GEOLOGICAL SURVEY CIRCULAR 780

Earthquake Hazards Reduction Program—Fiscal Year 1978 Studies Supported by the U.S. Geological Survey

EARTHQUAKE HAZARDS REDUCTION PROGRAM—FISCAL YEAR 1978 STUDIES SUPPORTED BY THE U.S. GEOLOGICAL SURVEY

Fault scarp of the earthquake that took place in the region of Pleasant Valley, Nev., in 1915 as viewed in 1957. The slope of the scarps can be used to estimate their age. Photograph by Robert E. Wallace.

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By Robert M. Hamilton

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A description of the expanded program including a list of projects, grants, and contracts

1978

United States Department of the Interior
CECIL D. ANDRUS, *Secretary*

Geological Survey
H. William Menard, *Director*

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Earthquake Hazards Reduction Program—Fiscal Year 1978 Studies Supported by the U.S. Geological Survey

By Robert M. Hamilton

THE EARTHQUAKE THREAT

The great earthquake (magnitude 8.5 on the Richter scale) that struck southern Alaska on March 27, 1964, showed how vulnerable the works of man are to the Earth's tremblings and provided a reminder of the potential for disaster that earthquakes pose for the heavily settled parts of the United States. An inkling of the destruction earthquakes can cause was given by the moderate-sized shock (magnitude 6.5) in San Fernando, Calif., on February 9, 1971, which caused more than 60 deaths and more than a half billion dollars in property damage. Figures 1 and 2 show examples of this damage.

More recently, on July 28, 1976, an earthquake of magnitude 8 struck northeastern China, resulting in enormous loss of life. Official

FIGURE 1.—House severely damaged by faulting during the San Fernando, Calif., earthquake in 1971. Wooden-frame structures, such as this house, rarely collapse during earthquakes. Thus, they are relatively safe places to be during a shock. Photo by Robert O. Castle.

FIGURE 2.—Highway interchange heavily damaged by the San Fernando earthquake in 1971. Photo by Robert E. Wallace.

counts of the casualties have never been announced, but one unconfirmed report puts the death toll at more than 600,000 people (Chinese Inf. Service, 1976). Other earthquake disasters in 1976 took place in Guatemala, causing 23,000 deaths; in Italy, causing 1,000 deaths; in New Guinea, causing several hundred deaths; in Indonesia, causing 500 deaths; in the Philippine Islands, causing 5,000 to 8,000 deaths; and in Turkey, causing 5,000 deaths. All together these losses make 1976 the second worst year for earthquake deaths in history. The worst year was 1556, when many more than 800,000 died in China. The losses continued to mount in 1977 as the Romanian earthquake in February killed 1,500.

Vivid news reports of these tragedies reminded Americans again and again of the

threat of earthquake disasters in the United States. Thirty-nine of the States have experienced earthquake damage, and all States are threatened by the economic disruption that would result from a great earthquake. Past earthquake losses in the United States have been relatively light owing to fortuitous circumstances; fewer than 1,700 Americans have died. The potential exists though for great losses. A great earthquake in Los Angeles, for example, could result in more than 10,000 deaths and $20 billion in damage. Earthquakes in southeastern Missouri, such as those that took place in 1811 and 1812, would cause damage as far as 600 km away.

EARTHQUAKE PROGRAMS OF THE FEDERAL GOVERNMENT

Studies of earthquakes have been conducted in the United States since early in this century, largely in universities. The National Science Foundation (NSF) has supported earthquake research since it was established. Until the early 1960's, however, earthquake research in the United States was not conducted at a high level of effort despite noteworthy individual contributions.

In the early 1960's, the need to detect underground nuclear explosions and to distinguish them from earthquakes led to a rapid expansion in seismological studies under the sponsorship of the U.S. Defense Advanced Research Projects Agency (DARPA). During this period, the Worldwide Standardized Seismograph Network (WWSSN) was established. Today DARPA continues to support seismology, including further important improvements in instruments to monitor global seismic activity.

Research on measures to mitigate the disastrous effects of earthquakes in the United States, however, has lagged. Some of the many reports that proposed programs to expand the research effort are listed on p. 29. An expanded earthquake research program based on the U.S. Task Force on Earthquake Hazard Reduction (Office of Science and Technology, Executive Office of the President) report of 1970 was implemented following the San Fernando earthquake of 1971. Supporters of earthquake research in Congress, however, did not believe that the increased effort was adequate. Legislation to fund earthquake research was introduced in several sessions of Congress through the mid-1970's, but was not passed.

A sense of urgency in dealing with the United States earthquake threat was felt in early 1976 when it was discovered that the land surface over a large area northeast of Los Angeles had risen by as much as 45 cm between 1959 and 1974 (fig. 3). Such land uplift was viewed with concern because similar bulges formed before destructive quakes near Niigata, Japan, in 1964 and near San Fernando, Calif., in 1971. The meaning of the uplift was obscure, however, because in some places, the formation of some bulges has not been followed by large tremors. In response to this potential threat, the National Science Foundation and the U.S. Geological Survey (USGS) reallocated about $2 million to support monitoring of the uplifted region. Since 1976, new instruments have been installed, and additional surveys have been undertaken.

ADMINISTRATION'S PROGRAM

Also in 1976, recognizing that the complex nature of the earthquake problem requires a blend of mitigation measures, the President's Science Advisor initiated a process to formulate a balanced plan of research for the two agencies of the Federal Government responsible for earthquake research: the U.S. Geological Survey and the National Science Foundation. This effort culminated in the submission of a report on September 15, 1976—the so-called Newmark Report (U.S. Natl. Sci. Found., RANN, and U.S. Geological Survey, 1976)—that proposed three options for increased studies and suggested balances among the various mitigation measures. Drawing upon the Newmark Report, the President sought funding in his FY (fiscal year) 78 budget at a level consistent with Option B of the report, the middle option.

HIGHLIGHTS OF THE NEWMARK REPORT

The Newmark Report:

- Established a balance among the six elements of research on earthquake-hazards mitigation: fundamental studies, prediction, hazards assessment, induced seis-

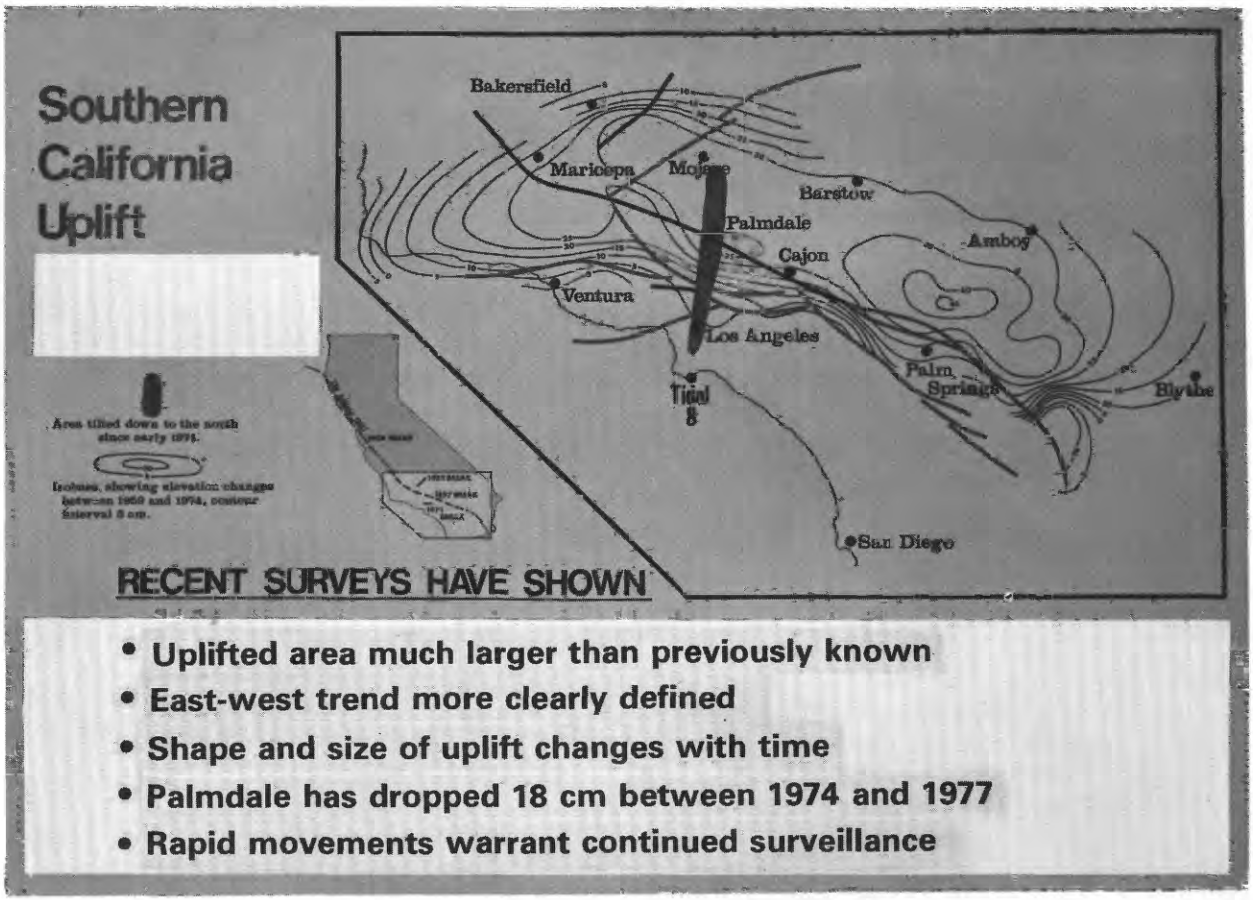

FIGURE 3.—Map showing land uplift in southern California. Such uplifts have sometimes preceded strong earthquakes. This one is of particular concern because it is in an area where a great earthquake last took place in 1857; therefore, the potential for another great earthquake is considered to be high.

micity, engineering, and research for utilization.

- Emphasized the importance of research studies spanning the range from the most basic studies to the most applied ones.
- Identified milestones for the research and anticipated public benefits.
- Specified three options for increased funding, which are summarized in table 1.

CONGRESSIONAL PROGRAM

In parallel with the Administration's planning for an expanded earthquake program, the Congress took action on the legislation that had been pending for several years. It passed the Earthquake Hazards Reduction Act of 1977 (appendix), and the President signed it into law on October 7, 1977. The Act calls for a program very similar in scope and level of effort to the Administration's plan. Thus, both branches of the Federal Government agreed on similar plans for attacking the problem.

HIGHLIGHTS OF THE EARTHQUAKE HAZARDS REDUCTION ACT OF 1977

The Earthquake Hazards Reduction Act of 1977:

- Required the preparation of an Implementation Plan specifying mechanisms for carrying out the Earthquake Hazards Reduction Program.
- Established the objectives and scope of studies to be conducted under the program.
- Required submission by the President to Congress of an annual report describing progress in reducing the risks of earthquake hazards.

TABLE 1.—*Three options proposed in the Newmark Report (US. Natl. Sci. Found., RANN, and U.S. Geol. Survey, 1976) and the amounts authorized in the Earthquake Hazards Reduction Act (P.L. 95–124) for increased funding of earthquake research*

[Figures are in millions of dollars]

	U.S. Geol. Survey	Nat. Sci. Found.	Coordinating Office	Total
FY 77	11.2	10.2	---	21.4
FY 78				
Option A	18.5	19.2	---	37.7
Option B	27.9	25.8	---	53.7
Option C	44.8	40.0	---	84.8
P.L. 95–124	27.5	27.5	1.0	56.0
FY 79				
Option A	27.8	22.2	---	50.0
Option B	37.8	32.4	---	70.2
Option C	53.2	42.9	---	96.1
P.L. 95–124	35.0	35.0	2.0	72.0
FY 80				
Option A	39.8	35.1	---	74.9
Option B	46.1	38.9	---	85.0
Option C	59.5	45.7	---	105.2
P.L. 95–124	40.0	40.0	2.0	82.0

- Specified authorizations for increased funding as summarized in table 1.

THE IMPLEMENTATION PLAN

The Earthquake Hazards Reduction Act of 1977 mandates that an Implementation Plan be prepared to establish (1) a means for coordinating the Earthquake Hazards Reduction Program, (2) strategy, (3) targets, (4) roles of Federal, State, and local governments, and (5) responsibilities of the various Federal agencies. The Office of Science and Technology Policy was designated by the President, in accordance with the Act, to prepare the plan. The plan will be submitted to the Congress in May 1978. By August 1978, the President will decide what governmental entity will be responsible for the program, roles, goals, priorities, target dates, methods of cooperation and coordination with States, and staffing.

OTHER EARTHQUAKE-RELATED FEDERAL PROGRAMS

In addition to the research programs of the USGS and the NSF under the Earthquake Hazards Reduction Program, and to the DARPA program for detection and discrimination of underground nuclear explosions, several other earthquake-related programs contribute substantially to the mitigation of earthquake hazards. The Reactor Hazards Research Program of the USGS and the Site Safety Research Program of the Nuclear Regulatory Commission (NRC) are of particular importance owing to their contributions to earthquake hazards assessment. The programs of the National Aeronautics and Space Administration (NASA) for long baseline geodetic positioning and of the National Oceanic and Atmospheric Administration/National Geodetic Survey (NOAA/NGS) for level and triangulation surveying contribute to studies of plate tectonics and prediction. Tsunami studies are conducted by NOAA and NSF. The various Federal construction agencies, such as the Army Corps of Engineers, Bureau of Reclamation, and Veterans Administration, conduct engineering design studies.

Coordination among these various programs is essential and has been accomplished effectively. A few specific examples will illustrate this point. All the agencies mentioned above have a liaison representative on the USGS Earthquake Studies Advisory Panel. NOAA and the USGS have a bilateral coordinating committee. USGS, NSF, and NRC grants and contracts managers participate in each others' evaluation meetings. Agencies transfer funds to other agencies to obtain needed expertise on mission programs. Overall, the level of cooperation is high.

THE EARTHQUAKE HAZARDS REDUCTION PROGRAM

The five basic strategies for mitigating earthquake losses are: (1) preparedness, (2)

land use, (3) building codes, standards, and design practices, (4) insurance and relief, and (5) information and education. The research activities necessary to establish a basis for these strategies are grouped for programmatic purposes into six main elements: (1) fundamental studies, (2) prediction, (3) induced seismicity, (4) hazards assessment, (5) engineering, and (6) research for utilization. This terminology is used in the Newmark Report, it is used in the President's justification of his proposed FY 78 budget, and it is consistent with the terminology used in the Earthquake Hazards Reduction Act of 1977 (see appendix).

The responsibility for research on earthquake hazards reduction is divided between the USGS and the NSF. The USGS is responsible for prediction, induced seismicity, and hazards assessment; the NFS is responsible for engineering and research for utilization. The USGS and the NSF are jointly responsible for fundamental studies. Within the USGS, the responsibility for management of the Earthquake Hazards Reduction Program is assigned to the Office of Earthquake Studies in the Geologic Division (see organization chart inside back cover).

FUNDING IN FISCAL YEAR 1978

The budget requests to Congress by the USGS and the NSF in FY 1978 for the Earthquake Hazards Reduction Program were consistent with Option B of the Newmark Report. Congress modified the USGS requests for two of the elements: For prediction research, $1,500,000 was added to expedite earthquake-prediction studies in foreign countries, and for induced-seismicity research, $800,000 was added to accelerate the definition of criteria for the safe siting of dams.

The NSF budget process is different from that of the USGS in that funds for NSF are not actually appropriated by the Congress to particular fields of study. The combination of Congressional appropriation and internal NSF allocation resulted in funding for fundamental earthquake studies and engineering studies being consistent with the Option B level and in funding for research for utilization being $2.5 million below the Option B level. The funding of the elements of the Earthquake Hazards Reduction Program for fiscal year 1978 is summarized in table 2 and figure 4.

ROLE OF UNIVERSITIES, PRIVATE GROUPS, AND GOVERNMENT AGENCIES OTHER THAN THE USGS

Non-USGS scientists participate extensively in all stages, including formulation, planning, and implementation, of the Earthquake Hazards Reduction Program. The reports that established the basis for the program were prepared mainly by university scientists. The Advisory Panel that submitted the Newmark Report was composed of university, private, and State and local government experts. Formulation of program options and review of proposals involve these same experts. Finally, many of the studies are carried out by members of the non-USGS earthquake-research community.

Only by involving people from all segments of the earthquake-research community could a truly national program be established and conducted. The extent of this involvement is shown in figure 5.

TABLE 2.—*Earthquake Hazards Reduction Program FY 1978 funding as enacted*

[See fig. 4]

Program element	USGS	NSF	Percentage of program
	Thousands of dollars		
Fundamental studies	2,650	5,300	14.9
Prediction	15,764*	-----	29.4
Induced seismicity	1,200	-----	2.2
Hazards assessment	10,607	-----	19.8
Engineering	-----	15,500	29.0
Research for utilization	-----	2,500	4.7
Totals	30,221	23,000	

* Includes $1,500,000 specifically for prediction studies in foreign countries.

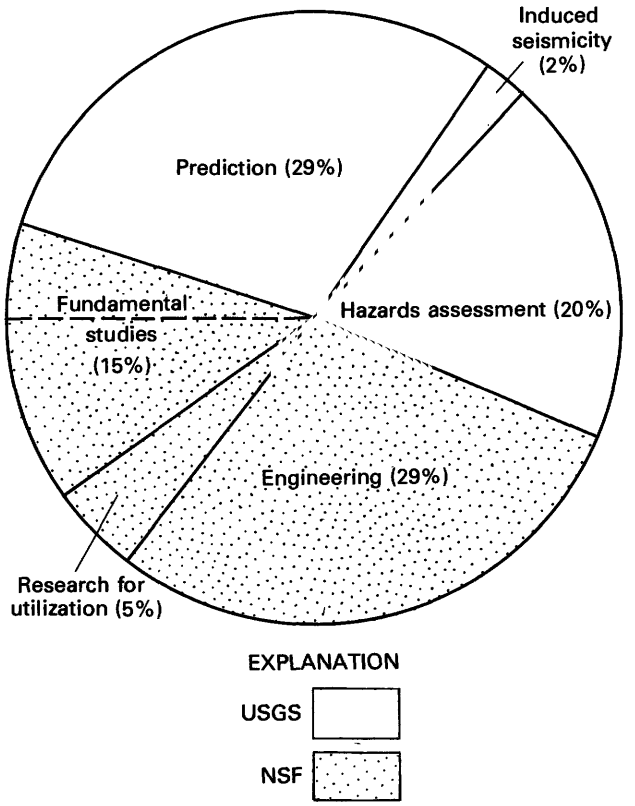

FIGURE 4.—Allocation of funds to the six elements of the Earthquake Hazards Reduction Program during FY 1978. See table 2.

RESEARCH ELEMENTS

In the following sections, the objectives, approach, and activities of the research elements of the Earthquake Hazards Reduction Program are described. For completeness, brief mention is made of the elements that are the responsibility of the NSF, but the focus is on the elements of USGS responsibility. The objectives are taken from the Newmark Report.

FUNDAMENTAL STUDIES

OBJECTIVES

- Obtain a comprehensive understanding of the natural phenomena involved in the earthquake process.
- Improve global networks of seismograph stations to provide a sound data base for studies in observational seismology and provide associated data services.

APPROACH

Much of the research to achieve the first objective is carried out in the universities and is funded by NSF. The USGS role in the fundamental-studies element is to achieve the second objective.

Progress in earthquake-hazards reduction must be founded on a sound understanding of the nature of earthquakes. Thus, the steady pursuit of knowledge is needed on a wide variety of subjects that may at first consideration appear to be esoteric, but that in fact establish the very basis for mitigation measures. These subjects include global seismicity, internal structure of the Earth, seismic-wave propagation, earthquake source mechanics, and plate tectonics.

MAJOR USGS ACTIVITIES

- Provide information on earthquakes to the public, to governmental agencies involved in disaster preparedness and re-

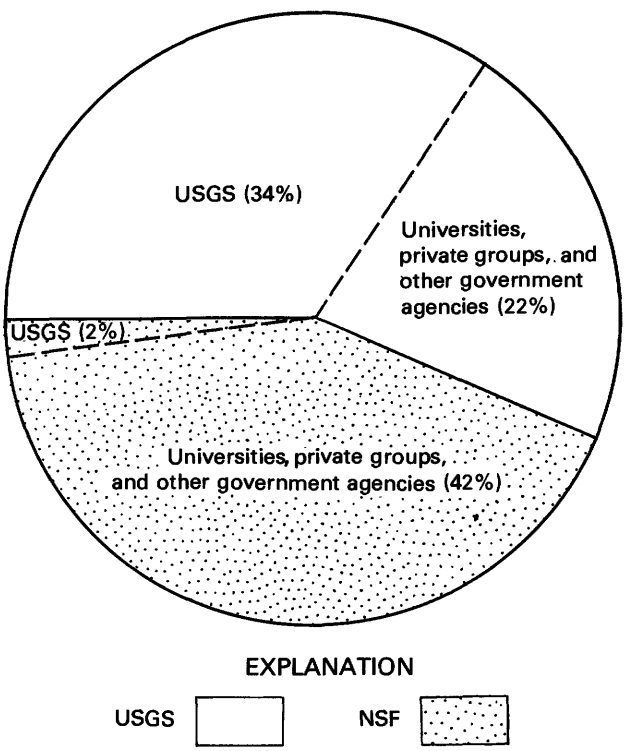

FIGURE 5.—Allocation of funds among universities, private groups, and government agencies under the Earthquake Hazards Reduction Program during FY 1978.

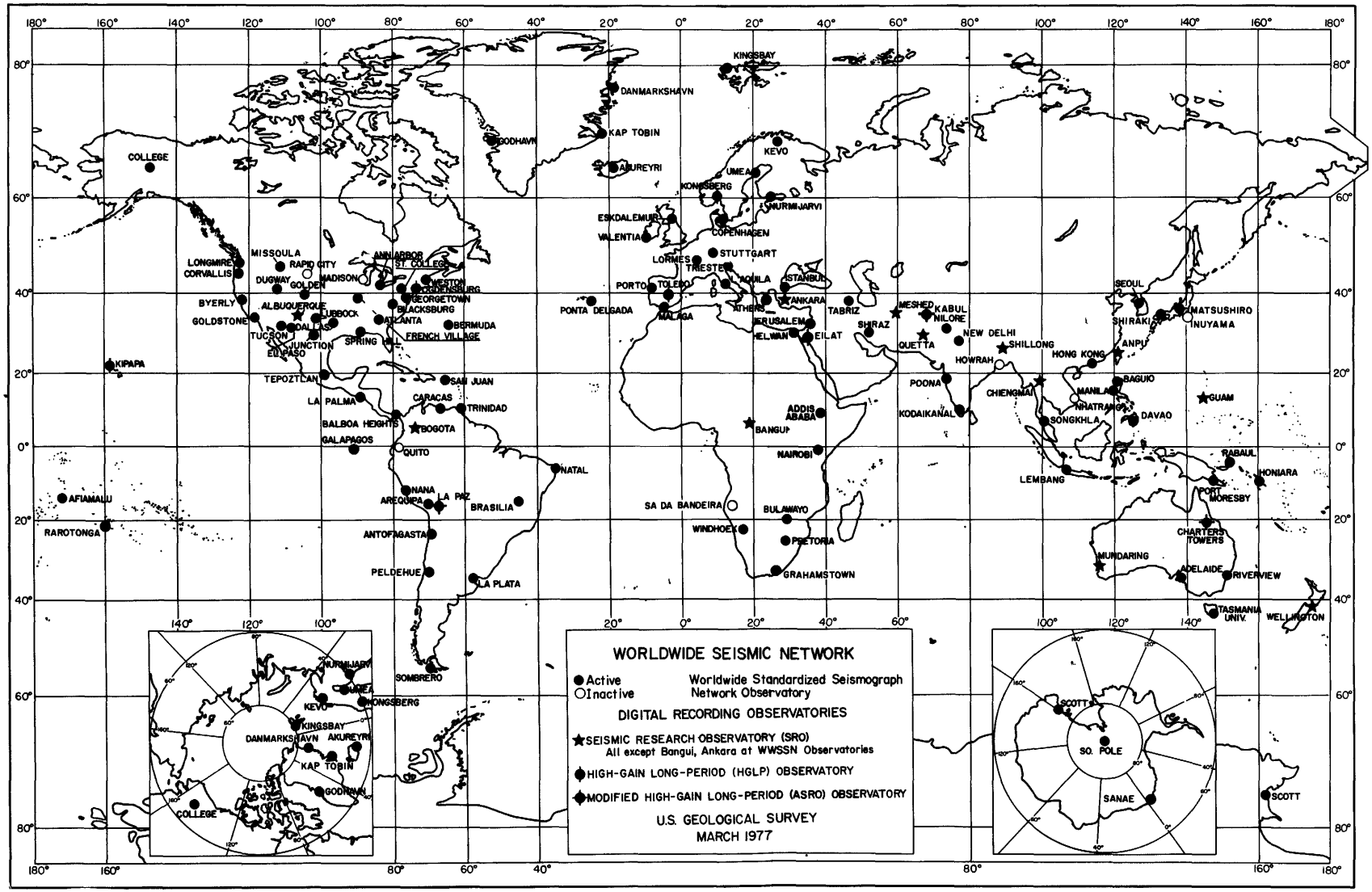

FIGURE 6.—Locations of the Worldwide Standardized Seismograph Network stations and the Global Digital Seismograph Network.

lief, and to researchers through the National Earthquake Information Service (NEIS).

- Operate and maintain the Worldwide Standardized Seismograph Network (WWSSN) and provide standard data to the Environmental Data Service, NOAA, for dissemination. The locations of the WWSSN stations are shown in figure 6.
- Provide data to the Tsunami Warning System operated by NOAA.
- With DARPA support, establish a global network of digital seismographs and associated data-collection and -analysis facilities. The locations of the digital stations are shown in figure 6.
- Conduct research on global seismicity, internal structure of the Earth, seismic-wave propagation, earthquake source mechanics, and plate tectonics.

PREDICTION

OBJECTIVES

- Predict moderate to large earthquakes in time and space and estimate limits of probabilities of their occurrence on the basis of detailed observation.
- Issue earthquake predictions, where possible, in a timely manner utilizing automated data-analysis systems.
- Reduce unreliable predictions of earthquakes by working toward a sound understanding of the physical basis for the precursory phenomena observed.

APPROACH

Instruments and surveys to detect earthquake precursors are being markedly expanded to provide an observational basis for laboratory and theoretical studies. The areas of greatest seismicity, both foreign and domestic, are the targets for the field studies to increase the chances of instruments being near the sources of future earthquakes. A focused program is underway to determine the physical properties of fault zones. This determination is considered to be essential for establishing a sound physical basis for prediction. Surveillance of the southern California uplift is continuing.

Research studies are being carried out jointly with universities, where considerable expertise for prediction was gained during the program to discriminate between earthquakes and underground nuclear explosions, and with other research groups. The allocation of funds to different types of prediction studies during fiscal year 1978 is shown in figure 7.

MAJOR ACTIVITIES

- Operate instruments and conduct surveys to detect earthquake precursors, including anomalies in land deformation, seismicity, source characteristics, seismic-wave propagation, electromagnetic field, geochemical phenomena, and animal behavior.
- Through drilling, geophysical surveys, and geologic studies, determine the physical properties of fault zones that affect the earthquake process.
- Analyze data, conduct laboratory experiments, and test theories to establish a physical basis for prediction.
- Conduct foreign studies to detect precursors and to benefit from foreign progress on prediction. Studies are planned or underway in the Caribbean, India,

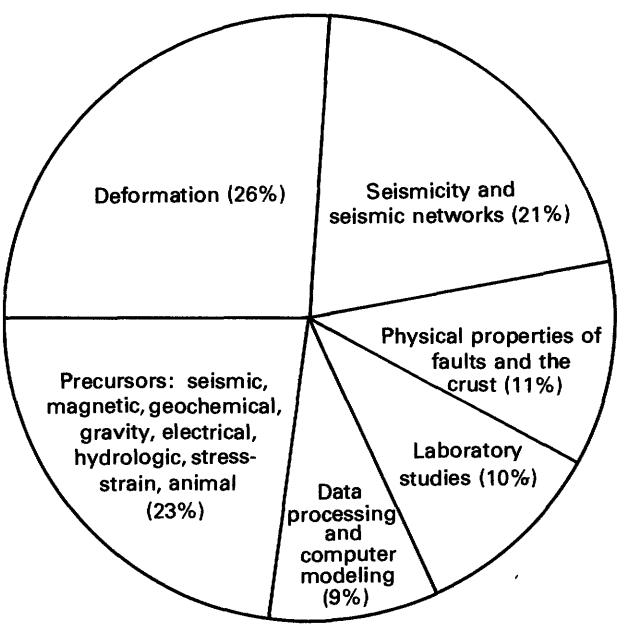

FIGURE 7.—Allocation of funds to different types of prediction studies during FY 1978.

Mexico, New Hebrides, Pakistan, Republic of China (Taiwan), Turkey, and the U.S.S.R.

- Maintain close contact with foreign countries that are conducting research on earthquake prediction, including Japan, the U.S.S.R., the Peoples Republic of China, and New Zealand.

INDUCED SEISMICITY

OBJECTIVES

- Devise techniques for diagnosing in advance whether reservoir impoundment or fluid injection in wells at a particular site holds the potential for triggering earthquakes.
- Devise techniques to permit safe operation of large reservoirs and deep injection wells including a basis for remedial action should earthquakes be triggered.
- Determine to what extent theories and models that are successful in explaining induced or triggered earthquakes apply to natural earthquake processes.
- Determine the feasibility of artificially modifying natural seismicity by measuring the physical properties of fault-zone materials in drill holes. Select a site for a field experiment.

APPROACH

An intensive examination is underway of reservoirs that have caused earthquakes and of those that have not. Critical factors will be sought that may establish a basis for selection of reservoir sites. In addition, a field experiment is being planned to determine the hydrologic and stress regimes at a reservoir that has caused earthquakes.

MAJOR ACTIVITIES

- Study the historical record of reservoir-induced seismicity and determine geologic and hydrologic factors diagnostic of potential induced seismicity.
- Confirm the hypothesized role of fluid pressures in reservoir-induced seismicity by measuring relevant properties at depth near a reservoir that has caused earthquakes.

HAZARDS ASSESSMENT

OBJECTIVES

- Determine the expected location, size, frequency, and characteristics of earthquakes and of associated surface faulting for various regions of the United States.
- Acquire a physical basis for predicting the character of damaging ground motion as a function of distance from a postulated earthquake and varying geologic site conditions.
- Acquire a physical basis for predicting the incidence, nature, and extent of earthquake-induced ground failure and flooding.
- Delineate geographical variations in the nature and likelihood of occurrence of earthquake hazards.
- Evaluate earthquake risk (that is, make a hazard assessment and a vulnerability analysis) on a nationwide and regional basis.

APPROACH

Comprehensive geological and geophysical studies are being conducted to determine the location of potential earthquake hazards and to acquire a basis for estimating their likelihood of occurrence and possible effects. Research studies are being carried out jointly with universities, State geological surveys, and private organizations. Allocation of funds to national, regional, and topical studies in the USGS hazards-assessment program for fiscal year 1978 is shown in figure 8. Major related studies are being conducted under the Reactor Hazards Research Program of the USGS and the Site Safety Research Program of the NRC. The USGS and NRC programs are complementary and closely coordinated. Allocation of funds by geographic region for regional earthquake–hazards studies being supported by the USGS and NRC is shown in figure 9. Research studies on tsunamis are funded primarily by NSF and NOAA.

MAJOR ACTIVITIES

- Produce seismic-risk maps for the United States.

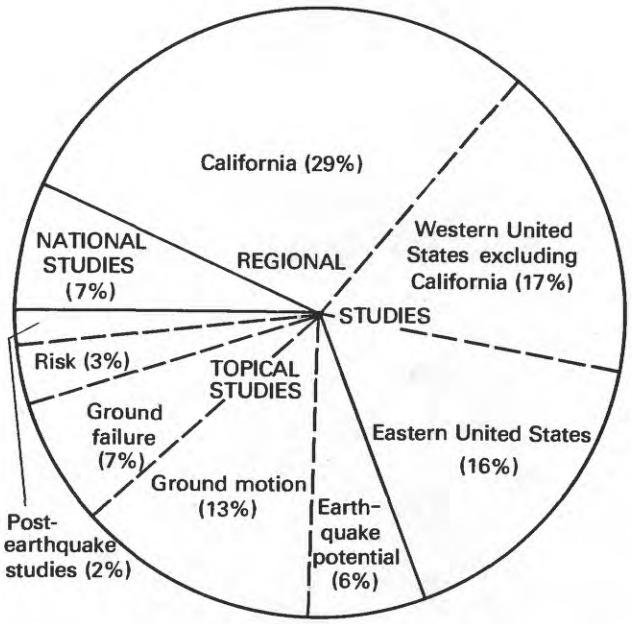

FIGURE 8.—Allocation of funds to national, regional, and topical studies in hazards assessment for FY 1978.

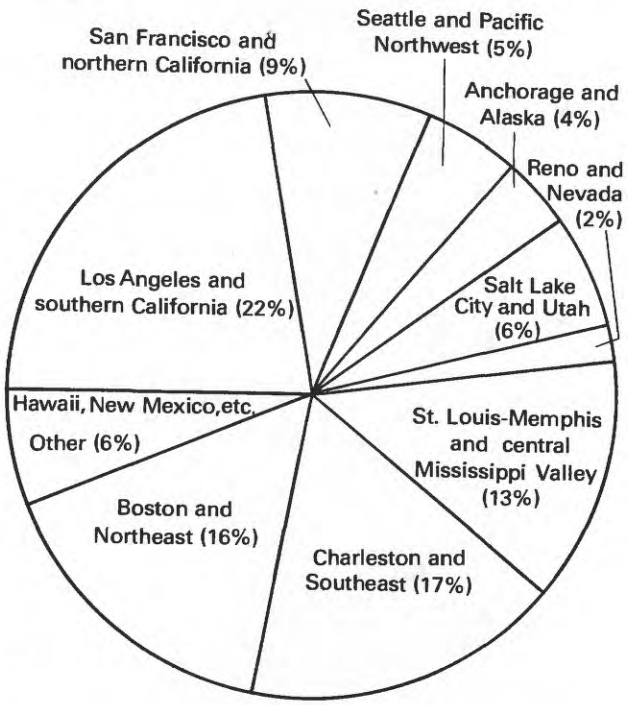

FIGURE 9.—Allocations of funds by geographic region for regional earthquake hazards studies being supported by the USGS and the Nuclear Regulatory Commission (NRC) in FY 1978. In this figure, funds are combined from the Earthquake Hazards Reduction Program of the USGS, the Reactor Hazards Research Program of the USGS, and the Site Safety Research Program of the NRC.

- Operate regional seismograph networks and conduct geophysical surveys and geologic studies to understand the cause of earthquakes in urbanized regions throughout the United States, including the central Mississippi Valley and the East Coast.
- Devise and demonstrate in the San Francisco Bay region improved methods for earthquake-hazards assessment on a scale useful to city and county agencies.
- Continue comprehensive assessments of earthquake hazards in the Los Angeles, San Diego, Seattle, Reno-Carson City, and Salt Lake City urban regions.
- Continue or initiate preliminary studies of earthquake hazards in the Anchorage, St. Louis, and Boston regions.
- Improve methods for determining earthquake recurrence intervals, modeling and predicting strong ground motion, estimating earthquake damage, and evaluating the potential for surface faulting and seismically induced ground failure. An example of ground failure is shown in figure 10, and the consequence of such failure is shown in figure 11.

ENGINEERING

OBJECTIVES

- Devise methods to characterize the nature of the input motions and corresponding response of simple systems for use in engineering analysis, planning, and design.
- Obtain comprehensive data on the nature of strong earthquake motions at typical sites and in representative structures.
- Devise in situ and laboratory methods to determine the dynamic properties of soils and analytical procedures to determine potential for failure of slopes, embankments, and foundations.
- Devise procedures based on both numerical and experimental studies for analyzing and characterizing the earthquake response of structures and structural elements.
- Devise analytical methods to evaluate the earthquake response of extended structures such as dams and bridges and of in-

FIGURE 10.—Lurching of the ground caused by liquefaction and lateral spreading in the Salinas Valley during the San Francisco earthquake in 1906. Photo from the J. C. Branner collection.

terconnected systems such as pipelines and transmission lines.

- Obtain information from observations of damage (or lack of damage) following earthquakes to support improvement of engineering analyses, design practices, and construction techniques. Some examples of serious damages are shown in figures 12 and 13.

APPROACH

The NSF has responsibility for managing the engineering research element. Workshops concerning various earthquake engineering topics are being sponsored to assess the current state of knowledge and to define research priorities. Research studies are being carried out by universities, private organizations, and Federal agencies. Under NSF support, the USGS operates the national program to collect, process, and disseminate strong-motion data recorded in structures and on the ground.

RESEARCH FOR UTILIZATION

OBJECTIVES

- Define options for the balance of measures to mitigate earthquake hazards by considering research, social, economic, legal, and political barriers and incentives to policy implementation.
- Assess the effects of public and private regulation and propose alternative regulations where necessary.
- Facilitate the beneficial utilization of earthquake-hazard mitigation measures by providing effective techniques for communicating information to the public and to decision makers.
- Increase the capability of public officials to mitigate earthquake hazards through land-use planning, preparedness planning, building regulation, and disaster response.

FIGURE 11.—Consequences of gound failure by liquefaction caused by shaking during the San Francisco earthquake in 1906. Photo from the J. C. Branner collection.

- Define alternatives the private sector could adopt for mitigating earthquake hazards.

APPROACH

The research for utilization element is the responsibility of NSF. The focus of this research is to prepare mechanisms and techniques for implementing the results of the research program. Each agency conducting research has responsibilities for facilitating research applications. To this end, the USGS has established a position of Deputy for Research Applications in the Office of Earthquake Studies; this official's specific task is to serve as a bridge between researchers and users.

PROJECTS, GRANTS, AND CONTRACTS FUNDED BY THE USGS

In this section, the studies that are being supported by FY 1978 USGS funds are listed. Both USGS projects and grants and contracts to non-USGS groups are included. The list includes fund commitments before March 1, 1978. The name, address, and phone number of the principal investigator is included as a source for information about the study. The following outline shows the organization of the list of projects, grants, and contracts:

I. Earthquake hazards studies
   A. Earthquake potential
      1. Tectonic framework, Quaternary geology, and active faults

FIGURE 12.—Total collapse of a reinforced concrete, multistory building from an earthquake at Varto, Turkey, in 1966. Photo by Robert E. Wallace.

a. California
b. Western United States excluding California
c. Eastern United States
d. United States—nationwide

2. Earthquake recurrence and age dating

B. Earthquake effects
1. Ground motion
2. Ground failure
3. Surface faulting
4. Postearthquake

C. Earthquake losses

II. Earthquake prediction studies
A. Location of areas where large earthquakes are most likely to take place
1. Syntheses of seismicity, tectonic, and similar data
2. Stress level

FIGURE 13.—Apartment building destroyed by the earthquake that struck the Philippine Islands in 1976. This type of reinforced concrete structure is particularly vulnerable to earthquakes. Photo by Robert E. Wallace.

B. Earthquake precursors
   1. General
   2. Seismological
   3. Ground deformation, tilt, and strain
   4. Gravity
   5. Magnetic
   6. Electrical
   7. Geochemical
   8. Water level
   9. Animal behavior
C. Data processing
D. Computer modeling

III. Induced-seismicity studies

IV. Studies in common support of hazards, prediction, and induced-seismicity element
   A. Seismicity and seismic networks
   B. Physical basis of earthquakes
      1. Physical properties of the crust and upper mantle
      2. Laboratory
      3. Source mechanics

V. Global seismology studies
   A. Research
   B. Seismograph station operation and design
   C. Data acquisition and dissemination

VI. General studies

I. EARTHQUAKE HAZARDS STUDIES

I.A. EARTHQUAKE POTENTIAL

I.A.1. TECTONIC FRAMEWORK, QUATERNARY GEOLOGY, AND ACTIVE FAULTS

I.A.1.a. CALIFORNIA

SOUTHERN CALIFORNIA

EARTHQUAKE HAZARDS MAPPING OF THE SAN ANDREAS FAULT ZONE, LOS ANGELES, CALIFORNIA, A. G. Barrows, State of California, Division of Mines and Geology, Resources Building, 1416 Ninth Street, Sacramento, Calif. 95814, (916) 445-1825.

TECTONIC GEOMORPHOLOGY OF THE PALMDALE UPLIFT AREA, SOUTHERN CALIFORNIA, S. B. Bull, University of Arizona, College of Earth Sciences, Department of Geosciences, Tucson, Ariz. 85721, (602) 884-2219.

ACTIVE FAULTS AND REGIONAL DEFORMATION IN THE WESTERN MOJAVE DESERT, CALIFORNIA, D. B. Burke, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2048.

QUATERNARY FAULTING IN SOUTHERN CALIFORNIA, M. M. Clark, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2623.

GEOMORPHIC STUDIES OF POST-PLEISTOCENE DEFORMATION ALONG THE SAN ANDREAS FAULT, WEST-CENTRAL TRANSVERSE RANGES, CALIFORNIA, J. C. Crowell, University of California, Santa Barbara, Department of Geological Sciences, Santa Barbara, Calif. 93106, (805) 961-3224.

GEOLOGIC INVESTIGATION OF THE RECENCY OF FAULT ACTIVITY BY SURFACE TRENCHING ON THE WHITTIER FAULT, D. L. Hannon, Leighton and Associates, 17975 Sky Park Circle, Irvine, Calif. 92714, (714) 556-1421.

EARTHQUAKE HAZARDS ASSOCIATED WITH FAULTS IN THE GREATER LOS ANGELES METROPOLITAN AREA, LOS ANGELES COUNTY, CALIFORNIA, R. L. Hill, State of California, Division of Mines and Geology, Resources Building, 1416 Ninth Street, Sacramento, Calif. 95814, (916) 445-1825.

EARTHQUAKE HAZARD STUDY OF THE SIERRA MADRE FAULT SYSTEM, B. Kamb, California Institute of Technology, Division of Geological and and Planetary Sciences, Pasadena, Calif. 91125, (213) 795-6811.

FAULTING AS A POTENTIAL EARTHQUAKE HAZARD IN URBAN SAN DIEGO, CALIFORNIA, M. P. Kennedy, State of California, Division of Mines and Geology, Resources Building, 1416 Ninth Street, Room 1341, Sacramento, Calif. 95814, (916) 445-1923.

STUDY OF EARTHQUAKE-DEFORMED STRATA IN HOLOCENE LAKE SEDIMENT IN AREA OF PALMDALE UPLIFT, SOUTHERN CALIFORNIA, D. L. Lamar, California Earth Science Corporation, 1318 Second Street, Santa Monica, Calif. 90401, (213) 395-4528.

TECTONICS OF THE EASTERN TRANSVERSE RANGES, D. M. Morton, U.S. Geological Survey, Branch of Western Environmental Geology, 11341 Lombardy Lane, Sunnymead, Calif. 92388, (714) 787-3628.

INVESTIGATION OF THE HOSGRI FAULT OFFSHORE SOUTHERN CALIFORNIA—POINT SAL TO POINT CONCEPTION, C. M. Payne, Fugro, Inc., 3777 Long Beach Blvd., Long Beach, Calif. 90807, (213) 595-6611.

BASEMENT TECTONIC FRAMEWORK STUDIES OF THE SAN ANDREAS FAULT SYSTEM, D. C. Ross, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2341.

QUATERNARY TECTONICS OF THE SALTON TROUGH, R. V. Sharp, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2596.

STUDIES OF LATE HOLOCENE BEHAVIOR OF THE SAN ANDREAS FAULT SYSTEM—SAN JUAN BAUTISTA TO THE SALTON SEA, K. E. Sieh, California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, Calif. 91125, (213) 795-6811, ext. 2108.

CLASSIFICATION AND MAPPING OF QUATERNARY SEDIMENTARY DEPOSITS FOR PURPOSES OF SEISMIC ZONATION, SOUTH COASTAL LOS ANGELES BASIN, ORANGE COUNTY, CALIFORNIA, E. C. Sprotte, State of California, Division of Mines and Geology, Resources Building, 1416 Ninth Street, Sacramento, Calif. 95814, (916) 445-1825.

QUATERNARY GEOLOGIC FRAMEWORK FOR EARTHQUAKE STUDIES IN THE LOS ANGELES REGION, J. C. Tinsley, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2037.

PROGRESSIVE GROWTH OF SOUTH END OF THE DEATH VALLEY FAULT ZONE AND CHRONOLOGY OF FAULTING, VOLCANISM, AND FAN DEVELOPMENT, B. W. Troxel, 626 Georgetown Place, Davis, Calif. 95616, (916) 746-5191.

GEOLOGIC AND GEOMORPHIC INVESTIGATION OF THE SAN GABRIEL FAULT ZONE, LOS ANGELES AND VENTURA COUNTIES, CALIFORNIA, F. H. Weber, Jr., State of California, Division of Mines and Geology, Resources Building, Room 1341, 1416 Ninth Street, Sacramento, Calif. 95814, (916) 445-1923.

SUBSURFACE GEOLOGY OF THE SAN GABRIEL, HOLSER, AND SIMI-SANTA ROSA FAULTS, TRANSVERSE RANGES, CALIFORNIA, R. S. Yeats, Oregon State University, Department of Geology, Corvallis, Oreg. 97331, (503) 754-2484.

TECTONICS OF THE WESTERN TRANSVERSE RANGES, R. F. Yerkes, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2350.

NORTHERN CALIFORNIA

TERTIARY AND QUATERNARY TECTONIC FRAMEWORK OF THE SAN FRANCISCO BAY REGION, E. E. Brabb, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2203.

HOLOCENE BEHAVIOR OF THE SAN ANDREAS FAULT—SAN JUAN BAUTISTA TO POINT ARENA, W. R. Cotton, Foothill-DeAnza Community College District, 12345 El Monte Road, Los Altos Hills, Calif. 94022, (415) 948-8590..

GRAVITY AND MAGNETICS OF THE SAN FRANCISCO BAY REGION, A. Griscom, U.S. Geological Survey, Branch of Regional Geophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2268.

SHALLOW SEISMIC REFRACTION INVESTIGATIONS, R. M. Hazelwood, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2759.

NEOTECTONICS OF THE SAN FRANCISCO BAY REGION, D. G. Herd, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2870.

GEOLOGIC FRAMEWORK AND TECTONIC HISTORY OF CENTRAL AND NORTHERN CALIFORNIA, W. P. Irwin, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2065.

GEOLOGIC INVESTIGATION OF RECURRENCE INTERVALS AND RECENCY OF FAULTING ALONG THE SAN GREGORIO FAULT ZONE, SAN MATEO COUNTY, CALIFORNIA, G. E. Weber, William Cotton and Associates, 314 Tait Avenue, Los Gatos, Calif. 95030, (408) 354-5542.

CALIFORNIA—STATEWIDE

VERTICAL TECTONICS IN CALIFORNIA AND THE WESTERN U.S., R. O. Castle, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2482.

TIME-STRATIGRAPHIC FRAMEWORK FOR MARINE SEDIMENTS OF THE CONTIGUOUS WESTERN U.S., R. T. Kilbourne, State of California, Division of Mines and Geology, Resources Building, 1416 Ninth Street, Sacramento, Calif. 95814, (916) 445-1825.

QUATERNARY TECTONICS OF PACIFIC COAST, K. R. Lajoie, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2642.

I.A.1.b WESTERN UNITED STATES EXCLUDING CALIFORNIA

SEISMOTECTONICS OF SOUTHWESTERN UTAH, R. E. Anderson, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-5109.

TECTONIC FRAMEWORK OF THE RIO GRANDE RIFT, NEW MEXICO, E. H. Baltz, U.S. Geological Survey, Branch of Central Environmental Geology, Denver Federal Center, Denver, Colo. 80225, (303) 234-2650.

SEISMOTECTONICS OF NORTHWESTERN UTAH, R. C. Bucknam, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-5089.

CHARACTERISTICS OF ACTIVE FAULTS IN THE GREAT BASIN, R. C. Bucknam, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-5089.

EARTHQUAKE RECURRENCE INTERVALS ON THE WASATCH FAULT, L. C. Cluff, Woodward-Clyde Consultants, 3 Embarcadero, Suite 700, San Francisco, Calif. 94111, (415) 956-7070.

INVESTIGATION OF TECTONIC DEFORMATION IN THE PUGET LOWLAND, WASHINGTON, P. Palmer, State of Washington, Department of Natural Resources, Olympia, Wash. 98504, (206) 753-6183.

ENGINEERING GEOLOGIC MAPPING FOR EARTHQUAKE HAZARDS EVALUATION IN THE UPPER COOK INLET-SUSITNA LOWLAND REGION, ALASKA, O. J. Ferrians, U.S. Geological Survey, Branch of Alaskan Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2247.

SEISMOTECTONICS OF THE PUGET SOUND PROVINCE, H. D. Gower, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2352.

SEISMOTECTONIC AND GEOMORPHIC EVOLUTION OF THE HOLOCENE BLACK ROCK FAULT, NORTHWESTERN NEVADA, L. T. Grose, Colorado School of Mines, Department of Geology, Golden, Colo. 80401, (303) 297-0300, ext. 806.

PATTERNS OF RECURRENT MOVEMENT ALONG THE WASATCH-HURRICANE-SEVIER FAULT ZONE, UTAH, W. K. Hamblin, Brigham Young University, Department of Geology, Provo, Utah 84602, (801) 374-1211, ext. 2469.

SURFICIAL GEOLOGY OF THE WASATCH FRONT, R. D. Miller, U.S. Geological Survey, Branch of Engineering Geology, Denver Federal Center, Denver, Colo. 80225, (303) 234-2960.

ACTIVE FAULTS AND TECTONIC DEFORMATION IN ALASKA, G. Plafker, U.S. Geological Survey, Branch of Alaskan Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2201

QUATERNARY GEOLOGY OF THE WASATCH FRONT, W. E. Scott, U.S. Geological Survey, Branch of Central Environmental Geology, Denver Federal Center, Denver, Colo. 80225, (303) 234-5215.

EARTHQUAKE-HAZARD MAPS: CARSON CITY, NEW EMPIRE AND SOUTH LAKE TAHOE QUANDRANGLES, D. Trexler, State of Nevada, Nevada Bureau of Mines, Mackay School of Mines, University of Nevada, Reno, Nev. 89507, (702) 784-6691.

I.A.1.c. Eastern United States

OFFSHORE AEROMAGNETIC STUDIES FOR CHARLESTON EARTHQUAKE PROBLEM: FEASIBILITY STUDY, J. C. Behrendt, U.S. Geological Survey, Branch of Regional Geophysics, Denver Federal Center, Denver, Colo. 80225, (303) 234-5917.

LATE TERTIARY AND QUATERNARY SHORELINE DATUM PLANES AND TECTONIC DEFORMATION IN THE SOUTHEASTERN UNITED STATES, B. W. Blackwelder, U.S. Geological Survey, Branch of Paleontology and Stratigraphy, Room 501, U.S. National Museum, Washington, D. C. 20244, (202) 343-5488.

SEISMOTECTONICS OF NORTHEASTERN U.S., W. H. Diment, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2731.

TECTONIC HISTORY OF THE EASTERN OZARK UPLIFT, E. E. Glick, U.S. Geological Survey, Branch of Central Environmental Geology, Denver Federal Center, Denver, Colo. 80225, (303) 234-3353.

TECTONIC FRAMEWORK OF THE NEW MADRID REGION, MISSOURI, FROM GEOPHYSICAL STUDIES, T. G. Hildenbrand, U.S. Geological Survey, Branch of Regional Geophysics, Denver Federal Center, Denver, Colo. 80225, (303) 234-5464.

ENGINEERING GEOLOGY OF METROPOLITAN BOSTON, C. A. Kaye, U.S. Geological Survey, Branch of Engineering Geology, 150 Causeway St., Room 1304, Boston, Mass. 02114, (617) 223-7200.

SEISMOTECTONICS OF THE CENTRAL MISSISSIPPI VALLEY, F. A. McKeown, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-5086.

SEISMIC-REFLECTION SURVEYS IN THE CENTRAL MISSISSIPPI VALLEY SEISMIC ZONE, F. A. McKeown, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Central, Denver, Colo. 80225, (303) 234-5086.

GEOLOGIC STUDY OF THE RAMAPO FAULT ZONE, NEW YORK, N. M. Ratcliffe, U.S. Geological Survey, Branch of Eastern Environmental Geology, City College, New York, Department of Earth and Planetary Science, 138 and Convent Avenue, New York, N. Y. 10031, (212) 690-6984.

HIGH-RESOLUTION SEISMIC-REFLECTION MAPPING OF FAULT ZONES IN THE UPPER MISSISSIPPI EMBAYMENT, J. L. Sexton, Southern Illinois University, Department of Geology, Carbondale, Ill. 62901, (618) 453-3351.

GEOPHYSICAL IDENTIFICATION OF TECTONIC FEATURES IN NORTHEASTERN U.S., R. Simpson, U.S. Geological Survey, Branch of Regional Geophysics, Denver Federal Center, Denver, Colo. 80225, (303)234-2623.

GEOLOGIC STUDY OF THE NORUMBEGA FAULT ZONE, EASTERN MAINE, D. R. Wones, U.S. Geological Survey, Branch of Eastern Environmental Geology, Virginia Polytechnic Inst. and State Univ., 4044 Derring Hall, Blacksburg, Va. 24061, (703) 951-5980.

I.A.1.d. United States—Nationwide

NEOTECTONIC SYNTHESIS OF THE U.S., C. M. Wentworth, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2474.

SEISMOGENIC ZONES OF THE U.S., J. I. Ziony, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2944 or 2214.

1.A.2. EARTHQUAKE RECURRENCE AND AGE DATING

COLLABORATION ON C-14 AND K/Ar DATING, B. R. Doe, U.S. Geological Survey, Branch of Isotope Geology, Denver Federal Center, Denver, Colo. 80225, (303) 234-4003.

SOIL MORPHOLOGY AND FAULT MOVEMENT, L. A. Douglas, Rutgers University, Department of Soils and Crops, New Brunswick, N. J. 08903, (201) 932-9800.

PALEOMAGNETIC STUDIES OF HOLOCENE FAULT DISPLACEMENT, G. S. Fuis, U.S. Geological Survey, Branch of Seismology, California Institute of Technology, Seismological Laboratory 252-21, Pasadena, Calif. 91125, (213) 795-6811, ext. 2957.

CORRELATING AND DATING QUATERNARY SEDIMENTS BY USE OF AMINO ACIDS, K. Kvenvolden, U.S. Geological Survey, Branch of Pacific-Arctic Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2817.

CORRELATION AND SEMIQUANTITATIVE AGE-DATING OF SOILS, D. Marchand, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2009.

QUATERNARY DATING TECHNIQUES, K. L. Pierce, U.S. Geological Survey, Branch of Central Environmental Geology, Denver Federal Center, Denver, Colo. 80225, (303) 234-2737.

URANIUM TREND DATING, J. N. Rosholt, U.S. Geological Survey, Branch of Isotope Geology, Denver Federal Center, Denver, Colo. 80225, (303) 234-4201.

TEPHROCHRONOLOGY OF CALIFORNIA, NEVADA, OREGON, AND WASHINGTON, A. M. Sarna-Wojcicki, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2745.

EARTHQUAKE-INDUCED DEFORMATIONAL STRUCTURES IN SEDIMENTS, J. D. Sims, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2252.

TECTONIC ANALYSIS OF ACTIVE FAULTS, R. E. WALLACE, U.S. Geological Survey, Office of Earthquake Studies, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2751.

I.B. EARTHQUAKE EFFECTS

I.B.1. GROUND MOTION

REVISION AND STUDIES OF MODIFIED MERCALLI INTENSITY SCALE, S. T. Algermissen U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-4014.

REGIONAL AND NATIONAL SEISMIC HAZARDS AND RISK ANALYSIS, S. T. Algermissen, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-4014.

PHYSICAL CONSTRAINTS ON SOURCE OF GROUND MOTION, D. J. Andrews, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2752.

CORRELATION OF NEAR-FIELD AND FAR-FIELD GROUND MOTION FOR DAMAGING EARTHQUAKES, T. C. Bache, Systems, Science and Software, P. O. Box 1620, La Jolla, Calif. 92038, (714) 453-0060.

INTERACTIVE DATA-PROCESSING CENTER FOR USGS GROUND-MOTION STUDIES, R. D. Borcherdt, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2755.

COMPUTER SUPPORT FOR NUMERICAL MODELING OF GROUND MOTION WITHIN USGS, R. D. Borcherdt, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2755.

DYNAMIC SOIL BEHAVIOR, A. T. F. Chen, U.S. Geological Survey, Branch of Engineering Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2605.

ATTENUATION OF SEISMIC WAVES IN THE U.S., A. F. Espinosa, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-5077.

SPECTRAL- AND TIME-DOMAIN ANALYSIS OF NEAR-FIELD RECORDING, J. P. Fletcher, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2962.

REGIONAL STUDIES OF SHEAR-WAVE VELOCITIES, J. F. Gibbs, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025 (415) 323-8111, ext. 2030.

ANALYSES OF STRONG GROUND MOTION RECORDS, T. C. Hanks, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2184.

NUMERICAL MODELING OF GROUND MOTION, S. T. Harding, U.S. Geological Survey, Branch of Ground Motion and Faulting, Denver Federal Center, Denver, Colo. 80225, (303) 234-5090.

GROUND RESPONSE IN THE SALT LAKE REGION, W. W. Hays, U.S. Geological Survey, Office of Earthquake Studies, Denver Federal Center, Denver, Colo. 80225, (303) 234-4029.

GROUND-MOTION MODELING AND PREDICTION, W. B. Joyner, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2754.

APPLICATION OF EARTHQUAKE MECHANISM STUDIES TO PREDICTION OF LONG-PERIOD GROUND MOTION AND RELATED PROBLEMS, H. Kanamori, California Institute of Technology, Division of Geological and Planetary Science, Pasadena, Calif. 91125, (213) 795-6811, ext. 2909.

DATA ACQUISITION IN SUPPORT OF GROUND-MOTION PROJECTS WITHIN USGS, K. W. King, U.S. Geological Survey, Branch of Ground Motion and Faulting, 3060 South Highland Drive, Las Vegas, Nev. 89109, (702) 734-3416.

THE ROLE OF ANELASTICITY IN EARTHQUAKE GROUND MOTION, T. V. McEvilly, University of California, Department of Geology and Geophysics, Berkeley, Calif. 94720, (415) 642-4494.

IMPROVED COMPUTER PROGRAMS FOR SEISMIC-HAZARD ANALYSIS AND STUDIES OF DURATION OF SHAKING, R. K. McGuire, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-2874.

EXPECTED EARTHQUAKE INTENSITIES IN THE LOS ANGELES REGION AND STUDIES OF EARTHQUAKE RECURRENCE, R. D. Nason, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2760.

EXPANSION OF USGS COMPUTER FOR DIGITAL INPUT, R. B. Park, U.S. Geological Survey, Branch of Ground Motion and Faulting, Denver Federal Center, Denver, Colo. 80225, (303) 234-5070.

GROUND RESPONSE IN THE LOS ANGELES REGION, A. M. Rogers, U.S. Geological Survey, Branch of Ground Motion and Faulting, Denver Federal Center, Denver, Colo. 80225, (303) 234-2869.

SEISMIC RESPONSE MAPPING OF SAINT LOUIS COUNTY, R. W. Stephenson, University of Missouri, Rolla, Department of Civil Engineering, Rolla, Mo. 65401, (314) 541-4470.

ANALYSIS OF STRONG-MOTION DATA AND THE EFFECTS OF EARTHQUAKE SOURCE PARAMETERS ON GROUND MOTION IN CALIFORNIA, M. N. Toksoz, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Mass. 02139, (617) 253-6382.

INSTRUMENT DEVELOPMENT FOR GROUND-MOTION INVESTIGATIONS AND GEOTECHNICAL STUDIES, R. E. Warrick, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2757.

IMPROVED BAYESIAN SEISMIC-INTENSITY MAPS OF CALIFORNIA AND LOSS ESTIMATION FROM EARTHQUAKE SHAKING ACTION, J. H. Wiggins, J. H. Wiggins Company, 1650 S. Pacific Coast Highway, Redondo Beach, Calif. 90277, (213) 378-0257.

DIFFRACTION OF WAVES BY THREE-DIMENSIONAL SURFACE TOPOGRAPHIES AND SUBSURFACE IRREGULARITIES, H. L. Wong, University of Southern California, Department of Civil Engineering, Los Angeles, Calif. 90007, (213) 741-7090.

I.B.2. GROUND FAILURE

A STUDY OF THE BEHAVIOR OF CEMENTED SOILS UNDER SEISMIC LOADING, G. W. Clough, Stanford University, Stanford, Calif. 94305, (415) 497-4164.

A STUDY OF THE SOILS IN SAN FRANCISCO INVOLVED IN LIQUEFACTION PHENOMENA DURING THE 1906 EARTHQUAKE, G. W. Clough, Stanford University, Stanford, Calif. 94305, (415) 497-4164.

DEVELOPMENT OF TECHNIQUES FOR EVALUATING SEISMIC HAZARDS ASSOCIATED WITH EXISTING CREEPING LANDSLIDES AND OLD DAMS, R. E. Goodman, University of California, College of Engineering, Berkeley, Calif. 94720, (415) 642-5525.

EARTHQUAKE-INDUCED LANDSLIDES: INVESTIGATION OF PREDICTIVE CRITERIA, E. L. Harp, U.S. Geological Survey, Branch of Engineering Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2529.

GROUND FAILURES CAUSED BY HISTORIC EARTHQUAKES, D. K. Keefer, U.S. Geological Survey, Branch of Engineering Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2557.

SURFICIAL LANDSLIDES TRIGGERED BY SEISMIC SHAKING—SAN FERNANDO EARTHQUAKE OF 1971, F. B. Leighton, Leighton and Associates, 17975 Sky Park Circle, Irvine, Calif. 92714, (714) 556-1421.

GROUND FAILURE RELATED TO THE NEW MADRID, MISSOURI, EARTHQUAKE, S. F. Obermeier, U.S. Geological Survey, Branch of Engineering Geology, National Center Stop 926, Reston, Va. 22092, (703) 860-6469.

INTERACTIONS BETWEEN GROUND MOTION AND GROUND FAILURE, R. C. Wilson, U.S. Geological Survey, Branch of Engineering Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2967.

SEISMICALLY INDUCED SHALLOW HILLSIDE FAILURES, B. C. Yen, California State University, Department of Civil Engineering, Long Beach, Calif. 90804, (213) 498-4809.

EXPERIMENTAL MAPPING OF LIQUEFACTION POTENTIAL, L. T. Youd, U.S. Geological Survey, Branch of Engineering Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2529.

I.B.3. SURFACE FAULTING

STATISTICAL ANALYSIS AND GEOMETRY OF SURFACE FAULTING, M. G. Bonilla, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2245.

I.B.4. POSTEARTHQUAKE

SEISMOLOGICAL FIELD INVESTIGATIONS, C. J. Langer, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-5091.

POSTEARTHQUAKE FIELD INVESTIGATIONS, R. A. Page, U.S. Geological Survey, Office of Earthquake Studies, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2461.

I.C. EARTHQUAKE LOSSES

THE CONSEQUENCES OF AN EARTHQUAKE PREDICTION ON STATISTICAL ESTIMATES OF SEISMIC RISK, J. L. Anderson, University of Southern California, Department of Geological Sciences, Los Angeles, Calif. 90007, (213) 741-2099.

RELATIONS BETWEEN GROUND MOTION, LOSSES, AND DAMAGE IN STRUCTURES, R. Husid, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-2833.

SEISMIC-DAMAGE ASSESSMENT FOR HIGH RISE BUILDINGS, R. E. Scholl, John A. Blume and Associates, 130 Jessie Street, San Francisco, Calif. 94105, (415) 397-2525.

SALT LAKE CITY BUILDING INVENTORY, K. V. Steinbrugge, Insurance Services Office, 550 California Street, San Francisco, Calif. 94104, (905) 781-8828.

II. EARTHQUAKE PREDICTION STUDIES

II.A. LOCATION OF AREAS WHERE LARGE EARTHQUAKES ARE MOST LIKELY TO TAKE PLACE

II.A.1. SYNTHESES OF SEISMICITY, TECTONIC, AND SIMILAR DATA

HEAT-FLOW STUDIES, A. H. Lachenbruch, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2646 or 2272.

II.A.2 STRESS LEVEL

EARTHQUAKE HAZARDS DETERMINATIONS BASED ON TECTONIC STRESS MEASUREMENTS, C. B. Archambeau, University of Colorado, Coop. Inst. for Research in the Environmental Sciences, Boulder, Colo. 80309, (303) 492-8028.

IN SITU STRESS MEASUREMENT, M. D. Zoback, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2034.

II.B. EARTHQUAKE PRECURSORS

II.B.1. GENERAL

DEEP-WELL MONITORING OF STRAIN-SENSITIVE PARAMETERS OVER THE SOUTHERN CALIFORNIA UPLIFT, T. L. Henyey, University of Southern California, Department of Geological Sciences, Los Angeles, Calif. 90007, (213) 741-6123.

PREDICTION MONITORING AND EVALUATION, R. N. Hunter, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colo. 80225, (303) 234-4041.

INTERPRETATION OF GEOPHYSICAL DATA PREMONITORY OF EARTHQUAKES, D. Jackson, University of California, Los Angeles, Department of Earth and Space Sciences, 3806 Geology Building, Los Angeles, Calif. 90024, (213) 825-6130.

CRUSTAL-STRUCTURE, EARTHQUAKE-PREDICTION AND INDUCED-SEISMICITY STUDIES IN SOUTH CAROLINA, P. Talwani, University of South Carolina, Department of Geology, Columbia, S.C. 29208, (803) 772-6449.

II.B.2. SEISMOLOGICAL

SEISMIC SLIP STUDIES IN CENTRAL CALIFORNIA, C. Bufe, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2567.

PREEARTHQUAKE AND POSTEARTHQUAKE SEISMIC PHENOMENA OF THE NOVEMBER 29, 1975, HAWAII EARTHQUAKE, R. S. Crosson, University of Washington, Geophysics Program, College of Arts and Sciences, Seattle, Wash. 98195, (206) 543-6505.

TELESEISMIC SEARCH FOR SEISMIC PRECURSORS, J. W. Dewey, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colo. 80225, (303) 234-4041.

GARM, U.S.S.R., SOURCE MECHANISM STUDIES, F. G. Fischer, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2321.

SEISMICITY AND SEISMIC-VELOCITY STUDIES AND CRUSTAL STRUCTURE IN SOUTHERN CALIFORNIA, H. Kanamori, California Institute of Technology, Division of Geological and Planetary Sciences, Seismological Laboratory, Pasadena, Calif. 91125, (213) 795-6811, ext. 2914.

HAWAIIAN SEISMIC STUDIES, F. W. Klein, U.S. Geological Survey, Branch of Field Geochemistry and Petrology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2321.

MICROEARTHQUAKE DATA ANALYSIS, W. H. K. Lee, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2630.

PREMONITORY AMPLITUDE CHANGES, A. Lindh, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2042.

IN SITU SEISMIC-WAVE VELOCITY MONITORING, T. V. McEvilly, University of California, Department of Geology and Geophysics, Berkeley, Calif. 94720, (415) 642-4494.

CHARACTERISTICS OF FORESHOCKS, P. Molnar, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Mass. 02139, (617) 253-5924.

CONTINUOUS MONITORING OF CRUSTAL VELOCITY CHANGES ON THE PALMDALE UPLIFT, R. A. Phinney, Princeton University, Department of Geological and Geophysical Sciences, Princeton, N. J. 08540, (609) 452-4118.

II.B.3. GROUND DEFORMATION, TILT, AND STRAIN

EARTHQUAKE PREDICTION AND CREEP AND STRAIN STUDIES IN SOUTHERN CALIFORNIA, C. R. Allen, California Institute of Technology, Division of Geology and Planetary Sciences, Seismological Laboratory, Pasadena, Calif. 91125, (213) 795-6811, ext. 2904.

OPERATION OF PINON FLAT OBSERVATORY, J. Berger, University of California at San Diego, Institute of Geophysics and Planetary Physics, La Jolla, Calif. 92093, (714) 452-2889.

FAULT-ZONE TECTONICS, R. O. Burford, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2574

CONTINUED MONITORING OF STRESS CHANGES NEAR ACTIVE FAULTS, B. R. Clark, Leighton and Associates, 17975 Sky Park Circle, Irvine, Calif. 92714, (714) 556-1421.

CONSTRUCTION AND USE OF A TRANSPORTABLE VERY LONG BASE LINE INTERFEROMETRY ELECTRONICS SYSTEM TO MONITOR TRANSCONTINENTAL STRAIN ACCUMULATION AND THE ROTATION OF THE EARTH, C. C. Counselman III, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Mass. 02139, (617) 253-7902.

THREE-DIMENSIONAL INTER-STATION COORDINATES TO ONE CENTIMETER, P. R. Escobal, Universal Data Systems, Inc., 1451 Quail Street, Newport Beach, Calif. 92660, (714) 752-7634.

IMPROVED STRESS-DETERMINATION PROCEDURES BY HYDRAULIC FRACTURING, C. Fairhurst, University of Minnesota, Department of Civil and Mineral Engineering, Minneapolis, Minn. 55456, (612) 373-3135.

TILT MEASUREMENTS IN THE NEW HEBRIDES ISLAND ARC: SEARCH FOR PRECURSERS AND OTHER ASEISMIC DEFORMATIONS RELATED TO EARTHQUAKE GENERATION IN A ZONE OF LITHOSPHERE SUBDUCTION, B. L. Isacks, Cornell University, Department of Geological Sciences, Ithaca, N.Y. 14853, (607) 256-2307.

TILT, STRAIN, MAGNETIC, AND TELLURIC MEASUREMENTS, M. Johnston, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2132.

RELEVELING OF SOUTHERN CALIFORNIA, M. Kumar, NOAA, National Geodetic Survey, Vertical Networks Branch, 6001 Executive Boulevard, Rockville, Md. 20852, (301) 443-8100.

DIRECT DETERMINATION OF STRAIN ACCUMULATION NEAR ACTIVE FAULTS FROM MEASURED GEODETIC DATA, R. D. Lynch, Computer Sciences Corporation, 6565 Arlington Blvd., Falls Church, Va. 22046, (202) 533-8877, ext. 6249.

MEKOMETER MEASUREMENTS IN THE IMPERIAL VALLEY, R. G. Mason, Imperial College of Science and Technology, Geology Department, London SW7 2BP, England.

GEODETIC STRAIN MONITORING, A. McGarr, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2708.

TILT OPERATIONS, C. Mortensen, U.S. Geological Survey, Branch of Techonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2583.

RECENT VERTICAL MOVEMENTS OF THE CRUST IN THE WESTERN U.S.: REDUCTION AND ANALYSIS OF LEVELING DATA AND ITS INTERPRETATION IN LIGHT OF RELATED SEISMOLOGICAL AND GEOLOGICAL INFORMATION, J. E. Oliver, Cornell University, Department of Geological Sciences, Ithaca, N.Y. 14853, (607) 256-2377.

CRUSTAL-STRAIN MEASUREMENTS AND ANALYSIS, J. C. Savage, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2633.

MULTI-WAVELENGTH DISTANCE MEASUREMENTS OF STRAIN IN CENTRAL CALIFORNIA, L. E. Slater, University of Washington, Applied Physics Laboratory, Seattle, Wash. 98105, (206) 543-1255.

TILTMETER RESEARCH IN NEW MADRID, MISSOURI, AND ADAK, ALASKA, W. Stauder, Saint Louis University, Department of Earth and Atmospheric Sciences, St. Louis, Mo. 63103, (314) 535-3300, ext. 206.

DRY-TILT AND NEAR-FIELD GEODETIC INVESTIGATIONS OF CRUSTAL MOVEMENTS, SOUTHERN CALIFORNIA, A. G. Sylvester, University of California, Santa Barbara, Marine Science Institute, Santa Barbara, Calif. 93106, (805) 961-3471.

DEPLOYMENT OF INSTRUMENTS TO MEASURE TECTONIC STRESS CHANGES IN THE SOUTHERN CALIFORNIA UPLIFT, H. S. Swolfs, Terra Tek, Inc., 420 Wakara Way, Salt Lake City, Utah 84108, (801) 582-2220.

PALEOGEODETICS, W. Thatcher, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2120.

POSTEARTHQUAKE DEFORMATION MONITORING, W. Thatcher, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2120.

SIGNAL ENHANCEMENT AND PREDICTION OF LOW-FREQUENCY MEASUREMENTS, M. D. Wood, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2595.

II.B.4. GRAVITY

DEVELOPMENT OF A PORTABLE ABSOLUTE GRAVIMETER WITH MICROGAL SENSITIVITY, J. E. Faller, University of Colorado, Joint Inst. for Lab. Astrophysics, Boulder, Colo. 80309, (303) 492-6793.

EVALUATION OF A GRAVIMETRIC TECHNIQUE AS AN EARTHQUAKE PRECURSOR METHOD ALONG THE SAN JACINTO AND SAN ANDREAS FAULT ZONES IN CALIFORNIA, J. D. Fett, Earth Science and Engineering, 27595 Santa Fe Street, Hemet, Calif. 92343, (714) 658-7509.

CONTINUOUS GRAVITY MEASUREMENTS IN THE REGION OF THE PALMDALE UPLIFT, J. M. Goodkind, University of California, Department of Physics, La Jolla, Calif. 92093, (714) 542-3666.

SOUTHERN CALIFORNIA GRAVITY SURVEYS AND ANALYSIS, R. C. Jachens, U.S. Geological Survey, Branch of Regional Geophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2168.

WATER-MASS AND GRAVITY VARIATIONS IN THE MISSISSIPPI VALLEY EARTHQUAKE BELT, L. D. McGinnis, Northern Illinois University, DeKalb, Ill. 60115, (815) 753-1944.

II.B.5. MAGNETIC

NOISE-REDUCTION TECHNIQUES FOR TECTONOMAGNETIC STUDIES, P. L. Bender, University of Colorado, Joint Inst. for Lab. Astrophysics, Boulder, Colo. 80309, (303) 492-6793.

MAGNETIC FIELD OBSERVATIONS, B. E. Smith, QUAKE PREDICTIONS, M. D. Fuller, University of California, Santa Barbara, Department of Geological Sciences, Santa Barbara, Calif. 93106, (805) 961-3158.

MAGNETOMETER ARRAY IN PALMDALE BULGE REGION, D. Jackson, University of California, Los Angeles, Institute of Geophysics and Planetary Physics, Los Angeles, Calif. 90024, (213) 825-1776.

MAGNETIC FIELD OBSERVATIONS, B. E. Smith, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2533.

A PROPOSAL TO INVESTIGATE THE PALMDALE UPLIFT USING DIFFERENTIAL MAGNETIC FIELD MONITORING OF TECTONIC STRESS, F. J. Williams, San Bernardino Valley College, Division of Mathematics and Physical Science, 701 South Mount Vernon Avenue, San Bernardino, Calif. 92403, (714) 885-0231.

II.B.6. ELECTRICAL

ELECTRICAL CONDUCTIVITY SOUNDING EXPERIMENTS IN SEISMICALLY ACTIVE AREAS, A. F. Kuckes, Cornell University, School of Applied Engineering Physics, College of Engineering, Ithaca, N.Y. 14853, (607) 256-4949.

HIGH-SENSITIVITY MONITORING OF RESISTIVITY AND SELF-POTENTIAL VARIATION IN THE PALMDALE AND HOLLISTER AREAS FOR EARTHQUAKE PREDICTION STUDIES, T. R. Madden, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Mass. 02139, (617) 253-6384.

TEMPORAL VARIATIONS OF ELECTRICAL RESISTIVITY AND ELECTRIC FIELDS ON THE SAN ANDREAS FAULT, F. Morrison, University of California, Berkeley, Department of Engineering Sciences, Berkeley, Calif. 94720, (415) 642-3804.

II.B.7. GEOCHEMICAL

INVESTIGATION OF RADON AND HELIUM AS POSSIBLE FLUID-PHASE PRECURSORS TO EARTHQUAKES, H. Craig, University of California, San Diego, Geological Research Division, Scripps Institute of Oceanography, La Jolla, Calif. 92093, (714) 452-3260.

ASSESSMENT OF THE U234/U238 ACTIVITY RATIO AS A POSSIBLE EARTHQUAKE PRECURSOR, R. C. Finkel, University of California, San Diego, Mt. Soledad Radioisotope Lab., S–002, La Jolla, Calif. 92037, (714) 452-2662.

LIGHT STABLE ISOTOPES, I. Friedman, U.S. Geological Survey, Branch of Isotope Geology, Box 25046, Denver Federal Center, Denver, Colo. 80225, (303) 234-3876.

DETERMINATION OF RADON FLUCTUATIONS AND AN ANALYSIS OF THE CONTRIBUTING FACTORS IN THE NORTHERN MISSISSIPPI EMBAYMENT, W. C. Hood, Southern Illinois University, Department of Geology, Carbondale, Ill. 62901, (618) 453-3351.

RADON AND WATER-WELL MONITORING, Chi-Yu King, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2706.

RADON ANALYSIS FOR SOUTHERN CALIFORNIA EARTHQUAKE PREDICTION, W. F. Libby, University of California, Los Angeles, Institute of Geophysics and Planetary Physics, Los Angeles, Calif. 90024, (213) 825-1881.

OXYGEN ISOTOPES, J. O'Neil, U.S. Geological Survey, Branch of Isotope Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2598.

HELIUM MONITORING FOR EARTHQUAKE PREDICTION, G. M. Reimer, U.S. Geological Survey, Branch of Uranium and Thorium, Box 25046, Denver Federal Center, Denver, Colo. 80225, (303) 234-5146.

GROUND WATER RADON CONTENT AS AN EARTHQUAKE PRECURSOR—CONTROLLED EXPERIMENTS AND FIELD STUDIES ALONG THE SAN ANDREAS FAULT FROM CAJON TO GORMAN, T. Teng, University of Southern California, Department of Geological Sciences, Los Angeles, Calif. 90007, (213) 741-6124.

II.B.8. WATER LEVEL

WATER-LEVEL MONITORING IN THE AREA OF THE PALMDALE UPLIFT AND SAN JACINTO FAULT ZONE, SOUTHERN CALIFORNIA, D. L. Lamar, California Earth Science Corporation, 1318 Second Street, Santa Monica, Calif. 90401, (213) 395-4528.

GROUND-WATER ANALYSIS, W. R. Moyle, Jr., U.S. Geological Survey, Water Resources Division, 24000 Avila Road, Laguna Niguel, Calif. 92677, (714) 831-4232.

STOCHASTIC SIGNAL PROCESSING AND ANALYSIS OF WATER-LEVEL DATA, P. Westlake, Environmental Dynamics, Inc., 1609 Westwood Blvd., Los Angeles, Calif. 90024, (213) 477-6277.

II.B.9. ANIMAL BEHAVIOR

BIOLOGICAL PREMONITORS OF EARTHQUAKES —A VALIDATION STUDY, L. S. Otis, Stanford Research Institute, Psychobiology and Physiology Department, Life Sciences Division, Menlo Park, Calif. 94025, (415) 326-6200.

CAN ANIMALS PREDICT EARTHQUAKES?, D. D. Skiles, University of California, Los Angeles, Institute of Geophysics and Planetary Physics, Los Angeles, Calif. 90024, (213) 825-2803.

BASE-LINE STUDIES OF THE FEASIBILITY AND RELIABILITY OF USING ANIMAL BEHAVIOR AS A COMPONENT IN THE PREDICTION OF EARTHQUAKES, K. L. Verosub, University of California, Davis, Department of Geology, Davis, Calif. 95616, (916) 752-6911.

II.C. DATA PROCESSING

PROCESSING OF MICROEARTHQUAKE DATA FOR EARTHQUAKE PREDICTION, K. Aki, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Mass. 02139, (617) 253-6397.

ESTABLISHMENT OF A SOUTHERN CALIFORNIA GEOPHYSICAL DATA ANALYSIS CENTER, D. G. Harkrider, California Institute of Technology, Division of Geological and Planetary Sciences, Seismological Laboratory, Pasadena, Calif. 91125, (213) 795-6811, ext. 2908.

NUMERICAL METHODS IN SEISMOLOGY: RAY-TRACING AND INVERSE PROBLEMS, H. B. Keller, California Institute of Technology, Division of Applied Science, Pasadena, Calif. 91125, (213) 795-6811.

DATA PROCESSING SERVICES, C. Lee, U.S. Geological Survey, Branch of Network Operations, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2080.

NETWORK SEISMIC DATA PROCESSING SYSTEMS, J.H. Pfluke, U.S. Geological Survey, Office of Earthquake Studies, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2034.

REDUCTION OF NOISE IN EARTHQUAKE PRECURSOR MEASUREMENTS, J. A. Steppe, U.S. Geological Survey, Branch of Tectonophyiscs, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2570.

MINICOMPUTER SYSTEMS DEVELOPMENT, P. R. Stevenson, U.S. Geological Survey, Branch of Network Operations, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2572.

II.D. COMPUTER MODELING

THEORETICAL MECHANICS OF EARTHQUAKE PRECURSORS, W. D. Stuart, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2756.

III. INDUCED-SEISMICITY STUDIES

GEOLOGIC/HYDROLOGIC INVESTIGATIONS TO IMPROVE UNDERSTANDING OF RESERVOIR-INDUCED SEISMICITY, R. M. Barker, U.S. Geological Survey, Office of Environmental Geology, National Center Stop 908, Reston, Va. 22092, (703) 860-6413.

STUDY OF RESERVOIR-INDUCED SEISMICITY, L. C. Cluff, Woodward-Clyde Consultants, 3 Embarcadero, San Francisco, Calif. 94111, (415) 956-7070.

STRESS AND HYDROLOGIC STUDIES ON SHALLOW HOLES IN SOUTH CAROLINA, R. M. Hamilton, U.S. Geological Survey, Office of Earthquake Studies, National Center Stop 905, Reston, Va. 22092, (703) 860-6471.

ACQUISITION OF DRILL RIG, C. B. Raleigh, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2893.

INDUCED SEISMICITY AT TOKTOGUL RESERVOIR, U.S.S.R., AND SEISMOTECTONICS OF THE TALAS-FERGANA FAULT, D. W. Simpson, Lamont-Doherty Geological Observatory of Columbia University, Palisades, N. Y. 10964, (914) 359-2900.

A STATISTICAL APPROACH TO RESERVOIR-INDUCED SEISMICITY, D. E. Stuart-Alexander, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2929.

IV. STUDIES IN COMMON SUPPORT OF HAZARDS, PREDICTION, AND INDUCED-SEISMICITY ELEMENTS

IV.A. SEISMICITY AND SEISMIC NETWORKS

LAMONT-DOHERTY NETWORK OF STATIONS IN NEW YORK STATE AND ADJACENT AREAS, Y. P. Aggarwal, Lamont-Doherty Geological Observatory of Columbia University, Palisades, N. Y. 10964, (914) 359-2900.

SOUTHERN CALIFORNIA SEISMIC ARRAYS, C. R. Allen, California Institute of Technology, Division of Geological and Planetary Sciences, Seismological Laboratory, Pasadena, Calif. 91125, (213) 795-6811, ext. 2904.

MICROPROCESSOR-BASED SEISMIC PROCESSING, R. V. Allen, U.S. Geological Survey, Branch of Network Operations, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2240.

EARTHQUAKE HAZARD STUDIES IN THE PACIFIC NORTHWEST, R. S. Crosson, University of Washington, Geophysics Program, College of Arts and Sciences, Seattle, Wash. 98195, (206) 543-8020.

OPERATION OF A SEISMIC-DATA COLLECTION AND ANALYSIS CENTER IN ALASKA, T. N. Davis, University of Alaska, Geophysical Institute, Fairbanks, Alaska 99701, (907) 479-7010.

IMPROVED U.S. EARTHQUAKE CATALOG, J. W. Dewey, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colo. 80225, (303) 234-4041.

CENTRAL CALIFORNIA SEISMIC NETWORK, J. P. Eaton, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2575.

A FIELD STUDY OF EARTHQUAKE PREDICTION METHODS IN THE CENTRAL ALEUTIAN ISLANDS, C. Kisslinger, University of Colorado, Coop. Inst. for Research in the Environmental Sciences, Boulder, Colo. 80309, (303) 492-8028.

SOUTHERN CALIFORNIA COOPERATIVE SEISMIC NETWORK, G. Fuis, U.S. Geological Survey, Branch of Seismology, c/o California Institute of Technology, Seismological Laboratory, Pasadena, Calif. 91125, (213) 795-6811, ext. 2956.

CENTRAL CALIFORNIA NETWORK OPERATIONS, W. D. Hall, U.S. Geological Survey, Branch of Network Operations, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2897.

CENTRAL AMERICAN SEISMIC STUDIES, D. H. Harlow, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2570.

ENHANCEMENT OF DATA ACQUISITION IN THE NEW MADRID SEISMIC ZONE, R. B. Herrmann, St. Louis University, Earth and Atmospheric Science Department, 221 North Grand Blvd., St. Louis, Mo. 63103, (314) 535-3300.

EARTHQUAKE PREDICTION STUDY AT THE TARBELA AND CHASHMA SEISMIC NETWORKS, PAKISTAN, K. H. Jacob, Lamont-Doherty Geological Observatory of Columbia University, Palisades, N. Y. 10964, (914) 359-2900.

SEISMICITY OF THE RIO GRANDE RIFT, L. H. Jaksha, U.S. Geological Survey, Branch of Global Seismology, Seismological Center, Kirtland AFB, East Bldg., Albuquerque, N. Mex. 87115, (505) 264-4637.

HAWAIIAN SEISMIC STUDIES SUPPORT, F. W. Klein, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2569.

SOUTHERN ALASKA SEISMIC STUDIES, J. C. Lahr, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2510.

PUERTO RICO SEISMIC PROGRAM, C. J. Langer, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-5091.

SEISMIC DATA LIBRARY OF WWSSN (Worldwide Standardized Seismograph Network) SEISMOGRAMS, W. H. K. Lee, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2630.

A COMPILATION OF NORTH AMERICAN STRESS DETERMINATIONS, F. J. Mauk, University of Michigan, Department of Geology and Mineralogy, Ann Arbor, Mich. 48109, (313) 764-2428.

NETWORK INSTALLATION, PERMITS, AND SUPPLIES, H. Mills, Branch of Network Operations, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2112.

A STUDY OF EARTHQUAKE PREDICTION AND THE TECTONICS OF THE NORTHEASTERN CARIBBEAN: A CONTINUING EXPERIMENT IN TWO MAJOR SEISMIC GAPS, A. J. Murphy, Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y. 10964, (914) 359-2900.

NATIONAL SEISMIC NETWORK FEASIBILITY STUDY, J. R. Peterson, U.S. Geological Survey, Branch of Global Seismology, Seismological Center, Kirtland AFB, East Bldg, Albuquerque, N. Mex. 10002, (505) 264-4637.

COORDINATION OF NORTHEAST U.S. SEISMIC NETWORK, P. W. Pomeroy, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, P.O. Box 224, Stone Ridge, N.Y. 12484, (914) 687-9150.

EARTHQUAKE RESEARCH AND NETWORK OPERATIONS IN THE INTERMOUNTAIN BELT-WASATCH FRONT, R. S. Smith, University of Utah, Salt Lake City, Utah 84112, (801) 581-7129.

EARTHQUAKE HAZARD STUDIES IN SOUTHEAST MISSOURI, W. Stauder, Saint Louis University, Department of Earth and Atmospheric Sciences, St. Louis, Mo. 63103, (314) 535-3300, ext. 206.

TOPICAL SEISMICITY STUDIES, A. C. Tarr, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colo. 80225, (303) 234-5078.

EARTHQUAKE HAZARD RESEARCH IN THE GREATER LOS ANGELES BASIN AND ITS OFFSHORE AREA, T. Teng, University of Southern California, Department of Geological Sciences, Los Angeles, Calif. 90007, (213) 741-6124.

COMPILATION OF PRE-1900 CALIFORNIA EARTHQUAKE HISTORY AND RELOCATION OF SELECTED INSTRUMENTALLY RECORDED EARTHQUAKES, T. R. Toppozada, State of California, Division of Mines and Geology, Resources Building, 1416 Ninth Street, Sacramento, Calif. 95814, (916) 445-1825.

INSTRUMENT DEVELOPMENT AND QUALITY CONTROL, J. Van Schaack, U.S. Geological Survey, Branch of Network Operations, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2584.

SEISMIC-HAZARD EVALUATION OF LARGE KNOWN AND SUSPECTED ACTIVE FAULTS IN WESTERN NEVADA, J. D. Van Wormer, University of Nevada, Mackay School of Mines, Seismological Laboratory, Reno, Nev. 89507, (702) 784-4975.

IV.B. PHYSICAL BASIS OF EARTHQUAKES

IV.B.1. PHYSICAL PROPERTIES OF THE CRUST AND UPPER MANTLE

MECHANICAL PROCESSES OF CRUSTAL FAULTING, A. D. M. Barnett, Stanford University, Department of Materials Sciences, Stanford, Calif. 94305, (415) 497-3716.

SEISMIC STUDIES OF FAULT MECHANICS, W. L. Ellsworth, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2778.

FAULT-ZONE STRUCTURE, J. Healy, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2535.

ACTIVE SEISMOLOGY APPLIED TO FAULT-ZONE PROPERTIES, D. P. Hill, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2139.

SEISMIC-REFLECTION MEASUREMENTS NEAR THE SAN ANDREAS FAULT, T. V. McEvilly, University of California, Department of Geology and Geophysics, Berkeley, Calif. 94720, (415) 642-4494.

THEORETICAL STUDIES OF THE ROLE OF PORE FLUID IN PREMONITORY PHENOMENA, J. B. Minster, California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, Calif. 91125, (213) 795-6811, ext. 2950.

HETEROGENEITY, PORE PRESSURE, AND DILATANCY IN CRUSTAL FAULTING, A. Nur, Stanford University, Department of Geophysics, Stanford, Calif. 94305, (415) 497-3716.

MECHANICS OF GEOLOGIC STRUCTURES ASSOCIATED WITH FAULTING, D. Pollard, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2635.

INTENSIVE STUDIES OF FAULT-ZONE PROPERTIES AND DRILLING IN THE SAN ANDREAS FAULT ZONE, C. B. Raleigh, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2893.

PALEODYNAMICS OF FAULTING, C. B. Raleigh, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2893.

COHERENT SEISMIC WAVE ANALYSIS, P. A. Reasenberg, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2049.

CRUSTAL INHOMOGENEITY IN SEISMICALLY ACTIVE AREAS, S. W. Stewart, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2525.

IV.B.2. LABORATORY

FABRIC, TEXTURAL CHARACTERISTICS, MINERALOGY, AND PETROCHEMISTRY OF INTRAFAULT MATERIAL ALONG THE SAN ANDREAS FAULT IN THE AREA OF THE PALMDALE UPLIFT, SOUTHERN CALIFORNIA, J. L. Anderson, University of Southern California, Department of Geological Sciences, Los Angeles, Calif. 90007, (213) 741-2717.

STRESS CORROSION CRACKING IN PREMONITORY EARTHQUAKE EVENTS, O. L. Anderson, University of California, Los Angeles, Institute of Geophysics and Planetary Physics, Los Angeles, Calif. 90024, (213) 825-2386.

DILATANCY AND MAGNETIC PROPERTIES OF ROCKS UNDER NONHYDROSTATIC STRESS, C. B. Archambeau, University of Colorado, Coop. Inst. for Research in the Environmental Sciences, Boulder, Colo. 80309, (303) 492-8028.

SOME SPECIFIC EXPERIMENTAL AND FIELD STUDIES PERTAINING DIRECTLY TO THE MECHANISMS OF SEISMIC AND ASEISMIC FAULTING, B. K. Atkinson, Imperial College of Science and Technology, Department of Geology, Royal School of Mines, Prince Consort Road, London SW7 2BP, England.

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TRANSIENT CREEP AND SEMIBRITTLE BEHAVIOR OF ROCKS, N. L. Carter, State University of New York, Stony Brook, N.Y. 11794, (516) 246-5945.

MECHANICS OF EARTHQUAKE FAULTING, J. Dieterich, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2573.

RECRYSTALLIZED GRAIN SIZE IN DUCTILE FAULT (MYLONITE) ZONES, M. A. Etheridge, Monash University, Department of Earth Sciences, Clayton, Victoria, Australia 3168, 03 541 0811, ext. 3791.

MACHINE SHOP, K. R. Harper, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2586.

EXPERIMENTAL ROCK MECHANICS, S. H. Kirby, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2872.

LABORATORY AND FIELD INVESTIGATIONS OF FAULT GOUGE, J. M. Logan, Texas A & M University, Center for Tectonophysics, College of Geosciences, College Station, Tex. 77843, (713) 845-3251.

FUNDAMENTALS OF DEFORMATION AND RUPTURE PROCESSES IN POROUS GEOLOGICAL MATERIALS (WITH APPLICATION TO EARTHQUAKE PREMONITORY EVENTS AND SOURCE MECHANISMS), J. R. Rice, Brown University, Division of Engineering, Providence, R.I. 02912, (401) 863-2886.

A STUDY OF THE ROLE OF PREMONITORY CREEP IN THE MECHANISM OF STICKSLIP FRICTION IN ROCKS, C. H. Scholz, Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y. 10964, (914) 359-2900.

EARTHQUAKE-RISK ANALYSIS USING NUMERICAL AND STOCHASTIC MODELS OF TIME-DEPENDENT STRAIN FIELDS, A. T. Smith, University of California, Santa Cruz, Division of Natural Sciences, Applied Science Building, Santa Cruz, Calif. 95064, (408) 429-2225.

EXPERIMENTAL SOURCE MECHANICS, R. Stewart, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2041.

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AN EXPERIMENTAL STUDY OF THE RHEOLOGY OF CRUSTAL ROCKS, J. Tullis, Brown University, Department of Geological Sciences, Providence, R.I. 02912, (401) 863-2240.

ELASTIC MODULUS, ELECTRICAL CONDUCTIVITY, AND FLUID PERMEABILITY IN ROCK, J. B. Walsh, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Mass. 02139, (617) 253-3381.

ELECTRICAL-RESISTIVITY AND PORE-WATER-PRESSURE CHANGES IN FRACTURED ROCKS DURING FRICTIONAL SLIDING: EFFECTS OF FAULT GOUGE ON THE SLIDING SURFACE, C. Y. Wang, University of California, Department of Geology and Geophysics, Berkeley, Calif. 94720, (415) 642-2288.

ROCK MECHANICAL INVESTIGATION OF FAULT GOUGE, C. Y. Wang, University of California, Department of Geology and Geophysics, Berkeley, Calif. 94720, (415) 642-2288.

ROLE OF FAULT GOUGE IN THE MECHANICS OF FAULTING, F. T. Wu, State University of New York, Binghamton, Department of Geological Sciences, Binghamton, N.Y. 13901, (607) 798-2512.

IV.B.3. SOURCE MECHANICS

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SPECTRAL- AND TIME-DOMAIN ANALYSIS OF NEAR-FIELD RECORDING OF EARTHQUAKES, J. P. Fletcher, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2962.

V. GLOBAL SEISMOLOGY STUDIES

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INVERSION OF DISPERSED SEISMOGRAMS, M. W. Major, Department of Geophysics, Colorado School of Mines, Golden, Colo. 80401, (303) 279-0300, ext. 262.

TOPICAL STUDIES IN GEOPHYSICS, L. C. Pakiser, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colo. 80225, (303) 234-2625.

SEISMICITY AND TECTONICS, W. J. Spence, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colo. 80225, (303) 234-4041.

V.B. SEISMOGRAPH STATION OPERATION AND DESIGN

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VI. GENERAL STUDIES

WORKSHOPS ON HAZARDS AND PREDICTION, J. F. Evernden, R. A. Page, P. L. Ward, U.S. Geological Survey, Office of Earthquake Studies, 345 Middlefield Road, Menlo Park, Calif. 94025, (415) 323-8111, ext. 2764.

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APPENDIX

EARTHQUAKE HAZARDS REDUCTION ACT OF 1977

Public Law 95-124
95th Congress

An Act

Oct. 7, 1977
[S. 126]

To reduce the hazards of earthquakes, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Earthquake Hazards Reduction Act of 1977.
42 USC 7701 note.

SECTION 1. SHORT TITLE.

That this Act may be cited as the "Earthquake Hazards Reduction Act of 1977".

42 USC 7701.

SEC. 2. FINDINGS.

The Congress finds and declares the following:

(1) All 50 States are vulnerable to the hazards of earthquakes, and at least 39 of them are subject to major or moderate seismic risk, including Alaska, California, Hawaii, Illinois, Massachusetts, Missouri, Montana, Nevada, New Jersey, New York, South Carolina, Utah, and Washington. A large portion of the population of the United States lives in areas vulnerable to earthquake hazards.

(2) Earthquakes have caused, and can cause in the future, enormous loss of life, injury, destruction of property, and economic and social disruption. With respect to future earthquakes, such loss, destruction, and disruption can be substantially reduced through the development and implementation of earthquake hazards reduction measures, including (A) improved design and construction methods and practices, (B) land-use controls and redevelopment, (C) prediction techniques and early-warning systems, (D) coordinated emergency preparedness plans, and (E) public education and involvement programs.

(3) An expertly staffed and adequately financed earthquake hazards reduction program, based on Federal, State, local, and private research, planning, decisionmaking, and contributions would reduce the risk of such loss, destruction, and disruption in seismic areas by an amount far greater than the cost of such program.

(4) A well-funded seismological research program in earthquake prediction could provide data adequate for the design, of an operational system that could predict accurately the time, place, magnitude, and physical effects of earthquakes in selected areas of the United States.

(5) An operational earthquake prediction system can produce significant social, economic, legal, and political consequences.

(6) There is a scientific basis for hypothesizing that major earthquakes may be moderated, in at least some seismic areas, by application of the findings of earthquake control and seismological research.

(7) The implementation of earthquake hazards reduction measures would, as an added benefit, also reduce the risk of loss, destruction, and disruption from other natural hazards and manmade hazards, including hurricanes, tornadoes, accidents, explosions, landslides, building and structural cave-ins, and fires.

(8) Reduction of loss, destruction, and disruption from earthquakes will depend on the actions of individuals, and organiza-

tions in the private sector and governmental units at Federal, State, and local levels. The current capability to transfer knowledge and information to these sectors is insufficient. Improved mechanisms are needed to translate existing information and research findings into reasonable and usable specifications, criteria, and practices so that individuals, organizations, and governmental units may make informed decisions and take appropriate actions.

(9) Severe earthquakes are a worldwide problem. Since damaging earthquakes occur infrequently in any one nation, international cooperation is desirable for mutual learning from limited experiences.

(10) An effective Federal program in earthquake hazards reduction will require input from and review by persons outside the Federal Government expert in the sciences of earthquake hazards reduction and in the practical application of earthquake hazards reduction measures.

SEC. 3. PURPOSE. 42 USC 7702.

It is the purpose of the Congress in this Act to reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program.

SEC. 4. DEFINITIONS. 42 USC 7703.

As used in this Act, unless the context otherwise requires:

(1) The term "includes" and variants thereof should be read as if the phrase "but is not limited to" were also set forth.

(2) The term "program" means the earthquake hazards reduction program established under section 5.

(3) The term "seismic" and variants thereof mean having to do with, or caused by earthquakes.

(4) The term "State" means each of the States of the United States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, the Commonwealth of the Mariana Islands, and any other territory or possession of the United States.

(5) The term "United States" means, when used in a geographical sense, all of the States as defined in section 4(4).

SEC. 5. NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM. 42 USC 7704.

(a) ESTABLISHMENT.—The President shall establish and maintain, in accordance with the provisions and policy of this Act, a coordinated earthquake hazards reduction program, which shall—

(1) be designed and administered to achieve the objectives set forth in subsection (c);

(2) involve, where appropriate, each of the agencies listed in subsection (d); and

(3) include each of the elements described in subsection (e), the implementation plan described in subsection (f), and the assistance to the States specified in subsection (g).

(b) DUTIES.—The President shall—

(1) within 30 days after the date of enactment of this Act, designate the Federal department, agency, or entity responsible for the development of the implementation plan described in subsection (f);

(2) within 210 days after such date of enactment, submit to the appropriate authorizing committees of the Congress the implementation plan described in subsection (f); and

Plan, submittal to congressional committees.

(3) by rule, within 300 days after such date of enactment—

(A) designate the Federal department, agency, or interagency group which shall have primary responsibility for the development and implementation of the earthquake hazards reduction program;

(B) assign and specify the role and responsibility of each appropriate Federal department, agency, and entity with respect to each object and element of the program;

(C) establish goals, priorities, and target dates for implementation of the program;

(D) provide a method for cooperation and coordination with, and assistance (to the extent of available resources) to, interested governmental entities in all States, particularly those containing areas of high or moderate seismic risk; and

(E) provide for qualified staffing for the program and its components.

(c) OBJECTIVES.—The objectives of the earthquake hazards reduction program shall include—

Earthquake resistant construction.

(1) the development of technologically and economically feasible design and construction methods and procedures to make new and existing structures, in areas of seismic risk, earthquake resistant, giving priority to the development of such methods and procedures for nuclear power generating plants, dams, hospitals, schools, public utilities, public safety structures, high occupancy buildings, and other structures which are especially needed in time of disaster;

Earthquake prediction.

(2) the implementation in all areas of high or moderate seismic risk, of a system (including personnel, technology, and procedures) for predicting damaging earthquakes and for identifying, evaluating, and accurately characterizing seismic hazards;

Model codes.

(3) the development, publication, and promotion, in conjunction with State and local officials and professional organizations, of model codes and other means to coordinate information about seismic risk with land-use policy decisions and building activity;

Earthquake-related issues, understanding.

(4) the development, in areas of seismic risk, of improved understanding of, and capability with respect to, earthquake-related issues, including methods of controlling the risks from earthquakes, planning to prevent such risks, disseminating warnings of earthquakes, organizing emergency services, and planning for reconstruction and redevelopment after an earthquake;

(5) the education of the public, including State and local officials, as to earthquake phenomena, the identification of locations and structures which are especially susceptible to earthquake damage, ways to reduce the adverse consequences of an earthquake, and related matters;

Research.

(6) the development of research on—

(A) ways to increase the use of existing scientific and engineering knowledge to mitigate earthquake hazards;

(B) the social, economic, legal, and political consequences of earthquake prediction; and

(C) ways to assure the availability of earthquake insurance or some functional substitute; and

(7) the development of basic and applied research leading to a better understanding of the control or alteration of seismic phenomena.

(d) PARTICIPATION.—In assigning the role and responsibility of Federal departments, agencies, and entities under subsection (b)(3)(B), the President shall, where appropriate, include the United States Geological Survey, the National Science Foundation, the Department of Defense, the Department of Housing and Urban Development, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the Energy Research and Development Administration, the Nuclear Regulatory Commission, and the National Fire Prevention and Control Administration.

(e) RESEARCH ELEMENTS.—The research elements of the program shall include—

(1) research into the basic causes and mechanisms of earthquakes;

(2) development of methods to predict the time, place, and magnitude of future earthquakes;

(3) development of an understanding of the circumstances in which earthquakes might be artificially induced by the injection of fluids in deep wells, by the impoundment of reservoirs, or by other means;

(4) evaluation of methods that may lead to the development of a capability to modify or control earthquakes in certain regions;

(5) development of information and guidelines for zoning land in light of seismic risk in all parts of the United States and preparation of seismic risk analyses useful for emergency planning and community preparedness;

(6) development of techniques for the delineation and evaluation of the political effects of earthquakes, and their application on a regional basis;

(7) development of methods for planning, design, construction, rehabilitation, and utilization of manmade works so as to effectively resist the hazards imposed by earthquakes;

(8) exploration of possible social and economic adjustments that could be made to reduce earthquake vulnerability and to exploit effectively existing and developing earthquake mitigation techniques; and

(9) studies of foreign experience with all aspects of earthquakes.

(f) IMPLEMENTATION PLAN.—The President shall develop, through the Federal agency, department, or entity designated under subsection (b)(1), an implementation plan which shall set year-by-year targets through at least 1980, and shall specify the roles for Federal agencies, and recommended appropriate roles for State and local units of government, individuals, and private organizations, in carrying out the implementation plan. The plan shall provide for—

(1) the development of measures to be taken with respect to preparing for earthquakes, evaluation of prediction techniques and actual predictions of earthquakes, warning the residents of an area that an earthquake may occur, and ensuring that a comprehensive response is made to the occurrence of an earthquake;

(2) the development of ways for State, county, local, and regional governmental units to use existing and developing knowledge about the regional and local variations of seismic risk in making their land use decisions;

(3) the development and promulgation of specifications, building standards, design criteria, and construction practices to achieve appropriate earthquake resistance for new and existing structures;

(4) an examination of alternative provisions and requirements for reducing earthquake hazards through Federal and federally financed construction, loans, loan guarantees, and licenses;

(5) the determination of the appropriate role for insurance, loan programs, and public and private relief efforts in moderating the impact of earthquakes; and

(6) dissemination, on a timely basis, of—

(A) instrument-derived data of interest to other researchers;

(B) design and analysis data and procedures of interest to the design professions and to the construction industry; and

(C) other information and knowledge of interest to the public to reduce vulnerability to earthquake hazards.

Report, filing with congressional committees.

When the implementation plan developed by the President under this section contemplates or proposes specific action to be taken by any Federal agency, department, or entity, and, at the end of the 30-day period beginning on the date the President submits such plan to the appropriate authorizing committees of the Congress any such action has not been initiated, the President shall file with such committees a report explaining, in detail, the reasons why such action has not been initiated.

(g) STATE ASSISTANCE.—In making assistance available to the States under the Disaster Relief Act of 1974 (42 U.S.C. 5121 et seq.), the President may make such assistance available to further the purposes of this Act, including making available to the States the results of research and other activities conducted under this Act.

(h) PARTICIPATION.—In carrying out the provisions of this section, the President shall provide an opportunity for participation by the appropriate representatives of State and local governments, and by the public, including representatives of business and industry, the design professions, and the research community, in the formulation and implementation of the program.

Program plan review.

Report to Congress.

Such non-Federal participation shall include periodic review of the program plan, considered in its entirety, by an assembled and adequately staffed group of such representatives. Any comments on the program upon which such group agrees shall be reported to the Congress.

Measures developed pursuant to paragraph 5(f)(1) for the evaluation of prediction techniques and actual predictions of earthquakes shall provide for adequate non-Federal participation. To the extent that such measures include evaluation by Federal employees of non-Federal prediction activities, such measures shall also include evaluation by persons not in full-time Federal employment of Federal prediction activities.

42 USC 7705.

SEC. 6. ANNUAL REPORT.

Submittal to congressional committees.

The President shall, within ninety days after the end of each fiscal year, submit an annual report to the appropriate authorizing committees in the Congress describing the status of the program, and describing and evaluating progress achieved during the preceding fiscal year in reducing the risks of earthquake hazards. Each such report shall include any recommendations for legislative and other action the President deems necessary and appropriate.

42 USC 7706.

SEC. 7. AUTHORIZATION OF APPROPRIATIONS.

(a) GENERAL.—There are authorized to be appropriated to the President to carry out the provisions of sections 5 and 6 of this Act (in addition to any authorizations for similar purposes included in

other Acts and the authorizations set forth in subsections (b) and (c) of this section), not to exceed $1,000,000 for the fiscal year ending September 30, 1978, not to exceed $2,000,000 for the fiscal year ending September 30, 1979, and not to exceed $2,000,000 for the fiscal year ending September 30, 1980.

(b) GEOLOGICAL SURVEY.—There are authorized to be appropriated to the Secretary of the Interior for purposes for carrying out, through the Director of the United States Geological Survey, the responsibilities that may be assigned to the Director under this Act not to exceed $27,500,000 for the fiscal year ending September 30, 1978; not to exceed $35,000,000 for the fiscal year ending September 30, 1979; and not to exceed $40,000,000 for the fiscal year ending September 30, 1980.

(c) NATIONAL SCIENCE FOUNDATION.—To enable the Foundation to carry out responsibilities that may be assigned to it under this Act, there are authorized to be appropriated to the Foundation not to exceed $27,500,000 for the fiscal year ending September 30, 1978; not to exceed $35,000,000 for the fiscal year ending September 30, 1979; and not to exceed $40,000,000 for the fiscal year ending September 30, 1980.

Approved October 7, 1977.

LEGISLATIVE HISTORY:

HOUSE REPORTS: No. 95-286, Pt. I accompanying H.R. 6683 (Comm. on Science and Technology) and No. 95-286, Pt. II accompanying H.R. 6683 (Comm. on Interior and Insular Affairs).

SENATE REPORT No. 95-130 (Comm. on Commerce, Science, and Transportation).

CONGRESSIONAL RECORD, Vol. 123 (1977):

May 12, considered and passed Senate.

Sept. 9, considered and passed House, amended, in lieu of H.R. 6683.

Sept. 23, Senate concurred in House amendment.

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ORGANIZATION OF THE GEOLOGICAL SURVEY

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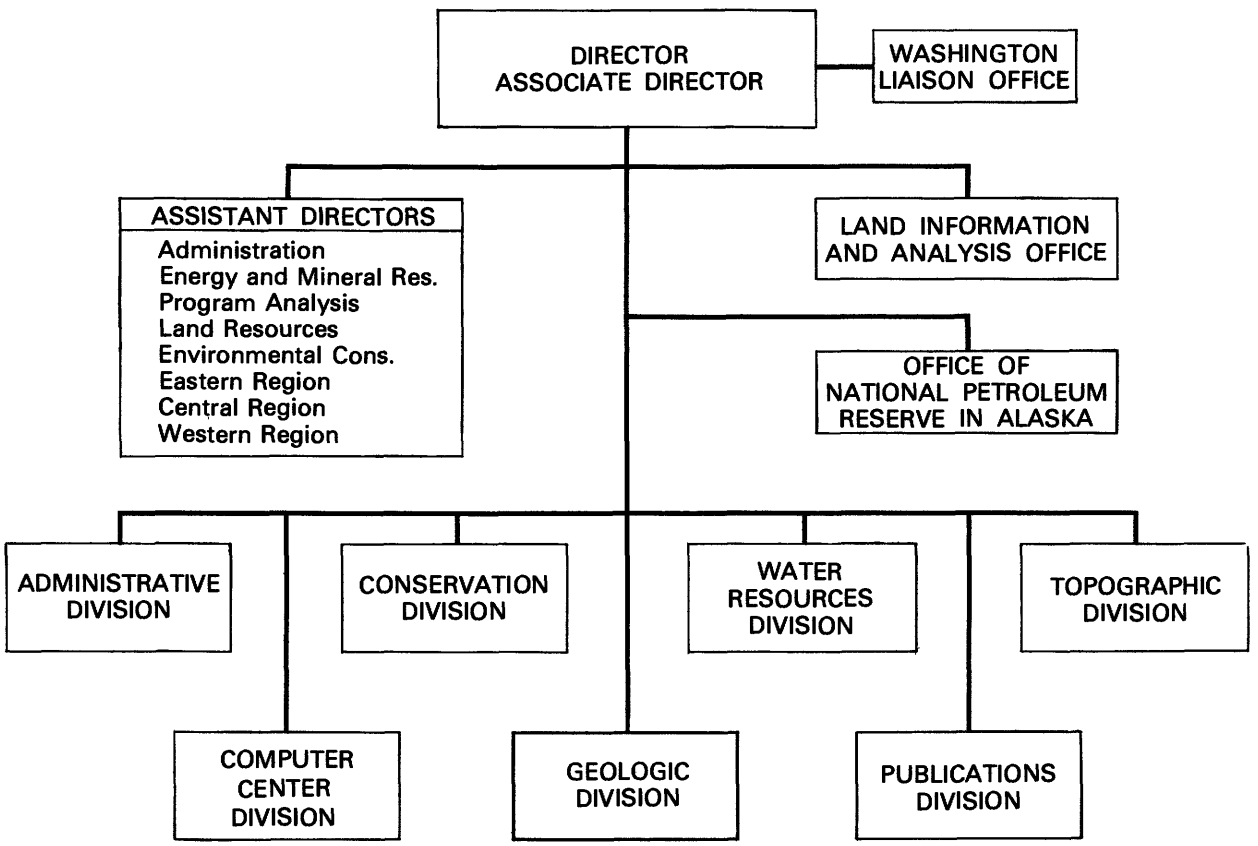
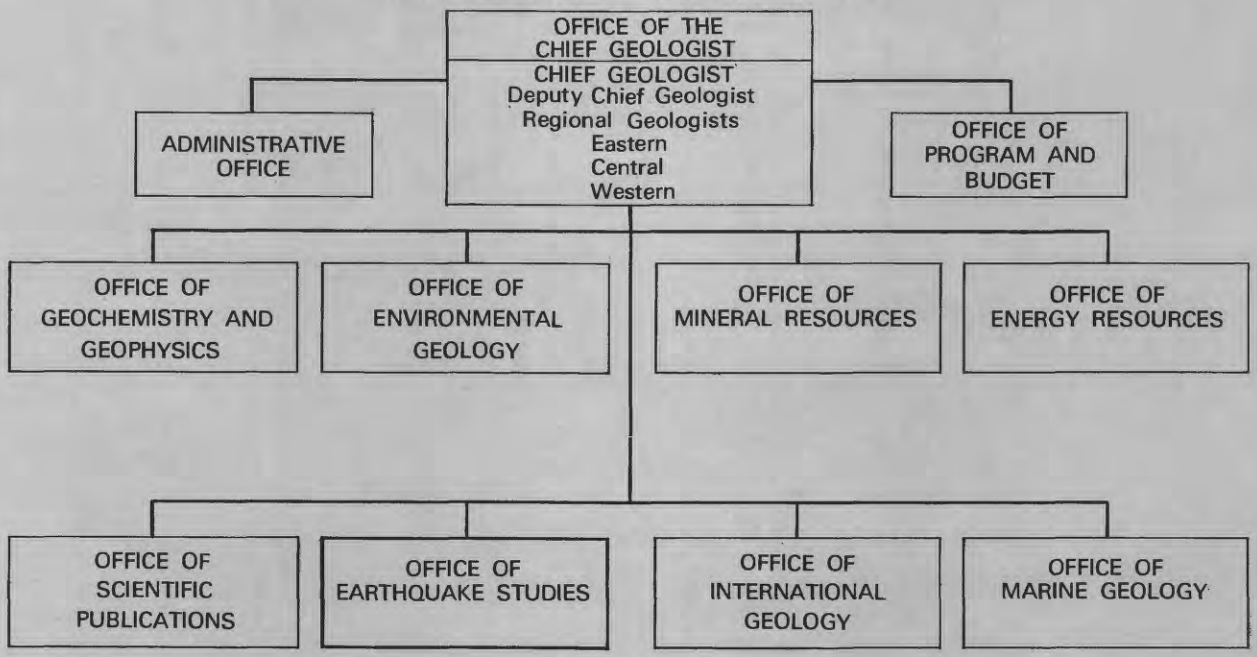


ORGANIZATION OF THE GEOLOGIC DIVISION



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