WASATCH FRONT FORUM

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NO. 2

WINTER
1986

EARTHQUAKE HAZARDS PROGRAM

The Wasatch Front Forum is not to be quoted or cited as a publication because much of the material consists of reports of progress and research activities and may contain preliminary or incomplete data and tentative conclusions.

DEADLINES FOR FUTURE ISSUES

SPRING 1987 .... JUNE 30, 1987
SUMMER 1987............ AUGUST 30, 1987
FALL 1987 ....OCTOBER 30, 1987

Information, contributions, questions and suggestions concerning future issues may be sent to Janine Jarva at Utah Geological and Mineral Survey, 606 Blackhawk Way, Salt Lake City, Utah 84108, (801) 581-6831.

This issue:

- ★ WENDY R. HASSIBE, EDITOR
- ★ Bill Brown, USGS, Associate Editor
- ★ Paula Gori, USGS, Associate Editor
- ★ Don R. Mabey, UGMS, Associate Editor
- ★ Art Tarr, USGS, Associate Editor

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Wendy Hassibe has been appointed Chief of the U.S. Geological Survey Public Inquiries Office and is now headquartered in Reston, Virginia. This will be the last issue of the Wasatch Front Forum that she will edit. Wendy has been editor of the Wasatch Front Forum since its first issue three years ago. The Forum has made a major contribution to the success of the Wasatch Front Earthquake Hazard Reduction Program, and most of the credit for this contribution belongs to Wendy. Speaking for the Associate Editors and the Utah Geological and Mineral Survey we congratulate Wendy on a job well done and wish her success in her new position. We will miss her.

Janine Jarva will be the new editor of the Wasatch Front Forum. Janine is in the Hazards Information Section of the UGMS. She has worked with me on the Wasatch Front Earthquake Program for three years and did most of the work on the Utah Earthquake Bibliography. As Janine takes over, the Wasatch Front Earthquake Program is placing greater emphasis on implementation and the Forum will reflect this change in emphasis. In the next issue new Associate Editors will be identified. Although the Associate Editors and contributors will represent several organizations, the production of the Forum will now be entirely by the UGMS.

Don Mabey

INVITATION TO TESTIFY...

Don Mabey, Deputy Director of the Utah Geological and Mineral Survey was invited by the U.S. House of Representatives Committee on Science, Space and Technology to testify March 10, 1987 on the fiscal year 1988 budget for the Earthquake Hazards Reduction Program. He was specifically asked to comment on the implementation activities in Utah. Mabey described the Wasatch Front Earthquake program with particular emphasis on the implementation effort and in the conclusion to his prepared statement said, "I can assure the committee that the efforts of the U.S. Geological Survey Earthquake Hazard Reduction Program in the Wasatch Front area of Utah are accomplishing the defined objectives. It is an outstanding example of a Federal effort aiding a state to accomplish a program that the state had neither the funding or technical resources to do alone. Similar programs can be expected to work in other areas, and I recommend that they be supported. I also want to stress that the success of the Wasatch Front Program was achieved because there was a strong foundation of scientific

Continued on next page

research on earthquake hazards and earthquake monitoring built by years of work supported by the National Earthquake Hazards Reduction Program. Any substantial reductions in this research and monitoring effort will undermine this foundation and in the long run prove to be unwise."

The 1987 session of the Utah State Legislature authorized state funding for an Earthquake Hazards Information Officer in the Utah Geological and Mineral Survey. This action had been recommended in 1983 by the Governor's Conference on Geologic Hazards and had been a major goal in the Wasatch Front Earthquake Hazards Program. This commitment by the Utah State Legislature at a time of severe budget constraints is an important recognition by the state of Utah of the seriousness of the earthquake hazard in Utah.

LIVING WITH THE EARTHQUAKE RISK

Albert M. Rogers
U.S. Geological Survey
Denver, Colorado

(From EARTHQUAKES & VOLCANOES, Volume 18, Number 3, 1986,U.S. Geological Survey)

The principal hazards from earthquakes are surface faulting, ground failure, and ground shaking. In coastal areas, tsunamis, or seismic sea waves, also are a potential hazard. We will consider each of these hazards briefly to assess their possible effects on the structures of man.

Surface faulting accompanies many large earthquakes, particularly in the western United States, and occurs when rock on either side of a fault is displaced at the earth's surface. The slip may be vertical, horizontal, or a combination of both. In major earthquakes, the movement along a fault can be as much as 35 feet and the length of the surface rupture as great as 250 miles. Even small amounts of slip can disrupt buried power, water supply, and communication lines. Vertical slip greater than a few inches can completely disrupt roadways where the fault crosses them. And, of course, faults that pass under structures are likely to cause severe structural damage if slippage occurs.

Ground failure, which includes landsliding, liquefaction, and settlement, is induced by earthquake shaking in some geologic materials having unfavorable physical properties. Landslides, for instance, can be caused by ground shaking, which starts the movement of loose soil and rock down a slope. The slope need not be steep. For example, the Turnagain Heights landslide in the Anchorage, Alaska, earthquake of 1964 resulted in the movement of 135 acres of material in an area having a slope of less than one-half degree. This slide destroyed about 57 homes, some of them moving 450-500 feet laterally.

One of the most spectacular examples of liquefaction occurred in Niigata, Japan, in 1964. In the simplest terms, liquefaction occurs when ground shaking produces high water pressure under the earth's surface and causes sand layers to act as a liquid. A number of high-rise buildings in Niigata sank more than 3 feet and some were tilted 80 degrees; the tilt was great enough to allow some residents to escape by walking down the face of the building.

Settlement is simply compaction of loose soils. This phenomenon can be damaging to roadways, particularly near bridge abutments where the roadbed may settle while the bridge remains fixed. In coastal areas, settlement of several inches can effect the coastline.

Tsunamis are fast-moving water-waves generated by certain types of earthquakes. These waves can travel hundreds or even thousands of miles from their source and may surge to damaging heights in coastal areas. Hawaii and Alaska have been repeatedly struck by severe tsunamis. California has also experienced several minor tsunamis, all of which have been under about 3 feet and have not been damaging.

Although all of these earthquake-induced phenomena can play an important role in causing damage, it is possible to experience an earthquake in which the damage is caused solely by ground shaking. In fact, in most earthquakes, ground shaking is the greatest hazard, causing the largest percentage of damage. Ground shaking is caused by earthquakes that travel away from the earthquake source and may cause damage at distances of as much as 50-75 miles.

Estimation of probable ground shaking is a complicated but important technique that can serve as useful input to land-use planning, earthquake resistant building design, and the estimation of losses from future earthquakes. Three major elements affect the severity of the ground shaking that may occur at any given location: the size of the earthquake, the distance to the earthquake source, and the geologic conditions.

In a general way, the larger magnitude earthquakes produce stronger ground shaking that occurs over broader areas than for a smaller event. However, regional differences in the earth's crust may modify this. In the central and eastern U.S., earthquake shaking attenuates less rapidly than in the west. For instance, the New Madrid, Missouri, earthquakes of 1811 and 1912, and the Charleston, South Carolina, earthquake of 1886, were felt over much larger areas than the 1906 San Francisco earthquake, even though the magnitude of the latter event was greater.

Site conditions are a major element affecting the likely intensity of ground shaking. Thick soils overlying solid rock tend to increase the level of ground shaking and prolong the duration of shaking. The degree to which this effect takes place is dependent on certain physical properties of the soil, especially its velocity, density, and thickness relative to the underlying rock.

Evaluation and mapping of potential earthquake hazards in major metropolitan areas will ultimately provide a useful data base for city planners, engineers, architects, and disaster relief planners. Such studies are currently under way in San Francisco, Los Angeles, Salt Lake City, and in Boston. In the near future, similar efforts may begin in other earthquake-prone areas.

The study of earthquake damage enables one to estimate how buildings will respond during future earthquakes, suggesting possible design improvements or estimates of future earthquake losses. A great deal can be learned in this manner, but several points are important.

The damage at the Veteran's Administration Hospital in the San Fernando Valley during the 1971 earthquake was caused by severe ground shaking, the buildings being nearly immediately above the buried earthquake source. The buildings constructed before 1933 were not designed to resist earthquake forces and 4 out of 26 buildings suffered total collapse. Of the 21 buildings built subsequent to 1933, only 4 suffered heavy damage, and these buildings, in general, suffered less damage than pre-1933 buildings. In other words, buildings constructed to meet seismic building code requirements generally fare better in earthquakes than structures that do not meet the code.

However, the Olive View Hospital, a structure that was built to meet the building code requirements in effect during the mid-1960's, suffered massive damage in the 1971 earthquake. Larger and longer ground motions could have caused total collapse. As it was, three lives were lost and the building had to be razed. The performance of this structure illustrates several important points. First of all, the building codes are minimum standards. Building codes are intended to safeguard occupants of the structure, not to prevent substantial damage in larger earthquakes that may render a structure useless. Facilities as critical as hospitals deserve extra planning and engineering attention because they have high occupancy rates, the patients are frequently incapacitated and unable to take even simple precautions to protect themselves, and these facilities are urgently needed following the earthquake. Hospitals should be sited to avoid possible surface faulting or ground failure, and they should be designed to remain functional after the greatest earthquake intensity that might be expected during the planned life of the structures. In fact, damage to hospitals experienced in the 1971 earthquake prompted new regulations at the state and federal level to insure that hospitals remain functional after an earthquake. Similar arguments can be made for other critical facilities such as power plants and police stations.

Damage to unreinforced masonry is of particular concern because many older buildings in urban renewal projects are of this type. Unreinforced masonry structures have responded extremely poorly in earthquakes all over the world. In the San Fernando earthquake, for example, 75-80 percent of the unreinforced masonry buildings in the San Fernando Valley were damaged; and most of these subsequently were either demolished or underwent major structural alteration or repair. This type of building can be a life threat to occupants and the public, and also a financial risk to the owner. Some of these kinds of buildings can be strengthened to meet the earthquake code.

It is possible that local building codes and plans to rehabilitate structures can be devised so that structures that represent high risk to life are dealt with before low-risk structures, and owners are given reasonable periods of time to make corrections. With regard to new buildings, it is important that construction practices meet the engineer's design requirements for earthquake resistance and that engineers and architects collaborate to produce designs that not only meet the codes but combine all the elements of the building in a fashion to minimize damage. Buildings may be designed or rehabilitated to withstand ground motions that will probably not be exceeded in the lifetime of the structure. The difficulty, of course, is deciding what level of probability is acceptable.

It is in this context that a restricted definition of hazard and the concept of risk can be helpful. Earthquake hazard can be defined as the probability of occurrence of a specified level of ground shaking in a specific period of time.

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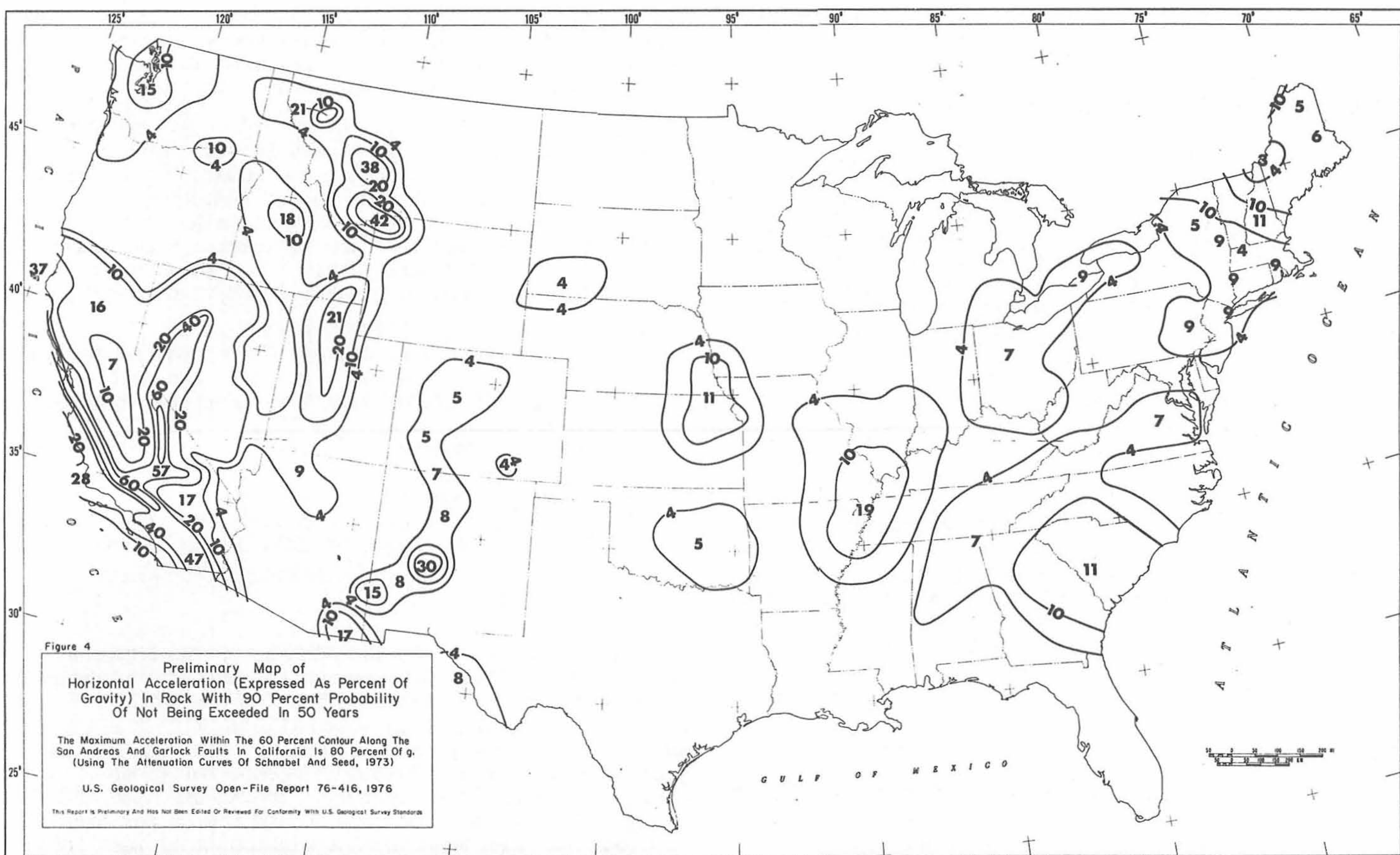


Figure 4

Preliminary Map of Horizontal Acceleration (Expressed As Percent Of Gravity) In Rock With 90 Percent Probability Of Not Being Exceeded In 50 Years

The Maximum Acceleration Within The 60 Percent Contour Along The San Andreas And Garlock Faults In California Is 80 Percent Of g. (Using The Attenuation Curves Of Schnabel And Seed, 1973)

U.S. Geological Survey Open-File Report 76-416, 1976

This Report Is Preliminary And Has Not Been Edited Or Reviewed For Conformity With U.S. Geological Survey Standards

Earthquake risk, on the other hand, is defined as the expected (or probable) life loss, injury, or building damage, given the probabilities that specified levels of ground shaking occur. The U.S. Geological Survey has recently prepared a preliminary earthquake-shaking hazard map of the United States. The map shows the peak horizontal accelerations on rock that have a 90 percent chance of not being exceeded in a 50 year period. Another way of stating this is that the map shows accelerations that have a 10 percent probability of being exceeded in any 50 years. The accelerations are contoured at levels ranging from 0.04-0.6 g. The lower value is the acceleration below which wind loading generally is expected to dominate the design of structures. Values as large as 0.8 are postulated within the 0.6 g contour close in to the Owens Valley and San Andreas faults in California.

This map is based on the historic seismic record and on reasonable suppositions about how ground motion attenuates with distances from the faults in different regions and what the largest possible earthquake is in each region. For instance, we know that very large earthquakes are possible in certain parts of the United States and that the rate of occurrence of earthquakes in many parts of the west is higher than in the midwest and east. We have already pointed out the difference in attentuation of ground shaking between the eastern and western U.S., and these factors have been incorporated in a quantitative way in the hazard map.

For ordinary structures, the hazard map probably represents the most useful estimate of the short-term shaking hazard that is available. This information, coupled with the probability of building damage due to ground shaking and the value of the building, enables us to calculate expected losses from earthquakes.

From Natural Hazards Observer ....

The sixth edition of the Pan American Health Organization's DISASTER PREPAREDNESS UPDATE was released in late 1986, and anyone concerned with relief services and medical problems after disasters ought to obtain a copy of this updated version. The UPDATE is a guide to about 500 of the documents collected regularly by PAHO's Emergency Preparedness and Disaster Relief Coordination Office. The cross-indexed entries reference both published and unpublished reports of potential interest to medical and health professionals active in disaster-stricken countries within PAHO's purview. The material - in English, French, and Spanish - deals particularly with public health aspects of disaster preparedness, prevention, and relief. Documents can be located by author, subject, or the country to which the description pertains.

COPIES OF DISASTER PREPAREDNESS UPDATE: A COMPUTERIZED INDEX OF EMERGENCY PREPAREDNESS AND DISASTER RELIEF BIBLIOGRAPHY MAY BE REQUESTED FROM THE EDITOR, DISASTER PREPAREDNESS IN THE AMERICAS, PAN AMERICAN HEALTH ORGANIZATION, 525 23RD STREET, N.W., WASHINGTON, DC 20037.

From FEMA - NETC ....

(National Emergency Training Center)

The FY 1987 Emergency Management Institute (EMI) catalog is now available. Courses offered are designed to meet the needs of people at various levels of state and local governments entrusted with the life, health and safety of citizens in times of emergency.

EMI makes this training available to private sector, volunteer, federal, state. and local officials on campus at Emmitsburg (Maryland), through state emergency services offices, and at various field locations.

This year's schedule includes 117 on-campus course offerings which address policy, planning, exercises, and technical issues for nearly every hazard of significant proportion in the United States. The 1987 catalog also details courses offered by state emergency management agencies under cooperative agreements funded by FEMA. These include such subjects as radiological safety, hazardous materials safety, shelter management, emergency planning, and the use of computers in emergency management.

Applications for EMI courses are available from local city/county emergency management offices and are contained in the catalog. Applications should be sent 90 days in advance of a course to ensure that space is available.

Course catalogs are available by writing: Registrar, National Emergency Training Center, 16825 South Seton Avenue, Emmitsburg, Maryland 21727.

DEFUSING NATURAL DISASTERS

"The American Planning Association has published a series of articles entitled "Symposium: Defusing Natural Disasters" in its Autumn 1986 Journal.

The series consists of an introduction and four articles: "Using Landslide Hazard Information in Planning," by Steven I. Gordon and Robert D. Klousner, Jr.; "Reassessing Earthquake Hazard Reduction Measures," by Peter J. May and Patricia R. Bolton; "Involving Homeowners in Flood Mitigation," by Shirley Bradway Laska; and "Metropolitan Flood Loss Reduction Through Regional Special Districts," by Rutherford H. Platt.

In his introduction, Gilbert White clearly defines the problem faced by community planners who must balance hazard mitigation with the other exigencies of their job; he asks, "Awaiting a disaster, can a community combine measures to alleviate the prospective distress with efforts to reach community goals for economic and environmental well-being?" His implication is that it can and should, and the articles that follow provide background information and new insights into the problems with which a community's planners must deal.

This issue of JAPA, THE JOURNAL OF THE AMERICAN PLANNING ASSOCIATION underscores the need for planners to evaluate strategies for mitigating the natural hazards threatening their communities. With the extensive bibliographies provided by each author, the journal should be a valuable reference for those officials. Individual copies of the Autumn 1986 JAPA (Volume 52, Number 4) cost $8.00 and may be purchased from the American Planning Association, 1313 East 60th Street, Chicago, Illinois 60637-2891.

PENROSE CONFERENCE

The Geological Society of America
Steamboat Springs, Colorado

July 12-17, 1987

This conference will investigate critical geological issues affecting or requiring public policy determination now or in the next several decades. Participants will reexamine political decisions of the past decade that have affected the geological community and the nation, and will discuss selected critical policy debates that are likely in the near future. The focus will be on the political decision-making process and on how earth scientists and related persons can increase geological input to public policy. Issues to be examined include disposal of high-level radioactive waste, both offshore and onshore petroleum and mineral exploration and development on restricted land, water transfers across legal boundaries, liability for catastrophic events in mapped geologic hazard areas, and other pertinent issues that have an impact on public health and well-being. Additional goals of the conference are to discuss how individuals and groups of scientists can best affect the political process, identify the geological issues and policy decisions that will most likely affect the general public into the 21st century, and provide a forum for in-depth discussion among geological and political scientists, environmental and resource management experts, and legislators. Leading spokespeople from legislative, geologic, political science, resource economics, and related disciplines will be invited as key speakers. The conference will be organized around several major themes: domestic geopolitical structure, the geologist's responsibilities to society, legal and political aspects of governmental decisions, and continuing eduction.

FOR ADDITIONAL INFORMATION, CONTACT DAVID A. STEPHENSON, ASSOCIATE, DAMES & MOORE, 7500 NORTH DREAMY DRAW DRIVE, SUITE 145, PHOENIX, ARIZONA 85020

Nature on the Rampage: OUR VIOLENT EARTH

National Geographic Society, 1986, 199 pp, $7.95. Order from the Special Publications Division, National Geographic Society, Department 1675, Washington DC 20036

> "Illustrated with numerous excellent photographs, this book is an overview of the many natural hazards that confront and challenge human society. The more photogenic hazards (i.e., tornadoes and volcanoes) receive considerable attention, but all natural hazards are considered. The physical causes of each hazard are briefly explained, as are the patterns of human settlement and activities that contribute to the hazardousness of a place. There is also a discussion of the methods society currently uses to cope with each hazard. The text is liberally spiced with anecdotal accounts from disaster survivors, relevant historical information, and discussions of the new technologies being developed to detect and warn society of potential disasters."

VOLUNTEER!!!

The U.S. Geological Survey has started a program for volunteers interested in science. Individuals over 16 or groups can work in the field, laboratory or office.

The Survey's motto - 'EARTH SCIENCE IN THE PUBLIC SERVICE' - describes the many kinds of activities available to volunteers: monitoring ground motion to study earthquakes, gathering of volcanic ash, sampling stream water affected by acid rain, measuring rainfall to study landslides, analyzing hydrologic data, giving tours and school talks, helping in libraries, archiving maps and rock cores, reviewing technical manuscripts, working with computers, even assisting with office work like accounting, data entry and retrieval, and project administration.

Volunteers can work for a few hours or extended periods, on one or many projects. Each volunteer signs an agreement describing the work. Anyone interested should contact Maxine Jefferson, Volunteer Program Coordinator, U.S. Geological Survey, Mail Stop 215, Reston, Virginia 22092, Phone 703-648-7439.

The volunteer program started last year as part of TAKE PRIDE IN AMERICA, an effort to involve the public more in taking care of public lands and resources.

WORLD DATA CENTER A FOR SEISMOLOGY

World Data Center A (WDC-A) announces the establishment of a new discipline center, WDC-A for Seismology, in the U.S.Geological Survey, Denver, Colorado.

WDC-A for Seismology will be operated by the National Earthquake Information Center, (NEIC), USGS Branch of Global Seismology and Geomagnetism, located in Golden, Colorado. It will be responsible for international data exchange involving analog and digital seismic observatory data, the historical seismogram microfilming project, and the near real-time determination of earthquake epicenters and source parameters.

NEIC has been providing international data services in these areas for a number of years. New initiatives in the exchange of digital seismic observatory data have clearly pointed to the advantages to be gained from operating within the World Data Center system.

World Data Center A for Solid Earth Geophysics (National Oceanic and Atmospheric Administration (NOAA), Boulder, Colorado) will continue essentially all its present functions, which include several aspects of seismology such as management of the retrospective earthquake epicenter and intensity data bases and related seismicity products, controlled source seismological data, strong motion data, its collections of seismic station bulletins and earthquake damage photographs, and a variety of tsunami programs.

As new WDC functions in seismology emerge, they will be assigned to the Solid Earth Geophysics or Seismology discipline centers by mutual agreement between USGS and NOAA.

Continued

World Data Center A for Seismology
Director: Dr.Robert P. Masse
USGS, MS-967, Box 25046
Denver Federal Center
Denver, Colorado 80225
303-236-1510

World Data Center A, Solid-Earth Geophysics
Director: Mr. Herbert Meyers
NOAA, E/GC1
325 Broadway
Boulder, Colorado 80303
303-497-6521

PROCEEDINGS OF THE 3RD NATIONAL CONFERENCE ON EARTHQUAKE ENGINEERING

held August 24-27, 1986 in Charleston, S.C.

....containing more than 200 state-of-the-art papers on these vital topics:

VOLUME I

- Seismic Hazard and Risk
- Ground Motion and Seismicity
- Geotechnical, Soil Stability, Soil-structure Interaction, and Foundations
- Special Structures, Critical facilities, and Dams

VOLUME II

- Response of Structures, Seismic Analysis and Spectra
- Tests on structures and components, experimental methods
- Nonstructural systems and building components

VOLUME III

- Seismic Structural Design - Seismic codes and standards
- Repair, strengthening, isolation and retrofit
- Lifelines - utilities, transportation systems, telecommunications, and other facilities
- Urban design, socioeconomic issues, public policy and preparedness

VOLUME IV

- Text of invited and Keynote Addresses
- List of participants

Being published as a four-volume set for $95.00. Volumes 1-3, containing 2300 pages of papers on all areas of earthquake engineering and hazard reduction are ready for mailing. Volume 4, will be completed in early 1987. Order from EARTHQUAKE ENGINEERING RESEARCH INSTITUTE (EERI), 6431 FAIRMOUNT AVENUE, SUITE 7, EL CERRITO, CALIFORNIA 94530 - 3624.

WILLIAM M. BROWN III, Office of Earthquakes, Volcanoes, and Engineering, U.S. Geological Survey, Menlo Park, California....."I am pleased (to announce) the availability of U.S. Geological Survey Open-File Report 86-401, the summary and edited proceedings of the WORKSHOP ON FUTURE DIRECTIONS IN EVALUATING EARTHQUAKE HAZARDS OF SOUTHERN CALIFORNIA held at the University of Southern California, Los Angeles, November 12-13,1986."
Some copies may still be available from William A. Brown III,U.S. Geological Survey, Office of Earthquakes, Volcanoes, and Engineering, Branch of Geologic Risk Assessment, Regional Landslide Research Group, 345 Middlefield Road, MS-998, Menlo Park, California 94025.

ARTICLES and REPORTS

R.D. BROWN, JR. AND W.J. KOCKELMAN
Editorial: Geologic principles for prudent land use; a decisionmaker's responsibility? Environmental Geology and Water Sciences, v. 8 no. 4, 1986, p. 173-174

T.L. HOLZER AND R.W. BRUHN
Land subsidence; its impacts and costs in the U.S. Underground Space, v.9, no.5-6, 1985, p.260-263

S.M. JACKSON AND JOHN BOATWRIGHT
Strong ground motion. Earthquake Spectra, in The Borah Peak earthquake of October 28, 1983. v.2, no.1, November 1985, p.51-59

D.K. KEEFER, R.C. WILSON, E.L. HARP AND E.W. LIPS
Landslides. Earthquake Spectra, in The Borah Peak Idaho earthquake of October 28, 1983, v. 2, no. 1, November 1985, p. 91-125

R.A. PAGE AND Z.R. LIU
Earthquake frequency and prediction. Bulletin of the Seismological Society of America. v. 76, no.5, October 1986. p. 1491-1499

ERDAL SAFAK
Sensitivity of structural response to ground motion source and site parameters, in Proceedings of the 2nd international conference on soil mechanics and earthquake engineering. Southampton:Comput. Mech. Cent., Berlin; Springer-Verlag, 1985, p.1.39-1.48

R.S. STEIN AND S.E. BARRIENTOS
Planar high-angle faulting in the Basin and Range: geodetic analysis of the 1983 Borah Peak, Idaho, earthquake. JGR. Journal of Geophysical Research. B.v.90, no.13,November 10, 1985, p. 11,355-11,366.

T.L. YOUD, E.L. HARP, D.K. KEEFER, R.C. WILSON
Liquefaction, Earthquake Spectra in the Borah Peak, Idaho earthquake of October 28, 1983. v.2, no.1, November 1985, p.71-89

UTAH EARTHQUAKE ACTIVITY

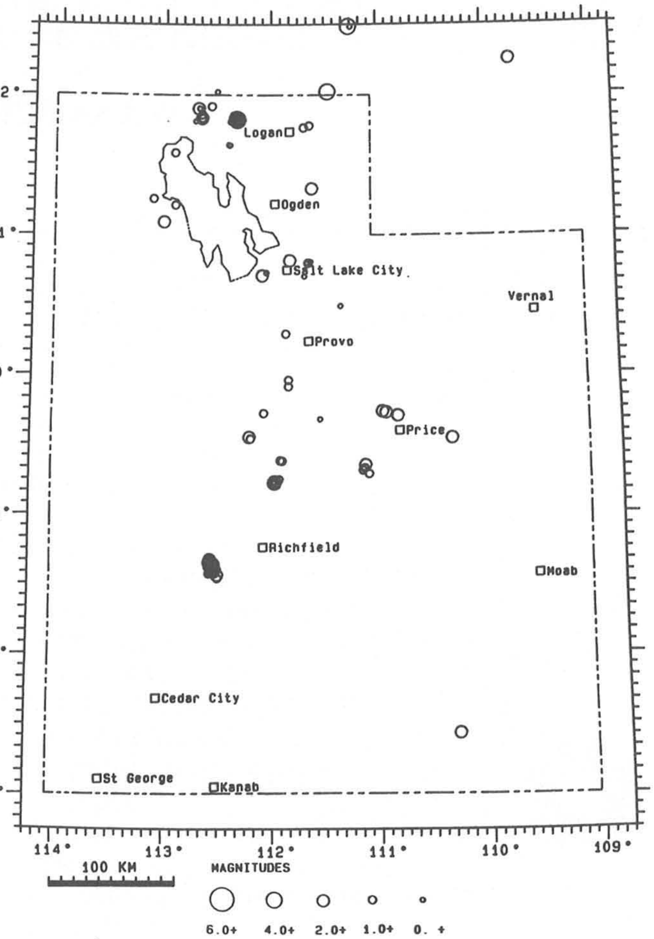
By Ethan D. Brown

UNIVERSITY OF UTAH SEISMOGRAPH STATIONS
DEPARTMENT OF GEOLOGY AND GEOPHYSICS

The University of Utah Seismograph Stations records an 81-station seismic network designed for local earthquake monitoring within Utah, southeast Idaho, and western Wyoming. During October 1 to December 31, 1986, 121 earthquakes were located within the Utah regfion, including 43 greater than magnitude 2.0. The epicenters in the accompanying figure show earthquake activity scattered throughout Utah's main seismic region with significant localized clustering. The largest earthquake during this time period, M_L 3.6, occurred on October 29, and was located 32 km WNW of Logan in northern Utah. This earthquake was reported felt in Tremonton, Utah, and other areas of Box Elder county. Felt earthquakes in the same epicentral area also occurred on October 31 (M_L 3.5) and December 31 (M_L 3.3). On October 1, a small earthquake of M_L 2.7 occurred 8 km northeast of Salt Lake City and was felt in the northeastern Salt Lake valley. An earthquake on November 13 (M_L 2.6), located under Magna, Utah was also felt in the Salt Lake valley. An earthquake of M_L 3.4 on October 5, located 50 km WSW of Richfield, Utah, was reported felt by a plant operator near Beaver, Utah.

Over half (73 out of 121) of the earthquakes recorded during the study period occur in three spatial clusters. The largest is one WNW of Logan and includes 35 earthquakes ($M_L \leq 3.6$) that occurred chiefly during October and early November. A smaller cluster of 12 events ($M_L \leq 2.4$) occurred at the end of October in the area of the March 24 M_L 4.4 Japanese Valley earthquake, about 55 km north of Richfield. A cluster of 26 events ($M_L \leq 3.4$) 50 km SW of Richfield includes the felt earthquake of October 5. This cluster occurs through the first week in October and is a continuation of activity which began in the last report period of July 24.

Additional information on earthquakes within Utah is available from the University of Utah Seismograph Stations, Salt Lake City, Utah 84112; telephone (801) 581-6274.



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Utah Geological and Mineral Survey
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