-303) 273-8557

Frolova, Nina, Joint Council of Seismology, & Earthquake Center, Ulyanovskoya Str. 51, Moscow 109004, Russia, Tel: (09-5) 271-27 80, Fax: (09-5) 271-30 28

G

Garcia, Delfin C., Philippine Institute of Volcanology, and Seismology, 29 Quezon Ave, Quezon City, Philippines

Gazetas, George, National Technical University of Athens, 42 Patission St., Athens, Greece, Tel: (30-1) 36911

Ghafory-Ashtiany, Mohsen, IIEES, P.O. Box 19395/3913, Tehran, Islamic Republic of Iran, Tel: (98-21) 275484, Fax: (98-21) 4378732

Giesecke, Alberto, Director CERESIS, Apartado 14-0363, Lima, Peru, Tel: (51-14) 336750, Fax: (51-14) 336750

Glergetti, Emrilo, Civil Preriction Midustry, V. Ulplano 11, Rome, Italy, Tel: (39-6) 6518298, Fax: (39-6) 6875531

Godefory, Pierre, Service Rispue et Genie Sismiques, 117 Avenue de Luminy 13009, Marseille, France

Gong, Si Li, Institute of Earthquake Engineering, Xiao Huong Zhuang, Post Box 752, Beiging 100013, China, Tel: (86-01) 4214354

Goodno, Barry J., Georgia Inst. of Technology, School of Civil Eng., Atlanta, GA 30332, USA, Tel: (1-404) 894-2227, Fax: (1-404) 894-2278

Gorshko, Alexander, Academy of Science, Warshavskoye sh. 79 kor. 2, Moscow 113556, Russia
Göcer, Orhan, Yildiz University, Faculty of Architecture, Balmumcu-Istanbul, Turkey, Tel: (90-1) 1597070

Grases, José, Universidad Centrla De Venezuela, Av. Mohedano #9, La Castellana, Caracas, Venezuela, Tel: (582) 2850608, Fax: (582) 2854155

Griesser, Jean-Claude, c/o Basleu & Hofmann Iug. AG, Forchstr No.395, 8029 Zurich, Switzerland, Tel: (41-1) 551122, Fax: (41-1) 535807

Gülkan, Polat, Middle East Technical University, Department of Civil Engineering, 06531 Ankar, Turkey, Tel: (90-4) 2237100/2446, Fax: (90-4) 2868627

Gündüz, A. Necmettin, Istanbul Technical University, Faculty of Civil Eng., Maslak 80626, Istanbul, Turkey, Tel: (90-1) 2763836; 2614007, Fax: (90-1) 2766587

Gupla, M.K., Department of Earthquake Engineering, University of Roorkee, Roorkee 247667, India, Tel: (91-133) 22349-228, Fax: (91-133) 23560

Gutierrez, Jorge, University of Costa Rica, Civil Eng. Dept., San Jose, Costa Rica, Tel: (506) 34 14 22, Fax: (506) 26 48 48

Gverra, Guerra, Universita' dDella Calabri, Dip. Scienze Della Terra. 87030, Castiglione Cosentino Stazione, Cosentza, Italy, Tel: (39-3) 86837073, Fax: (39-3) 866863505

H

Hakuno, Motohiko, Earthquake Research Institute, University of Tokyo, 1-1-1, Yayoi Bunkyo-ku, Tokyo 1134, Japan, Tel: (81-3) 3812-2111 ext. 5784, Fax: (81-3) 3814-6365

Hamida, Hassen Ben, Ministere de l'equipment et de l'habitat, cite Jardin Belvedere, TN-1002 Tunis, Tunisia, Tel: (216-1) 682 033

Hammoud, Assad, Civil Defence General Directorate, SYR-Damascus, Syria, Tel: (963-11) 444 900

Hammuda, Omar, Al-Fateh University, LAR-Tripoli, Libya, Tel: (218-21) 48 45 2

Hamouda, M. Mohamed, Direction de la Geologie, 5 rue Dades, Agdal, MA-Rabat, Morocco, Tel: (212-7) 774 726, Fax: (212-7) 777 943

Hancox, Graham, DSIR, Geology and Geophysics, P.O. Box 30368, Lower Hutt, New Zealand, Tel: (64-4) 699-059, Fax: 64-4) 666-168

Hansen, Andrew, Geotechnical Engineering Office, Hong Kong Government Planning Division, 11/Floor Civil Eng. Bld, 101 Princeess Margaret Rd., Homantin, Hong Kong, Tel: (852) 762 5375, Fax: (852) 714 0247

Hanson, Robert, University of Michigan, Civil & Environ Eng., 2340 G.G. Brown Building, Ann Arbor, MI 48109-2125, USA, Tel: (1-313) 764-5617, Fax: (1-313) 764 4292

Hart, Earl, California Division of Mines & Geology, 1145 Market Street, 3rd Floor, San Francisco, CA 94103-1520, USA, Tel: (1-415) 557-1654, Fax: (1-415) 5571435

Hasin, Rammali, Survey Dept. of Libya, P.O. Box 600, Lar-Tripoli, Libya

Hatchard, Trevor, Emergency Management Australia, P.O. Box 1020, Dickson, Australian Capital Territory 2602, Australia, Tel: 61 6 266 5408, Fax: 61 6 257 1490

Hatheway, Allen W., University of Missouri-Rolla, School of Mines & Metallurgy Dept. of Geological Engineering, 129 V. H. McNutt Hall, Rolla, MO 65402-0249, USA, Tel: (1-314) 341-4777, Fax: (1-314) 341-4192

Hatzfeld, Denis, INSU, LAGIT/IRIGM, BP53X 38041 Grenoble, Cedex, France, Tel: (33-76) 51 49 37, Fax: (33-76) 41 44 22

Hays, Walter W., U.S. Geological Survey, 905 National Center, Reston, VA 22092, USA, Tel: (1-703) 648-6711, Fax: (1-703) 648-6717

Healy, Jack, U.S. Goelogical Survey, 345 Middlefield Rd., MS 905, Menlo Park, CA 94025, USA

Henger, M., Bundesahstalt of Geowissens, Chaften in Rohstoftc, Alfred-Bents -Hairs, Postfach 510153, Germany

Hernried, Alan, Oregon State University, Dept. of Civil Eng., Apperson Hall 206, Corvallis, OR 97331-2302, USA

Hester, Norman C., State Geologist and Director, Indiana Geological Survey, 611 North Walnut Grove, Bloomington, IN 47405., USA, Tel: (1-812) 855-9350, Fax: (1-812) 855-2862

Hfaiedh, M. Mohamed, Institut de la Meterorolgie, BP 156, TN-2035, Tunis-Carthage, Tunisia, Tel: (216-1) 782 400

Hidalgo, Pedro, Universidad Catolica De Chile, Casilla 306- Correo 22, Santiago, Chile, Tel: (56-2) 5522375 ext. 4207, Fax: (56-2) 5525692

Holzer, Thomas L, U.S. Geological Survey, Mail Stop 977, 345 Middledfield Road, Menlo Park, CA 84025, USA, Tel: (1-415) 239-5613, Fax: (1-415) 329-5143

Hughes, Peter, The Center for Earthquake Research in Australia, P.O Box 276, Indooroopilly, Brisbane, Queensland, 4068, Australia, Tel: (61-7) 3789111, Fax: (61-7) 8781252

Hushmand, Behnam, CALTECH, Civil Engineering 104-44, Pasadena, CA 91125, USA, Tel: (1-818) 356-4232, Fax: (1-818) 356-4232

Hwang, Howard, Memphis State University, Center for Earthquake Research, and Information, Memphis, TN 38152, USA, Tel: (1-901) 678-2007, Fax: (1-901) 232-2857

Isikara, Ahmet Mete, Bosphoros University Kandilli Observatory, and Earthquake Research Institute, 81220 Cengelkoy, Istanbul, Turkey, Tel: (90-1) 3320277, Fax: (90-1) 3321711

Iwan, Wifred, California Inst of Technology, Mail Code 104-44, Pasadena, CA 91125, USA, Tel: (1-818) 256-4144, Fax: (1-818) 568-2719

Iwasaki, Toshio, Public Works Research Institute, Ministry of Construction, 1 Asahi, Tsukkuba 305, Japan, Tel: (81-2) 98642211 ext. 206

I

Ibrahim, Ezzeldin Mohamed, National Research Institute of Astronomy, and Geophysics, Cairo Helwan, Egypt, Tel: (20) 02 780645, Fax: (20) 02 782683

Idriss, I.M., Department of Civil Engineering, Univ of California, Davis, CA 95616, USA, Tel: (1-916) 725-5403, Fax: (1-916) 752-8924

Iglesias, Jesus, UAM, Av. San Pabo 180, Mexiço 32200 DF, Mexico, Tel: (52-5) 563-4694, Fax: (52-5) 382-4052

Iida, Masahiro, Earthquake Research Institute, University of Tokyo, 1-1-1 Yayoi Bunkyo-ku, Tokyo 1134, Japan, Tel: (81-3) 3812-2111 ext. 5785, Fax: (81-3) 3814-6365

Imbesi, Giuseppe, Dept of Urban Technology, Universita Degli Studi "La Sapienza", Facolta di Ingegneria, I-Roma, Italy, Tel: (39-6) 474 5198, Fax: (39-6) 844 1931

Ishihara, Kenji, University of Tokyo, Dept of Civil Eng. Faculty of Eng., 7-3-1 Hongo Bunkyo-ku, Tokyo 1134, Japan, Tel: (81-3) 3812-2111 ext. 6120

J

Jacob, Klaus, Lamont-Doherty Geol Observ., Columbia University, Palisades, NY 10964, USA, Tel: (1-914) 359-2900, Fax: (1-914) 359-5215

Jafari, M. Kazem, IIEES, P.O. Box 19395/3913, Tehran, Iran, Tel: (98-21) 275484, Fax: (98-21) 4378732

Jalouqa, Kamal, Municipality of Greater Amman, P.O. Box 132, Amman, Jordan, Tel: (962) (6) 636111, Fax: (962) (6) 649420

Jaime, Alberto, Instituto de Ingenieria, Ciudad Universitaria, DF 04510, Mexico, Tel: (524) 5489793, Fax: (524) 5483044

Jaradat, Mohammad, Natural Resources Authority, P.O. Box 7, Amman, Jordan, Tel: (962) (6) 811300, Fax: (962) (6) 811866

Jibson, Randall W., U.S. Geological Survey, Mail Stop 966, Federal Center, Denver, CO 80225, USA, Tel: (1-303) 273-8577

Jones, Nicholas, The Johns Hopkins University, Department of Civil Engineering, Baltimore, MD 21218-2686, USA, Tel (1-410) 516 7874, Fax: (1-410) 516-7473

K

Kaddoumi, Mohammad Fawaz, Royal Scientific Society, Building Research Center, P.O. Box 925819, Amman, Jordan, Tel: (962) (6) 844701, Fax: (962) (6) 844806

Kafri, Uri, Geological Survey, 30 Malchei Israel St., IR-Jerusalem 95501, Israel, Tel: (972-2) 208-203, Fax: (972-2) 380 688

Kaila, Krishan Lal, National Geophysical Research Inst., Uppal Rd Hyderabad, 500 007, Andhra Pradesh, India, Tel: (91) 851784, Fax: (91) 854164

Kasai, Kazuhiko, Illinois Institute of Technology, Dept. of Civil Eng., Armour College of Eng., Chicago, IL 60616, USA

Kausel, Edgar, University of Chile, Department of Geophaysics, Casilla 22813, Santiago, Chile, Tel: (56-2) 6982071 ext. 324, Fax: (56-2) 712799

Kazuhiko, Kawashima, Public Works Research Inst., Tsukuba Science City, Ibaraki-Ken 305, Japan, Tel: (81-298) 64-2211 445, Fax: (81-298) 64-0598

Kebeasy, Rashad, National Institut of Astronomy, and Geophysics, ET-Cairo-Helwan, Egypt, Tel: (20-2) 782 683

Keefer, David, U.S. Geological Survey, 345 Middlefield Rd., MS 998, Menlo Park, CA 94720, USA

Keintzel, Einar, Universitat Karlsruhe, Institut Für, Massivbauam Fasanen garten, W-7500 Karlsruche 1, Germany, Tel: (07-21) 6084096, Fax: (07-21) 693075

Kelly, James, EERC, 1301 South 46th Street, Richmond, CA 94804, USA

Khattri, K.N., Department of Earth Sciences, University of Roorkee, Roorkee 247667, U.P. India,

King, Andrew, BRANZ, Private Bag 325, Punirz, New Zealand

Kiremidjian, Anne, Stanford University, Terman Eng. Center 238, Dept of Civil Eng., Stanford, CA 94305-4020, USA, Tel: (1-415) 723-4164, Fax: (1-415) 725-8662
Kiureghian, Armen Der, University of California, Dept. of Civil Engineering, Berkeley, CA 94720, USA

Klaveren, P. Van, BETHOUX Nicole, Serice De l'Environnement, 5 Avenue de Fontvielle, MC 98000, Moncaco, Tel: (33) 93 15 81 49, Fax: (33) 93 15 92 33

Kobayashi, Hiroyoshi, Professor of Nippon Institution of Technology, President of Strong Motion Earthquake Obervation Council, 1-51-14 Umegaoka Setagaya-ku, Tokyo 154, Japan, Tel: (81-480) 34 2941, Home: (81-3) 3429-1717

Koller, Martin, Resonance, 21 Rue Jacques Grosselin, 1227 Carouge, Geneva, Switzerland, Tel: (41-22) 301 02 53, Fax: (41-22) 342 49 37

Komak-Panah, Ali, IIEES, P.O. Box 19395/3913, Tehran, Iran, Tel: (98-21) 275484, Fax: (98-21) 4378732

Kondili, Jani, Seismological Centre, AL-Tirana, Albania, Tel: (355-42) 28274, Fax: (355-42) 34304

Krawinkler, Helmut, Stanford University, Department of Civil Engineering, Stanford University M/C 4020, Stanford, CA 94305-4020, USA, Tel: (1-415) 725-0360, Fax:
(1-415) 725-8662

Kreger, Michael E., University of Texas at Austin, 10100 Burnet Road, Asutin, TX 78758-4497, USA

Kubo, Tetsuo, Dept. Architecture, Nagoya Inst. of Technology, Gokiso-machi, Showa-ku Nagoya 466, Japan

Kudo Kazuyoshi, Professor of Structural Engineering, Department of Architecture, School of Engineering, Nogoya Institute of Technology Gakiso-Machi, Showa-Ku Nagoya 466, Japan, Tel: (81-3) 3812211 ext 5792, Fax: (81-3) 38146365

Kumar, Ashwina, University of Roorkee, Dept. of Earthquake Engineering, University of Roorkee, U.P. 247667, India, Tel: (91-133) 22349, Fax: (91-133) 23560

Kyriakides, Christos, Dept. Town Planning and Housing, CY-Nicosia, Nicosia, Cyprus, Tel: (357-2) 302 362

L

Laporte, Gaston, University of Costa Rica, Departamento de Svelos, Eswela de Ingenieria Civil, 2060 Universidad de Costa Rice, Costa Rica, Tel: (506) 24-24-08, Fax: (506) 53-73-31

Laramia, V.K., Department of Earthquake Engineering, University of Roorkee, Roorkee 247667, India, Tel: (91-133) 22349, Fax: (91-133) 23560

Lazaro III, Angel, Nat'l Soc For Seismolohy & Eq. Eng., LL Bldg. 160-A, Panay Ave Cor. E. Delos Santos Ave, Quezon City, Philippines, Tel: (63-2) 8158961, Fax: (63-2) 8152747

Lekides, V., Institute of Engineering Seismology, and Earthquake Engineering, Hapsa 1, 54626 Thessaloniki, Greece, Tel: (30-31) 545389, Fax: (30-31) 545392

Leeds, David J., Leeds and Associates, 11972 Chalon Rd., Los Angeles, CA 90049, USA, Tel: (1-310) 472-0282

Lind, Niels C., University of Waterloo, Department of Civil Engineering, Waterloo Ontario, N2L G1, Canada, Tel: (519) 885 1211, Fax: (519) 888 6197

Littleton, Clem, Emergency Management Australia, P.O. Box 1020, Dickson, Australian Capital Territory 2602, Australia, Tel: 61 6 266 5523, Fax: 61 6 257 1490

Loh, Chin-Hsiung, National Taiwan University, Department of Civil Engineering, Taipei, Taiwan, Tel: (886-2) 3634043, Fax: (886-2) 3625044

Longhi, Guiseppe, ENEL- Ente Nazionale per l Energia Elettrica, Direzione Delle Costruzioni, Viale Regina Margherita, 13700198 Roma, Italy, Tel: (39-6) 85098712, Fax: (39-6) 85092736

Lopez-Arroyo, Alfonso, Instituto C.C. Edwardo Torrja, Serrano Galuache s/u, 280033 Madrid, Spain, Tel: (341) 3020440 ext. 269, Fax: (341) 3020700

M

Mader, George, William Spangle and Assoc., 3240 Alpine Rd., Portola Valley, CA 94028, USA, Tel: (1-415) 854-6001, Fax: (1-415) 854-6070

Mahar, Jim, University of Illinois, 4 College Park CT., Savoy, IL 61874, USA

Makropoulos, Kostas, Dept of Geophysics, University of Athens, GR-15784, Athens, Greece, Tel: (30-1) 724 3217

Malavassi, Eduardo, Universidad Nacional, Apartado Postal 86, 3000 Heredia, Costa Rica, Tel: (506) 37-45-70, Fax: (506) 38-00-86

Mallard, David J., Nuclear Electric Plc, Barnett Way, Barnwood, Gloucester GL4 7RS, United Kingdom, Tel: (452) 652967, Fax: (452) 653853

Malone, A.W., Geotechnical Eng., Office of Civil Eng., 101 Princess Margaret Rd., Kowloon, Hong Kong, Tel: (852) 762-5087, Fax: (852) 714-0064

Mândrescu, Neculai, Centre of Earth Physics, P.O. MG-2, Bucharest-Magurele, Romania, Tel: (40) 897620

Mangion, John, Waterworkd dept., Beltissebh, M-Valletta, Malta, Tel: (356) 232 671

Manzone, Jean-Michel, Service De l'Environment, Ministere D' ETAT, Place De La Visitation, 9800, Monaco, Tel: (33) 93158512, Fax: (33) 93159293

Marsan, Paolo, National Seismic Survey, 8 Via Curtatone, 00185 Rome, Italy, Tel: 39 (6) 44 55 607, Fax: 39 (6) 44 66 745

Maranzana, Franco, SEISMED, Via Napoli 10/A, 16136 Genova, Italy, Tel: 39 10 214507, Fax: 39 10 297503

Marcellini, Alberto, Consiguo Nazionale Delle Ricerche, Istituto Di Ricerca Sul Riscllo Se Souco, Via Ampere 56, 20131 Milano, Italy, Tel: (39-2) 70600866, Fax: (39-2) 2663030

Margaris, Vassilis N., Institute of Engineering Seismology, and Earthquake Engineering, 1 Hapsa Str. (54626), Thessaloniki, Greece, Tel: (30-31) 545389; 53249, Fax: (33-31) 545392

Martin, Antonio Jesus Martin, Instituto Geografico, Nacional, Edificio Sevilla 2-Pl 8 Mod 9 Avda S. Francisco Javier 9, 41018 Sevilla, Spain, Tel: (34-5) 464 4256, Fax: (34-5) 46 1377

Martin, Christophe, B.R.G.M., Risques Naturels et Geoprospective, 117 Avenue de Luminy, F-13009 Marseille, France, Tel: (33-91) 41 24 46, Fax: (33-91) 41 15 10

Mayer-Rosa, Dieter, Institute of Geophysics, ETH-Honggerberg, CH-8093 Zurich, Switzerland, Tel: (41- 1) 3772605, Fax: (41-1) 3711864

McCrink, Tim, California Division of Mines, & Geology, 1416 Ninth St., Sacramento, CA 95814, USA

McCue, Kevin, Australian Geological Survey Organisation, Australian Seismological Center, GPO Box 378, Canberra ACT 2601, Australia, Tel: (079) 30 9777, Fax: (079) 36 1361

McGuire, Robin K., Risk Engineering, Inc, 5255 Pine Ridge Road, Goldon, CO 80403, USA, Tel: (1-303) 278-9800, Fax: (1-303) 278-9803

McNutt, Stephen, Geophysical Institute, University of Alaska, Fairbanks, AK 99775-0800, USA, Tel: (1-907) 474-7131, Fax: (1-907) 474-5618

McVerry, Graeme, Institute of Geological & Nuclear Science, P.O. Box 30-368, Lower Hutt, New Zealand, Tel: (64-4) 569-0273, Fax: (64-4) 569-0600

Mdaghri-Alaoui, M. Hassan, Ministere de l'habitat, 13 rue Harryad, MA-Rabat, Morocco, Tel: (212-7) 734 539

Meli, Roberto, Instituto de Ingenieria, UNAM, Ciudad Universitaria, Mexico 04510 DF, Mexico, Tel: (52-5) 548-9794, Fax: (52-5) 548-3044

Mendoza, Carlos Javier, Instituto de Ingenieria, UNAM, Ciudad Universitaria, Mexico 04510 DF, Mexico, Tel: (52-5) 548-9794, Fax:(52-5) 548-3044

Mendes, Victor Luis A., R. Escola Polite cnica 58, 1200 Lisboa, Portugal

Mengtan, Gao, State Seismological Bureau P.R. of China, Institute of Geophysics, SSB 5 Minzu Xue Yuan South Road, Beijing 100081, China, Tel: (86-1) 8417856, Fax: (86-1) 8415372

Michaelides, Alecos K., Civil Engineering, Ministry of Communications & Works, Nicosie, Cyprus, Tel: (357-2) 302 407

Michel, M. Claude, Les Granges, Chemin du Castellas, F-13540 Purycard, France, Tel: (33) 42 92 18 34

Midorikawa, Saburoh, Tokyo Inst. of Tech., 4259 Nagatsuta, Okohama Japan

Migani, Marcello, ISMES S.P.A., Viale Giulio Cesare 29, 24100 BerGamo, Italy, Tel: (39-3) 35 307239, Fax: (39-3) 39 35 211191

Mihailov, Vladmir, IZIIS, Institute of Earthquake Engineering and Engineering Seismology, P.O. Box 101, Salvador Aljende 73, 91000, Skipje, Macedonia, Tel: 38 91 227-122, Fax: 3891 222-224

Milutinovic, Zoran, IZIIS, Institute of Earthquake Engineering and Engineering Seismology, P.O. Box 101, Salvador Aljende 73, 91000, Skipje, Macedonia, Tel: 38 91 227-474, Fax: 3891 222-224

Miri-Behrouz, Gat, Housing Foundation of Iran, University of Tehran-Engineering College, P.O. Box 4563, Iran, Tel: (98-21) 4406339, Fax: (98-21) 4378732

Modaressi, Hormoz, B.R.G.M., 4S.GEG, Avenue de Concyr B.P. 6009, 45060 Orleans Cedex, France, Tel: (33-38) 64 30 73, Fax: (33-38) 64 36 43

Moehle, Jack P., EERC, University of CA at Berkeley, 1301 South 46th Street, Richmond, CA 94804, USA, Tel: (1-510) 231-9554, Fax: (1-510) 231-9471

Mohammadioun, Bagher, CEA, IPSN/DAS/BERSSIN, CEN- BPG, Foutenay-Aux-Roses 92265, France, Tel: (33-14) 65 47 411, Fax: (33-14) 65 48130

Monge, Joaquin, University of Chile, Dept. of Civil Engineering, Blanco Encalada N° 2120, 4° Piso Casilla 2281/3 Santiago, Chile, Tel: (56-2) 6982071, Fax: (56-2) 6712799

Mora, Sergio, Depto. Geologia, I.C.E., La Sabana, APO 100321000, San Jose, Costa Rica, Tel: (506) 20 71 41, Fax: (506) 31 47 44

Morales, Luis Diego, Comision Nacional, DE Emergencias, P.O. Box 5258-1000, San Jose, Costa Rica, Tel: (506) 20-20-20, Fax: (506) 20-20-54

Mori, Toshio, Sismological and Volcanological Dept., Japan Mateorological Agency, Management Division JMA, 1-3-4 Ohtemachi Chiyoda-Ku 100 Tokyo, Japan, Tel: (81-3) 32128341, Fax: (81-3) 32123648

Moulin, Jean M., 42 rue de la Belle Feuille, F-92100 Boulogne, France, Tel: (33-1) 46 04 10 35

Mouroux, Pierre, BRGM, 117 Avenue d Luminy, F-13009 Marseille, France, Tel: (33-91) 41 24 46, Fax: (33-91) 41 15 10

Moyano Acelledo, Pedro M., IDIEM University of Chile, Plaza ercilla 883 Casilla 1420, Santiago, Chile, Tel:(562) 6982071/142, Fax: (562) 267128979

Moyzakis, Harris, Risques Naturels et Geoprosctive, NTUA, Laboratory for Earthquake Eng., Polytechioupolis, GR-15700 Athens, Greece, Tel: (30-1) 778 5637, Fax: (30-1) 7706308

Murty, K.S., 3 Shivshankar Apts, 156 Shivajinagar, Nagpur 440010, India, Tel: (91) 532411

Muzio, Costante, UNDP, Svetozara Markovica 58, YU- 11000 Belgrade, Yugoslavia, Tel: (38-11) 683 666, Fax: (38-11) 658 395

N

Najar, Younes, Laboratoire des ponts et des chausses, Ministere de l'equipment et de l'habitat, Cite Jardin Belvedere, TN-Tunis, Tunisaia, Tel: (216-1) 682 003; 280 469,

Nateghi-Alahi, Fariborz., IIEES, P.O. Box 19395/3913, Tehran, Iran, Tel: (98-21) 275484, Fax: (98-21) 437-8732

Neri, Giancaizls, Cnr- Istituto Intern. Di Vullanologia, Piazza Roma 2, 35123 Catania, Italy, Tel: (39-9) 5448086, Fax: (39-9) 5435801

Nesin, Basoz, Middle East Tech.Univ., 6. Cadde 37 Sokak 41/4, Bahgeleyler, Turkey

Nicoletti, Mario, National Seismic Survey, 8 Via Curtatone, 00185 Rome, Italy, Tel: 39 (6) 44 55 607, Fax: 39 (6) 44 66 745

Nikolaos, Theodeilidis, Institute of Engineering Seismology, and Earthquake Engineering, Hapsa 1, 54626 Thessaloniki, Greece, Tel: (30-31) 545389, Fax: (30-31) 545392

Nisar, Ahmed, Dames & Moore, 2101 Webstar Street Suite 300, Oakland, CA 94612, USA

Nishenko, Stuart, U.S. Geological Survey, Denver Federal Center, Mail Stop 967, Denver, CO 80225, USA, Tel: (1-303) 236-1506

Norio, Abeki, Kanto Gakuin University, Dept. of Architecture College of Eng., Mutsuura-cho 4834 Kanazawa-ku, Yokohama-shi, 236, Japan, Tel: (81-5) 78-2001 ext 2621, Fax: (81-45) 784-8153

Novelo, David, Instituto de Geofisica, UNAM, Ciudad Universitaria, Mexico 04510 DF, Mexico, Tel: (52-5) 548-9938, Fax: (52-5) 548-9938

O

O'Rourke, Michael, Rensselaer Polytechnic Institute, Dept of Civil & Environ Eng., Troy, NY 12181-3590, USA, Tel: (1-518) 276-6933, Fax: (1-518) 276-4833

Obermeier, Stephen, U.S. Geological Survey, Mail Stop 922 National Center, Reston, VA 22092, USA, Tel: (1-703) 648-6791

Ohtani, Keiichi, National Research Inst., for Earth Science and Disaster Prev., Tennodai 3-1 Tsukuba-shi, Ibaraki, 305, Japan, Tel: (81-298) 511611, Fax: (81-298) 515658

Okumura, Koji, Geological Survey of Japan, 1-1-3 Higashi Tsukuba, Ibaraki 305, Japan, Tel: (81-2) 98543688, Fax: (81-2) 98543533

Olalla, Claudio, Geotechnical Laboratory, ,Alfonso XII No. 3, Marid 28014, Sapin, Tel: (34) 3357300, Fax: (34) 5277442

Olig, Susan, Utah Geological Survey, 2363 South Foothill Dr., Salt Lake City, UT 84109-191, USA, Tel:(1-801) 467-7970, Fax: (1-801) 467-4070

Oliveira, Carlos Sousa, National Laboratory for Civil Engineering, Avenida do Brasil 101, Lisbon 1799, Portugal, Tel: (351-1) 8482131, Fax: (351-1) 897660

Ordaz, Mario, Instituto de Ingenieria, UNAM, Ciudad Universitaria, Mexico 04510, DF, Mexico, Tel: (525) 622 3467, Fax: (525) 548 3044

Ortigosa, Pedro, IDIEM/ University of Chile, Casilla, 22813 Santiago, Chile, Tel: (56-2) 6982071, Fax: (56-2) 712799

Özkan, Yener, Middle Eart Technical University, Civil Engineering Department, Ankara, Turkey

P

Pak, Ronald Y. S., University of Colorado at Boulder, Eng. Center Ot 4-21, Campus Box 428, Boulder, Co 80303-0428, USA

Panah, Ali Komak, IIEES, P.O. Box 19395/3913, Tehran, Iran, Tel: (9821) 275484, Fax: (9821) 4378732

Panza, Giuliano, Istituto Di Geodenie Geofisica, Via Dell 'Universita 7, 34100 Trieste, Italy, Tel: (39-40) 301 1406, Fax: (39-40) 311793

Paolucci, Roberto, Technical University of Milan, Piaza L. da Vinci 32, 20133 Milano, Italy

Papastamatiou, Dimitri, National Technical University of Athens, 157 00 Polytechnic Campus, Athens, Greece, Tel: (30-1) 7785637, Fax: (30-1) 7706308

Pavicevic, Bozidar, University of Montenegro, Civil Engineering Faculty, 81000 Podgorica, Yugoslavia, Tel: 38 81 41 447, Fax: 38 81 13 891

Pecker, Alain, Geodynamique et Stucture, 157 Rue de Blains, 92 220 Bagneux, France, Tel: (33-1) 46 65 00 11, Fax: (33-1) 46 65 58 54

Pedersen, Ian, The Center for Earthquake Research in Australia, P.O. Box 276, Indooroopilly, Brisbane, Queensland, 4068, Australia, Tel: (61-49) 263822, Fax: (61-7) 3789111

Pender, M.J., Civil Eng. Dept., University of Auckland, Privat Bag, Auckland, New Zealand

Perkins, Jeanne, ABAG, P.O. Box 2050, Oakland, CA 94604-2050, USA, Tel: (1-510) 464-7934, Fax: (1-510) 464-7975

Perkins, David, U.S. Geological Survey, Mail Stop 966, Federal Center, Denver, CO 80225, USA, Tel: (1-303) 273-8554

Petrini, Vincenzo, GNDT-CNR, Via Nizza 128, Rome-00198, Italy, Tel: (39-6) 655 5616, Fax: (39-6) 8546129

Petrovski, Jakim, Civil Engineering Faculty, 81000 Podgorica, Yugoslavia, Tel: 38 11 625-022

Pitarka, Arben, Academy of Sciences, Seismological Centre, AL-Tirana, Albania, Tel: (355-42) 28274, Fax: (355-42) 23854

Pitilakis, Kyriazis D., Aristotle University of Thessaloniki, School of Eng. Dept. of Civil Eng.Geotechnical Eng. Division, P.O. Box 450, GR-54006 Thessaloniki, Greece, Tel: (30-31) 991531, Fax: (30-31) 206138

Pojani, Niko, Seismological Centre, AL-Tirana, Albania, Tel: (355-42) 28274

Poland, Chris D., H.J. Degenkolb Associates, 350 Sansome Street Suite 900, San Francisco, CA 94104, USA, Tel: (1-415) 392-6952, Fax: (1-415) 981-3157

Pomar, Salvador, Centro Nacional de Prevencion, de Desastres, Av. Delfin Madrigal 665 Co. 1, Santo Domingo, 04360 Mexico DF, Mexico, Tel: (525) 658-5127, Fax: (525) 554-8041

Pou, Antonio, Secretaria General de Medio Ambiente, Castellana 67, E-28071 Madrid, Spain, Tel: (34-1) 553 5600, Fax: (34-1) 533 7811

Power, Maurice, Geomatric Consultants Inc, 100 Pine Street, 10th Floor, San Francisco, CA 94111, USA, Tel: (1-415) 434-9400, Fax: (1-415) 434-1365

Psycharis, I.N., National Techional University, Lab for Earthquake Engineering, Polytechnic Campus, Zografos, 157 00, Greece, Tel: (30-1) 7709482, Fax: (30-1) 770608

Pujol, Rosendo, University of Costa Rica, Escuela de Ingenieria Civil, 0260 Universidad de Costa Rica, Costa Rica, Tel: (506) 24-2408, Fax: (506) 26-73-31

Punong Bayan, Raymundo, Philippine Institute of Volcanology & Seismology, 29 Quezon Ave., Quezon City, Philippines

Q

Qi-Meng, Feng, Institute of Engineering Mechanics, 9 of Xuefu Road, Harbin 150080, China, Tel: (86-451) 61104, Fax: (86-451) 64755

R

Rabinowitz, Nitzan, Institute for Petroleum Research & Geohphsics, No 1 Hamashsicv St. P.O.B. 2286, Holon, Israel, Tel: (972-3) 805112, Fax: (971-3) 802925

Radogna, Paolo, DAM S.P.A., Via Paolo Costa 7, I-48100 Ravenna, Italy, Tel: (39-544) 32 303

Rasöz, Nesrin, Middle East Tech. Univ, METU, 06531 Ankara, Turkey

Rattien, Stephen, National Research Conucil, 2101 Constitution Ave. N.W., Washington, D.C. 20418, USA, Tel: (1-202) 334-3600, Fax: (1-202) 334-3362

Real, Charles, California Division of Mines & Geology, 801 K. Street, MS 12-31, Sacramento, CA 95814-3508, USA, Tel: (1-916) 323-8550, Fax: (1-916) 324-1396

Reichle, Michael, California Division of Mines & Geology, 801 K. Street., Sacramento, CA 95814-3508, USA

Reitherman, Robert, The Reitherman Company, 939 Santiago Avenue, Half Moon Bay, CA 94019, USA

Ricciardi, Giovanni, Osservatorio Vesuviano, Via Manzoni Zu 9, 80123 Napolil, Italy, Tel: (39-8) 17695906, Fax: (39-8) 17694239

Riddell, Rafael, Universidad Catolica De Chile, Casilla 306-Correo 22, Santiago, Chile, Tel: (56-2) 552-4243 ext. 4243, Fax: (56-2) 552-5692

Rix, Glenn J., Georgia Inst. of Technology, School of Civil Engineering, Atlanta, GA 30332-0335, USA, Tel: (1-404) 894-2292, Fax: (1-404) 894-2278

Rodriguez, Fernando, Universidad Catolica De Chile, Casilla, 306-Correo 22, Santiago, Chile, Tel: (56-2) 5522375 ext. 4207, Fax: (56-2) 5525692

Roeder, Charles, University of Washingotn, Dept of Civil Eng., 233 B. More Hall FX-10, Seattle, WA 98195, USA, Tel: (1-206) 543-6199, Fax: (1-206) 543-1543

Rogers, Albert M., U.S. Geological Survey, Denver Federal Center, MS 966, Box 25046, Denver, CO 80225, USA, Tel: (1-303) 273-8553, Fax: (1-303) 278-8600

Rojahn, Christopher, Applied Technology Council, 555 Twin Dolphin Dr., Suite 270, Redwood City, CA 94065, USA, Tel: (1-415) 595-1542, Fax: (1-415) 593-2320

Rollins, Kyle, Brigham Young University, Civil Eng. Dept., 368 Clyde Building, Provo UT 84602, USA, Tel: (1-801) 378-6334, Fax: (1-801) 378-2478

Romeo, Roberto W., National Seismic Survey, 8 Via Curtatone, 00185 Rome, Italy, Tel: 39 (6) 44 55 607, Fax: 39 (6) 44 66 745

Romo, Miguel A, Instituto de Ingenieria, UNAM, Ciudad Universitaria, Mexico 04510, DF, Mexico, Tel: (525) 622 3467, Fax: (525) 548 3044

Rosenblueth, Emilio, Instituto de Ingenieria, UNAM De Mexico, Ciudad Universitaria, Mexico 04510 DF, Mexico, Tel: (52-5) 622-3422, Fax: (52-5) 548-5418

Rosenhaupt, Saky, Consulting Engineers, 25 Hatzmaut St., Haifa 33033, Israel, Tel: (972-4) 242 635,

Ross, Katharyn, NCEER, State University of New York, 104 Red Jacket Quadrangle, Box 610025, Amherst, NY 14261-0025, USA, Tel: (1-716) 645-3391, Fax: (1-716) 645-3399

Romo, Miguel A, Instituto de Ingenieria, UNAM, Ciudad Universitaria, Mexico 04510 DF, Mexico, Tel: (525) 622-3500, Fax: (525) 548-3044

Rouhban, Badaoui, UNESCO, Earth Science, 7 Place de Fontenoy, 75700 Paris, France, Tel: (33-14) 56 84 120, Fax: (33-14) 30 61 776

Rozen, Arnon, 17 Ramban St., IR-Kfar Jona 40300, Iran, Tel: (972-53) 686 152, Fax: (972-53) 686 747

Ruiz, Daniel, Departamento del Distrito Federal, 0 Plaza de la Constitucion Esquina, Pino Surez 2 Piso, Col. Centro 06068 DF, Mexico, Tel: (52-5) 512-8604, Fax: (52-5) 522-7380

Russi, Marino, Osservatorio Geofisico, GROTTA GIGANTE, I-3400 Trieste, Italy, Tel: (39-40) 21 401, Fax: (39-40) 32 7307

Rüttener, Erik, Swiss Seismological Service, ETH- Honggerberg, CH-8093 Zunich, Switzerland, Tel: (41-1) 3772463, Fax: (41-1) 3712556

Ryland, Harvey, Executive Director, CUSEC, 2630 East Holmes Road, Memphis, TN 38118-8001, USA, Tel: (1-901) 345-0932, Fax: 91-901) 345-0998

Rynn, Jack, The Center for Earthquake Research in Australia, P.O. Box 276 Indooroopilly, Brisbane, Queensland, 4068, Australia, Tel: (61-7) 374-2260; Fax: (61-7) 3789111

S

Safak, Erdal, U.S. Geological Survey, Mail Stop 922, National Center, Reston,VA 22092, USA, Tel: (1-703) 648-6534

Sandi, Horea, INCERC Dept of Structural & Earthquake Engineering, Sos. Pantelimon 266, R 79614 Bucharest, Romania, Tel: (40-1) 6274085 Fax: (40-1) 3128062

Santana, Guillermo, Universidad De Costa Rica, Laboratorio de Ingenieria Sismica, 2060 Universidad de Costa Rica, Costa Rica, Tel: (506) 53-7331, Fax: (506) 53-7331

Saragoni, Gustaro Rodolfo, University of Chile, Casilla 2283, Santiago, Chile, Tel: (56-2) 2224503, Fax: (56-2) 2223351

Sánchez-Sesma, S Francisco J., Instituto de Ingeniería, Ciudad Universitaria, Mexico 04510 DF, Mexico, Tel: (52-55) 50-215 ext 3627, Fax: (52-55) 48-3044

Sauter, Franz, Franz Stuter & Asociados, Apartado Postal 12731, 1000 San Jose, Caota Rica

Sbeinati, Mohamed, Atomic Energy Commission, PO Box 6091, SYR-Damascus, Syria, Tel: (963-11) 668 114

Schaeffer, Malcolm, Duke Power Company, P.O. Box 1006, Mail Code EC1OD, Charlotte, NC 28201-1006, USA, Tel: (1-704) 382-8647, Fax: (1-704) 382-9843

Scherbaum, Frank, Univ. Miuchen, Tust. F. Geophysik, Theresienstr. 41/IV, W 8000 Minchen 2, Germany, Tel: (49-8923) 942704

Schindler, C.M., Swiss Federal Inst. of Technology, Inst. of Engineering Geology, ETH-Hoggerberg, 8093 Zunch, Switzerland, Tel: (41-1) 3772751

Schuster, Rober, U.S. Geological Survey, Mail Stop 966, Federal Center, Denver, CO 80225, USA, Tel: (1-303) 236-1633

Schweig, Buddy, U.S. Geological Survey, CERI, Memphis State Unv., Memphis, TN 38152, USA, Tel: (1-901) 678-2007, Fax: (1-901) 323-2857

Sengezer, Betûl Syin, Yildiz Universitesi Sehir, ve bolge Planlama Bolumu, Istanbul, Tukey, Tel: (90) 1597070-389, Fax: (90) 3382423

Serva, Leonello, ENEA-DISP, Via Vitaliano Brancati 48, 00144 Roma, Italy, Tel: (39-6) 50072196, Fax: (39-6) 50072856; 2916

Sgarbi, Milen, Via Collina 33, I-38100 Trento, Italy, Tel: (39-46) 236-804

Shahrooz, Bahram M., University of Cincinnati, Civil & Environ Eng. Dept, 741 Baldwin (ML 71), Cincinnati, OH 45221-0071, USA, Tel: (1-513) 556-3677, Fax: (1-513) 556-2599

Shakal, Anthony, CDMG-, Strong Motion Studies, 801 K. Street, Mail Stop 13-35, Sacramento, CA 95814-3500, USA, Tel: (1-916) 323-7481, Fax: (1-916) 323-7778

Shapira, Avi, Inst. for Petroleum Research and Geophysics, P.O. Box 2286, Holon 58122, Israel, Tel: (972) 3 805112, Fax: (972) 3 802925

Shedlock, Kaye M., U.S. Geological Survey, Mail Stop 966, Federal Center, Denver, CO 80225, USA, Tel: (1-303) 273-8579

Sheja-Taheri, Jafar, Ferdowsi Unversity of Mashad, Iran School of Sciences, Mashad, Iran, Tel: (98-21) 275484, Fax: (98-21) 4378732

Shing, Benson, University of Colorado, Engineering Center OT 4-21, Campus Box 428, Boulder, CO 80309-0428, USA, Tel: (1-303) 492-8026, Fax: (1-303) 492-7317

Shiono, Keishi, Tokyo Metropolitan University, Department of Civil Engineering, 1 Minami-Ohsawa 1-Chome Hachioji, Tokyo 192-03, Japan, Tel: (81-426) 77-1111 ext. 4527, Fax: (81-426) 77-2772

Sholan, Jamal Mohamed, Seismological Observatory Center, P.O. Box 78175, Dhamar, Republic of Yemen, Tel: 967 659 0597, Fax: 967 650 2519

Shütz-Müller, Ingolf, UNDP/OPS, United Nations, New York NY 10017, USA, Tel: (1-212) 906-6500, Fax (1-212) 906-6501

Simone, Brouo De, Istituto Nazionale DI Geofisica, Via DI Villa Ricotti 42, 00161 ROMA, Italy, Tel: (39-6) 42101

Singh, J.P., Geospectra Inc., 3095 Richmond Pkwy Suite 213, Richmond, CA 94806, USA, Tel: (1-510) 222-5700, Fax: (1-510) 222-5988

Singh, M.P., Nartional Seince Foundation, BCS Room 1130, 1800 G. Street N.W., Washington, D.C. 12055, USA

Singh, Shri Krishna, Instituto de Geofisica, UNAM, Ciudad Universitaria, Mexico 04510, DF, Mexico, Tel: (525) 622-4127, Fax: (525) 550-2486

Sinha, Arun Kumar, Superintending Engineer, Income Tax Dept., 7/35 Tilak Nagar, Kanpur U.P. 440 001, India

Sinvhal, Amita, University of Roorkee, Department of Earthquake Engineering, University of Roorkee, Roorkee U.P. 247667, India, Tel: (91-1332) 2349 ext. 414, Fax: (91-1332) 3560

Slu, David, Klohn Leonoff Ltd., 10251 Shell Bridge Way, Richmond British Columbia, Canada, Tel: (60-4) 2730311, Fax: (60-4) 2794300

Smith, Warwick, DSIR Geology and Geophysics, P.O. Box 1320, Wellington, New Zealand, Tel: (64-4) 710-977

Smolka, Anselm, Munich Reinsurance Company, Koeniginstr 107, D-8000 Muenchen 40, Germany, Tel: (49-89) 38915294, Fax: (49-89) 399056

Sobaih, Mohamed, Faculty of Engineering, University of Cairo, ET-Cairo, Egypt

Soddu, Pierluigi, National Seismic Survey, 8 Via Curtatone, 00185 Rome, Italy, Tel: 39 (6) 44 55 607, Fax: 39 (6) 44 66 745

Souloumiac, Richard, Bureau Veritas, 147 B15, Place Des Reflets Cedex 44, 92077 Paris La Defense, France, Tel: (33-14) 29 15 291, Fax: (33-14) 29 41 52 90

Spasojevic, Miroslav, Mimistry of Foreign Affairs, 11000 Beograd, Yugoslavia, Tel: (38-11) 625 022

Sritharan, Sri S., Dept. of AMES, University of California, San Diego, La Jolla, CA 92093-0413, USA

Srivastava, Lakshmans S., University of Roorkee, Earthquake Engineering Department, 92 Vigyan Kunj, Roorkee U.P. 247667, India, Tel: (91-133) 22349, Fax: (91-133) 23560

Stuart, Harold, The Center for Earthquake, Research in Australia, P.O. Box 276 Indooroopilly, Brisbane, Queensland, 4068,Australia, Tel: (61-7) 378 9111, Fax: (61-7) 878 1252

Studer, Jost, Studer Engineering, Steinwresstr. 30, CH-8032 Zurich, Switzerland,

Suárez, Gerardo, Instituto de Geofisica, UNAM, Apartado Postal 21-499, Mexico 04000 D.F., Mexico, Tel: (525) 548-5892, Fax: (525) 550-2486

Suhadolc, Peter, Istituto Geodesia Geofisica, Via dell 'Universita 7, I-34100 Trieste, Italy, Tel: (39-40) 301 0134

Sulieman, Hasan, Technical Orgnization of Public Works, P.O. Box 82131, Tripoli, Libya, Tel: (218-21) 32807

Sulstarova, Edward, Seismological Center, Tirana, Albania, Tel: (355-42) 28274

Sursock, Iskandar, Centre for Geophysical Research LeBanon, c/o 25 Avenue Paul doumer, 75116 Paris, France, Tel: (33-1) 47048366, Fax: (33-1) 47049033

Suyagh, Faisal Tuma, Royal Scientific Society, Building Research Center, P.O. Box (925819), Amman, Jordan, Tel: (962) 6 844701, Fax: (962) 6 844806

Suzuki, Go, 125-10 Arako Okusa, Tahara Atsumi, Aichi 441-34, Japan, Tel: (81-2) 9847712, Fax: (81-2) 98477480

Suzuki, Takeyasu, Technical Research & Develop Institute, Kumagi Gumi Co, Ltd., 1043 Shimoyama Onigakubo, Tsukuba-City Ibaraki Pref. 300-22, Japan, Tel: (81-298) 47-7502, Fax: (81-298) 47-7480

T

Takeuchi, Yoshihiro, Osaka Institute of Technology, 5-16-1 Omiya 5 Asahiku, Osaka 535, Japan, Tel: (81-6) 952-3131, Fax: (81-6) 957-2132

Tao, Xiaxin, Institute of Engineering Mechanics S.S.B., 9 Xuefu Road, Harbin 150080, China, Tel: (86-451) 61125-309, Fax: (86-451) 64755

Teves-Costa, Maria Paula, Universidade de Lisboa, Centro De Geofisica, R: Da Escola Politecnica No. 58, 1200 Lisboa, Portugal, Tel: (351-1) 608028/9, Fax: (351-1) 3953327

Thenhaus, Paul, US Geological Survey, Mail Stop 966, Federal Center, Denver, CO 80225, USA, Tel: (1-303) 236-1610

Thibaul, Christian, Cete Mediterranée, 56 bd. Stalingrad, F-06000 Nice, France, Tel: (33) 93 89 51 84, Fax: (33) 93 56 55 31

Thiel, Charles C., 365 San Carlos, Piedmont, CA 94611, USA

Tiedemann, Herbert, Consultant, Swiss Reinsurance Group, Stefan Rotthalerstrasse 5, D-8052 Moosburg, Switzerland, Tel: (49-8761) 8771

Tingey, Jim, Utah Division of Comprehensive, Emergency Management, State Office Building, Room 1110, Salt Lake City, UT 84114, USA, Tel: (1-801) 538-3400

Tinsley, John, U.S. Geological Survey, Br. W. Regional Geology, 345 Middlefield Road, Menlo Park, CA 94025, USA, Tel: (1-415) 329-4928, Fax: (1-415) 329-4936

Toki, Kenzo, Kyoto University, Disaster Prevention Res. Inst., Gakasho, Uji 611 Kyoto, Japan

Tokida, Ken-ichi, Public Works Research Institute, 1 Asaahi Tsukuba-shi, Ibaraki-ken 305, Japan, Tel: (81) 0298-64-2211, Fax: (81) 0298-64-0598

Tomatsu, Yukio, Nishimatsu Construction Co. Ltd., 2570 Shimo-Tsuruma Yamato-City, Kanagawa-Pre. 242, Japan

Tomazevic, Miha, Institute for Testing and Research, in Materials and Structures, Dimiceva 12, 61109 Ljubljana, Slovenia, Tel: (38-61) 183-261, Fax: (38-41) 348 363

Trabelsi, Hamadi, Insitut national de la meteorologie, BP 156 TN-2035 Tunis-CarthageTunisia, Tel: (216-1) 782 400, Fax: (216-1) 784 608

Trumbull, Gunner, OYO Pacific, 123 Townsend St., Suite 655, San Fracisco, CA 94107, USA, Tel (2-415) 543-9030, Fax: (1-415) 543-9032

Tsotsos, S., Aristotle University, Dept. of Geotechnical Engineering, Thessalonki 54006, Greece, Tel: (30-31) 992630, Fax: (30-31) 206138

Tubbesing, Susan K., Earthquake Engineering Research Institute, 449 14th Street, Suite 320, Oakland, CA 94612-1902, USA, Tel: (1-510) 451-0905, Fax: (1-510) 451-5411

Tucker, Brian, OYO Pacific, 123 Townsend Street, Suite 655, San Francisco, CA 94107, USA, Tel: (1-415) 543-9030, Fax: (1-415) 543-9032

Tumarkin, Alexei, International Inst. of Earthquake Pred., Warshavskoye sh.79 kor. 2, Moscow 113556, Russia

Tung, Albert, San Jose State University, Civil Engr & Appl Mechanics, One Washington Square, San Jose, CA 95192-0083, USA

U

Uang, Chia-Ming, Northeastern University, 360 Huntington Ave., Boston, MA 02115, USA, Tel: (1-617) 437-4248, Fax: (1-617) 437-4419

Ücer, Balamir, Bosphoros University, Kandilli Observatory and Earthquake, Eng. Research Inst., Cergallroy, Istanbul 81220, Turkey, Tel: (90-1) 3320240

V

van Essche, Ludovic, UNDRO, Palais des Nations, CH-1211 Geveva 10, Switzerland, Tel: (41-22) 733 5623, Fax: (41-22)
733 2010

Varese, Giovanni, UNDRO, Palais des Nations, CH-1211 Geveva 10, Switzerland, Tel: (41-22) 733 5623, Fax: (41-22)
733 2010

Villaraza, Carlos M., Philippine Institute of Volcanology & Seismology, 29 Quezon Ave., Quezon City, Philippines, Tel: (63-2) 8158961 ext. 305, Fax: (63-2) 8152747

Villevieille, Adelin, Conseil general des ponts et chausees, Misnistere de l'equipement, 23-25 ave F. Roosvelt, F-75008 Paris, France, Tel: (33-1) 42 56 45 86

Vinale, Filippo, Universita' Di Napoli, Istituto DI Tecnica Delle Fondazioni, Via Claudio 21, 80125 Napoli, Italy, Tel: (39-81) 7683469; 7683478, Fax: (39-81) 7683481

Viora, Raoul, 1 ave des Castellans, 98000, Monaco, Tel: (33) 93 15 85 51, Fax: (33)
93 15 85 50

Vougioukas, E.A., National Technical University of Athens, Lab. For Earthquake Engineering, 157 00 Polytechnic Campus, Athens, Greece, Tel: (30-1) 7785637, Fax: (30-1) 7706308

W

Wafa, Mohamed, Survey Dept. of Libya, PO Box 600, LAR-Tripoli, Libya, Tel: (218-21) 830 850

Watts, Bryan, Klohn Leonoff Ltd., 10200 Shellbridge Way Richmond, British Columbia V6X 2W7, Canada, Tel: (1-604) 2730311, Fax: (1-604) 279-4300

Wen, Yi-Kwie, University of Illinois, 3129e NCEL 205 N. Mathews, MC250, Urbana,
IL 61801, USA, Tel: (1-217) 333-1328, Fax: (1-217) 333-9464

Williams, David J., Senior Lecturer in Geomechanics, Department of Civil Engineering, The University of Queensland, Brisbane, Queensland 4072, Australia, Tel: (61-7) 365 3642, Fax: (61-7) 378-9111

Wyllie, Loring A., H.J. Degenkolb Assoc., 350 Sansome St., Suite 900, San Francisco, CA 94549, USA, Tel: (415) 392-6952, Fax: (1-415) 981-3157

X

Xie, Junfei, Institute of Engneering Mechanics, 9 Xuefu Road, Harbin 150080, China, Tel: (86-451) 63901-260, Fax: (86-451) 64755

Xie, Li-li, Istitute of Engineering Mechanics, 9 Xuefu Road, Harbin 150080, China, Tel: (86-451) 61104, Fax: (86-451) 64755

Y

Yakut, Atimet, Middle East Tchnical University, Civil Engineering, TR-Ankara, Turkey, Tel: (90-4) 223 7100,

Yeh, Yeong-Tein, Institute of Earth Sciences, P.O. Box 23-59, Taipei, Replic of China, Tel: (886-2) 3630214 ext 349, Fax: (886-2) 3629563

Youd, T. Leslie, Brigham Young University, Department of Civil Engineering, 368 Clyde Building, Provo, Utah 84602, U.S.A., Tel: (1-801) 378-6327, Fax: (1-801) 378-2478

Yüzügüllü, Özal, Bosphoros University, Kandilli Observatory & Earthquake Research Institute, Gengelköy, Istanbul, Turkey, Tel: (90-1) 332027, Fax: (90-1) 3321711

Z

Zaoji, Shi, Institute of Engineering Mechanics, 9 Xuefu Road, Harbin 150080, China, Tel: (86-541) 61104, Fax: (86-541) 64755

Zargar, Akbar, Shahid Beheshti University, School of Architecture and Urban Planning, Tehran, Iran

Zhang, Guomim, Prediciton and Analysis Centes of S.S.B, 63 of Fuxing Road, Beijing 100036, China, Tel: (86-01) 8215522

Zhang, Kexu, Institute of Engineering Mechanicx, 9 Xuefu Road, Harbin 150080, China, Tel: (86-451) 62091-236, Fax: (86-451) 64755

Zimmerman, Tom, Illinois Emergency Mangement Agency, 110. E. Adams, Springfield, IL 62706, USA, Tel: (1-217) 782-4448, Fax: (1-217) 782-2589

Country Listing

Albania

Kondili, Jani
Pitarka, Arben
Pojani, Niko
Sulstarova, Eduard
Belazougui, Mohamed
Benblidia, Mohammed
Bezeggoud, Mourad
Chaker, Amar
El-Foul, Djamal
Farsi, Mohamed

Australia

Brennan, Ted
Hatchard, Trevor
Hughes, Peter
Littleton, Clem
McCue, Kevin
Pedersen, Ian
Rynn, Ja ck
Stuart, Harold
Williams, David J.

Bulgaria

Boncheva, Haritina

Canada

Lind, Niels C.
Slu, David
Watts, Bryan

Chile

Astroza, Maximiliano
Cruz, Ernesto
Hidalgo, Pedro
Kausel, Edgar
Monge, Joaquin
Moyano Acelledo, Pedro M.
Ortigosa, Pedro
Riddell, Rafael
Rodriguez, Fernando
Saragoni, Gustaro Rodolfo

China

Chen, Zhangli
Gong, Si Li
Mengtan, Gao
Qi-Meng, Feng
Tao, Xiaxin
Xie, Junfei
Xie, Li-li
Zaoji, Shi ina
Zhang, Guomim
Zhang, Kexu

Costa Rica

Gutierrez, Jorge
Laporte, Gaston
Malavassi, Eduardo
Mora, Sergio
Morales, Luis Diego
Pujol, Rosendo
Santana, Guillerm
Sauter, Franz

Croatia

Anicic, Drazen

Cyprus

Constantinou, George
Elefthriou, Serghis
Kyriakides, Christos
Michaelides, Alecos K.

Egypt

El-Samad, Megahed
Ibrahim, Ezzeldin Mohamed
Kebeasy, Rashad

England

Ambraseys, Nicholas N
Mallard, David J.

France

Bard, Pierre-Yves
Betbeder-Matibet, Jacques
Bourade, Michel Salah
Czitrom, Gabor
Davidovici, Victor
Cara, Michel
Godefory, Pierre
Hatzfeld, Denis
Martin, Christophe
Michel, M. Claude
Modaressi, Hormoz
Mohammadioun, Bagher
Moulin, Jean M.
Mouroux, Pierre
Pecker, Alain
Rouhban, Badaoui
Souloumiac, Richard
Sursock, Iskandar
Thibaul, Christian
Villevieille, Adelin

Germany

Boujer, K. P.
Eibl, Walter
Henger, M.
Keintzel, Einar
Scherbaum, Frank
Smolka, Anselm

Greece

Argyrakis, Kostas
Carydis, Panayotis. G.
Gazetas, George
Lekides, V.
Makropoulos, Kostas
Margaris, Vassilis N.
Moyzakis, Harris
Nikolaos, Theodeilidis
Papastamatiou, Dimitri
Pitilakis, Kyriazis D.
Psycharis, I.N.
Tsotsos, S.
Vougioukas, E.A.

Hong Kong

Hansen, Andrew
Malone, A.W.

India

Agrawal, R.C.
Agrawal, P.N.
Chandrasekaran, A.R.
Gupla, M.K.
Kaila, Krishan Lal
Kumar, Ashwina
Laramia, V.K.
Murty, K.S.
Sinha, Arun Kumar
Sinvhal, Amita
Srivastava, Lakshmans S.

Iran

Bahavar, M.
Bahrainy, Hossein
Behrouz, Gatmiri
Ghafory-Ashtiany, Mohsen
Jafari, M. Kazem
Komak-Panah, Ali
Miri-Behrouz, Gat
Nateghi-Alahi, Fariborz.
Panah, Ali Komak
Rozen, Arnon
Sheja-Taheri, Jafar
Zargar, Akbar

Israel

Kafri, Uri
Rabinowitz, Nitzan
Rosenhaupt, Saky
Shapira, Avi

Italy

Alzona, Sabina
Berardi, Raniero
Capocecera, Paloe
Carlo, Arrigo
Casciati, Fabio
Casirati, Mario
Cipollini, Attilio
Colozza, Riccardo
Crespellani, Teresa
De Marco, Roberto
Dolce, Mauro
Eva, Claueho
Fäh, Donat
Faravelli, Lucia
Marsan, Paolo
Ferrini, Maurizio
Glergetti, Emrilo
Gverra, Guerra
Imbesi, Giuseppe
Longhi, Guiseppe
Maranzana, Franco
Marcellini, Alberto
Migani, Marcello
Neri, Giancaizls
Nicoletti, Mario
Panza, Giuliano
Paolucci, Roberto
Petrini, Vincenzo
Radogna, Paolo
Ricciardi, Giovanni
Romeo, Roberto W
Russi, Marino
Serva, Leonello
Sgarbi, Milen
Simone, Brouo De
Soddu, Pierluigi
Suhadolc, Peter
Vinale, Filippo

Japan

Abe, Katsuyuki
Hakuno, Motohiko
Iida, Masahiro
Ishihara, Kenji
Iwasaki, Toshio
Kazuhiko, Kawashima
Kobayashi, Hiroyoshi
Kubo, Tetsuo
Kudo, Kazuyoshi
Midorikawa, Saburoh
Mori, Toshio
Norio, Abeki
Ohtani, Keiichi
Okumura, Koji
Shiono, Keishi
Shiono, Keishi
Suzuki, Go
Suzuki, Takeyasu
Takada, Shiro
Takeuchi, Yoshihiro
Toki, Kenzo
Tokida, Ken-ichi
Tomatsu, Yukio

Jordan

Akour, Hasan
Al-Aqaileh
Al-Sa'ad, Nedam
Barghouti, Amjad
El-Kaysi, Kays K.
Jalouqa, Kamal
Jaradat, Mohammad
Kaddoumi, Mohammad Fawaz
Suyage, Faisal Tuma

Libya

Hammuda, Omar
Hasin, Rammali
Sulieman, Hasan
Wafa, Mohamed

Macedonia

Mihailov, Vladimir
Milutinovic, Zoran

Malta

Bartolo, Mari
Mangion, John

Mexico

Almora, David
Buen, Oscar de
Calderón-Macras, Carlos
Esteva, Luis
Iglesias, Jesus
Jaime, Alberto
Meli, Roberto
Mendoza, Carlos Javier
Novelo, David
Ordaz, Mario
Pomar, Salvador
Romo, Miguel A
Rosenblueth, Emilio
Romo, Miguel A
Ruiz, Daniel
Sánchez-Sesma, S Francisco J.
Singh, Shri Krishna
Suárez, Gerardo

Monaco

Bethoux, Nicole
Manzone, Jean-Michel
Viora, Raoul
Klaveren, P. Van

Morocco

Ben Sari, Driss
Cherrabi, Abdelkader
Hamouda, M. Mohamed
Mdaghri-Alaoui, M. Hassan

Netherlands

Boer, Jan de

New Zealand

Hancox, Graham
King, Andrew
McVerry, Graeme
Pender, M.J.
Smith, Warwick
Sritharan, Sri S.

Peru

Giesecke, Alberto

Philippines

Garcia, Delfin C.
Lazaro III, Angel
Punong Bayan, Raymundo
Villaraza, Carlos M.

Portugal

Mendes, Victor Luis A.
Oliveira, Carlos Sousa
Teves-Costa, Maria Paula

Romania

Mândrescu, Neculai
Sandi, Horea

Russia

Frolova, Nina
Gorshko, Alexander
Tumarkin, Alexei

Slovenia

Tomazevic, Miha

Spain

Blazquez, Rafael
Carreno, Emilio
Cuellar, Vicente
de Justo, José Luis
Lopez-Arroyo, Alfonso
Martin, Antonio Jesus
Olalla, Claudio
Pou, Antonio

Switzerland

Ammann, Walter J.
Chatelain, Catherine
Griesser, Jean-Claude
Koller, Martin
Mayer-Rosa, Dieter
Rüttener, Erik
Schindler, C.M.
Studer, Jost
Tiedemann, Herbert
Van Essche, Ludovic
Varese, Giovanni

Syria

Abou-Roumieh, Hassan
Alghafari, Ahmad
Hammoud, Assad
Sbeinati, Mohamed

Taiwan

Loh, Chin-Hsiung
Yeh, Yeong-Tein

Tunisaia

Najar, Younes
Trabelsi, Hamadi
Hamida, Hassen Ben
Hfaiedh, M. Mohamed

Turkey

Ansal, Atila M.
Erdik, Mustafa
Ergünay, Oktay
Göcer, Orhan
Gülkan, Polat
Gündüz, A. Necmettin
Isikara, Ahmet Mete
Nesin, Basoz
Özkan, Yener
Rasöz, Nesrin
Sengezer, Betûl Syin
Ücer, Balamir
Yakut, Atimet
Yüzügüllü, Özal

United States

Abrams, Daniel
Adeli, Hojjat
Algermissen, Ted
Arabasz, Walter
Barrows, Allan
Bauer, Robert
Bernal, Dionisio
Bertero, Vitelmo
Bielak, Jacobo
Bolt, Bruce
Bonneville, David
Borja, Ronaldo I.
Brabb, Earl E.
Bufe, Charles
Celebi, Mehmet
Cheng, Franklin Y.
Chopra, Anil K
Cording, E.D.
Cramer, Chris H.
Crone, Anthony
Davis, James
Deodatis, George
Dong, Weimin
DuMontelle, Paul B.
Eggert, Donald
Englehardt, Michael D.
Fenves, Gregory
Frankel, Author
Goodno, Barry J.
Hanson, Robert
Hart, Earl
Hatheway, Allen W.
Hays, Walter W.
Healy, Jack
Hernried, Alan
Hester, Norman C.
Holzer, Thomas L
Hushmand, Behnam
Hwang, Howard
Idriss, I.M.
Iwan, Wifred
Jacob, Klaus
Jibson, Randall W.
Jones, Nicholas
Kasai, Kazuhiko
Keefer, David
Kelly, James
Kiremidjian, Anne
Kiureghian, Armen Der
Krawinkler, Helmut
Kreger, Michael E
Leeds, David J.
Mader, George
Mahar, Jim
McCrink, Tim
McGuire, Robin K.
McNutt, Stephen
Moehle, Jack P.
Nisar, Ahmed
Nishenko, Stuart
O'Rourke, Michael
Obermeier, Stephen
Olig, Susan
Pak, Ronald Y. S.
Perkins, Jeanne
Perkins, David
Poland, Chris D.
Power, Maurice
Rattien, Stephen
Real, Charles
Reichle, Michael
Reitherman, Robert
Rix, Glenn J.
Roeder, Charles
Rogers, Albert M.
Rojahn, Christopher
Rollins, Kyle
Ross, Katharyn
Ryland, Harvey
Safak, Erdal
Schaeffer, Malcolm
Schuster, Rober
Schweig, Buddy

Shahrooz, Bahram M.
Shakal, Anthony
Shedlock, Kaye M.
Shing, Benson
Shütz-Müller, Ingolf
Singh, J.P.
Singh, M.P.
Thenhaus, Paul
Thiel, Charles C.
Tingey, Jim
Tinsley, John
Trumbull, Gunner
Tubbesing, Susan K.
Tucker, Brian
Tung, Albert
Uang, Chia-Ming
Youd, T. Leslie
Wen, Yi-Kwie
Wyllie, Loring A.
Ziony, Joseph
Zimmerman, Tom

Venezuela

Grases, José

Yugoslavia

Muzio, Costante
Pavicevic, Bozidar
Petrovski, Jakim
Spasojevic, Miroslav

DIRECTORY OF INTERNATIONAL PROFESSIONALS INVOLVED IN THE PRACTICE OF SEISMIC ZONATION

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Mrs. Linda R. Huey
U.S. Geological Survey
Office of Earthquakes, Volcanoes, and Engineering
905 National Center
Reston, VA 22092
USA

✍ ✍

(Please Print or Type:)

Printed Name: ____________________ ____________________
Last Name **First Name**

Affiliation: ____

Address: ____

____

____

Country __________________________

Telephone: ____
Country Code, City Code, Telephone Number

Fax: ____
Country Code, City Code, Telephone Number

APPENDIX E

DIRECOTRY OF PROFESSIONALS INVOLVED IN THE NEW INITIATIVE IN SEISMIC ZONATION OF THE CENTRAL UNITED STATES EARTHQUAKE CONSORTIRUM (CUSEC) STATES

Bauer, Bob
Illinois State Geological Survey
615 E. Peabody Drive
Champaign, IL 61820-6964
(P) 217-244-2394
(F) 217-244-0029
E-mail: bauer@geoserv.isgs.uiuc.edu

Berg, Thomas
Ohio Division of Geological Survey
4383 Fountain Square Drive, Bldg B
Columbus, OH 43224-1362
(P) 614-265-6988
(F) 614-268-3669

Bograd, Michael B. E.
Mississippi Office of Geology
P.O. Box 20307
Jackson, MS 39289-1307
(P) 601-961-5528
(F) 601-961-5521

Burchett, Raymond R.
Nebraska Geological Survey
113 Nebraska Halll
Lincoln, NE 68588-0517
(P) 402-472-3471
(P) 402-472-7520
(F) 402-472-2410
E-mail: burchett@unlinfo.unl.edu

Bush, Bill
Assistant State Geologist
Arkansas Geological Commission
3815 West Roosevelt Road
Little Rock, AR 72204
(P) 501-324-9165
(F) 501-663-7360

DuMontelle, Paul B.
Illinois State Geological Survey
615 E. Peabody Drive
Champaign, IL 61820-6964
(P) 217-333-5114
(F) 217-244-2785
E-mail:dumontel@geoserv.isgs.uiuc.edu

Durham, Tom
CUSEC
2630 E. Holmes Road
Memphis, TN 38118-8001
(P) 901-345-0932
(F) 901-345-0998

Eggert, Don
Indiana Department of Natural Resources
Geological Survey Division
611 North Walnut Grove
Bloomington, IN 47405
(P) 812-855-1366
(F) 812-855-2862

Faust, Elaine
Tennessee Division of Geology
13th Floor, L & C Tower
401 Church St.
Nashville, TN 37243-0445
(P) 615-532-1500
(F) 615-532-0231

Haney, Donald C.
Kentucky Geological Survey
UK 228 Mining & Mineral Resources
Lexington, KY 40506-0107
(P) 606-257-5500
(F) 606 257-1147

Hansen, Mike
Ohio Division of Geological Survey
4383 Fountain Square Drive, Bldg B
Columbus, OH 43224-1362
(P) 614-265-6580
(F) 614-268-3669

Harris, Jamie
Kentucky Geological Survey
University of Kentucky
Lexington, KY 40506-0107
(P) 606-257-3016
(P) 606-257-4777
(F) 606-257-1147
E-mail: super109@ukcc.uky.edu

Hays, Walter W.
U.S. Geological Survey
905 National Center
Reston, VA 22092
(P) 703-648-6711
(F) 703-648-6717

Hempen, Gregory L.
USAED St. Louis
CELMS-ED-GG
1222 Spruce St.
St. Louis, MO 63103-2833
(P) 314-331-8441
(F) 314-331-8244

Hester, Norman C.
Indiana Department of Natural Resources
Geological Survey Division
611 North Walnut Grove
Bloomington, IN 47405
(P) 812-855-5067
(F) 812-855-2862

Hoffman, Dave
Missouri Dept. of Natural Resources
Division of Geology and Land Survey
P.O. Box 250
Rolla, MO 65401
(P) 314-368-2144
(F) 314-368-2111

Johnston, Arch C.
CERI-Memphis State
Memphis State University
Memphis, TN 38152
(P) 901-678-2007
(F) 901-323-2857

Kiefer, John D.
Kentucky Geological Survey
UK 228 Mining & Mineral Resources
Lexington, KY 40506-0107
(P) 606-257-5500
(F) 606 257-1147
E-mail: kiefer@kgs.mm.uky.edu

Knox, S. Cragin
Mississippi Office of Geology
P.O. Box 20307
Jackson, MS 39296-1307
(P) 601-961-5503
(F) 601-961-5521

Leighton, Morris W.
Illinois State Geological Survey
615 E. Peabody Drive
Champaign, IL 61820-6964
(P) 217-333-5111
(F) 217-244-7004

Luther, Edward T.
Tennessee Division of Geology
13th Floor, L & C Tower
401 Church St.
Nashville, TN 37243-0445
(P) 615-532-1500
(F) 615-532-0231

Marsalis, Bill
Louisiana Geological Survey
P.O. Box G
University Station
Baton Rouge, LA 70893
(P) 504-388-8385
(F) 504-388-5328

McFarland, John David
Arkansas Geological Commission
Vardelle Parham Geology Center
3815 West Roosevelt Road
Little Rock, AR 72204
(P) 501-324-9165
(F) 501-663-7360

Millin, Jeanne
Federal Emergency Management
Agency
Region V Office
175 W. Jackson
Chicago, IL 60604
(P) 312-408-5540
(F) 312-408-5551

Pavey, Rick
Ohio Division of Geological Survey
4383 Fountain Square Drive, Bldg B
Columbus, OH 43224-1362
(P) 614-265-6599
(F) 614-268-3669

Satterfield, Ira R.
Missouri Geologic Survey
P.O. Box 250
Rolla, MO 65401
(P) 314-368-2160
(F) 314-368-2111

Schweig, Buddy
U.S. Geological Survey
c/o Center for Earthquake Research
and Information
Memphis State University
Memphis, TN 38152
(P) 901-678-4974
(F) 901-323-2857

Street, Ronald L.
University of Kentucky
Lexington, KY 40506
(P) 606-257-4777
(F) 606-257-1147

Wigley, Perry B.
Nebraska Geological Survey
University of Nebraska
113 Nebraska Hall
901 N. 17th St.
Lincoln, NE 68588-0517
(P) 402-472-3471
(F) 402-472-2410
E-mail: pwigley@unlinfo.unl.edu

Williams, James H.
Missouri Dept. of Natural Resources
Division of Geology and Land Survey
P.O. Box 250
Rolla, MO 65401
(P) 314-368-2101
(F) 314-368-2111

DIRECTORY OF PROFESSIONALS INVOLVED IN THE NEW INITIATIVE IN THE EASTERN MEDITERRANEAN REGION (EMR): REDUCTION OF EARTHQUAKE LOSSES IN THE EMR (RELEMR)

DR. FATHY ABDEL-HAY
ATOMIC ENERGY AUTHORITY
101 KASR EL-EINY
CAIRO
EGYPT
PHONE: 202-262-0256
FAX: 202-262-0238
TELEX:
E-MAIL:

DR. AMIRA M. ABDEL-RAHMAN
ASSOCIATE PROFESSOR IN SOIL MECHANICS AND FOUNDATION ENGINEERING
GENERAL ORGANIZATION FOR HOUSING, BUILDING & PLANNING RESEARCH
19, GABALAYA STREET, LIBON BUILDING, FLAT 42
ZAMALEK - CAIRO
EGYPT
PHONE: 202-716722 (OFFICE), 202-3418285 (HOME)
FAX:
TELEX:
E-MAIL:

DR. MOHAMMAD S. AL-HADDAD
ENGINEER
CIVIL ENGINEERING DEPARTMENT
KING SAUD UNIVERSITY
P. O. BOX #800
RIYADH 11421
SAUDI ARABIA
PHONE: 9661-467-7008
FAX: 9661-467-4254
TELEX:
E-MAIL:

DR. MOHAMMAD G. AL-IBIARY
TANTA UNIVERSITY, FACULTY OF SCIENCE
P. O. BOX 9557 CHILDREN VILLAGE
NASR CITY, CAIRO 11878
EGYPT
PHONE: 202-273-5128
FAX: 202-273-5128
TELEX:
E-MAIL:

DR. ABDULLAH M. ALAMRI
PROFESSOR
DEPARTMENT OF GEOLOGY - KING SAUD UNIVERSITY
P.O. BOX 2455
RIYADH, 11451
SAUDI ARABIA
PHONE: 9661-467-6198/467-6212
FAX: 9661-488-3751
TELEX:
E-MAIL:

PROFESSOR DR. RAMSES NASHED HANNA ALBERT
HEAD, GENERAL SEISMOLOGY DEPARTMENT
NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
C/O: FARES MAALAWY, 29 NASR KHALIFA STREET
ROD-EL FARAG, CAIRO
EGYPT
PHONE: 202-782683
FAX: 202-782683
TELEX:
E-MAIL:

DR. SAHIL ALSINAWI
PROFESSOR OF SEISMOLOGY
UNIVERSITY OF SANA'A, GEOLOGY DEPARTMENT
MAEEN POST OFFICE BOX 13022
SANA'A
YEMEN
PHONE: 9671-20052
FAX: 9671-200-564
TELEX:
E-MAIL:

DR. AHMED ABUBAKR AMMAR
PROFESSOR OF APPLIED GEOPHYSICS
HEAD, EXPLORATION DIVISION
NUCLEAR MATERIALS AUTHORITY
P.O. BOX 530
MAADI, CAIRO
EGYPT
PHONE: 202-353-2426 (OFFICE), 202-283-7209 (HOME)
FAX: 202-352-6212
TELEX: 20313 EGNMC
E-MAIL:

MR. GAMAL ATWA
CHAIRMAN
SINAI COAL COMPANY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-284-4706/284-4708
FAX: 202-284-4706
TELEX:
E-MAIL:

DR. MUAWIA BARAZANGI
SEISMOLOGIST
DEPARTMENT OF GEOLOGICAL SCIENCES AND
INSTITUTE FOR THE STUDY OF THE CONTINENTS
CORNELL UNIVERSITY, SNEE HALL
ITHACA, NY 14853
U.S.A.
PHONE: 1-607-255-6411
FAX: 1-607-254-4780
TELEX: WUI 6713054
E-MAIL:

MR. NABIL ZAKI BASTA
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-831242
FAX:
TELEX:
E-MAIL:

DR. ABDEL RAHIM BAYOUMI
PROFESSOR OF GEOPHYSICS
FACULTY OF SCIENCE, CAIRO UNIVERSITY
GIZA
EGYPT
PHONE: 202-346-3560
FAX: 202-62884 OR 202-5727556
TELEX:
E-MAIL:

DR. AMOS BEIN
DIRECTOR
GEOLOGICAL SURVEY OF ISRAEL
30, MALKHEI YISRAEL ST.
JERUSALEM 95501
ISRAEL
PHONE: 972-2-314-258
FAX: 972-2-380-688
TELEX:
E-MAIL:

DR. ZIAD R. BEYDOUN
PROFESSOR EMERITUS OF GEOLOGY
AMERICAN UNIVERSITY OF BEIRUT
P.O. BOX 11-0236/3208
BEIRUT
LEBANON
PHONE: 961-1-368-213 RES.
FAX: 1-212-478-1995/478-3830
TELEX: 20801 LE
E-MAIL:

DR. FIRYAL BOU-RABEE
PROFESSOR
GEOLOGY DEPARTMENT - KUWAIT UNIVERSITY
P.O. BOX 5969
SAFAT 13060
KUWAIT
PHONE: 965-532-5334
FAX: 965-531-9191
TELEX:
E-MAIL:

DR. ROBERT C. BUCKNAM
GEOLOGIST
U.S. GEOLOGICAL SURVEY
MS 966, BOX 25046
DENVER, CO 80225-0046
U.S.A.
PHONE: 1-303-273-8566
FAX: 1-303-273-8600
TELEX:
E-MAIL: BUCKNAM@GLDVXA.CR.USGS.GOV

DR. MEHMET CELEBI
RESEARCH CIVIL ENGINEER
U.S. GEOLOGICAL SURVEY
345 MIDDLEFIELD ROAD (MS 977)
MENLO PARK, CA 94025
U.S.A.
PHONE: 1-415-329-5623
FAX: 1-415-329-5163/329-5143
TELEX:
E-MAIL: MCELEBI@ISDMNL.USGS.GOV
CELEBI@ESG.WR.USGS.GOV

DR. G. CONSTANTINOU
DIRECTOR
GEOLOGICAL SURVEY DEPARTMENT
MINISTRY OF AGRICULTURE AND NATURAL RESOURCES
NICOSIA
CYPRUS
PHONE: 357-2-302-405
FAX: 357-2-367-911
TELEX:
E-MAIL:

DR. A. ATEF DARDIR
ADVISOR TO MINISTER OF PETROLEUM & MINERAL WEALTH
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-831671
FAX: 202-820128
TELEX:
E-MAIL:

DR. HANAFI DEEBIS
NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
HELWAN - CAIRO
EGYPT
PHONE: 202-782683
FAX: 202-782683
TELEX:
E-MAIL:

DR. F. WOLFGANG EDER
DIRECTOR, DIVISION OF EARTH SCIENCES
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
7, PLACE DE FONTENOY
75352 PARIS
FRANCE
PHONE: 331-4568-4115
FAX: 331-4567-5143
TELEX:
E-MAIL:

DR. FERIAL EL BEDEWI
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-835617
FAX: 202-820128
TELEX:
E-MAIL:

DR. NABIL EL HAZEK
CHAIRMAN
NUCLEAR MATERIALS AUTHORITY
P. O. BOX 530 EL MAADI
CAIRO
EGYPT
PHONE: 202-352-2168
FAX: 202-352-6212
TELEX:
E-MAIL:

MR. B. EL HAKIM
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-831242 (OFFICE), 202-355-3470 (HOME)
FAX: 202-820128
TELEX:
E-MAIL:

DR. ZUHAIR EL-ISA
PROFESSOR
FACULTY OF SCIENCE - GEOLOGY DEPARTMENT
UNIVERSITY OF JORDAN
AMMAN
JORDAN
PHONE: 9626-843-555 UNIV; 844-265 HOME
FAX: 9626-832-318
TELEX:
E-MAIL:

MR. SAID HASSAN EL KAWA
DEPARTMENT MANAGER
ZAAFARAN OIL COMPANY
38 STREET 270 EL MAADI
CAIRO
EGYPT
PHONE: 202-352-8999
FAX:
TELEX:
E-MAIL:

MR. KAYS EL-KAYSI
DIRECTOR, GEOPHYSICS AND TECH. SERV. DEPT.
NATURAL RESOURCES AUTHORITY
P. O. BOX 7
AMMAN
JORDAN
PHONE: 9626-811300
FAX: 9626-811866
TELEX: 21415 JO
E-MAIL:

MR. ALY A. EL SAYED
DIRECTOR OF SEISMIC DEPARTMENT
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-831242
FAX: 202-820128
TELEX:
E-MAIL:

DR. M. MAMOUN EL SAYED
PROFESSOR OF SEISMOLOGY
NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
HELWAN - CAIRO
EGYPT
PHONE: 202-788887
FAX: 202-782683
TELEX:
E-MAIL:

MR. ABDEL FATTAH EL-SHARIF
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-831242
FAX: 202-820128
TELEX:
E-MAIL:

DR. M. A. EL SHARKAWI
HEAD, GEOLOGY DEPARTMENT
UNIVERSITY OF CAIRO
GIZA
EGYPT
PHONE: 202-348-3966
FAX:
TELEX:
E-MAIL:

DR. ADNAN SHIHAB-ELDIN
DIRECTOR
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
CAIRO
EGYPT
PHONE: 202-354-5599/3036
FAX: 202-354-5296
TELEX:
E-MAIL:

DR. MUSTAFA ERDIK
PROFESSOR
BOGAZICI UNIVERSITY, KANDILLI OBSERVATORY & RESEARCH INSTITUTE
81220 CENGELKOY
ISTANBUL
TURKIYE
PHONE: 90-216-332-6560
FAX: 90-216-332-1711
TELEX:
E-MAIL: KANDIL@TRBOUN.BITNET

DR. OKTAY ERGUNAY
DIRECTOR GENERAL
GENERAL DIRECTORATE OF DISASTER AFFAIRS
MINISTRY OF PUBLIC WORKS AND SETTLEMENT
ANKARA 06520, P.K. 763
TURKIYE
PHONE: 90-312-287-8954/45
FAX: 90-312-287-8924
TELEX:
E-MAIL:

DR. M. M. FAHIM
PROFESSOR
NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
HELWAN - CAIRO
EGYPT
PHONE: 202-780046
FAX: 202-782683
TELEX:
E-MAIL:

DR. DOMENICO GIARDINI
GSHAP COORDINATOR
NATIONAL GEOPHYSICAL INSTITUTE
VIA DI VIGNA MURATA 605
00143 ROME
ITALY
PHONE: 396-51-860-487
FAX: 396-50-411-81
TELEX: 620246 INGROM
E-MAIL: GIARDINI@IN8800.CINECA.IT

DR. Y. ABDEL HADI
CHAIRMAN
UNIVERSITY OF CAIRO, DEPARTMENT OF GEOPHYSICS
GIZA
EGYPT
PHONE: 202-572-7435
FAX: 202-628884/572-7556
TELEX:
E-MAIL:

MR. MOHAMMED ABDEL HALIM
LECTURER ASSISTANT
NUCLEAR POWER AUTHORITY
101 KASR EL-EINI
CAIRO
EGYPT
PHONE: 202-262-0237
FAX: 202-262-0238
TELEX:
E-MAIL:

DR. ROBERT M. HAMILTON
SEISMOLOGIST
U.S. GEOLOGICAL SURVEY
922 NATIONAL CENTER
RESTON, VA 22092
U.S.A.
PHONE: 1-703-648-6550
FAX: 1-703-648-6908
TELEX:
E-MAIL:

MR. HANY HAMROUSH
SCIENTIFIC AFFAIRS SPECIALIST
U.S. EMBASSY
8 KAMAL EL-DIN SALAH STREET
GARDEN CITY - CAIRO
EGYPT
PHONE: 202-357-2556
FAX: 202-357-3200
TELEX:
E-MAIL:

DR. WALTER W. HAYS
SEISMOLOGIST
U.S. GEOLOGICAL SURVEY
905 NATIONAL CENTER
RESTON, VA 22092
U.S.A.
PHONE: 1-703-648-6711
FAX: 1-703-648-6717
TELEX:
E-MAIL:

DR. ALI HEBEISH
PRESIDENT
ACADEMY OF SCIENCES
CAIRO
EGYPT
PHONE:
FAX:
TELEX:
E-MAIL:

DR. HANY HELAL
PROJECT OFFICER
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
CAIRO
EGYPT
PHONE: 202-354-5599/3036
FAX: 202-354-5296
TELEX:
E-MAIL: BITNET:UHSHI@FRUNES21

DR. AHMED GOUDA HUSSAIN
NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
HELWAN - CAIRO
EGYPT
PHONE: 202-782683
FAX: 202-782683
TELEX:
E-MAIL:

DR. ABDEL AZIZ HUSSEIN
HEAD, GEOLOGICAL SURVEY SECTOR, EGSMA
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA-CAIRO
EGYPT
PHONE: 202-282-5482
FAX: 202-820128
TELEX:
E-MAIL:

DR. AMIN IBRAHIM HUSSEIN
NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
48 ABTAL EL-YAMEN STREET
EL-KHIMA - CAIRO
EGYPT
PHONE: 202-78887
FAX: 202-782683
TELEX:
E-MAIL:

DR. EZZ AL DIN IBRAHIM
HEAD, SEISMOLOGY DEPARTMENT
NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
HELWAN - CAIRO
EGYPT
PHONE: 202-780-645
FAX: 202-782-683
TELEX:
E-MAIL:

MR. RIAD IMAM
SENIOR ENGINEERING ADVISOR
USAID C/O U.S. EMBASSY
8 KAMAL EL-DIN SALAH STREET
GARDEN CITY - CAIRO
EGYPT
PHONE: 202-357-3369
FAX:
TELEX:
E-MAIL:

DR. AHMET M. ISIKARA
DIRECTOR
KANDILLI OBSERVATORY AND EARTHQUAKE RESEARCH INSTITUTE
81220 CENGELKOY
ISTANBUL
TURKIYE
PHONE: 90-216-308-0511/22 (OBSERVATORY) OR 90-216-332-9554 (DIRECT)
FAX: 90-216-332-1711
TELEX: 25411 BOUNTR
E-MAIL:

DR. MOHAMMAD JARADAT
SEISMOLOGIST
NATURAL RESOURCES AUTHORITY
P. O. BOX 7
AMMAN
JORDAN
PHONE: 9626-811300/9626-827970
FAX: 9626-811866
TELEX:
E-MAIL:

DR. IAAKOV KARCZ
GEOLOGIST
GEOLOGICAL SURVEY OF ISRAEL
30, MALKHEI YISRAEL ST.
JERUSALEM 95501
ISRAEL
PHONE: 972-2-314-273
FAX: 972-2-380-688
TELEX:
E-MAIL: KARCZ@VMS.GSI.GOV.IL

MR. M. L. ABDEL KHALEK
PROFESSOR OF STRUCTURAL GEOLOGY/DEPARTMENT OF GEOLOGY
UNIVERSITY OF CAIRO, FACULTY OF SCIENCE
20 EL ARNAB STREET
DOKKI, GIZA
EGYPT
PHONE: 202-360-6900
FAX:
TELEX:
E-MAIL:

MR. DARWISH KHALID
EXPLORATION GENERAL MANAGER
ZAAFARAN OIL COMPANY
38 STREET 270 EL MAADI
CAIRO
EGYPT
PHONE: 202-352-8999
FAX:
TELEX:
E-MAIL:

MR. MOHAMMAD ABDEL AZIZ MANSOUR
GENERAL PETROLEUM COMPANY
NASER CITY - CAIRO
EGYPT
PHONE: 202-610975
FAX:
TELEX:
E-MAIL:

MR. FRANCO MARANZANA
COORDINATOR
SEISMED
VIA NAPOLI 10/A
18-16134 GENOA
ITALY
PHONE: 391-021-4507
FAX: 391-029-7503
TELEX:
E-MAIL:

DR. CLAUDIO MARGOTTINI
THE HEAD, NATURAL EXTREME EVENTS DIVISION
ENERGY AND ENVIRONMENT AGENCY (ENEA)
ITALIAN AGENCY FOR NEW TECHNOLOGIES, ENERGY AND ENVIRONMENT
VIALE ANGUILLARESE 301
00060 S. MARIA DI GALERIA - ROME
ITALY
PHONE: 06-30481
FAX: 06-3048-4203
TELEX: 613296 ENEACAI
E-MAIL:

MR. J. P. MASSUE'
EXECUTIVE SECRETARY
OPEN PARTIAL AGREEMENT ON MAJOR NATURAL DISASTERS
COUNCIL OF EUROPE
F-67075 STRASBOURG CEDEX
FRANCE
PHONE: 33-88-412614
FAX: 33-88-412787
TELEX:
E-MAIL:

DR. DIETER MAYER-ROSA
SEISMOLOGIST
INSTITUTE OF GEOPHYSICS
ETH-HONGGERBERG
ZURICH CH-8093
SWITZERLAND
PHONE: 411-633-2602
FAX: 411-371-1864
TELEX: 823480 EHEB CH
E-MAIL: DIETER@SEISMO.IFG.ETHZ.CH

DR. WAFIK MESHREF
DEPUTY CHAIRMAN EGPC FOR PETROLEUM AGREEMENTS
EGYPTIAN GENERAL PETROLEUM CORPORATION
P. O. BOX 2130
MAADI, CAIRO
EGYPT
PHONE: 202-353-1451
FAX: 202-353-1451
TELEX: 92049 PETMISR
E-MAIL:

MR. JERRY MEYER
SCIENCE OFFICER
AMERICAN EMBASSY
8 KAMAL EL-DIN SALAH STREET
GARDEN CITY - CAIRO
EGYPT
PHONE: 202-357-3892
FAX: 202-357-2181
TELEX:
E-MAIL:

DR. MICHELE MIELE
SCIENTIFIC ATTACHE
ITALIAN EMBASSY
CORNICHE EL NIL 1079
GARDEN CITY - CAIRO
EGYPT
PHONE: 202-354-3194/5
FAX: 202-354-0657
TELEX:
E-MAIL:

PROF. DR. JOSEPH SIDKY MIKHAIL
DIRECTOR
NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
HELWAN - CAIRO
EGYPT
PHONE: 202-782-683
FAX: 202-782-683
TELEX: 93070
E-MAIL:

MR. CLAUS MILKEREIT
GEOPHYSICIST
GEOFORSCHUNGSZENTRUM POTSDAM
TELEGRAFENBERG A31
D 14473 POTSDAM
GERMANY
PHONE: 49-331-310-328
FAX: 49-331-310-253
TELEX:
E-MAIL: ONLINE@GFZ-POTSDAM.DE

DR. MAGDI A. ALHAY MOHAMED
GEOPHYSICIST
ZAAFARAN OIL COMPANY
37 ROAD 250 NEW MAADI
CAIRO
EGYPT
PHONE: 202-352-8999
FAX:
TELEX:
E-MAIL:

DR. SAHEIR TAWFIC MOHAMED
SEISMOLOGIST
NUCLEAR POWER AUTHORITY
101 EL ZOHAR
NASER CITY
EGYPT
PHONE: 202-262-0236
FAX: 202-262-0238
TELEX:
E-MAIL:

DR. TALAL A. MOKHTAR
PROFESSOR
FACULTY OF EARTH SCIENCES - KING ABDULAZIZ UNIVERSITY
P.O. BOX 1744
JEDDAH
SAUDI ARABIA
PHONE: 9662-695-2892
FAX: 9662-695-2892
TELEX:
E-MAIL:

MR. SEYFEDDIN MUAZ
DIRECTOR, BUILDING RESEARCH CENTER
ROYAL SCIENTIFIC SOCIETY
P. O. BOX 925819
AMMAN
JORDAN
PHONE: 9626-844701
FAX: 9626-844806
TELEX
E-MAIL:

DR. GABER NAIM
CHAIRMAN
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM RD.
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-831-671
FAX: 202-820-128
TELEX: 22695 GEOSU UN
E-MAIL:

DR. AMOS NUR
PROFESSOR
STANFORD UNIVERSITY
MITCHELL 317
STANFORD, CA 94305-2215
U.S.A.
PHONE: 1-415-723-9526 OR 0839
FAX: 1-415-723-1188
TELEX:
E-MAIL:

MR. MUSTAFA F. NUSEIBEH
HEAD, HYDROLOGY DIVISION
APPLIED RESEARCH INSTITUTE
CARITAS STREET
BETHLEHEM - WEST BANK
ISRAEL
PHONE: 972-2-958660 (OFFICE), 972-2-959730 (HOME)
FAX: 972-2-741889
TELEX:
E-MAIL:

MR. JEAN RASSAT
ADVISER, EEC DELEGATION, CAIRO
COMMISSION OF THE EUROPEAN COMMUNITIES
6 IBNZANKI STREET - ZAMALEH
CAIRO
EGYPT
PHONE: 202-341-9393
FAX:
TELEX:
E-MAIL:

DR. SAMIR RIAD
CHAIRMAN, GEOLOGY DEPARTMENT
ASSUIT UNIVERSITY, FACULTY OF SCIENCE
ASSUIT
EGYPT
PHONE: 202-348-5586
FAX: 202-349-6295/208-832-2564
TELEX:
E-MAIL:

DR. IBRAHIM AL RIFAIY
PROFESSOR OF GEOLOGY
KUWAIT UNIVERSITY
KUWAIT
PHONE: 965-4810481
FAX: 965-4816487
TELEX: 5969 SUFAT
E-MAIL:

DR. YAIR ROTSTEIN
MANAGING DIRECTOR
INSTITUTE FOR PETROLEUM RESEARCH AND GEOPHYSICS
P.O. BOX 2286
HOLON 58122
ISRAEL
PHONE: 972-3-805-112
FAX: 972-3-802-925
TELEX: 381611 SEISM IL
E-MAIL: YAIR@IPRG.ENERGY.GOV.IL

DR. BADAOUI M. ROUHBAN
PROGRAM SPECIALIST, DIVISION OF EARTH SCIENCES
UNITED NATIONS EDUCATIONAL, SCIENTIFIC, AND CULTURAL ORGANIZATION
7, PLACE DE FONTENOY
75352 PARIS
FRANCE
PHONE: 331-4568-4120
FAX: 331-4567-5143
TELEX:
E-MAIL:

DR. HAMED SAYED SABER
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-256-9173
FAX: 202-820128
TELEX:
E-MAIL:

DR. AHMED SAMIH SHABAAN
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-823243
FAX: 202-820128
TELEX:
E-MAIL:

MR. I. M. SHALABY
GEOLOGIST, HEAD OF MINING SECTOR
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-385-0933/829662
FAX: 202-829662/820128
TELEX:
E-MAIL:

ENG. JAMAL MOHAMED SHOLAN
GENERAL DIRECTOR, SEISMOLOGICAL OBSERVATORY CENTER
MINISTRY OF OIL AND MINERAL RESOURCES
P.O. BOX 78175
DHAMAR
REPUBLIC OF YEMEN
PHONE: 967-650-0597 (OFFICE), 967-656-5094 (RESIDENCE)
FAX: 967-650-2519
TELEX:
E-MAIL:

DR. AVI SHAPIRA
DIRECTOR
SEISMOLOGICAL DIVISION - INST. PETROLEUM RES. & GEOPHYSICS
P.O. BOX 2286
HOLON 58122
ISRAEL
PHONE: 972-3-805-112
FAX: 972-3-802-925
TELEX: 381611 SEISM IL
E-MAIL: AVI@IPRG.ENERGY.GOV.IL

DR. S. SHENOUDA
ASSOCIATE PROFESSOR
INSTITUTE OF NATIONAL PLANNING
P.O. BOX 2692 HORREYA
HELIOPOLIS - CAIRO
EGYPT
PHONE: 202-269-2843
FAX:
TELEX:
E-MAIL:

DR. FREDERICK O. SIMON
GEOCHEMIST
U.S. GEOLOGICAL SURVEY
917 NATIONAL CENTER
RESTON, VA 22092
U.S.A.
PHONE: 1-703-648-6055
FAX: 1-703-648-4227
TELEX: 248148 GEOINT
E-MAIL: FSIMON@USGS.GOV

DR. DAVID SIMPSON
PRESIDENT
INCORPORATED RESEARCH INSTITUTIONS FOR SEISMOLOGY (IRIS)
1616 N. FT. MYER DRIVE, SUITE 1050
ARLINGTON, VA 22209
U.S.A.
PHONE: 1-703-524-6222
FAX: 1-703-527-7256
TELEX:
E-MAIL: SIMPSON@IRIS.EDU

DR. M. SOBAIH
PROFESSOR
DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF CAIRO
GIZA
EGYPT
PHONE: 202-572-7991
FAX: 202-723-486
TELEX:
E-MAIL: FRCU::IN%EZZAT@CAIRO.EG

DR. ISKANDAR SURSOCK
DIRECTOR
CENTRE FOR GEOPHYSICAL RESEARCH
NATIONAL COUNCIL FOR SCIENTIFIC RESEARCH
P.O. BOX 16-5783
BEIRUT
LEBANON
PHONE: (331) 47-04-83-44
FAX: (9611) 39-76-97 OR (331) 47-04-90-33
TELEX:
E-MAIL: AS34@CALVACOM.FR

MR. AHMED SWEDAN
DIRECTOR GENERAL OF MINING PROJECTS
EGYPTIAN GEOLOGICAL SURVEY AND MINING AUTHORITY
3 SALAH SALEM STREET
ABBASSIYA - CAIRO
EGYPT
PHONE: 202-789026
FAX:
TELEX
E-MAIL:

DR. CHARLES A. TABET
SEISMOLOGIST
GEOLOGY DEPARTMENT - AMERICAN UNIVERSITY OF BEIRUT
P.O. BOX 11-0236/26
BEIRUT
LEBANON
PHONE: 350000 OR 340740, EXTENSION 4160 OR 4167
FAX: 1-212-478-1995/3830
TELEX:
E-MAIL:

DR. RAGAE EL TAHLAWI
PRESIDENT
ASSUIT UNIVERSITY
ASSUIT
EGYPT
PHONE: 202-348-5586
FAX: 202-349-6295/208-832-2564
TELEX:
E-MAIL:

DR. ALI TEALEB
HEAD OF DEPARTMENT OF GEOMAGNETISM, GEOCHEMISTRY,
AND GEOELECTRICITY
NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
HELWAN - CAIRO
EGYPT
PHONE: 202-780645
FAX: 202-782683
TELEX:
E-MAIL:

DR. HERBERT TIEDEMANN
ENGINEERING CONSULTANT
SWISS RE GROUP (RETIRED)
STEFAN-ROTTHALER-STR. 5
D-85368 MOOSBURG
GERMANY
PHONE: 08-761-8771
FAX: 0049-8761-63871
TELEX:
E-MAIL:

DR. SAMI HABIB YACOUB
PROGRAM SPECIALIST/ENGINEER
USAID CAIRO
106 KASR EL AIMI STREET
CAIRO
EGYPT
PHONE: 202-357-3616/3316
FAX:
TELEX:
E-MAIL:

MR. RUCHAN YILMAZ
GENERAL DIRECTORATE OF DISASTER AFFAIRS
MINISTRY OF PUBLIC WORKS AND SETTLEMENT
ANKARA 06520
TURKIYE
PHONE: 30-312-287-36-45/46
FAX: 30-312-287-89-24
TELEX:
E-MAIL:

PROFESSOR IZUMI YOKOYAMA
JICA EXPERT
c/o NATIONAL RESEARCH INSTITUTE FOR ASTRONOMY AND GEOPHYSICS
HELWAN - CAIRO
EGYPT
PHONE:
FAX:
TELEX:
E-MAIL:

United Nations Educational,
Scientific and Cultural Organization

United States Geological Survey

International Association for
Seismology and Physics of
the Earth's Interior

Secretariat for the International
Decade for National Disaster Reduction

Stanford University

Earthquake Engineering Research
Institute

California Department of Conservation
Division of Mines and Geology

Central United States Earthquake
Consortium State Geologists