ANNALI DI GEOFISICA, VOL. 42, N. 6, December 1999

The GSHAP Global Seismic Hazard Map

Domenico Giardini (1), **Gottfried Grünthal** (2), **Kaye M. Shedlock** (3) **and Peizhen Zhang** (4)

(1) *Institute of Geophysics, ETH Zurich, Switzerland*

(2) *GeoForschungsZentrum, Potsdam, Germany*

(3) *U.S. Geological Survey, Golden, CO, U.S.A.*

(4) *Institute of Geology, China Seismological Bureau, Beijing, China*

Abstract

The Global Seismic Hazard Assessment Program (GSHAP), a demonstration project of the UN/International Decade of Natural Disaster Reduction, was conducted in the 1992-1998 period with the goal of improving global standards in seismic hazard assessment. The GSHAP Global Seismic Hazard Map has been compiled by joining the regional maps produced for different GSHAP regions and test areas; it depicts the global seismic hazard as Peak Ground Acceleration (PGA) with a 10% chance of exceedance in 50 years, corresponding to a return period of 475 years.

Key words *earthquakes – global seismicity – seismic hazard assessment – seismic risk – UN/IDNDR*

1. Introduction

The Global Seismic Hazard Assessment Program (GSHAP) was launched in 1992 by the International Lithosphere Program (ILP) with the support of the International Council of Scientific Unions (ICSU), and endorsed as a demonstration program within the framework of the United Nations International Decade for Natural Disaster Reduction (UN/IDNDR).

Minimization of the loss of life, property damage, and social and economic disruption due to earthquakes depends on reliable estimates of seismic hazard. National, state, and local governments, decision makers, engineers, planners, emergency response organizations, builders, universities, and the general public require seismic hazard estimates for land use planning, improved building design and construction (including adoption of building construction codes), emergency response preparedness plans, economic forecasts, housing and employment decisions, and many more types of risk mitigation. The GSHAP was designed to provide a useful global seismic hazard framework and serve as a resource for any national or regional agency for further detailed studies applicable to their needs.

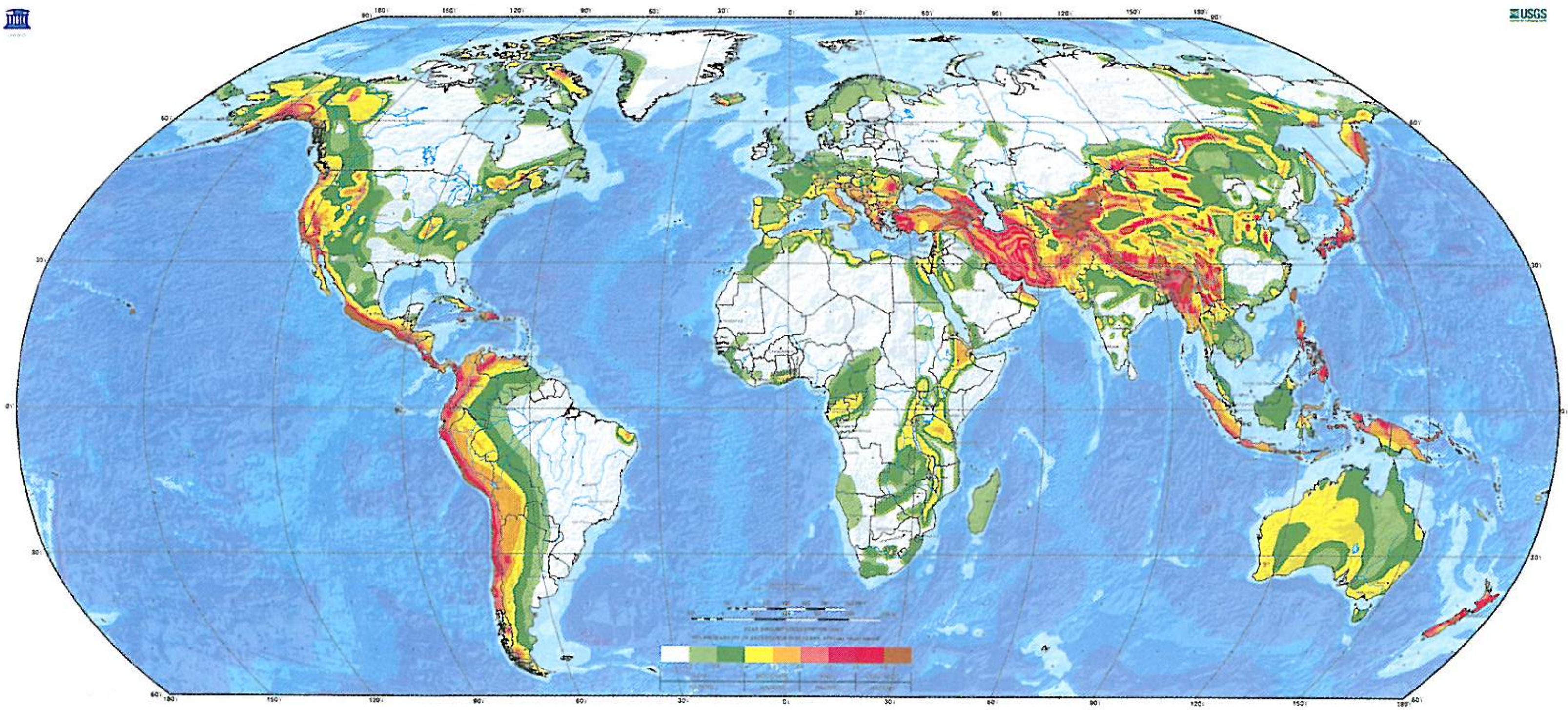
This report accompanies the publication of the GSHAP Global Seismic Hazard Map, compiled by joining the regional maps produced for different GSHAP regions and test areas. A summary of the hazard assessment procedures followed during GSHAP and the list of the main contributors is given.

Mailing address: Prof. Domenico Giardini, Chair of Seismology and Geodynamics, Institute of Geophysics, ETH Hoenggerberg, CH-8093, Zurich, Switzerland; e-mail: giardini@seismo.ifg.ethz.ch

GLOBAL SEISMIC HAZARD MAP

Produced by the Global Seismic Hazard Assessment Program (GSHAP),
a demonstration project of the UN/International Decade of Natural Disaster Reduction, conducted by the International Lithosphere Program.

Global map assembled by D. Giardini, G. Grünthal, K. Shedlock, and P. Zhang
1999



2. The assessment of seismic hazard

Seismic hazard is defined as the probable level of ground shaking associated with the recurrence of earthquakes. The assessment of seismic hazard is the first step in the evaluation of seismic risk, obtained by combining the seismic hazard with vulnerability factors (type, value and age of buildings and infrastructures, population density, land use, date and time of the day). Frequent, large earthquakes in remote areas result in high seismic hazard but pose no risk; on the contrary, moderate earthquakes in densely populated areas entail small hazard but high risk.

The basic elements of modern probabilistic seismic hazard assessment can be grouped into four main categories:

1) *Earthquake catalogues and databases* – The compilation of a uniform database and catalogue of seismicity for the historical (pre-1900), early-instrumental (1900-1964) and instrumental periods (1964-today).

2) *Earthquake source characterization* – The creation of a master seismic source model to describe the spatial-temporal distribution of earthquakes, using evidence from earthquake catalogues, seismotectonics, paleoseismology, geomorphology, mapping of active faults, geodetic estimates of crustal deformation, remote sensing and geodynamic models.

3) *Strong seismic ground motion* – The evaluation of ground shaking as function of earthquake size and distance, taking into account propagation effects in different tectonic and structural environments and using direct measures of the damage caused by the earthquake (the seismic intensity) and instrumental values of ground motions.

4) *Computation of seismic hazard* – The computation of the probability of occurrence of ground shaking in a given time period, to produce maps of seismic hazard and related uncertainties at appropriate scales.

Seismic hazard maps depict the levels of chosen ground motions that likely will, or will not, be exceeded in specified exposure times. Hazard assessment programs commonly specify a 10% chance of exceedance (90% chance of non-exceedance) of some ground motion parameter for an exposure time of 50 years, corresponding to a return period of 475 years. Peak ground acceleration, a short-period ground motion parameter that is proportional to force, is the most commonly mapped ground motion parameter because current building codes that include seismic provisions specify the horizontal force a building should be able to withstand during an earthquake. Short-period ground motions affect short-period structures, *e.g.*, one-to-two story buildings, the largest class of structures in the world.

3. Compilation of the global hazard map

In order to mitigate the risk associated with the recurrence of earthquakes, the GSHAP fostered a regionally coordinated, homogeneous approach to seismic hazard evaluation (Giardini and Basham, 1993; Basham and Giardini, 1993; Giardini, 1999). The GSHAP strategy was to establish a mosaic of regions lead by selected regional centers and of multinational test areas under the coordination of large working groups. Some areas, specifically the Mediterranean and the Middle East, were included in several overlapping projects. In addition, the GSHAP allied with existing hazard projects to avoid duplications and strengthen cooperation across borders (*i.e.* in the Balkans and Near East). Working groups of national experts representing the different disciplines required for seismic hazard assessment were assembled for each region or test area. These working groups produced common regional earthquake catalogues and source characterizations, and compiled or computed regional hazard values. In some cases (parts of Africa, the Western Pacific, and North America) the GSHAP hazard map was derived from published materials.

The compilation of the GSHAP Global Seismic Hazard Map, planned to be one of the main products of the program, was based on the integration of all results from GSHAP regions and test areas in three greater GSHAP areas: 1) the Americas (Shedlock and Tanner, 1999); 2) Asia, Australia and Oceania (Zhang *et al.*, 1999;

McCue, 1999), and 3) Europe, Africa and the Middle East (Grünthal *et al.*, 1999). The compilation was conducted at USGS, Golden CO. The global map follows closely the maps produced by the GSHAP regions and test areas, and in particular the regional compilations. Some adjustments were required in order to render the map more homogeneous and significant differences with the regional maps can be seen in the Philippines, the Himalayan provinces of India and Iran.

The global compilation entailed only the integration of existing hazard maps. No attempt was made to compile global data-sets such as earthquake catalogues and seismic source models.

Finally, an editorial committee supervised the integration of the results of all the regional projects into the global seismic hazard map.

4. The GSHAP Global Seismic Hazard Map

The GSHAP Global Seismic Hazard Map depicts Peak Ground Acceleration (PGA) with a 10% chance of exceedance in 50 years, corresponding to a return period of 475 years. The site classification is rock everywhere except Canada and the United States, which assume rock/firm soil reference ground conditions. This GSHAP map depicts the likely level of short-period ground motion from earthquakes in a fifty-year window. The map colors chosen to delineate the hazard roughly correspond to the actual level of the hazard. The cooler colors represent lower hazard while the warmer colors represent higher hazard. Specifically, white and green correspond to low hazard (0-8% *g*, where *g* equals the acceleration of gravity); yellow and orange correspond to moderate hazard (8-24% *g*); pink and red correspond to high hazard (24-40% *g*); and dark red and brown correspond to very high hazard (40% *g*). In general, the largest seismic hazard values in the world occur in areas that have been, or are likely to be, the sites of the largest plate boundary earthquakes.

The PGA values were combined with a shaded relief base map using ARC/Info 7.2.1 Geographic Information System (GIS) software. The cell size of the PGA and relief base grids is 0.0833 degrees.

Acknowledgements

National agencies, international scientific associations, seismological observatories and research institutions and individual scientists supported or participated in the GSHAP. In total, over 500 scientists contributed to this global undertaking. The insignia of primary contributors appear on the map. The list of primary contributors is given in Appendix.

Some proprietary software for hazard computation (FRISK88M) was supplied freely to GSHAP by R. McGuire.

REFERENCES

BASHAM, P. and D. GIARDINI (1993): Technical guidelines for global seismic hazard assessment, *Ann. Geofis.*, **36** (3-4), 15-24.

GIARDINI, D. (1999): The Global Seismic Hazard Assessment Program: 1992-1999, *Ann. Geofis.*, **42** (6) 957-974 (this volume).

GIARDINI, D. and P. BASHAM (1993): The Global Seismic Hazard Assessment Program (GSHAP), *Ann. Geofis.*, **36** (3-4), 3-13.

GRÜNTHAL, G., C. BOSSE, S. SELLAMI, D. MAYER-ROSA and D. GIARDINI (1999): Compilation of the GSHAP regional seismic hazard for Europe, Africa and the Middle East, *Ann. Geofis.*, **42** (6), 1215-1223 (this volume).

MCCUE, K. (1999): Seismic hazard mapping in Australia, the Southwest Pacific and Southern Asia, *Ann. Geofis.*, **42** (6), 1191-1198 (this volume).

SHEDLOCK, K. and J.G. TANNER (1999): Seismic hazard map of the western hemisphere, *Ann. Geofis.*, **42** (6), 1199-1214 (this volume).

ZHANG, P., Y. ZHI-XIAN, H.K. GUPTA, S.C. BHATIA and K.M. SHEDLOCK (1999): Global Seismic Hazard Assessment Program (GSHAP) in continental Asia, *Ann. Geofis.*, **42** (6), 1167-1190 (this volume).

Appendix. Principal contributors to the GSHAP Global Seismic Hazard Map.

Compilers

D. Giardini (ETH Zurich, Switzerland), G. Grünthal (GFZ-Potsdam, Germany), K. Shedlock (USGS, Golden, CO, U.S.A.) and P. Zhang (CSB, Beijing, China)

Editorial Board

P. Basham (Canada), D. Giardini (Switzerland), G. Grünthal (Germany), H. Gupta (India), D. Mayer-Rosa (Switzerland), K. McCue (Australia), R. McGuire (U.S.A.), K. Shedlock (U.S.A.), P. Zhang (China)

Principal contributors for Central-North America

J. Adams (Canada), S. Alvarez (El Salvador), T. Barnhard (U.S.A.), P. Basham (Canada), E. Camacho (Panama), N. Cardoze (Panama), N. Dickman (U.S.A.), M. Feuillard (Guadeloupe), A. Frankel (U.S.A.), V. García-Acosta (Mexico), L. Gomez (Dominican Republic), S. Halchuk (Canada), S. Hanson (U.S.A.), M. Hopper (U.S.A.), F. Klein (U.S.A.), E. Leyendecker (U.S.A.), L. Lynch (Trinidad), L. Mansinha (Canada), G. Martinéz (México), C. McQueen (U.K.), W. Montero (Costa Rica), G. Morán (El Salvador), V. Moreno (Puerto Rico), C. Mueller (U.S.A.), M. Ordaz (Mexico), M. Ortega (Panama), U. Osuji (Trinidad), G. Peraldo (Costa Rica), D. Perkins (U.S.A.), G. Rogers (Canada), W. Rojas (Costa Rica), K. Shedlock (U.S.A.), J. Shepherd (Trinidad), G. Súarez (Mexico), J. Tanner (Canada), J. Toral (Panama), M. Villagrán (Guatemala), J. Viode (Martinique), D. Weichert (Canada), R. Wesson (U.S.A.), C. Zelaya-Goodman (Mexico), R. Zúñiga (Mexico)

Principal contributors for South America

J. Alva (Peru), M. Araujo (Argentina), M. Arellano (Ecuador), M. Assumpçao (Brasil), M. Bufaliza (Argentina), R. Cabré (Bolivia), J.C. Castano (Argentina), C. Dimaté (Colombia), L. Drake (Bolivia), J. Escalon (Colombia), A. Fuenzalida (Colombia), A. Giesecke (Peru), R. Goberna (Colombia), J. Grases (Venezuela), E. Kausel (Chile), J. Mendoza (Venezuela), L. Ocola (Peru), J. Ramirez (Colombia), H. Rendón (Venezuela), K. Rowley (Trinidad), A. Sarria (Colombia), K. Shedlock (U.S.A.), J. Shepherd (Trinidad), E. Silgado (Peru), A. Singer (Venezuela), J. Tanner (Canada), J. Velásquez (Paraguay), A. Veloso (Brasil), H. Yepes (Ecuador), C. Zelaya-Goodman (Mexico)

Principal contributors for Europe-Mediterranean

A-Q. Amrat (Jordan), C. Bosse (Germany), T. Camelbeeck (Belgium), I. Cecić (Slovenia), M. Chadi (Tunisia), T. de Crook (Holland), A. Drumya (Moldova), D. El Foul (Algeria), M. El Khoubbi (Syria), M. Erdik (Turkey), M. García-Fernández (Spain), J.-C. Gariel (France), D. Giardini (Switzerland), S. Gregersen (Denmark), G. Grünthal (Germany), B. Guterch (Poland), P. Halldorsson (Iceland), W. Hays (U.S.A.), M. Herak (Croatia), E. Ibrahim (Egypt), P. Labak (Slovakia), J. Lapajne (Slovenia), C. Lindholm (Norway), W. Lenhardt (Austria), M.-J. Jiménez (Spain), P. Maentyniemi (Finland), K. Makropoulos (Greece), J.-M. Martínez-Solares (Spain), D. Mayer-Rosa (Switzerland), B. Muço (Albania), R. Musson (U.K.), C. Papaioannou (Greece), G. Papakyriacou (Cyprus), L. Peruzza (Italy), S. Riad (Egypt), P. Scandone (Italy), V. Schenk (Czech Republic), Z. Schenkova (Czech Republic), S. Sellami (Switzerland), A. Shapira (Israel), D. Slejko (Italy), C. Sousa-Oliveira (Portugal), M. Stucchi (Italy), E. Sulstarova (Albania), B.-A. Tadili (Morocco), V. Ulomov (Russia), R. Verbeiren (Belgium), R. Wahlstroem (Sweden), B. Zabukovec (Slovenia), T. Ziros (Hungary)

Principal contributors for Asia

K. Abdullabekov (Uzbekistan), T. Annaka (Japan), T. Ashirov (Turkmenistan), Ayzberg (Byelorussia), S. Balassanian (Armenia), S. Bhatia (India), S.-N. Chang (Taiwan), T. Chelidze (Georgia), J. Choudhury

Appendix. (*continued*).

(Bangladesh), M. Erdik (Turkey), M. Gao (China), D. Garcia (Philippines), A. Gassanov (Azerbaijan), M. Ghafory-Ashtiany (Iran), D. Giardini (Switzerland), H. Gupta (India), N. Kondorskaya (Russia), T. Kronrod (Russia), A. Kurskeev (Kazakhstan), M. McGuire (U.S.A.), G. Molchan (Russia), S. Negmatullaev (Tadzhikistan), M. Pandey (Nepal), L. Peng Siong (Malaysia), B. Pustovitenko (Ukraine), E. Rogozhin (Russia), K. Shedlock (U.S.A.), M. Swe (Myanmar), B. Tavakoli (Iran), A. V. Timush (Kazakhstan), V. Trifonov (Russia), A. Turdukulov (Kyrgyzstan), V. Ulomov (Russia), N.D. Xuyen (Vietnam), Z. Yang (China), P. Zhang (China)

Principal contributors for Africa

K. Atakan (Norway), L. Chapola (Malawy), D. Hlatywayo (Zimbabwe), F. Kebede, (Ethiopia), D. Lombe (Zambia), V. Midzi (Zimbabwe), I. Nyambok (Kenya), S. Sellami (Switzerland), F. Tugume (Uganda), G. Turyomurugyendo (Uganda)

Principal contributors for SW Pacific - SE Asia

W. Boyce (Samoa), K. McCue (Australia), G. McVerry (New Zealand), R. Punong-Bayan (Philippines), H. Shah (Indonesia)

Cartography and GIS

A. Tarr (USGS, Golden, CO, U.S.A.), N. Trevor (USGS, Golden, CO, U.S.A.), U. Lemgo (GFZ-Potsdam, Germany)

Hazard computation software

R. McGuire (Risk Engineering Inc., Boulder, CO, U.S.A.)