EARTHQUAKE HAZARDS REDUCTION PROGRAM

PROJECT SUMMARIES — 1979-80

Marilyn P. MacCabe, Editor

U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

Open-File Report 81-41

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INTRODUCTION

by

John R. Filson

This report describes activities of the U.S. Geological Survey under the National Earthquake Hazards Reduction Program for fiscal year 1979 and the first half of fiscal year 1980 (October 1, 1978 through March 31, 1980).

The national program was authorized by the Earthquake Hazards Reduction Act of 1977. In this program the responsibilities of the Geological Survey are to:

— Conduct research on the nature of earthquakes, earthquake prediction, hazards evaluation and delineation, and induced seismicity.

— Evaluate, with the advice of the National Earthquake Prediction Council, earthquake predictions.

— Prepare national seismic risk maps.

—Provide data and information on earthquake occurrences and hazards.

The USGS earthquake hazards program is divided into four major elements. These elements and a brief description of the goals of each are:

— Earthquake Hazard and Risk Assessment - to identify the earthquake hazard potential on a national and regional basis and to evaluate the risk due to this hazard.

— Earthquake Prediction - to forecast the time, place, and magnitude of damaging earthquakes.

— Global Seismology - to conduct fundamental studies of seismological phenomena and to provide a sound data base for studies in observational seismology and public earthquake information services.

— Induced Seismicity - to prevent or mitigate the effects of earthquakes induced by the activities of man.

Funding for these elements is summarized in table 1.

We hope this report allows the reader to assess our accomplishments to date, the current status of our research efforts, and the directions we have taken to attain our goals.

TABLE 1.--Funding for the major elements of the USGS Earthquake Program, 1978 to 1981

Program element	1978	1979	1980	1981
		(thousands of dollars)		
Earthquake prediction	15,575	15,764	15,190	15,610
Earthquake hazards and risk assessment	10,422	10,885	11,001	11,277
Global seismology and earthquake information	2,558	2,884	3,532	3,656
Induced seismicity	1,179	1,199	1,202	1,288
Disaster warning	100	100	103	102
Totals	29,734	30,832	30,128	31,933

HIGHLIGHTS OF MAJOR ACCOMPLISHMENTS

OCTOBER 1, 1978 to MARCH 31, 1980 (FY 1979-1980)

EARTHQUAKE HAZARDS

by

Robert D. Brown, Jr.

The earthquake hazards program consists of over 100 projects carried out by universities, private companies, state geological surveys and the USGS. The projects are classified as national, regional, or topical, according to the focus of the effort (table 2). National hazards studies are directed toward obtaining a reliable probabilistic assessment of earthquake hazard and risk for the nation. Regional studies are concerned with the delineation and assessment of earthquake-related geologic hazards within urban regions subject to high seismic risk.

Earthquake hazards to be assessed include ground shaking, liquefaction, landsliding, coastal uplift and subsidence, surface faulting and water waves. As the first step in earthquake hazards assessment, topical studies seek to improve the physical basis for predicting the nature and likelihood of earthquake-related geologic hazards, particularly ground shaking, liquefaction and landsliding; to develop more reliable techniques and procedures for assessing earthquake potential of geologic structures or a geological province; and to develop more refined methods for estimating earthquake losses.

TABLE 2.--Percent of funds allocated to regional, national, and topical studies in Earthquake Hazards Program, FY 1980

Regional Studies		50
California	20	
Western U.S. (excluding CA)	18	
Eastern U.S.	12	
National Studies		15
Topical Studies		35
Earthquake potential	13	
Ground motion	12	
Ground failure	7	
Risk	2	
Post earthquake studies	1	
		100%

Accomplishments in FY 1979 and the first half of FY 1980 are summarized below.

National Studies

— Developed computer programs that estimate the probability of different levels of ground motion and accommodate the variability in attenuation, maximum earthquake magnitude, and fault length.

— Completed the planning and feasibility study for a national earthquake catalog, and began to assemble and analyze data for the catalog.

— From numerous seismic networks gathered data on earthquake activity in the Pacific Coast States (including Alaska), the Intermountain seismic belt (Utah, Montana, Idaho), the Mississippi Valley, the northeastern United States, and the southeastern United States.

Regional Studies

California

— Continued geologic research on known or suspected active fault, to establish recurrence rates and degree of hazard.

— Expanded geologic and geographical studies to evaluate crustal deformation and its relation to such geologic processes as faulting, folding, and regional warping or uplift.

— Continued mapping of Quaternary deposits in southern California, and measurements of the wave velocities in both northern and northeastern California as a basis for maps, now being prepared, that will predict the intensity of ground shaking and the likelihood of ground failure.

Western U.S. (excluding California)

— Continued onshore and offshore geologic and geophysical surveys of the Puget Sound region have identified several suspected fault zones, and show the distribution of geologic units are susceptible to ground failure or to unusually intense shaking.

— Continued mapping in the Anchorage-Susitna lowlands region of surficial geologic deposits are susceptible to earthquake-induced ground failure, and conducted seismologic and geologic studies to evaluate fault activity and potential earthquake hazards in other parts of Alaska.

— Gathered additional data on earthquake recurrence, the accuracy of faulting, and distribution of liquefiable geologic materials in the Intermountain Seismic Belt, especially the area near Salt Lake City and to the north and south.

Eastern U.S.

— Identified gravity, magnetic, and geologic trends that coincide with current seismicity in the upper Mississippi Valley; the interpreted geologic relations define a north-northeast-trending problem along which the boundary faults are a possible source of damaging earthquakes.

— Seismic monitoring and geophysical surveys in the Charleston, South Carolina, area indicate severe subsurface structures that are associated with small earthquakes.

— The analysis of seismic records, of geophysical data, and geologic maps suggests that earthquakes in the northeastern U.S. can be related to several fault zones among which northeast-striking reverse faults are especially common near the Atlantic Coast.

— Continued regional and local studies of long term rate of deformation to provide a basis for evaluating the magnitude of faulting in seismically active regions.

Topical Studies

— Continued to develop new ways of dating fault movements by the use of soil stratigraphy, dating and correlating volcanic ash layers, and isotope age-dating methods.

— Demonstrated, through a number of related investigations, that several characteristics of ground motion are closely related to features of the fault surface or seismic source.

— Obtained, from several California earthquakes in the range of M 5.5 to M 6.6, new data that quantifies the intensity of ground motion within 5 km of active faults.

— Improved the ability to predict site ground motion, and to define those geologic and geophysical data needed for such predictions.

— Developed new, faster and more efficient, methods of gathering, processing, and analyzing ground motion data in studies of aftershock sequences.

— Facilitated the development, by local government, of a geographical data site that can provide regional maps showing active faults and areas susceptible to such specific hazards as intense ground shocking, liquefaction, or earthquake induced landslides.

EARTHQUAKE PREDICTION

by

C. Barry Raleigh

The existence of a major seismic gap along the San Andreas fault in Southern California, when accentuated by the rapid uplift and deflation of the Southern California bulge, stimulated an intensive program of research in that area. In the past two years we have detected anomalous fluctuations in the formerly uniform pattern of accumulation of strain. Laser ranging measurements have shown a reversal in the north-south compressional strain of $3x10^{-7}$ per year over most of the networks in Southern California by late 1979. The new pattern was characterized by NE-SW extension with positive dilatation of the land area. During this period, investigators at Cal Tech found anomalously high emanation of radon from wells in the Transverse Ranges. Earthquakes of greater than M=5 were more than usually frequent with the M=6.7 Imperial Valley earthquake occurring during this period. Large aftershocks of M=5 earthquakes occurred at much higher rates than in the previous 30 to 40 years.

The anomalous pattern of strain disappeared by early 1980 with a return to the earlier north-south compressional pattern. The radon anomalies also returned to normal. Recently, however, it appears that strains at Palmdale have rapidly become extensional again and the first signs of increasing radon in Transverse Range wells have appeared in August 1980. These results constitute the first clear indications that radon emanations are correlated with large-scale tectonic events, notably, episodes of extensional strain in this case.

The earlier episode of extensional strain, and increased radon emanation were associated in time with a period of seismic quiescence in the Imperial Valley. A three-fold reduction in the numbers of small earthquakes from the background continued for three months up until the time of the M=6.7 Imperial Valley earthquake. From a year to six months prior to the earthquake a remarkably large tilt took place along a 100 meter level line at the north end of the Imperial fault. The fault has a large normal component of displacement in this area and the pre-earthquake tilting (about $5x10^{-4}$ radians) was in the correct direction to be accounted for by a buried creep event having down-to-the-east displacement.

TABLE 3.--Earthquake Prediction Program allocation of funds, FY 1980

Activity	% Total Budget
Seismic networks (includes support functions, routine analysis, some research)	28
Instrumental strain, tilt networks (includes support functions, routine analysis, some research)	12
Automatic data processing development (hardware, software for digital processing, and analysis of seismic, and other data)	9
Geodetic surveys (trilateration and leveling surveys, including analysis of data)	8
Other observational networks (radon = 4, electric/magnetic = 2, water wells = 1, biological 1, gravity = 1)	9
Analysis of seismic data (seismicity patterns, etc.)	6
Laboratory measurements (brittle behavior, rheology, elastic properties)	6
Earth structure using active seismic sources (refraction surveys, velocity changes)	6
Theoretical studies (mechanics of faulting)	4
Thermal-mechanical framework of seismogenic regions (heat flow observations and analysis)	3
In-situ stress, pore pressure (drilling, logging and analysis)	3
Source mechanisms (observations and analytical studies of seismic source characteristics)	3
Instrument development (Pinon Flat Observatory, other developments)	2
Geologic framework studies	1
	100%

Radon variations prior to moderate or large earthquakes are now well-documented in Iceland from work done at Lamont-Doherty Geological Observatory, in Southern California by the University of California at San Diego, Cal Tech and the University of Southern California, the People's Republic of China, and in the USSR. Although it remains an enigma that some wells show the increases and others do not, the phenomenon appears to be well correlated with earthquakes and an effort to understand the mechanism is now underway.

A new council on Earthquake Prediction has been established by the Director of the USGS. The council will review predictions which appear to have some scientific validity and advise the Director of their opinion of the data and the appropriateness of the prediction.

GLOBAL SEISMOLOGY

by

William J. Spence

The Global Seismology program involves all aspects of the recording, processing, and analysis of data associated with earthquakes and large explosions around the world. Activities cover a wide spectrum of earthquake seismology and interpretation of seismic data; computation of earthquake parameters; seismicity studies; research on improved methods of determining earthquake location and earthquake size, including studies on earth structure, seismic ray tracing, moment tensor and seismic moment, and magnitudes; and dissemination of the results to the scientific community, government agencies, and the public.

The National Earthquake Information Service (NEIS) in Golden serves as a focus for the international exchange of earthquake data. NEIS activities involve:

1. Collection and reduction of seismic data from seismographs around the world.

2. Publication of hypocenter data associated with recent seismicity.

3. Maintenance of a 24-hour notification service to provide timely data following major or significant earthquakes.

4. Release of information in response to public inquiries.

Major accomplishments in FY 1979-1980 are summarized below:

— Canvassed 116 earthquakes in 20 states for felt and damage data by questionnaire and/or field study. The largest U.S. earthquake studied was the Ms = 7.1 (Ms = 7.6) St. Elias, Alaska event of February 28, 1979. Preliminary Determination of Epicenter (PDE) monthly listings and Earthquake Data Reports (EDR) were published through March 1980.

— Studied earth structure in the Rio Grande Rift, New Mexico, and in the Sierra Nevada Mountains, California. A three-dimensional inversion of teleseismic P-wave delays across a seismic network spanning the Rio Grande Rift shows that low P-wave velocities extend beneath the rift to a depth of about 200 km, relative to P-wave velocities under the High Plains Province. Seismic waves propagating across the Sierra Nevada, California, from earthquakes and explosions are delayed from all directions except that of the Nevada Test Site to the east. Early arrivals from the Nevada Test Site can be explained, if they emerge in the "shadow zone" through a high-velocity crust from a sharp eastern edge of the Sierran root. Synthesis of all seismic data indicates that the root projects downward into the mantle to a depth of about 60 km beneath the highest Sierra.

— Relocated 147 earthquakes that occurred in the eastern United States and adjacent Canada in the interval 1924 to 1976 using regional velocity models with subsidiary phases and jointly computed station corrections. Eighty-six percent of these earthquakes occurred in the upper 10 km of the earth's crust, with many of those in the 10 to 20 km depth range occurring in the Province of Quebec. Forty-four percent of these have 90% confidence ellipses on their epicentral coordinates that are less than 10 km in length. These relocations constitute a much improved picture of the seismicity of the study area.

— Developed a system to interactively analyze and display digital seismic data using a minicomputer. Automated methods can be used to extract seismic wave arrival time, polarization and spectra from digital time series. Earthquake focal mechanisms and associated confidence regions can be determined from a limited set of body-wave first motions. A computer program has been developed that deconvolves the instrument response from SRO digital data by combining long and short period seismograms to yield broad-band displacement records. The same program also yeilds in the time domain broad-band velocity and velocity-squared seismograms. The stability and high quality of the SRO digital data preserves the high-frequency, spectral-phase information that is necessary for the accurate determination of pulse characteristics. Applying the latter program to real digital data from three deep earthquakes shows that a small number of digital stations permit good estimates of a number of source parameters and allows the source geometry to be constrained.

— Study of the characteristics of seismicity prior to the Peruvian earthquake of 74.10.03 (M = 7.8) and the Adak, Alaska earthquake of 77.11.04 (M = 6.7) shows significantly increased levels of seismicity near the main shock source regions during an extended period before each main shock, suggesting that critical stresses were being approached during this period in a zone at least a few tens of kilometers in length.

— The analysis of actual and synthetic seismograms, generated by using a spectral method (the full wave theory), demonstrates that significant frequency dependent effects are incurred by body waves propagating through the Earth. These effects include diffraction, tunneling, and the system of rays that arise from a cusp or a caustic. Attenuation has also been found to be frequency dependent in the Earth. The spectral peaks of normal modes may be split by a laterally heterogeneous Earth. These findings imply that studies of the seismic source would be imprecise without significant corrections for propagation effects in the raw data.

INDUCED SEISMICITY

by

Charles G. Bufe

The study of induced seismicity involves detection and interpretation of temporal changes in the seismicity of an area resulting from the acts of man. Program objectives include developing an understanding of mechanisms whereby earthquakes are induced and devising techniques for predicting the tectonic response of a partricular site to reservoir impoundment, fluid injection, or fluid withdrawal.

Induced seismicity studies funded in FY 1979-1980 fall into one or more of four categories.

1. Development of a data base of factors relating to induced seismicity, permitting a statistical, "pattern recognition" approach to evaluation of potential for induced seismicity at a specific site.

2. Deployment of surface instrumentation (principally seismographs) to document seismicity levels and earthquake locations and characteristics before and after reservoir impoundment or to conduct site-specific studies of earthquake activity related to fluid injection or withdrawal.

3. Geologic studies of tectonic regimes in which earthquakes are (or are not) triggered by reservoir impoundment.

4. Borehole measurements of stress, permeability, pore pressure, and seismic velocities in or near clusters of induced earthquakes.

Major accomplishments in FY 1979-1980 include:

— Interstation spacing in the telemetered network at Monticello, South Carolina was decreased to improve the accuracy of depth determination. Most of the events induced by impoundment of Monticello Reservoir were found to be within 1 km of the surface, and thus within the depth range for which borehole measurements of stress and pore pressure have been made.

— A temporary network of digital event recorders was deployed at Monticello. The network provides a unique set of broadband, high dynamic range digital seismograms of shallow induced earthquakes. Spectral analysis of these data will provide estimates of seismic source dimension and stress drop for these events.

— Pressure measurements in a borehole drilled into a cluster of induced earthquakes at Monticello have shown the presence of a fracture zone in communication with the reservoir.

— A telemetered seismic network has been installed at the Cogdell-Canyon Reef oilfield near Spyder, Texas, to monitor earthquakes induced by water injection for secondary recovery.

PROJECT SUMMARIES

EARTHQUAKE HAZARDS

Earthquake Potential

Tectonic Framework, Quaternary Geology, and Active Faults

California

EARTHQUAKE HAZARDS MAPPING OF THE SAN ANDREAS FAULT ZONE, LOS ANGELES COUNTY, CALIFORNIA, A. G. Barrows, State of California, Division of Mines and Geology, Department of Conservation, Resource Building, 1416 Ninth Street, Sacramento, California 95814, (916) 445-1825.
Goal: To map fault traces and geology along the San Andreas fault zone in Los Angeles County.
Investigations: Detailed geologic maps and reports were produced for the Valyermo, Lake Hughes, east-half Quail Lake, and west-half Three Points segments totaling approximately 32 km of the San Andreas fault zone (fig. 1). The 1:12,000-scale geologic maps on orthophoto bases supplement the annotated fault maps produced during the previous year for these segments. This study emphasizes geologic data, particularly Quaternary alluvial history, that permit interpretation of the recency of activity along many individual fault strands within the segments. We are preparing annotated fault maps of the Pine Canyon and east-half Three Points segments of the fault zone. These maps will be on orthophoto bases at a scale of 1:12,000. The 15 km stretch of the fault zone currently under investigation lies 20 to 35 km southeast of Gorman.

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, California 94025, (415) 323-8111, ext. 2203.
Goals: (1) To provide a four-dimensional analysis of crustal deformation during Cenozoic time, (2) to predict the effects of earthquakes on a regional basis, and (3) to coordinate earthquake hazard reduction studies.
Investigations: The location of major faults is interpreted from aeromagnetic and gravity anomalies and from the distribution of different geologic units, such as serpentinite. These data are also used to establish crustal structure in order to locate epicenters with greater precision and to better understand the deformation of the various fault blocks. We are preparing seismic zonation maps for San Mateo County showing where ground failure is likely to occur, probable intensities, and the possible consequences for various structures on a regional basis. Geologic mapping of fault zones to establish the rates and amounts of fault movement continues.

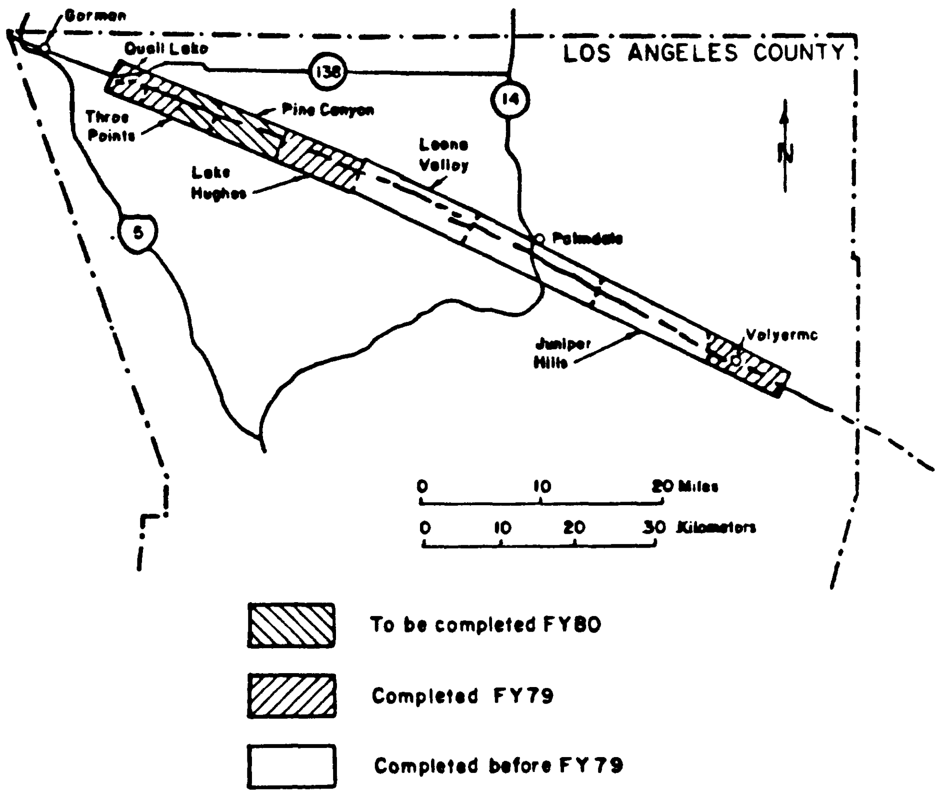

FIGURE 1.—Location of completed and current segment fault and geologic maps of the San Andreas fault zone in Los Angeles County.

SURFACE FAULT TRACES AND HISTORIC EARTHQUAKE EFFECTS NEAR LOS ALAMOS VALLEY, SANTA BARBARA, CALIFORNIA, G. E. Brogan, Woodward-Clyde Consultants, 3 Embarcadero Center, Suite 700, San Francisco, California 94111.

Goal: To evaluate the historical earthquake effects of the 1902 and 1915 earthquakes in the Los Alamos area and to evaluate potential sources of these earthquakes.

Investigations: The study includes compilation of historic records of the 1902 and 1915 earthquakes, interpretation of low-sun-angle aerial photographs covering 325 square miles, geomorphic and structural interpretation of possible faulting, and trenching across a fault trace east of Los Alamos.

QUARTERNARY DEPOSITS AND TECTONICS OF THE ANTELOPE VALLEY, WESTERN MOJAVE REGION, CALIFORNIA, D. B. Burke, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2048.

Goals: (1) To analyze Quaternary deposits and tectonics of northern Los Angeles County and vicinity for the purpose of seismic hazard zonation of the region near the juncture of the San Andreas and Garlock Faults, and (2) to develop improved techniques for the study of stratigraphy and structure in the subsurface of alluviated basins and/or compile geotechnical information germain to hazards reduction and engineering in Quaternary deposits.

Investigations: We are mapping Quaternary materials in the study area at 1:62,000 scale and active crustal structures of the region at 1:24,000 scale. Site investigations on active structures include fault scarp and profile measurements and monumenting of structures to record future activity. Soils and near-surface materials of the region will be sampled and analyzed. In addition, we are constructing computer programs and associated methodology for compilation, integration, and graphic display of stratigraphic and geotechnical data on Quaternary materials from diverse sources.

VERTICAL TECTONICS, R. O. Castle, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2482.
Goal: To determine the tectonic evolution of vertical crustal movements in southern California and the western United States.
Investigations: Possible deficiencies in the measurement system have required that we investigate height-dependent systematic errors associated with geodetic leveling and reassess the so-called "sea-slope" problem.

QUATERNARY FAULTING IN SOUTHERN CALIFORNIA, M. M. Clark, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2623.
Goal: To investigate and map recently active surface traces of faults in southern California.
Investigations: Project efforts include trenching across the Garlock fault at Koehn Lake, field studies of creep at the Garlock fault in Fremont Valley, and mapping of active faults along the eastern slope of the Sierra Nevada — including Hilton Creek fault zone and Lone Pine fault. We are preparing strip maps (1:24,000) of Hilton Creek, Elsinore, and San Andreas fault southeast of Whitewater River. These maps will also include the normal faults of Indio and Mecca Hills.

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, California 94022, (415) 948-8590.
Goal: To locate and evaluate sites along the 1906 reach of the San Andreas fault that contain detailed, decipherable, and datable Holocene and/or late Quaternary records of slip events.
Investigations: We are compiling and evaluating available historic and current data on the 1906 trace of the San Andreas fault. Existing aerial photographs will be examined and field reconnaissance of nonurbanized and forested areas will be made to identify fault segments warranting detailed surface and subsurface investigations.

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, California 93106, (805) 961-3224.
Goal: To determine the pattern and origin of tectonic movements in the southern California uplift region.

Investigations: Field studies of landforms along the San Andreas fault zone in the Big Bend region reveal clear evidence of many recurrences of ground displacement. Field and computer investigations of deformed erosional surfaces or terraces occurring in a broad band on either side of the fault show very irregular surfaces that rise north of the fault and then plunge quickly toward the San Joaquin Valley. The magnitude of these irregularities suggests considerable tectonic deformation of Quaternary surfaces since their formation.

QUATERNARY TECTONICS, OFFSHORE LOS ANGELES-SAN DIEGO AREA, H. G. Greene, U.S. Geological Survey, Pacific-Arctic Branch of Marine Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 856-7047.
Goals: (1) To determine the total length of the Palos Verdes Hills fault zone in offshore southern California and its tectonic relationship to the Newport-Inglewood-Rose Canyon fault system, and (2) to determine the history of displacement along the Palos Verdes Hills fault zone with emphasis on Quaternary offset.
Investigations: A marine geophysical and sampling survey will be performed to accurately delineate possible offshore extensions of the Palos Verdes Hills fault in the Gulf of Santa Catalina. We will map the geologic structure in the vicinity of La Jolla Canyon and the geologic structure and sedimentary features on both sides and adjacent to the Palos Verdes Hills fault in a 100 to 200 square kilometer area in western San Pedro Bay.

GEOPHYSICAL STUDIES, WESTERN TRANSVERSE RANGES, A. Griscom, U.S. Geological Survey, Branch of Regional Geophysics, 345 Middlefield Road, Menlo Park, California, 94025, (415) 323-8111, ext. 2268.
Goals: To examine the tectonic setting of the western Transverse Ranges, California, with particular emphasis on relationships to active or recently active faults, areas of active uplift or subsidence, and areas of active seismicity.
Investigations: We are obtaining information on the location, distribution, and configuration of concealed and exposed magnetic rock units from aeromagnetic data. These data are interpreted in conjunction with available gravity, seismic, and geologic information. Aeromagnetic maps display a variety of aeromagnetic anomalies that are associated with plutonic, volcanic, and ultramafic rocks. Analysis of these anomalies and patterns by quantitative methods should significantly extend our knowledge of the tectonics in this study region.

GRAVITY AND MECHANICS OF THE SAN FRANCISCO BAY REGION, A. Griscom, U.S. Geological Survey, Branch of Regional Geophysics, 345 Middlefield Road, Menlo Park, California, 94025, (415) 323-8111, ext. 2268.
Goal: To produce interpreted aeromagnetic and gravity maps of the San Francisco Bay region.
Investigations: Aeromagnetic and gravity data of the San Francisco Bay region have revealed hidden structural elements and intrusive bodies. Evidence suggests that aspects of some igneous bodies (i.e., serpentinized versus non-serpentinized ultramafics) may have a direct relation to earthquakes. These features will be delineated and incorporated into an integrated lithologic and structural depiction of the region. Where necessary, we will incorporate other geophysical methods to place more rigorous limits on the features derived from aeromagnetic and gravity data.

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

Goal: To synthesize geologic, geophysical, and geodetic information on Quaternary tectonic movement in the ten-county San Francisco Bay region.

Investigations: Geologic and seismologic data are used to calculate the seismic hazard for the San Francisco Bay region. Risk-levels are assigned by determining the acceleration that would likely accompany earthquakes on recently active faults in the region.

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

Goal: To determine the tectonic development of the northern California region and the relation of the tectonics to seismicity.

Investigations: The western border of North America is an accumulation of fragments of island arcs and oceanic crust that has been swept against and accreted to the continent. We are determining the ages of the various arc and oceanic fragments and the times of their accretion by methods that include sampling radiolarian cherts in both coherent and melanged parts of the tectonic slices. Paleomagnetism of the rocks are studied to determine the paleolatitudes of the sites where the tectonic slices originated and the net amount the rocks rotated during transport to their present location. We are also studying the coincidence of high carbon dioxide in springs in zones of seismicity (fig. 2).

TECTONIC GEOMORPHOLOGY AND EARTHQUAKE HAZARDS: NORTH FLANK, CENTRAL VENTURA BASIN, CALIFORNIA, E. A. Keller, University of California, Santa Barbara, Department of Geological Sciences, Santa Barbara, California 93106, (805) 961-3268.

Goal: To determine the nature, extent, and chronology of late Pleistocene and Holocene earthquake and other tectonic activity on the northern flank of the Central Ventura Basin (Ojai to Fillmore, California).

Investigations: We are conducting geologic mapping to produce a tectonic land form map and developing a soil chronology to assist in dating of land forms and possible earthquake events. Where possible, we will obtain absolute dates for deposits or surfaces that have been deformed by recent tectonic activity; evaluate deformed erosional and depositional surfaces to determine rates of recent deformation; and evaluate the earthquake hazard associated with active and potentially active faults in the study area.

RECENCY AND CHARACTER OF FAULTING OFFSHORE FROM METROPOLITAN SAN DIEGO, CALIFORNIA, M. P. Kennedy, State of California, Division of Mines and Geology, Division Headquarters, 1416 Ninth Street, Room 1341, Sacramento, California 95814, (916) 445-1923.

Goals: To identify the character of faulting and the recency of movement along major fault zones offshore from metropolitan San Diego between the Mexican border and Oceanside.

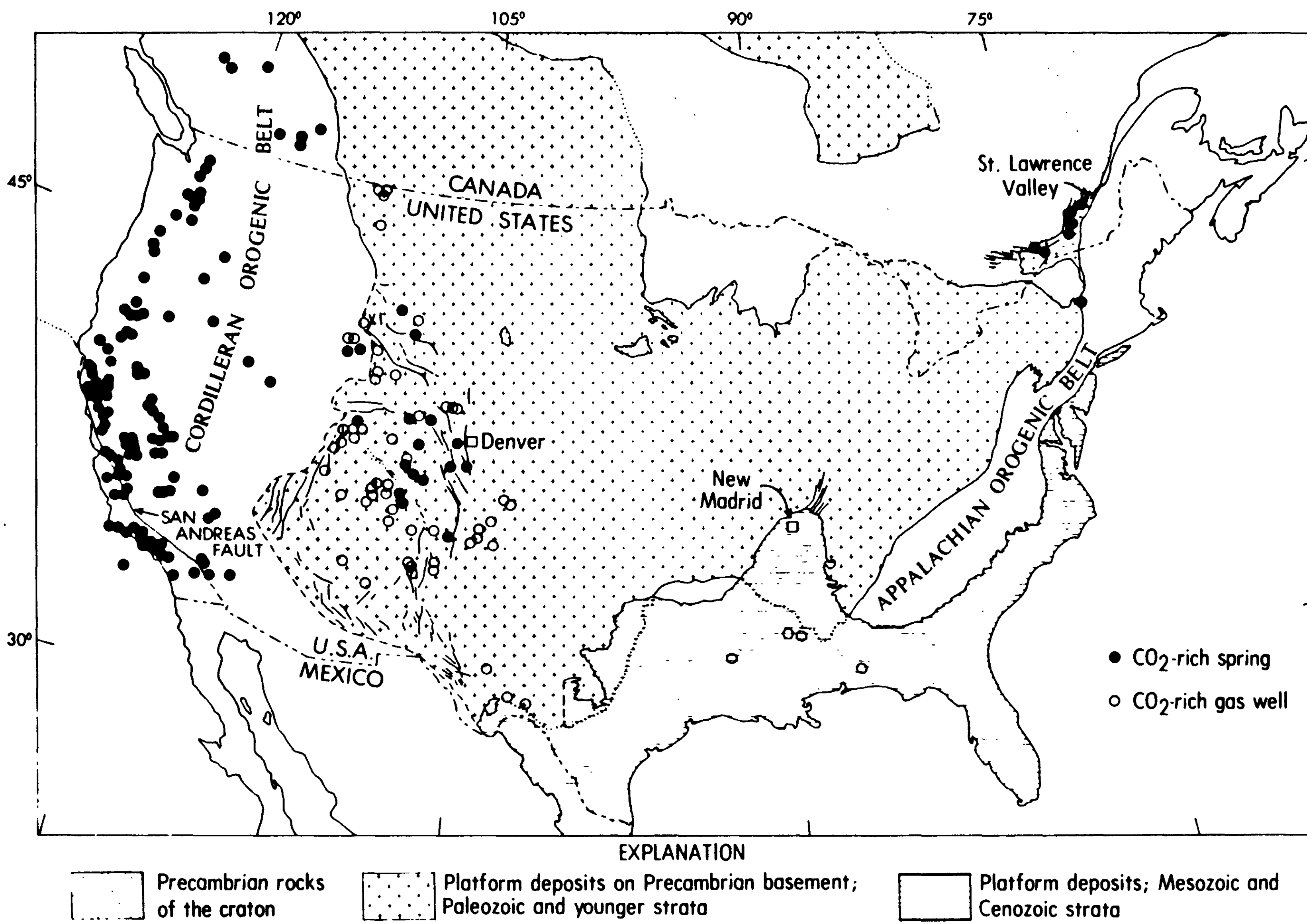

FIGURE 2.—Map showing the distribution and tectonic setting of carbon dioxide rich springs and gas wells in the conterminous U.S. and adjacent parts of Canada.

Investigations: We are conducting a detailed study of fault movement to establish slip rates and recurrence along the San Diego Trough, Coronado Bank, and Rose Canyon fault zones. Faults are identified by high resolution, subbottom reflection profiling techniques. The age of faulted sediment is determined by isotopic age dating of core samples, acoustic stratigraphy, paleontology, and superposition.

QUATERNARY TECTONICS OF THE PACIFIC COAST, K. R. Lajoie, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2642.
Goal: To determine the styles and rates of crustal deformation (folds, faults, and uplift) along the Pacific Coast of the United States during late Quaternary time by mapping and dating emergent marine terraces and deposits.
Investigations: Tectonic uplift rates along the Pacific Coast are derived from amino-acid dated marine terrace deposits. Near major bends in the San Andreas fault at Cape Mendocino and in the Transverse Ranges, uplift rates are derived from carbon-14 dating of fossils, mollusk shells, and driftwood in marine deposits up to 37 m above sea level. At Ventura, we are examining a stream terrace deposit graded to a SkA marine terrace and offset by the Javon Canyon fault. Offset events are recorded in the alluvial deposits on the downthrown side of the fault. Radiocarbon dating of peat beds in sag pond deposits exposed by sea cliff erosion is used to determine offset events on a major branch of the San Gregorio fault in San Mateo County.

EARTHQUAKE HAZARD STUDIES, UPPER SANTA ANA VALLEY AND ADJACENT AREAS, SOUTHERN CALIFORNIA, D. M. Morton, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, California 94025, (213) 323-8111, ext. 2353.
Goal: To map faults, landslides, and delineation in valley areas of major Quaternary deposits in order to further understand the complex tectonic framework of the Riverside-San Bernardino-Redlands area.
Investigations: We are continuing paleomagnetic and potassium-argon dating of young basalts in southern Mojave Desert, San Bernardino Mountains, San Gorgonio Pass, and northern Peninsular Ranges. Fault studies will be conducted in the San Gorgonio Pass-southern San Bernardino Mountains area and we will continue to map surficial materials of the Perris Block area.

BASEMENT TECTONIC FRAMEWORK STUDIES OF THE SAN ANDREAS FAULT SYSTEM, D. C. Ross, Branch of Earthquake Tectonics and Risk, U.S. Geological Survey 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2341.
Goal: To determine the offsets of granitic and metamorphic basement rocks across the White Wolf-Breckenridge-Kern Canyon fault system.
Investigations: Field studies involve reconnaissance geologic mapping and sampling of the basement rock units exposed along the fault system from Walker Basin north to the Forks of the Kern (a distance of about 80 km). Laboratory investigations include modal analyses of stained slabs of the granitic rocks and petrographic examination of thin sections of granitic and metamorphic rocks.

DETAILED ANALYSIS OF DEFORMATION ASSOCIATED WITH THE MELONES FAULT: A DEEPLY ERODED FORMER PLATE BOUNDARY, WESTERN SIERRA NEVADA, CALIFORNIA, R. A. Schweickert, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, (914) 359-2900.
Goal: To analyze the wallrock deformation associated with the southern part of the Melones fault — an ancient, deeply eroded major crustal fault, in the Sierra Nevada foothills (fig. 3).
Investigations: We are making detailed structural traverses across the Melones fault in transects where the effects of several phases of reactivation can be distinguished. The different phases have been established and several transects have been identified where no reactivation occurred; this is where the deformation related to Jurassic movements is being examined. Field data are augmented by petrographic studies of strain mechanisms. A paleomagnetic study is underway to constrain the magnitude and direction of offset on the fault during the Jurassic.

SALTON TROUGH TECTONICS, R. V. Sharp, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2596.
Goal: To determine the recency of fault movement within the Imperial Valley.
Investigations: We conducted a trenching study of the Imperial fault between the All-American Canal and the Mexican border to determine the relationship of 1940 displacement to older episodes of movement. Based on an estimated sedimentation rate of 0.5 cm/yr, we suggest that the last pre-1940 seismic event associated with major slip might have occurred more than 900 to 1,000 years ago. Mapping of Quaternary faulting within the seismic belt of the San Jacinto fault zone in western Imperial Valley is continuing. In addition, we have begun a study of major Quaternary boundary faults on the west margin of the Salton Trough.

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, California 91125, (213) 795-6811, ext. 2108.
Goal: To determine the temporal and spatial relationships of the latest large earthquake along the San Andreas fault system.
Investigations: We are establishing the dates of several large earthquakes from subsurface studies at one or more sites in the Carrizo Plain and correlating these events with previously dated Pallett Creek earthquakes. Similar subsurface studies will be conducted at two sites along the San Jacinto fault zone in San Bernardino. Geomorphologic studies along the fault in the Badlands (southeast of San Bernardino) will characterize the magnitude of slip along this reach.

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, Department of Conservation, Resource Building, 1416 Ninth Street, Sacramento, California 95814, (916) 445-1825.
Goals: To collect, catalog, and interpret sufficient data to delineate the areal extent, subsurface configuration, physical characteristics, and the expected seismic response of Quaternary sedimentary units within the study area.

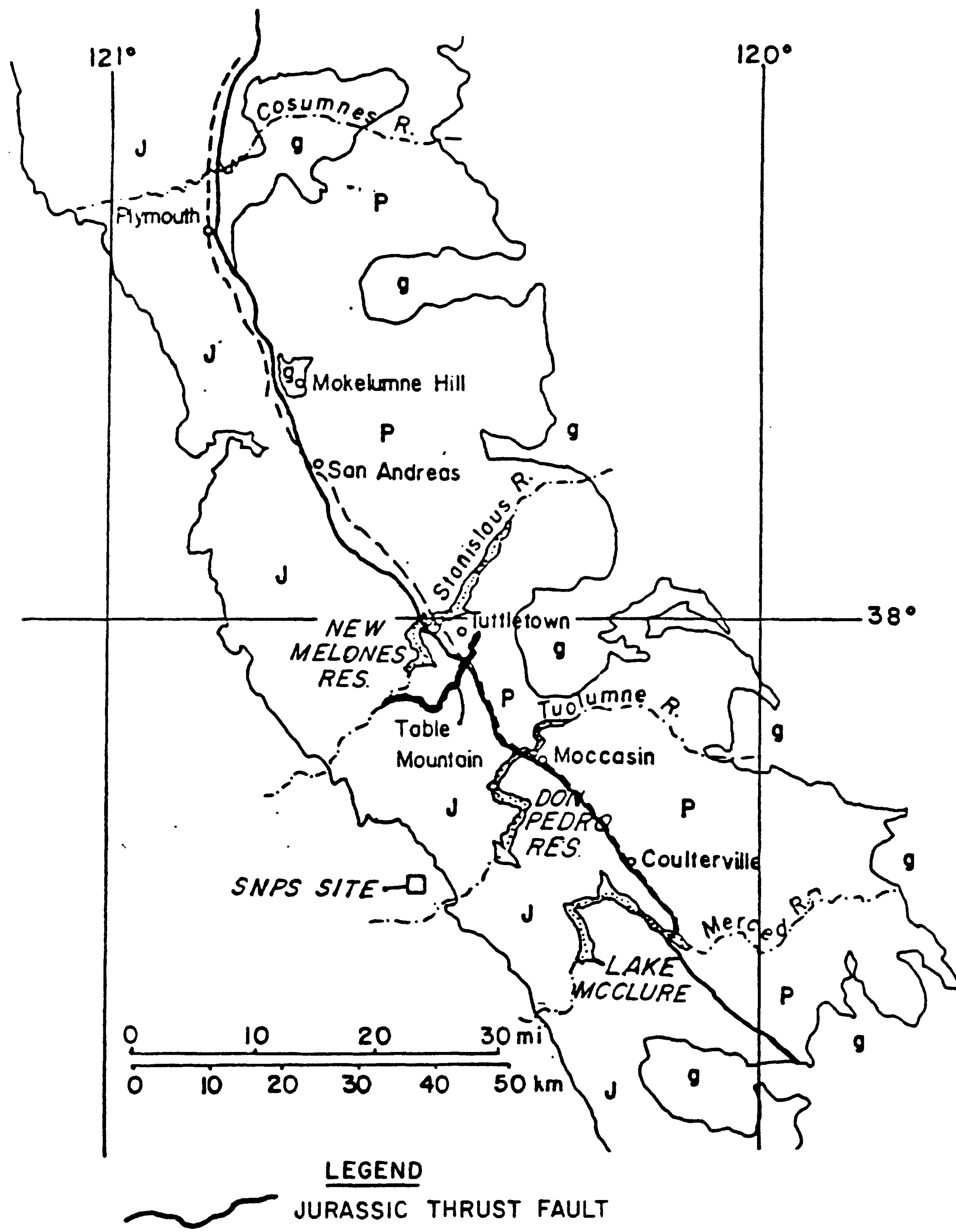

FIGURE 3.—Location map of southern part of Melones fault. (Heavy line marks trace of Jurassic thrust fault.)

Investigations: This project locates, acquires, and catalogs available surface and subsurface data from private and governmental organizations. These data will be used to prepare interpretive maps showing spatial distribution of Quaternary soils and the potential secondary response of Quaternary sediments to seismically induced ground shaking. Other representations will include: isopach, lithofacies, depositional environment, and soil characteristics maps.

SEISMIC HAZARD STUDY OF THE WESTERN PORTION OF THE GARLOCK FAULT, J. C. Stepp, Fugro, Incorporated, 3777 Long Beach Boulevard, Long Beach, California 90807, (213) 595-6611.

Goal: To obtain data on recent movements of the Garlock fault between its intersection with the San Andreas fault and Oak Creek Pass north of Mojave, California (fig. 4).

Investigations: Three areas were selected for detailed investigation based on literature search, photogeologic analysis, and ground reconnaissance. The areas chosen were Castac Lake, Twin Lakes, and Oak Creek Canyon. Field activities include seismic refraction profiles, topographic surveys, exploratory trenching, age dating, and geomorphic analysis. Data are compiled on enlarged aerial photographs with superimposed topographic contours.

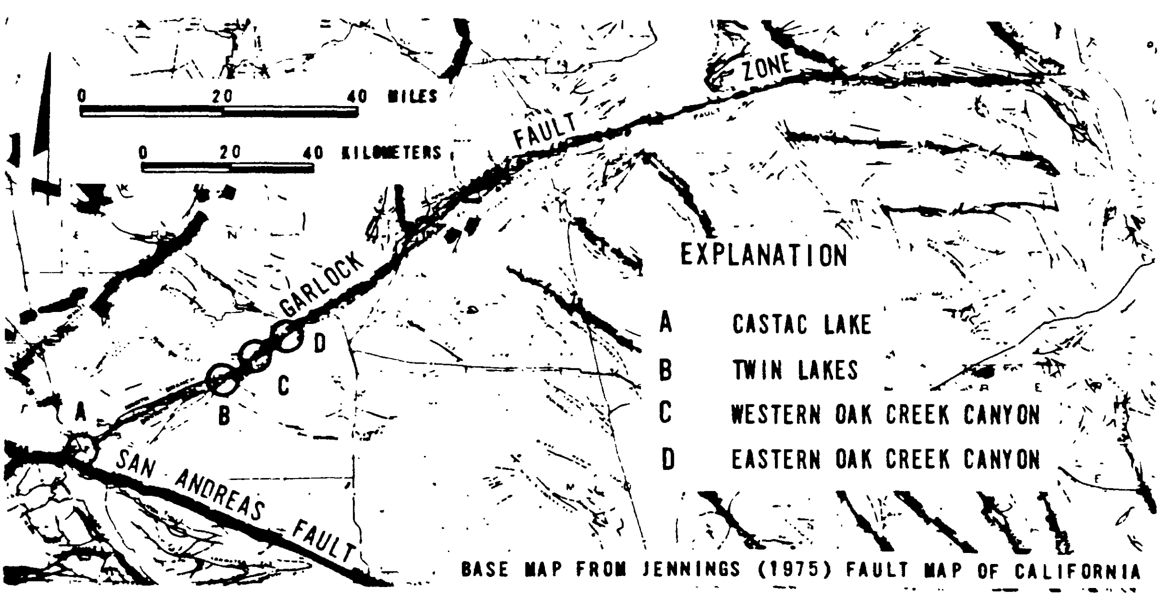

FIGURE 4.—Location map of study area along Garlock fault.

QUATERNARY 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, California 94025, (415) 323-8111, ext. 2037.
Goal: To understand the Quaternary evolution of the Los Angeles Basin.
Investigations: A combination of photogeologic, geomorphic, pedologic, and sedimentologic techniques and historical records are used to map the Quaternary surficial geology in the Los Angeles basin. Carbon-14 age determinations serve as a focal point for correlation of Late Pleistocene and Holocene deposits, and for studies of sedimentation and tectonic deformation rates. Relative time control is based chiefly on pedologic criteria. A comparison of pseudo-relative response velocity (PSRV) ratios for alluvial sites referenced to basement shows that sedimentary texture and geologic age of materials are geologic parameters that may best explain trends observed for 40 sites representing the range of near-surface geologic materials.

GEOLOGIC INVESTIGATION OF THE MARINE TERRACES OF THE SAN SIMEON REGION AND PLEISTOCENE ACTIVITY ON THE SAN SIMEON FAULT ZONE, CALIFORNIA, G. E. Weber, Weber and Associates, 127 Pryce Street, Santa Cruz, California 95060.
Goals: To determine a late Pleistocene history of movement along the San Simeon fault zone, including: the probable rates of movement, the style of deformation, probable recurrence intervals, and the most recent episodes of movement on both the fault zone as a whole and the individual faults within the zone.
Investigations: We are attempting to achieve these goals through detailed field mapping of the marine terraces and the faults from the Cape San Martin area south to Cayucos. If the terraces in the terrace sequence can be correlated between fault blocks and on opposite sides of the fault zone, we can estimate the vertical component of motion on the fault and estimate the rates of motion. Similarly, horizontal components of movement and the rates of motion can be determined from the offset of shoreline angles of marine terraces.

EARTHQUAKE HAZARDS ASSOCIATED WITH THE SANTA MONICA-RAYMOND, VERDUGO-EAGLE ROCK, AND BENEDICT CANYON FAULT ZONES, LOS ANGELES, CALIFORNIA, F. H. Weber, Jr., State of California, Division of Mines and Geology, Resources Building, Room 1341, 1416 Ninth Street, Sacramento, California 95814, (916) 445-1923.
Goal: To assess the earthquake hazard potential associated with the Vergo-Eagle Rock, Benedict, and related faults of the north-central Los Angeles area.
Investigations: Character and recency of movement along these faults is being determined by surface geologic mapping, geophysical studies, and studies of groundwater and other subsurface data. Because the region is mostly urbanized, we are using older aerial photographs and soils maps to assist in delineating geologic features related to faulting. The geophysical studies have consisted of gravity surveys which have furnished data used to prepare a gravity map of the region on a scale of 1:48,000.

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, Oregon 97331, (503) 754-2484.
Goal: To study the subsurface geology of the San Gabriel, Holser, and Simi-Santa Rosa

faults in order to determine the seismic and ground rupture hazard in the western Transverse Ranges.
Investigations: We will construct approximately 85 cross-sections at right angles to the three faults. These sections will concentrate on control within oil fields, then extend out across the extensive interfield wildcat well control and to surface geology. We are obtaining existing oil field cross-sections and modifying these to include new data. Regional structure contour maps will be drawn at critical horizons, unconformities, and fault surfaces. Contour maps will be constructed in the San Gabriel, Holser, and Simi-Santa Rosa faults and on other local faults in areas of extensive well control. Displacement models and stress trajectory sections will be based on the evaluation of structure contour maps of faults and horizons, isopach and facies maps of critical intervals, and paleogeologic maps at angular uncon- formities. Data on these faults and studies of other faults of the western Transverse Ranges will be used to construct a seismotectonic model of the Ventura basin depicting the structural development of the area through time.

EARTHQUAKE HAZARDS STUDIES, VENTURA BASIN AND ADJACENT AREAS, SOUTHERN CALIFORNIA, R. F. Yerkes, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2350.
Goal: To identify the tectonic framework and earthquake hazards in the western Transverse Ranges.
Investigations: In Area A (fig. 5), our evaluation of earthquake hazards continues via interpretation of pre-development and modern aerial photography, trenching, analysis of soils, geomorphology, and subsurface well data. Mollusks and tephra are dated to derive rates of fault movement and deformation of late Pleistocene-Holocene deposits. Mapped geologic structures are correlated with earthquake focal mechanisms, aeromagnetic and gravity anomalies, and relocated and evaluated pre-1975 earthquake data. Studies of shallow geology of the Oxnard plain continue. In Area B, we are retrieving, relocating, and evaluating earthquake data from 1932 to 1975 in order to derive focal mechanisms and test their correlation with mapped structural elements. This expansion to the east and southeast of the integrated geologic-seismic study of the western Transverse Ranges will aid us in identifying the geologic habit and relative activity of faults.

Western US (excluding California)

SOUTHWESTERN UTAH SEISMOTECTONIC STUDIES, R. E. Anderson, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-5109.
Goal: To study the seismotectonics of southwestern Utah.
Investigations: Project efforts in Iron County include: trenching studies of faults at Enoch and Fremont Wash, field studies of the 800 km area of suspected Holocene uplift in southern Escalante Valley, and mapping of the Braffits Creek and North Hills area. In Millard County we are conducting field investigations of selected bedrock structures in the Tunnel Spring Mountains.

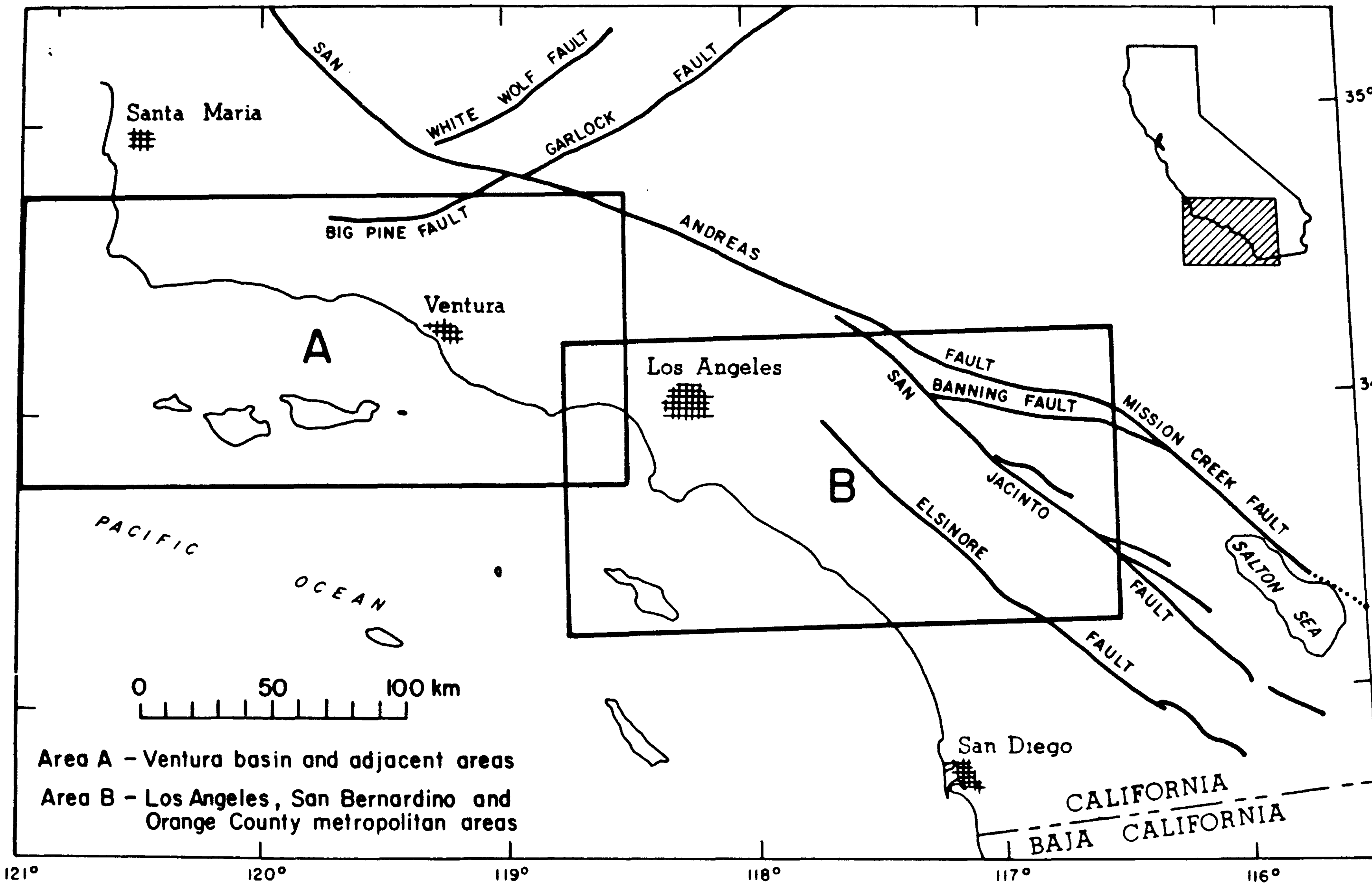

FIGURE 5.—Location map of study areas in southern California.

QUATERNARY FAULT MAP OF THE RENO QUADRANGLE, J. W. Bell, State of Nevada, Bureau of Mines and Geology, University of Nevada, Reno, Nevada 89557, (702) 784-6691.

Goals: (1) To compile all existing published and unpublished young fault maps within the quadrangle, (2) to map young faults in unstudied portions of the quadrangle, and (3) to assess recency and recurrence of movement on all major fault zones (fig. 6).

Investigations: New low, sun-angle aerial photography (1:40,000) is being flown to provide complete, uniform coverage of the quadrangle. This photography will be used to cross check existing mapping and to map unstudied areas. The late Quaternary glacial, lacustrine, alluvial, tephra, and soil stratigraphic record will be utilized in a field program designed to evaluate the recency and recurrence of movement of major structures; in particular, the portions of the Sierra Nevada Frontal Fault Zone and the Walker Lane which lie within the quadrangle, and the Carson Lineament and Olinghouse Fault Zone. Selected sites will be trenched to provide additional data. The product of these investigations will be a 1:250,000 scale map showing young faults categorized by recency of movement and illustrating the intensity and distribution of Quaternary-age tectonic activity within the area.

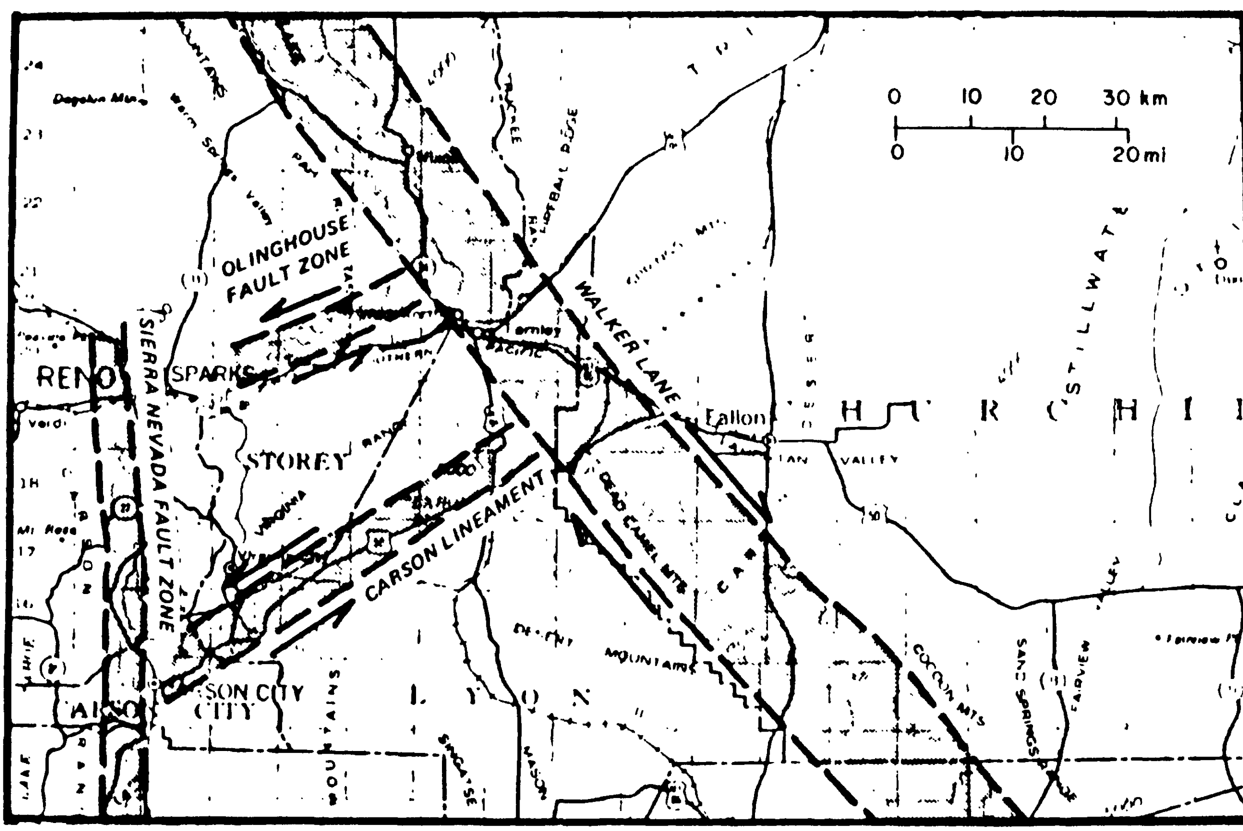

FIGURE 6.—Major structural features within the Reno quadrangle.

SEISMIC HAZARDS OF THE HILO 7-1/2' QUADRANGLE, J. M. Buchanan-Banks, U.S. Geological Survey, Branch of Engineering Geology, Hawaiian Volcano Observatory, Hawaii Volcanoes National Park, Hawaii 96718, (808) 967-7328.
Goal: To delineate seismic-related geologic hazards within the Hilo quadrangle, Hawaii.
Investigations: Our geologic mapping (including structure and dating of flows) of the Hilo 7-1/2' quadrangle delineates areas of potential ground failure during seismic shaking, areas of strong seismic ground amplification, areas of tsunami inundation and flooding, and localities and extent of hazardous faults.

NORTHWESTERN UTAH SEISMOTECTONIC STUDIES, R. C. Bucknam, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-5089.
Goals: (1) To map the distribution of late-Quaternary faults according to estimated age of last movement, and (2) to assess the rate, areal extent, and geometry of known and suspected Holocene deformation.
Investigations: Maps of northwestern Utah showing the location and estimated age of fault scarps in unconsolidated alluvium are being prepared at scales of 1:250,000 and 1:500,000. Tectonic maps will be prepared from existing geodetic data and from evaluations of level-line resurveys in critical areas. These efforts will provide a basis for investigating the relationships among various tectonic elements, Quaternary faulting, and historic seismicity.

ANCHORAGE-SUSITNA LOWLANDS EARTHQUAKE HAZARDS MAPPING, O. J. Ferrians, U.S. Geological Survey, Branch of Alaskan Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2247.
Goal: To complete engineering-geologic mapping of the Upper Cook Inlet-Susitna Lowland region for earthquake hazards identification and evaluation.
Investigations: This project continues to assess the response of regional surficial materials to ground shaking, ground failure, and surface faulting using slope evaluations, hydrologic, and other geotechnical studies.

SEISMOTECTONICS ANALYSIS OF THE PUGET SOUND PROVINCE, H. D. Gower, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, California 94025 (415) 323-8111, ext. 2325.
Goals: To evaluate potential earthquake generating structures and to develop a seismotectonic model that can serve as a basis for assessing earthquake potential in the Puget Sound region.
Investigations: A tectonic map based on marine seismic profiles is being made of the eastern Strait of Juan De Fuca. Surface and subsurface lithologic and physical property data are used to prepare seismic response and liquefaction-induced ground failure in selected areas near Seattle. We are preparing a seismotectonic map of the Puget Sound region from tectonic, geologic, geophysical, subsurface, and seismic data. Bedrock geologic mapping of the Seattle and Port Townsend 1:100,000 scale sheets is nearly completed.

SONORAN EARTHQUAKE OF 1887: EARTHQUAKE TECTONICS OF SOUTHERN ARIZONA, SONORA, AND CHIHUAHUA, D. G. Herd, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2870.
Goals: To investigate the geologic cause of the 1887 Sonoran earthquake and search for other recently active faults in the Sonoran Desert in order to establish the earthquake potential of southern Arizona and adjoining northern Mexico.
Investigations: The geologic setting of the Sonoran earthquake of 1887 will be explored by aerial photographic interpretation and reconnaissance field mapping (1:50,000). Accounts of the earthquake will be reviewed and compared with the geologic record to reconstruct a detailed picture of the earthquake and its effects. Recently active faults in the study area will be mapped by aerial photographic interpretation and limited field work. The faults will be classified, where sufficient geologic information exists, by age of last displacement.

PUGET SOUND LOWLAND FOCUSED GEOPHYSICAL STUDIES, M. L. Holmes, U.S. Geological Survey, Pacific-Arctic Marine Geology, 1107 N.E. 45th Street, Suite 110, Seattle, Washington 98105.
Goals: (1) To define the character of the southern margin of the Seattle (Bouguer) gravity minimum, (2) to obtain enough information about compressional velocities (and therefore densities) of the sedimentary section beneath the gravity anomaly to allow quantitative modeling of the causative geology, and (3) to relate regional seismicity patterns to the structural and tectonic interpretations that satisfy the upgraded gravity data and seismic velocity structure.
Investigations: Marine seismic refraction (sonobuoy) sounding of the velocity structure and sedimentary rock thickness beneath the Seattle gravity minimum is to be conducted in an experimental mode. Results should permit improved modeling of the source of this very large amplitude (80 milligals) but short wave length anomaly. Marine and land gravity observations will be made to locally upgrade existing maps in critical areas. All available geologic and geophysical data will be used to test geologic models.

TECTONIC FRAMEWORK OF THE RIO GRANDE RIFT, NEW MEXICO, N. M. Machette, U.S. Geological Survey, Branch of Central Environmental Geology, Denver Federal Center, Denver, Colorado 80225, (303) 234-5167.
Goal: To investigate the spatial and temporal patterns of Quaternary tectonism along the La Jencia fault, central New Mexico.
Investigations: We are excavating, mapping, sampling, and describing four exploratory trenches along the trace of the La Jencia fault in order to establish a detailed fault chronology. Surficial geologic data and scarp morphometric data are collected to access the relationship between scarp degradation rates, parent material influences, and ages of surface ruptures. These two investigations may allow the widespread application of scarp morphology studies as a dating tool for faults in other parts of the Rio Grande rift.

SURFICIAL GEOLOGY OF THE WASATCH FRONT, UTAH, R. D. Miller, U.S. Geological Survey, Branch of Engineering Geology, Denver Federal Center, Denver, Colorado 80225, (303) 234-2960.
Goal: To prepare surficial geologic and physical properties maps in order to further our understanding of the ground response of geologic materials along the Wasatch Front.

Investigations: The distribution of surficial materials is compiled in both the Great Salt Lake Valley and Utah Lake Valley on a scale of 1:100,000 topographic base. This effort included a limited drilling program in the lowlands of both valleys. Five holes of over 100 feet were placed in the unconsolidated lake and delta deposits near Provo, Salt Lake City, Farmington, and on the delta of the Bear River. Undisturbed samples were collected in Shelby tubes for laboratory analysis of physical properties. Surface and in-hole geophysics supplemented the drilling program. We will produce a physical properties map of the same area and on the same topographic base utilizing the surficial geologic map, data from drill hole samples and samples collected throughout the mapped area, as well as ground response data obtained from the Ground Response of the Salt Lake City Area Project.

ACTIVE FAULTS AND TECTONIC DEFORMATION IN ALASKA, G. Plafker, U.S. Geological Survey, Branch of Alaskan Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2201.
Goal: To assess the hazards in Alaska from tectonic displacement, seismic shaking, and secondary geologic effects (fig. 7).
Investigations: We are studying uplifted shorelines in the Lynn Canal, Chatham Strait, and Glacier Bay areas of southeastern Alaska to determine the amount and rate of uplift since the 1959 survey of tidal benchmarks in the area. Uplifted shorelines in Yakutat Bay were examined to determine amount and nature of displacements related to the 1899 earthquakes, as well as movement possibly resulting from pre-1899 earthquakes. Marine terraces in the Icy Cape segment of the Yakataga seismic gap were studied to provide information on the amount and rate of Holocene uplift. The meizoseismal region of the 28 February 1979 Saint Elias earthquake was investigated to evaluate geologic effects related to that event.

QUATERNARY STRATIGRAPHY OF THE WASATCH FRONT, W. E. Scott, U.S. Geological Survey, Branch of Central Environmental Geology, Denver Federal Center, Denver, Colorado 80225, (303) 234-5215.
Goals: (1) To develop a stratigraphic and chronologic framework for Quaternary deposits in the eastern Bonneville basin and (2) to estimate age, magnitude, and frequency of Quaternary surface faulting along the Wasatch Front.
Investigations: We are employing stratigraphic studies, radiocarbon dating of reliable materials, and relative-age dating techniques (including soil development and amino-acid stereochemistry) to obtain better resolution of the age of Lake Bonneville and related deposits. These investigations will enhance our understanding of the history of Lake Bonneville. Studies of morphology, height, and length of fault scarps and ages of deformed deposits are being used to estimate rates of tectonism and recurrence intervals of surface faulting.

STRATIGRAPHY OF PRE-VASHON QUATERNARY SEDIMENTS APPLIED TO THE EVALUATION OF A PROPOSED MAJOR TECTONIC STRUCTURE IN ISLAND COUNTY, WASHINGTON, K. L. Stoffel, State of Washington, Department of Natural Resources, Division of Geology and Earth Resources, Olympia, Washington 98504.
Goals: To correlate stratigraphically equivalent units within the Whidbey Formation across a proposed major tectonic structure and to determine the amount of vertical tectonic movement along the structure.

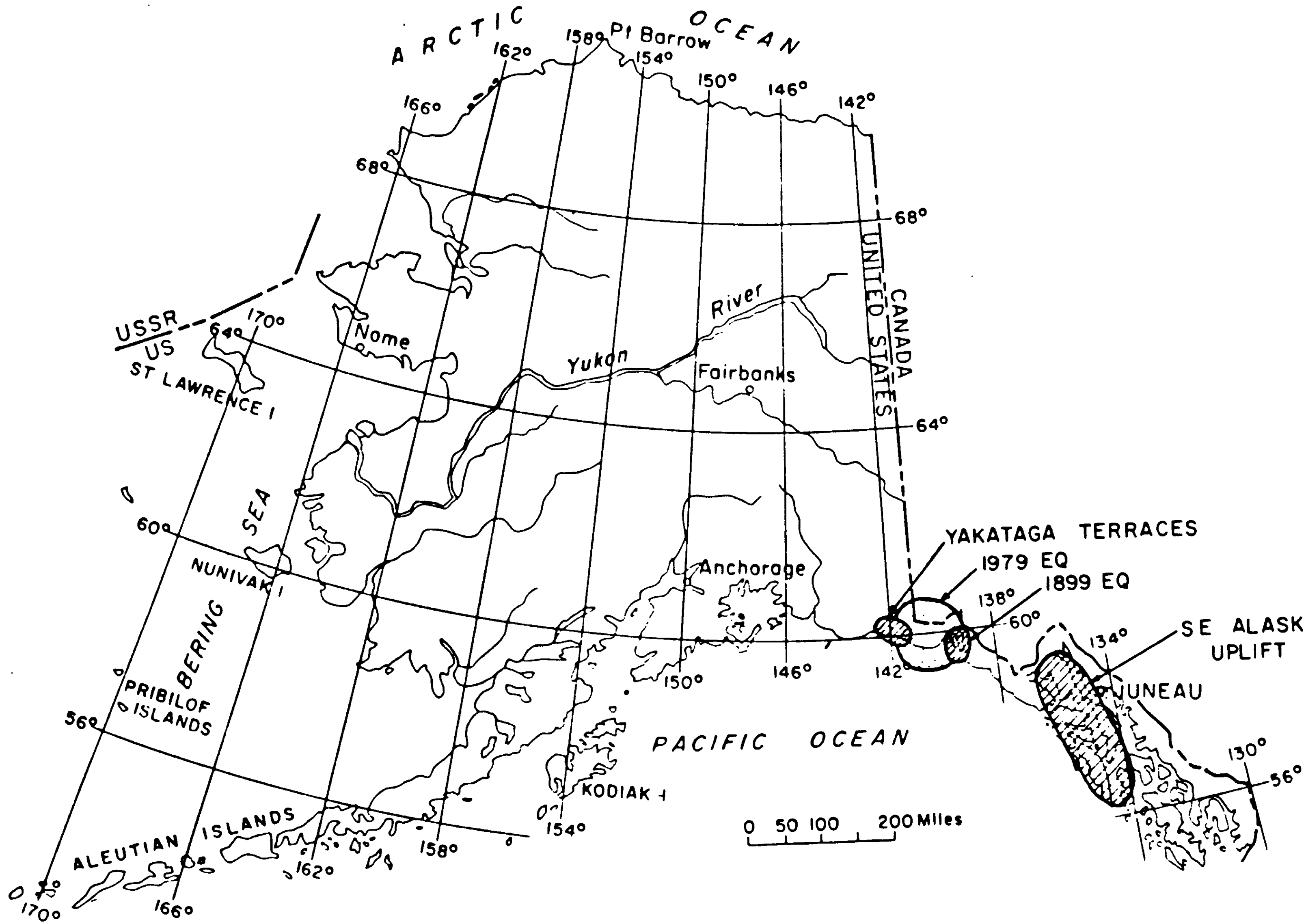

FIGURE 7.—Location map of study areas in southeastern Alaska.

Investigations: We are conducting stratigraphic studies of Quaternary nonglacial sediments on Whidbey Island, Washington, in an attempt to "fingerprint" the Whidbey Formation. Once it is defined by sedimentary petrologic criteria, we hope to be able to correlate outcrops of this formation. Detailed field work is conducted at the Double Bluff section of the Whidbey Formation.

GEOLOGIC MAPPING OF THE VISTA AND STEAMBOAT 7-1/2' QUADRANGLES, NEVADA, D. Trexler, State of Nevada, Nevada Bureau of Mines, Mackay School of Mines, University of Nevada, Reno, Nevada 89557, (702) 784-6691.

Goals: (1) To prepare geologic maps showing the distribution of Quaternary units based on their lithostratigraphic and sedimentologic patterns and (2) to map the location of faults, age of last movement, number of repeated movements, and the subsurface nature of the faults.

Investigations: Geologic mapping at 1:24,000 scale will provide information on the composition, textural parameters, and the degree of lithification of the units and their distribution. We will interpret low sun-angle photography (1:12,000) to obtain information on the location, relative age of faults based on scarp morphology, and selection of sites for trenching. Trenches across selected fault traces will be made to determine the spatial relation of fault scarp to fault trace, subsurface expression of the shear zone, and stratigraphic relationships. These field studies will aid in interpreting frequency of movement and age of last movement. The geologic information will be coupled with engineering and shear-wave velocity data in order to determine the seismic response of the units — the initial step in preparing earthquake hazards maps.

GEOTECHNICAL SOILS INVESTIGATIONS, UPPER COOK INLET, ALASKA, R. G. Updike, Alaska Division of Geological and Geophysical Surveys, 3001 Porcupine Drive, Anchorage, Alaska 99551, (907) 279-1433.

Goals: (1) To establish an engineering soils data bank of geotechnical borehole logs and test results for the Upper Cook Inlet region, (2) to determine the present-day susceptability for sensitive clay failure and liquefaction of Quaternary soils in response to a seismic event, and (3) to map and characterize the failure potential for critical areas of the Anchorage municipality.

Investigations: The borehole information for several hundred locations have been obtained and indexed. We are utilizing a segment of this data in a pilot project in the Government Hill area. Specifically, we are testing a hypothesis that discrete engineering geologic facies exist in the Bootlegger Cove formation, that these facies may be characterized regarding engineering characteristics, and that these facies can be mapped in detail (fig. 8). This project is nearing completion and the hypothesis appears well-supported. A strain history model for post-1964 earthquake behavior of Anchorage landslides is being developed utilizing Digitilt inclinometer monitoring. Regional studies of Quaternary soils involving field mapping, sampling, and testing of historic slides around Upper Cook Inlet is supplying information on the variability of failure potential and mechanics. Field work has been initiated to better determine Holocene activity on the Castle Mountain fault, approximately 35 km west of Anchorage.

FIGURE 8.—Bootlegger Cove formation, facies transition from diamicton at left to silty fine sand planar bedding at right, Redoubt Bay Alaska. (Updike, 1979)

TECTONIC TILT MEASUREMENTS USING LAKE LEVELS, S. H. Wood, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Boise State University, Boise, Idaho 83702, (208) 385-1631.

Goals: (1) To measure and monitor rates of vertical crustal movement using level water surfaces, and (2) to relate contemporary tectonics to the Quaternary geologic record.

Investigations: Recorded lake levels are referenced to benchmarks at three or more points on large lakes to detect tilt (fig. 9). Active areas are continuously monitored, where feasible, to obtain a detailed history of contemporary vertical crustal movement. Lake-level data, geodetic data, seismicity, and the Quaternary geologic history of southern Alaska and the Intermountain Seismic Belt will be studied to better understand earthquake tectonics and rates of vertical crustal movement.

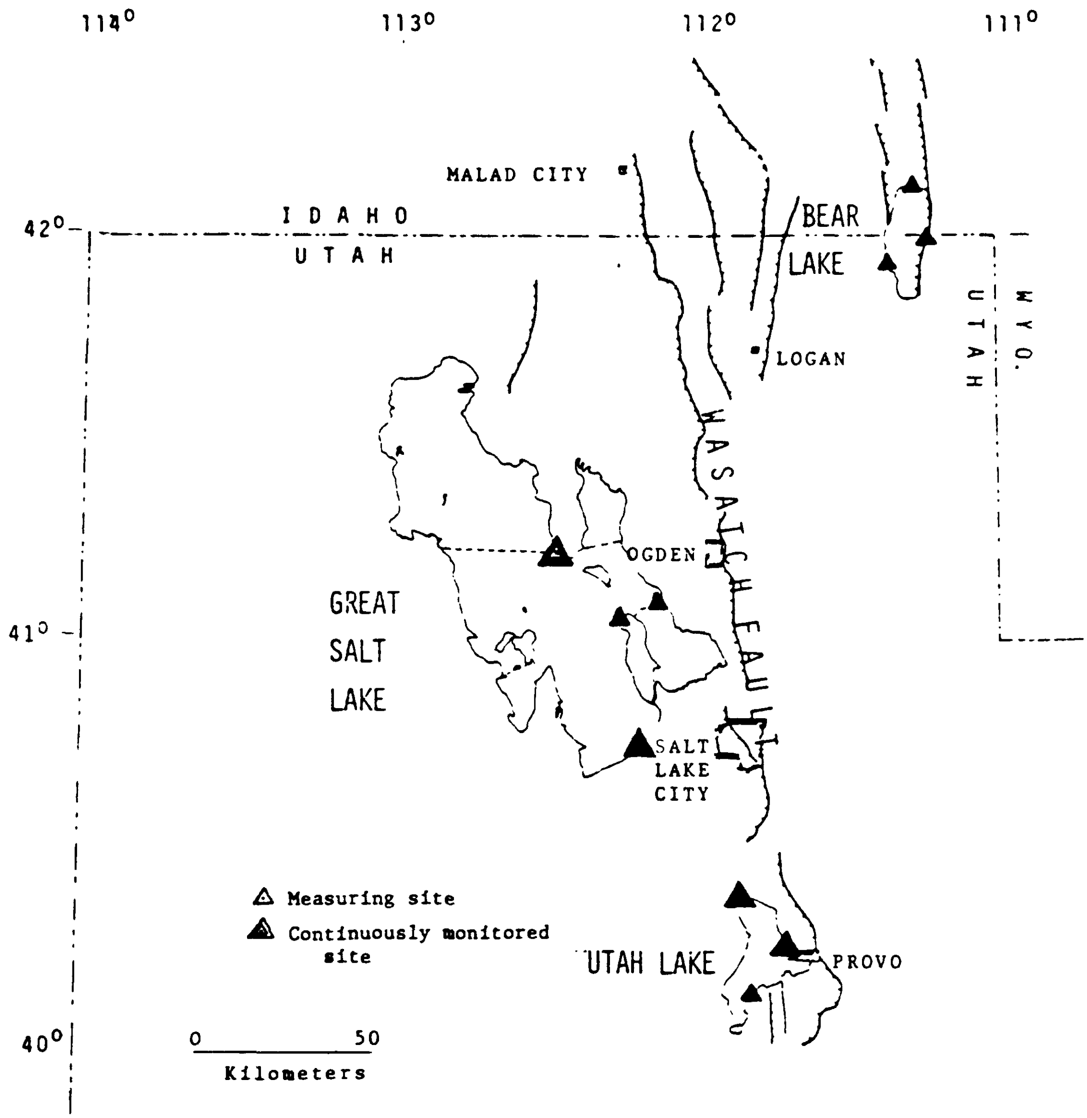

FIGURE 9.—Quaternary faults (after Smith, 1974) and measuring sites for tectonic tilt using lake levels in the Ogden-Salt Lake City, Utah area.

GEOPHYSICAL AND TECTONIC INVESTIGATIONS OF THE INTERMOUNTAIN SEISMIC BELT, M. L. Zoback, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 928 National Center, Reston, Virginia 22092.

Goal: To determine the neotectonic style of deformation within the study region.

Investigations: The study area appears to mark a transition between Basin and Range extensional tectonics and a general state of compression within the Colorado Plateau interior. We are analyzing existing geophysical data to infer subsurface basement configuration and to determine fault offsets, particularly in regions of Quaternary offsets. New geophysical data will be collected in key areas to fill gaps in existing coverage. Field studies will be conducted to determine the modern pattern of displacement and the principal stress orientation.

Eastern US

LATE TERTIARY AND QUATERNARY SHORELINE DATUM PLANES AND TECTONIC DEFORMATION IN THE SOUTHEASTERN UNITED STATES, T. M. Cronin U.S. Geological Survey, Branch of Paleontology and Stratigraphy, 970 National Center, Reston, Virginia 22092, (703) 860-6381.

Goals: (1) To determine the trend and magnitude of Pliocene and Pleistocene vertical crustal displacement of the emerged part of the Atlantic continental margin and (2) to explain these movements in terms of possible mechanisms including hydroisostacy, crustal unloading due to erosion, glacio-eustatic sea level history, and continental margin subsidence.

Investigations: We are using paleontologic and radiometric dating methods to locate and date crustal movements of the emerged Atlantic coastal plain during the last 5 million years. By combining study of cores and outcrops of marine sediments and geomorphic analyses of relict shorelines, we are using the shorelines as datum planes to calculate uplift rates in southeastern Virginia, the Cape Fear Arch region of North and South Carolina, and the Charleston, South Carolina region.

SEISMOTECTONICS OF NORTHEASTERN UNITED STATES, W. H. Diment, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, MS-935 National Center, Reston, Virginia 22092, (703) 860-6520.

Goal: To identify potential seismic-hazard zones in the northeastern U.S.

Investigations: This project evaluates existing geophysical, geologic, and seismologic data in order to identify seismogenic zones warranting further study.

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

Goals: (1) To detail tectonic development of the eastern part of the Ozark uplift and (2) to determine whether rifting is involved in the development of the "Ozark front," the zone of transition between the Ozark uplift and the syncline of the seismically active Mississippi Embayment.

Investigations: Previously logged cuttings from test holes in the Newport area were reexamined and cuttings from several recently drilled deep testholes were logged. We are preparing isopach and structure contour maps of this area. A preliminary geologic map of the Mississippi embayment area revises past efforts and shows the distribution of rocks of Paleozoic age beneath the cover of Cretaceous and younger sediment. The semimentary record of the Ozark front will be analyzed to determine when rifting was an effective phenomenon and whether it has had a periodicity that may contribute to the understanding of intraplate earthquakes.

EASTERN U.S. SEISMICITY AND TECTONIC STUDIES, R. M. Hamilton, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 935 National Center, Reston, Virginia 22091, (703) 860-6529.
Goal: To determine the relation between seismicity and geologic structure in the eastern United State.
Investigations: Multichannel, common-depth-point, seismic reflection profiling is being used in the New Madrid and Charleston seismic regions to delineate fault zones and other tectonic features related to seismicity. A seismic refraction study will be conducted to determine deep crustal structure in the New Madrid region.

TECTONIC FRAMEWORK OF THE NEW MADRID REGION FROM GEOPHYSICAL STUDIES, T. G. Hildenbrand, U.S. Geological Survey, Branch of Regional Geophysics, Denver Federal Center, Denver, Colorado 80225, (303) 234-5464.
Goals: To analyze the geophysically-inferred structures underlying the Mississippi Embayment and to determine possible relationships between these structures and seismicity.
Investigations: A recently compiled Bouguer gravity map and aeromagnetic map of upper Mississippi Embayment and surrounding region reveal several prominent anomalies that reflect major geological structures. We are analyzing the data in order to delineate the shape, dimensions, age, and related physical properties of these structures. A detailed truck magnetometer survey was conducted for the purpose of determining a relationship between faulting and dike-injection. In addition, exploratory electromagnetic traverses were carried out to probe for conductive structures in the embayment.

CENTRAL AND EASTERN UNITED STATES EARTHQUAKE STUDY, M. F. Kane, U.S. Geological Survey, Branch of Regional Geophysics, Denver Federal Center, Denver, Colorado 80225, (303) 234-2623.
Goal: To develop a regional tectonic model of the central and eastern United States that is compatible with the gravity, magnetic, terrain, regional geologic, and seismicity data.
Investigations: Regional scale gravity, aeromagnetic, basement, and tectonic compilations of the central and eastern United States are being analyzed for coincident anomaly zones, trends, and regional patterns. These elements are being interpreted in terms of basement domains using major discontinuities and inferred broad regions of distinctive lithology and structure. The results are compared with seismicity, terrain, and geologic provinces for evidence of tectonic patterns developed from the beginning of Mesozoic time to present.

ENGINEERING GEOLOGY OF THE BOSTON METROPOLITAN REGION, C. A. Kaye, U.S. Geological Survey, Branch of Engineering Geology, 150 Causeway St., Room 1304, Boston, Massachusetts 02110, (617) 223-7200.

Goal: To develop surficial, subsurface, and submarine geology maps for the central Boston and offshore Massachusetts Bay areas.

Investigations: We prepared a stratigraphically sequential series of maps of the central Boston area using logs of more than 25,000 foundation borings. These 1:6,000-scale maps provide a 3-dimensional picture of surficial deposits and a detailed picture of bedrock geology (from rock cores). In addition, 1:24,000-scale quadrangle maps of surficial and bedrock geology have been prepared for Lexington, Boston North, Lynn, Marblehead South, Nantasket, Hull, Boston South, and Newton. Submarine geology of the harbor and offshore Massachusetts Bay has been mapped using a grid of subbottom acoustical profiles.

QUATERNARY STRATIGRAPHY AND BEDROCK STRUCTURAL FRAMEWORK OF GILES COUNTY, VIRGINIA, R. C. McDowell, U.S. Geological Survey, Branch of Eastern Environmental Geology, 928 National Center, Reston, Virginia 22092, (703) 860-6503.

Goals: To locate effects of modern seismic activity on Quaternary surficial deposits, and to determine the relationship between the Paleozoic structure and neotectonics in the area.

Investigations: Project efforts include developing the Quaternary history of the area, establishing a stratigraphic framework, and mapping surficial deposits. Trenching of terrace deposits will aid in working out relative and absolute ages. In addition, the Paleozoic bedrock structure is being examined for evidence of post-Paleozoic movement. All of these findings will be related to results of a separate study of the seismic activity in the area.

NORTHEASTERN U. S. SEISMICITY AND TECTONICS, N. M. Ratcliffe, U.S. Geological Survey, Branch of Eastern Environmental Geology, U. S. Geological Survey, MS-925, National Center, Reston, Virginia 22092, (703) 860-6406.

Goal: To determine the attitude, distribution, and movement history of faults within the Ramapo fault zone in order to identify faults that may be related to historic seismic activity.

Investigations: Field studies and trenching are concentrated in selected parts of the Peekskill, Haverstraw, Thiels, Popolpen Lake, West Point, and Osdawana Lake quads. At these sites, bedrock and surficial deposits will be mapped in detail. Glacial and post glacial deposits will be examined for evidence of recent fault movement and unconformities at the north end of the Triassic basin. Geochronologic dating of sericite, palygorskite, and stilpnomelane will establish minimum ages for mapped faults of the Ramapo zone.

MISSISSIPPI VALLEY SEISMOTECTONICS, D. P. Russ, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-5087.

Goals: (1) To provide evidence and rationale to establish a relationship of seismicity to geologic structural elements in the Mississippi Valley, (2) to establish a basis for estimating recurrence intervals of earthquakes in the Mississippi embayment, and (3) to use above items to establish areal limits of seismicity for use in seismic hazard assessment.

Investigations: Areas of suspected faults are being mapped and trenched to determine the character and recurrence intervals of faulting. Reflection and refraction seismic profiles and well logs are being used to characterize subsurface structure and tectonic style. River terraces will be studied using geomorphic analyses, sedimentation techniques, and computer modeling in order to detect effects of Quaternary surface warping.

GEOPHYSICAL IDENTIFICATION OF TECTONIC FEATURES IN NORTHEASTERN U.S., R. Simpson, U.S. Geological Survey, Branch of Regional Geophysics, Denver Federal Center, Denver, Colorado 80225, (303) 234-2623.
Goal: To identify geophysical anomalies and tectonic features related to seismicity in the northeastern U.S.
Investigations: New aeromagnetic and marine geophysical data have been collected offshore over structures which may be related to some of the larger historic earthquakes. Truck magnetometer data was collected over the Ramapo and Flint Hill faults in cooperation with geologic studies of these features. We are compiling available gravity and magnetic data for map production at scales compatible with geologic investigations.

STRUCTURAL FRAMEWORK OF EASTERN UNITED STATES SEISMIC ZONES, R. L. Wheeler, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-5087.
Goals: (1) To identify seismically-related structures in the eastern United States, and particularly in southwestern Virginia, and (2) to seek seismically-related patterns in geologic, geophysical, and topographic characteristics of the Appalachian region of the southeastern United States.
Investigations: We are compiling and analyzing existing data, improving an existing pattern recognition program, and developing efficient methods to map joint intensity. We are also developing methods to look through thrust complexes masking possible basement faults.

National

NEOTECTONIC SYNTHESIS OF THE UNITED STATES, C. M. Wentworth, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2474.
Goal: To prepare a neotectonic map of the conterminous United States at a scale between 1:7,500,000 and 1:2,500,000.
Investigations: The deformation history indicated by the geologic record through Pliocene and Quaternary time will be summarized in terms of relative movements and their amounts and rates. The map will show faults, folds, vertical and resolvable horizontal movements, and related geologic control. Projections from the styles and rates of pre-Pliocene deformation will be separately included where appropriate in order to better depict horizontal movement. Reference includes: local indication of fault offset; local and regional datums, such as unconformities and old shorelines; sedimentary evidence of upland erosion and basin subsidence and deformation; and geomorphic evidence of change or stability.

SEISMOGENIC ZONES OF THE UNITED STATES, J. I. Ziony, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2944 or 2214.
Goals: (1) To evaluate the geologic, geophysical, and seismologic character of earthquake-generating areas of the United States and adjacent continental shelves; and (2) to develop a national seismotectonic map.
Investigations: We are holding a series of workshops with regional geologic and geophysical experts to delimit seismogenic zones for various sectors of the central and eastern United States. An intensive analysis is underway to determine the relationships between southeastern U.S. seismicity and Cenozoic faulting, Triassic basins and dikes, and regional geophysical parameters.

Earthquake Recurrence and Age Dating

PHYSICAL AND MATHEMATICAL DESCRIPTIONS OF ACTIVE FAULTS, R. C. Bucknam, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-5089.
Goals: To determine the number, ages, and sizes of late-Quaternary faulting events in selected areas of the Great Basin and the relationships between the surface expression of the faults and local geologic factors that control the sizes and locations of the events.
Investigations: We will conduct local detailed mapping of segments of active faults (primarily along the Wasatch fault, Utah) to delineate intervals of late-Quaternary surface faulting resulting from a single event. Surface faults will be characterized by amounts of offset, scarp slope angles, and detailed descriptions of the morphology of the faults and associated secondary features, such as grabens. The data will be analyzed and compiled in formats useful in probalistic earthquake hazard evaluations and local land use planning.

COLLABORATION ON C-14 AND K/Ar DATING, B. R. Doe, U.S. Geological Survey, Branch of Isotope Geology, Denver Federal Center, Denver, Colorado 80225, (303) 234-4003.
This project participates with various field geologists in determining the age of faulting by radio-carbon, potassium-argon, and fission-track dating techniques.

SOIL MORPHOLOGY AND FAULT MOVEMENT, L. A. Douglas, Rutgers University, Department of Soils and Crops, New Brunswick, New Jersey 08903, (201) 932-9800.
Goal: To define and describe the micromorphological features unique to faulted soils.
Investigations: We are studying faulted soils in the western United States. Major emphasis is placed on faults that have moved during historical times and on soils with well developed B horizons. Faults exposed by trenching are described and mapped prior to sampling. Undisturbed and oriented soil samples will be taken along a transect from the zone of movement to a distance where faulting has not affected the soil. We are using conventional petrographic and fluorescent microscopic techniques to characterize the micromorphological properties of these soils.

NEOTECTONICS IN MEADE COUNTY, KANSAS, G. A. Izett, U.S. Geological Survey, Branch of Central Environmental Geology, Denver Federal Center, Denver, Colorado 80225, (303) 234-2835.

Goal: To determine the neotectonic history of the Meade artesian Basin area in southwestern Kansas.

Investigations: Project efforts include: mapping deposits in critical areas along the faults, collecting and studying the volcanic ash beds in the deposits, and determining fission track ages of the ashes. Mammal fossils are collected, identified, and studied to determine their ages. Geophysical logs of oil and gas wells in areas near faults will be studied to determine amounts of offset.

A NEW METHOD OF ALLUVIAL AGE DATING BASED ON PROGRESSIVE WEATHERING, WITH APPLICATIONS TO THE TIME-HISTORY OF FAULT ACTIVITY IN SOUTHERN CALIFORNIA, B. Kamb, California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, California 91125, (213) 795-6811.

Goal: To evaluate the CVS Method for assessing the relative ages of alluvial deposits.

Investigations: A new method (CVS Method) for assessing the relative ages of alluvial deposits by measuring P-wave velocities in clasts of known lithology contained in these deposits is being evaluated in terms of the technique used and the results obtained. The evaluation includes comparison between CVS measurements obtained by different observers on the same clast sample populations. We are applying the CVS method systematically to alluvial deposits of known relative age in order to determine the degradation in clast sound velocity with time and to assess the ability of the method to distinguish among deposits of different age.

CORRELATING AND DATING QUATERNARY SEDIMENTS BY AMINO ACIDS, K. A. Kvenvolden, U.S. Geological Survey, Branch of Pacific-Arctic Marine Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 856-7150

Goal: To refine and extend the current methodology for stratigraphic correlation and geochronology.

Investigations: Both gas and automated ion exchange chromatography are used to determine amino acids in samples of shells, bones, and sediments. We will increase sensitivity of our methods and investigate other time dependent chemical reactions in order to corroborate the results of stereochemical studies. Continuing studies will compare our results with those obtained by other geochronologic methods.

MAGNETOSTRATIGRAPHY OF SEDIMENTS IN THE ATLANTIC COASTAL PLAIN, J. C. Liddicoat, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, (914) 359-2900, ext. 521.

Goal: To date sedimentary units and formations by paleomagnetism as an adjunct to investigations identifying and measuring Neogene tectonin activity in the southeastern United States.

Investigations: Paleomagnetic samples for either outcrop, fully-oriented Shelby tube and split-spoon cores, or deep sea cores of the 1976 AMCORP are used to date stratigraphy along the continental margin. The magnetostratigraphic data will help to improve the chronology of stratigraphic units where previous field mapping, radiometric and amino acid dating, paleontology, and palynology have been used with mixed success.

SOIL CORRELATION AND DATING, WESTERN REGION, D. E. Marchand, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2009.

Goal: To describe, sample, and analyze the chronosequences of soils in a range of climatic-vegetational environments in the western United States where the absolute ages of Quaternary deposits are known.

Investigations: We are sampling multiple chronosequences of soils formed on alluvium and marine terrace deposits derived from granitic, volcanic, sedimentary, and metamorphic rocks. Field descriptions of soils include: horizon boundaries, color, texture, clay films, consistency, structure, and field pH. Complete particle size, x-ray diffraction, exchange capacity, and free iron oxides are among the 12 laboratory parameters determined. Major and trace element analysis will be routinely run if preliminary results are favorable.

THE DETERMINATION OF THE MAGNITUDE AND DATE OF DIP-SLIP FAULTING BY DISCORDANCE IN SETS OF MEAN SEA LEVEL CURVES, W. S. Newman, City University of New York, Queens College, Flushing, New York 11367, (212) 520-7651.

Goal: To determine both magnitude and frequency of motion along the Ramapo Fault Zone in southeastern New York State adjacent to the Indian Point Nuclear Reactor Complex.

Investigations: The project attempts to determine Holocene neotectonic deformation along a north-striking transect across the Ramapo Fault Zone by developing a series of sea level curves within and on both sides of the fault zone. The transect is 100 kilometers long. The results indicate tilting towards the south as well as graben-like subsidence within the fault zone.

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

Goal: To develop and improve Quaternary dating techniques, Quaternary time stratigraphies, and local or regional neotectonic histories.

Investigations: A variety of relative-age methods are being investigated in an attempt to extract numerical age estimates, especially where relative age methods can be calibrated by radiometric techniques and (or) where they can be applied to important time stratigraphies or neotectonic histories. Specific studies involve hydration-rind dating of obsidian; uranium-series dating of caliche rinds; scarp degradation through time; weathering rinds on andesite and basalt as an age indicator; and the developing through time of several soil properties, including general morphology, B horizon thickness and clay content, and carbonate contentent and morphology. Study localities range geographically from Virginia to California with concentrated investigations in the Rocky Mountain states. In addition, we are using geomorphic and relative-age methods to improve our understanding of the neotectonic history of Colorado and New Mexico. Neotectonic maps of these areas are being compiled.

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

Goal: To determine the feasibility of uranium-trend dating as a reliable technique for estimating the age of alluvium deposition over the range of 5,000 to 900,000 years.

Investigations: The dating technique consists of determining an isochron from analyses of several samples covering the various soil horizons in a given alluvium unit. Approximately four to nine samples of each unit are analyzed. In each sample an accurate determination of the abundance of U-238, U-234, Th-230, and Th-232 is required. Alluvium units of known age of deposition or those represented by a good geochronological correlation will be measured to evaluate the reliability of this technique. Units producing suitable isochrons will be used to calibrate the time scale of the dating technique over the range of about 5,000 to 900,000 years. High quality isotopic data will be obtained from an alpha spectrometer. We plan to derive a mathematical model, based on Bateman equations, in order to determine if an independent mathematical solution exists to calculate the age of alluvium deposition from uranium-trend isochron slopes.

TRENCHING STUDIES OF THE SAN ANDREAS FAULT, D. Rust, Humboldt State University, Department of Geology, Arcata, California 95521, (707) 826-3165.
Goals: (1) To identify and radiometrically date the succession of past great earthquakes in the "Big Bend" reach of the San Andreas fault north of Los Angeles, and (2) to determine an average long-term rate of displacement for this reach of the fault.
Investigations: A large backhoe trench was dug across the active fault zone in an area of recent lacustrine and distal fan sedimentation. Detailed logs of the trench walls were compiled, with particular attention to evidence for individual faulting events. We then collected 20 charcoal samples in order to radiometrically date the events recognized. Two backhoe trenches were dug near the edge of a landslide that had been bisected and offset 40 meters by displacement on the main trace of the San Andreas fault. We examined the walls and collected charcoal samples for determining an age of deposit.

TEPHROCHRONOLOGY OF THE WESTERN REGION, A. M. Sarna-Wojcicki, U.S. Geological Survey, Branch of Western Environmental Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2745.
Goal: To identify, correlate, and date late Cenozoic tephra in the western states in order to provide age and stratigraphic data for site-specific and regional geologic hazards studies.
Investigations: Project efforts primarily focus on areas of high seismicity and high population density; areas in the path of intensive development; and areas where critical facilities are sited or planned. Volcanic ashes and tuffs are mapped and samples are chemically analyzed by neutron activation, X-ray fluorescence, electron microprobe, and wet chemical, as appropriate. Quantitative data for each analyzed sample are matched by computerized statistical routines to determine correlations. Fisson-track ages will be determined on selected samples to calibrate the tephrochronological time jcale, and to obtain independent checks on correlations.

QUATERNARY REFERENCE CORE, CLEAR LAKE, CALIFORNIA, J. D. Sims, U.S. Geològical Survey, Branch of Earthquake Tectonics and Risk, 345 Middlèfield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2252.
Goals: To conduct deep-coring operations in Clear Lake and collect a core in an uninterrupted sequence of Quaternary lacustrine deposits up to 700 m long in order to provide a stratigraphic reference section for further study of Quaternary tectonic basins and permit comparisons with paleoclimatic data from cores in the deep ocean basins.

Investigations: Start-up and logistical support are the major activities of this project. Studies conducted on samples collected in prior shallow drilling operations include: (1) analysis of the Cache Formation around Clear Lake to determine Pleistocene and Pliocene tectonic, geomorphic, and paleoclimatic histories; (2) reanalysis of stratigraphy of Clear Lake cores taken in 1975 incorporating new data from carbon-14 analyses; (3) mercury analyses of modern and ancient sediments from Clear Lake to determine natural and man-induced flux of mercury into the lake over the past 30,000 years; and (4) grain-size analyses on samples from the Kerr-McGee core KM-3 from Searles Lake, California (in cooperation with G. I. Smith, USGS, and Joseph Liddicoat, Lamont-Doherty). The KM-3 is well studied and will be compared with cores from Clear Lake.

PALEOSEISMIC INDICATORS IN SEDIMENTS, J. D. Sims, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2252.

Goals: (1) To study lacustrine and sag pond sediments in seismically active areas in the United States in order to determine recurrence intervals from earthquake-induced structures, tectonic-induced sedimentation, and date of formation of sag ponds; and (2) to perform detailed geologic and structural mapping in the San Andreas Fault Zone between Hollister and Cholame, California.

Investigations: Undisturbed samples were studied from cores collected in the Imperial Valley (ancient Lake Cahuilla) and Koehn Lake, California, and Skilak Lake, Alaska. The study of sag ponds along the San Andreas Fault Zone is aimed at determining the age of formation, number and magnitude of individual slip events, and interpond correlation of discrete seismic and tectonic events. Along with the sag pond studies, geologic mapping at 1:12,000 scale depicts the character of deformation and delineates subsidiary faults, steps, splays, and discontinuities. Laboratory experimental models were constructed to examine the kinetics of formation of earthquake-induced structures in sediments.

STUDY OF EARTHQUAKE RECURRENCE INTERVALS ON THE WASATCH FAULT, UTAH, F. H. Swan, III, Woodward-Clyde Consultants, Three Embarcadero Center, Suite 700, San Francisco, California 94111, (415) 956-7070.

Goals: To assess the recurrence interval of moderate to large magnitude earthquakes produced by surface faulting along the Wasatch fault zone.

Investigations: Exploratory trenching, analysis of fault scarp morphology and scarp-derived colluvial deposits, and detailed geologic mapping are being conducted at selected sites along the 370 km fault to characterize late Pleistocene and Holocene behavior. Data are being collected on recurrence of surface faulting earthquakes along different segments of the fault, cummulative displacement in Quaternary strata or different ages, slip rate, displacement per event, and magnitude of past earthquakes. The detailed geological studies focus on faulted Lake Bonneville deposits and faulted alluvial and colluvial deposits at the selected localities (fig. 10). Age determinations of the displaced deposits are based on radiocarbon dates and correlations with deposits and soil of known age. The data are being used to assess the recurrence of moderate to large magnitude earthquakes produced by surface faulting along the entire Wasatch fault zone.

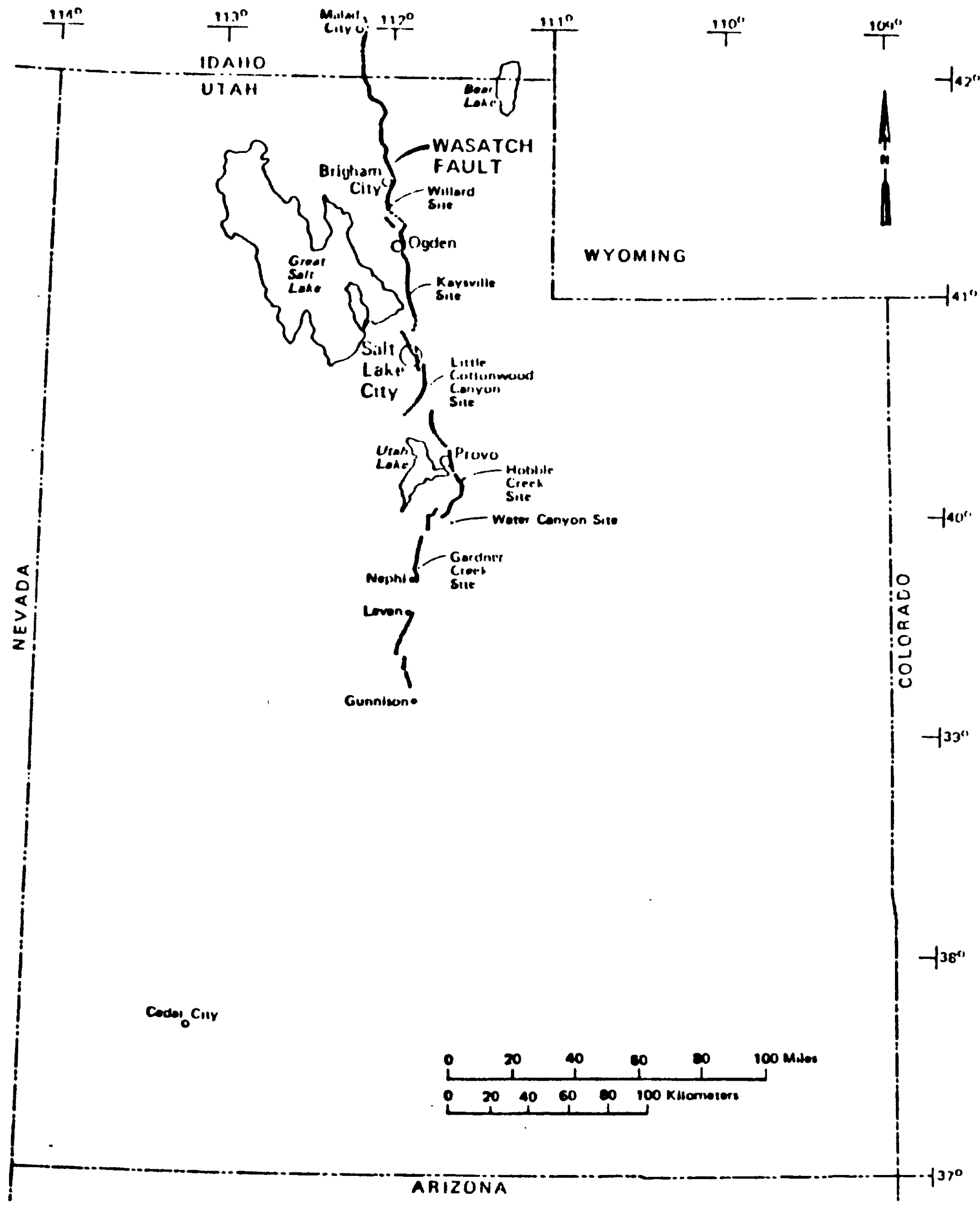

FIGURE 10.—Regional location map of study sites along the Wasatch fault.

TECTONIC ANALYSIS OF ACTIVE FAULTS, R. E. Wallace, U.S. Geological Survey, Office of Earthquake Studies, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2751.
Goal: To develop methods for interpreting paleoseismicity from the forms and sizes of scarps developed during historic and prehistoric earthquakes.
Investigations: We are analyzing fault scarp morphology in an attempt to develop geomorphic criteria for dating movements and estimating recurrence of displacement events on young faults. Although scarp profiles are useful reconnaissance indicators of age, rates of scarp change are influenced by several variables and require determinations of normalizing factors for climate, rock type, and scarp height (fig. 11).

Earthquake Effects

Ground Motion

SEISMICITY AND RELATED DATA FOR HAZARD ANALYSIS, S. T. Algermissen, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-4014.
Goals: (1) To prepare and publish a revised seismicity catalog for the United States, and (2) to prepare a revision of the Modified Mercalli Scale of 1931.
Investigations: A seismicity catalog of the United States for earthquakes I to greater than VI will include isoseismal maps and other data useful in earthquake hazard analyses. State seismicity maps will be reviewed for additions or deletions of earthquakes, change of Modified Mercalli intensity, earthquake location, etc. We will also prepare a recommended revision of the MMI scale to amend outdated criteria.

REGIONAL AND NATIONAL SEISMIC HAZARD AND RISK ASSESSMENT, S. T. Algermissen, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-4014.
Goal: To develop new probabilistic ground motion models.
Investigations: This project will extend the probabilistic description of ground acceleration in the continguous United States by mapping maximum accelerations in rock in a 200-year period at the 90 percent probability level. Computer programs for probabilistic ground motion calculations are generalized to include finite length of faulting, uncertainty in fault strike, and uncertainty in ground motion attenuation.

A NEW ATTEMPT AT SEISMIC ZONING MAPS FOR SOUTHERN CALIFORNIA, C. R. Allen, California Institute of Technology, Seismological Laboratory, Pasadena, California 91125, (213) 795-6811.
Goals: To produce a more realistic zoning map of southern California.
Investigations: We are obtaining geologic data relating to the relative and absolute degrees of activity of faults in the southern California area. These data will be combined with seismological and historical information in the production of a zoning map of southern California.

FIGURE 11.—Hebgen fault scarp, Montana, upper frame taken immediately after earthquake in 1959 (Stacy, 1959). Lower frame taken in 1978 showing change in slope resulting from 19 years of degradation (Wallace, 1978).

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, California 94025, (415) 323-8111, ext. 2752.

Goal: To understand the generation of high-frequency strong ground motion in terms of physical processes at the earthquake source.

Investigations: A random faulting model was constructed in which a fault surface is conceived to have random geometric irregularities at all length scales. Stress changes in an earthquake is a random fluctuating function of position and time. The ground motion has a high-frequency spectrum that is an inverse power law. Peak acceleration would be infinite without attenuation along the propagation path.

3-D NEAR FIELD MODELING AND STRONG GROUND MOTION PREDICTION IN A LAYED MEDIUM, R. J. Archuleta, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2062.

Goal: To determine the ground motion in the vicinity of an earthquake.

Investigations: We intend to evaluate those parameters that can severely affect the ground motion by simulating earthquakes numerically. The parameters under study are the stress state on the fault, types of faulting (strike-slip and dip-slip), and the geological properties of the medium.

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, California 92038, (714) 453-0060.

Goal: To determine the extent to which the near-field ground motion may be constrained by far-field data, particularly the teleseismic P wave recordings.

Investigations: The teleseismic P wave recordings of four moderate-sized earthquakes (1975 Pocatello Valley, Idaho; 1975 Yellowstone Park; 1968 Borrego Mountain, California; and 1975 Oroville, California) were studied by comparing synthetic and observed seismograms. A detailed model of the Pocatello Valley event was constructed to match the long and short period recordings while remaining consistent with near-field studies of the geology and aftershock distribution. To fit the data, it was necessary to construct a variable stress drop, variable rupture velocity model. We computed ground motions at ranges from 150 to 770 kilometers using the Pocatello Valley earthquake model and realistic earth models. The results were compared to empirical estimates of peak ground motion (displacement, velocity, and acceleration) attenuation in the western United States.

INTERACTIVE DATA PROCESSING CENTER FOR GROUND MOTION STUDIES, L. M. Baker, U.S. Geological Survey, Branch of Ground Motion and Faulting, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2703.

Goal: To provide a convenient, state-of-the-art tool for studies of earthquake sources, wave propagation, ground response, and strong motion.

Investigations: The interactive data processing center consists of a PDP-11/70 minicomputer and associated peripherals running under the vendor-supplied real-time operating system, RSX-11M. Incoming field data is transferred to on-line disk storage from several digital playback units, from in-house digitizers, and from outside sources (on nine-track magnetic tape). Using familiar (FORTRAN) techniques, real and synthetic data are analyzed, printed on terminals and line-printers, or displayed on Tektronix, Versatec, and CalComp plotters.

GROUND MOTION PREDICTION AT SELECTED STRONG-MOTION SITES, D. M. Boore, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2754.
Goal: To develop methods for predicting strong ground motion at specific sites in terms of source characteristics, propagation path, and site conditions.
Investigations: Studies under this project include: (1) shallow refraction profiles and downhole P and S velocity surveys in the Chalome, Gilroy, Taft, and Imperial Valley (California) areas to provide data for modeling strong motion records; (2) statistical analysis of strong motion data; and (3) recording and analysis of aftershocks of the Imperial Valley earthquake of 1979.

COMPUTER SUPPORT FOR NUMERICAL MODELING OF GROUND MOTION, R. D. Borcherdt, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2755.
Goal: To coordinate numerical modeling efforts designed to infer characteristics of earthquake source and path propagation effects.
Investigations: Finite difference models are used to define near-field ground motion from strike-slip and thrust models. Models utilizing disk-ray theory and the Cagniard de Hoop method are employed to define synthetic seismograms.

DEVELOPMENT AND ACQUISITION OF INSTRUMENTATION FOR THE GROUND MOTION PROGRAM, R. D. Borcherdt, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2755.
Goal: To establish an interactive data processing center to utilize state-of-the-art interactive techniques for analyzing recordings of aftershocks, large earthquakes, and nuclear explosions.
Investigations: The center is designed to process digital cassette tapes and strong motion records on film and paper. Complimentary equipment includes the new Eclipse 230, the interactive graphics CRT, and the Gould electrostatic plotter. Data acquired for earthquake source, wave propagation, ground response, and strong motion studies will be used to develop methodologies for predicting strong motion for potentially damaging earthquakes.

DYNAMIC SOIL BEHAVIOR, A. T. F. Chen, U.S. Geological Survey, Branch of Engineering Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2605.
Goal: To develop realistic nonlinear stress-strain relations for soils in order to improve the capability of predicting earthquake ground motion.
Investigations: Large-strain, undrained cyclic testing of San Francisco Bay mud was conducted to demonstrate the effects of three-dimensional loading. Application of stress-strain relations in equivalent-linear ground-motion analyses was examined. We developed the static torque-twist relations for cylindrical soil samples with various stress-strain behaviors and proposed a more accurate data-interpretation procedure for torsional soil tests. Non-linear, free-vibrational response of cylindrical soil samples was analyzed and the current standards for torsional pendulum tests were evaluated. In addition, computations were performed to show the effect on site response of methods of estimating in-situ nonlinear soil behavior.

THE INFLUENCE OF LOCAL SITE GEOLOGY ON STRONG GROUND MOTIONS, S. M. Day, Systems, Science and Software, P. O. Box 1620 La Jolla, California 92038, (714) 453-0060.

Goal: To develop and evaluate analytical methods for predicting site response to earthquake ground motion.

Investigations: This study utilizes synthetic seismogram methods to construct the base-rock seismic motion of a site. An endochronic constitutive theory was developed for representing the nonlinear, hysteretic response of soil deposits to earthquake ground motion. The predictive capabilities of this approach are being examined through comparisons with equivalent linear analyses and ground motion data. The main computational tools are: a wave number-integration method for computing synthetic near-field accelerograms; a transient, dynamic finite element method for computing the nonlinear response of soils; and the SHAKE seismic analysis code for computing soil response by the equivalent linear method.

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

Goal: To study the attenuation of short-period seismic waves with strong and weak levels of ground motion in the conterminous United States.

Investigations: We are examining the following data bases: (1) 44 domestic earthquakes and 92 explosions in the magnitude range of 3.5 to 6.4, recorded on short-period instruments throughout the United States; (2) 50 events recorded in the New England region with magnitudes ranging from 1.8 to 3.2; (3) 35 events recorded in the central United States in the magnitude range of 1.5 to 3.5; (4) 31 NTS events recorded on strong-motion instruments in the distance range of 1 to 20 km; (5) 64 events recorded in the western United States on strong-motion instruments with local magnitudes greater than 4.0 in the distance range of 5 to 300 km; and (6) the Imperial Valley, California, earthquake of 15 October 1979 strong-motion recordings. These data bases are used to determine the attenuation of Lg-waves in the conterminous United States, regional attenuation relations at near and intermediate epicentral distances, and attenuation scaling laws relating strong and weak levels of ground motion to the local magnitude scale.

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

Goals: To provide seismic and geologic data at locations of strong motion instruments and to provide data for seismic zonation studies in the Los Angeles and San Francisco regions.

Investigations: We are measuring shear-wave velocities using a downward technique to provide velocity and geologic logs for use in characterizing sites at locations of strong motion instruments. Priority is given to those locations which have recorded important earthquake data. In addition, shear wave velocity measurements are being used to define units with distinct seismic velocities which are useful for seismic zonation.

ANALYSIS OF NATURAL SEISMICITY AT ANZA, T. C. Hanks, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2184.

Goals: To develop more refined models for the mechanics of crustal fault zones in order to predict earthquakes of magnitude 4 or greater near Anza and to estimate strong ground motion.

Investigations: We will obtain and analyze earthquake location and source mechanism data for approximately 100 earthquakes a year in the magnitude range of 2 to 4 along a 30 km stretch of the San Jacinto fault near Anza. Equipment includes ten broad-band high dynamic range digital seismographs and ten digital force-balanced accelerographs.

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

Goal: To determine the relative importance of various factors producing observed ground motion.

Investigations: Accelergrams for two of the larger events (M 4.0 and M 4.9) in the Oroville aftershock sequence are examined to determine how source processes influence ground motion and to establish the effects of wave propagation on these records. Data processing consists of producing time histories of true ground acceleration, velocity, and displacement using standard techniques to correct for instrument response. Acceleration records will be integrated and additional processing will include rotation of the horizontal components to resolve the ground motion into radial and transverse. A set of programs based on the Cagniard-de Hoop method will be used to generate synthetic seismograms.

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

Goal: To develop a methodology for predicting variations in strong ground shaking across known geologic structures.

Investigations: This project determines the variations in geology or geotechnical properties of rock that contribute to the variations in strong ground shaking. Tests will involve a comparison of existing or acquired seismic recordings across known structures. Models will combine transient dynamic finite element and other existing numerical methods.

GROUND RESPONSE IN THE SALT LAKE CITY, UTAH, REGION, W. W. Hays, U.S. Geological Survey, Branch of Ground Motion and Faulting, Denver Federal Center, Denver, Colorado 80225, (303) 234-4029.

Goals: (1) To acquire geophysical and geologic data for ground response research and (2) to develop probabilistic earthquake ground-shaking hazard maps for the principal urban areas along the Wasatch Front, Utah.

Investigations: We are analyzing nuclear-explosion, ground-motion data recorded at approximately 65 sites concentrated principally in the urban areas of Logan, Ogden, Salt Lake City, Provo, and Cedar City, Utah. These data are being used to determine the relative ground response throughout the region. Site-specific and regional geologic data are being collected and integrated with the ground motion data to provide a basis for evaluating the earthquake ground-shaking hazard and seismic risk of the region. Our ultimate objective is to provide data for improved earthquake-resistant design in Utah and other geographic areas.

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, California 91125, (213) 795-6811, ext. 2909.
Goal: To study the relationship between faulting and strong ground motion.
Investigations: We developed a method for synthesizing seismograms using accelerograph and Wood-Anderson responses. This method will be applied to determine the local magnitude of major California earthquakes using digitized accelergrams from the Earthquake Engineering Research Laboratory at CalTech. Computations of long-period ground motions are based on the dislocation model used in the analysis of the Guatemala earthquake. We plan to develop an extended version of this model in order to obtain more detailed information regarding the complexity of earthquake faulting.

COLLECTION OF BASIC GEOPHYSICAL DATA FOR SEISMIC ZONATION STUDIES, K. W. King, U.S. Geological Survey, Branch of Ground Motion and Faulting, Denver Federal Center, Denver, Colorado 80225, (303) 734-5087.
Goals: To obtain data from nuclear explosions and to finalize the data set in the Wasatch fault zone and in the Los Angeles area.
Investigations: We obtained good ground response data from NTS nuclear events recorded in Salt Lake City and Los Angeles areas. Analysis is proceeding in each geographic area.

GROUND MOTION PARAMETERS, R. B. Matthiesen, U.S. Geological Survey, Branch of Seismic Engineering, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2881.
Goals: To interface with the structural engineering community and to expand the utilization of strong-motion data for structural engineering applications.
Investigations: This project evaluates present seismic design zones relative to recorded building response, and propose appropriate criteria for seismic zonation for building design. With a view to evaluating current use of response spectra in building design, we are developing models and procedures for including nonlinear structural response and nonlinear soil-structure interaction into routine response calculations. Such nonlinear efffects will be included in routine strong-motion data processing.

EARTHQUAKE INTENSITY AND RECURRENCE STUDIES, R. D. Nason, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2760.
Goal: To determine the distribution of earthquake damage and seismic intensity of the 1906 earthquake using modern understanding of earthquake effects.

Investigations: Recent studies have shown that the original seismic intensity maps of the 1906 earthquake were made with major assumptions that need correction, which indicates the need for a major revision of the intensity maps. The detailed distribution of the 1906 earthquake damage and seismic intensity is being newly determined site by site to produce a corrected seismic intensity map for use as basic data in seismic risk analysis.

COMPUTER-BASED EARTHQUAKE MAPPING, SAN FRANCISCO BAY AREA, D. A. Olmstead, Association of Bay Area Governments (ABAG), Hotel Claremont, Berkeley, California 94705, (415) 841-9730.
Goals: To provide a series of earthquake maps that could be used by local governments in their seismic safety and safety programs, and could provide an input to various other planning programs at ABAG.
Investigations: Several data files that have not been available in ABAG's computer-based geographic data system have been developed, either by digitizing maps or by obtaining existing machine-readable data sets. These data files are being combined in various ways to produce a series of earthquake hazard map files for the San Francisco Bay Area. Various applications for these hazard map files are being explored, including developing an automated environmental assessment procedure, compiling sample composite maps, and comparing the amount of land affected and the jurisdictions affected. Much effort is being made to ensure that this information is effectively communicated to city and county staff.

EARTHQUAKE MAPS FOR DEVELOPING AREAS, D. A. Olmstead, Association of Bay Area Governments, Hotel Claremont, Berkeley, California 94705, (415) 841-9730.
Goals: (1) To provide a wide variety of detailed information on earthquake hazards in rapidly developing areas in the Bay Area and (2) to ensure that this information is applicable to the needs of a variety of local government staff in several departments.
Investigations: The developing west-facing ridgelands of the East Bay hills in Santa Clara, Alameda and Contra Costa Counties and the area surrounding Petaluma in Sonoma County have been chosen as study areas. ABAG staff are collecting detailed information on landslides, geology, and topography in these areas to supplement existing earthquake hazard map files in their computer-based geographic data system. Products will be keyed to a series of model applications suggested by local staff.

PORTABLE ARRAY — GLOBAL STRONG MOTION PROJECT, N. A. Orsini, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111.
Goal: To obtain critical near-source ground motion data from large earthquakes and aftershocks.
Investigations: Data will be obtained from permanent and temporary arrays in foreign countries. Agreements with selected countries will be arranged through the State Department in order to facilitate the rapid deployment of portable strong motion systems.

DATA PROCESSING, GOLDEN, R. B. Park, U.S. Geological Survey, Branch of Ground Motion and Faulting, Denver Federal Center, Denver, Colorado 80225, (303) 234-5070.
Goal: To provide data processing support for earthquake hazards studies.

Investigations: We are expanding the PDP 11/40 system in Golden to include input of digital cassette recordings and interactive graphic data processing. This expansion will allow real-time data editing, rapid and accurate amplitude and time measurement, selective processing of seismogram time slices, and other processes requiring interactive techniques.

SEISMIC ZONATION STUDIES IN LOS ANGELES BASIN, A. M. Rogers, U.S. Geological Survey, Branch of Ground Motion and Faulting, Denver Federal Center, Denver, Colorado 80225, (303) 234-2869.

Goals: (1) To collect and analyze ground response data in the Los Angeles Basin region and (2) to produce relative ground shaking hazard maps of the study area.

Investigations: Nineteen NTS nuclear explosions have been utilized to obtain 157 three-component records in the Los Angeles Basin region. These data have been processed to obtain digital seismograms of ground velocity, Fourier spectra, PSRV spectra, and alluvium-to-rock spectrals ratios. The latter quantity approximates in situ transfer function. The mean site transfer function has been computed over several period bands in the period range of the recorded signal, 0.1 to 10.0 seconds. These data are being studied in relation to the geological conditions and properties of near-surface soils underlying the site. Site transfer functions obtained from the nuclear data are also being compared with site transfer functions obtained from the San Fernando earthquake at the 29 sites where both sources have been recorded. An open-file report presenting all of the data used in this study is being completed.

MICROZONATION OF THE MENPHIS, TENNESSEE, AREA, S. Sharma, Purdue University, School of Civil Engineering, W. Lafayette, Indiana 47907.

Goal: To prepare microzonation maps for the Memphis, Tennessee, area.

Investigations: We have gathered information concerning the geology of surficial deposits and seismology of the study area. Synthetic seismograms have been prepared for use in the response analysis. These synthetic seismograms do not necessarily depict any one particular earthquake but allow one to infer the magnitude of response of the soil layer to horizontal motion. The response analysis will be performed by using the soil-profiles obtained from the boreholes. All the layers, with their assigned physical properties, will be investigated for their response to the various horizontal motions resulting from the synthetic seismograms. We will be using a computer program which will consider reflection and refraction at the soil layer interfaces. This will allow us to predict the true ground motion which is to be expected from a bedrock motion input. Once the expected ground motion has been formulated, we will prepare maps indicating zones showing: qualitative estimates of ground response, the natural frequency of the soil layer, liquefaction and subsidence potential, and landslide susceptibility.

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

Goal: To provide the data necessary to define the magnitude of seismic risk and the nature of seismically associated geologic hazards in the Creve Coeur region of St. Louis County.

Investigations: Existing information is used to select design earthquakes likely to occur along known fault traces. Field and laboratory studies identify the physical parameters of various soil-bedrock conditions and provide the data for analyzing response spectra and time histories of ground motion for specific soil condition studies. These findings will be used to compute the anticipated ground motions for different seismic microzones and to prepare ground response maps.

GROUND MOTION PREDICTIONS FOR THE LOS ANGELES BASIN FROM A MAJOR SAN ANDREAS EARTHQUAKE, J. Sweet, Del Mar Technical Associates, P. O. Box 1083, Del Mar, California 92014.
Goal: To formulate a computer model to predict ground motion in the Los Angeles Basin resulting from various earthquakes on the San Andreas fault.
Investigations: We are investigating the potential earthquake hazard of the Los Angeles basin resulting from a strike-slip event on the San Andreas fault. The specific location of the fault rupture will be in the vicinity of the observed Southern California Uplift. Our approach is twofold. Strong ground motion time histories will be predicted at several stations surrounding various hypothesized ruptures along the San Andreas fault. Intensity attenuation relationships will be deduced from these studies. These attenuation models, in turn, will be utilized to develop seismic risk models for the Los Angeles basin.

GEOTECHNICAL STUDIES, R. E. Warrick, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2757.
Goal: (1) To obtain a set of field recording systems suitable for a variety of data collecting tasks, and (2) to conduct in-situ empirical studies of wave attenuation and propagation.
Investigations: We will obtain a set of ten 3-component digital recorders with velocity sensors and appropriate signal conditioning. These units will be useful in studies of aftershocks, source mechanisms, amplification, attenuation, wave propagation, ambient noise, crustal structure, and continental shelf seismic activity. Site specific studies comparing geologic and geotechnical properties with seismic velocities and attenuation will be extended to sub-regional classification of areas in terms of predicted ground response to earthquake excitation.

DIFFRACTION OF WAVES BY THREE-DIMENSIONAL SURFACE TOPOGRAPHIES AND SUBSURFACE IRREGULARITIES, H. L. Wong, University of Southern California, Department of Civil Engineering, Los Angeles, California 90007, (213) 741-7090.
Goal: To develop methods for analyzing local ground amplification effects.
Investigations: Project efforts focus on the study of problems related to soil amplification effects caused by surface topography and subsurface irregularities. We will extend the existing one- and two-dimensional analyses to the most general three-dimensional models and to all types of incident seismic waves. The least-squares method for wave propagation problems is based entirely on continuum mechanics solutions. The combined discrete-continuous approach is a "substructuring" type procedure for synthesizing the results of both continuous and discrete modeling. These methods will be compared with existing exact solutions and will be used to analyze the affects of surface topography and subsurface irregularities; the influence of different types of waves; and the affects of material contrast between two irregular layers.

GROUND MOTION PREDICTION AND EASTERN U.S. EARTHQUAKE MONITORING, F. T. Wu, State University of New York, Department of Geological Sciences, Binghamton, N. Y. 13901.
Goals: (1) To develop a method for using small earthquakes to predict the near source ground motion of a large earthquake, and (2) to establish stations in northern and western New York.
Investigations: The theoretical basis of an "Impulse Response" method of ground motion prediction has been developed. The ground motion caused by a large earthquake can be viewed as a convolution of the impulse responses with an appropriate source time-space function. The recording of small earthquakes on force-balance accelerometers has proved to be feasible. Additional activities include establishing one station in the Long Sault Dam near Massena, New York.

Ground Failure

A STUDY OF THE BEHAVIOR OF CEMENTED SOILS UNDER SEISMIC LOADING, G. W. Clough, Stanford University, Stanford, California 94305, (415) 497-4164.
Goal: To examine the response of cemented soils to dynamic loading induced during an earthquake.
Investigations: We will conduct in-situ and laboratory tests of naturally and artificially cemented soils. A unique self-boring pressuremeter unit provides the means of in-situ testing. Thin section and electron microscope studies of cemented soils will determine structure changes at various levels of loading up to and including failure. Static and dynamic triaxial tests will be performed on both dry and moist samples under drained and undrained conditions. We will use beam tension or Brazilian tension tests on cemented soils in order to study both dry and moist soil response. Tension loads will be applied as monotonically increasing and repetative cyclic. The findings from cyclic tests will be used to explain potential splitting phenomena at the crown of a cemented soil slope under seismic loading.

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, California 94720, (415) 642-5525.
Goal: To develop tools for assessing the degree of risk associated with existing dams and landslides.
Investigations: We are developing a device to provide essential data for seismic analysis of old dams over 25 feet high with reservoirs greater than 50 acre feet in volume. Following laboratory tests of the prototype device, boreholes will be drilled to 50 feet at the Crystal Springs Dam and at two other sites. A combination dilatometer and impression packer will be installed to record all fractures in their correct absolute orientations and to determine the in-situ deformability of the rock mass. We also plan to provide a tool for identifying areas of high seismic landsliding risk independent of geomorphic features and other qualitative indicators of past sliding. A multi-channel recording creepmeter (with precision of several ten-thousanths of an inch) will be used to

study surface creep rates for existing landslides in the California Coast Ranges. Measuring periods will vary from 4 to 24 hour intervals. Sites will be reoccupied at least four times a year. We will relate surface creep measurements with existing subsurface inclinometer records at selected sites.

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

Goals: (1) To examine the influence of seismicity on landslide generation and activity, (2) to develop the capability of predicting probable areas and failure modes of seismically-induced landslides on a regional basis, and (3) to summarize and present predictive criteria in a format useful for integration into a comprehensive scheme of seismic zonation.

Investigations: Project activities are directed at measuring actual ground accelerations causing rock and soil failure in earthquake aftershocks. This will be accomplished with the use of rapidly deployable portable digital strong motion accelerographs. The strong motion systems will be emplaced at sites of slope failure triggered by an earthquake; subsequent aftershock ground motion will then be recorded and correlated with progressive slope failure from aftershock activity. These efforts will provide a measure of threshold ground motion required to initiate failure from steep rock and soil slopes. We will compare ground motion data with site characteristics (rock types, structural discontinuities, cementation) to determine the most important parameters governing failure and the ground shaking levels at which failure takes place. Strong motion systems will also be used to study the effect of topography upon ground motion—and therefore upon ground failure. We are continuing experimental mapping of seismic slope stability for San Mateo County, California, and initiating similar analyses of other areas of seismic slope failure hazards.

STUDY OF LIQUEFACTION IN NOVEMBER 23, 1977 EARTHQUAKE, SAN JUAN PROVINCE, ARGENTINA, I. M. Idriss, Woodward-Clyde Consultants, 3 Embarcadero Center, Suite 700, San Francisco, California 94111, (415) 956-7070.

Goal: To evaluate the influence of various geologic factors on the observed spatial distribution of liquefaction.

Investigations: Initial efforts included studies of the character and distribution of soils, surface sediments, ground water, surface water, and geomorphic and geologic features. These studies were followed by a subsurface exploratory program and laboratory tests were carried out for classifying the subsurface materials. Engineering studies were conducted to relate geology, soil properties, and ground motions to the observed liquefaction.

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

Goal: To catalog and analyze existing information on ground failures caused by earthquakes.

Investigations: This project reviews literature on all historic earthquakes during which ground failures occurred, identifies the mechanisms of ground failure most commonly associated with earthquakes, and describes the geologic and seismic environments in which they occur. The literature search is supplemented by post-earthquake field investigations. Data are being analyzed to determine the most prevalent modes of failure during earthquakes and to correlate the incidence of failure with various geologic and seismic parameters.

EVALUATION OF THE CONE PENETROMETER FOR LIQUEFACTION HAZARD ASSESSMENT, G. R. Martin, Fugro, Incorporated, 3777 Long Beach Blvd., Long Beach, California 90807, (213) 595-6611.
Goal: To evaluate the potential of Cone Penetrometer for use in assessment of liquefaction hazard on a regional or site specific basis.
Investigations: The Cone Penetrometer Test is rapid (2 cm/sec), easily standardized, and does not require boring. We are examining the influence of geologic origin, age, and physical properties of cohesionless soils upon the Cone Penetrometer Test-Standard Penetrometer Test correlations. If we can show that the properties of the soils influence both CPT and SPT data in a predictable manner, then the CPT method will provide a valuable approach for liquefaction hazard assessment.

EARTHQUAKE-INDUCED LIQUEFACTION AND SUBSIDENCE OF GRANULAR MEDIA, S. Nemat-Nasser, Northwestern University, Technological Institute, Department of Civil Engineering, Evanston, Illinois 60201, (312) 492-5513.
Goal: To identify the major micromechanical factors essential for the description of the consequent densification of drained soils, and liquefaction of undrained saturated soils.
Investigations: We are conducting theoretical studies of the behavior of dry or saturated granular materials under cyclic shearing. Comparisons have been made with published experimental results. We are obtaining additional experimental results in order to verify the validity of the theoretical assumptions, and to quantify the material parameters.

GROUND FAILURE RELATED TO THE NEW MADRID EARTHQUAKE, S. F. Obermeier, U.S. Geological Survey, Branch of Engineering Geology, National Center, 12201 Sunrise Valley Drive, Reston, Virginia 22092, (703) 860-6406.
Goals: To compare the distribution of sand boils with the geologic character of sediments and to correlate this information with proposed epicenter locations.
Investigations: This project evaluates geologic factors influencing sand boil distribution—such as presence and thickness of impermeable capping material, thickness of material susceptible to liquefaction, and age of sediments. Depth to groundwater table, presence of artesian heads, and other hydrologic factors are also examined. Field engineering tests at selected localities have been conducted to distinguish differences in liquefaction potential.

INTERACTIONS BETWEEN GROUND MOTION AND GROUND FAILURE, R. C. Wilson, U.S. Geological Survey, Branch of Engineering Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 856-7126.
Goals: (1) To study the effect of spectral ground motion characteristics on ground failure and (2) to develop techniques for mapping the potential for seismic-induced ground failure.

Investigations: We are developing techniques for comparing the failure spectra for various materials and slope conditions with the seismic response spectra calculated from strong-motion records in order to estimate the probability of failure as a function of various ground motion parameters. Maps of predicted ground motion and estimated ground failure susceptibility will be combined to map the potential for ground failure on a regional scale.

PRELIMINARY EFFECTS OF LIQUEFACTION POTENTIAL IN AND NEAR SAN JUAN, PUERTO RICO, T. L. Youd, U.S. Geological Survey, Branch of Engineering Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 856-7117.

Goal: To prepare a liquefaction potential map for the San Juan, Puerto Rico, metropolitan area.

Investigations: We are analyzing geotechnical data in preliminary liquefaction susceptibility zones for the Bayamon, Carolina, and San Juan quadrangles, 1:20,000 scale.

EXPERIMENTAL MAPPING OF LIQUEFACTION POTENTIAL, T. L. Youd, U.S. Geological Survey, Branch of Engineering Geology, 345 Middlefield Road, Menlo Park, California 94025, (415) 856-7117, ext. 2529.

Goals: (1) To develop techniques for compiling interpretive maps of liquefaction and ground failure potential, and (2) to determine quantitatively the factors controlling the occurrence of liquefaction and associated ground failures.

Investigations: Techniques using probability concepts and empirical correlations were developed for mapping the seismicity and ground motion attenuation characteristics of an area. These ground-failure opportunity maps are combined with regional maps of ground failure susceptibility in order to make a preliminary assessment of liquefaction-induced ground failure potential. Past earthquake reports and reconnaissance surveys of ground failures associated with liquefaction are used to determine the geotechnical, geologic, hydrologic, and seismologic factors controlling this phenomenon. We are developing instrumentation for measuring pore pressures generated in saturated sands during earthquakes. These devices will be deployed after a major earthquake to monitor pressure changes in liquefiable materials.

Surface Faulting

SURFACE FAULTING STUDIES, M. G. Bonilla, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2245.

Goal: To compile and analyze historic data on surface faulting in order to improve estimates of future rupture length, displacement, and earthquake magnitude.

Investigations: Regression analyses are performed to determine the relationships among fault length, displacement, and earthquake magnitude (or seismic moment) for historic surface fault events. The maximum expected values of these parameters are computed at various exceedance probabilities. Average values will be obtained for displacements and widths of main faults, and mathematical models will be developed for estimating the occurrence probability of subsidiary ruptures. Field investigations of new surface faulting include studies in Imperial Valley and Livermore Valley, California.

Post-Earthquake Studies

POST-EARTHQUAKE FIELD INVESTIGATIONS, R. D. Brown, U. S. Geological Survey, Office of Earthquake Studies, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2461.

SEISMOLOGICAL FIELD INVESTIGATIONS, C. J. Langer, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-5091.
Goal: To obtain and analyze post-earthquake seismic data.
Investigations: Several post-earthquake studies were conducted to obtain aftershock data. Analyses of these data resulted in the location of aftershock hypocenters, the determination of magnitudes, "b" values and focal mechanism solutions, and an assessment of tectonic implications.

Earthquake Losses

AN ALTERNATING MARKOV MODEL FOR EARTHQUAKE OCCURRENCES, H. C. Shah, Stanford University, Department of Civil Engineering, Stanford, California 94305, (415) 497-3664.
Goal: To develop a seismic hazard model based on alternating Markov Processes and to apply this model to a specific region.
Investigations: We will model earthquake occurrences as time and space dependent events. The model will address the questions of temporal and spatial clustering as well as time and space gaps in seismic occurrences. Alternating Markovian processes will be used to model sequences of earthquake events, their locations along known geologic faults, and amounts of energy releases from them. We will then apply the model to a study area in California and compare the results to actual observations.

SEISMIC DAMAGE ASSESSMENT FOR HIGH RISE BUILDINGS, R. E. Scholl, John A. Blume and Associates, 130 Jessie Street, San Francisco, California 94105, (415) 397-2525.
Goals: To improve quantitative reliability and to refine earthquake damage prediction procedures for high-rise buildings.
Investigations: This project collects and correlates worldwide seismic response/damage data for high-rise buildings, related earthquake ground motion data, intensity estimates, and structural response information. Theoretical analyses will establish motion-damage relationships for various types of high-rise buildings based on the engineering fundamentals of dynamic response prediction and available structure component damage criteria. Assembled empirical data will be correlated with theoretically derived models of structure damage to establish damage prediction reliability and to identify future research needs.

LOSS ASSESSMENT SENSITIVITY OF ALTERNATIVE RISK MAPPING PROCEDURES, J. H. Wiggins, J. H. Wiggins Company, Redondo Beach, California 90277, (213) 378-0257.
Goal: To evaluate the effects of various seismic hazard mapping procedures on economic loss projections.
Investigation: Three hazard maps will be used in this study: (1) the Algermissen and Perkins (1976) map, (2) the ATC-3 (1978) map, and (2) the J. H. Wiggins Company map (1975). Loss projections will be made using the J. H. Wiggins Company exposure model for the United States. This model describes the building wealth of the United States by type, value, age, and quality of construction of each county. Project tasks include: evaluation and digitization of the three seismic hazard maps, digitization of the building wealth-exposure model, identification of potential users of the exposure model, computation of annualized loss estimates based on each seismic hazard map, subregionalization of loss estimates, and sensitivity analysis.

Transfer of Research Findings

RESEARCH APPLICATIONS, W. W. Hays, U.S. Geological Survey, Office of Earthquake Studies, Denver Federal Center, Denver, Colorado 80225, (303) 234-4029.
Goals: To establish and maintain a close working relationship with Federal, state, and local government agencies; private groups, universities; professional groups; and individuals to insure the utilization and implementation of earthquake research results.
Investigations: Activities associated with this project are varied and include: serving on the Steering Committee of the Interagency Committee on Seismic Safety in Construction, contributing to the FEMA-NSF-DOE-USGS Summer Institute on Multiprotection Design, assisting DOE in the development of a research program in geothermal induced seismicity, providing support to the Utah Seismic Safety Advisory Council, serving on the Continuing Education Committee of Earthquake Engineering Research Institute, and contributing to the technical activities of the Seismic Analysis Task Force of the American Society of Civil Engineers Committee on Nuclear Structures and Materials and the Site Evaluation committee of the American Nuclear Society. Several conferences have been convened to establish closer working relationships and to communicate the current state-of-the-knowledge in selected fields. The two most recent conferences were, "Earthquake Prediction Information," held in January 1980, in Los Angeles, California and "Evaluation of Regional Seismic Hazards and Risk," held in August, 1980 in Santa Fe, New Mexico. Proceedings are published for each conference. Geological Survey Circular 816, "Program and Plans of the U.S. Geological Survey for Producing Information Needed in National Seismic Hazards and Risk Assessment, Fiscal Years 1980-84," was published in December, 1979.

EARTHQUAKE PREDICTION

Location of Areas Where Large Earthquakes Are Most Likely to Occur

Syntheses of seismicity and tectonic data

HEAT-FLOW AND TECTONIC STUDIES, A. H. Lachenbruch, Branch of Tectonophysics, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2646 or 2272.
Goal: (1) To determine how global tectonic forces are converted into recurring earthquakes in the San Andreas fault zone and (2) to study discrete thermal events as possible precursors of earthquakes.
Investigations: We shall continue our thermal studies of the energetics of the San Andreas fault zone by extending regional heat-flow coverage to the extension of the San Andreas system in the Salton Sea area and by making heat-flow determinations in the "Big Bend" area of the San Andreas fault. We are continuing heat-flow determinations along the Garlock fault and, if possible, on other strike-slip faults, measuring heat flow in conjunction with the downhole stress measurements. In addition, we are monitoring borehole temperatures at selected sites in or near the San Andreas fault and continuing to follow up reports of sudden temperature changes in wells in seismic areas.

Stress level

EARTHQUAKE HAZARDS DETERMINATIONS BASED ON TECTONIC STRESS MEASUREMENTS, C. B. Archambeau, University of Colorado, CIRES, Boulder, Colorado 80309, (303) 492-8028.
Goal: To determine the hypocentral location, extent of failure zone, and the magnitude or total energy release for future California earthquakes based on regional estimates of lithospheric stress.
Investigations: This study is based on the stress analysis technique developed for delineating high stress zones along the Alaskan-Aleutian, Kuriles-Kamachatka and Japan arcs. Standard m_b and M_s measurements from seismic network recordings are compared with synthetic seismogram measurements using a relaxation source model of earthquakes to infer fault dimensions and stress drops. The extent and magnitude of tectonic stress levels are used to delineate zones of high stress that are likely to be the locations of future events. We will focus on two high-risk areas where considerable digital seismic data are available from local networks—the southern California uplift region along the bend of the San Andreas fault and the San Bernardino-Riverside area. A variable frequency magnitude method will be used to process available digital data. This method is based on body wave (P or S) magnitudes at 2 or more frequencies in the range 0.2 cps to 10 cps.

PALEOGEODETICS, W. Thatcher, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2120.
Goals: (1) to conduct detailed studies of data and models appropriate to the southern California uplift, (2) to search for new data sources relevant to aseismic crustal deformation and earthquake processes, and (3) to suggest new measurements based on the above studies.
Investigations: Project efforts focus on the collection and analysis of existing historic triangulation data relevant to horizontal crustal deformation along the southern San Andreas fault system. Our findings will be related to interseismic strain accumulation and episodic movements, such as the 1959/1974 southern California uplift.

IN-SITU STRESS MEASUREMENT, M. D. Zoback, Branch of Tectonophysics, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2034.
Goals: To determine the magnitude and orientation of tectonic stresses and the mechanical and fluid flow properties of crustal materials in and near fault zones.
Investigations: A variety of geophysical measurements, including in-situ stress, pore pressure and permeability, seismic velocity, and the state of natural fracturing, has been measured in wells and boreholes at several locales. At Monticello Reservoir, a site of reservoir-induced seismicty in South Carolina, measurements were made in two wells drilled to a depth of 1.1 km into the hypocentral zone of the earthquakes. In the vicinity of the San Andreas fault, measurements were made in several wells (approximately 225 m deep) located about 4 km from the fault in the western Mojave Desert. Two wells were drilled into the active trace of the San Andreas in central California; geophysical logs were run and fault zone materials were exhumed for analysis.

Earthquake Precursors

General studies

STUDIES OF THE SEISMIC AND CRUSTAL DEFORMATION PATTERNS OF AN ACTIVE FAULT: PINON FLAT OBSERVATORY, J. Berger, University of California at San Diego, Institute of Geophysics and Planetary Physics, La Jolla, California 91125, (213) 795-6811, ext. 2904.
Goals: (1) To monitor continuously the secular deformation rates associated with tectonic activity in the area, (2) to establish a reference station consisting of the most stable and sensitive instrumentation available in an attempt to determine true ground deformation rates and thus set limits of detectable anomalous behavior, and (3) to measure the stability of surface benchmarks relative to the crustal rocks below.
Investigations: The Pinon Flat Geophysical Observatory is located in the Santa Rosa Mountains, 20 km south of Palm Springs. The Observatory presently includes the following instrumentation: four biaxial shallow borehole tiltmeters, three 732 m laser strainmeters, one 50 m fluid tiltmeter, one 25 m laser optical anchor, three dry tilt arrays, six strainmeter end pier tiltmeters, two electrolevel tiltmenter, two superconducting gravimeters, one Project IDA gravimeter, one USGS strong motion accelerograph, one long period horizontal accelerometer, three long period seismometers, one short period vertical seismometer, ten environmental monitoring

instruments, five multichannel digital recorders, and twenty-six analog monitoring recorders. With this instrumentation, we monitor the southern end of the San Jacinto fault and continue with the collection, reduction, and interpretation of the variety of seismic and crustal deformation data.

TECTONIC MONITORING OF THE SOLOMON AND NEW HEBRIDES ISLANDS REGIONS, M. T. Gladwin, University of Queensland, Department of Physics, St. Lucia, Australia 4067, (07) 377-2432.
Goal: To provide information on the relevance of current intensive monitoring of small earthquakes to the prediction of large and potentially catastrophic ones.
Investigations: This project will collect tilt, strain, and magnetic field measurements in the Solomon Islands and New Hebrides Islands regions in the South Pacific. The high seismicity of these regions gives reasonable expectation of the capture of probably six shallow magnitude 6 or greater events per year and one shallow event with magnitude 7 or greater per year. Information at this relatively high event rate will either provide reinforcement of the techniques at present in use in California, or will suggest modifications necessary for observation of precursive phenomena specific to larger events in a time scale which will allow the changes to be incorporated effectively into the California programs.

DEEPWELL MONITORING OF STRAIN-SENSITIVE PARAMETERS OVER THE GREATER SOUTHERN CALIFORNIA UPLIFT, T. L. Henyey, University of Southern California, Department of Geological Sciences, Los Angeles, California 90007, (213) 741-6123.
Goals: (1) To measure physical and chemical parameters that reflect changes in subsurface stress along the San Andreas Fault within the greater southern California uplift region, and (2) to evaluate the usefulness of those parameters as tectonic stress transducers.
Investigations: A series of 20 deep wells has been prepared for instrumentation. These wells, ranging to 1.7 km depth, are in the San Andreas fault zone or within 15 km of the fault between Banning and the Lake Hughes area of southern California. Research includes: groundwater chemistry (radon), acoustic emission, RF emissions, groundwater table (turbidity-temperature), and rock permeability studies.

PREDICTION MONITORING AND EVALUATION, R. N. Hunter, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-4041.
Goal: To provide statistical, objective answers to public questions about individuals making earthquake prediction.
Investigations: Predictions from any source are dated and filed for future evaluation if necessary. Funding limits have prevented any evaluation, scoring, or program development.

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, California 90024, (213) 825-6130.
Goals: To develop statistical criteria for recognizing temporary anomalies in geophysical data, and to interpret any such anomalies in terms of their physical cause.

Investigations: We are analyzing leveling data for southern California in order to determine the mode of deformation resulting on the Southern California Uplift. We are also continuing to study P wave arrival times for southern California in our search for evidence of temporal velocity variations.

SEISMICITY AND EARTHQUAKE PREDICTION STUDIES IN TURKEY, M. N. Toksoz, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Massachusetts 02139.
Goal: To analyze and interpret seismic and other data in order to identify patterns and precursory phenomena for the development of a prediction capability.
Investigations: Two permanent stations, a dense network along the N. Anatolian fault zone, creep meters, and water level detectors for regional tilt measurements are being installed in Turkey. Data from the new network will complement data from other seismic stations in Turkey. We will continue analysis of seismicity patterns and identification of seismic gaps.

Seismological studies

SEISMIC STUDIES FOR EARTHQUAKE PREDICTION, C. Bufe, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2567.
Goal: To develop an understanding of earthquake mechanics and the physical properties of fault zones by seismological techniques.
Investigations: Project efforts have been directed toward development of patch recurrence models and toward estimation of absolute stresses from variation in focal mechanisms with depth. Investigations of spatial and temporal variation in stress orientation and redistribution of stress on a regional scale following moderate-to-large earthquakes are also being pursued.

REMOTE MONITORING OF SOURCE PARAMETERS FOR SEISMIC PRECURSORS, G. L. Choy, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, CO 80225, (303) 234-4041.
Goals: (1) To search for spatial and temporal changes in source parameters or the signature of body and surface waves that can be associated with an imminent major earthquake or a change in the stress state of a region, and (2) to evaluate the effectiveness of a standardized and digitally recording network of seismographs as a remote monitor for these spatial and temporal changes.
Investigations: We sought to design and implement techniques of processing (SRO) digital data. This processed output (e.g., deconvolved displacement, velocity or velocity squared) would be in a convenient form for extracting source parameters. We also consolidated several programs to develop a technique for generating seismograms that incorporates propagation and source effects. Using these programs, we analyzed the rupture characteristics of two deep earthquakes. The parameters extracted from body phases produced by these earthquakes provided the insight required to examine shallow earthquakes where one must account for the surface reflected wave forms that are not well separated in time. We are also examining sequences of earthquakes in various

regions. By studying the records of displacement and velocity, we hope to discern a pattern of stress drop or rupture propagation in a sequence of earthquakes which could have been used to predict the main shock.

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

Goal: To determine the characteristics of the 1975 Hawaii earthquake.

Investigations: We located and studied the magnitude, frequency, areal distribution, and focal mechanism of over 3,500 foreshocks and aftershocks surrounding the November 29th event. The main earthquake appears to have been caused by the seaward movement of an immense block of crust perhaps 10 km thick, 50 km wide, and of unknown but substantial length. We believe the slip surface is a zone of weakness which coincides with an earlier discovered low velocity layer. Most aftershocks, and perhaps most of the high frequency seismic radiation, originate in a region adjacent to the rift zones--at the upper end of the crustal block, where stress accumulates by magmatic processes.

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

Goal: To identify patterns in the occurrence of moderate teleseismically-recorded earthquakes that are precursory to major earthquakes.

Investigations: Aftershock zones of major earthquakes and prior activity from the regions surrounding the aftershock zones are defined more precisely with hypocenters relocated by relative-location methods. Hypotheses on seismicity precursory to major earthquakes are tested with the more precise hypocenters. The Bongard pattern recognition algorithm is used to search for characteristics of seismicity and tectonics, or combinations of characteristics, that indicate that a particular moderate earthquake is likely to be followed by a stronger earthquake or, conversely, that particular moderate earthquake is not likely to be followed by a stronger earthquake.

PRECURSORY STRAIN/SEISMIC ANOMALY STUDIES ON A STRIKE SLIP FAULT SYSTEM, E. T. Endo, U. S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111.

Goals: To test various geophysical methods as earthquake prediction tools.

Investigations: Our study focuses on the Kaoiki fault system on the island of Hawaii. We are continuing earth strain measurements (e.g., leveling, day tilt, and EOM array) and analyzing the existing earthquake phase data for the Kaoiki region in order to determine if strain changes are occurring and if they can be correlated with seismicity.

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

Goal: To study the spectral content of the earthquake source mechanism in the Garm region.

Investigations: Field experiments will take place beneath the crest of the Peter I Range, in close cooperation with the Complex Seismological Expedition (CSE) of the Institute of Physics of the Earth in Moscow. After identifying and correcting propagation and near-station effects, we will determine the dependancy of source spectrum estimates on azimuth and take-off angle relative to the predicted focal mechanism; the limit of resolution in seismic moment and stress drop estimates; and the variability of source parameters in space and time.

SEISMICITY STUDIES FOR EARTHQUAKE PREDICTION IN SOUTHERN CALIFORNIA USING A MOBILE SEISMOGRAPHIC ARRAY, H. Kanamori, California Institute of Technology, Division of Geological and Planetary Sciences, Seismological Laboratory, Pasadena, California 91125, (213) 795-6811, ext. 2914.

Goals: (1) To study the regional seismicity, (2) to monitor the temporal velocity changes, and (3) to survey microearthquake activity in southern California.

Investigations: Earthquake location for the period 1950 to 1972 will be upgraded using an improved model of southern California crustal structure and master event relocation techniques. Fault mechanism solutions are constructed and the seismicity is analyzed statistically for spatial and temporal patterns associated with the occurrence of larger earthquakes. Quarry blasts in the Gorman, Mojave, Victorville, Corona, Gypsum Canyon, and Hector areas are regularly monitored for possible velocity changes. Portable seismograph trailors are used to monitor the microearthquake activity at two sites on the San Jacinto fault—the intersection of the San Jacinto and San Andreas faults and the Palmdale area. These surveys provide valuable data for precise locations and focal mechanism solutions on earthquake activity levels below the magnitude thresholds for standard array detection. Data from previous surveys are analyzed to delineate migration patterns and specific zones of activity.

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

Goal: To develop and apply methods for analyzing seismic precursory phenomena and for relating seismicity and focal mechanisms to geological processes.

Investigations: Singular value decomposition was applied to invert arrival-time data from microearthquake networks. Computer programs for two-dimensional ray tracing for continuous and discontinuous velocity models were developed using an adaptive finite difference method. A generalized inversion package is being developed to solve an over-determined system of $Ax = b$, and to compute the resolution and information density matrices. A three-dimensional ray-tracing package is being designed to trace a minimum path between source and station, and compute the travel time and derivatives. With a set of master events, we will be able to deduce the three-dimensional crustal structure and accurately locate earthquakes. Accurate location and a proper crustal structure model will allow us to deduce focal mechanisms. With these results it will then be possible to test whether any seismic precursory phenomena exist before moderate-size earthquakes.

PARKFIELD PREDICTION EXPERIEMENT, A. Lindh, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2042.

Goal: To analyze seismic data in conjunction with geodetic observations to develop the ability to predict the next magnitude 5.5 Parkfield earthquake.

Investigations: We will closely monitor all instruments in our continuously expanding geodetic network of alignment arrays, dry tilt arrays, creepmeters, strainmeters, and tiltmeters, and use this information to build a strong working hypothesis against which slip and stress distribution along this segment of the San Andreas can be predicted and measured.

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

Goals: (1) To complete an evaluation of the feasibility of using a VIBROSEIS system to monitor travel-times of deep crustal reflections and first arrivals in a search for variations indicating stress change, and (2) to establish a routine monitoring system along the San Andreas fault.

Investigations: Monitoring experiments have indicated a scatter of repeated travel-time measurements of order 0.1%, and seasonal variations of up to 1% in response to changes in near-surface soil moisture. Extensive changes have been made in equipment and procedures which should reduce these noise levels significantly. In the spring of 1980, monitoring will begin on a number of paths along the creeping zone of the San Andreas fault in central California, in both a long-term program of nominally weekly measurements and short-term experiments, to further search for variations related to tidal stresses (fig. 12).

STUDY OF THE FORESHOCK-MAINSHOCK-AFTERSHOCK SEQUENCE OF THE 1978 OAXACA EARTHQUAKE, K. McNally, California Institute of Technology, Division of Geological and Planetary Sciences, Seismological Laboratory, Pasadena, California 91125, (213) 795-6811.

Goal: To continue our cooperative research with the Instituto de Geofisica, Universidad Nacional Autonoma de Mexico to study sequence of earthquakes in Mexico recorded by their permanent array stations as well as our joint portable array in Oaxaca.

Investigations: We will utilize data from portable and permanent seismic arrays to determine the crustal velocity structure in the coastal region of the Oaxaca earthquakes for precise locations of the foreshock and aftershock activity and a relocation of the mainshock. We hope to clarify the nature of spatio-temporal changes in seismicity associated with seismic gaps and large earthquakes in the study area. We also plan to analyze the waveforms of events occurring in the near-source region for time dependent variations reflecting changes in source or crustal properties causal to the gap. In order to fully understand the significance of the foreshock activity in terms of stress buildup mechanism leading to the mainshock, we will make detailed investigations into the source process of the 1978 mainshock. We hope that detailed study of the 1978 Oaxaca mainshock, combined with the local foreshock data of unprecedented quality, will resolve many important details of stress concentration mechanism prior to large subduction zone events.

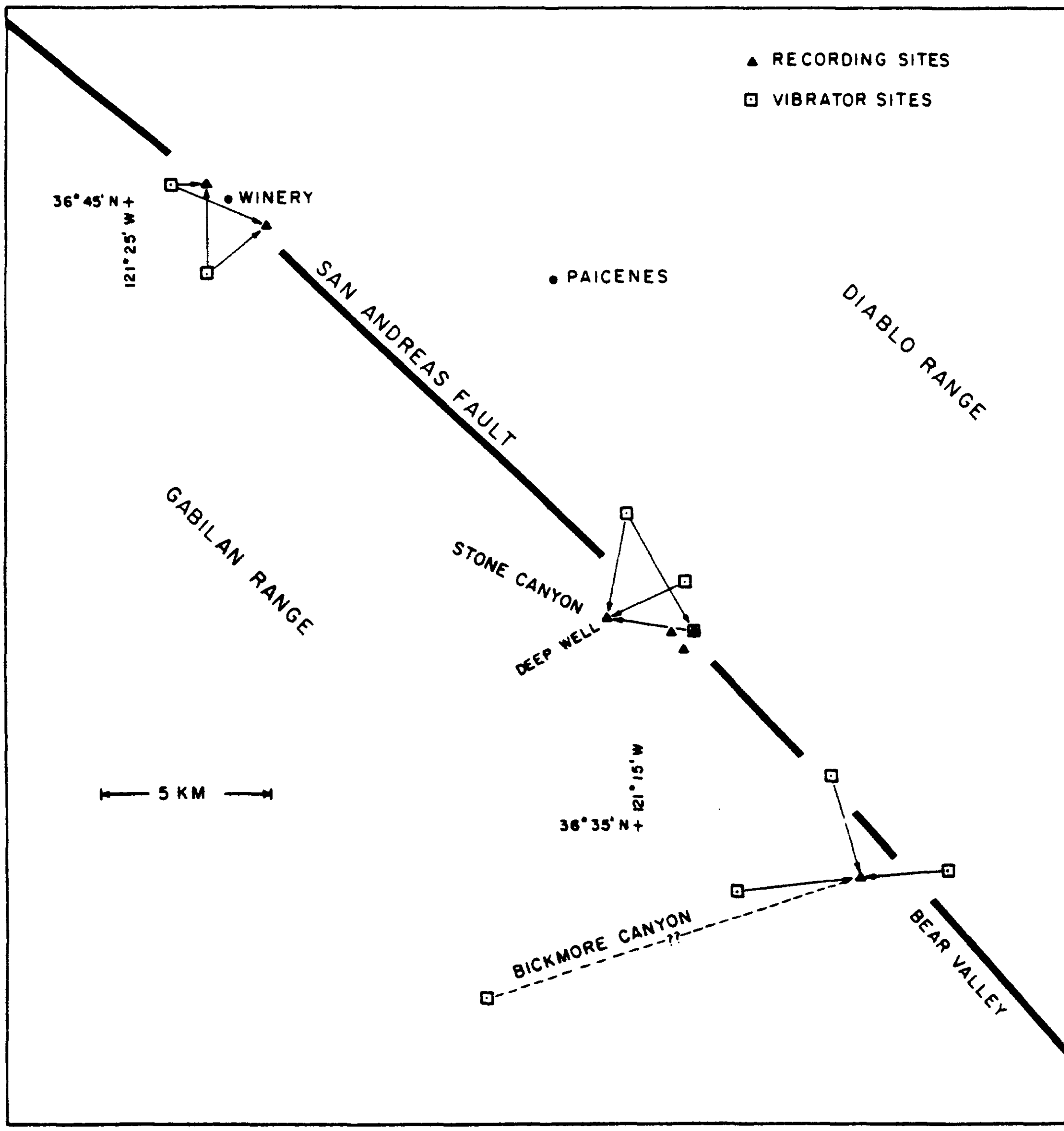

FIGURE 12.—Location map of proposed monitoring sites.

CHARACTERISTICS OF FORESHOCKS AND SHORT TERM DEFORMATION IN THE SOURCE AREA OF MAJOR EARTHQUAKES, P. Molnar, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Massachusetts 02139, (617) 253-5924.
Goal: To search for geologic criteria to explain foreshock phenomena.
Investigations: We plan to construct a catalog of equal to or greater than magnitude 7 earthquakes using existing data for the years 1897 to 1973. From this data base we will examine regional seismicity in the year preceeding each major event in order to find evidence of foreshock activity. Foreshocks will be examined in terms of their frequency, magnitude, and proximity to mainshock epicenters.

CONTINUOUS MONITORING AND INTERPRETATION OF CRUSTAL VELOCITY CHANGES NEAR PALMDALE, CALIFORNIA, R. A. Phinney, Princeton University, Department of Geological and Geophysical Sciences, Princeton, New Jersey 08540, (609) 452-4118.
Goal: To use artificial sources for establishing the phenomenology of arrival-time anomalies in the southern California uplift region.
Investigations: The primary source is a marine airgun operated from a fixed shotpoint in Bouquet Reservoir. Principal receivers are hydrophones set in boreholes near the University of Southern California at distances of 6 to 50 km from the source. Signals received from shot groups automatically fired at two-hour intervals are summed at the data collection point at USC. Previously operated portable stations will be reestablished 2 to 8 km from the shotpoint in order to extend the data base for shallow paths.

PRECURSORY SEISMICITY PATTERNS BEFORE LARGE EARTHQUAKES, M. Wyss, University of Colorado, Geological Sciences, Boulder, Colorado 80303, (303) 492-8028.
Goal: To recognize precursory seismicity patterns before recent large earthquakes.
Investigations: We will collect and analyze seismicty data before 39 recent major earthquakes. Our analysis will be centered on recognizing precursory seismicity fluctuations by graphical and algorithm techniques.

Ground deformation, tilt, strain studies

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, California 91125, (213) 795-6811, ext. 2904.
Goal: To maintain and monitor existing installations of strainmeters, tiltmeters, creepmeters, and alignment arrays.
Investigations: Three recording creepmeters, six Kinemetrics tiltmeters, and an array of four strainmeters are installed in Cholame Valley where recent episodes of creep have been established. Three new alignment arrays between Parkfield and Cholame complement these monitors. Six permanent creepmeters in the Imperial Valley are recording continuously; all were installed across recently active surface traces because of en-echelon cracks in road pavement.

CRUSTAL DEFORMATION MEASUREMENTS NEAR YAKATAGA, GULF OF ALASKA, R. Bilham, Lamont-Doherty Geological Observatory of Columbioa University, Palisades, New York 10964, (914) 359-2900

Goal: To predict the time of occurrence of a magnitude 8 earthquake that has been forecast to occur in the Yakataga region of the Gulf of Alaska in the next few decades.

Investigations: Nine 17 m long, carbon-fiber strainmeters were installed in shallow trenches at Katalla, Yakataga, and Icy Bay in August 1979 (fig. 13). Data from these instruments are recorded locally and also transmitted via satellite as hourly mean strain values. The resolution of each strainmeter is a few parts in 10^{-9} and we hope to recognize precursors in the period range 30 days to one hour. A study of strain precursors reported from other regions indicates that we could expect to see a coherent strain signal with amplitudes between 10^{-6} and 10^{-4} strain on all nine instruments should a magnitude 8 earthquake be imminent. The experiment is unusual in that all of the instruments are located above a rupture zone forecast from seismic gap theory.

CONTINUED OPERATION OF STRESSMETER NET, SOUTHERN CALIFORNIA, B. R. Clark, Leighton and Associates, 17975 Sky Park Circle, Irvine, California 92714, (714) 556-1421.

Goal: To detect small changes in the ambient stress field near fault zones prior to earthquakes.

Investigations: The stressmeter array is monitoring stress levels at eight active or proposed sites along the San Andreas and Sierra-Madre fault systems in southern California. A few specific sites are being recorded on an hourly basis, and all sites are measured regularly at two-week intervals. In addition, the stressmeter sensors have been tested extensively in the laboratory and corrected calibration curves have been generated. The stressmeters have a sensitivity of approximately 100 millibars, above the level of obvious earth tides, but sensitive enough to detect anamalous changes of ground stress associated with nearby earthquakes. The sensors are installed at a depth of approximately 20 meters beneath the ground surface.

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

Goal: To construct a transportable Mark III data reduction system for eventual use in monitoring strain accumulation over continental distances.

Investigations: We are constructing a transportable, very-long-baseline interferometry (VLBI) electronic system to monitor transcontinental strain accumulation for possible use in earthquake prediction. This system will contain all of the electronics needed for a VLBI geodetic station, from the dual wide-band low noise receivers through the tape recorder, but excluding the frequency standard and the water vapor radiometer needed for atmospheric delay calibration. System performance will be tested at the Haystack Observatory in a suitable VLBI experiment involving other large antennas to maximize the achieveable signal-to-noise ratios.

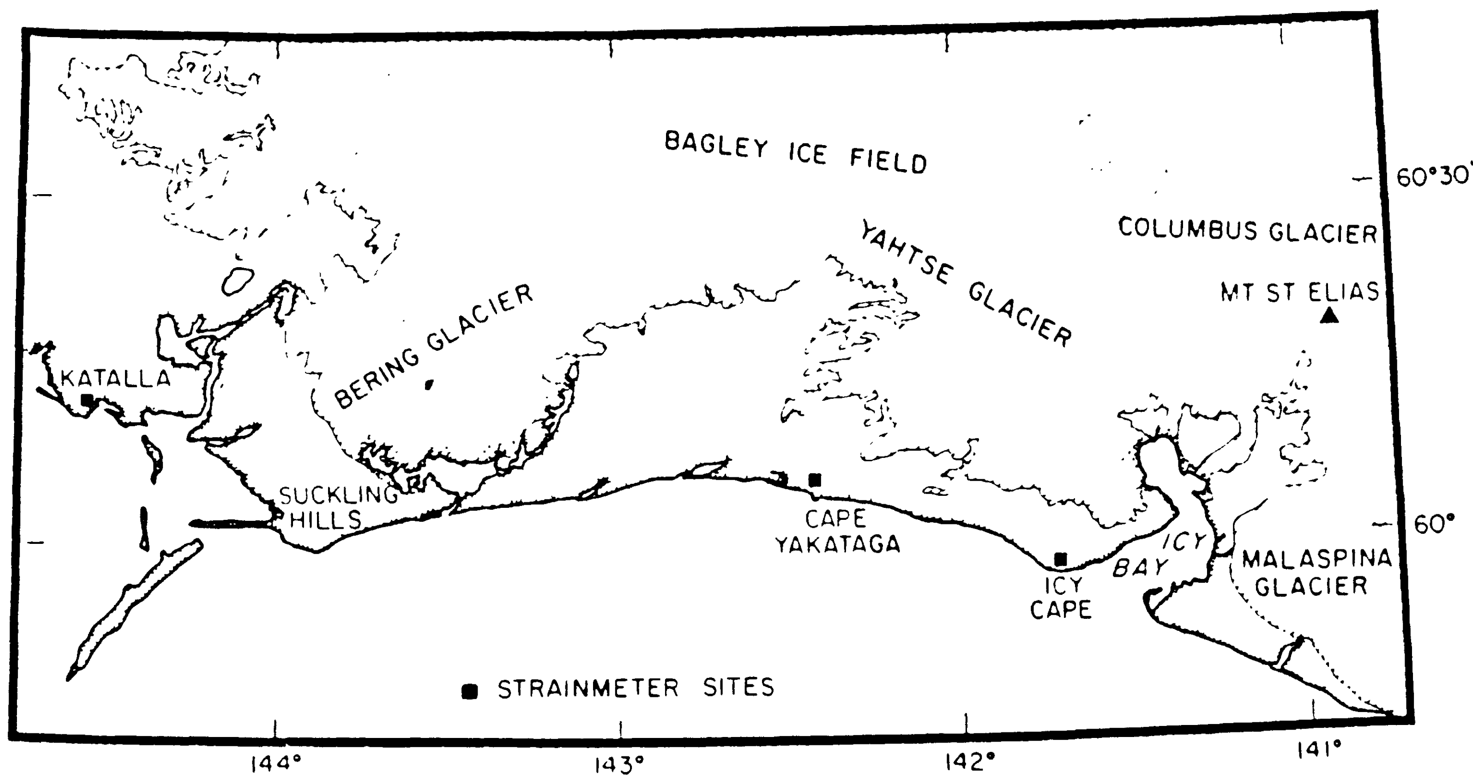

FIGURE 13.—Gulf of Alaska coastline between Katalla and Icy Bay. Strainmeters are located at Katalla, Cape Yakataga, and Icy Cape.

MEASUREMENT AND ANALYSIS OF THE NEAR-SURFACE STRESS FIELD IN THE VICINITY OF ACTIVE FAULTS IN SOUTHERN CALIFORNIA, T. Engelder, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, (914) 359-2900, x. 284.

Goal: To characterize the nature of the stress field near faults at different stages in the accumulation of strain prior to the rupture of those faults during an earthquake.

Investigations: We will make additional samples of the stress field in previously measured sites south of Palmdale in order to increase the density and areal extent of these sites. Some of the sites used in 1977 will be reoccupied to test for temporal variations in the stress field. We will also make stress measurements along other parts of the locked section of the fault to the north of the 1977 area.

IMPROVED STRESS DETERMINATION PROCEDURES BY HYDRAULIC FRACTURING, C. Fairhurst, University of Minnesota, Department of Civil and Mineral Engineering, Minneapolis, Minnesota 55456, (612) 373-2968.

Goal: To improve the reliability of hydraulic fracturing as a technique for determining in-situ stress.

Investigations: A series of fracture reopening experiments have been conducted in a biaxial stress field with the borehole axis inclined to the principal stress directions. We are designing a vertical loading frame to extend the tests on 15" cubic granite specimens to a full triaxial state. Pressurizing fluid flow rate is servo controlled to allow examination of the effect of varying flow rates. Tests are designed to provide information on the controlled reopening of fractures to enable prediction of the complete in-situ stress field. Field work will be conducted in the same rock as used for the experiments to assess experimentally determined procedures. Hydraulic fracturing results will be compared to overcoring stress measurements.

THEODOLITE MEASUREMENTS OF CREEP RATES ON SAN FRANCISCO BAY REGION FAULTS, J. Galehouse, San Francisco State University, Department of Geosciences, 1600 Holloway, San Francisco, California 94132, (415) 469-1204.

Goal: To measure creep on various San Francisco Bay area faults.

Investigations: We are monitoring creep rate at ten established stations on the Antioch, Calavaras, Concord, Hayward, Seal Cove, and San Gregorio faults. We plan to establish a minimum of seven new stations at additional sites on the Hayward and San Andreas faults and monitor the creep rate at these stations.

A MULTI-PURPOSE CRUSTAL STRAIN OBSERVATORY AT DALTON TUNNEL COMPLEX, SAN GABRIEL MOUNTAINS, T. L. Henyey, University of Southern California, Department of Geological Sciences, Los Angeles, California 90007, (213) 741-6123.

Goals: (1) To provide a field test laboratory for comparing instruments, testing new ideas, and developing a cooperative multilateral instrument approach to earthquake prediction; and (2) to resolve both short and long term anomalies associated with earthquakes and secular crustal strain in an active tectonic regime.

Investigations: An old tunnel with 70 m and 150 m perpendicular arms is being refurbished to house the instrument cluster (fig.14). Initial instruments to be installed include: an acoustic emissions recorder, a continuous radon counter, gravimeter, groundwater level-turbidity-temperature, long-baseline fluid tiltmeters, carbon fiber strainmeters, a long-period seismometer, bubble tiltmeters, and strong motion accelerographs. Gravity and level lines will also be run periodically in the surrounding area.

AN ASSESSMENT OF REFRACTION ERROR AND DEVELOPMENT OF METHODS TO REMOVE ITS INFLUENCE FROM GEODETIC LEVELING, S. R. Holdahl, NOAA, National Ocean Survey, Rockville, Maryland 20852, (301) 443-8423.

Goals: (1) To determine whether refraction error is adversely affecting calculations of vertical crustal movements which are based on comparisons of repeated levelings, and (2) to develop a means of correcting old leveling observations in order to remove refraction error.

Investigations: A vertical temperature profile can be modeled using historical records of solar radiation, precipitations, and other data recorded by surveyors when observing. The modeled temperature profile is input to Kukkamakii's refraction correction. The modeled vertical temperature difference, between 50 and 250 cm, can be tested by comparing to observed values. The correction itself will be tested formally, using a site with instrumentation configured in such a way as to induce leveling refraction. The success of the correction will be proportional to its ability to remove the induced refraction error.

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

Goal: To obtain observations of slow deformations that can be related to the accumulation and release of strain at shallow depths in the New Hebrides subduction zone in order to determine the existence of possible signals precursory to the frequently occurring large, shallow earthquakes in the region.

Investigations: A network of seven Kinemetrics bubble-level tiltmeters and two arrays of benchmarks are installed for continuous recording of tilt measurements. Measurements of sea level variations (recorded naturally in the coastal tidal zone and by two tide gauges) complement these data. The leveling technique is an effective means of monitoring long term tilt. The tiltmeters are better suited for large, short-period (minutes to months) signals.

CRUSTAL DEFORMATION OBSERVATORY: COORDINATION AND DATA ANALYSIS, D. Jackson, University of California, Los Angeles, Department of Earth and Space Sciences, 3806 Geology Building, Los Angeles, California 90024, (213) 825-6130.

Goals: To formulate a comprehensive plan for the continuous measurement of tectonic strain and tilt, and to search for an optimal site for at least one high accuracy observatory.

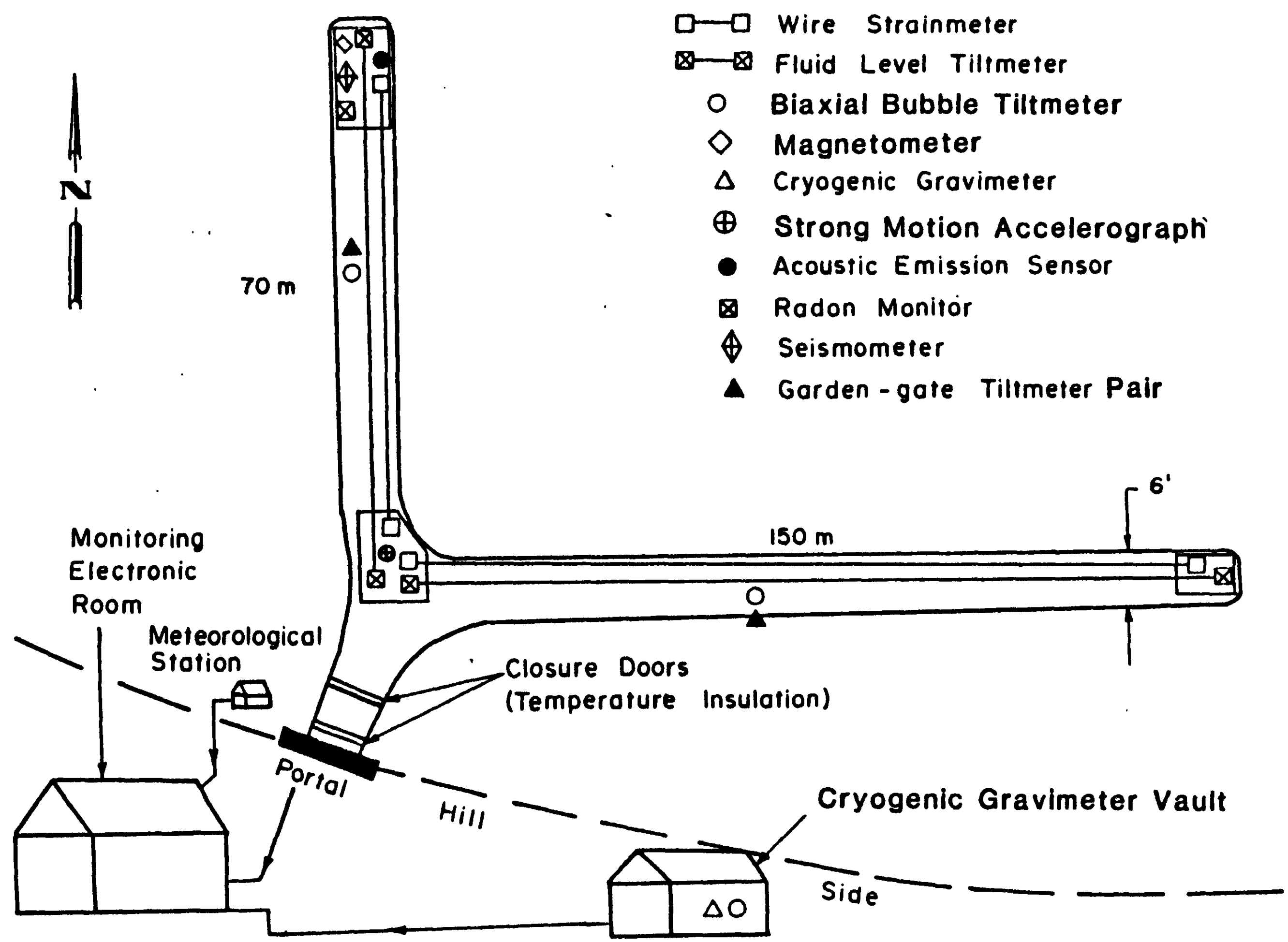

FIGURE 14.—Schematic drawing of Dalton Observatory.

Investigations: We plan to test and evaluate several measurement techniques at Pinon Flat Observatory. Our search for a satisfactory site for a planned high accuracy observatory will focus within a region of present tectonic activity. Following these activities, we will conduct an intensive study of the coupling between the crust and several types of movements and benchmarks.

TILT, STRAIN, AND MAGNETIC FIELD MEASUREMENTS, M. Johnston, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2132.
Goal: To understand the mechanics of earthquakes by comparing tilt, strain, and magnetic field variations occurring as a result of fault activity.
Investigations: Continuous monitoring of various types of crustal deformation parameters now occurs at more than 100 points throughout the San Andreas fault system. Sample rates with digital telemetry are typically six per hour. Data are immediately available in an interactive minicomputer for testing, plotting, and checking. Precursor algorithms can be routinely run on the data but await demonstration of reliable relationships between earthquakes and the various parameters.

CRUSTAL DEFORMATION OBSERVATORY, G. King, Cambridge University, Department of Geodesy and Geophysics, Madingley Rise, Madingley Road, Cambridge, England.
Goal: To resolve whether strain and tilt associated with tectonism can be effectively monitored on the Earth's surface.
Investigations: This project will install several tiltmeters of different design between two points on the earth (500 m apart) to establish instrument fidelity. Next, an area of tectonic interest will be selected to study the wavelength of surface tilt noise, the degree of surface elastic inhomogeneity and the process of tectonic deformation. Our contribution to the project is to install a 500 m pressure measuring tiltmeter that has been developed in Cambridge, England.

MEKOMETER MEASUREMENTS IN THE IMPERIAL VALLEY, R. G. Mason, Imperial College of Science and Technology, Geology Department, London SW7 2BP, England.
Goal: To resurvey previously installed compact geodetic network in close proximity to the Imperial Fault.
Investigations: The Mekometer will be used to measure all possible lines from each station within the Imperial fault sector. This instrument is provided with an optical plummet that can be continuously monitored throughout the measurement. Instrument position can be maintained to $\pm$ 0.1 mm. In addition, we expect to center the Kern Type DM1000 (110 mm dia.) reflector to within $\pm$ 0.1 mm, with a resulting probable error in the line distance of 0.2 mm due to miscentering. With the improved accuracy accomplished through field calibration of the cavity frequency, we hope to achieve probable errors of not more than 1 ppm.

GEODETIC STRAIN MONITORING, A. McGarr, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2708.
Goal: To obtain information on crustal strain changes in selected areas of interest along the San Andreas fault system.

Investigations: A new two-color laser distance measuring device will be used to measure line length changes over distances of 5 to 10 km to a precision of a part in 10^7 in the vicinity of Palmdale, California. Measurements repeated weekly over each line will provide a picture of crustal strain with high resolution in both space and time.

TILT OPERATIONS, C. Mortensen, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2583.
Goals: (1) To manage the operation of tiltmeter networks, and (2) to monitor local and regional crustal deformation along sections of the San Andreas fault and other seismically active faults in the western United States.
Investigations: This project operates and monitors tiltmeters at 80 sites in northern and southern California. In central California, parallel records from three sites with redundant tiltmeters are studied to determine surface tilt signal and noise characteristics. We are also evaluating alternative techniques for stablizing shallow borehole tiltmeter installations at a small number of sites in northern California.

RECENT VERTICAL MOVEMENTS OF THE CRUST IN THE WESTERN UNITED STATES: 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, New York 14853, (607) 256-2377.
Goal: To examine and interpret available leveling data as they relate to seismicity and current geologic activity in order to further the understanding of contemporary dynamics of intracontinental regions.
Investigations: A comprehensive analysis of all releveling observations in the western U.S. will be undertaken in order to evaluate the utility of these measurements for geodynamic studies and, when warranted, use this information to investigate tectonic activity. Particularly promising areas include: the Rio Grande rift, New Mexico; the Diablo Plateau, West Texas; the Oregon-Washington coast; the Nevada seismic zone; Hebgen Lake, Montana; and northern California.

CRUSTAL STRAIN, J. C. Savage, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2633.
Goal: To measure the spatial and temporal dependence of strain accumulation along the San Andreas fault and other major faults in California and Nevada.
Investigations: Geodolite surveys are capable of measuring the annual strain accumulation (about 0.2 microstrain per year) along major faults in the western United States. Such strain measurements are made annually at about 20 sites in California and less frequently at other sites in Nevada, Washington, New Mexico, Utah, Montana, and Alaska.

MEASUREMENT AND ANALYSIS OF THE NEAR-SURFACE STRESS FIELD IN THE VICINITY OF ACTIVE FAULTS IN SOUTHERN CALIFORNIA, M. L. Sbar, University of Arizona, Department of Geosciences, Tucson, Arizona 85721, (602) 626-4849.
Goals: To determine the state of stress along a portion of the San Andreas fault and to model the observed stresses using finite element analysis in terms of strain history and boundary properties and geometry.

Investigations: We are conducting a finite element analysis in order to model both the magnitude and spatial variation in observed stresses near the fault. Preliminary analysis has been restricted to two-dimensional horizontal models, with emphasis placed on concentrating strain in the models near the fault and on determining the effects of various boundary conditions applied on the edge of the models. Anisotropic elements are being included to model elastic parameters whose values may depend on orientation with respect to the fault. These elements, when applied to models that include both fault geometry and strain history, will be used to study the horizontal spatial variation in observed stresses.

CRUSTAL DEFORMATION OBSERVATORY NEAR SAN ANDREAS FAULT IN CENTRAL CALIFORNIA, L. E. Slater, University of Colorado, CIRES, Boulder, Colorado 80309, (303) 492-8028.
Goal: To examine the relationships between aseismic fault slip, local earthquakes, and local changes in geodetic line lengths and relative changes in elevation between monuments several hundred meters apart.
Investigations: We are using a multi-wavelength EDM (MWDM) instrument with a precision of 1 part in 10 million. Line lengths within the radial array are measured daily whenever possible. We are installing the new, long-baseline, two-fluid tiltmeter within the MWDM array. This will allow simultaneous vertical and horizontal crustal deformation measurements to be made to state-of-the-art precision. We have developed a thermally compensating monument for the vertical measurements that we expect to be stable to better than 0.05 mm over the entire range of expected temperatures. We are also completing a major modification of the MWDM instrument that will greatly increase its reliability and mobility.

TILTMETER RESEARCH IN NEW MADRID, MISSOURI, W. Stauder, Saint Louis University, Department of Earth and Atmospheric Sciences, St. Louis, Missouri 63103, (314) 535-3300, ext. 206.
Goal: To test shallow borehole tiltmeters and operate them in Missouri and Alaska.
Investigations: A comparison pair of Kinemetrics Model TM-1 tiltmeters has been installed in the New Madrid seismic region. Six tiltmeters have been installed on Adak Island at 10 to 400 meter intervals. We developed techniques for solving physical and interface problems and for adapting the tiltmeters to the harsh environments of these sites. Instruments at both locations track favorably and show a good baseline stability.

CRUSTAL DEFORMATION OBSERVATORY: PRECISION GEODESY, A. G. Sylvester, University of California, Santa Barbara, Marine Science Institute, Santa Barbara, California 93106, (805) 961-3471.
Goal: To conduct precise geodetic surveys of crustal strain and tilt at a central Crustal Deformation Observatory.
Investigations: Our project is designed to complement and control the studies of other investigators who are using electronic and electro-optical methods. Vertical crustal strain will be monitored several times annually by precision leveling of arrays of permanent benchmarks (fig. 15). We will monitor tilt by leveling and by dry tilt arrays; local horizontal strain will be monitored by a short-range electronic distance meter. Additional arrays of benchmarks will be established and periodically leveled elsewhere in tectonically active and interesting areas in southern California in order to monitor

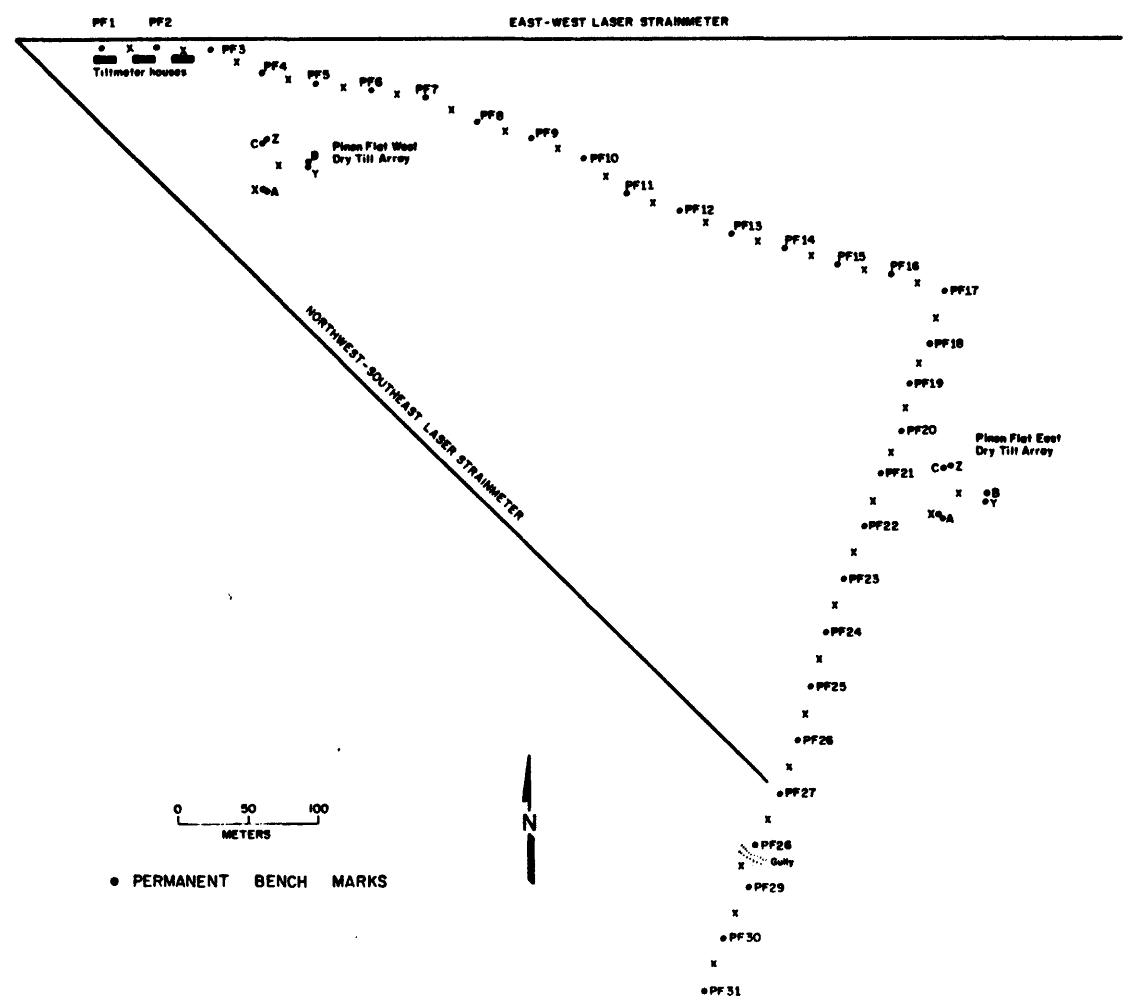

FIGURE 15.—Plan of precise level line and dry tilt arrays at Pinon Flat, California.

vertical crustal strain not only for determination of optimal sites for eventual deployment of electronic tiltmeters, but also to study the nature of nearfield vertical strains across active faults.

DRY TILT AND NEARFIELD GEODETIC INVESTIGATIONS OF CRUSTAL MOVEMENTS, SOUTHERN CALIFORNIA, A. G. Sylvester, University of California, Santa Barbara, Marine Science Institute, Santa Barbara, California 93106, (805) 961-3471.
Goal: To document the temporal and spatial aspects of tilt and nearfield vertical strain around major faults in southern California.
Investigations: We have established 45 dry tilt arrays throughout the Transverse Ranges, particularly in the vicinity of the San Andreas fault and along the system of frontal faults on the south edge of the San Gabried Mountains. The arrays, consisting of from three to six permanent benchmarks, are precisely leveled nine times annually. We have also established 17 short level lines across different kinds of active faults in such diverse places as San Fernando, Death Valley, Palmdale, San Juan Bautista, Santa Barbara, and the southern San Joaquin Valley. These lines range in length from 500 to 1600 m and are resurveyed according to first order, first class procedures from one to four times annually.

Gravity studies

PERIODIC PRECISION GRAVIMETRIC OBSERVATIONS IN THE VICINITY OF THE SOUTHERN CALIFORNIA UPLIFT, J. D. Fett, Earth Science and Engineering, 27595 Santa Fe Street, Hemet, California 92343, (714) 658-7509.
Goal: To monitor elevation changes in and about the southern California uplift region.
Investigations: We installed a network of 86 gravity stations across the San Andreas fault system from the Salton Trough to the south of the Carrizo Plain. The stations are spaced about every 5 km along seven lines approximately normal to the fault. Monthly observations are made with two LaCoste and Romberg model D "Microgal" gravimeters.

CONTINUOUS GRAVITY MEASUREMENTS IN THE REGION OF THE SOUTHERN CALIFORNIA UPLIFT, J. M. Goodkind, University of California, San Diego, Department of Physics, La Jolla, California 92093, (714) 542-3666.
Goals: To measure secular variations in gravity at a fixed location and to correlate them with tilt measurements and leveling and gravity surveys in the surrounding region.
Investigations: Superconducting gravimeters have been deployed at several locations in the United States. Three are in southern California at Lytle Creek, Pinon Flat, and Otay Mountain. Gravity variations of order 1 μgal can be observed with these instruments. However, in order to ascertain that these variations result from geophysical phenomena of interest, the uninteresting ones must be identified and accounted for. This requires complicated data analysis of high quality data as well as simultaneous measurements of gravimeter tilt, ground water level, atmospheric pressure, and other environmental variables.

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

Goal: To conduct high-precision gravity surveys in southern California for the purpose of detecting and monitoring temporal variations of elevation and subsurface density.

Investigations: A broad-scale network consisting of approximately 320 high-precision gravity stations is established in areas of known and suspected uplift in southern California. These stations are located at bedrock sites on roughly a 15 km x 15 km grid covering about 70,000 square kilometers and resurveyed approximately every six months. Our observations indicate that meter-dependent systematic errors contribute to overall uncertainties in the measured gravity changes. We believe that these errors result in part from the combined effects of long-term gravity meter drift and a fine-scale nonlinearity in the gravity-meter calibration function. This combination could cause apparent gravity changes on the order of 20 microgal or more between surveys whether or not the same meter is used for remeasurement.

REFINEMENT OF CRYOGENIC GRAVITY METER FOR EVENTUAL DEPLOYMENT IN PORTABLE FORM, J. A. Tuman, California State College, Stanislaus, Monte Vista Road, Turlock, California 95380.

Goals: (1) To refine the present cryogenic gravity meter, (2) to design and construct a portable cryogenic gravity meter, and (3) to study the secular variations of the earth's gravitational field, which are independent of short term and long term tidal effect, but are directly related to earthquake activity.

Investigations: For the present, we are refining the performance of our cryogenic gravity meter, and we are also developing computer programs in order to transmit the 16 bit digital data from the PET digital computer to large computers for data analysis. Some preliminary studies were carried out for the design of a portable cryogenic gravity meter.

LOCAL CHANGES IN THE GRAVITY AND MAGNETIC FIELDS DUE TO TECTONIC STRAIN, J. B. Walsh, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Massachusetts 02139, (617) 253-3381.

Goal: To apply theoretical results to existing studies of surface deformation and fault configuration.

Investigations: We derived the Green's functions which couple the changes in the horizontal and vertical components of the gravity field with a source of deformation at depth. These functions permit one to calculate changes in gravity due to any dislocation source by a straightforward integration over a finite surface, rather than use the procedure involving a numerical integration over an infinite volume. We propose to apply the results of this analysis to natural events for which field data are available. We also propose to develop theory for half-space containing a layer with low density. We believe our technique will work for the most important case where the anomalous layer is at the surface.

Magnetic studies

THE MAGNETIC RESPONSE OF ROCKS TO UNIAXIAL COMPRESSION: EFFECT OF CONFINING PRESSURE AND TEMPERATURE, M. D. Fuller, University of California, Santa Barbara, Department of Geological Sciences, Santa Barbara, California 93106, (805) 961-3158.

Goal: To understand and utilize magnetic precursors of earthquakes.

Investigations: Polycrystalline magnetite and rock samples containing magnetite were subject to isothermal uniaxial compression and stress cycling. The changes in magnetization were observed continuously as a function of stress and the changes in direction and magnitude of magnetization were inferred. Different responses were dependent in part on the initial remanent state. An anomalous increase in magnetization is found to be reversible under stress cycling. We also note large rotations of magnetic direction. A rock containing fine-grain magnetic material was found to show no response—in contrast to the observations with polycrystalline magnetite and rocks with coarse grain magnetic particles. These results draw attention to the variety of stress responses and the desirability of three-component field observations to detect possible magnetic precursors of earthquakes.

MAGNETOMETER ARRAY IN THE SOUTHERN CALIFORNIA UPLIFT REGION, D. Jackson, University of California, Los Angeles, Institute of Geophysics and Planetary Physics, Los Angeles, California 90024, (213) 825-1776.

Goal: To establish an array of five continuously recording proton-precession magnetometers in the southern California uplift region.

Investigations: We selected and mapped five sites that satisfy all of our criteria including low magnetic and topographic gradients. We plan to test our magnetometers at closely-spaced sites in order to determine whether the dominant source of noise is instrumental or related to inhomogeneity of atmospheric magnetic fields.

INVESTIGATION OF THE SOUTHERN CALIFORNIA 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, California 92403, (714) 885-0231.

Goal: To look for temporal changes in the magnetic field in southern California related to tectonic stress.

Investigations: A two-dimensional array of 51 magnetometer stations monitors the San Andreas fault zone from Quail Lake to the Indio Hills and the San Jacinto fault zone from Pearblossom to Borrego Springs. We established these stations at 15 km intervals along the fault zone and equipped them with buried benchmark-like sensor holders. During the past year, we made 105 simultaneous, 10-minute observations at the station pairs. By "differencing" the data for each station pair, we obtain a number that is related to tectonic stress in the crustal rocks. Results to date clearly indicate that the method is responding to broad, non-seismic tectonic change. Magnetic data and differential level data coincide, indicating the same tectonic change in form and time.

Electrical studies

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

Goal: To apply a controlled source electromagnetic method in a search for changes in the electrical conductivity of the earth's crust.

Investigations: We studied the electrical structure of the San Andreas Fault in the Hollister area using the University of California (Berkeley) electric dipole transmitter near Paicines to perform an electromagnetic induction experiment. Approximate analysis of these data revealed the gross features of the electrical conductivity structure of the study area. We are now developing the computer programs to do a more careful analysis of the data and to study changes in the electromagnetic response due to stress induced changes in conductivity in the fault zone.

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, Massachusetts 02139, (617) 253-6384.

Goals: To develop the capability of detecting stress induced electrical effects using passive measurements over large areas, and to tie any such observations with other effects being monitored in the study area as an aid to earthquake prediction.

Investigations: We are making resistivity variation and self potential measurements on two arrays in the San Andreas--one centered at Palmdale and one centered at San Juan Bautista. The measurements are passive using the telluric signals picked up on long telephone line antennas. The resistivity variations are obtained by tensor cancellations of the telluric signals received on the various dipoles. At present, we can detect resistivity variations of 0.2% using 10 days data. The cancellations also expose small self potential variations which would otherwise be lost in the larger telluric signals. When the electrodes are well behaved, we can detect 0.1 mv/km of self potential. These levels may still need to be improved for useful prediction studies and we are working on achieving such improvements.

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

Goals: (1) To determine whether electrical resistivity and/or self-potential variations precede seismic activity in the San Andreas fault zone, and (2) to determine the mechanisms for such variations if they do occur.

Investigations: We are monitoring temporal electrical resistivity and self-potential variations along the San Andreas fault zone, between Hollister and San Benito in central California. Transmitter cables are buried in plastic pipes, and insulated armor-plated wire and lead receiving electrodes are installed at receiver sites. Five 2-channel, synchronous resistivity detectors permit simultaneous acquisition of orthogonal field data from four receiver sites. During the past year, we completed several studies on possible mechanisms for resistivity and self-potential variations generated by a dilatancy process precursory to earthquakes.

STUDY OF ATMOSPHERIC ELECTRIC PROCESSES AND THEIR ASSOCIATION WITH EARTHQUAKES, J. E. Nanevicz, SRI International, 333 Ravenswood Avenue, Menlo Park, California 94025, (415) 326-6200, ext. 2609.
Goal: To identify electric anomalies associated with earthquakes.
Investigations: We will set up four field meters in various locations to collect data, under microprocessor control, and store the data in digital form on a cassette tape. This data base can be used to suggest and test theories about possible earthquake mechanisms, to assess the possible response of animals to changes in atmospheric electrical parameters, and to evaluate electric fields as an earthquake warning system.

Geochemical studies

RADON AS AN EARTHQUAKE PRECURSOR IN ICELAND, W. S. Broecker, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964.
Goal: To monitor the radon content of geothermal wells in Iceland adjacent to an active plate boundary.
Investigations: Techniques have been developed for sampling the two-phase geothermal water and we have shown that radon can be reproduceably measured. Sampling networks have been established and are routinely operating in the Southern Iceland Seismic Zone (seven stations) and the Tjornes Fracture Zone (two stations) in northern Iceland. The wells range in depth from 50 m to 1500 m and the temperature of the water is from 50 to 100 degrees C. Samples are also regularly being collected in the Krafla-Namafjall high temperature geothermal field, an area of current tectonic activity.

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, California 92093, (714) 452-3260.
Goals: To measure radon, helium, dissolved gas, and stable isotope relationships in thermal waters and their correlations with seismic activity.
Investigations: We are measuring dissolved radon, helium, nitrogen, argon, and methane in 16 thermal wells and springs along the Elsinore, San Jacinto, and San Andreas faults (fig. 16). Helium-3/helium-4 and stable isotope ratios in water are also measured, as well as lead-210 and radium-226. Based on linear arrays of dissolved gas concentrations, we developed a two-component model for the origin of these gases. Pre-seismic event fluctuations in radon and helium are being studied in terms of variations in these gaseous components. We are also installing and collecting film strips at sites on the Imperial Fault and at our radon monitoring sites for soil radon studies being carried out at Menlo Park.

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, California 92037, (714) 452-2662.
Goal: (1) To develop and implement techniques for measuring uranium isotope ratios, and (2) to determine the feasibility of using uranium isotopes as earthquake precursors.

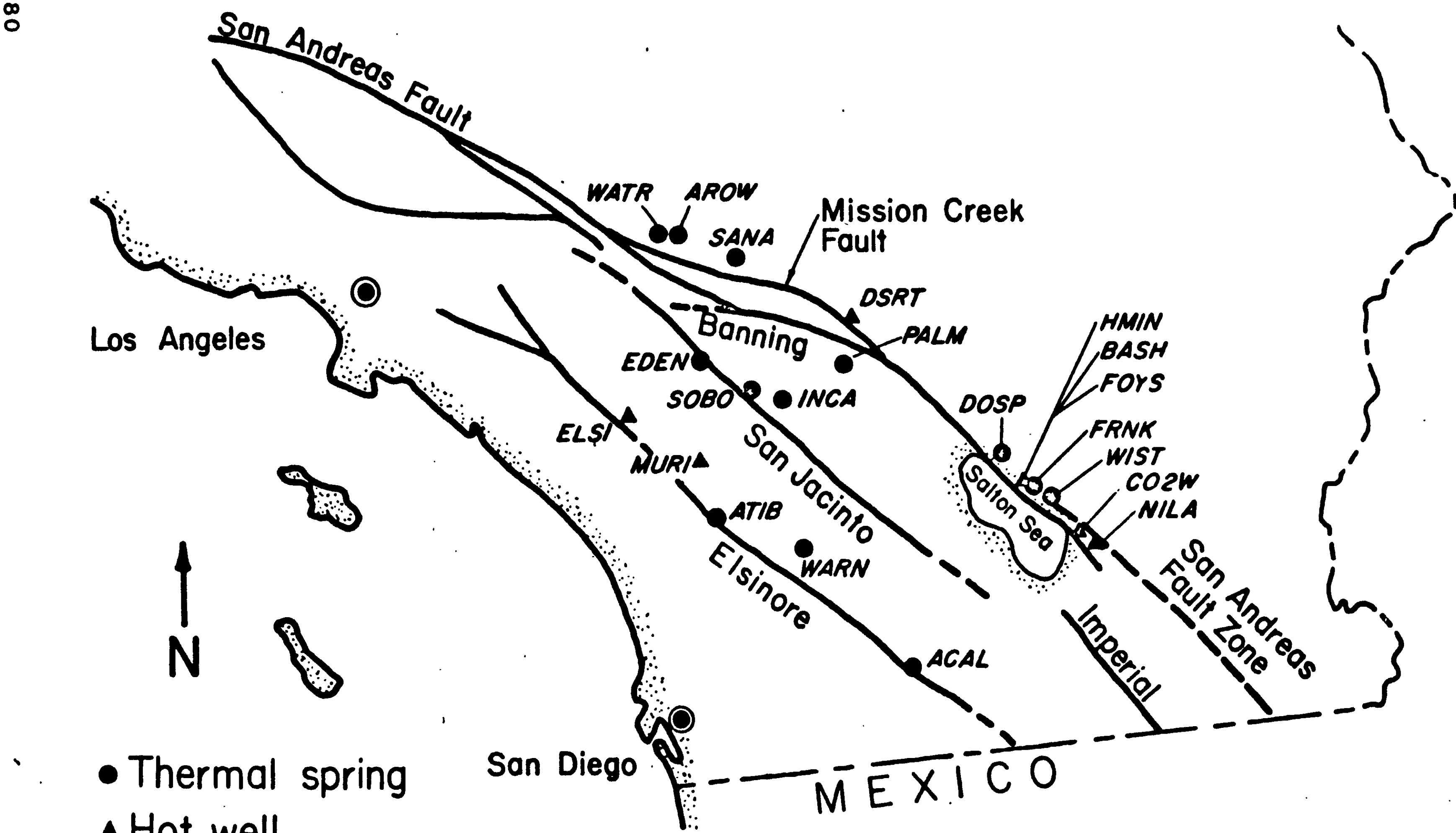

FIGURE 16.—Radon and helium monitoring sites in southern California.

Investigations: Uranium determinations are made from the same sampling network used by Craig to measure radon and helium from springs along the San Andreas, San Jacinto, and Elsinore fault systems in southern California (fig. 16). The implementation phase of this project will perfect extraction and purification techniques, determine detector background levels and efficiencies, prepare spikes, and establish laboratory procedures. During the survey phase, samples from all relevant springs will be collected to determine uranium concentrations. These determinations will be correlated with other geochemical variables and with seismic activity. A limited monitoring program, confined to one or two selected springs, will provide sampling and measurements for assessing normal variability and for isolating non-seismic causes of anomalies.

LIGHT STABLE ISOTOPES, I. Friedman, U.S. Geological Survey, Branch of Isotope Geology, Box 25046, Denver Federal Center, Denver, Colorado 80225, (303) 234-3876.
Goal: To explore the possibility of using helium and hydrogen in earthquake prediction.
Investigations: Helium appears to be the most likely element to pursue in the prediction of earthquakes. Eight atoms of helium are formed for every decay of U-238 and six atoms for every decay of Th-232. Unlike radon, which decays away with a half-life of 3.8 days, helium is stable. We are currently monitoring helium in wells and in soil and natural gases. Daily samples are collected from two networks. One well sampling network extends along the Brawley-Salton Sea area and another is located in Montana adjacent (100 km radius) of Hebgen Lake. An automated helium sniffer has operated continuously near Gardiner, Montana, for over 1-1/2 years. This instrument makes hourly analysis of a nearby water well that is highly enriched in helium. The data is recorded on the spot and also telemetered via GOES satellite.

RADON AND WATER WELL MONITORING, C-Y King, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2706.
Goal: To search for useful geophysical and geochemical precursors to earthquakes in groundwater and soil gas along seismically active faults. Parameters monitored include radon content and water level and quality.
Investigation: We are using the Track-Etch method to continuously monitor the radon content of soil gas at about 100 sites along active faults in California. Measurements show large episodic variations (several hundred percents) that are often spatially coherent over long fault segments (tens of km). Periods of high radon content often coincide with or precede periods of high seismicity. Data recorded at some sites also show significant seasonal variations. Radon content of groundwater is continuously monitored at two artesian wells in California. Water level is continuously recorded and water quality (temperature, salinity, conductivity, pH) is periodically measured at about 10 wells in central California.

COMPARISON OF RADON MONITORING TECHNIQUES, THE EFFECTS OF THERMOELASTIC STRAINS AND THE DEVELOPMENT OF A RADON MONITORING NETWORK FOR EARTHQUAKE PREDICTION, M. H. Shapiro, California Institute of Technology, W. K. Kellogg Radiation Laboratory, Pasadena, California 91125, (213) 795-6811, ext. 1587.
Goals: (1) To establish a network of computer controlled, fully-automated radon monitoring sites in southern California; (2) to examine the relationship between

subsurface radon levels and seismicity; (3) to examine the influence of environmental factors, such as temperature and rainfall on subsurface radon levels; and (4) to compare different techniques for continuous monitoring of subsurface radon levels.
Investigations: We have deployed six second-generation, microprocessor controlled, fully-automated radon-thoron monitors. One of these has been sited at San Juan Bautista in central California at a location close to the San Andreas fault. Two other types of continuous radon monitors also are in operation at this site to obtain side-by-side comparisons of radon data. The other five radon-thoron monitors have been sited along the frontal faults of the Transverse Ranges of southern California. Data from all the monitors are transmitted via dial-up telemetry to an Andromeda 11/B computer at Kellogg Laboratory for storage and analysis. Plots of the radon and thoron data from each site are updated and examined regularly for correlations with local seismicity and with environmental factors. A third-generation, radon-thoron monitor will be added to the southern California network shortly. This unit will include sensors to measure the water level and water temperature in the same borehole used to monitor radon. A gas chromatograph will be interfaced to this monitor and will be used to measure levels of hydrogen, helium, and methane in the borehole.

GROUNDWATER 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, California 90007, (213) 741-6124.
Goals: (1) To evaluate the usefulness of groundwater radon as a subsurface stress transducer and (2) to develop continuous radon content measurement equipment.
Investigations: We are monitoring 14 sites (fig. 17) in southern California for variation in groundwater radon content. These sites include hot and cold springs, water wells, and deep mine shafts. We have built and tested a field version of a continuous radon counter. Additional units are under construction.

Water-level studies

WATER LEVEL MONITORING ALONG THE SAN ANDREAS AND SAN JACINTO FAULTS, SOUTHERN CALIFORNIA, D. L. Lamar, Lamar-Merifield, Geologists, 1318 Second Street, Santa Monica, California 90401, (213) 395-4528.
Goal: To establish a network of water level observation wells in a variety of rock types within and adjacent to the San Andreas and San Jacinto fault zones in southern California with the objective of observing anomalous water-level fluctuations which may be earthquake precursors.
Investigations: We are currently monitoring water levels in approximately 35 abandoned water wells along the San Andreas fault between Palmdale and Valyermo and along the San Jacinto fault zone between San Jacinto Valley and Ocotillo Wells. These observation wells penetrate a variety of bedrock types, including basement complex, volcanic rock, and Quaternary deposits adjacent to the fault zones and probable fault breccia and gouge within the fault zones. This distribution permits comparison of water-level changes in different rock types within and outside the fault zone. Stevens Type F water-level recorders continuously measure water levels in several wells; levels in other wells are monitored on a daily to semi-monthly basis with the aid of volunteers. Long-term

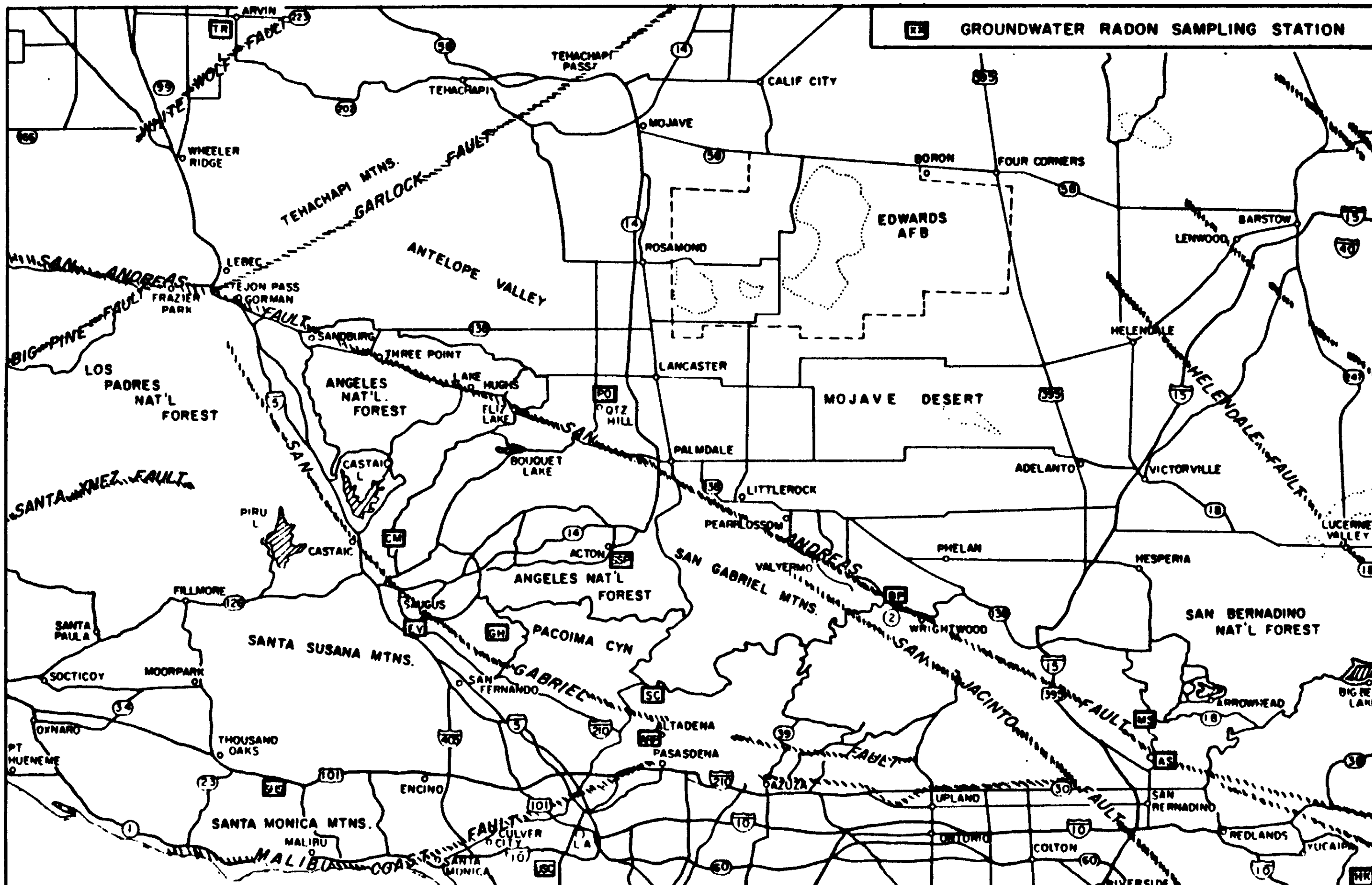

FIGURE 17.—Location map of groundwater radon sampling stations.

water-level variations are compared with rainfall, and short-term fluctuations due to tidal forces and atmospheric pressure are observed. Data on earthquakes in the region are compared with water-level variations to determine if any anomalous changes occur prior to earthquakes.

GROUND-WATER ANALYSIS, W. R. Moyle, Jr., U.S. Geological Survey, Water Resources Division 24000 Avila Road, Laguna Niguel, California 92677, (714) 831-4232.
Goal: To determine the precursory value of temporal and spatial changes in the water level and temperature in artesian wells.
Investigations: Water level changes are monitored in seven selected wells from the Palmdale area to Imperial. Each well is equipped with a continuous Imperial water-level recorder. In addition, barometric pressure, earth tides, air temperature, rainfall, and pumpage are measured to quantify the causes of "natural noise" in water-level monitoring systems.

STOCHASTIC SIGNAL PROCESSING AND ANALYSIS OF WATER LEVEL DATA, P. Westlake, Environmental Dynamics, Inc., 1024 Pico Blvd., Santa Monica, California 90405, (213) 399-9135.
Goals: To develop a reliable means of eliminating non-tectonic variations from water level data in order to facilitate the early detection of any water level earthquake precursors that may occur.
Investigations: This project uses existing water level data along with associated climatological and land tidal information for southern California. Digitized data is utilized in computer programs which perform stochastic signal processing of individual well records. The signal processing employs multiple regression techniques which separate out influences of no interest (e.g., barometric and tidal) from influences which are of interest (e.g., tectonic).

Animal behavior studies

BIOLOGICAL PREMONITORS OF EARTHQUAKES - A VALIDATION STUDY, L. S. Otis, Stanford Research Institute, Psychobiology and Physiology Department, Life Sciences Division, Menlo Park, California 94025, (415) 326-6200.
Goal: To set up a network of qualified observers to report daily the occurrence of typical and unusual animal behavior.
Investigations: Volunteer observers are selected on the basis of their experience, reliability, motivation, objectivity, and proximity to animal subjects. Each observer is assigned an identification code and telephones a toll-free number (hot line) that is operational 24 hours a day to report any observations of unusual animal behavior. The message is automatically recorded on tape along with the date and time, by an independent circuit. To monitor compliance, observers are also required to call the hot line on a designated day once each week to "check in" whether or not they have observed any unusual behavior. In addition, each observer keeps a daily log of observed animal activity. Hot line data will be used to determine the relationship between animal behavior and seismic activity. Log data will also be used to establish baseline levels of normal and unusual animal behavior for each seismic region in the network.

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

Goal: To conduce long-term studies of animal behavior in seismically active areas in order to determine if correlations exist between changes in activity patterns and subsequent seismic events.

Investigations: We have established two animal behavior monitoring facilities in northern and southern California near the San Andreas fault. Our subjects are pocket mice and kangaroo rats kept in individual, outdoor, artifical burrow systems. Twenty kangaroo rats are housed indoors in individual running wheel cages equipped with light and temperature controls. Instruments are continuously and automatically recording the locomotor activity of the animals. We have also installed instruments for continuously recording air temperature, relative humidity, barometric pressure, and rainfall. These data are essential. If our animals should exibit behavioral changes prior to a nearby seismic event, we must know whether significant environmental events not related to the seismic event occurred; and if they did, whether or not our animals have previously responded to such changes in the absence of subsequent seismicity.

BASELINE 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, California 95616, (916) 752-6911.

Goals: (1) To evaluate the suitability of using dairy cattle milk production records as a precursor index, and (2) to determine the credibility of post-earthquake reports of premonitory animal behavior.

Investigations: We are making quantitative studies of existing milk production records to determine whether significant reductions in production occur just before earthquakes. Records of milk-producing herds in California have been obtained from the statewide network of agricultural extension agents and farm advisors. These records are compared with regional seismicity and with other non-seismic factors (such as meteorological conditions).

Data Processing

DEVELOPMENT OF A QUANTITATIVE MODEL OF STRESS IN A SEISMIC REGION AS A BASIS FOR EARTHQUAKE PREDICTION, K. Aki, Massachusetts Institute of Technology, Department of Earth and Planetary Sciences, Cambridge, Massachusetts 02139, (617) 253-6397.

Goals: To determine the distribution of incremental stress inside the earth and find its correlation with earthquake precursors.

Investigations: A special finite-element method has been designed to find an incremental stress in the earth from known surface displacements and the stress-free condition at the surface. The scheme has been tested using artificial data for a homogeneous half-space. We are applying it to the actual data from southern California geodimeter and levelling network during the southern California uplift episode. The state of stress at the depth of a few kilometers can be considerably different from the horizontal stress measured on the surface. The estimated incremental stress shows some correlation with observations on geomagnetic field and earthquake swarm activities.

FOR THE ESTABLISHMENT OF A SOUTHERN CALIFORNIA GEOPHYSICAL DATA AND ANALYSIS CENTER, D. G. Harkrider, California Institute of Technology, Division of Geological and Planetary Sciences, Seismological Laboratory, Pasadena, California 91125, (213) 795-6811, ext. 2908.
Goal: Systems and software will be developed to monitor, record, transmit, process, and store data measured by geophysical instruments.
Investigations: We built a prototype of the digital data logging and direct dialup telephone-telemetry (CROSS-TIM) system. Eighteen equivalent units will be constructed and deployed at existing monitoring sites in southern California. Computerized on-line system (CEDAR) software has been developed to monitor the southern California seismic array, detect seismic events, and initiate recording. Both CEDAR and the off-line data processing system are operational. The development of supporting software for the TIM units and for the central computer system is nearly complete.

NUMERICAL METHODS IN SEISMOLOGY: RAY-TRACING AND INVERSE PROBLEMS, H. B. Keller, California Institute of Technology, Division of Applied Science, Pasadena, California 91125, (213) 795-6811.
Goals: (1) To develop a computer code for computationally efficient and accurate solution of the three-dimensional ray-tracing problem, and (2) to apply the code to solve the inverse problem of determining local crustal structure.
Investigations: For a large class of velocity profiles, the three-dimensional, ray-tracing problem of basic interest in earthquake prediction can be formulated as a purely algebraic problem. Special techniques for solving the ray-tracing problem employ a very fast computer code. A homotopy continuation method employed in the code is superior to the commonly used shooting methods. The code permits the inclusion of several surfaces of material discontinuity of arbitrary shape. An additional feature is the calculation of phase shifts, caustic locations, and relative amplitudes. The efficient ray-tracing schemes, along with variational techniques and least squares, can be used to develop new methods for solving inverse problems.

DATA PROCESSING SERVICES, C. Lee, U.S. Geological Survey, Branch of Networks, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2080.
Goal: To provide operations support for the network analog tape recorder, on-line seismic processor, analog playback facilities, minicomputers, and remote terminals.
Investigations: Special tasks this year include implementing an automatic tape dubbing facility to merge three analog tapes and implementing automatic tape playback systems.

REDUCTION OF NOISE IN EARTHQUAKE PRECURSOR MEASUREMENTS, J. A. Steppe, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2570.
Goal: To develop techniques for improving the sensitivity of observations.
Investigations: Development of noise reduction techniques contributes to the earthquake prediction program goal of observing and evaluating earthquake precursors. The sensitivity of the observations is improved by reducing the noise level and thus increasing the signal-to-noise ratio. Initial efforts will focus on removing from magnetometer network data extraneous variations not caused by tectonic stress changes.

MINICOMPUTER SYSTEMS DEVELOPMENT, P. R. Stevenson, U.S. Geological Survey, Branch of Networks, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2572.
Goal: To provide a hybrid analog and digital system for processing network data within 8 to 32 hours of seismic events.
Investigations: An interactive seismic data processing system is being developed around the Eclipse S200 computer. Waveform data from over 500 seismic stations recorded on five analog tapes are digitized and merged. Phase arrivals, amplitudes, etc. are picked automatically and checked by an operator interactively using a Tektronix 4014 display. The events are located and results filed on archive tapes. The system is being used to augment central California processing.

Numerical Modeling

MECHANICAL PROCESSES OF CRUSTAL FAULTING, A. D. M. Barnett, Stanford University, Department of Materials Science, Stanford, California 94305, (415) 497-3716
Goal: To develop models for examining the mechanics of crustal faulting.
Investigations: Self-similar solutions of dislocation group dynamics are applied to aseismic faulting processes. A constant dislocation multiplication rate was found to account for the measured displacement and strain rate changes near the San Andreas fault; however, this simple model does not accurately predict field measurements in the fault far-field. The accumulation and release of strain along a strike-slip plate boundary are studied in terms of a two-dimensional continuum model. A modification of earlier models of the San Andreas fault was developed to include a non-zero creep strength at depth to allow for larger coseismic slip. Additional studies include two-dimensional, strike-slip faulting in a variable modulus crust.

THEORETICAL MECHANICS OF EARTHQUAKE PRECURSORS, W. D. Stuart, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2756.
Goal: To construct theoretical models for crustal deformation occurring before earthquakes on strike-slip and thrust faults.
Investigations: We analyzed a two-dimenjional model for strike-slip faulting to determine mechanical conditions permitting earthquake instabilities and distinctive precursory deformation. Fault constitutive properties were assumed to include strain softening beyond a peak stress, where the peak stress itself had a maximum near the earthquake focus. Inertia limited instabilities (earthquakes) are possible only for certain crustal rigidities and fault properties, otherwise a rapid aseismic fault slip episode results. In theory, instabilities, but not rapid aseismic slip episodes, are preceded by fairly distinctive strain rate increases near the fault trace, suggesting the existence of similar forms in the field. In combination with strain softening, aging (the increase of fault strength with time) seems capable of qualitatively explaining certain episodic seismic and aseismic deformation patterns observed in field data.

STUDY OF RESERVOIR-INDUCED SEISMICITY, L. C. Cluff, Woodward-Clyde Consultants, 3 Embarcadero, San Francisco, California 94111, (415) 956-7070.
Goal: To develop a methodology for evaluating the potential for reservoir-induced seismicity.
Investigations: The methodology for evaluating the potential for reservoir-induced seismicity at Auburn Dam will be refined to include available world-wide data on 300 very deep (more than 150 m) and deep (more than 92 m) reservoirs. Geologic mapping in the reservoir areas will identify the location and characteristics of faults, shear zones, and other geologic features and structures. Age and activity of surface faults will be assessed by trenching in areas overlain by young and datable deposits. Available literature, imagery and seismologic records for selected reservoirs will be reviewed. Reservoirs having accepted cases of reservoir-induced seismicity will be selected for further geophysical studies. Theoretical and regional tectonic modeling will integrate all data to assess the potential for reservoir-induced seismicity at each reservoir under study.

INDUCED SEISMICITY STUDIES IN SOUTH CAROLINA, R. M. Hamilton, U.S. Geological Survey, Office of Earthquake Studies, National Center Stop 905, Reston, Virginia 22092, (703) 860-6471.
Goal: To provide agencies responsible for constructing dams with a procedure for assessing the potential of inadvertantly triggering earthquakes by a planned reservoir.
Investigations: The absolute state of stress is measured in a seismogenic volume of rock near reservoirs responsible for earthquakes. The relationships among the stresses, fluid pressures, and geologic structure are also determined. From a knowledge of the orientation of pre-existing faults, the state of stress, and pore fluid pressure likely to be generated by filling the reservoir, we should be able to predict whether a given reservoir will trigger earthquakes.′ The hydraulic conductivity in the fault zone must also be determined to allow an estimate of time lag between filling the reservoir and triggering earthquakes. A 16-station seismic network was installed around the Montecello reservoir in South Carolina where filling in December 1977 resulted in a large number of small earthquakes. A 3,500-foot hole will be drilled into the seismogenic region. Stresses, fluid pressures, and transmissibility will be measured; and a seismic refraction survey will determine the local velocity structure.

A SEISMIC SPECTRAL DISCRIMINANT FOR RESERVOIR-INDUCED EARTHQUAKES, L. T. Long, Georgia Institute of Technology, School of Geophysical Sciences, Atlanta, Georgia 30332, (404) 894-2860.
Goal: To evaluate a seismic spectral discriminant which can identify areas where reservoirs will induce earthquakes.

Investigations: Preliminary data indicate that earthquakes induced by reservoirs have displacement spectra that decay inversely proportional to the cube of frequency. In contrast, earthquakes in areas where reservoirs do not induce seismic activity have displacement spectra that decay inversely proportional to the square of frequency. We investigated the theoretical basis for the differences in spectral slope by evaluating published source models. A cubic decay is indicative of a transsonic rupture velocity on a smooth or lubricated fault where the tractional resistance is insufficient to cause irregular motion or premature arrest of slip.

CRUSTAL LOADING AND INDUCED SEISMICITY AT THE YACAMBU RESERVOIR, VENEZUELA, C. H. Scholz, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, (914) 359-2900.

Goal: To study crustal loading and induced seismicity at the Yacambu Reservoir, Venezuela.

Investigations: We are measuring the mechanical and hydraulic response of the earth to the application of a large known load and pore pressure gradient: the filling of a large reservoir. These results will be combined with a study of seismicity induced by the reservoir in an attempt to understand the mechanism of induced seismicity. The reservoir to be studied, the Yacambu, is in the northern Venezuelan Andes. This reservoir will fill the valley containing a secondary branch of the seismically active Bocono fault, and is less than 20 km from the primary trace. The reservoir is scheduled to be filled to a depth of 150 meters in 1980. The project will be cooperative effort between Lamont-Doherty and the Venezuelan agency, Fundacion Venezolana de Investagaciones Sismologicas.

GEOLOGICAL AND GEOPHYSICAL STUDIES OF INDUCED SEISMICITY AT NUREK RESERVOIR, D. W. Simpson, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, (914) 359-2900.

Goals: (1) To study the influence of geological structure in controlling induced seismicity, (2) to examine the dynamic characteristics of induced earthquakes, and (3) to integrate seismological and geological data in an effort to understand the mechanism of induced seismicity.

Investigations: A nine-station seismograph network is monitoring induced seismicity occurring at the world's deepest man-made lake. Seismicity patterns and fault-plane solutions are being compared with geological data to identify the active structure in the reservoir region. Variations in water depth in the reservior are being compared with the level of seismicity to determine the infulence of rapid changes in water level. This grant supplements other sources of funding. The project is part of a US-USSR Exchange in Earthquake Prediction.

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

Goals: (1) To study reservior-induced seismicity at Toktogul Reservoir, Kirgizia, USSR; and (2) to study the tectonic setting of Toktogul Reservior and the Talas-Fergana fault.

Investigations: Eight seismic stations have been installed at Toktogul to augment an existing five-station Soviet network. Spatial and temporal changes in induced seismicity, which is occurring beneath the 215 m high dam, are being studied. LANDSAT images, Soviet seismicity catalogs and a review of Soviet geological literature are being used to study the seismotectonics of Central Asia, with emphasis on the Toktogul area and the Talas-Fergana fault. This project is part of a US-USSR Exchange in Earthquake Prediction.

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, California 94025, (415) 323-8111, ext. 2929.

Goal: To establish a set of criteria for identifying reservoirs most likely to trigger earthquakes.

Investigations: We are collecting existing data on 1600 large (100 million cubic meters) reservoirs, world wide. All reasonable physical parameters will be systematically evaluated and correlated in order to determine which factors affect reservoir-induced seismicity.

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

Goals: (1) To obtain the velocity structure of South Carolina in order to better utilize seismic data collected by the network, and (2) to develop and test a model for predicting earthquakes using seismic and other parameters.

Investigations: The South Carolina seismic network consists of seven stations on the Coastal Plain and three stations in the crystalline Carolina Piedmont. A five-station network is installed near Middleton Place in the Summerville-Charleston area—the epicenter of the devastating 1886 earthquake. Quarry blasts are monitored to supplement these network data. The origin time is obtained by deploying a Sprengnether MEQ 800 portable seismograph equipped with a fast motor providing recording speed up to 600 mm/min.

STUDIES IN COMMON SUPPORT OF HAZARDS, PREDICTION, AND INDUCED SEISMICITY

Seismicity and Seismic Networks

EARTHQUAKE HAZARD STUDIES IN NORTHEASTERN UNITED STATES, Y. P. Aggarwal, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, (914) 359-2900.

Goal: To study the seismic phenomena and earthquake hazard in northeastern United States.

Investigations: The Lamont-Doherty Network consists of 30 seismic stations that provide high-quality data for determining precise location and depth of earthquakes; the source properties of these events; and the relationship among stress, seismicity, and geologic or geophysical features. Additional studies focus on crustal and upper mantle velocity structure, strong motion and spectral content of earthquakes in New York State, and phenomena premonitory to earthquakes. This grant supplements other sources of funding.

PENNSYLVANIA SEISMIC MONITORING NETWORK, S. S. Alexander, Pennsylvania State University, Department of Geophysics, University Park, Pennsylvania 16802, (814) 865-2622.

Goals: (1) To operate the Pennsylvania Seismic Monitoring Network, and (2) to establish the patterns of earthquake activity in the entire northeastern United States.

Investigations: We will establish a regional seismic network centered in Pennsylvania capable of monitoring local and regional seismic activity. Base-line data on the spatial and temporal distribution of seismic events will be collected. Particular emphasis will be placed on calibrating regional travel-time and attenuation characteristics and refinement of crustal velocity models through precise location and timing of large quarry blasts over the region. We will construct seismicity maps for Pennsylvania and surrounding areas and relate the patterns to structural features and tectonic stresses to establish overall patterns of seismicity.

PORTABLE BROADBAND SEISMIC SYSTEM, S. S. Alexander, Pennsylvania State University, Department of Geophysics, University Park, Pennsylvania 16802, (814) 865-2622.

Goal: To assemble two 12-element portable broad-band seismic systems that can be used in a variety of modes to supplement the fixed networks comprising the Northeastern U.S. Seismic Network.

Investigations: The key characteristics of the field system are: portability, broad-band digital recording in the vertical or horizontal mode, digital multichannel field recording capability for both short time (expanded scale) recording and continuous operation for the order of days, FM radio telemetry from individual sensors to a central field recording site or to interfaces with telephone telemetry to a distant central recording location, and 9-track (800 or 1600 Bpi) digital data tapes that can be processed on a wide variety of general purpose digital computers.

SUPPORT OF SOUTHERN CALIFORNIA SEISMIC ARRAYS, C. R. Allen, California Institute of Technology, Division of Geological and Planetary Sciences, Seismological Laboratory, Pasadena, California 91125, (213) 795-6811, ext. 2904.
Goals: (1) To operate the main seismic network in southern California, and (2) to prepare earthquake catalogs.
Investigations: The Caltech Earthquake Detection and Recording (CEDAR) system is receiving and recording 123 seismic signals. We have homogeneous coverage down to around magnitude 2.5 over all of southern California south of the Inyo County line, and homogeneous coverage down to magnitude 1.5 over more than one-half of this area in which station coverage is relatively dense. Ten stations retain on-site photographic recording in order to accommodate a wide variety of instruments and guard against massive telemetry failure. Compared with Develocorder scanning, the CEDAR system is detecting more earthquakes, timing them with greater accuracy, and using less expenditure of manpower per event.

MICROPROCESSOR BASED SEISMIC PROCESSING, R. V. Allen, U.S. Geological Survey, Branch of Networks, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2240.
Goals: (1) To improve our capability for fully automatic on-line earthquake locating and processing, (2) to allow collection and analysis of seismic data at 100 Hz or greater with dynamic range approaching 70 db, and (3) to lower telemetry costs by allowing seismic stations to report only when an event is present.
Investigations: We are developing a system for detecting, timing, and processing earthquakes on a single seismic trace. The system will be based on a low-power microprocessor for field use where required. Using about 10 of these systems, we will build a prototype automatic on-line, office-based, earthquake detection and location system operating with signals from 80 existing USGS telemetered stations. In addition, we plan to develop a field unit based on a system that records and transmits only seismic events, or descriptors derived from them. All of the above-mentioned equipment will be used to examine a large suite of small earthquakes for precursors to larger events.

VERY LONG PERIOD SEISMIC STUDIES IN THE U.S.S.R., J. Berger, University of California, San Diego, Institution of Geophysics and Planetary Physics, Scripps Institution of Oceanography, La Jolla, California 92093, (714) 452-2889.
Goals: To collect and study data from two Project IDA stations in the USSR.
Investigations: Under the US/USSR "Agreement on Cooperation in the Field of Environmental Protect," we operate two very long period seismic stations which we installed in the Soviet Union. The stations are located in the very seismic region of central Asia and near the Kamchatka-Kermadec seismic zone. The data from these stations are being used to study variations in the long period spectral content of local earthquakes, possibly premonitory to large events; temporal changes in tidal admittances associated with changes in local elastic properties; secular changes in g associated with tectonic uplift; and properties of tsunamigenic earthquakes.

COOPERATIVE U.S.-MEXICO SEISMIC HAZARD AND EARTHQUAKE PREDICTION STUDIES IN NORTHWEST MEXICO, J. N. Brune, University of California, San Diego, Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, La Jolla, California 92093, (714) 452-2890.

Goal: To design and construct a digital telemetering array of seismic stations for Northern Baja California.

Investigations: This project is being conducted with the scientists and staff of the Center for Scientific Investigation and Higher Education of Ensenada, Baja California. Because the use of microwave links for data transmission between the Mexicali Valley and Ensenada was found to be extremely noisy and unreliable, a radio (VHF and UHF) telemetry system has been designed and tested over short ranges in the vinicity of Ensenada. The system consists of VHF radio links between each station and San Pedro Martir peak, where the data will be multiplexed and transmitted on UHF to Ensenada. While work continues on the array, we installed three temporary stations in Northern Baja California to complement existing analog stations. Data from these temporary stations will allow more accurate epicentral locations of events along the San Miguel Fault zone than previously available. In addition, the digital stations (3 components) will provide the opportunity to examine spectral characteristics of the recorded waveforms for studies of regional variations in stress drops and attenuation.

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

Goals: To operate the western Washington seismic network, study the distribution of earthquakes, and look for possible earthquake precursors.

Investigations: The western Washington seismograph network consists of 22 permanent telemetered stations plus LON (WWSSN). Under separate projects, additional stations are being installed near Mount St. Helens to monitor the recent volcanic-related earthquakes, and also on the Olympic peninsula. Digital recording of telemetered stations on a statewide basis has been implemented and is currently operating in conjunction with conventional film recording. Present emphasis is on the intense seismic activity beneath Mount St. Helens, which is in the process of renewing its eruptive activity. Subsequent improvement in the digital recording scheme and off-line computerized network data processing are planned. A uniform data set through 1978 is currently being reviewed for interpretation of regional seismicity, tectonics, and structure. We are also conducting detailed studies of several larger earthquakes and swarms and investigating the implications for regional hazard evolution.

REANALYSIS OF INSTRUMENTALLY-RECORDED U.S. EARTHQUAKES, J. W. Dewey, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-4041.

Goals: (1) To obtain more accurate hypocenters of regionally and teleseismically-recorded U. S. earthquakes, (2) to provide confidence ellipses showing the range of uncertainty of the hypocenters, and (3) to estimate magnitudes that are consistent from region to region.

Investigations: Hypocenters are relocated with regional travel-time tables using arrival times of first-arriving P waves, Pg phases at regional distances, S waves, and Lg phases at regional distances. The location algorithm is based on the method of joint hypocenter determination. Magnitudes (m_{bLg}) are assigned using regionalized magnitude formulas. Revised hypocenters and magnitudes are interpreted in terms of current hypotheses on the seismotectonics of the United States.

INTERPRETATION OF HISTORICAL EARTHQUAKE REPORTS AND SEISMICALLY-INDUCED SURFACE PHENOMENA IN ARIZONA, S. M. Dubois, State of Arizona, Bureau of Geology and Mineral Technology, 845 N. Park Avenue, Tucson, Arizona 85719, (602) 626-2733.

Goals: To analyze historical earthquake data and construct isoseismal maps for Arizona.

Investigations: On the basis of damage and felt reports, we will assign maximum intensity ratings, revise epicenter locations, and construct isoseismal maps. For moderate and large events, instrumental records will be sought in order to calculate revised magnitude and b-values. An attempt will be made to study attenuation patterns for large events. Our results will be summarized in a thoroughly-documented earthquake catalog. A second feature of this project is the investigation of reports regarding mass movements, liquefaction, and groundwater disturbances induced by seismic activity, especially in the vicinity of major urban centers in Arizona. The project should provide fundamental information to be used in assessing seismic risk in the state.

CENTRAL CALIFORNIA NETWORK DEVELOPMENT, J. P. Eaton, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (425) 323-8111, ext. 2575.

Goal: To extend the central and southern California seismic networks in order to provide more uniform moderate density coverage of the San Andreas fault system and contiguous seismically active regions of California.

Investigations: In central California an additional 100 stations are needed, about half to broaden the southern part of the net and extend it to the Transverse Ranges, and half to extend the northern part of the network to the Klamath Mountains. In southern California an additional 75 stations are needed to provide moderate density coverage of the Transverse Ranges and parts of the San Jacinto and San Andreas faults near Salton Sea. Extended coverage will also proivide selective augmentation of the network in the northern Mojave Desert and along the eastern flank of the Sierra Nevada.

CENTRAL CALIFORNIA SEISMIC NETWORK PROCESSING, J. P. Eaton, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (425) 323-8111, ext. 2575.

Goals: (1) To identify and delineate active faults in central California and assess their potential for producing damaging earthquakes, (2) to develop improved models of earthquake-generating processes and earthquake-source mechanisms, and (3) to provide a high quality source of unreduced and reduced data on earthquakes in central California as a basis for more detailed seismic and related non-seismic studies.

Investigations: Recordings from the 250-station, multi-purpose, central California Seismic Network are telemetered continuously to the central laboratory facility in Menlo Park, where they are analyzed to determine origin times, magnitudes, and hypocenters of earthquakes occurring in or near the network. Data in various forms summarize the seismic history of the region and provide the basis for further research in seismicity, earthquake hazards, and earthquake mechanics and prediction. The network also contributes to research on the sources of geothermal energy and provides seismic monitoring for environmental hazards around dam sites in northern California.

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

Goal: To maintain the central California telemetry recording center for all seismic, tilt, magnetometer, strain, creep, and radon instruments.

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

Goals: (1) To study tectonics in Central America using earthquake locations, (2) to search seismicity patterns preceeding earthquakes of magnitude 5.0 and larger for precursory phenomena, (3) to provide data for earthquake hazard reduction programs in Central America, and (4) to examine seismic and ground-tilt phenomena associated with volcanic activity in order to develop a capability for forecasting volcanic eruptions.

Investigations: A 16-station, seismograph network has been operating in Nicaragua since early 1975. The installation of a 22-station seismograph network in Guatemala was completed in December 1979. Both of these networks are providing the data necessary to locate micro-earthquakes occurring within the respective countries. The micro-earthquake locations will be used to delineate regions of high seismicity, produce maps for hazard reduction programs, provide a base for studying the mechanics of earthquake generation, and determine if precursory seismicity patterns occur prior to the larger earthquakes. In addition, members of this project are involved in ongoing efforts to train local scientists, engineers, and technicians in the operation and maintenance of seismograph networks and basic data reduction techniques.

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

Goals: (1) To examine earthquake processes in the New Madrid seismic zone and (2) to improve models for earthquake ground motion prediction.

Investigations: Sixteen micropower seismographs will be added to the existing southeast Missouri seismic array. Four stations will be placed along the southeastern flanks of the Ozark uplift, eight along the active seismicity trend, and four near Gratio, Tennessee, where 40 unlocated events per quarter are observed with S-P times less than one second. Surface wave focal mechanism studies of earthquakes and microearthquakes occurring along the linear seismicity trends near New Madrid indicate mostly strike-slip faulting. The results of these studies imply that the regional tectonic stress fields causing contemporary earthquakes differ from those that caused the Mississippi Embayment and the infered rifting. On the basis of the microearthquake investigations, a study of seismic risk has begun.

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

Goal: To evaluate the contemporary seismicity, crustal structure, and upper mantle structure of the Rio Grande Rift in New Mexico.

Investigations: We are operating and maintaining a 13-station seismic network around the Albuquerque Basin. A 4-1/2 year data base has been accumulated and a detailed study of some 300 earthquakes which occurred near the Albuquerque volcanoes was carried out. We expanded the seismic network by installing four stations in the Colorado Plateaus province of northwest New Mexico and one station in the High Plains province in eastern New Mexico.

INSTRUMENT DEVELOPMENT AND QUALITY CONTROL, E. G. Jensen, U.S. Geological Survey. Branch of Networks, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2050.

Goals: To develop specifications for new seismic systems, evaluate new equipment after purchase, and develop operational procedures for its use.

Investigations: A prototype microprocessor event recorder built by ARGOS Systems is currently being tested and evaluated. We are also evaluating the Kinemetrics tiltmeter to find ways of improving its accuracy and reliability. These improvements will then be implemented on approximately 100 units. Tests are being performed on Bell and Howell VR3700 record and playback units in order to accurately define proper setup procedures.

SOUTHERN CALIFORNIA COOPERATIVE SEISMIC NETWORK, C. Johnson, U.S. Geological Survey, California Institute of Technology, Pasadena, California 91125, (213) 795-6811, ext. 2957.

Goals: (1) To develop a detailed understanding of the seismicity of southern California and (2) to provide an instrumental basis for the prediction of earthquakes in this region.

Investigations: We will study the tectonic and structural implications of the seismic gap located along the San Andreas (Banning-Mission Creek) fault from the Salton Sea to Cajon Pass, the increased seismicity observed along the San Andreas northwest of Cajon Pass, and the seismicity boundary between the seismically active central part of the Mojave Desert and the seismically quiet eastern part. Three existing stations will be redeployed and three new stations will be installed to monitor these study areas. Installation of 3-component seismometer sets at nine existing stations in the network will enhance recordings of S waves for earthquake depth detection and special earthquake prediction studies.

SEISMOLOGICAL RESEARCH RELATED TO EARTHQUAKE PREDICTION AND HAZARD REDUCTION, H. Kanamori, California Institute of Technology, Pasadena, California 91125, (213) 795-6811.

Goal: To conduct seismological studies to enhance earthquake prediction and hazard reduction research.

Investigations: We are continuing to monitor large quarry blasts occurring in southern California as part of our P-wave velocity studies. Microearthquake surveys, using portable seismographic trailers, are being conducted along the San Andreas fault zone between the Salton Sea and Desert Hot Springs. We are also developing tools required to manipulate the rapidly growing southern California earthquake catalog for seismicity studies.

A FIELD STUDY OF EARTHQUAKE PREDICTION METHODS IN THE CENTRAL ALEUTIAN ISLANDS, C. Kisslinger, University of Colorado, CIRES, Boulder, Colorado 80309, (303) 492-8028.
Goal: To study precursors in terms of physical models of earthquakes and tectonic processes.
Investigations: The fourteen 2-component, short-period seismometers and eight bubble-level borehole tiltmeters operating on and near Adak Island, Alaska, provide data for determining the spatial and temporal distribution of seismicity, and the position and focal mechanism characteristics of the seismic activity relative to the zone of subduction. These data are being used to search for premonitory variations in the rates of activity, in b-values, in focal mechanisms, and in tilt, before earthquakes of m 5.0 or greater occurring in the Adak region.

SOUTHERN ALASKA SEISMIC STUDIES, J. C. Lahr, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2510.
Goal: To perform long term seismic and crustal deformation measurements in order to (1) evaluate the seismic hazards in populated areas and areas of proposed future development, (2) document premonitory earthquake phenomena which might be used for earthquake prediction, and (3) develop an understanding of the tectonic process that generates earthquakes in south-central Alaska.
Investigations: Seismic data are collected and analyzed from a regional network of seismograph stations extending from western Cook Inlet to eastern Prince William Sound and as far north as the Talkeetna Mountains. The data establish an important base of information for the study of the tectonic deformation, the potential for moderate-to-large earthquakes, and the nature of strong ground motion in southern Alaska.

PUERTO RICO SEISMIC PROGRAM, C. J. Langer, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-5091.
Goal: To locate earthquake hypocenters and define the seismicity in the vicinity of Puerto Rico.
Investigations: Data from the continued operation of the 15-station Puerto Rico seismographic network are being used to: (1) define the local and near regional seismogenic zones on and in the vicinity of Puerto Rico, (2) determine how these seismogenic zones relate to known or suspected geologic structures, and (3) increase the understanding of the tectonic processes operative within this section of the Caribbean plate. The results of these studies are fundamental to the assessment of the earthquake potential, seismic risk, and associated earthquake hazards of Puerto Rico.

SEISMIC DATA LIBRARY OF WWSSN SEISMOGRAMS, W. H. K. Lee, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2630.
Goals: To organize and maintain the Seismic Data Library comprised of WWSSN film chips, 16 mm develocorder film seismograms of the California Network, and magnetic tapes.

STONY BROOK SEISMIC NETWORK ON LONG ISLAND, NEW YORK, R. C. Liebermann, State University of New York at Stony Brook, Department of Earth and Space Sciences, Long Island, New York 11794, (516) 246-6090.
Goals: (1) To conduct seismic noise survey to identify sites on Long Island with low enough background noise to record local and regional earthquakes and thereby increase the geographical coverage of the Northeastern U.S. Seismic Network (NEUSSN), and 2) to install two permanent seismograph stations on these sites.
Investigations: Two sites for NEUSSN stations have been identified: Lloyd's Neck (91-4-5 in fig. 18) in central Long Island on the Long Island Sound, and Shelter Island (SB-3-4-5) off the eastern end of Long Island. In the course of this study, we also completed a survey of the macroseismic effects on Long Island from an earthquake of 30 January 1979 in Cheesequake, New Jersey.

A STUDY OF EARTHQUAKE PREDICTION AND THE TECTONICS OF THE NORTHEASTERN CARRIBEAN: A CONTINUING EXPERIMENT IN TWO MAJOR SEISMIC GAPS, W. R. McCann, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, (914) 359-2900.
Goal: To examine the complex seismicity and tectonics of the northeastern Caribbean for the purpose of evaluating its earthquake potential.
Investigations: Lamont-Doherty has been operating and analyzing the data from a 17-station, radio-telemetered seismic network in the northeastern Caribbean. The research includes the development of the capability to quickly recognize changes in basic parameters that may be useful in the prediction of earthquakes. These parameters include spatial patterns of seismicity, b-values, the rate of earthquake occurrence, and stress drop. We intend to use surface wave analysis, in conjunction with network data, to determine the focal mechanisms of small events in the area to gain a better understanding of this complex region.

EARTHQUAKE AND SEISMICITY RESEARCH USING SCARLET AND CEDAR, J. B. Minster, California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, California 91125, (213) 795-6811.
Goals: To use digital short period seismographic data from southern California local earthquakes recorded through the CEDAR system on the 160-station SCARLET network in order to (1) characterize and monitor patterns of seismicity in southern California and (2) refine regional structural models of crust and upper mantle.
Investigations: Project activities include developing capabilities for estimating, analyzing, and displaying physical parameters characterizing southern California seismicity; identifying long term evolution of seismicity patterns; and determining superimposed short term patterns which might be appropriate for monitoring. We will use CEDAR data base to refine crust and upper mantle structure and establish preliminary calibration of SCARLET network (theoretically and empirically) with the help of teleseismic recordings.

INTEGRATION OF THE LAKE JOCASSEE SEISMIC STATION INTO THE SOUTH CAROLINA SEISMIC NETWORK, N. Olson, South Carolina Geological Survey, Harbison Forest Road, Columbia, South Carolina 29210, (803) 758-6431.
Goal: To tie the isolated Lake Jocassee seismic station into the South Carolina seismic network via telephone.

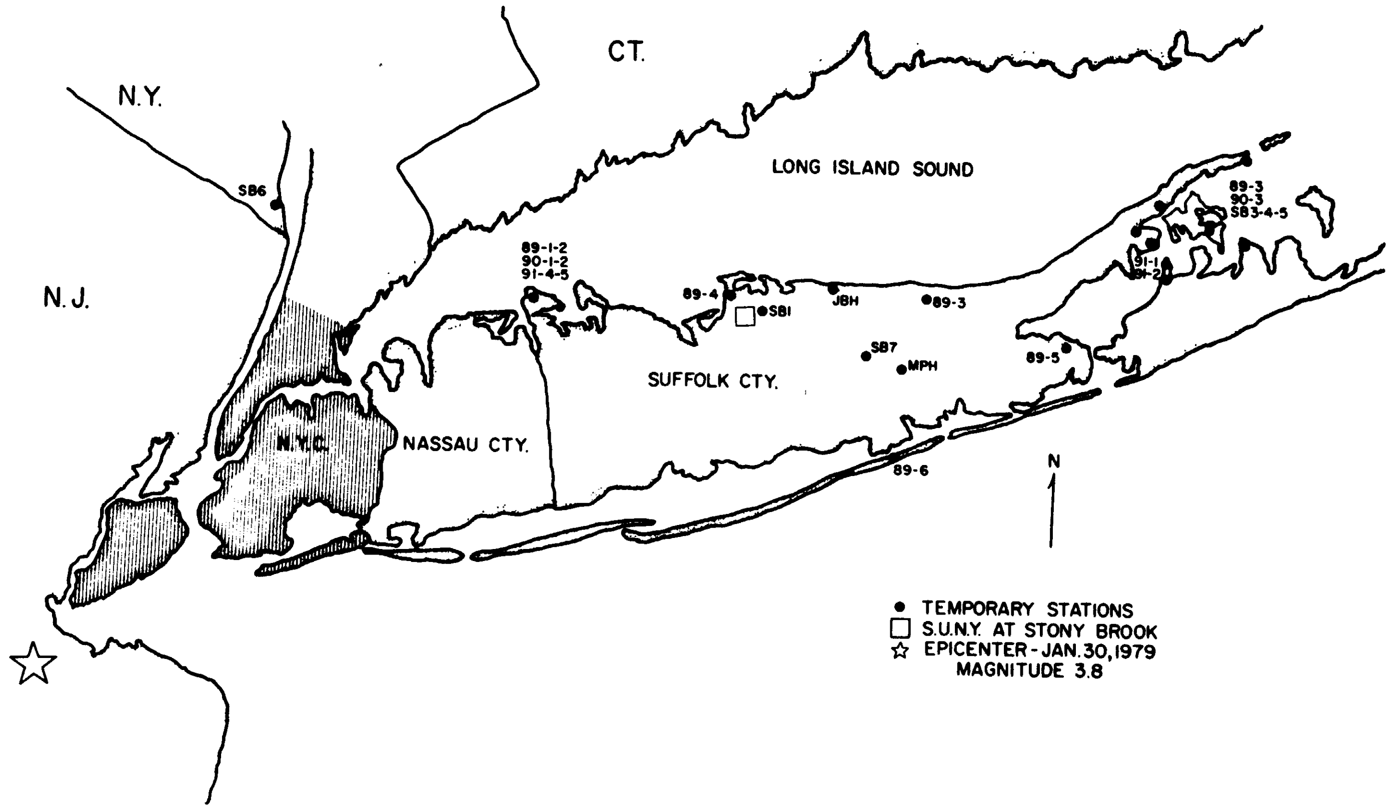

FIGURE 18.—Location map of northeastern U.S. seismic network stations.

Investigation: The data generated by the Lake Jocassee seismic station will be used in the continuing studies of induced seismicity in the Lake Jocassee-Lake Keowee area.

NATIONAL DIGITAL SEISMOGRAPH NETWORK (NDSN) DESIGN, J. Peterson, U.S. Geological Survey, Branch of Global Seismology, Kirtland AFB-East, Albuquerque, New Mexico 87115, (505) 264-4637.
Goal: To develop a concept and design for a wideband, large dynamic range seismograph system that may be used in the proposed National Digital Seismograph Network.
Investigations: We are developing a triaxial seismograph system that will produce data in the frequency band from .01 to 10 Hz and operate over an amplitude range from ambient earth noise at a quiet site to an acceleration of 0.1 g. Preliminary studies indicate that two types of seismometers, operating over the same frequency band but in different amplitude ranges, will be required. Modified conventional long-period seismometers and force-balance accelerometers are the two types of instruments considered most appropriate for this study and prospective models have been selected and ordered for testing.

ANALYSIS OF OLD (1888-1950) DUPLEX-PENDULUM AND WIECHERT SEISMOGRAMS OF LARGE AND MODERATE EARTHQUAKES IN WESTERN NEVADA, K. Priestley, University of California, San Diego, Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, La Jolla, CA 93092 (714) 452-3205.
Goal: To study the historic seismic record to better assess the long-term seismic trends for the Reno-Carson City region.
Investigations: Existing seismic data provide only approximate locations and magnitudes of older events. We will use various techniques developed within the past few years to refine location and magnitude for these earthquakes. These parameters will then be compared with known geologic structure and with current seismicity to obtain a more complete picture of the earthquake hazard in western Nevada.

SEISMICITY, EARTHQUAKE POTENTIAL, SEISMIC RISK, EARTHQUAKE SOURCE MECHANISMS, AND SHEAR PATTERNS IN THE WESTERN GREAT BASIN, A. Ryall, University of Nevada, Seismological Laboratory, Reno, Nevada 89557, (702) 784-4975.
Goals: (1) To provide relatively uniform seismic coverage for a detailed study of active faults in the populated Sierra Nevada-Basin and Range boundary zone, (2) to recommend modifications to seismic zone maps that will better reflect current knowledge of earthquake potential in the Nevada region; and (3) to study earthquake swarms in the area east of Mono Lake, and their relation to volcanic processes.
Investigations: We are studying modifications that might be made to zoning maps to better reflect the current state of knowledge in long-term risk evaluation for the Nevada region. For example, fault zones in western Nevada and eastern California that could be subject to major offsets should immediately be rezoned as high risk areas. However, maps of epicenters and active faults suggest that subsequent analysis might lead to some relaxation of this high-risk categorization for crustal blocks that can be shown to be relatively stable. Further, there is evidence that maximum horizontal acceleration for large earthquakes in a normal faulting environment may be less than for earthquakes

of comparable magnitude in areas of strike-slip or thrust faulting. Our basis for recommending changes will be comparisons of current and historic seismicity with regional geology, as well as comparisons of historic earthquake intensities in the immediate vicinity of fault breaks with those observed in area (e.g., the San Andreas fault zone—outside the Basin and Range province).

COOPERATIVE TECTONIC STUDIES FROM SEISMIC NETWORK DATA IN CENTRAL ITALY, L. Seeber, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, (914) 359-2900.
Goals: This cooperative effort between Lamont-Doherty and the Instituto Nazionale di Geofisica (ING) will (1) study the active tectonics and develop a model for the central Appennines, and (2) explore the hypothesis that great earthquakes can occur on the Appennine detachment.
Investigations: The data from the seismic network established by the ING is the primary tool used to study the active tectonics in the central Appennines. Historic records and old instrumental data are studied for evidence of great Appennine detachment earthquakes and for their characteristics (e.g., rupture dimension and recurrence times).

EARTHQUAKE PREDICTION STUDIES IN PAKISTAN, L. Seeber, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, (914) 359-2900.
Goals: (1) To study natural and induced seismicity in the reservoir area and provide an estimate of the seismic hazard, and (2) to study Himalayan continental collision tectonics in both the large and the small scale.
Investigations: Of the three networks we established, two are now operated by our Pakistani counterparts and provide precise hypocenter locations with which we can resolve details of the active tectonics (fig. 19). A preliminary updated analysis of the network data is carried out on site in order to monitor, as early as possible, any induced or natural changes in the seismicity. Teleseismic data, as well as other geophysical and geological data concerning the Himalayan arc, are compared to the detailed data we obtain from the networks at the northwestern terminus of this arc. By this approach we are developing a new model of the active tectonics in the Himalaya.

EARTHQUAKE RESEARCH AND NETWORK OPERATIONS IN THE INTERMOUNTAIN BELT-WASATCH FRONT, R. B. Smith, University of Utah, Salt Lake City, Utah 84112, (801) 581-7129.
Goals: (1) To assess seismic hazard along the Wasatch Front, (2) to determine whether earthquake prediction based on premonitory seismic changes is feasible in this area, and (3) to investigate the inter-relationship of seismicity, tectonics, and active normal faulting in the Wasatch Front area.
Investigations: The telemetered seismic network along the Wasatch Front, Utah, consists of 43 vertical and 12 horizontal seismometers (fig. 20). Data from the network are the basis for current research, which focuses on the mechanical and sectional behavior of the Wasatch fault zone and the identification of likely areas for the next moderate to large earthquakes in the Wasatch Front area. Critical aspects of earthquake potential in this area include: (1) major microseismic gaps along the Wasatch fault; (2) significant horizontal strain accumulation involving a reversed strain field across one of these gaps near Ogden, Utah; (3) geologic evidence from prehistoric surface faulting suggesting that a major earthquake is either due or overdue somewhere on the 370-km-long Wasatch

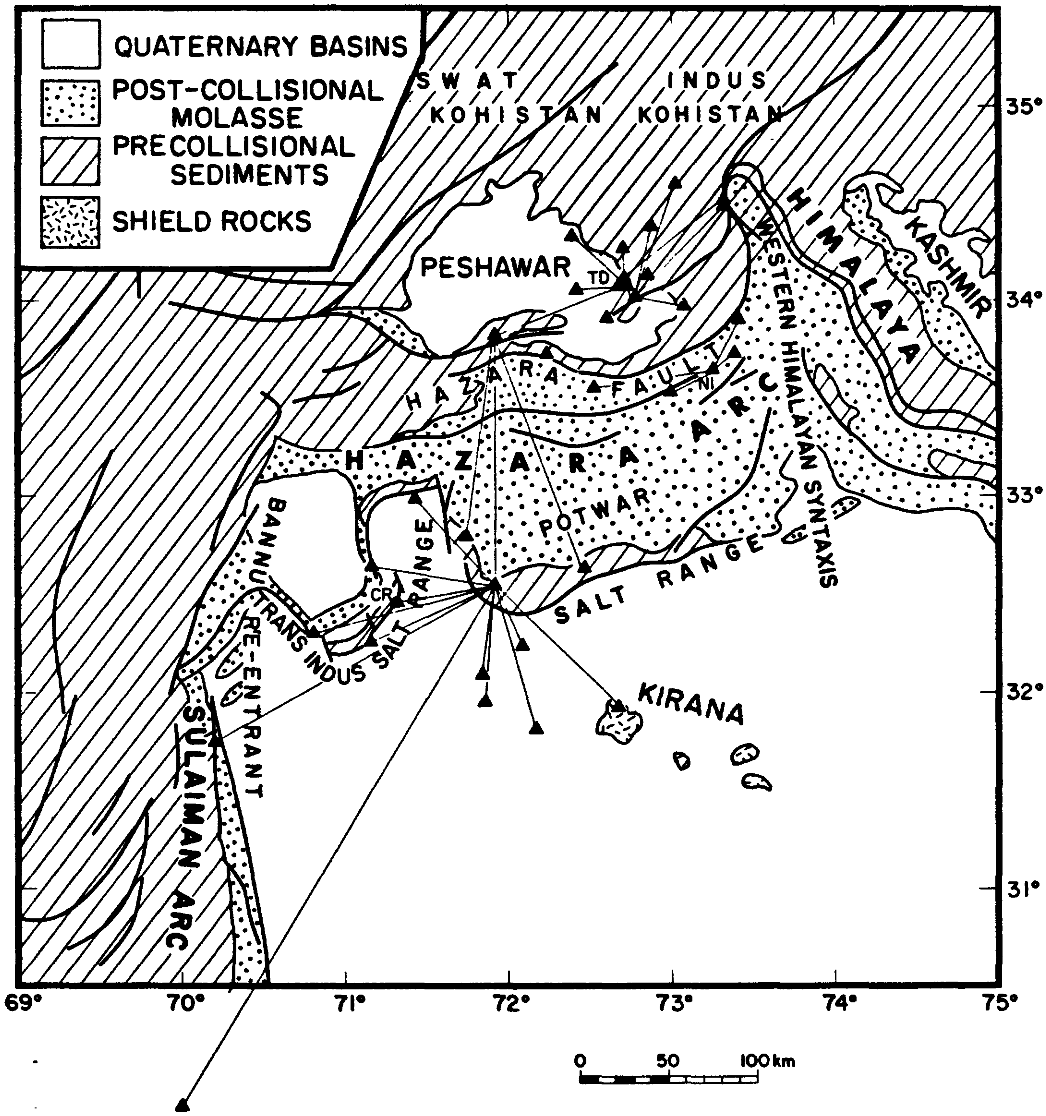

FIGURE 19.—Seismic networks (L-DGO-WAPDA and L-DGO-PAEC) in northern Pakistan.

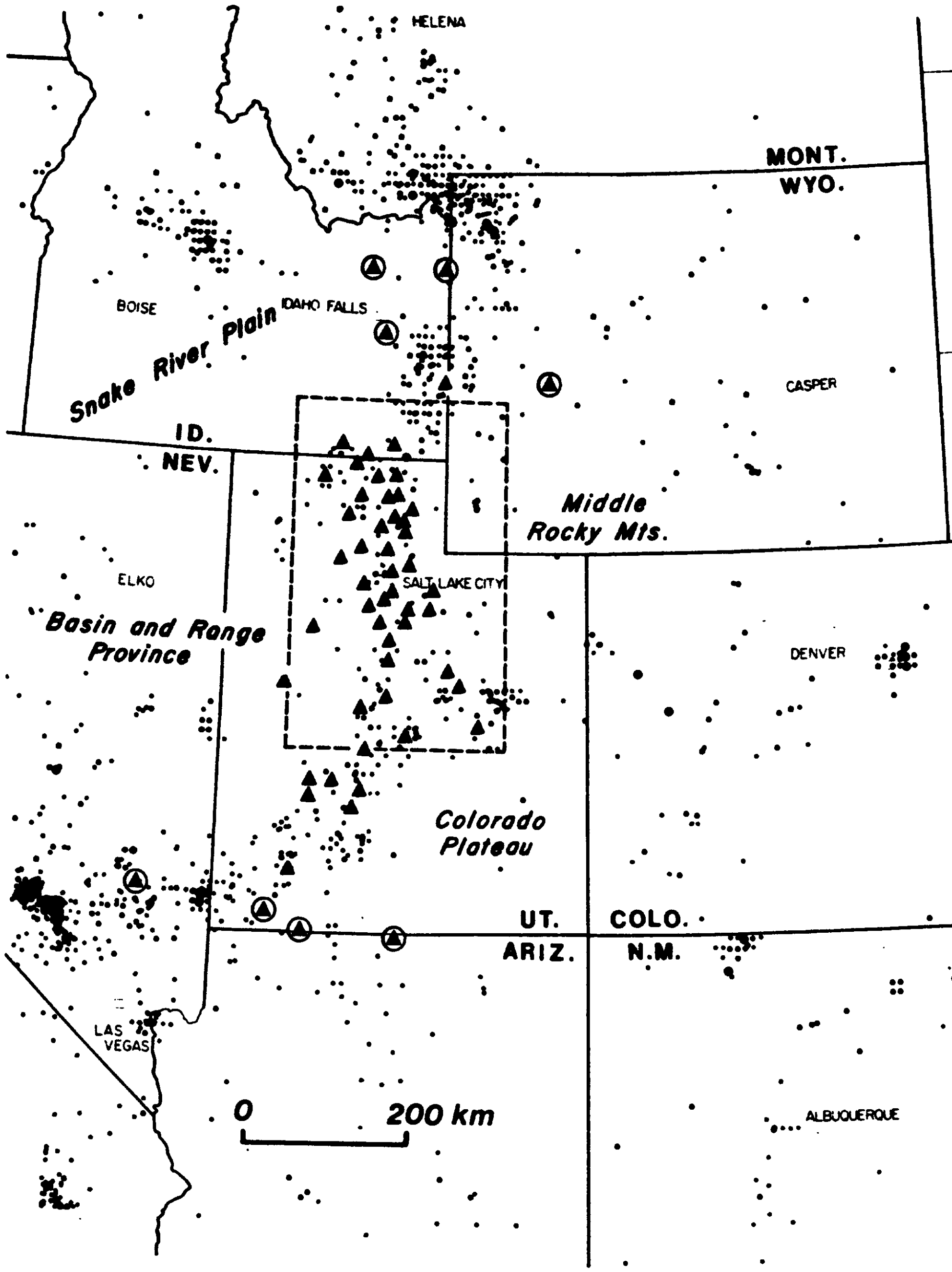

FIGURE 20.— University of Utah seismic network.

fault; and (4) the current existence of a 300-km-long seismicity gap for earthquakes of M 3.5 or greater along the main axis of the Intermountain seismic belt between 38.9 N and 41.5 N. The research includes: multifaced studies of seismicity, numerical modeling of stress fields, studies of attenuation and magnitude/moment calibration, reprocessing of existing reflection data across the Wasatch fault, statistical studies of space-time seismicity patterns, and real-time monitoring of seismic parameters.

EARTHQUAKE HAZARD STUDIES IN SOUTHEAST MISSOURI, W. Stauder, Saint Louis University, Department of Earth and Atmospheric Sciences, St. Louis, Missouri 63103, (314) 535-3300, ext. 206.
Goal: To study the earthquake hazard in the southeast Missouri seismic zone.
Investigations: Ground displacement, velocity, and acceleration data have been obtained from strong-motion records triggered by one of the larger earthquakes within the southeast Missouri seismic zone. These data, together with source studies, recurrence rates, and attenuation studies, provide the basis for ground-motion prediction and seismic risk determinations.

NATIONAL EARTHQUAKE CATALOG, J. N. Taggart, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (505) 234-5079.
Goals: (1) to develop a plan for the preparation of a national earthquake catalog within five years, and (2) to coordinate the operational and research activities necessary to produce the catalog.
Investigations: The OES has identified the preparation of a national earthquake catalog as a priority item during the next five years. The target date for preparation and technical review of the catalog is September 1984. The plan identifies four principal elements in the development and publication of a national earthquake catalog. These elements are: data preparation, related research, data base development, and catalog preparation.

EARTHQUAKE DATA-BASE STUDIES, A. C. Tarr, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-5078.
Goals: (1) To improve the earthquake data base, and (2) to evaluate detection and location capabilities of seismic networks.
Investigations: Existing seismological data will be compiled into a catalog featuring hypocenter coordinates, origin time, magnitude, moment, maximum intensity, focal mechanism, and error estimates. The detection and location capabilities of various seismic networks will be evaluated over time to characterize the limitations of older networks and to determine the effects of adding local and regional seismic networks to the current detection threshold map.

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, California 90007, (213) 741-6124.
Goals: (1) To determione the spatial and temporal distribution of earthquakes in the Los Angeles basin and its offshore areas, (2) to investigate the possible causal effects of water flooding of Los Angeles basin oilfields for earthquake occurrence, and (3) to develop software for automated fault-plane solution determination.

Investigations: Earthquake activity and related seismic phenomena in the Los Angeles Basin is monitored by an 18-element short-period seismic network (fig. 21). Data from the network are used in seismic hazard and seismotectonic analyses. We are continuing our development and operation of downhole seismometers.

PREPARATION OF ISOSEISMAL MAPS AND SUMMARIES OF REPORTED EFFECTS FOR PRE-1906 CALIFORNIA EARTHQUAKES, T. R. Toppozada, State of California, Division of Mines and Geology, Department of Conservation, Resource Building, 1416 Ninth Street, Sacramento, California 95814, (916) 445-1825.
Goal: To compile and upgrade information on pre-1900 California earthquakes.
Investigations: We are preparing a catalog of pre-1900 California earthquakes having a maximum reported intensity of VI(RF) or greater. Historical literature on approximately 122 events are evaluated for reported intensity, epicenter location, and local magnitude. New or revised estimates will be assigned as needed. Isoseismal maps will be constructed and all relevant information will be published. Key data will also be entered into a magnetic tape file compatible with the existing post-1900 earthquake catalog compiled and maintained by the Califonia Division of Mines and Geology.

FIELD EXPERIMENT OPERATIONS, J. Van Schaack, U.S. Geological Survey, Branch of Networks, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2584.
Goal: To assist in the implementation of field experiments.
Investigations: This support project maintains and operates a broad range of seismic sensing and recording systems, provides radio and telephone telemetry systems, and coordinates all radio telemetry frequency authorizations requested by the Office of Earthquake Studies.

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, Nevada 89507, (702) 784-4975.
Goal: To evaluate earthquake activity in the western Nevada seismic zone.
Investigations: Well-located earthquakes with magnitudes of 2.8 or larger were selected in the Mina region for focal mechanism studies. All reliable solutions indicate normal faulting in response to northwest to west-northwest extension. Analysis of teleseismic P-wave relative residuals indicates crustal thickening to the southwest of Mina. Future investigations will concentrate in the Reno area in an effort to determine whether the Dog Valley lineament is a fault. Eight stations will be retained in Mina to maintain a location capability.

EARTHQUAKE DATA SYSTEMS, P. Ward, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, (415) 323-8111, ext. 2838.
Goals: To procure computer systems and develop software for analysis of seismic data.
Investigations: Six PDP 11/70 and PDP 11/34 computers have been installed at the University of Washington, University of Colorado, St. Louis University, Lamont, CalTech, and Menlo Park. We are developing software that emphasizes a tool-user's approach. A wide variety of high-level tools are being written that can be easily combined to do a specific task by using a custom-written main program or GEOLAB, an interactive language. Some high level tools under development include: a subroutine to pick P-wave arrivals, a subroutine to decode a variety of time codes, a hypocenter location routine, and a variety of travel-time routines.

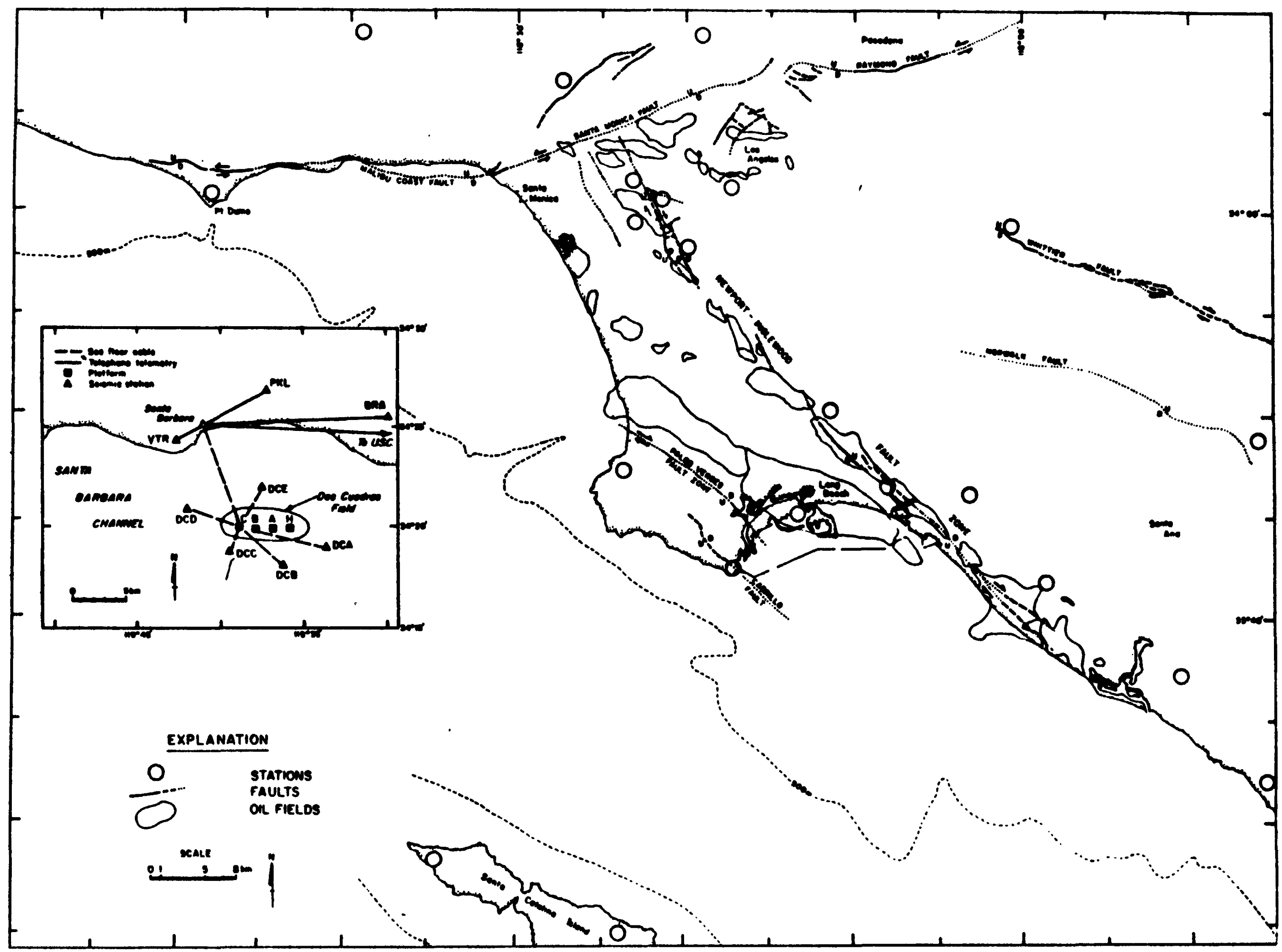

FIGURE 21.—Los Angeles Basin seismic network.

SEISMIC RISK IN THE ASSAM GAP, EASTERN INDIA, M. Wyss, University of Colorado/NOAA, Cooperative Institute for Research in Environmental Sciences, Boulder, Colorado 80309, (303) 492-8028.

Goal: To study the significance of the changes of seismicity rate at the edges of and within the Assam gap.

Investigations: This project cooperates with Roorkee University, Indian Geodetic Survey, Indian Geological Survey, Indian Meterological Depoartment, National Geophysical Research Institute, and School of Earthquake Engineering of Roorkee. Planned activities include leveling lines, gravity profiles, magnetic surveys, seismological and strong motion studies.

Physical Basis of Earthquakes

Physical properties of the crust and upper mantle

MOTAGUA FAULT (GUATEMALA) AFTERSLIP, R. C. Bucknam, U.S. Geological Survey, Branch of Earthquake Tectonics and Risk, Denver Federal Center, Denver, Colorado 80225, (303) 234-5089.

Goals: (1) To obtain a detailed time history of afterslip at 4 sites along the Motagua fault; (2) to determine the manner in which displacement propagates along the fault, and (3) to trace the long-term (4 to 5 years) behavior of afterslip (creep).

Investigations: We will install recording creepmeters along a 50 km section of the 230 km long surface rupture when the regular nature of coseismic displacements indicate that the section behaved as a unit during the earthquake. The section is separated at each end by prominent displacement discontinuities where alignment arrays will be installed to see if there are similar discontinuities in afterslip behavior. Measurements will be simplified by the relatively high afterslip rate still occurring along the fault.

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

Goal: To develop quantitative, kinematic models of plate boundary motion which satisfy available geological, seismological, and geodetic constraints.

Investigations: Microearthquakes, by virtue of their distribution in a broad belt astride principal through-going faults, provide detailed information about the mechanics of fault movement not easily duplicated by other observations. We are constructing a uniform earthquake catalog using USGS central California records from the period 1969 to 1977. A new method for relating tectonic stress to fault slip will be developed and applied to tectonically interesting areas along the fault system. Generalized inverse theory will be used to determine the stress field(s) consistent with a suite of focal mechanisms. In addition, we plan to develop methods for studying (1) the distribution of stress and strain along the fault system, (2) the nature of the tractions which drive plate boundary motion, and (3) the mechanics of locked and creeping segments of the fault system and the transition between them. These efforts should provide a quantitative framework for evaluating the kinematics of seismic precursory phenomena.

FAULT ZONE STRUCTURE, J. Healy, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2535.
Goal: To define the extent of an anomalous mass of low-velocity rocks located along the San Andreas fault in central California.
Investigations: A zone of low-velocity rocks about 4 km wide and to depths of more than 5 km appears to extend from a point near Parkfield to a point north of Hollister where it may branch and follow the creeping sections of the Calaveras fault. The fact that this zone coincides with creeping sections of the fault suggests that it is stress-induced and related to the tectonic process. In order to determine the extent of this zone, we will use new seismic refraction systems along the whole length of the San Andreas fault and especially near Bear Valley.

ACTIVE SEISMOLOGY IN FAULT ZONES, D. P. Hill, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2139.
Goal: To define the structure and physical properties of crustal and upper mantle rocks in a region of active faults in order to determine the physical conditions and tectonic processes leading to earthquakes.
Investigations: We are using refraction and reflection profiles from controlled sources to obtain (1) high-resolution P- and S-wave velocity models of the crust and upper mantle structure at selected sites along active fault zones, and (2) regional velocity models from calibration shots within existing seismograph networks.

STRESS ANALYSIS OF A DEEPLY ERODED ANALOG OF THE SAN ANDREAS FAULT, D. L. Kohlstedt, Cornell University, Ithaca, New York 14853, (607) 256-7144.
Goal: To determine paleostress levels within and along the Ikertog shear zone in Greenland.
Investigations: The Ikertog shear zone may be a deeply eroded, Precambrian analog of the San Andreas system. Quartz-bearing rocks have been collected from the Ikertog shear zone near Sondre Stromfjord AFB. We are studying the dislocation densities, dynamically recrystallized grain size and sub-grain size of the quartz to determine stress levels on the fault when it was active.

INVESTIGATION OF THERMAL REGIME ACROSS THE SAN JACINTO FAULT, T.-C. Lee University of California at Riverside, Institute of Geophysics and Planetary Physics, Riverside, California 92521, (714) 787-4506.
Goals: (1) To refine estimation on temperature distribution near an active fault, (2) to provide an energy constraint on suggestions for plausible models for earthquake prediction and focal mechanism study, and (3) to understand long-term nature of faulting.
Investigations: We drilled six 100-meter holes in the southern California batholith along a profile across the San Jacinto fault. From the northeast to the southwest, the holes were located at 16, 7, 0.5, 1, 5, and 20 km from the fault trace. Temperature logging has been made regularly to detect the effect, if any, of seasonal groundwater fluctuations. Core samples and chip samples are used to determine the thermal conductivity of rocks. From the measured conductivity and temperature gradient, the heat flow pattern and temperature near the fault trace are deduced and their implications on faulting mechanisms are made.

CENTRIFUGE MODELING OF EARTHQUAKES, AIR-GUN SEISMIC VELOCITY, AND ATTENUATION MEASUREMENTS IN THE SAN ANDREAS FAULT ZONE, Hsi-Ping Liu, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2731.

Goals: (1) To equip a field borehole seismic source for active seismic experiments in the San Andreas fault zone, (2) to develop instruments for direct laboratory measurement of rock internal friction at seismic periods and amplitudes and to apply the results of such measurements to field measurements in the San Andreas fault zone, and (3) to develop materials and techniques for centrifuge scale modeling of crustal faults.

Investigations: A borehole airgun with field air supply is now ready for seismic velocity and attenuation measurements over a baseline of 5 km in the San Andreas fault zone in central California. We are employing the method of tracing stress-strain loops to measure rock internal friction at seismic body wave periods ($\sim$1 sec) and strain amplitudes ($\sim 10^{-8}$). Different weak (strength $\sim$10 bars) and brittle materials are tested for scale models of centrifuge modeling of earthquake faults.

DEVIATORIC STRESSES IN THE EARTH'S CRUST AND UPPERMOST MANTLE, M. McNutt, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111.

Goals: To illuminate the earth's response to known stresses from both topographic loading and earth tides in order to derive rheology-independent stress bounds.

Investigations: An analysis of the stress regime in the earth's crust was conducted in two parts. The first project involved a regional analysis of North American gravity anomalies, which constrain the long-term (hundred million year) rheology and deviatoric stress level in the continental crust. The second project considered stress on the very much shorter time scale corresponding to the earth tides. The most immediate purpose of this study was to investigate the hypothesis of Mr. James Berkland, the Santa Clara County Geologist, that an eight day "seismic window" commencing with each syzygy (new or full moon) represents an earthquake-prone period for the San Jose area. From a more scientific viewpoint, if one could find a convincing correlation between tides and seismicity, the known stress levels associated with the tides would provide a constraint on the stress regime under which faulting occurs.

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, California 91125, (213) 795-6811, ext. 2950.

Goal: To determine whether the time scale associated with dilatant stabilization is consistent with observed premonitory events.

Investigations: Project efforts focus on solving the integro-differential problem of coupled deformation - pore fluid diffusion for simple geometries of weakened zone fault models. The geometry and rheology are varied to span the range of field observations and laboratory experiments.

ACTIVE SEISMOLOGY IN FAULT ZONES, W. D. Mooney, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111.

Goal: To measure the seismic velocity structure and physical properties of the crust and upper mantle in seismotectonic zones in order to better understand the physical conditions and tectonic processes leading to earthquakes.

Investigations: We have conducted explosion seismology and aftershock investigations in the Imperial Valley, Coyote Lake (Gilroy) region and in the Livermore Valley. Highly detailed structural and velocity information is being derived from dense seismograph spacing and numerous shot points.

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

Goals: To study the dynamic ground motion near the fault during an earthquake, the character of dilatant ground deformation, and reservoir-induced faulting.

Investigations: Ground motion studies will focus on the long period aspect of dynamic faulting in a half-space by examining the effects of rupture velocity and depth dependence of slip on computed accelerograms. Studies of the short period will consider a random part in the fault motion—such as a spatially variable frictional stress or elastic moduli along the fault; the variability of friction along a fault; and the effect of this variability on rupture velocity and particle motion. We will study the nature of non-uniform dilatant surface strains and displacements by using a semi-analytical-iterative method to solve the non-linear partial differential equations which govern the dilatancy strain field. A combination of analytical and numerical schemes will be used to study the time dependence of induced seismic activity, including the migration of epicenters with time and the relation between seismic rate and reservoir loading rate.

ROCKS UNDER GEOTHERMAL CONDITIONS, L. Peselnick, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2394.

Goals: (1) To develop instrumentation for measuring internal friction (Q) of rocks at seismic frequencies (0.1-10.0 Hz), seismic strain amplitudes (10^{-8} - 10^{-7}), and at elevated pressure and temperature (3 kbar, 400°C); (2) to analyze internal friction data in rocks; and (3) to conduct laboratory and theoretical studies of elastic rock properties.

Investigations: Direct observations of stress and strain in rocks are obtained using capacitive displacement transducers. Cyclic stress wave-forms are applied using an electrically driven solenoid or a piezoelectric transducer. Internal friction for rocks and other materials are determined from the observed stress-strain hysteresis loops as a function of frequency, strain amplitude, confining pressure and temperature. Interpretation of results in terms of physical mechanisms of rock internal friction are presented. Other studies include ultrasonic measurements of P and S velocities in rocks at elevated pressure and temperature and application of the results to interpretation of physical properties of the crust and upper mantle.

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

Goals: (1) To identify and map in detail examples of geologic structures such as tensile cracks, shear fractures, folds and brick bands associated with faulting; (2) to understand the processes of formation of these structures by theoretical and experimental analysis; and (3) to study the relationship between these processes and motion on a fault leading to an earthquake.

Investigations: We are conducting field mapping and thin section investigation of faults, fractures, related structures in granitic rocks of the Mt. Abbot quadrangle, central Sierra Nevada, California. Theoretical analyses focus on the stability of an array of propagating entensional cracks in an elastic material and a two-dimensional, elastic fault model which includes the complete mechanical interaction of discrete fault segments. We are conducting experimental analysis of slip initiation and propagation along echelon fault segements.

COHERENT SEISMIC WAVE ANALYSIS, P. A. Reasenberg, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2049.
Goal: To develop methods for analyzing the lateral variations in crustal velocity in the San Andreas fault zone.
Investigations: We are devising a computer program (ARRAY) to process data for coherent wave analysis. The array processing technique resolves relative p-delays using data from the Centipede portable array and central California microearthquake network.

A TIME-DEPENDENT, FINITE ELEMENT MODEL OF SOUTHERN CALIFORNIA STRAIN FIELDS, A. T. Smith, University of California, Earth Sciences, Santa Cruz, California 95064, (408) 429-2225.
Goal: To analyze earthquake risk in southern California by using numerical and stochastic models of time-dependent strain fields.
Investigations: Fault creep instablities are coupled with asthenospheric stress relaxation to induce premonitory time-dependent surface deformations. Applications to southern California use a time-dependent finite element analysis and geodetic constraints. We completed the time-dependent, finite element code for three-dimensional models. The solution routines are incorporated into new plotting routines for three-dimensional perspective and contouring of the displacements. Seismic slip instabilities are incorporated into the solution code. We are currently developing strike-slip finite element models and we will incorporate time-dependent material properties and nonlinear constitutive relations along the fault.

INTERPRETATION OF DEEP CRUSTAL REFLECTION DATA FOR STRUCTURE AND PHYSICAL PROPERTIES NEAR ACTIVE FAULTS, S. B. Smithson, University of Wyoming, Department of Geology, Laramie, Wyoming 82071, (307) 766-5280.
Goals: To reprocess and interpret the COCORP deep crustal reflection line across the San Andreas fault at Parkfield.
Investigations: We are starting with the field data and totally reprocessing seismic reflection data along this line beginning with severe editing of the field data to remove noise. Many different causes are degrading the data and must be attacked.

CRUSTAL INHOMOGENEITY IN SEISMICALLY ACTIVE AREAS, S. W. Stewart, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2525.
Goal: To use microearthquake waveform data, primarily from the USGS Central California Microearthquake Network, to study relationships between crustal heterogeneity and spatial/temporal variations in seismicity.

Investigations: In order to have microearthquake waveform data readily available, an online digitizing and data recording system is being designed. This system will monitor the short-period seismic stations within the central California network and will write out to disc or magnetic tape the complete seismic waveforms of all detected events. Event detection will be supplied from the microprocessor-based realtime earthquake location system presently in development. The data recording system is designed to handle up to 512 seismic stations, each station digitized at a rate of 100 samples per second. The digitized waveform data, demultiplexed and edited, will reside in the PDP 11/70 UNIX system in Menlo Park.

Laboratory studies

PETROLOGIC COMPARISON OF CATACLASTIC ROCKS FROM SHALLOW AND DEEPER CRUSTAL LEVELS WITHIN THE SAN ANDREAS FAULT SYSTEM OF SOUTHERN CALIFORNIA, J. L. Anderson, University of Southern California, Department of Geological Sciences, Los Angeles, California 90007, (213) 741-2717.
Goal: To provide the physical and compositional data on fault gouge and other intrafault materials necessary for laboratory modelling of rock failure and earthquake prediction studies.
Investigations: Shallow core samples (depth ranging from 3 to 15 meters) will be taken from the Mecca Hills area, Big Pine Junction and Tejon Pass. A drill core from the Lake Hughes area will be used to obtain samples from depths ranging from 180 to 360 meters. Sampling will be on a statistical basis to insure that samples and their variations are representative of each site. The deep core will allow the determination of textural and compositional variables as a function of moderate depth. At each of the shallow core sites, one or more channel samples will be collected by coring along and across the exposed fault trace. A randomized block spot-sampling design with several nested levels will be superimposed across the fault trace to seek vertical and/or lateral trends by inferential statistical techniques. Laboratory analysis of these samples will determine: mineralogy and petrology by x-ray diffraction and standard petrographic techniques; internal structures and fabric by x-radiography; petrochemistry by x-ray fluorescence, atomic absorption spectrophotometry, and uv-vis colormetric spectrophotometry; grain size by current sedimentologic techniques; and grain-surface microtextures by transmission and scanning electron microscopy.

MYLONITIC ROCKS FROM MAJOR FAULT ZONES, J. R. Anderson, State University of New York-Binghamton, Department of Geological Sciences, Binghamton, New York 13901, (607) 798-6722.
Goal: To determine the physical and chemical conditions prevalent at depth within fault zones.
Investigations: Cataclastic rocks are being sampled from exposed fault zones in the San Andreas-San Jacinto fault system in southern California. The sampled fault rocks represent a considerable range of metamorphic grade and therefore a corresponding variety of depths within the zones. These samples are being analyzed petrographically and microchemically with the electron microprobe, and chemically for whole rock composition using rapid silicate analysis methods. We are also investigating, with lesser emphasis, several cataclastic zones in the Adirondack region of northeastern New York.

MECHANISMS OF FRACTURE AND FRICTION OF CRUSTAL ROCKS IN SIMULATED GEOLOGIC ENVIRONMENTS, B. K. Atkinson, Imperial College of Science and Technology, Department of Geology, Royal School of Mines, Prince Consort Road, London SW7 2BP, England.

Goal: To predict, through laboratory studies, the fracture and friction properties of granites and basalts under environmental conditions pertaining in the upper 15 km of major fault zones.

Investigations: Fracture mechanics experiments at high temperatures and pressures of stress corrosion crack growth and associated acoustic emission, as well as friction experiments at low rates of displacement in the presence of pore fluids, are run to determine the shear strength of crustal rocks under these modes of deformation. Microstructural and microchemical studies are made of deformed specimens to identify deformation mechanisms. These findings are incorporated in deformation mechanism maps which are used to predict rock behavior during natural deformation.

ROCK MECHANICS, J. D. Byerlee, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2453.

Goals: To study the physical processes involved in the deformation of rocks at high pressure and to apply the results of these experiments to problems of earthquake prediction and control.

Investigations: We will attempt to determine whether the magnitude and anisotropy of seismic velocity and attenuation in rock preceding failure or sudden slip is sufficiently large to be detected in large-scale field experiments. Additional studies will focus on determining the conditions necessary for creep instability to occur during sliding on faults.

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

Goal: To investigate the behavior of common rock types at pressures and temperatures indigenous to depths of 5 to 20 km.

Investigations: We are studying existing mechanical data on the transient creep of rocks at elevated temperature. Sections of specimens experimentally deformed in the transient or work-hardening regime will be reexamined to determine the nature and importance of semi-brittle behavior. We want to know whether the operation of thermally-activated processes in this regime tend more to open new fractures or close existing ones by relaxation. Experimental findings will guide studies to determine if semi-brittle behavior is evident in naturally deformed rocks from well-determined depths.

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

Goal: To study the role of rock friction and related micro-mechanical processes that control the mechanics of fault slip and earthquake precursors.

Investigations: A large-scale, 3000-ton capacity biaxial deformation apparatus is used to investigate pre-and co-seismic fault processes. Results on studies of small samples confirm that preseismic slip arises from non-uniformity of stress on the fault surface. These results further suggest that preseismic fault displacements scale with fault dimensions. Experimental and theoretical studies of the mechanisms and possible scaling laws for preseismic slip will continue, with emphasis given to the effect of fault gouge parameters. The details of rupture propagation will be examined experimentally and compared with theoretical models and earthquake observations.

MACHINE SHOP SERVICES, K. R. Harper, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2586.
This project provides machine shop services primarily for the laboratories.

EXPERIMENTAL ROCK MECHANICS, S. H. Kirby, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2872.
Goal: To establish the rheological laws for rocks appropriate to the aseismic zones by experiments and theoretical analysis of solid state flow in rock-forming silicates.
Investigations: Determination of dislocation velocity is based on transient creep behavior. The dislocation velocity is measured in synthetic quartz as a function of stress and temperature. The flow strength of clinopyroxenite has been measured over a range of strain rate and temperature. A low temperature, high stress regime shows little sensitivity to variation and is associated with microfracturing and twinning. A high temperature, low stress regime shows strong effects of strain rate and temperature and is associated with a diffusion-controlled dislocation creep mechanism. Oriented diopside and bronzite single crystals show a significant variation in strength with orientation of the compression direction. These variations have been related to the mechanisms of plastic deformation and crystal structure.

LABORATORY AND FIELD INVESTIGATIONS OF FAULT GOUGE, J. M. Logan, Texas A & M University, Center for Tectonophysics, College of Geosciences, College Station, Texas 77843, (713) 845-3251.
Goal: To investigate fault mechanisms of gouge-host rock systems along pre-existing natural faults in order to determine the operative physical principles governing shallow-focus earthquakes.
Investigations: Laboratory studies focus on the mechanical behavior of simulated fault gouge materials at room and elevated temperatures, the generation of fault gouge, the frictional characteristics of serpentinite, variations of compressional wave velocities, and dilatancy. Field studies have been conducted in the United States and Guatemala in an attempt to correlate the laboratory results with natural features.

FUNDAMENTALS OF DEFORMATION AND RUPTURE PROCESSES IN POROUS GEOLOGICAL MATERIALS, J. R. Rice, Brown University, Division of Engineering, Providence, Rhode Island 02912, (401) 863-2868.
Goals: To develop constitutive relations for porous geological materials and to use these laws in mathematical models for the inception of rupture and for quasi-static creep motions on shear faults.

Investigations: We developed mathematical models for several different quasi-static processes believed to occur prior to earthquakes. One group of models entails a spherical inclusion of nonlinear, high fissured material in a homogeneous, porous elastic matrix. System response to slowly increasing, remotely-applied shearing tractions is such that if the inclusion material exhibits strain-softening behavior, its deformation ultimately becomes unstable—no continuing quasi-static solution can be found. This ultimate instability represents an earthquake, and the time interval of accelerating but quasi-static deformation preceding the instability represents an observable precursory period. In the second group of models, the potential failure zone is a flat, crack-like region reminiscent of a pre-existing fault. The driving force needed for a stable or unstable propagation of a slippage zone is related to the effects of dilatant and frictional behavior of the fault gauge, and the effect of an infiltrating pore fluid in the surrounding rock. Recent work has also focussed on the interdependence of fault zone instability and tectonic stressing as governed by plate motions. Estimates of rates of stress transfer from newly ruptured fault segments into neighboring "gaps" have been obtained from a generalized Elsasser-type plate/foundation model which exhibits delayed stressing due to viscoelastic relaxation of the asthenosphere.

LARGE SCALE ROCK FRACTURE EXPERIMENT, C. H. Sondergeld, University of Colorado, CIRES, Boulder, Colorado 80309, (303) 492-8028.

Goals: To develop a portable acoustic emission monitoring system which would permit hypocenter and focal mechanism determination during the deformation of a large ($1m^3$) specimen carried out under the U.S. - Soviet agreement.

Investigations: An acoustic emission monitoring system has been constructed around Nicolet digital oscilloscopes. The system permits statistics (e.g., number and rate of activity) to be measured independently. It employs eight transducers and can capture waveforms in real time, and store them on magnetic disks for further investigations. The system permits microseismology to be carried out during the deformation of rock samples. We have used it successfully to study the uniaxial deformation of Westerly granite. Transducers appropriate for the large scale fracture experiment have also been evaluated during an actual experiment on a (0.5m x 0.5m x 0.7m) granite block in the Soviet Union.

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

Goal: To study the relationship between dynamic strain changes and fault slip under shear stress.

Investigations: We constructed a laboratory fault model consisting of a square slab of granite (ca. 2.0m x 2.0m x 0.5m), loaded on its edges. A sawed, polished surface passes through the sample. Application of stress to the edges of the sample results in slip over limited areas of the polished surface. Static and dynamic strain changes caused by loading and slip are recorded to allow measurement of rupture velocity, radiation pattern, stress drop, strain spectra, and seismic efficiency. These data will be used to determine details of fault propagation and to test theoretical predictions.

ROCK PHYSICS, R. Stewart, U.S. Geological Survey, Branch of Tectonophysics, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2041.

Goals: To examine the relationship between elasticity and other geophysically or geologically observable quantities in order to determine the lithology, fluid pressure, and stress in crustal rocks of tectonically active areas.

Investigations: Elastic wave velocities in relevant rocks are measured under crustal conditions of confining pressure, temperature, and fluid pressure. Knowledge of the elastic response of crustal rocks under realistic environmental conditions can be used to interpret the results of seismic surveys and gravity measurements in terms of crustal and fault zone structure, distribution of pore fluids, and the relationship between velocity anisotropy and stress.

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

Goals: To study the processes controlling the deformation behavior of rocks in the brittle-ductile transition regime.

Investigations: We have conducted deformation experiments on the common crustal polyphase rocks granite and diabase, and monomineralic aggregates and their constituent phases, over a wide range of crustal temperatures and pressures, at both "wet" and "dry" conditions. Detailed petrographic and transmission electron microscope (TEM) observations of the deformed samples have been made to identify the grain-scale deformation mechanisms operative at all of these conditions and to relate them to the macroscopic yield behavior. We have found a transition from microcracking at lower temperatures to dislocation glide and climb at higher temperatures; the transition temperature varies for different minerals, and is lowered by the presence of trace amounts of water. Studies are currently underway to empirically measure flow laws for the polyphase and the monomineralic aggregates, and to develop a finite element model which will allow the properties of the polyphase aggregate to be predicted from a knowledge of the flow law of its constituents, and their volume proportions and geometrical arrangement.

ROCK MECHANICAL INVESTIGATION OF CLAY AND CLAYEY GOUGE AT HIGH PRESSURES AND TEMPERATURES, C. Y. Wang, University of California, Department of Geology and Geophysics, Berkeley, California 94720, (415) 642-2288.

Goal: To examine the mechanical properties of clayey and cataclastic gouge and mylonites along the San Andreas fault.

Investigations: This project studies (1) the mechanical strength of gouge materials under pressure up to 3 kb and controlled pore pressure, and (2) pre-failure diagnostics of gouge materials, such as creep, dilatancy, and pore pressure change. Laboratory experiments are performed on clayey gouges collected along the San Andreas fault and relatively homogeneous cataclastic rocks chosen from several locations. Findings will be applied to study the different mechanical behaviors along differenct sections of the San Andreas fault.

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

Goals: (1) To estimate the depths of clay gouge formation, (2) to evaluate the variation of fault gouge as a function of wall rock composition, and (3) to evaluate the role of gouge in the mechanics of faulting.

Investigations: We will determine the mineralogy and/or chemical composition of wall rock, rock fragments, clay fractions, and the chemistry of pore solutions in relatively young fault zones. Clayey fault gouge samples will be collected from surface outcrops, trenches, and deep tunnels and mines. Some large block cores will be obtained and prepared for triaxial tests. The ratios of stable oxygen isotopes in clays will be used to study the formation temperature of gouges containing two or more clay minerals. We will also examine gouge-like cataclastic rocks from several old (inactive) fault zones in the Adirondacks to determine the amount of water involved in the formation of minerals, the mineral assemblage, and the temperature range under which they were formed.

Source mechanics

DIGITAL SIGNAL PROCESSING OF SEISMIC DATA, W. H. Bakun, U.S. Geological Survey, Branch of Seismology, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2777.

Goal: To develop methodologies for obtaining details of earthquake source and propagation path operators from a set of seismograms recorded on a dense array surrounding the earthquake epicenter.

Investigations: USGS microearthquake catalogs for central California are used to search for seismic precursors to large earthquakes.

STATISTICAL FAULT MODELS, D. M. Boore, U.S. Geological Survey, Branch of Ground Motion and Faulting, 345 Middlefield Road, Menlo Park, California 94025, (415) 323-8111, ext. 2698.

Goals: (1) to develop efficient means for calculating impulse response of geologic systems, and to incorporate this impulse response into previously developed statistical fault models to generate synthetic accelerograms.

Investigations: We are developing an inexpensive method for computing Green's functions which was developed from Chapman's WKBJ theory. This method will allow us to separate the effects of wave propagation into two parts: the propagation to the site, using Chapman's method; and the propagation through local sediments, using any one of several existing techniques. We also developed a stochastic fault model in which rupture velocity, dislocation rise time, dislocation amplitude, and rupture length are given by probability distribution functions. A program was written which uses an efficient way of computing acceleration time histories corresponding to the stochastic fault model.

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, California 94025, (415) 323-8111, ext. 2962.

Goal: To study the rupture mechanism of earthquakes.

Investigations: In May and June of 1979, we deployed five to six digital cassette recorders around the Monticello reservoir, South Carolina—a site of induced seismicity. The purpose of this experiment was to obtain spectra from a suite of intraplate earthquakes that would also have relevance to induced seismicity and tectonic stress. Each recording system has a 3-component set of 2 Hz velocity transducers and each channel was digitized at 200 samples/second by a 12 bit analog to digital converter. Our analysis of the data will include calculating the moment, stress drop, dynamic stress drop, and direction of rupture propagation. We will synthesize these data with tectonic features associated with the reservoir and in-situ stress measurements.

RETRIEVAL OF EARTHQUAKE SOURCE MECHANISMS USING SOUTHERN CALIFORNIA SEISMIC NETWORKS, J. A. Orcutt, Scripps Institution of Oceanography, Geological Research Division, La Jolla, California 92093, (714) 452-2887.

Goal: To examine the phenomenological moment tensor representation for retrieving source characteristics for earthquakes at local and regional distances.

Investigations: We have evaluated the use of the moment tensor representation of the source for earthquakes in the Imperial Valley sequence of October, 1979.

The extensive USGS explosion seismology study conducted earlier in the year permits the computation of accurate and adequate synthetic seismograms for this locale using Wavenumber Integration and Discrete Wavenumber-Finite Element methods. The stability of the inverse problem has been improved in the face of disparate data by using the L1 norm and linear programming. The technique allows accurate and simple evaluation of source parameters in sparsely space networks where classical fault plane solutions are inadequate.

GLOBAL SEISMOLOGY STUDIES

Research

EARTH STRUCTURE, B. R. Julian, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-4041.
Goal: To develop programs for studying earth structure and earthquake mechanism.
Investigations: The capability of the full wave theory has been expanded and applied to synthesize SH body waves. These synthetic waveforms are used to study upper mantle structure and to examine the consequences of assuming the validity of ray theory. A scattering matrix has been programmed to give the reflection/transmission coefficients for all possible interactions of a body wave with a discontinuity. When incorporated into full wave theory, this program will enable us to synthesize all possible body waves. A separate study is under way to determine the velocity and attenuation profiles of the lower mantle, and the outer and inner core by synthesizing waveforms of the type S(diff), SmKS, SKiKS, and SKIKS.

DIGITAL DATA ANALYSIS, B. R. Julian, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-4041.
Goal: To develop an interactive data processing system for monitoring global seismic activity.
Investigations: This new system will use digital seismic data and reported time and amplitude data. The system will interface with ARPANET for the mutual exchange of data and information.

TOPICAL STUDIES IN GEOPHYSICS, L. C. Pakiser, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-2625.
Goal: To determine crustal and upper-mantle structure of selected areas in the western United States.
Investigations: We reinterpreted all profiles from a 1964 and 1965 seismic reconnaissance of the southern Rocky Mountains. One set of profiles traversed the San Juan, Sawatch, and Park Ranges along a line extending from Lumberton, New Mexico, across Colorado to Sinclair, Wyoming. Crustal thickness averages about 48 km in the San Juan, Sawatch, and Park Ranges, but decreases to about 40 km between Wolcott and Sinclair. The second profile traverses portions of the Front and Laramie Ranges along a series of recording sites north of Climax, Colorado. The crust in the Front Range is about 52 km thick and is distinctly separated into upper and lower units. The crust thins to about 37 km in the Laramie Range. A study of the root of the Sierra Nevada is based on a profile recorded along the Sierra in 1966. A previous interpretation indicates an average crustal thickness of about 44 km between Truckee, California, and the high Sierra to the south. A reinterpretation of this profile is in progress.

SEISMICITY AND TECTONICS, W. J. Spence, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-4041.
Goals: (1) To study the tectonic processes that produce large earthquakes and the faulting processes associated with these events, and (2) to test hypothesized empirical models of seismicity patterns precursory to large subduction-zone earthquakes.
Investigations: We are determining focal mechanisms of key earthquakes in Peru and integrating these with results from our previous studies on relocated seismicity of Peru and on the 1974 Peru earthquake series. In our study of the mantle structure beneath the Rio Grande Rift, we are using three-dimensional, seismic ray tracing algorithm to invert a set of teleseismic P-way delay data, with the objective of determining the meximum depth and degree of velocity anomaly in the upper mantle. In addition. we are investigation the main shock source properties of the 28 February 1979 St. Elias (SE Alaska) earthquake.

Seismograph station operation and design

USGS AND COOPERATING OBSERVATORIES, H. M. Butler, U.S. Geological Survey, Branch of Global Seismology, Kirtland AFB, Albuquerque, New Mexico 87115, (505) 264-4637.
Goal: To provide technical and operational support to observatories.
Investigations: Project activities include technical advice and assistance to the stations; engineering support; equipment replacement, calibration, and repair; and the provision of operating supplies.

WORLD-WIDE STANDARDIZED SEISMOGRAPH NETWORK, H. M. Butler, U.S. Geological Survey, Branch of Global Seismology, Kirtland AFB, Albuquerque, New Mexico 87115, (505) 264-4637
Goal: To insure a continued flow of high quality seismic data from network stations.
Investigations: Field activities consist of maintenance and calibration visits to the 113 stations of the World-Wide Network of Standardized Seismographs. Stations are provided with spare parts, operational supplies, and replacement modules.

U.S. SEISMIC NETWORK, M. A. Carlson, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-3994.
Goal: To upgrade the quantity and quality of data received by the U.S. Seismic Network.
Investigations: Sixty-four channels of data from the U.S. Seismic Network are recorded continuously in real time at the NEIS main office in Golden, Colorado. Data is used by personnel on earthquake alert standby for rapid location of significant earthquakes worldwide.

SYSTEMS ENGINEERING FOR SUPPORT OF SEISMOGRAPH NETWORKS, H. E. Clark, Jr., U.S. Geological Survey, Branch of Global Seismology, Kirtland AFB, Albuquerque, New Mexico 87115, (505) 264-4637.
Goal: To convert or redesign seismic and observatory equipment and systems to microprocessor controlled systems.
Investigations: New microprocessor-based seismic instrumentation systems and circuits are being designed and tested to improve seismic systems performance and lower cost.

TSUNAMI NETWORK SUPPORT, H. E. Clark, Jr., U.S. Geological Survey, Branch of Global Seismology, Kirtland AFB, Albuquerque, New Mexico 87115, (505) 264-4637.
Investigations: We completed our preliminary plans for the installation of four TT-3 Tide Systems in the South American area.' This project is a joint effort between the USGS and NOAA/NWS. These four Tide Systems will operate over the GOES SATELLITE Network. Installation of these stations will ilmprove the tide reading response time for TSUNAMI detection for seismic events near the western coastal areas of South America.

OPERATE EUREKA, NEVADA SEISMOGRAPH, W. A. DePaoli, P.O. Box 261, Eureka, Nevada 89316, (702) 237-5263.
Seismograph station is operated under contract with individual. Preliminary analysis is performed and records are sent to NEIS.

INSTALL AND SERVICE FOREIGN AND DOMESTIC SEISMOGRAPH INSTRUMENTS, E. R. Ferrigno, Ford Aerospace and Communications Corporation, Engineering Services Division, 3900 Welsh Road, Willow Grove, Pennsylvania 19019, (215) 659-7700, ext. 2394.
Provides service to WWSSN stations, SRO, and High-Gain Long Period systems. When required, project installs stations.

ALBUQUERQUE OBSERVATORY, L. H. Jaksha, U.S. Geological Survey, Branch of Global Seismology, Kirtland AFB, Albuquerque, New Mexico 87115, (505) 264-4637
Goal: To produce seismic data for earthquake studies on a global, regional, and local scale.
Investigations: The instrumentation being operated includes an SRO station, WWSSN station, New Mexico statewide net, San Juan Basin net, and Albuquerque Basin net. Two seismic refraction experiments were carried out—one in the Datil-Mogollon volcanic field in southwest New Mexico and the other in central Arizona. We installed a high-gain long-period station in facilities provided by New Mexico Tech in Socorro. The data will be telemetered to Albuquerque and recorded on a digital machine.

OPERATE GALAPAGOS ISLANDS SEISMOGRAPH, C. MacFarland, Charles Darwin Research Station, Casilla 58-39, Guayaquil, Ecuador.
This station is part of the WWSSN system. Records are sent to Golden, Colorado.

OPERATE TUCSON, ARIZONA SEISMOGRAPH, H. W. Pierce, University of Arizona, Arizona Bureau of Mines, Geological Survey Branch, 845 North Park Avenue, Tucson, Arizona 85719, (602) 884-2733.
Seismograph station is operated in cooperation with the Arizona Bureau of Mines. Records are also produced from WWSSN system of instruments. Data are telemetered directly to Golden, Colorado.

OPERATE MISSOULA, MONTANA SEISMOGRAPH, A. Qamar, University of Montana Foundation, Missoula, Montana 59801, (406) 243-6560.
This station is part of the WWSSN system and is operated under contract with the University of Montana. Records are sent to NEIS.

SEISMIC OBSERVATORIES, H. Whitcomb, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 8025, (303) 234-2625.
Goal: To record and provisionally interpret seismological and geomagnetic data.
Investigations: This project maintains and operates seismological and geomagnetic instruments at various observatories and provides seismological data for the preliminary determination of earthquake epicenters. At Guam and Newport, Washington, 24-hour watches are maintained to provide input to the Tsunami Warning Service operated at Honolulu Observatory. The Newport observatory was upgraded by adding real-time recording of short-period vertical seismic data from eight additional stations in the U.S. This Observatory will eventually assume night time responsibility for the Early Earthquake Reporting System. This means that during off duty hours, information on felt and damaging earthquakes in the United States and world-wide events with magnitudes greater than approximately 6.5 will be located and reported from Newport rather than from the NEIS in Golden, Colorado.

Data acquisition and dissemination

PROVIDE SEISMIC DATA TO NEIS, W. J. Arabasz, University of Utah, 307 Park Building, Salt Lake City, Utah 84112, (801) 581-6201.
Records from WWSSN contract station and from the University of Utah network are sent to NEIS.

NATIONAL EARTHQUAKE INFORMATION SERVICE, E. P. Arnold, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-3994.
Goal: To provide rapid and comprehensive hypocenter location service to the government and scientific community.
Investigations: All computer programs are being converted to run on the Honeywell computer. The flow of seismic data has been improved by increasing the number of stations reporting by telegram and direct computer link. In addition to publishing bulletins of earthquake parameters, we are continuing to provide public information services on recent earthquakes.

PROVIDE SEISMIC DATA TO NEIS, B. A. Bolt, University of California, Wheeler Hall, Berkeley, California 94702, (415) 642-3977.
Provides NEIS with data from University of California network.

GOLDEN SEISMIC DATA ANALYSIS CENTER, R. P. Buland, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-4041.

PROVIDE SEISMIC DATA TO NEIS, M. Friedman, California Institute of Technology, 1201 E. California Blvd., Pasadena, California 91125, (213) 795-8806.
Provides NEIS with data from CalTech network.

DIGITAL NETWORK DATA PROCESSING, J. P. Hoffman, U.S. GEological Survey, Branch of Global Seismology, Kirtland AFB, Albuquerque, New Mexico 87115, (505) 264-4637.
Goal: To process digital seismic data recorded on magnetic tapes from the Global Digital Seismic Network.
Investigations: We are constructing network-day tapes consisting of 24 hours of seismic data from each station of the Global Network. All computer hardware equipment necessary to assemble the network-day tapes has been installed and is operating. This consists of two PDP 11/34 Processors, two larege disc pac memory systems, several tape drives and various other terminals, printers, and plotters. The 11/34 Processors are using the UNIX Operating System, Version 6.

WORLDWIDE EARTHQUAKE RESEARCH DATABASE, W.H.K. Lee U. S. Geological Survey, Branch of Seismology, 345 Middlefield Road., Menlo Park, California 94025, (415) 323-8111, ext. 2630.

SEISMOGRAM REVIEW AND DATA SERVICES, R. P. McCarthy, U.S. Geological Survey, Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-5080.
Goals: (1) To improve station performance, (2) to reduce flow-time of WWSSN seismograms, and (3) to transfer review data to ADP format.
Investigations: Quality control and technical review were conducted on the 240,000 seismograms generated by the World-Wide Standardized Seismograph Network (WWSSN) comprising 110 stations in 60 countries. Station performance reports were provided to station directors, sponsors, and involved agencies.

PROVIDE PRESS CLIPPINGS, T. E. Paley, International Press Clipping Bureau, 5 Beckman Street, New York, New York 10038, (212) 267-5450.
Sends worldwide newspaper clippings on felt earthquake reports to NEIS.

PROVIDE SEISMIC DATA TO NEIS, Fr. J. W. Skehan, S. J., Boston College, Chestnut Hill, Massachusetts 02167, (617) 899-0950.
Operates WWSSN station and small network. Sends records to NEIS.

U. S. EARTHQUAKES, C. W. Stover, U. S. Geological Survey,. Branch of Global Seismology, Denver Federal Center, Denver, Colorado 80225, (303) 234-3994

Goals: (1) To collect, evaluate, and publish U.S. earthquake locations and damage information, and (2) to publish seismicity maps of earthquake activity on a world-wide basis.

Investigations: United States earthquake data on location, magnitude, intensity, damage, and other appropriate parameters were processed for 1976 and are being prepared for publication in quarterly circulars. The seismicity map of the conterminous U.S. for 1965 to 1974 is complete; and a series of state seismicity maps are being prepared.

INDEX OF PRINCIPAL INVESTIGATORS