





(200)
R295
no. 78-347

✓ UNITED STATES (DEPARTMENT OF THE INTERIOR)

GEOLOGICAL SURVEY

Reports - Open file series

REPORT OF STATUS OF REACTOR HAZARDS RESEARCH PROGRAM

FISCAL YEARS 1976 - 1977

cal by *1926-*
C. M. Wentworth, Program Manager
Reactor Hazards Research Program
Menlo Park, California

TM
EW
Tward

Open-file report 78-347

Prepared February 1977

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards.

285327



CONTENTS

I. Introduction and Summary	1
II. Objectives of Program	3
III. Program Budget and List of Projects and Grants	7
IV. Interchange of Funds with Other Survey Programs . . .	12
V. Description of Projects within Geological Survey . . .	14
VI. Description of Grants	64
VII. Major Program Accomplishments in Fiscal Year 1976 . .	66
VIII. Program Goals for Fiscal Year 1977	67
IX. Publications from the Program	68

FIGURES

1. Sources and flow of geologic information during study, selection, and licensing of reactor sites and designs	4
---	---

TABLES

1. Summary of funding and program content, FY 1975-1977 .	2
2. FY 77 budget by Office and Branch	7
3. FY 77 budget within Office of Environmental Geology .	8
4. Projects and Grants funded in FY 77	9

I. INTRODUCTION AND SUMMARY

The Reactor Hazards Research Program is a Geological Survey program directed at expediting the safe siting and design of power reactors in the United States through topical and regional work on major geological hazards, particularly faulting, earthquake shaking, volcanism, and gross failure of foundation materials (table 1). It is complimentary to the more directed research sponsored by the Nuclear Regulatory Commission on problems raised by license applications, and is coordinated with that and with other Survey programs that deal with geological hazards.

In fiscal year 1977 the Program supports all or part of 46 projects and sub-projects engaged in work throughout the United States. It is funded at about \$2.7 M Bureau-level, which is an increase of about \$1.3 M over fiscal year 1976 (table 1). Work in the Program takes place largely within the Offices of Environmental Geology, Earthquake Studies and Geochemistry and Geophysics in Geologic Division, as well as through one project in Topographic Division and one supported as an outside grant. One additional project is supported through contribution to the Landslide Hazard Reduction Program in the Office of Environmental Geology.

Much of the effort of the Program is directed at understanding tectonic settings and the potential for fault movement and major earthquakes in the northeast, the southeast, and in the west coast states. Research on better understanding of the historic seismic record in the east and of the prediction of the detailed character of strong ground motion is also underway. Aseismic faulting is being studied in the Gulf Coast and western alluvial basins, volcanic hazards and their expected distributions are under study in the west and catastrophic avalanches are being considered. Work is underway both 1) to better understand the physical behavior of hazardous processes and 2) to improve our ability to evaluate their history of occurrence in the recent past, the two principal means of evaluating events expectable in the near future.

The work of the first two years of the Program is now beginning to yield abundant and significant results, and as many as 60-70 maps and reports should be submitted for publication by the end of fiscal 1977. It is clear that our understanding of the nature and distribution of hazardous geologic processes in the U.S. can be greatly improved and the process of assuring safe siting and design of power reactors made both surer and more efficient. Significant progress has already been made in this direction, although it is small compared to the need.

The origin and expectable distribution of major earthquakes in the eastern U.S. is still uncertain, the best means of evaluating earthquake and faulting hazard there and even in the west is still to be developed, the potential for surface faulting in the Gulf Coast seems more extensive than supposed, and other hazards deserve greater attention. As our understanding improves, more confident identification of areas free of particular hazard and of maximum limits to hazards in various places can be made, and safe siting and design of reactors can thus be made more efficient.

Table 1. Summary of Funding and Program Content, FY 1975-1977

Reactor Hazards Research Program

Showing Approximate Bureau-level Funding and Percent of Dollar Effort by Topic

	<u>FY 75</u>	<u>FY 76</u>	<u>FY 77</u>
BUREAU-LEVEL FUNDING	\$~1.3M	\$~1.4M	\$~2.7M
PERCENT EFFORT BY TOPIC			
Tectonics and Earthquakes- Total	68%	69.5%	75.4%
Cenozoic Tectonics	54	60.5	61.6
Modern Tectonics	4.5	7.5	5.2
Seismicity	6.5	1.5	4.2
Seismic Shaking	3	0	4.4
Quaternary Dating	10.5	16	13.6
Liquefaction and Landslides	5	1	1.3
Aseismic Faulting and Subsidence	14.5	10	7.2
Volcanic Hazards	2	3.5	2.5

II. OBJECTIVES OF REACTOR HAZARDS RESEARCH PROGRAM

The Reactor Hazards Research Program is designed 1) to identify and improve our understanding of geologic processes that may be hazardous to nuclear power reactors and 2) to determine the geographic distribution and expected frequency and severity of these processes in order to help expedite the safe siting and design of civilian power reactors in the United States.

The Need

Nuclear power reactors in large numbers are part of most strategies for meeting the growing limits on petroleum availability and the expanding demand for electrical power in the nation, and about 100 reactors are already built or under construction. It is essential that power reactors be built in places that are free of hazardous natural events or that they be designed to successfully withstand them, in order to prevent accidental release of radioactive materials as well as to assure a reliable power supply for the nation.

This has created an urgent need for better understanding of geologic hazards, particularly of fault movement, earthquake shaking, volcanic eruption, and gross failure of foundation materials. Research toward this end is sponsored both by the Nuclear Regulatory Commission (NRC) and by the U.S. Geological Survey, and extensive site-related investigations are required of power utilities as part of the Federal licensing process.

Nuclear Regulatory Commission - Licensing and Research

The Nuclear Regulatory Commission seeks to assure the safe siting and design of power reactors through a rigorous licensing procedure that requires extensive geologic-seismologic study of proposed reactor sites using information from various sources (fig. 1). The Geological Survey participates with the Regulatory Staff in safety evaluation of those license applications for which the NRC requests aid. This site evaluation work is separate from both the Reactor Hazards Research Program and NRC-funded research within the Geological Survey.

Neither the nature of the hazardous processes nor the geologic character of regions of siting interest are well enough understood, however, to maximize safety and economy together, either in site selection and reactor design or in the licensing procedure itself. As a result, safety decisions must still be made in the face of serious uncertainties, leading to higher conservatism, higher costs and greater exposure to error. Utilities encounter long and costly delays as the regulatory process seeks to ensure public safety, and some sites must be abandoned after long and costly investigation.

To answer questions specifically raised by license applications, NRC sponsors directed research that amounts to \$2.75M for geology and seismology in fiscal year 1977, including \$1.1 M for the work of the Reactor Environmental Safety Research Program in the Geological Survey.

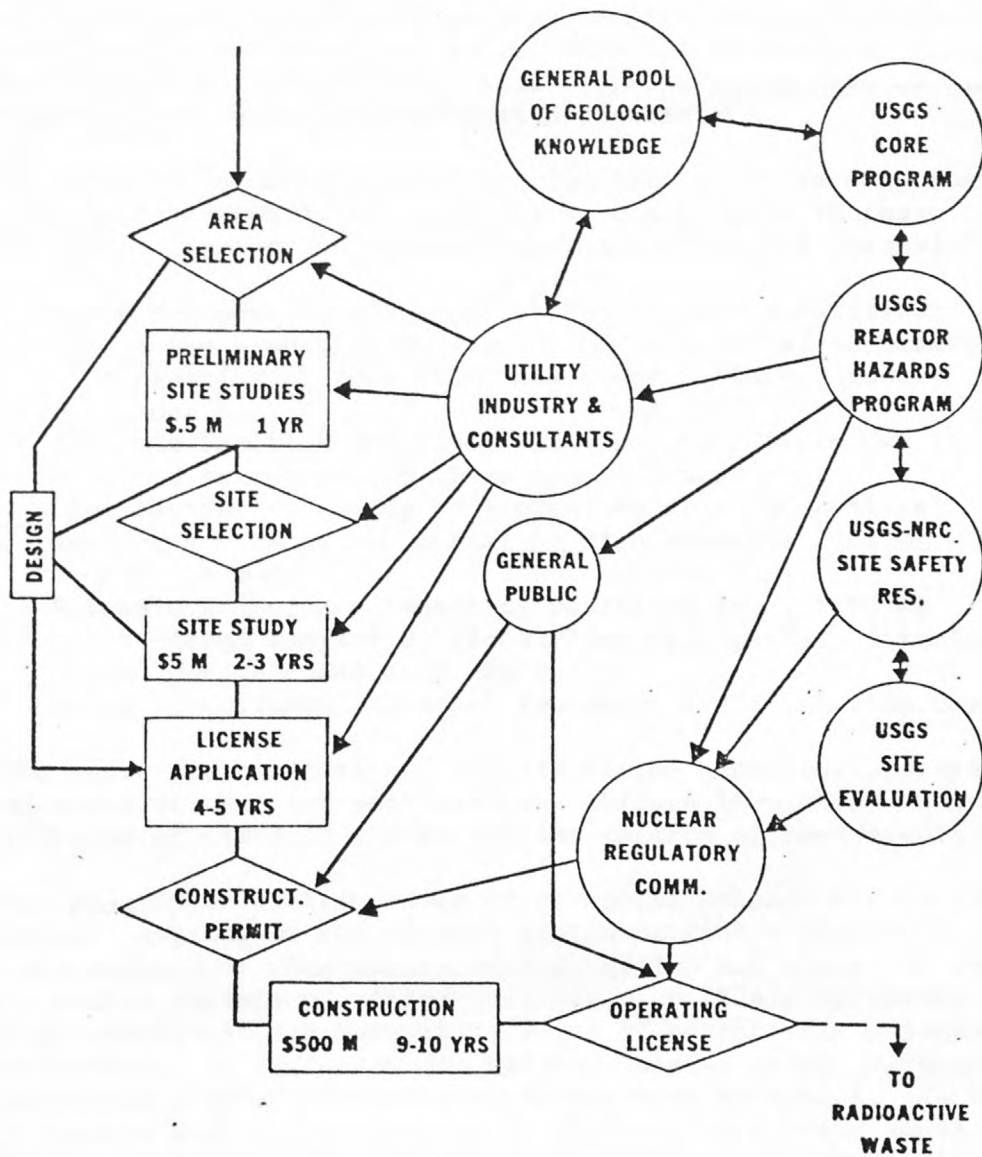


Figure 1. Sources and Flow of Geologic Information During Study, Selection, and Licensing of Reactor Sites and Designs.

Reactor Hazards Research Program

The Reactor Hazards Research Program of the Geological Survey, in contrast, looks beyond immediate licensing questions to study regional geologic settings and the constraints they may pose reactors and to develop techniques and understanding of processes that are needed in regional studies and site evaluations. Better knowledge about the hazardous processes, available in advance, will allow problem sites to be avoided, site investigations to be more efficient, and independent safety reviews to be faster and surer. The chance of later discovery of unanticipated hazards at sites will be greatly reduced, as will the abandonment of sites and the overdesign of reactors.

The Program focuses on geologic processes that can deny the use of otherwise desirable sites for reactors or can greatly increase the cost of their proper design and construction, including (as feasible):

- Fault Movement - ground offset, earthquake generation;
- Earthquake - shaking of ground and structures; secondary triggering of foundation and slope failures, public chaos;
- Aseismic Faulting and Fissuring - ground failure due to fluid extraction or gross landsliding;
- Liquefaction - leading to foundation or slope failure;
- Avalanche - impact or burial by high velocity flow of rock or mud;
- Volcanic Eruption - impact or burial by lava, ash, or triggered mudflow or flood; loading, coating, abrasion and public chaos from ash fall;
- Solution-Collapse - loss of foundation into solution cavities.

The behavior, habitats and effects of the hazardous processes are studied wherever they are best observed through laboratory analysis and investigation of historic events and the relicts of past events.

The geographic distributions of potential hazards are studied and delineated. Regions of the country are identified within which different kinds and degrees of constraints on safe siting and design of reactors exist. Within regions of siting interest, the likely habitats, past frequency of occurrence and possible effects of potentially hazardous events are documented. In regions where serious hazards exist, favorable areas are identified within which safe sites may best be sought. In many parts of the country much basic research is required to achieve these results, including geologic mapping, geophysical studies, and the development of techniques.

The Program does not identify or evaluate specific sites for reactors. This is the responsibility of the power utilities working within the context of the regulatory process and the best possible regional and topical information. Nor does it address directly either the environmental effects of reactor operation or accident or the management and disposal of radioactive wastes.

The Reactor Hazards Research Program and NRC-funded safety research are not alone in seeking an understanding of major geologic hazards in the United States. The results of numerous other programs have considerable impact on the safe siting and design of power reactors (represented by Geologic Knowledge and USGS Core Program in fig. 1), particularly work underway in the Geological Survey on Environmental Overviews, Earthquake Hazards Reduction, Geologic Framework and Analysis, Volcanic Hazards, Landslide Hazard Reduction and Environmental Assessment of the Outer Continental Shelf. Because of extensive common interest, the Reactor Hazards Research Program coordinates with these other programs, but contrasts with them both in priorities and content because of its more specific focus on reactor safety.

III. PROGRAM BUDGET AND LIST OF PROJECTS AND GRANTS

The Reactor Hazards Research Program is part of the line item in the Geological Survey budget called Environmental Aspects of Energy, which as a whole received an appropriation of about \$6-1/2 M in fiscal year 1977. Within this, the Bureau-level funding for the Reactor Hazards Research Program itself in FY 77 is about \$2.7 M. The approximate proportion of this \$2.7 M applied in FY 77 to the various topics of concern to the Program is shown in table 1 in the Introduction and Summary.

Table 2 below shows the distribution of FY 77 monies by organizational unit. Table 3 shows the Program budget as perceived within the lead office for the Program. Each project and sub-project supported by the Program is listed in Table 4 and is more fully described in the following section, V.

Table 2. FY 77 Budget by Office and Branch

Reactor Hazards Research Program

	<u>Branch sub-totals</u>	<u>Totals</u>
Bureau-Level Total		<u>\$2,732,200</u>
Geologic Division		<u>2,660,200</u>
Office of Environmental Geology		2,160,200
Computer	\$ 15,000	
Analytical Labs	83,000	
Paleontology and Stratigraphy	127,000	
Eastern Environmental Geology	665,400	
Kentucky Geology	40,100	
Central Environmental Geology	161,200	
Western Environmental Geology	826,600	
Engineering Geology	196,200	
Astrogeologic Studies	13,700	
Landslide Hazard Reduction Program	32,000	
Office of Earthquake Studies		275,000
Earthquake Mechanics and Prediction	7,500	
Seismicity and Earth Structure	106,500	
Earthquake Hazards	156,000	

Office of Geochemistry and Geophysics	\$ 225,000
Regional Geophysics	\$ 72,000
Electromagnetism and Geomagnetism	63,375
Field Geochemistry and Petrology	4,875
Isotope Geology	77,000
Topographic Division	<u>45,000</u>
Geodetic Section, Eastern Mapping Center	45,000
Grants	<u>27,000</u>

Table 3. FY 1977 Budget Within Office of Environmental Geology,
Reactor Hazards Research Program

	<u>Sub-totals</u>	<u>Totals</u>
Total Program Through Office		<u>\$2,200,200</u>
COEG		170,000
Topographic Div.	\$45,000	
Grant	27,000	
Computer	15,000	
Analytical Labs	83,000	
Eastern		665,400
Kentucky		40,100
Central		161,200
Western		826,600
Engineering		196,200
Astro		13,700
P & S		127,000

Table 4. Projects and Grants Funded by Reactor Hazards
Research Program in FY 1977

GEOLOGIC DIVISION

Office of Environmental Geology

Bureau-Level Funding
from Reactor Hazards
Research Program

Branch of Eastern Environmental Geology

1.	9510-01417	Newell: Reactor Hazards East	
		Management and accounting project consisting of:	
2.		Newell: Cenozoic Tectonics, Southeastern U.S.	\$300,780
3.		Pavich: Saprolite Formation and Age, Virginia Piedmont	76,320
4.		Lyttle: Modern Vertical Crustal Movements, Eastern U.S.	14,400
5.		Lyttle's 1/4 my funded by Reactor Hazards in	15,700 ^c
		Drake: Central Appalachian Tectonic history-9510-01926	
6.	9510-01910	Reinhardt: Stratigraphy and Structure of the Georgia Coastal Plain	48,900 ^b
7.	9510-00517	Pavrides: Tectonics of Northeast Virginia Piedmont	104,900
8.	9510-01925	Owens: Stratigraphy and Structure of Cape Fear Arch, South Carolina	67,900
9.	9510-01606	Van Driel: Computer Applications in Environmental Geology	36,500 ^d

Branch of Kentucky Geology

10.	9520-01777	Olive: Plio-Pleistocene Geology of Northern Mississippi Embayment	\$ 40,100 ^d
-----	------------	---	------------------------

Branch of Central Environmental Geology

11.	9530-01559	Pierce: Quaternary Dating Techniques	\$ 55,200
12.	9530-01609	Verbeek: Faulting in the Texas Coastal Plain	53,900
13.	9530-01930	Glick: Tectonic History of Eastern Ozark Uplift	52,100 ^d

Branch of Western Environmental Geology

14.	9540-01450	Wentworth: Management of Reactor Safety Research Programs	\$ 66,600
15.	9540-01592	Tabor: Tectonic and Quaternary History, Wenatchee Reg., Wash.	141,200
16.	9540-01612	Lucchitta: Cenozoic Tectonics of West-Central Arizona	57,600
17.	9540-01624	Bartow: Tectonic Studies, San Joaquin Valley-Southern Sierran Foothills, California	212,700
18.	9540-01943	Helley: Sacramento Valley-Northern Sierran Foothills, California	105,700
19.	9540-01625	Todd: Peninsular Ranges Tectonics	59,500
20.	9540-01947	Sarna: Tephrochronology, Western U.S.	99,400
21.	9540-01944	Fox: Tectonic Analysis, Washington	42,700 ^a
22.	9540-01945	Harwood: Origins of Northeastern Seismicity-Geology	31,200
23.	9540-01616	Morton: Eastern Transverse Ranges Tectonics	10,000 ^c
24.	9540-01946	Thru Landslide Hazard Reduction Program-Brown: Catastrophic Rockfall Avalanches	32,000

Branch of Engineering Geology

25.	9550-01600	Mullineaux: Volcanic Hazards Overview	\$ 24,600 ^a
26.	9550-00647	Crandell: Volcanic Hazards	40,000 ^a
27.	9550-01602	Nichols: In-situ Stress in Vermont Granite	23,200 ^a
28.	9550-01627	Holzer: Ground Failure Related to Extraction of Ground Water	108,400

Branch of Astrogeologic Studies

29.	9580-01634	Hodges: Reconnaissance from Imagery, California Great Valley	13,700
-----	------------	--	--------

Branch of Paleontology and Stratigraphy

30.		Support provided to the Branch through 9590-00874	127,000
-----	--	---	---------

Office of Earthquake Studies

Branch of Earthquake Mechanics and Prediction

31.	9930-01184	Healy: Stress Measurement	7,500 ^c
-----	------------	---------------------------	--------------------

Branch of Seismicity and Earth Structure

32.	9920-01901	Dewey: Reassessment of Historic Instrumental Earthquake Data	55,000
33.	9920-01745	Pomeroy: Northeast Seismic Network	32,500 ^a
34.	9920-01745	Pomeroy: Origins of Northeastern Seismicity-Seismology	19,000

Branch of Earthquake Hazards

35.	9940-01913	Joyner: Synthetic Strong-Motion Seismograms	112,000
36.	9940-01503	McKeown: Geologic Parameters of Seismic Source Areas	23,000
37.	9940-01267	Page: Fault Length vs. Magnitude/Moment Relationships	21,000 ^d

Office of Geochemistry and Geophysics

Branch of Regional Geophysics

38.	9730-00364	Kane: Origins of Northeastern Seismicity - Geophysics	50,000
39.	9730-01894	Jackens: Deformation and Ground Failure Geophysical Studies	22,000

Branch of Electromagnetism and Geomagnetism

40.	9780-01956	Towle: Deep Electromagnetic Soundings in New England	48,750
41.	9780-01955	Flanigan: Geophysical Mapping of Shallow Faults	14,625

Branch of Field Geochemistry and Petrology

42.	9720-00602	Swanson: Columbia River Basalt	4,875 ^c
-----	------------	--------------------------------	--------------------

Branch of Isotope Geology

43.	9740-00378	Rosholt: Uranium-Series Dating of Soils and Caliches	\$ 36,500 ^d
44.	9740-00377	May: Thermal Luminescence Dating of Quaternary Carbonates	20,500 ^d
45.	9740-00374	Rubin: Geochronology (Reston) C-14 Method	5,000 ^c
46.	9740-01568	Robinson: Radiocarbon Geochronology (Menlo Park)	5,000 ^c
47.	9740-00377	Lanphere: Geochronology (Menlo Park) K-Ar	10,000 ^c

TOPOGRAPHIC DIVISION

Eastern Mapping Center

Geodetic Section

Wright: Vertical Elevation Studies

\$ 45,000

GRANTS

University of Delaware

Wehmiller: Amino Acid Dating of Quaternary Fossils

\$ 27,000

^aPartial funding from Reactor Hazards Research Program

^bAdditional support provided from Branch of Paleontology and Stratigraphy

^cSupplemental funding only from Reactor Hazards Research Program

^dAdditional, supplemental funding provided from other sources.

IV. INTERCHANGE OF FUNDS WITH OTHER SURVEY PROGRAMS

A. Funds Received from Other Programs: None

B. Funds Provided to Other Programs: Bureau-Level Total - \$32,000

1. To Landslide Hazard Reduction Program, Office of Environmental Geology - \$32,000, for:

24. CATASTROPHIC ROCKFALL AVALANCHES-PHYSICAL AND GEOLOGIC CHARACTERISTICS 9540-01946

R. D. Brown, Branch of Western Environmental Geology

To provide a preliminary review of catastrophic landslides to determine the extent of hazard they may pose to reactors in the U.S. and how to pursue their evaluation.

C. Interaction with Other Programs

1. The management project (9540-01450) of the Reactor Hazards Research Program also provides management for the Reactor Environmental Safety Research Program funded by the Nuclear Regulatory Commission, which consists in FY 77 of 14 projects with total Bureau-Level funding of \$1,125,000.
2. Several projects are funded jointly by Reactor Hazards and other programs or receive principal funding elsewhere and a contribution from the Reactor Hazards Research Program. These are listed here with their Reactor Hazards funding, as well as being described in section V.:

Engineering Geology Program

Joint Funding

In-Situ Stress in Vermont Granite - Nichols \$23,200

Geologic Framework and Synthesis Program

Joint Funding

Tectonic Analysis, Washington - Fox \$42,700

Supplemental Funding

Central Appalachian Tectonic History - Lyttle (Drake) \$15,700

Eastern Transverse Ranges Tectonics, Calif. - Morton \$10,000

Regional Mapping and Analysis

Supplemental Funding

Geochronology (Reston) C-14 method - Rubin \$ 5,000

Geochronology (Menlo Park) K-Ar dating - \$10,000

Lanphere (also supported by Mineral Resources)

Environmental Overviews Program

Joint Funding

Volcanic Hazards Overview - Mullineaux \$24,600

Volcano Hazards Program

Joint Funding

Volcanic Hazards - Crandell \$40,000

Supplemental Funding

Columbia River Basalt - Swanson \$ 4,875

Office of Earthquake Studies

Joint Funding

Northeast Seismic Network - Pomeroy \$32,500
plus \$20,000 in FY 76 Reactor Hazards
funds (funding of whole network involves
major contributions from other sources).

Supplemental Funding

Stress Measurement - Healy \$ 7,500
Eastern Transverse Ranges Tectonics, Calif.-
Morton - See under GFS

Energy Lands Program

Supplemental Funding

Radiocarbon Geochronology (Menlo Park) - \$ 5,000
Robinson (also supported by Geologic
Division)

V. DESCRIPTION OF PROJECTS WITHIN THE GEOLOGICAL SURVEY

The Reactor Hazards Research Program in fiscal year 1977 supports 45 research projects or subprojects in the Geological Survey, 44 in Geologic Division and one in Topographic Division. Of these, 34 are totally funded by the Program or receive only supplemental additional funding from other sources, 5 are jointly funded by the Program and other sources, and 7 receive only supplemental funding from Reactor Hazards.

Brief descriptions of these projects follow, indicating project objectives and the logic of Program support, progress and products in the past fiscal year, significant changes in funding, staffing or project direction, and level of effort this year.

In most cases the projects described stand as separate formal projects, but some are distinguishable parts of more complex projects. Where formal project titles are uninformative or the project chief is not the principal investigator, they are reduced to parentheses and more appropriate headings or names are shown. Products in fiscal year 1976 are shown as published or to Branch, although now some of the latter are in press or published. Professional man-years include WAE as well as regular professional effort.

1. REACTOR HAZARDS, EAST

9510-01417

W. L. Newell, Branch of Eastern Environmental Geology

Project started - FY 75; To be completed - FY 80

This project is an accounting and management device in the Branch of Eastern Environmental Geology, and consists of four largely independent parts that are separately described:

2. Cenozoic Tectonics, Southeastern U.S. - Newell
3. Saprolite Formation and Age - Pavich
4. Modern Vertical Crustal Movements - Lyttle
5. 1/4 man year of Lyttle's participation in Drake-Central Appalachian Tectonic History: 9510-01926

Bureau-Level Funding in FY 77:

The parts are described under their individual headings.

Whole Project: 5-1/2 professional man-years

\$407,200 - Reactor Hazards Research Program

2. CENOZOIC TECTONICS, SOUTHEASTERN U.S., part of 9510-01417
(part of Reactor Hazards, East)

W. L. Newell, Branch of Eastern Environmental Geology

Project started - FY 75; To be completed - FY 80

This project focuses principally in Virginia and northeastern Georgia and cooperates with other similarly directed projects in the southeast, including Northeast Virginia Piedmont-Pavrides, Cape Fear Arch-Owens, West Georgia Coastal Plain-Reinhardt, and the NRC-funded Charleston, South Carolina, Earthquake Investigation - Rankin and others.

Objectives:

To determine the tectonic framework, stratigraphic and geomorphic record and history and recency of faulting in selected parts of the south-eastern U.S. where Cenozoic faulting has recently been recognized. Detailed and reconnaissance geologic mapping, structural and stratigraphic studies of Coastal Plain and basement rocks, and study of the Quaternary evolution of the topography and its soils and surficial deposits will be carried out, including compilation of geologic maps of the Rappahannock-Potomac region (1:100,000) and of the Belair, Georgia area.

This work will be a major contribution to the assessment of the history and recency of tectonic deformation in the southeast and the possible relation of any late Cenozoic structures there-to modern seismicity.

Progress in FY 76:

- The four east-side-down reverse faults of the Stafford fault zone in Virginia displace upland gravels of uncertain, possibly late Miocene-Pliocene, age, although no offsets have yet been found in Quaternary deposits. The zone has an aggregate vertical offset of 120 m on the Cretaceous base of the Coastal Plain sediments, a length of at least 50 km along the fall line and is aligned with some and parallel to other faulted Triassic basins and older structures.
- Reconnaissance mapping in Virginia reveals no clear offset of the distinctive Eocene Marlboro Clay Member across the Brandywine structure (limit of recognition perhaps 10 feet), despite similarities to the nearby Stafford fault zone and suggestions of Quaternary structural control from anomalous terrace heights, transition over the structure from fluvial to estuarine terrace sediments and peculiar bends in the Rappahannock River itself.
- Detailed, multidisciplinary study of part of the Belair fault zone along the fall line in northeastern Georgia has invalidated the basis for preliminary conclusions of Holocene offset: currently demonstrable offsets are Cretaceous to probably Tertiary, but the possibility of late Cenozoic movements is as yet unresolved.
- Evidence for fault offset of Wisconsinan glacial deposits and glacial pavements was carefully sought but not found northwest of the Adirondacks in New York and along bedrock faults in various parts of New England. Thus the most direct geologic evidence for active faults appears absent or unprofitably difficult to find in the glaciated northeast, at least in the absence of better guides for focussing the effort.

Products in FY 76:

Published:

- Mixon, R. B., and Newell, W. L., 1975, Faults and flexures along the inner edge of the Atlantic Coastal Plain in northeastern Virginia: Geol. Soc. America Abs. with Programs, v. 8.
- Mixon, R. B., and Newell, W. L., 1976, Preliminary investigation of faults and folds along the inner margin of the Coastal Plain in northeastern, Virginia: U.S. Geol. Survey open-file report no. 76-330, including three 7-1/2 minute quadrangles showing selected details.
- Newell, W. L., Prowell, D. C., and Mixon, R. B., 1976, Detailed investigation of a Coastal Plain - Piedmont fault contact in northeastern Virginia: U.S. Geol. Survey open-file report no. 76-329.
- O'Connor, B. J., and Prowell, D. C., 1976, The geology of the Belair fault zone and basement rocks of the Augusta, Georgia area: Georgia Geological Society Guidebook for 11th Annual Meeting and Field Trip, p. 21-32.
- O'Connor, B. J., and Prowell, D. C., 1976, Post-Cretaceous faulting along the Belair fault zone near Augusta, Ga.: Geol. Soc. America Abs. with Programs, v. 8, pp. 236-237.
- Prowell, D. C., 1976, Implications of Cretaceous and Post-Cretaceous faults in the eastern United States: Geol. Soc. America Abs. with Programs, v. 8, pp. 247-250.
- Prowell, D. C., O'Connor, B. J., and Rubin, M., 1975, Preliminary evidence for Holocene movement along the Belair fault zone near Augusta, Ga.: U.S. Geol. Survey open-file report 75-680, 12 p.

To Branch:

- Gibson, T., and others, Biostratigraphy of the Oak Grove core, Northern Neck, Virginia: to be Abs. for Am. Assoc. Petroleum Geologists, Southeast Section Meeting.
- Mixon, R. B., and Newell, W. L., Preliminary investigation of faults and folds along the inner margin of the Coastal Plain in northeastern Virginia: to be an article for Geology.
- Newell, W. L., Prowell, D. C., and Mixon, R. B., Detailed investigation of a Coastal Plain-Piedmont fault contact in northeastern Virginia: to be an article for Geology.
- Newell, W. L., and Rice, D. D., Structural control of the Cumberland River and its ancestral channels at Flat Lick, Kentucky: to be an article for U.S. Geol. Survey Jour. Research.
- Reinhardt, J., Newell, W. L., and Mixon, R. B., Lithostratigraphy of the Oak Grove core, Northern Neck, Virginia: to be Abs. for Am. Assoc. Petroleum Geologists, Southeast Meeting.

Changes Planned in FY 77:

Transfer Prowell's focus to northern Virginia through New Jersey after completion of Belair work, transfer most of Lyttle's effort to Drake-central Appalachian Tectonic History (9510-01926), transfer Volckmann's efforts from New York to Triassic basins south of New Jersey, and expand Quaternary effort to include now-promising Piedmont geomorphology in Virginia.

Bureau-Level Funding in FY 77:

4 professional man-years

\$300,780 - Reactor Hazards Research Program

3. SAPROLITE FORMATION AND AGE, VIRGINIA PIEDMONT part of 9510-01417 (part of Reactor Hazards, East)

M. J. Pavich, Branch of Eastern Environmental Geology

(W. L. Newell)

Project started - FY 75; To be completed - FY 80

Objectives:

To determine how and at what rates rocks are altered to saprolite in different geologic and hydrologic environments, as a basis for using saprolite profiles in determining geomorphic histories and recency of faulting in crystalline terranes lacking late Cenozoic stratigraphy. Work will include geochemical, petrologic, and geomorphic study 1) of small drainage basins where bedrock is uniform and the hydrologic and hydrochemical regimes can be carefully monitored, 2) of critical occurrences of saprolite, and 3) of the Rappahannock River basin to compare soils formed on saprolite with soils on various late Cenozoic deposits to determine saprolite-soil ages.

This work will help determine how saprolite can be used as a time-stratigraphic marker in the southeast to examine geomorphic histories and recencies of faulting where better late Cenozoic control is lacking.

Progress in FY 76:

- A system to monitor hydrology and hydrochemistry and thereby provide data on dissolved solids produced by saprolite-forming chemical reactions is now in operation in a small granitic drainage basin (Davis Run of the Occoquan River basin).
- Textural, mineralogical and chemical analysis of saprolite profiles from various Piedmont rock types have been made in order to compare profiles on various rock types and to relate saprolite character to hydrochemical regimes determined for small basins.
- The rate of saprolite formation is a function of the rate of ground water circulation, a conclusion emphasized by comparison between a saprolite profile that developed beneath less than 100 feet of Coastal Plain sediments where circulation is restricted and nearby exposed profiles subject to active ground-water circulation. Despite continuing erosion during its formation, the exposed saprolite is thicker than the buried saprolite, indicating that it has formed at a faster rate than where water circulation was slower.

Products in FY 76:

To Branch:

Leo, G. W., Pavich, M. J., and Obermeier, S. F., Mineralogical, chemical, and physical properties of saprolite overlying crystalline rocks, Fairfax County, Va.: to be Abs. for Geol. Soc. America.

Pavich, M. J., and Obermeier, S. F., Post-Miocene weathering beneath the Atlantic Coastal Plain: to be abstract for Geol. Soc. America.

Planned Changes in FY 77:

Emphasis will be transferred to study of the Rappahannock drainage basin in cooperation with the geomorphic work of Newell-Cenozoic Tectonics, Southeastern U.S. (1): small-basin monitoring will continue.

Bureau-Level Funding in FY 77:

1 professional man-year

\$76,320 - Reactor Hazards Research Program

4. MODERN VERTICAL CRUSTAL MOVEMENTS, EASTERN U.S. part of 9510-01417 (part of Reactor Hazards, East)

P. T. Lyttle, Branch of Eastern Environmental Geology
(W. L. Newell)

Project started - FY 75; To be completed - FY 80

In practice this project directs and includes the compilation and analysis of level surveys by D. S. Wright, Modern Elevation Changes, Eastern U.S. (48), Topographic Division, which is also separately described.

Objectives:

To identify modern elevation changes in the eastern U.S. through analysis of repeated level surveys and assess any indicated vertical crustal movements and their relation to geologic structure, terrane evolution, and modern tectonic regimes. Particular attention will be given to quality of data, detailed analysis of level surveys, and relation of rates and styles of movements to causal factors.

This work will determine whether and how analysis of past leveling can be used as a guide to or means of determining the presence and style of recent deformation in the east.

Progress in FY 76:

- Significant real vertical movements (1-5mm/50-100 km/yr) have occurred within the past 45 years in at least parts of 9 eastern states based on profile analysis of about 3,500 km of repeated survey lines. Separate profiles tend to show remarkable similarity within the same geomorphic or geologic provinces.
- Reversals in direction of vertical movement are commonly indicated where several surveys have been repeated along a single line, suggesting cyclic movement.

- Long-term extrapolation of modern rates of vertical movement seems unreasonable, because landforms do not corroborate differential vertical changes within 100 km that would be as much as 1 km/200,000 years: episodic and-or cyclic movements therefore seem required.

Products in FY 76:

None.

Planned Changes in FY 77:

Lyttle's principal research focus is transferred by his Branch to Drake-Central Appalachian Tectonic History (9510-01926), however he will continue (1/4 man-year) to provide leadership and geologic analysis for the vertical crustal movements studies.

Bureau-Level Funding in FY 77:

1/4 professional man-year

\$14,400 - Reactor Hazards Research Program

5. CENTRAL APPALACHIAN TECTONIC HISTORY 9510-01417

P. T. Lyttle, Branch of Eastern Environmental Geology

(part of Lyttle's participation in Drake's project on Central Appalachian tectonics 9510-01926)

Objectives:

To better understand the origin of the Appalachian mountain range and the processes involved in its evolution, particularly the role played by each of the three major Paleozoic orogenies and their interrelations, through geologic studies to prepare a geologic cross-section across the central Appalachians in central Pennsylvania.

Reactor Hazards Participation:

Drake's Central Appalachian project is in the Geologic Framework and Synthesis Program, and is receiving 1/4 man-year of support for P. T. Lyttle from the Reactor Hazards Research Program through Reactor Hazards, East: 9510-01417.

Bureau-Level Funding in FY 77:

1/4 professional man-year

\$15,700 - Reactor Hazards Research Program

6. STRATIGRAPHY AND STRUCTURE OF THE GEORGIA COASTAL PLAIN 9510-01910
(West Georgia Coastal Plain)

J. Reinhardt, Branch of Eastern Environmental Geology

Project started - FY 76; To be completed - FY 81

Objectives:

To determine the stratigraphic history (lithologic, paleontologic, and sedimentologic) of well exposed but poorly known Coastal Plain sediments (Upper Cretaceous and lower Tertiary) from eastern Alabama to central Georgia through detailed and reconnaissance mapping, study of drill holes, and compilation of a 1:100,000-scale geologic map. These sediments form the transition between the differing Atlantic and Gulf Coastal Plains, so that the work will provide a basis for a better understanding of the geologic history of the whole region as well as allowing an evaluation of the history, style and recency of tectonic deformation in the study area.

This work will develop a base of knowledge and expertise needed to allow use of the Georgia Coastal Plain record for tectonic evaluation.

Progress in FY 76:

- Study of sedimentation patterns of the Upper Cretaceous Eutaw Formation in the Chattahoochee River area has defined the lateral extent and sedimentary structures of various lithofacies that have then been assigned to subenvironments within an ancient barrier island complex.
- The major styles of sediment deformation in the Chattahoochee region consist of 1) asymmetrical doming commonly associated with small-scale brittle deformation, 2) sandstone dike injection associated with joint sets, and 3) plastic deformation associated with load structures. These modes of deformation are largely lithology dependent and probably occurred during sediment compaction.

Products in FY 76:

Published:

Reinhardt, J., and Cleaves, E. T., 1976, Adjustment of saprolite to sediment loading along the Fall Line (Abs.): Geol. Soc. America Abs. with Programs, v. 8, no. 2, p. 254.

Planned Changes in FY 77:

None.

Bureau-Level Funding in FY 77:

1-1/2 professional man-years

\$48,900 - Reactor Hazards Research Program

(also 1/2 man-year provided through Branch of Paleontology and Stratigraphy)

7. TECTONICS OF NORTHEAST VIRGINIA PIEDMONT 9510-00517

L. Pavlides, Branch of Eastern Environmental Geology

Project started - FY 77; To be completed - FY 80

Objectives:

To study Piedmont-geologic history, using detailed (1:24,000) and reconnaissance mapping, supported by petrography and geochemistry, and physical exploration of selected faults, in order to understand the evolution, character and distribution of faults in the northeast Virginia Piedmont. Emphasis will be placed on the extension of the Cenozoic faults of the Stafford zone from the Coastal Plain southward into the Piedmont, the nature of the aligned Spotsylvania geophysical lineament, and the possible hereditary relation of brittle structures to older metamorphic structures.

This work will extend study of tectonic structures involving Coastal Plain sediments into the ancient crystalline rocks of the Piedmont and will examine the persistence of crustal weaknesses through time.

Progress in FY 76:

- Possible extensions of the Brooke and Hazel Run faults of the Stafford zone (recently documented to the northeast in the Coastal Plain) and discordant foliations and a possible breccia along the Spotsylvania lineament have been identified by reconnaissance mapping and are initial targets for more detailed work on brittle structure.
- An en echelon set of northeast-trending and probably coeval faults has been recognized that post-dates the 350-m-y-old Berea pluton. This set of faults includes the fault documented through the North Anna reactor site and two others that offset the contact between Quantico Slate and the Fredericksburg complex.
- A large, northeast-trending antiformal zone in Fredericksburg complex(?) recognized in the Lake Anna West quadrangle is aligned with an anti-formally folded synform to the northeast and is bounded on the west by a discordant contact with Quantico Slate that is either an unconformity or a major fault.

Products in FY 76:

Published:

Pavlidis, Louis, 1976, Guidebook for field trips 1 and 4, Piedmont geology of the Fredericksburg Virginia area and vicinity: Geol. Soc. America, Northeast-Southeast Section Mtg., Arlington, Va., 44 p.

Changes Planned in FY 77:

Earlier Northeast Virginia Piedmont project modified and transferred to Reactor Hazards Research Program in order to focus work on Stafford faults and other brittle deformation in the Piedmont.

Bureau-Level Funding in FY 77:

1-3/4 professional man-years

\$104,900 - Reactor Hazards Research Program

8. STRATIGRAPHY AND STRUCTURE OF CAPE FEAR ARCH, NORTH CAROLINA 9510-01925
(Cape Fear Arch)

J. P. Owens, Branch of Eastern Environmental Geology

Project started - FY 77; To be completed - FY 81

Objectives:

To determine the stratigraphy and depositional history of the Cape Fear Arch region in North Carolina and northern South Carolina and to identify structure in the Coastal Plain sediments and underlying crystalline rocks. Principal methods will be detailed and reconnaissance geologic mapping of Cretaceous to Quaternary Coastal Plain sediments, supported by extensive shallow augering and interpretation of geophysical surveys. The result will be an analysis of the tectonic history of the Cape Fear Arch, a principal east-trending structure of the Atlantic Coastal Plain that separates embayments with different histories.

This work on a major regional arch in Coastal Plain sediments will fill a serious gap in studies of the Atlantic Coastal Plain and will aid in evaluating the history and recency of tectonic deformation in the southeast.

Progress in FY 76: New project

- Thick sequences of lower Cretaceous sediments that occur north of the Cape Fear arch are absent or as-yet unrecognized on or south of the arch. Their absence would make the arch a major boundary between different tectonic provinces at least during the early development of the Atlantic basin.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

Establish new project.

Bureau-Level Funding in FY 77:

1-1/2 professional man-years

\$67,900 - Reactor Hazards Research Program

J. N. Van Driel, Branch of Eastern Environmental Geology

Project started - FY 75; To be completed - continuing

Objectives:

To develop computer analysis and graphic display techniques to support geologic investigations. Two programs of great potential value are now being evaluated and modified for Survey use:

1. DASCH, an information storage and retrieval system designed to store lithostratigraphic data from outcrop and borehole and produce tabular and graphic compilations, including cross-sections and isopleth maps, for use during research and in preparing final analyses and supporting illustrations.
2. Computer composite mapping, which permits rapid and economical combining of various kinds and scales of map information to produce composite maps and multi-factor derivative maps.

This work will directly support Coastal Plain work in Georgia and elsewhere and may be broadly applicable to treating areal data on geologic hazards.

Progress in FY 76:

- The DASCH system is nearly operational: it has been translated from its original German, edited, and modified for use on the Survey's Reston computer, and data input procedures have been established, including a standardized set of abbreviations for geologic descriptions (with Reinhardt-Georgia Coastal Plain).
- The computer composite mapping program can accommodate a variety of scales and types of information, as demonstrated by the successful compilation of a set of isopachous maps for the Appalachian Basin at 1:2.5 million scale, and the production of a 5-factor map at 1:24,000 showing the inferred relative stability of the land surface during earthquake shaking in the Sugarhouse 7-1/2-minute quadrangle, Utah.

Products in FY 76:

Published:

Van Driel, J. N., and Stewart, J. C., 1976, The role of computer mapping in the decision-making process for Montgomery County, Maryland: Review of Public Data Use, v. 4, N4.

Changes Planned in FY 77:

Transfer project to Reactor Hazards Research Program.

Bureau-Level Funding in FY 77:

1 professional man-year

\$36,500 - Reactor Hazards Research Program
OE from other sources.

10. PLIO-PLEISTOCENE GEOLOGY OF NORTHERN MISSISSIPPI EMBAYMENT 9520-01777

W. W. Olive, Branch of Kentucky Environmental Geology

Project started - FY 76; To be completed - FY 77

Objectives:

To determine the age and configuration of upland gravels ("Lafayette" gravel) in the northern Mississippi embayment as a possible time and structural horizon from which to assess late Cenozoic deformation. A 1:250,000-scale geologic map will be compiled of the Jackson Purchase area in Kentucky from detailed mapping and a 1:500,000-scale reconnaissance map prepared of the whole region to show the distribution, thickness and basal altitudes of the gravel(s). Evidence of provenance, dispersal patterns and age will also be sought.

This work will help determine the extent to which upland gravels in the upper Mississippi Embayment can contribute to understanding late Cenozoic tectonic history and its relation to modern seismicity.

Progress in FY 76:

- Widespread gravel of the "Lafayette" formation buries extensive bed-rock surfaces with altitudes of 420 to 500 feet above sea level, and appears to represent a single continuum of deposition during Miocene or Pliocene time.
- Epeirogenic uplift since initial gravel deposition has been about 500 feet.
- The gravel is composed largely of chert, sandstone and quartzite similar to that in the Paleozoic rocks surrounding the embayment, but contains rare agate and quartzite closely resembling "Lake Superior Agate" and Baraboo Quartzite. This supply of rock types that apparently were derived far to the north suggests transport by an ancestral, pre-Pleistocene Mississippi River.

Products in FY 76:

None.

Changes Planned in FY 77:

Complete the project.

Bureau-Level Funding in FY 77:

2/3 professional man-year

\$40,100 - Reactor Hazards Research Program
OE from Branch of Kentucky Geology

11. QUATERNARY DATING TECHNIQUES

9530-01559

K. L. Pierce, Branch of Central Environmental Geology

Project started - FY 75; To be completed - FY 80

Objectives:

To study Quaternary dating techniques and time stratigraphy through 1) review of current knowledge and active research in the U.S. in order to guide the Reactor Safety Research Programs on research needs and opportunities, and 2) selected topical studies in collaboration with other specialists to investigate and improve relative dating techniques by developing quantitative calibration: weathering rinds on stones, obsidian hydration dating, loess stratigraphy and associated soils and volcanic ashes, U-series dating of calcic and non-calcic soils, radioactive emissions from soils, and stimulation of better definition of volcanic ash stratigraphy in the western U.S.

Quaternary dating is a key in determining the recent histories of hazardous geologic processes. This work provides both a substantial basis for Program decisions on efforts in Quaternary dating and an essential coordinating tie in applying various dating techniques to practical field problems.

Progress in FY 76:

- U-series dating has been successfully applied to stratified caliche rinds on the bottoms of boulders in a soil on a faulted alluvial fan in Idaho, and supports a 1 m/10,000 year average rate of late Quaternary faulting. Ages of rind strata of about 17,500, 67,000 and 133,000 years are corroborated by three independent controls: the age progression itself, a $0.25 \text{ my} \pm 100\%$ superhydration age on a volcanic ash in the fan, and similarly developed outer rinds associated with the $15,000 \pm 5,000$ -year glaciation.

- Weathering rinds on basaltic and andesitic stones promise to serve as quantitative discriminators of Quaternary glacial deposits that differ by as little as 30% in age in the range of about 12,000 to 2 million years, and, with proper accounting for rock type and local climate, should yield quantitative ages. This is based on 5,000 measurements of rinds 0.1 to more than 2 mm thick made on stones from seven well defined, widely distributed Quaternary glacial sequences in the western U.S. The resulting ages are consistent with available independent controls.

Products in FY 76:

Published:

- Burke, R. M., and Birkeland, P. W., 1976, Reevaluation of the late Pleistocene glacial sequence along the eastern escarpment of the Sierra Nevada, California (Abs.): Geol. Soc. America Abs. with Programs, 1976 Annual Meeting, v. 8, no. 6, p. 796.
- Colman, S. M., and Pierce, K. L., 1976, Weathering rinds as a Quaternary age-dating technique, western United States (Abs.): Geol. Soc. America Abs. with Programs, 1976 Annual Meeting, v. 8, no. 6, p. 818.
- Eaton, G. P., Prostka, H. J., Oriel, S. S., and Pierce, K. L., 1976, Cordilleran thermotectonic anomaly: I. Geophysical and geological evidence of coherent Late Cenozoic intraplate magmatism and deformation: Geol. Soc. America Abs. with Programs, 1976 Annual Meeting, v. 8, no. 6, p. 818.
- Pierce, K. C., Obradovich, J. D., and Friedman, Irving, 1976, Obsidian hydration dating and correlation of Bull Lake and Pinedale Glaciations near West Yellowstone, Montana: Geol. Soc. America Bull., v. 87, p. 703-710.

To Branch:

- Colman, S. M., and Pierce, K. L., Summary table of Quaternary dating techniques: to be U.S. Geol. Survey MF "map".
- Pierce, K. L., Glaciological evaluation of a reconstructed Late Pleistocene glacial system, northern Yellowstone National Park area, U.S.A.: to be abstract for INQUA.
- Pierce, K. L., History and dynamics of glaciation of the northern Yellowstone National Park area: to be U.S. Geol. Survey Professional Paper.

Prostka, H. J., Eaton, G. P., Pierce, K. L., and Oriel, S. S., The Cordilleran thermotectonic anomaly: to be an article for Geol. Soc. America Spec. Paper.

Rosholt, J. N., and Pierce, K. L., Uranium-series dating of stratified caliche rinds: to be an article for U.S. Geol. Survey Jour. Research.

Changes Planned in FY 77:

About 15% of Pierce's time will be provided for work on developing a Survey program on climate change. Part of S. Colman's time will be diverted to Verbeek-South Texas Lineaments.

Bureau-Level Funding in FY 77:

1-1/5 professional man-years

\$55,200 - Reactor Hazards Research Program

12. FAULTING IN THE TEXAS GULF COAST (South Texas Lineaments)

9530-01609

E. R. Verbeek, Branch of Central Environmental Geology

Project started - FY 75; To be completed - FY 79

Objectives:

To evaluate the behavior of faults and the potential for surface faulting in the Texas Gulf Coast through mapping of surface faults, determining recency of fault movement, evaluating natural and artificial causes of movement (principally growth faulting and withdrawal of underground fluids) and study of photo-lineaments and their patterns at various scales. Photo-reconnaissance techniques for identifying lines of potential surface offset will be sought.

This work will help determine the areal extent, likely magnitude, and means of recognizing potential aseismic surface faulting in the Gulf Coast.

Progress in FY 76:

- Surface faults are common features of the Texas Gulf Coast, and form a regional pattern dominated by northeast-trending complex graben that crudely parallel the coast, with a generally subordinate fault system that crosses the graben at high angles. This pattern has been carefully documented in several areas, and many of the faults are evident on high altitude imagery.
- Many faults in the Texas Gulf Coast exhibit surface scarps that range from 10 cm to 1.5 m. high in late Quaternary deposits (the extraordinary Hockley scarp is about 12 m high in Pleistocene deposits) and some, particularly in the Houston region, have displaced streets, houses and other modern structures.

- There may be natural potential for modern surface faulting throughout the Texas Gulf Coast. Although ground-water withdrawal in the Houston region is probably responsible for accelerated surface fault movements as well as general ground subsidence there, the documentation that some faults break modern structures in areas of little or no surface subsidence suggests a natural component of fault motion as well.

Products in FY 76:

None.

Changes Planned in FY 77:

Focus effort on preparing a fault map of part of the Houston area and reconnoitering the occurrence of surface faulting elsewhere in Texas Gulf plain. Add S. Colman to project part-time to provide geomorphic expertise.

Bureau-Level Funding in FY 77:

1-1/4 professional man-years

\$53,900 - Reactor Hazards Research Program

13. TECTONIC HISTORY OF EASTERN OZARK UPLIFT
(North Arkansas Structure)

9530-01930

E. E. Glick, Branch of Central Environmental Geology

Project started - FY 77; To be completed - FY 79

Objectives:

To provide basic stratigraphic and structural information about the eastern Ozark uplift in Arkansas and Missouri to aid understanding of the tectonic history and modern seismicity of the northern Mississippi embayment, with design of work and products subject to modification as work by F. A. McKeown and others in the embayment proceeds. Structure and isopach maps for the Newport (24 7-1/2' quads) and Pocahontas (32 7-1/2' quads) areas in Arkansas will be compiled at 1:125,000 from the results of extensive past work and limited additional field checking to show the base and thickness of Paleozoic rocks, the base and thickness of Cretaceous and Tertiary, pre-gravel deposits, and the base, thickness, distribution and source of upland gravels. Similar reconnaissance information will be developed for southeastern Missouri.

This work will provide valuable structural-stratigraphic information about the eastern Ozarks for use in the Earthquake Hazards study of the major New Madrid earthquakes in the adjacent Mississippi Embayment.

Progress in FY 76: New project

- Much of the needed information in the Newport and Pocahontas areas exists as file data and the expertise of Glick gained during work on the geologic map of Arkansas.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

Begin new project to take advantage of Glick's Arkansas experience and file data.

Bureau-Level Funding in FY 77:

1 professional man-year

\$52,100 - Reactor Hazards Research Program

\$ 3,000-\$5,000 OE - Earthquake Hazards Reduction Program

14. MANAGEMENT OF REACTOR SAFETY RESEARCH PROGRAMS 9540-01450
(Reactor Hazards Program)

C. M. Wentworth, Branch of Western Environmental Geology

Project started - FY 75; To be completed - continuing

Objectives:

Under the authority of the Chief, Office of Environmental Geology, to manage the SIR-funded Reactor Hazards Research Program and the Reactor Environmental Safety Research Program funded by the Nuclear Regulatory Commission (NRC), in order to most effectively expedite the safe siting and design of commercial power reactors in the U.S. through topical and areal studies of geologic processes of potential hazard to power reactors.

Progress in FY 76:

- Arranged for detailed, multidisciplinary field scrutiny and further investigation of the age of most recent movement on the Belair fault zone in Georgia, where Holocene offset had recently been proposed.
- Arranged that a scientist-coordinator be added to the multidisciplinary investigation of the Charleston, South Carolina earthquake of 1886.
- Arranged for effective use of a major increase in FY 77 for the Reactor Hazards Research Program.
- Expanded participation in both programs to better include the Offices of Earthquake Studies and of Geochemistry and Geophysics in planning and in work.
- Arranged the Origins of Northeastern Seismicity projects, (Geology, Geophysics, Seismology) for FY 77, as a key step in expanding the study of eastern earthquakes and neotectonics.

Products in FY 76:

No formal reports.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

1 professional man-year;

\$66,600 - Reactor Hazards Research Program

15. TECTONIC, STRATIGRAPHIC, AND QUATERNARY HISTORY,
WENATCHEE REGION, WASHINGTON

9540-01592

(Wenatchee 2-Degree Sheet)

Project started - FY 75; To be completed - FY 83

The partially supported work of Swanson, Columbia River Basalt (42) is carried out in cooperation with this project.

Objectives:

To determine regional structural patterns, Cenozoic tectonic history, Quaternary geology and recency of faulting in the Wenatchee region in central Washington, which straddles the Cascades at the junction of the older crystalline terrane to the north and the Tertiary volcanics of the central Cascades to the south. Here continued crustal activity,

including at least some local Quaternary movements, is suggested by graben, Tertiary sedimentary and volcanic basins, fault zones, and regional lineaments. 1:100,000 geologic maps will be prepared using existing work, new field mapping, isotopic dating and careful attention to stratigraphic correlations across structures and facies changes.

This work will be a major contribution to understanding the structure and tectonic history of central Washington and to assessment of the potential for surface faulting and earthquakes there.

Progress in FY 76:

- Evidence of Quaternary faulting is lacking along the major faults that mark the north-trending Chiwaukum graben, although some uncertainty remains and a major earthquake may have occurred in the area in 1872: the youngest demonstrated offset on the Entiat fault is post-42 m.y. and on the Leavenworth fault is post-15 m.y.; 13,000-year-old glacial deposits are not offset by the Entiat fault.
- Detailed mapping of sandstone of the early Tertiary Swauk formation and fission track ages of about 50 m.y. on interbedded tuffs show that the Swauk interfingers westward with volcanic rocks of similar age. This contrasts with previous views that the Swauk was deposited prior to eruption of the volcanics, modifies the age assessments of both, and suggests important changes in stratigraphic correlation within the main mass of Tertiary volcanics to the west, which bears ultimately on tectonic interpretations.
- Quaternary movement is indicated on the three east-trending faults in northern Kittitas Valley that offset 3.7 m.y.-old alluvium but do not affect alluvium correlated with the 0.13 to 0.14 m.y.-old glaciation of the region. The faults are probably reverse, suggesting north-south compression, and their southeastward en echelon trend may reflect right-lateral strain on the Olympic-Wallowa lineament.

Products in FY 76:

Published:

- Porter, Stephen C., 1976, Stratigraphy and distribution of tephra from Glacier Peak (of 12,000 years ago) in the North Cascade Range, Washington: U.S. Geol. Survey open-file report 76-186.
- Whetten, John T., 1976, Tertiary sedimentary rocks in the central part of the Chiwaukum graben, Washington (Abs.): Geol. Soc. America Abs. with Programs, v. 8, no. 3, p. 420.
- Whetten, John T., and Laravie, Joseph A., 1976, Preliminary geologic map of the Chiwaukum 4 northeast 7-1/2-minute quadrangle, Chiwaukum graben, Washington: U.S. Geol. Survey MF Map 794, 1:24,000.

To Branch:

- Frizzell, V. A., and Tabor, R. W., Stratigraphy of Tertiary arkoses and their included monolithologic fanglomerates and breccias in the Leavenworth fault zone, central Cascades, Washington: to be abstract for Geol. Soc. America.
- Waite, R. B., Jr., 1976, Missoula Flood sans Okanogan Lake: to be abstract for Geol. Soc. America.
- Waite, R. B., Jr., Evolution of glaciated topography of upper Skagit drainage basin, Washington: to be article for Arctic and Alpine Res.
- Waite, R. B., Jr., Late Cenozoic deposits and tectonism in Kittitas Valley, Washington: to be article for U.S. Geol. Survey Jour. Research.
- Waite, R. B., Jr., Rockslide avalanche across tongue of late-Fraser Cordilleran ice in Pasayten Valley, Washington: to be article for Geology.
- Whetten, J. T., Sedimentology and structure of part of the Chiwaukum graben, Washington: to be abstract for Geol. Soc. America.

Changes Planned in FY 77:

- One quarter of Waite's time is diverted to provide Quaternary expertise for Fox's Tectonic Analysis, Washington (21).
- Budget limitations have caused work on the Eocene sediments of the Chiwaukum graben and details of its bounding Entiat fault by J. T. Whetten of the University of Washington to be deferred and possibly terminated.

Bureau-Level Funding in FY 77:

2-1/2 professional man-years

\$141,200 - Reactor Hazards Research Program

16. CENOZOIC TECTONICS OF WEST-CENTRAL ARIZONA

9540-01612

I. Lucchitta, Branch of Western Environmental Geology

Project started - FY 76; To be completed - FY 77

Objectives:

In the basin-range west of the Colorado Plateau, to prepare geologic maps of four 7-1/2-minute quadrangles through detailed mapping and of two others largely by compiling previous work. This will identify any Quaternary faults and establish local Cenozoic tectonic history as an aid to understanding regional relations in an area at the north-west end of a belt of anomalously northeast-trending ranges where the Texas lineament and the Wasatch line intersect.

This work will provide a local assessment of recent tectonics, perspective on the tectonically quiet Mojave-Sonorran zone to the west recently proposed by W. J. Carr, and a basis for better interpretation of regional tectonics.

Progress in FY 76:

- Diverse older crystalline rocks and overlying Cenozoic clastic, evaporitic and volcanic rocks are cut by 1) low angle thrusts that involve crystalline rocks and Tertiary sediments and shed and overrode chaotic breccias and 2) by younger, northwest-trending high-angle faults that cut all but the youngest, Quaternary, deposits.
- Evidence of faulting appears absent in the diverse and abundant Quaternary deposits in the area, except for one possible Quaternary outcrop cut by several small faults.

Products in FY 76:

To Branch:

Lucchitta, Ivo, and Suneson, Neil, A middle-Cenozoic tectonic breccia in west-central Arizona: description and implications (Abs.): for Geol. Soc. America, 1977 Rocky Mountain Section Meeting.
_____, Cenozoic volcanism and tectonism, west-central Arizona (Abs.): for Geol. Soc. America, 1977 Cordilleran Section Meeting.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

1 professional man-year

\$57,600 - Reactor Hazards Research Program

17. TECTONIC STUDIES, SAN JOAQUIN VALLEY -
SOUTHERN SIERRAN FOOTHILLS, CALIFORNIA

9540-01624

J. A. Bartow, Branch of Western Environmental Geology

Project started - FY 75; To be completed - FY 80

This project works in close cooperation with the complimentary Sacramento Valley project (18).

Objectives:

To determine the regional Cenozoic depositional and tectonic history of the San Joaquin Valley (southern Great Valley) and adjacent southern Sierran foothills, through surface and subsurface geologic studies, with emphasis on recency of deformation and stratigraphic, radiometric, geomorphic, and pedologic means of dating it. This deep marine to non-marine sedimentary basin records Cenozoic deformation internally and along its borders and contains a nearly complete Quaternary record of great local and topical value.

This work, together with that of the Sacramento Valley project (18), will be a major contribution to the assessment of the history and recency of deformation and the potential for faulting and earthquakes in the Great Valley and Sierran foothills.

Progress in FY 76:

- At least 14 cycles of deposition, soil formation during surface stability, and incision by erosion are recorded by the Quaternary non-marine deposits mapped in the eastern San Joaquin Valley. These appear to correlate with long Quaternary records elsewhere, and offer excellent local Quaternary dating control as well as superb continental data on Quaternary climate variations.
- Evidence for recency of movement on a set of faults east of Bakersfield that trend northeastward out into the San Joaquin Valley, some of which showed small surface offsets during the 1952 Arvin-Tehachapi earthquakes, is significantly extended west- and northwestward by apparent offsets of a previously unrecognized Quaternary unit (possible correlative of middle (?) Pleistocene Riverbank Formation).

Products in FY 76:

Published:

- Bartow, J. A., and Doukas, M. P., 1976, Geology of the Oil Center, Rio Bravo Ranch, Lamont, and Edison 7-1/2-minute quadrangles, California: U.S. Geol. Survey open-file report 76-592, map scale 1:62,500.
- Marchand, D. E., 1976, Preliminary geologic maps showing Quaternary deposits of the northern Merced area, eastern San Joaquin Valley, Merced and Stanislaus Counties, California: U.S. Geol. Survey open-file report 76-836, 1:24,000 (8 7-1/2' quads).
- Marchand, D. E., 1976, Preliminary geologic maps showing Quaternary deposits of the Merced area, eastern San Joaquin Valley, Merced County, California: U.S. Geol. Survey open-file report 76-837, 1:24,000, (7 7-1/2' quads).
- Marchand, D. E., 1976, Preliminary geologic maps showing Quaternary deposits of the southern Merced area, eastern San Joaquin Valley, Merced and Madera Counties, California: U.S. Geol. Survey open-file report 76-838, 1:24,000, (7 7-1/2' quads).
- Marchand, D. E., 1976, Preliminary geologic maps showing Quaternary deposits of the Chowchilla area, eastern San Joaquin Valley, Madera and Merced Counties, California: U.S. Geol. Survey open-file report 76-839, 1:24,000, (5 7-1/2' quads).
- Marchand, D. E., 1976, Preliminary geologic maps showing Quaternary deposits of the Daulton area, eastern San Joaquin Valley, Madera County, California: U.S. Geol. Survey open-file report 76-840, 1:24,000, (4 7-1/2' quads).
- Marchand, D. E., 1976, Preliminary geologic maps showing Quaternary deposits of the Madera area, eastern San Joaquin Valley, Madera and Fresno Counties, California: U.S. Geol. Survey open-file report 76-841, 1:24,000, (8 7-1/2' quads).
- Marchand, D. E., and Harden, Jennifer, 1976, Soil chronosequences, northeastern San Joaquin Valley, California [abs.]: American Quaternary Assoc., Abstracts of the Fourth Biennial Mtg., Tempe, Ariz., p. 110.

To Branch:

- Bartow, J. A., and Doukas, M. P., Preliminary geologic map of the southeastern margin of the San Joaquin Valley: to be 1:125,000 MF map.
- Helley, E. J., Geologic map of the alluvial fan of the Chowchilla River and adjacent foothill area, Mariposa, Merced, and Madera Counties, California: to be 1:62,500 MF map with text.
- Marchand, D. E., Late Cenozoic climatic history of central California as inferred from the surface and subsurface stratigraphy of the eastern San Joaquin Valley (abs.).
- Marchand, D. E., and Allwardt, Alan, Late Cenozoic stratigraphic units, northeastern San Joaquin Valley, California: to be an article for U.S. Geol. Survey Bull.

Changes Planned in FY 77:

The earlier Great Valley project is restricted to the southern San Joaquin Valley, its staff is enlarged from 2 to 3-1/2 professionals, and a complimentary project is established to study the northern, Sacramento Valley.

Bureau-Level Funding in FY 77:

3-1/2 professional man-years

\$212,700 - Reactor Hazards Research Program

18. SACRAMENTO VALLEY-NORTHERN SIERRAN FOOTHILLS, CALIFORNIA 9540-01943

E. J. Helley, Branch of Western Environmental Geology

Project started - FY 77; To be completed - FY 80

This project works in close cooperation with the complimentary San Joaquin project (17).

Objectives:

To determine the regional Quaternary depositional and structural history of the Sacramento Valley (northern Great Valley) and Sacramento Delta and the Mesozoic and Cenozoic history of the adjacent Sierran foothills through surface and subsurface geologic studies and selected hydrologic and geophysical studies, with emphasis on the geometry and recency of deformation and the stratigraphic, geomorphic and pedologic means of dating it. This is a deep sedimentary basin similar to the San Joaquin (17), but consisting largely of alluvial deposits.

This work, together with that of the San Joaquin project (17), will be a major contribution to the assessment of the history and recency of deformation and the potential for faulting and earthquakes in the Great Valley and Sierran foothills.

Progress in FY 76: Preliminary work for this new project yields:

- Soil stratigraphy can be used as a principal tool to efficiently distinguish and map surficial Quaternary deposits, as developed through work in the San Francisco Bay region and the San Joaquin Valley.
- The western margin of the Sacramento Valley in Yolo County contains scattered northwest-trending faults that displace Holocene deposits.
- Displacements of late Tertiary and some Quaternary units (based on trench examinations and the work of consultants) are indicative of continuing late Cenozoic movement along the complex Foothills fault system east of the northern Great Valley, which is consistent with the slight surface rupture accompanying the M 6 Oroville earthquake of August, 1975.

Products in FY 76:

None - new project.

Changes Planned in FY 77:

Begin project in order to increase rate of progress of earlier Great Valley project and give greater attention to faults in Sierran foothills.

Bureau-Level Funding in FY 77:

1-1/2 professional man-years

\$105,700 - Reactor Hazards Research Program

19. PENINSULAR RANGES TECTONICS, CALIFORNIA

9540-01625

V. R. Todd, Branch of Western Environmental Geology

Project started - FY 75; To be completed - FY 79

Objectives:

To establish mappable geology in the poorly known south Santa Ana block east of San Diego, California, identify any faults within the block and those that form its eastern margin and determine their histories and recencies of movement, and understand the emplacement, metamorphic and deformational history of the southern Peninsular Ranges batholith, through detailed and reconnaissance mapping, supported by petrology and isotopic dating, and including compilation of a 1:125,000-scale geologic map.

This work will determine the extent to which the south Santa Ana block is broken by faults, evaluate their significance, and provide important perspective on the geologic history of sothern California.

Progress in FY 76:

- Three newly recognized fault zones with probable Quaternary displacement suggest that at least the eastern third of the south Santa Ana block is broken by faults that splay southward from the southern end of the right-lateral part of the Elsinore fault zone. The faults follow the metamorphic grain of the rocks, vertically displace the sheeted plutonic complexes, and at least some faults in each zone have young topographic expression and locally appear to cut colluvium.
- Additional faults cutting late Quaternary sediments have been found along the southeastern trend of the Elsinore fault zone at the eastern margin of the Santa Ana block: these form complexes of short breaks with vertical displacement rather than being throughgoing faults.
- The batholith is syntectonic, and consists of sheeted plutonic complexes that were emplaced in a sedimentary pile during folding and amphibolite facies metamorphism. Both plutonic and metasedimentary rocks acquired a steeply dipping metamorphic foliation and were thrown into a series of large open folds.
- A major change in postulated magma evolution may be required, for the large gabbro bodies (San Marcos) seem to be roof pendants restricted to synformal troughs, and thus to predate the granitic rocks, rather than being younger, deeply rooted stocks.

Products in FY 76:

Published:

- Hoggatt, W. C., and Todd, V. R., 1976, Potassium-argon dating of metamorphic and plutonic rocks from Cuyamaca Peak and Mount Laguna 15' quadrangles, San Diego County, California (abs.): Geol. Soc. America Abstract with Programs, v. 8, no. 3, p. 382-383.
- Todd, V. R., and Hoggatt, W. C., 1976, The Elsinore fault zone in the Tierra Blanca Mountains, eastern San Diego County, California (abs.): Geol. Soc. America Abstract with Programs, v. 8, no. 3, p. 416-417.

To Branch:

- Todd, V. R., Geologic map and cross-section of Cuyamaca Peak 7-1/2-minute quadrangle, San Diego County, California: to be U.S. Geol. Survey open-file map, 1:24,000.
- Todd, V. R., Mafic plutonic rocks of two ages in the Peninsular Ranges batholith, south-central San Diego County, California: to be abs. for Geol. Soc. America, Cordilleran Section, 1977.
- Todd, V. R., Syntectonic batholithic rocks in south-central San Diego County, California--a preliminary report: to be paper in Cal. Div. Mines & Geol. Bull.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

1-3/4 professional man-year

\$59,500 - Reactor Hazards Research Program

20. TEPHROCHRONOLOGY, WESTERN U.S.

9540-01947

A. M. Sarna-Wojcicki, Branch of Western Environmental Geology

Project started - FY 77; To be completed - FY 80

Objectives:

To identify, characterize, and date widespread late Cenozoic volcanic ashes and tuffs in California and other western regions, and thereby provide an accurate and ubiquitous time-stratigraphic framework within which tectonic and other geologic events and sequences can be dated and correlated. Ash and tuff correlations are based on trace- and minor element analyses of glass separates, which are dated using fission track and K-Ar age techniques. Fission track dating is being done within the project under the supervision of Charles Meyers.

This work will help establish a detailed and coordinated late Cenozoic ash stratigraphy in the western U.S., which will serve as a key tool in determining the histories of hazardous geologic events.

Progress in FY 76:

- The Friant Pumice (age: $0.6 \pm .02$ my), one of several ashes and tuffs documented in the California Great Valley and adjacent areas, forms a particularly widespread time marker that has been identified 300 km to the south near Ventura, 450 km to the southeast in the Salton trough, and probably in the Mojave Desert.
- The opportunity for absolute age calibration of Plio-Pleistocene biostratigraphy in California is offered by 6 ashes in a 6000-meter-thick marine sedimentary section near Ventura. Three of these ashes are now correlated with previously dated ashes (ages 0.6, ~0.7, and 1.2 my) and 3 are under study.
- Identification of the Lawlor Tuff (age: 4.0 my) over a large region in California has overcome paleontologic limitations and permitted correlation of horizons within the Sonoma Volcanics, continental Livermore gravels, and marine Etchegoin Formation.

Products in FY 76:

Published:

Sarna-Wojcicki, A. M., 1976, Correlation of late Cenozoic tuffs in the central Coast Ranges of California by means of trace- and minor-element chemistry: U.S. Geol. Survey Prof. Paper 972.

Changes Planned in FY 77:

Formalize as a new project, and expand and help focus on Reactor Hazards needs, an informal activity underway in Western Environmental for the past four years.

Bureau-Level Funding in FY 77:

1-1/4 professional man-years

\$99,400 - Reactor Hazards Research Program

21. TECTONIC ANALYSIS, WASHINGTON

9540-01944

K. F. Fox, Branch of Western Environmental Geology

Project started - FY 77; To be completed - FY 77

Objectives:

To prepare a tectonic analysis of Washington state in the perspective of plate tectonics, primarily using existing data. The resultant 1:500,000-scale tectonic map will include domains of coherent stratigraphy and structure and their boundaries, major geologic lineaments, past stress orientations from structural features, present plate geometry and recently active volcanoes and faults.

This work will provide a coherent synthesis of existing tectonic data and a basis for designing further research on recent tectonics in the state of Washington.

Progress in FY 76:

None, new project.

Products in FY 76:

To Branch:

Fox, K. F., Jr., Alkaline rocks of south-central British Columbia and northeastern Washington (Abs.): for Geol. Soc. America Rocky Mountain Section Mtg., 1977.

Changes Planned in FY 77:

Establish new, 1-year project.

Bureau-Level Funding in FY 77:

1-1/4 professional man-years

\$42,700 - Reactor Hazards Research Program

\$42,700 - Geologic Framework and Synthesis Program

22. ORIGINS OF NORTHEASTERN SEISMICITY-GEOLOGY
(New England Seismicity)

9540-01945

D. S. Harwood, Branch of Western Environmental Geology

Project started - FY 77; To be completed - FY 77

One of three coordinated projects with geophysics (Kane-38) and seismology (Pomeroy-34) working on origin of northeastern seismicity.

Objectives:

To provide the leadership for and the geologic part of a short-term multidisciplinary effort to 1) identify and examine geologic mechanisms hypothesized to explain the significant but enigmatic seismicity of the northeastern U.S. and 2) design a research program to determine the origins of northeastern seismicity. Available geologic and other data and ideas will be gathered, synthesized and further interpretations drawn therefrom, and spatial and possible causal relations will be examined between seismicity and geology, geologic history, and the present tectonic setting of the region.

This work will help guide the effective study of northeastern seismicity, which must be understood before confident and efficient evaluation of seismic hazard will be possible.

Progress in FY 76:

None, new project.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

Establish new project.

Bureau-Level Funding in FY 77:

1/2 professional man-year

\$31,200 - Reactor Hazards Research Program

23. EASTERN TRANSVERSE RANGES TECTONICS, CALIFORNIA 9540-01616

D. M. Morton, Branch of Western Environmental Geology

Project started - FY 74; To be completed - FY 80

Objectives:

To determine the tectonic history of the Eastern Transverse Ranges in southern California, particularly the late Cenozoic history, relate this history to the "Palmdale bulge" and evaluate the nature and extent of earthquake hazards.

Reactor Hazards Participation:

This is a project in the Geologic Framework and Synthesis Program, with substantial support from the Earthquake Hazard Reduction Program, to which the Reactor Hazards Research Program contributes \$10,000 toward Other Expenses to aid the study of the differences in geologic history and modern tectonic setting in different parts of southern California.

Bureau-Level Funding in FY 77:

\$10,000 - Reactor Hazards Research Program

\$181,600 - Earthquake Hazards Reduction and Geologic Framework and Synthesis Programs

25. VOLCANIC HAZARDS OVERVIEW

9550-01600

D. R. Mullineaux, Branch of Engineering Geology

Project started - FY 76; To be completed - FY 78

This project is jointly supported by the Reactor Hazards Research Program and by the Environmental Overviews Program of which it is a formal part. It interacts closely with Crandell-Volcanic Hazards (26).

Objectives:

To assess and portray the kinds, frequency, severity, and locations of potential volcanic hazards in the 48 conterminous states at scales of 1:7,500,000 and 1:2,500,000 or larger. And to determine the thickness and distribution of specific major tephra deposits from Cascade Range volcanoes for use as models of likely future tephra eruptions, including layer Yn from Mt. St. Helens, the most voluminous tephra erupted in the last few thousand years, and (if feasible) the largest single showerbed from the 6600-year-old eruption of Mt. Mazama, the most voluminous eruption in post-glacial time.

This work will provide a current assessment of volcanic hazard in the western U.S., including careful attention to ash fall, which is of special concern for reactors.

Progress in FY 76:

- A preliminary appraisal of volcanic hazards in the 48 conterminous states, published as MF-786, indicates that large-scale ashfall, pyroclastic flow, and mudflow hazards are virtually restricted to areas downwind and downvalley from Cascade Range volcanoes. Minor ashfall, lava flow, and pyroclastic flow hazards are widely but sparsely distributed throughout the western United States. Catastrophic ashflows from a few widely spaced centers are possible and effects would be widespread, but such eruptions are of very low frequency.

- Studies of the thickness and distribution of the large postglacial tephra layer Yn from Mount St. Helens reveal that potential thicknesses of tephra from eruptions of Cascade volcanoes similar to Mount St. Helens are greater than previously recognized. New data indicate that representative maximum thicknesses of layer Yn at distances of more than 50 km from the volcano are mostly 25-50% greater than indicated by the best previous data. Thus tephra presents a somewhat more severe hazard to reactor sites than previously thought.
- Ash beds in slackwater sediments associated with the last major scabland flood across the Columbia Plateau of Washington have been correlated with pumice layers of tephra set S from Mount St. Helens. This correlation indicates that the last major scabland flood occurred only about 13,000 years ago, instead of about 18,000 years ago as was previously believed.

Products in FY 76:

Published:

- Crandell, D. R., 1976, Preliminary assessment of potential hazards from future volcanic eruptions in Washington: U.S. Geol. Survey Misc. Field Studies Map MF-774.
- Mullineaux, D. R., 1976, Preliminary map of volcanic hazards in the 48 conterminous United States: U.S. Geol. Survey Misc. Field Studies Map MF-786.
- Mullineaux, D. R., Miller, C. D., and Harlow, David, 1976, Reconnaissance study of volcanic hazards from Cotopaxi volcano, Ecuador: U.S. Geol. Survey open-file report 76-799, 20 p. (also transmitted as Project Report of Ecuador Investigations, (IR) EC-5, to AID, U.S. Dept. of State).
- Natural hazards on the Island of Hawaii, 1976: U.S. Geol. Survey non-technical pamphlet, prepared from material provided by D. W. Peterson and D. R. Mullineaux.

To Branch:

- Mullineaux, D. R., Volcanic hazards: extent and severity of potential tephra hazard interpreted from layer Yn from Mount St. Helens, Washington: to be Abs. for 1977 Cordilleran Mtg., Geol. Soc. America.

Changes Planned in FY 77:

Provide partial support from Reactor Hazards Research Program in order to aid study of maximum recent tephra eruptions and the appraisal of potential volcanic hazards of Oregon.

Bureau-Level Funding in FY 77:

1 professional man-year

\$24,600 - Reactor Hazards Research Program

\$33,800 - Environmental Overviews Program

26. VOLCANIC HAZARDS

9550-00647

D. R. Crandell, Branch of Engineering Geology

Project started - FY 68; To be completed - continuing

This project is part of the Volcano Hazards Research Program with about 1/3 of its support in FY 77 from the Reactor Hazards Research Program. It interacts closely with Mullineaux-Volcanic Hazards Overview (25).

Objectives:

To study the late Quaternary behavior of volcanoes from their deposits, investigate various kinds of volcanic phenomena represented by the deposits, and develop techniques of volcanic hazards appraisal in order to provide expert advice to other agencies and to appraise potential volcanic hazards in the western conterminous U.S. and Hawaii for engineering design, land use, and disaster response and hazard mitigation. Hazards appraisals underway include a statewide appraisal for California.

This work will provide understanding of the nature and means of assessment of hazardous volcanic eruptions, using the Cascade volcanoes that are of particular interest for U.S. reactors, and will help establish the ash stratigraphy of the western U.S.

Progress in FY 76:

- Studies of the eruptive history of Mount Hood, Oregon indicate that, if future eruptions are like those of post-glacial time, the principal hazards will be hot pyroclastic flows on the flanks of the volcano and mudflows down valleys for distances as great as 75 km. Although tephra erupted directly by the volcano has been infrequent and of very small volume, clouds of hot ash generated by future pyroclastic flows could affect areas 10-20 km downwind from Mount Hood.
- A reconnaissance of the lower Stillaguamish River valley in western Washington revealed that at least one large volcanic mudflow traveled at least 90 km from Glacier Peak volcano and entered the Puget Sound lowland during the time since the last major glaciation. This mudflow caps a terrace near Arlington that is 12 m above present river level, and presumably occurred during the explosive eruptive period between 12,000 and 13,000 years ago that also produced voluminous pumice deposits.

- A technique has been developed by which the emplacement temperatures of volcanic deposits can be determined by use of thermoremanent magnetism. This technique will aid in determining the origin of coarse, unsorted deposits of volcanic rock debris, and thereby assist in reconstructing the eruptive history of volcanoes. The procedure probably can be applied to other geologic problems which require temperature information,

Products in FY 76:

Published:

- Christiansen, R. L., and Miller, C. D., 1976, Volcanic evolution of Mt. Shasta, California: Geol. Soc. America Abs. with Programs, v. 8, no. 3, p. 360-361.
- Crandell, D. R., 1976, Volcanic-hazards studies in the Pacific Northwest--a progress report, in Geomorphology of the Canadian Cordillera and its bearing on mineral deposits: Geol. Assoc. Canada, Cordilleran Sec. Programme and Abs., p. 15.
- Crandell, D. R., and Mullineaux, D. R., 1976, Potential hazards from future eruptions of Mount St. Helens Volcano, Washington: U.S. Geol. Survey open-file report 76-491, 25 p.
- Hoblitt, R. P., and Kellogg, K. S., 1976, Emplacement temperatures of unsorted and unstratified deposits of volcanic rock debris as determined by paleomagnetic techniques: Geol. Soc. America Abs. with Programs, v. 8, no. 6, p. 919-920.
- Malone, S. D., and Frank, David, 1976, Monitoring Mount Baker volcano: U.S. Geol. Survey Earthquake Inf. Bull., v. 8, no. 2, p. 21-25.

To Branch:

- Crandell, D. R., Volcanic hazards: article for Encyclopedia of Applied Geology.
- Crandell, D. R., and Rubin, Meyer, Late-glacial and post-glacial eruptions at Mount Hood, Oregon: to be abs. for 1977 Cordilleran Mtg., Geol. Soc. America.
- Frank, D. G., Meier, M. F., and Swanson, D. A., Assessment of increased thermal activity at Mount Baker, Washington, March 1975-March 1976: to be U.S. Geol. Survey Prof. Paper 1022-A.
- Friedman, Jules, Frank, D. G., Infrared surveys, radiant flux, and total heat discharge from Mount Baker volcano, Washington, between 1970 and 1975: to be U.S. Geol. Survey Prof. Paper.
- Hoblitt, R. P., and Kellogg, K. S., Emplacement temperatures of unsorted and unstratified deposits of volcanic rock debris as determined by paleomagnetic techniques: to be article for Geol. Soc. America Bull.
- Hyde, J. H., and Crandell, D. R., Post-glacial volcanic deposits at Mount Baker, Washington, and potential hazards from future eruptions: to be Prof. Paper 1022-B, map scale 1:250,000.

Changes Planned in FY 77:

David Frank was returned from regular full-time to WAE status, with resultant additional demand on project OE for salary.

Bureau-Level Funding in FY 77:

3 professional man-years

\$40,000 - Reactor Hazards Research Program

\$80,000 - Volcano Hazards Research Program

\$ 2,300 - Engineering Geology Program

27. IN-SITU STRESS IN VERMONT GRANITE
(In-Situ Stress)

9550-01602

T. C. Nichols, Jr.

Project started - FY 75; To be completed - FY 77

This project is jointly funded by the Engineering Geology Program and the Reactor Hazards Research Program.

Objectives:

To determine the magnitude and rate of external elastic and time dependent deformation released by quarrying a large (10x10x6 m) block of granite at Barre, Vermont in order to determine the relation of these deformations to changes of internally measured strain energy and to relate the strain energy to tectonic history.

This work will help explore the possible significance of stored strain energy in crystalline rock to in-situ stress measurements and to the founding of reactors on or in hard rock.

Progress in FY 76:

- Data attained from periodic deformation measurements on and within a large segment of outcropping granite and from strain relief tests on granite specimens in the laboratory demonstrate deformations that further corroborate the previous years finding, namely that:
 - There is sufficiently large near-surface strain energy to cause measurable surface deformations.

- There is a large component of stored strain energy in the Barre Granite at the outcrop and in specimens that becomes relieved in a time-dependent manner, primarily as a consequence of quarrying.
- The rock stress field cannot be entirely explained by lithostatic or other externally applied forces, as there is a measurable component of internally stored strain energy.
- Thermal changes cannot account for the external and internal deformations that occur with time. Many portions of outcrop expanded while the rock cooled.

Products in FY 76:

Published:

Nichols, T. C., Jr., and Savage, W. Z., 1976, Rock strain recovery-factor in foundation design, in Rock engineering for foundations and slopes: Proc. of a Specialty Conf. sponsored by Geotechnical Engineering Div. of Am. Soc. Civil Engineers, Boulder, v. 1, p. 34-54.

To Branch:

Nichols, T. C., Jr., and Varnes, D. J., Rocks--residual stress: to be an article in Encyclopedia of Applied Geology.

Changes Planned in FY 77:

Complete the work and prepare reports.

Bureau-Level Funding in FY 77:

1 professional man-year

\$23,200 - Reactor Hazards Research Program

\$39,300 - Engineering Geology Program

28. GROUND FAILURE RELATED TO EXTRACTION OF GROUND WATER 9550-01627
(Fissuring-Subsidence Research)

T. L. Holzer, Branch of Engineering Geology

Project started - FY 76; To be completed - FY 79

Objectives:

To seek a precise understanding of the relation between withdrawal of ground water and resultant faulting and fissuring of the ground and to develop reliable criteria for predicting such ground failure. Field and theoretical studies will be carried out on selected examples in the U.S. where surface deformation appears due to fluid withdrawal, using geologic, geodetic and hydrologic data.

This work will provide a basis for evaluating the potential for ground failure in areas subject to extraction of ground water and for distinguishing that from tectonics as a cause of fault movement.

Progress in FY 76:

- Modern surface faulting near Picacho, Arizona was recognized and demonstrated to be causally related to withdrawal of ground water.
- A means of distinguishing tectonic faulting from that driven by fluid extraction is suggested by the successful application of dislocation theory to the records of repeated level surveys along closely spaced bench marks across the Picacho fault.
- Large tension cracks in alluvial basins, here called earth fissures, are caused by shrinkage due to decline of the water table, rather than by distortion due to land subsidence as previously thought. Fissures in central Arizona, Las Vegas Valley, Nevada and San Joaquin Valley, California are best associated directly with water table declines rather than with subsidence, they extend deep into the alluvial section, and they can be demonstrated from field relations to propagate upward toward the ground surface, rather than downward.

Products in FY 76:

Published:

Holzer, T. L., and Davis, S. N., 1976, Earth fissures associated with water-table declines [abs.]: Geol. Soc. America Abstracts with Programs, v. 8, no. 6, p. 923-924.

To Branch:

Holzer, T. L., 1976, Potential active surface faulting associated with subsidence - Las Vegas Valley, Nevada: U.S. Geol. Survey admin. report.

Holzer, T. L., Davis, S. N., and Lofgren, B. E., Active surface faulting caused by ground-water extraction near Picacho, Arizona: to be abstract for Geol. Soc. America, Cordilleran Section, 1977.

Changes Planned in FY 77:

Project staff is increased by addition of J. Buchanan-Banks (1/4 man-year). Extra OE is provided for drilling to investigate subsurface geology and collect geotechnical samples near the Picacho fault, Arizona. The cooperative work of Jackens-Deformation and Ground Failure Geophysical Studies (39) is added to the Program.

Bureau-Level Funding in FY 77:

1-1/4 professional man-year

\$108,400 - Reactor Hazards Research Program

29. GEOLOGIC RECONNAISSANCE FROM IMAGERY, CALIFORNIA GREAT VALLEY 9580-01634
(Reactor Hazards)

C. A. Hodges, Branch of Astrogeologic Studies

Project started - FY 75; To be completed FY 77

This project cooperates closely with the San Joaquin (17) and Sacramento Valley (18) projects in studying the Great Valley.

Objectives:

To investigate the Cenozoic and Holocene tectonic history of the eastern Great Valley of California, insofar as it can be discerned from high-altitude imagery from LANDSAT, U-2 aircraft, SKYLAB, and side-looking radar, and to evaluate the use of such imagery and the processing techniques applicable to it for such tectonic analyses.

This work will aid study of the Great Valley and help determine to what extent rapid image-reconnaissance can aid evaluation of tectonic hazards in the western U.S.

Progress in FY 76:

- Color composites of LANDSAT imagery made by the very inexpensive Diazo process are vastly superior to black and white prints of individual frequency bands and appear to be comparable to expensive computer-enhanced images for the purposes of this study.
- The dominant lineament trends mapped from LANDSAT imagery are NW-SE, but conspicuous cross-structures and divergent trends also occur.

Products in FY 76:

None.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

1/4 professional man-year

\$13,700 - Reactor Hazards Research Program

30. BRANCH OF PALEONTOLOGY AND STRATIGRAPHY

\$127,000 is assessed for the Branch of Paleontology and Stratigraphy, and is applied as salary support to project 9590-00874. Part of this is returned to the Program by the Branch directly as 1/2 professional man-year working on the Georgia Coastal Plain project (6).

Bureau-Level Funding in FY 77:

\$127,000 - Reactor Hazards Research Program

31. STRESS MEASUREMENT

9930-01184

J. Healy, Branch of Earthquake Mechanics and Prediction

Objectives:

To develop and apply techniques for measuring in-situ stress in bore holes by the hydrofracture method. A sealed-off section of the hole is pressured and fractured and the greatest and least principal stresses are calculated from failure and shut-in pressures and their orientations determined from the fracture orientation, assuming one principal stress along the borehole due to overburden. Knowledge of stress distribution in the ground is needed to properly understand the physics of earthquake sources, and may be useful in evaluating the potential for earthquake and fault movement along individual faults or in particular terranes.

Reactor Hazards Participation:

This is a project in the Office of Earthquake Studies to which the Reactor Hazards Research Program contributes support for the development and evaluation of borehole stress measurements as an aid to understanding modern tectonics, particularly in the eastern U.S.

Bureau-Level Funding in FY 77:

\$ 7,500 - Reactor Hazards Research Program

\$156,400 (est.) - Office of Earthquake Studies

32. REASSESSMENT OF HISTORIC INSTRUMENTAL EARTHQUAKE DATA 9920-01901
(U.S. Seismogenic Provinces)

J. W. Dewey, Branch of Seismicity and Earth Structure

Project started - FY 77; To be completed - FY 80

This project works in concert with J. I. Ziony - Seismogenic Zones of the U.S. in the Earthquake Hazards Reduction Program to improve the definition and characterization of seismogenic provinces in the U.S.

Objectives:

To develop a catalog of reliable hypocenters and magnitudes for instrumentally recorded earthquakes in the eastern U.S., and ultimately for the whole of the country, in order to standardize magnitudes and correct the severe mislocations of many routinely determined epicenters for use in evaluation of seismogenic structures and provinces. Relocation of hypocenters will be done by joint hypocenter determination, with calibration events located by ray-tracing methods. Revised magnitudes (m_b , m_{bLg} , and M_S) will be computed where possible.

This work will extract the best available data concerning instrumentally recorded eastern U.S. earthquakes to permit effective use of those earthquakes in attempts to characterize and understand their sources.

Progress in FY 76:

New project.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

Establish new project.

Bureau-Level Funding in FY 77:

0.65 professional man-years

\$55,000 - Reactor Hazards Research Program

33. NORTHEAST SEISMIC NETWORK

part of 9920-01745

P. W. Pomeroy, Branch of Seismicity and Earth Structure

Project started - FY 77; To be completed - continuing

This project provides the coordination and some of the operating funds for a large seismic network involving 5 universities, one state geological survey, the U.S. Geological Survey, and several sources of funds.

Objectives:

To establish, maintain, and coordinate a regional seismic network of about 85 stations having nearly uniform recording capability for all events greater than m_b of 2 in the 10 northeastern states, in cooperation with 6 sub-network operators. Locations, depths, origin times, and magnitudes of earthquakes are determined and exchanged between the subnetworks and with the Earth Physics Branch of the Canadian Department of Energy, Mines and Resources. A bulletin of network results is published quarterly.

The gathering of adequate data concerning earthquakes in the northeast as they occur, the specific task of the northeast net, is a prerequisite for understanding the origin of those earthquakes.

Progress in FY 76:

- The network is a cooperative endeavor of the several subnetwork operators, the USGS, and the several sources of funds. It has been in existence for several years, coordinated through the USGS by Pomeroy.
- Publication of a quarterly network bulletin was begun in FY 77 to report data for all northeastern earthquakes.
- Two thirds of the 85-station network to be completed in FY 77 is now in operation.

Products in FY 76:

Published:

- Chiburis, E. F., and Ahner, R. O., Seismicity of the Northeastern United States, October 1, 1975 - December 31, 1975: Bull. no. 1, Northeastern U.S. Seismic Network.
- Chiburis, E. F., and Ahner, R. O., Seismicity of the Northeastern United States, January 1, 1976 - March 31, 1976: Bull. no. 2, Northeastern U.S. Seismic Network.
- Chiburis, E. F., and Ahner, R. O., Seismicity of the Northeastern United States, April 1, 1976 - June 30, 1976: Bull. no. 3, Northeastern U.S. Seismic Network.

Changes Planned in FY 77:

Establish the provision of a network coordinator by the USGS as a formal project.

Bureau-Level Funding in FY 77:

0.4 professional man-year (coordinator only)

The whole of the Northeast Seismic Network requires about \$650,000 in FY 77, of which \$102,500 from the USGS is provided through this project, with other funds provided directly to subnetwork operators:

To this project:

- \$ 32,500 - FY 77 Reactor Hazards Research Program
- 20,000 - FY 76 carryover, Reactor Hazards Research Program
- 50,000 - Office of Earthquake Studies

To subnetwork operators directly (including data analysis):

- \$380,000 - Nuclear Regulatory Commission
- 100,000 - New York State Energy Research and Development Authority
- 50,000 - National Science Foundation
- 10,000 - New York State Geological Survey

34. ORIGINS OF NORTHEASTERN SEISMICITY-SEISMOLOGY part of 9920-01745
(part of Northeast Seismic Network)

P. W. Pomeroy, Branch of Seismicity and Earth Structure

Project started - FY 77; To be completed - FY 77

One of three coordinated projects with Geology (Harwood-22) and Geophysics (Kane-38) working on origins of northeastern seismicity.

Objectives:

To provide the seismologic part of a short-term, multidisciplinary effort 1) to identify and examine geologic mechanisms hypothesized to explain the significant but enigmatic seismicity of the northeastern U.S. and 2) to design a research program to determine the origins of northeastern seismicity. The spatial distribution of epicenters and available fault plane solutions will be examined to identify key areas for detailed study of the interrelations between geology and seismic events, and seismologic evaluation of suggested causal mechanisms will be begun.

This work will help guide the effective study of northeastern seismicity, which must be understood before confident and efficient evaluation of seismic hazard will be possible.

Progress in FY 76:

None, new project.

Products in FY 76:

None, new project.

Products in FY 77:

Harwood, D. S., Kane, M. F., and Pomeroy, P. W., A program of research to determine the origins of seismicity in the northeastern U.S.: to be U.S. Geol. Survey admin. report.

Changes Planned in FY 77:

Establish new project.

Bureau-Level Funding in FY 77:

0.4 professional man-year

\$19,000 - Reactor Hazards Research Program

35. SYNTHETIC STRONG MOTION SEISMOGRAMS

9940-01913

W. B. Joyner, Branch of Earthquake Hazards

Project Started - FY 77; To be completed - FY 80

Objectives:

To develop economical methods for generating seismologically realistic time histories of ground motion from spatially extended earthquake sources. This will incorporate current understanding of earthquake sources and the generation and propagation of seismic waves into the prediction of strong ground motion in the absence of close-in strong motion records for large earthquakes. Time histories will be computed for statistical source models, which will be so adjusted that the time histories will have far-field spectra that match those of real strong motion records. Dislocation theory will be used in preference to the more expensive finite-element or finite-difference techniques.

This work will develop important scientific insights into the physical controls on strong ground motion and will provide realistic time histories for use in analyzing the seismic response of reactors.

Progress in FY 76:

New project.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

Establish new project involving the collaboration of several scientists and engineers in the Branches of Earthquake Hazards and Seismic Engineering.

Bureau-Level Funding in FY 77:

2.26 professional man-years

\$112,000 - Reactor Hazards Research Program

36. GEOLOGIC PARAMETERS OF SEISMIC SOURCE AREAS

9940-01503

F. A. McKeown, Branch of Earthquake Hazards

Project started: FY 77; To be completed - FY 78

Objectives:

To seek the controlling differences in geologic character of various seismic source areas in order to begin to quantitatively relate the source properties of seismic areas to fault patterns, lengths, orientations, modes and amounts of displacement. Fault dimensions, fault displacements, and shear moduli, together with other structural, petrologic and tectonic characteristics, will be graphically and-or statistically treated and used to estimate earthquake moments, frequencies, and magnitudes for specific areas.

This work will address the fundamental relations between earthquakes and regional tectonics, which must be understood before geologic data can be confidently used in evaluating earthquake potential.

Progress in FY 76:

Fault lengths and orientations had been compiled prior to initiation of the project for more than 15 fault zones or tectonic regimes in California, Nevada, and the Kentucky-Illinois fluorspar district and various statistical parameters calculated.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

Establish new project.

Bureau-Level Funding in FY 77:

1/3 professional man-year

\$23,000 - Reactor Hazards Research Program

37. FAULT LENGTH VS MAGNITUDE/MOMENT RELATIONS

9940-01267

R. A. Page, Branch of Earthquake Hazards

Project started - FY 77; To be completed - FY 78

Objectives:

To provide a basis for more accurate estimation of maximum earthquake magnitudes for design purposes by determining the quantitative relations between fault length and magnitude and seismic moment, using rupture areas delineated by aftershock hypocenters as a more realistic measure of length than the typically used minimum length from surface rupture. Rupture lengths to an accuracy of ± 10 -25% will be sought from recent detailed aftershock investigations, supplemented as necessary by original study including relocation of teleseismically recorded aftershocks greater than 6.5.

This work will bring pertinent seismologic data to bear on the critical problem of estimating maximum earthquake magnitudes from structural information, particularly fault length.

Progress in FY 76: -

None, new project.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

Establish new project.

Bureau-Level Funding in FY 77:

0.8 professional man-year

\$21,000 - Reactor Hazards Research Program

\$ 4,800 - Earthquake Hazards Reduction Program

38. ORIGINS OF NORTHEASTERN SEISMICITY-GEOPHYSICS 9730-00364
(New England Earthquake Studies)

M. F. Kane, Regional Geophysics

Project started - FY 77; To be completed - FY 77

One of three coordinated projects with Geology (Harwood-22) and
Seismology (Pomeroy-34) working on origins of northeastern seismicity.

Objectives:

To provide the geophysical part of a short-term multidisciplinary effort to 1) identify and examine the geological mechanisms hypothesized to explain the significant but enigmatic seismicity of the northeastern U.S., and 2) to design a research program to determine the origins of northeastern seismicity. The correlation of seismicity of central New England and surrounding regions with crustal structure derived from magnetic and gravity measurements will be studied.

This work will help guide the effective study of northeastern seismicity, which must be understood before confident and efficient evaluation of seismic hazard will be possible.

Progress in FY 76:

New project.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

0.5 professional man-year

\$50,000 - Reactor Hazards Research Program

39. DEFORMATION AND GROUND FAILURE GEOPHYSICAL STUDIES 9730-01894

R. C. Jachens, Regional Geophysics

Project started - FY 77; To be completed - FY 78

This project will provide geophysical participation in Holzer's Ground Failure Related to Extraction of Ground Water (28).

Objectives:

1) To help determine the physical mechanisms active during ground deformation and failure caused by the extraction of ground water, and 2) to help define the geological conditions which control the location of this type of failure.

Progress in FY 76:

New project.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

.27 professional man-year

\$22K Reactor Hazards Research Program. Cooperative with Holzer's project, Fissuring-Subsidence Research, 9550-01627, which is also funded by the Reactor Hazards Program.

\$22,000 - Reactor Hazards Research Program

40. DEEP ELECTROMAGNETIC SOUNDINGS IN NEW ENGLAND

9780-01956

J. N. Towle, Electromagnetism and Geomagnetism

Project started - FY 77; To be completed - FY 79

This project will be coordinated with Kane's Origins of Northeastern Seismicity-Geophysics (38).

Objectives:

1) To investigate the correlation between northeastern U.S. seismicity and the deep electrical structure of New England, particularly the seismicity zone trending northward from Cape Ann, 2) to interpret the electrical anomalies in terms of physical properties and, ultimately, in terms of the geological framework, and 3) (under Ted Madden of M.I.T.) to map the distribution of near-surface electrically conductive, metamorphic rocks which may affect the deep electrical sounding.

This work will help determine the value of deep electrical work in seeking to understand eastern earthquakes.

Progress in FY 76:

New project.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

1/6 professional man-year

\$48,750 - Reactor Hazards Research Program

Grants will be awarded to CIRES at the Univ. of Colorado to perform the data processing and interpretation for magnetic array study and magnetotelluric soundings and to Ted Madden of Massachusetts Institute of Technology to perform the shallow conductor study.

41. GEOPHYSICAL MAPPING OF SHALLOW FAULTS

9780-01955

V. J. Flanigan, Electromagnetism and Geomagnetism

Project started - FY 77; To be completed - FY 78

Objectives:

To apply state-of-the-art geophysical methods in the detection and mapping of shallow faults. Particular attention will be paid to understanding the physical properties of shallow faults.

Progress in FY 76:

New project.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

.15 professional man-year

\$14,625 - Reactor Hazards Research Program

42. COLUMBIA RIVER BASALT

9720-00602

D. A. Swanson, Field Geochemistry and Petrology

Project started - FY 71; To be completed - FY 82

This is a cooperative activity with Tabor's Wenatchee 2 degree Sheet project (15).

Objectives:

To map the extent and structure of Columbia River Basalt in the Wenatchee quadrangle.

Progress in FY 76:

Completed mapping of Columbia River Basalt in southeast corner of Wenatchee quadrangle.

Products in FY 76:

None.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

1/3 professional man-years (attributable to Reactor Hazards):

\$ 4,875 - Reactor Hazards Research Program

\$51,300 - Volcanic Hazards Research Program

43. URANIUM-SERIES DATING OF SOILS AND CALICHES parts of 9740-00378
(Applied Uranium Geochemistry)

J. N. Rosholt, Isotope Geology

Project started - FY 76; To be completed - FY 78

Objectives:

To test the feasibility of dating selected soils and caliches by uranium-series techniques and if feasible, apply these techniques to areas of interest to the Reactor Hazards Research Program.

This work will examine possible late Quaternary dating techniques that would expand present capabilities.

Progress in FY 76:

- Evaluated $\text{Th}^{230}/\text{U}^{234}$ dating of travertine and arid zone soil carbonates that are useful for calibrating soil dating techniques.

Products in FY 76:

Published:

Rosholt, J. M., $\text{Th}^{230}/\text{U}^{234}$ dating of travertine and caliche rinds,
(Abs.): Geol. Soc. America Abstract with Programs, v. 8, no. 6,
p. 1076.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

1/2 professional man-year

\$36,500 - Reactor Hazards Research Program

\$ 3,000 - Water Resources Division (Erosion rate and hydrologic changes due to future climatic changes)

44. THERMAL LUMINESCENCE DATING OF QUATERNARY CARBONATES part of 9740-00377
(Geochronology-Menlo Park)

R. J. May, Isotope Geology
(M. Lanphere)

Project started - FY 77; To be completed - FY 79

Objectives:

To determine the feasibility of thermal luminescence dating of young carbonate materials such as fossils and caliche.

This work will examine a possible late Quaternary dating technique that would expand present capabilities.

Progress in FY 76: New project.

- Preliminary evaluation of thermal luminescence properties of carbonates indicates a dating technique may be possible.

Products in FY 76:

None, new project.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

1 professional man-year

\$20,500 - Reactor Hazards Research Program

\$13,400 - Geothermal Program (for Thermal Luminescence work on volcanic rocks)

45. GEOCHRONOLOGY (Reston) C-14 Method

9740-00374

M. Rubin, Isotope Geology

Project started - FY 53; To be completed - continuing

Reactor Hazards Participation:

Supplemental funding is provided the project to encourage scientist collaboration, as well as C-14 age determinations, for dating problems of interest to the Reactor Hazards Research Program.

Progress in FY 76:

Dated samples related to Belair fault, Georgia.

Products in FY 76:

Prowell, D. C., O'Connor, B. J., and Rubin, M., 1975, Preliminary evidence for Holocene movement along the Belair fault zone near Augusta, Ga.: U.S. Geol. Survey open-file report, 75-680.

Bureau-Level Funding in FY 77:

\$ 5,000 - Reactor Hazards Research Program
\$87,400 - Regional Mapping and Analysis
\$ 1,000 - Geologic Division

46. RADIOCARBON GEOCHRONOLOGY (Menlo Park) 9740-01568

S. Robinson, Isotope Geology

Project started - FY 74; To be completed - continuing

Reactor Hazards Participation:

Supplemental funding is provided the project to encourage scientist collaboration, as well as C-14 age determination, for dating problems of interest to the Reactor Hazards Research Program.

Bureau-Level Funding in FY 77:

1 professional man-year
\$ 5,000 - Reactor Hazards Research Program
\$10,000 - Energy Lands Program
\$56,600 - other sources

47. GEOCHRONOLOGY (Menlo Park) K-Ar Dating 9740-00377

M. A. Lanphere, Isotope Geology

Project started - FY 71; To be completed - continuing

Reactor Hazards Participation:

Supplemental funding is provided the project to encourage continuation of the guest-investigator program of the K-Ar dating facility in Menlo Park for projects of the Reactor Hazards Research Program.

Bureau-Level Funding in FY 77:

\$ 10,000 - Reactor Hazards Research Program
\$278,600 - other sources

48. MODERN ELEVATION CHANGES, EASTERN U.S.

D. S. Wright, Geodetic Section, Eastern Mapping Center

Project started - FY 75; To be completed - FY 79

This work is directed by Lyttle - Modern Vertical Crustal Movements, and is also included in the description of that project.

Objectives:

To select and analyze lines of repeated level surveys in the eastern U.S. in cooperation with geologic investigations in order to identify elevation changes along profile lines and evaluate their geodetic validity.

Progress in FY 76:

- Profiles of elevation changes have been prepared along 3,500 km of repeated level lines in parts of nine eastern states since spring, 1975.
- A 17 cm error was demonstrated in the first-order Macon-Savannah survey line in Georgia run by the U.S. Coast and Geodetic Survey in 1917, which has served as a principal reference line for all subsequent surveying in the region. Discovery of the error obviated the necessity of geologic evaluation of this apparent modern offset on-strike with a Cenozoic fault.

Products in FY 76:

- No formal products.
- The major error in the 1917 Macon-Savannah level line described above has been corrected in both USGS and National Geodetic Survey files.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

\$45,000 - Reactor Hazards Research Program

VI. DESCRIPTION OF GRANTS

One grant at the Program level is active in FY 77. Additional grants at project level also exist.

49. AMINO-ACID DATING OF QUATERNARY FOSSILS 14-08-0001-G-247 (Application of Fossil Amino-Acid Enantiomeric Ratios to Problems in Quaternary Geochronology)

J. F. Wehmiller, Department of Geology, University of Delaware

Grant started - FY 76 (June, 1975); To be completed - FY 79

Objectives:

To develop and improve techniques of using amino-acid enantiomeric ratios to date Quaternary fossils in order to provide a reliable dating technique for materials beyond the reach of radiocarbon dating and less than about 1 my old. Two mutually supportive approaches will be used: 1) amino-acid stereochemical analysis of fossils of various taxa from deposits with rigorous stratigraphic and (where possible) chronologic control over broad latitudinal range from both the east and west coastal marine records and 2) experimental modeling of diagenetic reactions via high-temperature pyrolysis experiments on several types of modern calcareous organisms.

Progress in FY 76:

- The feasibility study using material from coastal southern California has demonstrated the geologic applicability of the amino-acid dating technique. The technique is extremely useful for correlation purposes and provides reliable age estimates back to about one million years.
- Systematic generic effects on the observed rates of racemization do exist, an observation previously made only for foraminifera from deep sea sediments. Of the six molluscan genera studied in detail from 10 localities along the west coast, Protothaca, Saxidomus and Tivela seem to form a slow group and Macoma, Tegula and Epilucina form a faster group in which the enantiomeric ratios are 30-50% greater.
- Marine terraces of post-Sangamon age have been recognized at Goleta, California and Cape Blanco, Oregon. Apparent amino-acid ages of selected molluscs from these localities are about 30,000-40,000 years, which suggests that previous young radiometric dates (C-14 and Th-230) are valid, and that terraces younger than the predominant low Sangamon terraces do exist.

Products in FY 76:

To Branch

Wehmiller, J. F., and Belknap, D. F., Alternative kinetic models for the interpretation of amino acid enantiomeric ratios in Pleistocene molluscs: to be a paper for Quaternary Research.

Wehmiller, J. F., Lajoie, K. R., Kvenvolden, K. A., Peterson, Etta, Belknap, D. F., Kennedy, G. L., Addicott, W. O., Vedder, J. G., and Wright, R. W., Correlation and chronology of west coast marine terrace deposits by fossil amino-acid stereochemistry - technique evaluation, relative ages, kinetic model ages, and geological implications: to be U.S. Geol. Survey Prof. Paper.

Changes Planned in FY 77:

None.

Bureau-Level Funding in FY 77:

1 professional man-year

\$27,000 - Reactor Hazards Research Program

MAJOR PROGRAM ACCOMPLISHMENTS IN FISCAL YEAR 1976

- Evidence for fault offset of Wisconsinan glacial deposits and glacial pavements was carefully sought but not found northwest of the Adirondacks in New York and along bedrock faults in various parts of New England. Thus the most direct geologic evidence for active faults in these glaciated seismic areas appears absent or unprofitably difficult to find, at least in the absence of better guides for focussing the effort.
- Cenozoic reverse faults have been found in some parts and may exist in many parts of the Atlantic coastal plain. A system of such faults has been documented along and east of the fall line in Virginia and a zone of reverse faults has been mapped at the margin of the coastal plain in northeastern Georgia. Similar faults are suspected elsewhere, in association with Triassic faults.
- Preliminary results suggest that significant natural potential for modern surface faulting may exist throughout the Texas Gulf Coast. Although withdrawal of ground water in the Houston region increases surface faulting there, documentation of modern surface faulting elsewhere in areas of little or no surface subsidence suggests a natural component of fault movement as well.
- Extraction of ground water has been demonstrated to be capable of causing surface fault displacement in an Arizona alluvial basin. Successful application of dislocation theory to the records of repeated level surveys along closely spaced bench marks across the Picacho fault there also suggests a means of distinguishing such movement from tectonic faulting.
- Unexpected young faults have been documented in three western areas. The eastern third of the south Santa Ana block in southern California is broken by north-trending faults of apparent dip-slip character that exhibit evidence of Quaternary offset. The Foothill fault zone in the Sierran foothills of California contains fault strands that offset Quaternary materials (based on trench examinations and the work of consultants), as well as one strand that broke the ground surface during the M 6 1975 Oroville earthquake. Three short, east-trending faults in Kittitas Valley, Washington show Quaternary offset that may be related to the nearby Olympic-Wallowa lineament.
- Two Quaternary dating techniques that have previously been used in only limited or crude fashion have been carefully demonstrated to provide useful correlation and age information. Amino acid dating of marine molluscs based on time-dependent change in the ratio of right- and left-handed isomers clearly is successful if attention is paid to generic and latitudinal variation (apparent age range - 0 to 1 million years). Measurement of thickness of weathering rinds on basaltic and andesitic stones has been demonstrated to be very promising as a means of correlating and dating glacial deposits (age range about 12,000 to 2 million years).

VIII. PROGRAM GOALS FOR FISCAL YEAR 1977

- To expand geophysical participation in the program in order to identify and begin needed geophysical research and to provide cooperative geophysical participation in existing projects.
- To expand seismologic participation in the program in order to begin or expand work on 1) improving the historic earthquake catalogue, 2) understanding the relation between earthquakes and tectonics, and 3) devising the best means of predicting time histories of strong ground motion, including high frequency components of particular interest for reactor design, in the absence of adequate records of real earthquakes.
- To review existing and newly devised hypotheses for the origin of the enigmatic seismicity of the northeastern U.S. and develop plans for a research program to understand the origin(s) of northeastern earthquakes.
- To expand work on the Atlantic coastal plain and adjacent Piedmont to determine the extent and significance of Cenozoic reverse faults now documented there and their relation to older structure, both brittle Triassic faults and older metamorphic structure.
- To pursue development of two additional techniques that may become Quaternary dating methods: thermal luminescence of carbonates (fossils, caliche, vein fillings), and U-series ratios that yield isochrons for calcic soils and accretions and non-calcic soils.
- To expand work in the California Great Valley to follow up promising work in Quaternary stratigraphy and Cenozoic geologic history and to extend that work to be adjacent Foothill fault zone, which has recently been recognized to exhibit Quaternary displacement.
- To document the existent, character, and geologic means of recognition of surface breaking faults in the Houston region, Texas, and determine the areal extent of such faulting in the whole Texas coastal plain, to follow up indications that natural as well as artificial processes may be driving modern offsets.
- To begin to have the work of the first two years of the Program yield numerous reports of results in the technical literature.

IX. PUBLICATIONS RESULTING
FROM REACTOR HAZARDS RESEARCH PROGRAM

U.S. Geological Survey

1975 - 1976

including some associated work

- Bartow, J. A., and Doukas, M. P., 1976, Geology of the Oil Center, Rio Bravo Ranch, Lamont, and Edison 7-1/2 minute quadrangles, California: U.S. Geol. Survey open-file report 76-592, map scale 1:62,500.
- Burke, R. M., and Birkeland, P. W., 1976, Reevaluation of the late Pleistocene glacial sequence along the eastern escarpment of the Sierra Nevada, California: Geol. Soc. America Abs. with Programs, v. 8, no. 6, p. 796.
- Chiburis, E. F., and Ahner, R. O., Seismicity of the Northeastern United States; October 1, 1975 - December 31, 1975: Bull. no. 1, Northeastern U.S. Seismic Network.
- ____ Seismicity of the Northeastern United States, January 1, 1976 - March 31, 1976: Bull. no. 2, Northeastern U.S. Seismic Network.
- ____ Seismicity of the Northeastern United States, April 1, 1976 - June 30, 1976: Bull. no. 3, Northeastern U.S. Seismic Network.
- Christiansen, R. L., and Miller, C. D., 1976, Volcanic evolution of Mt. Shasta, California: Geol. Soc. America Abs. with Programs, v. 8, no. 3, p. 360-361.
- Colman, S. M., and Pierce, K. L., 1976, Weathering rinds as a Quaternary age-dating technique, western United States: Geol. Soc. America Abs. with Programs, v. 8, no. 6, p. 818.
- Crandell, D. R., 1975, Assessment of volcanic risk on the island of Oahu, Hawaii: U.S. Geol. Survey open-file report 75-287, 18 p.
- ____ 1976, Preliminary assessment of potential hazards from future volcanic eruptions in Washington: U.S. Geol. Survey Misc. Field Studies Map MF-774.
- Crandell, D. R., and Mullineaux, D. R., 1976, Potential hazards from future eruptions of Mount St. Helens volcano, Washington: U.S. Geol. Survey open-file report 76-491, 25 p.
- Eaton, G. P., Prostka, H. J., Oriel, S. S., and Pierce, K. L., 1976, Cordilleran thermotectonic anomaly: I. Geophysical and geological evidence of coherent late Cenozoic intraplate magmatism and deformation: Geol. Soc. America Abs. with Programs, v. 8, no. 6, p. 818.

- Hoggatt, W. C., and Todd, V. R., 1976, Potassium-argon dating of metamorphic and plutonic rocks from Cuyamaca Peak and Mount Laguna 15' quadrangles, San Diego County, California: Abs. with Programs, v. 8, no. 3, p. 382-383.
- Lajoie, K. R., Weber, G. E., Tinsley, J. C., and Wallace, J. B., 1975, Late Pleistocene coastal tectonics, Half Moon Bay, California: Geol. Soc. America Abs. with Programs, v. 7, no. 3, p. 338.
- Lajoie, K. R., Wehmiller, J. F., Kvenvolden, K. A., Peterson, E., and Wright, R. H., 1975, Correlation of California marine terraces by amino-acid stereochemistry: Geol. Soc. America Abs. with Programs, v. 7, no. 3, p. 338.
- Marchand, D. E., 1976, Late Cenozoic stratigraphy and history of the northeastern San Joaquin Valley: some early results of a regional study: Geol. Soc. America, Cordilleran Section, 72d Annual Mtg., Abs. with Programs, v. 8, no. 3, p. 393-394.
- _____, 1976, Preliminary geologic maps showing Quaternary deposits of the northern Merced area, eastern San Joaquin Valley, Merced and Stanislaus Counties, California: U.S. Geol. Survey open-file report 76-836, 1:24,000, (8 7-1/2' quads).
- _____, 1976, Preliminary geologic maps showing Quaternary deposits of the Merced area, eastern San Joaquin Valley, Merced County, California: U.S. Geol. Survey open-file report 76-837, 1:24,000 (7 7-1/2' quads).
- _____, 1976, Preliminary geologic maps showing Quaternary deposits of the southern Merced area, eastern San Joaquin Valley, Merced and Madera Counties, California: U.S. Geol. Survey open-file report 76-838, 1:24,000, (7 7-1/2' quads).
- _____, 1976, Preliminary geologic maps showing Quaternary deposits of the Chowchilla area, eastern San Joaquin Valley, Madera and Merced Counties, California: U.S. Geol. Survey open-file report 76-839, 1:24,000, (5 7-1/2' quads).
- _____, 1976, Preliminary geologic maps showing Quaternary deposits of the Daulton area, eastern San Joaquin Valley, Madera County, California: U.S. Geol. Survey open-file report 76-840, 1:24,000, (4 7-1/2' quads).
- _____, 1976, Preliminary geologic maps showing Quaternary deposits of the Madera area, eastern San Joaquin Valley, Madera and Fresno Counties, California: U.S. Geol. Survey open-file report 76-841, 1:24,000 (8 7-1/2' quads).
- Marchand, D. E., and Harden, Jennifer, 1976, Soil chronosequences, northeastern San Joaquin Valley, California: American Quaternary Assoc., Abs. of the Fourth Biennial Mtg., Tempe, Ariz., p. 110.

- Miller, C. D., and Crandell, D. R., 1975, Postglacial pyroclastic-flow deposits and lahars from Black Butte and Shastina, west of Mt. Shasta, California: Geol. Soc. America Abs. with Programs, v. 7, no. 3, p. 347-348.
- Mixon, R. B., and Newell, W. L., 1975, Faults and flexures along the inner edge of the Atlantic Coastal Plain in northeastern Virginia: Geol. Soc. America Abs. with Programs, v. 8, no. 2, p. 231-232.
- _____, 1976, Preliminary investigation of faults and folds along the inner margin of the Coastal Plain in northeastern Virginia: U.S. Geol. Survey open-file report no. 76-330, including three 7-1/2-minute quadrangles at 1:24,000 showing selected details.
- Mullineaux, D. R., 1976, Preliminary map of volcanic hazards in the 48 conterminous United States: U.S. Geol. Survey Misc. Field Studies Map MF-786.
- Newell, W. L., Prowell, D. P., and Mixon, R. B., 1976, Detailed investigation of a Coastal Plain - Piedmont fault contact in northeastern Virginia: U.S. Geol. Survey open-file report no. 76-329.
- Nichols, T. C., Jr., and Savage, W. Z., 1976, Rock strain recovery-factor in foundation design, in Rock engineering for foundations and slopes: Proc. of a Specialty Conf. sponsored by Geotechnical Engineering Div. of Am. Soc. Civil Engineers, Boulder, v. 1, p. 34-54.
- O'Connor, B. J., and Prowell, D. C., 1976, Post-Cretaceous faulting along the Belair fault zone near Augusta, Ga.: Geol. Soc. America Abs. with Programs, v. 8, no. 2, p. 236-237.
- _____, 1976, The geology of the Belair fault zone and basement rocks of the Augusta, Georgia area: Georgia Geological Society Guidebook for 11th Annual Meeting and Field Trip, p. 21-32.
- Owens, J. P., Prowell, D. C., and Higgins, B. B., 1976, Tectonic origin of deformed strata in the upper coastal plain of South Carolina: Geol. Soc. America Abs. with Programs, v. 8, no. 2, p. 240.
- Pavrides, Louis, 1976, Guidebook for field trips 1 and 4, Piedmont geology of the Fredericksburg, Virginia area and vicinity: Geol. Soc. America, Arlington, Va., 44 p.
- Pierce, K. C., Obradovich, J. D., and Friedman, Irving, 1976, Obsidian hydration dating and correlation of Bull Lake and Pinedale Glaciations near West Yellowstone, Montana: Geo. Soc. America Bull., v. 87, p. 703-710.

- Porter, Stephen C., 1976, Stratigraphy and distribution of tephra from Glacier Peak (of 12,000 years ago) in the North Cascade Range, Washington: U.S. Geol. Survey open-file report 76-186.
- Prowell, D. C., 1976, Implications of Cretaceous and Post-Cretaceous faults in the eastern United States: Geol. Soc. America Abs. with Programs, v. 8, no. 2, p. 249-250.
- Prowell, D. C., O'Connor, B. J., and Rubin, M., 1975, Preliminary evidence for Holocene movement along the Belair fault zone near Augusta, Ga.: U.S. Geol. Survey open-file report 75-680, 12 p.
- Reinhardt, J., and Cleaves, E. T., 1976, Adjustment of saprolite to sediment loading along the Fall Line: Geol. Soc. America Abs. with Programs, v. 8, no. 2, p. 254.
- Rosholt, J. M., 1976, Th²³⁰/U²³⁴ dating of travertine and caliche rinds: Geol. Soc. America Abs. with Programs, v. 8, no. 6, p. 1076.
- Sarna-Wojcicki, A. M., 1976, Correlation of late Cenozoic tuffs in the central Coast Ranges of California by means of trace- and minor-element chemistry: U.S. Geol. Survey Prof. Paper 972.
- Todd, V. R., and Hoggatt, W. C., 1976, The Elsinore fault zone in the Tierra Blanca Mountains, eastern San Diego County, California: Geol. Soc. America Abs. with Programs, v. 8, no. 3, p. 416-417.
- Whetten, J. T., 1976, Tertiary sedimentary rocks in the central part of the Chiwaukum graben, Washington: Geol. Soc. America Abs. with Programs, v. 8, no. 3, p. 420.
- Whetten, J. T., and Laravie, J. A., 1976, Preliminary geologic map of the Chiwaukum 4 northeast, 7-1/2-minute quadrangle, Chiwaukum graben, Washington: U.S. Geol. Survey MF Map 794, 1:24,000.

USGS LIBRARY-RESTON



3 1818 00073495 2