April 1985 Volume 13 Number 2

WASHINGTON GEOLOGIC NEWSLETTER

USGS Photo

Mount Rainier volcano near Seattle, Washington, has an estimated 156 billion cubic feet – more than one cubic mile – of snow and ice on its summit and slopes, according to a new U.S. Geological Survey study. This picture was taken August 17, 1981, from the northwest looking southeast, with Mowich Lake in the center foreground.

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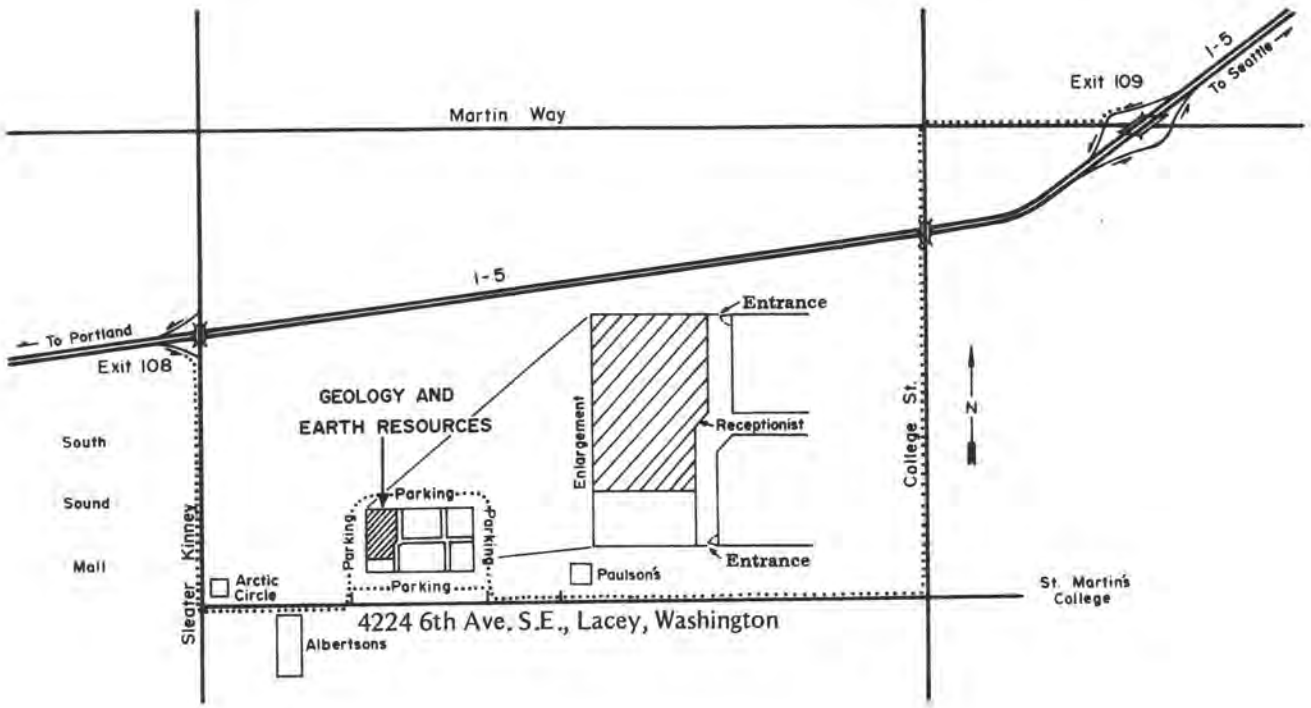

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The Washington Geologic Newsletter, a quarterly report of geologic articles, is published by the Division of Geology and Earth Resources, Department of Natural Resources. The newsletter is free upon request.

The Division also publishes bulletins, information circulars, reports of investigations, and geologic maps. A list of these publications will be sent upon request.

PROCLAMATION

WHEREAS, earthquakes have caused deaths and damage in Washington State in the past; and

WHEREAS, earthquakes are a natural threat that will always be a part of our lives in Washington State; and

WHEREAS, a damaging earthquake could occur anywhere in Washington with absolutely no warning; and

WHEREAS, the citizens of Washington State must be made aware of the potential threat of earthquakes and of those things that can be done before, during and after an earthquake to save lives, protect property and mitigate damages and injuries;

NOW, THEREFORE, I, Booth Gardner, Governor of the State of Washington, do hereby proclaim April 7 through April 13, 1985 as

EARTHQUAKE AWARENESS WEEK

in Washington.

Signed, this 1st day of March, 1985.

BOOTH GARDNER, GOVERNOR

Governor Booth Gardner signs "Earthquake Awareness Week" Proclamation for April 7-13, 1985. In attendance left to right: Dorothy Roberts, Lobbyist, Washington Congress of Parents and Teachers; Carole Martens, Assistant, University of Washington Geophysics Department; Lora Murphy, Assistant Director, Washington State Department of Emergency Management; Ray Lasmanis, State Geologist, Department of Natural Resources; Merl Sterling, Director, Pierce County Department of Emergency Management; Hugh Fowler, Director, State Department of Emergency Management; Sue Ann (Sam) Henderson, Coordinator, Puget Sound Earthquake Preparedness Project, Washington State Department of Emergency Management; Phil Cogan, Public Information Officer, Federal Emergency Management Agency, Region X.

"GUIDEBOOK FOR DEVELOPING A SCHOOL EARTHQUAKE SAFETY PROGRAM" TO BE AVAILABLE THIS SUMMER

By Robert L. Logan *

Many residents of Washington State are not aware of the fact that they live in an area where a severe earthquake could occur without warning. The last damaging earthquake shook western Washington 20 years ago in 1965 and another occurred 16 years earlier in 1949. These two earthquakes combined to cause over $200 million (1983 dollars) in property damage, killed 15 people and injured scores of others. Because damaging events happen relatively infrequently or at erratic intervals, the awareness of earthquake damage potential in Washington may diminish to dangerously low levels between quakes. Thus, many people are ill prepared to take appropriate protective action during and immediately after an earthquake. To prevent complacency, Washingtonians must occasionally be reminded of the dangers that can be brought on by a major earthquake. Furthermore, the more vulnerable segments of the population need to know how to protect themselves from quakes' disastrous effects.

In lieu of actually having a disastrous earthquake the best way to raise public awareness is to get earthquake hazards into the news. To accomplish this, each year the Governor announces Earthquake Awareness Week. This year Earthquake Awareness Week was April 7-13. Each year the press covers the Governor's pronouncement and runs a few articles, but a week later earthquake hazards are forgotten again, almost. Fortunately, there are a few dedicated individuals who work hard at earthquake hazard mitigation year-round.

One such person is State Seismologist Linda Noson, whose office is located at the University of Washington. Linda is also the project director of the Seattle Earthquake Safety and Education Project (SESEP), funded by the Federal Emergency Management Agency (FEMA). She and Carole Martens, project assistant, are in the final stages of preparing a "Guidebook for Developing a School Earthquake Safety Program." The guidebook is conceived "as an aid for developing plans to avoid or reduce adverse consequences that might otherwise occur at schools in the event of an earthquake." Developing safety plans for schools is a logical place to begin earthquake hazard mitigation, because the very young (and very old) are the most susceptible and helpless segments of society in the event of a large-scale disaster. However, the guidebook is so exhaustive in its coverage, that it can conceivably be used by other groups to better prepare Washingtonians for "the next big one."

The guidebook was designed on the premise that the degree of seismic safety is dependent on two main problems; potential earthquake hazards and inadequate preparation. These factors are addressed in a systematic step-by-step process that includes nearly every conceivable aspect of earthquake disaster planning. The guidebook includes the entire school community of principal, teachers, staff, parents, and students in the preparedness process. It is not just a response plan but an ongoing activity that includes conducting earthquake drills, the development of emergency response and shelter plans, assessing the earthquake hazards in the school, and classroom discussions and activities to help the students understand the importance of taking earthquake-ready action.

To facilitate ease in planning, the guidebook is organized into several chapters and appendices. The chapters cover the following subjects: The planning process, earthquake drills, emergency response planning, communication, post-earthquake shelter, and hazard assessment.

THE PLANNING PROCESS

Suggestions on how to plan a comprehensive earthquake safety program are presented in the guidebook. Suggestions on how to recruit support and generate interest are followed by suggestions on management techniques for an effective continuing organization. Tips such as dividing the program into manageable elements are provided. An account of the current state of preparedness in many of our schools is given to help generate interest. Figure 1 is an example of a suggested program component and illustrates some of the tasks to be addressed.

EARTHQUAKE DRILLS

The guidebook points out that "because earthquakes strike without warning, life-protecting actions must be taken immediately at the first indication of ground shaking." It suggests earthquake preparedness measures

* Geologist with Division of Geology and Earth Resources.

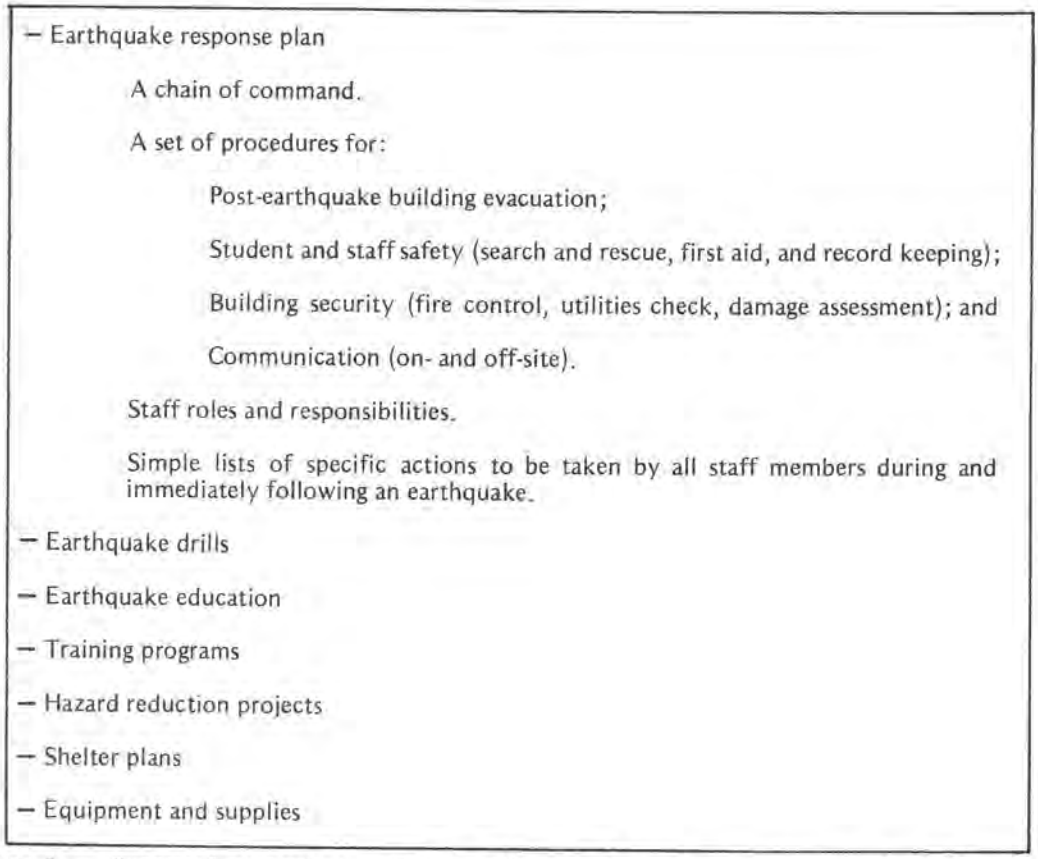

Figure 1. – Suggested program components. Several of these components can be further divided into planning units as shown in the first example.

that help prepare students and staff to react immediately and appropriately at the first indication of ground shaking. It provides suggestions for teaching students where to seek shelter and how to protect themselves from falling objects.

Students are taught what to expect during an earthquake, for example, that earthquakes can be extremely noisy, that windows may shatter, and things may fall. Such advance information helps reduce anxiety and increase confidence so that students will know how to protect themselves during an earthquake. The guidebook also provides advice on how to conduct classroom drills, how to develop procedures for evacuating the school building after an earthquake and how to practice and evaluate the effectiveness of earthquake drills.

EMERGENCY RESPONSE PLAN

This section provides a detailed list of anticipated first-hour priorities and suggests means of coping with the tasks at hand. It emphasizes the need to respond immediately by reacting to the situation as the result of being well drilled and prepared, because, in the event of an earthquake, there will not be time to stop and read a manual.

In addition to anticipated needs, this section gives suggestions on how to evaluate staff resources and training needs, what to include in an emergency response plan, and how to achieve quick and efficient action. Sample questionnaires are presented that are designed to evaluate staff resources and needs. Figure 2 is an example. The suggested emergency response plan should include a chain of command, what authority is responsible for directing emergency response activities, a set of procedures for first aid, search and rescue, communications, and so forth. A very thorough appendix addresses the means of accomplishing these needs. In short, this section emphasizes the need to "be prepared."

EMERGENCY COMMUNICATION

The need for communication following an earthquake is critical. Because electrical power and telephone lines may be disrupted for hours after an event, it is necessary to develop alternate means of communication. Parents need to be aware of emergency plans so that their actions, due to concern for their children, do not interfere with the school safety operation. Parents should be instructed not to rush to the school for their children as they are likely to impede emergency vehicles or other aid operations. Figure 3 is a suggested "letter to parents" that is designed to reassure and inform parents of emergency procedures, thereby reducing concern while in-

BRIGHTON SCHOOL
EARTHQUAKE PREPAREDNESS

To help prepare our building's plan of response to an earthquake, we need to know what skills and/or training staff members have had. Please mark all appropriate boxes in this section.

I HAVE THIS AND IT IS CURRENT	I HAD THIS, BUT IT HAS EXPIRED	I'D BE INTERESTED IN TAKING THIS	
			Red Cross Basic First Aid
			Red Cross Multi-Media First Aid
			Red Cross Advanced First Aid
			Red Cross First Aid Instructor Training
			CPR (Medic II) Training
			Industrial First Aid
			Other (Please list - e.g. EMT, Paramedic)
			Mountaineering First Aid

In the event of major damage, which is possible but unlikely, we would need to cover several areas, such as supervision of children, running a first aid station, meeting parents, searching the building for missing persons, communicating with the outside world, fire suppression, etc. Please indicate below which of these you would feel qualified and most comfortable to do.

YES	MAYBE	NO	
			Supervising students
			Running a first aid station
			Searching the building
			Communications
			Greeting parents
			Other (please describe)

NAME _____

Figure 2. – Sample of suggested form to help determine staff resources or needs.

Policies and rules parents are expected to follow should be firmly stated at parent meetings and in frequent letters to parents. Consider sending letters immediately after the occurrence of significant earthquakes in other parts of this country. Start your letter with "On . . ., a damaging earthquake occurred in . . . . Because our school is located in an earthquake-prone area, we want to remind you that in the event of an earthquake . . . ." Your "Letters to Parents" might include the following:

In the event of an earthquake:

No student will be dismissed from school unless a parent (or individual designated by a parent) comes for him/her.

No child will be allowed to leave with another person, even a relative or babysitter, unless we have written permission to that effect or that particular person is listed on the student's emergency card in our files. With this in mind, if your child's card is not up to date, please request a new card from our office.

All parents, or designated parties, who come for students must have them signed out at the office or at the temporary Student Release Station at the entrance to the schoolyard. Signs will be posted (indicate where) if this alternate location is required.

We are prepared to care for your children in times of critical situations. If you are not able to reach the school, we will care for your child here. We have a number of people with first-aid certificates, and we will be in communication with various local emergency services. We do ask for your help in the following areas:

- Please do not call the school – we must have the lines open for emergency calls.
- Following an earthquake or other emergency, do not immediately drive to the school – streets and access to our school may be cluttered with debris. The school access route and street entrance areas must remain clear for emergency vehicles.
- Do turn your radio to . . . or . . . on the A.M. dial. Information and directions will be given over the radio. Remember to allow time for information to be collected and relayed to the station.

Figure 3. – Suggestions of points to include in letters to parents.

creasing cooperation. The communication section of the guidebook also suggests alternate means of communication with emergency service agencies. Various colored flags, plastic panels, and walkie talkies are examples of devices that might be especially useful in communicating with aircraft, possibly the only source of help during the critical first few minutes.

POST-EARTHQUAKE SHELTER PLANNING

This section addresses the need for caring for children whose parents are unable to reach the school, and suggests means for providing both short and long term shelter and care. It emphasizes the importance of not releasing children to travel the streets that would probably be covered by debris and fallen power lines. This section, like the others, gives very detailed suggestions on how to fulfill the need for shelter.

HAZARD ASSESSMENT

This section was designed to reduce hazards within the school, and hazards to the school from external sources. For example, internal hazards could be from falling objects, fire, gas leaks, or fallen electrical fixtures, while external hazards could be caused by the school's proximity to hazardous material sites, dams or disrupted evacuation routes. Again, very detailed and thorough suggestions are made. Figure 4 is an example of just one of the many forms suggested for assessing various aspects of hazard reduction.

Two additional sections will be incorporated into the guidebook. They are entitled "Earthquake Education" and "Community Partnerships." Appendices A through H will also accompany the guidebook. Several of these appendices will be in brochure format and can be used independently by the different groups within the school

COMMITTEE WORK PLAN
CLASSROOM HAZARD ASSESSMENT

- Tally classroom hazards from Classroom Hazard Inventory forms.
- Recommend remedies/objectives.
- Develop and assign tasks.

Planning Problem: Classrooms contain:

____ unsecured bookcases,

____ unsecured freestanding cabinets,

____ unsecured wall shelves,

____ unsecured TV monitors, and

____ rolling pianos.

(Give numbers of bookcases, cabinets, etc., involved.)

Recommendation: Determine and implement best procedures for securing bookcases, cabinets, wall shelves, TVs, and rolling pianos.

Tasks:

Meet with maintenance personnel at school or district office.

Determine whether or not parents can be recruited to help.

Determine cost of bolts, brackets, etc.

Identify possible funding support.

Establish work schedule.

Conduct project.

Person Responsible:_____ Report Due:_____

Figure 4. – Committee work plan for addressing classroom hazards

community. For example, Appendix B is the teacher's package for earthquake drills and Appendix C is an earthquake safety checklist.

Not enough can be said about the thoroughness of the guidebook; it even has an appendix that explains how to help cope with emotional problems such as anxiety brought on by earthquakes, an aspect not usually considered, but nonetheless important. Because of such thoroughness many of the suggestions in the guidebook may be applied to disaster situations other than earthquakes.

The guidebook is scheduled to go to press this summer and should be available in the fall. Its release will be announced in our newsletter. For further information contact Linda Lawrance Noson, Project Director, University of Washington, Geophysics Program AK-50, Seattle, WA 98195, (206) 543-7640.

LEGISLATIVE UPDATE

As of April 25, Substitute Senate Bill 3448, primarily concerning structural safety in public school buildings, is still alive. It apparently is being held up by the House over budgeting concerns.

Substitute House Bill 493, establishing a Seismic Safety Commission, has passed both houses and now awaits the Governor's signature (or veto).

Anyone interested in the progress of the bill should call the Legislative Hotline (1-800-562-6000) or contact Carole Martens at (206) 543-0817 or 524-4921. Carole is a registered citizen lobbyist and has been actively involved in the Seattle Earthquake Safety and Education Project.

Vic Condiotty/Seattle Times

The failure of unreinforced brick parapets on building fronts was responsible for this damage which occurred during the 1965 earthquake. This photo was taken on South King Street in Seattle.

PLATE TECTONICS AND WASHINGTON EARTHQUAKES

by Linda Lawrance Noson *

The surface of the earth is made up of pieces that move very slowly on a thin, soft layer about 60 miles underground. These pieces are called plates. Most of the ground underneath the Pacific Ocean moves as one plate (Pacific Plate). North America and the western part of the ground under the Atlantic ocean moves as another plate (North American Plate). Ninety percent of the world's earthquakes occur at the boundaries between plates where pressure builds up between them.

There are three kinds of plate boundaries: (1) a spreading boundary, where one plate moves away from another causing new hot material to "bleed" up into the opening between them; (2) a convergent boundary where one plate moves toward another causing either a collision zone or an overlapping of plates, and (3) a transform boundary where two plates move past each other side-by-side.

The spreading boundary and the transform boundary are both visible at the earth's surface causing spreading ridges and surface faults, respectively. The San Andreas

* Seismologist, University of Washington.

Fault in California is an example of a transform boundary between the North American Plate and the Pacific Plate. The side-by-side motion between these two plates breaks the surface, bending roads, fences, and rivers as the two plates move past each other. Both of these types of boundaries have shallow earthquakes.

The convergent boundary is not at the surface, but down below where one plate slides underneath the other. The greatest pressures exist along this boundary and thus the largest earthquakes occur there. Smaller earthquakes do occur in the overlying plate as well. Washington is over the convergent boundary between the North American Plate and the downward moving Juan de Fuca Plate. Our largest earthquakes have occurred deep underneath Puget Sound. Therefore, major surface faults like the San Andreas do not occur in Washington. A fault map of Washington would not be useful to determine where future earthquakes might occur, but would instead be an historical record of past earth movements. If you are interested in Washington earthquakes, then look at earthquake maps not fault maps.

In general, how big an earthquake is expected to occur depends upon how large an area may break. At spreading boundaries where the plates are thin and hot, earthquakes are small. Convergent boundaries would be expected to have the biggest earthquakes because of the large area between the two overlapping plates. This area would be much larger than along a transform boundary (imagine two playing cards overlapped, versus edge-to-edge). The 1964 magnitude 8.6 Alaska earthquake occurred along the convergent boundary between the North American Plate and the downward moving Pacific Plate. Transform boundaries have much larger earthquakes than spreading boundaries (the San Francisco 1906 earthquake was a magnitude 8.25), but are not expected to have ones as large as those at convergent boundaries.

Although Washington is over a convergent boundary, the largest earthquake reported in the state has only been a magnitude 7.5. Why have we not had the larger Alaska-type earthquakes here? It has been suggested that (1) the Juan de Fuca Ridge where new hot material is coming up, is so close that the convergent boundary is too warm and breaks before sufficient pressure can be built up to cause a great earthquake; (2) the Juan de Fuca Plate is no longer moving underneath the North American Plate; instead the pressures in the area primarily come from movement between the North American and Pacific Plates; eventually transform faults would be expected to develop in the area; (3) the Juan de Fuca Plate is still moving down, but special conditions cause it to move aseismically (without earthquakes); or (4) we will have a "great" earthquake in the future, we just don't have them as often as at other convergent boundaries.

The fourth possibility is disturbing, and detailed studies are now being carried out in an attempt to determine how likely it is that a "great" earthquake will occur in Washington. One such study compared our convergent boundary to others around the world. Areas with similar rates of movement between the convergent plates, with material of the same age as that comprising the Juan de Fuca plate have had greater than magnitude 8.0 earthquakes. The conclusion of that report was that we probably have had greater than magnitude 8.0 earthquakes in the distant past, before records were kept, and we should expect such earthquakes in the future. How often such an earthquake would occur, however, could be once a century or once a millenium. We hope that ongoing research can refine the probable length of this interval.

EARTHQUAKES IN THE NEWS

The Geophysics program at the University of Washington reports that January, February, and March, 1985, were very shaky in Washington. Eighteen (18) earthquakes with magnitudes greater than or equal to 2.7 were recorded by instruments at the University of Washington. Compared to earthquake data collected since 1969, only 10 percent of past quarters were as active. We seem, therefore, to be experiencing a slight increase in earthquakes at or above magnitude 2.7. Since similar increases have happened before, it is thought that the recent trend may be a normal variation in the number of earthquakes.

Six (6) of these earthquakes caused ground motions strong enough to be felt by people living nearby: (1) Jan. 11 (5:08am) a magnitude 3.3 earthquake, 20km deep, located 4 miles north of Winslow on Bainbridge Island, was felt around Winslow, Discovery Bay (southeast of Port Townsend), Poulsbo, and Port Ludlow. Some people were awakened, houses shuddered, shook and rattled; (2) Feb. 10 (12:29pm) a magnitude 3.9 earthquake, 13km deep, located in northeastern Oregon vibrated a few chairs at the Umatilla Army Depot; (3) Feb. 28 (9:01am) a magnitude 3.7 earthquake, 46km deep, located near Seattle jolted the area, jiggling some pictures and shades; (4) March 5 (6:13am) a 9km deep, magnitude 3.1 earthquake located about 5 miles north of Arlington was reported as felt; (5) March 18 (9:15am) a magnitude 3.5, 52km deep event located in the Gig Harbor area rattled dishes in Gig Harbor and Tacoma and gently rocked the Kirkland, Edmonds, and Seattle areas; (6) March 20 (6:39pm) a magnitude 3.0, 7km deep event located north of Renton shook Renton, Bellevue, and Seattle.

On March 13 (11:35am) a magnitude 6.0 earthquake occurred along the very active Blanco Fracture Zone about 140 miles west of Coos Bay, Oregon. People in Portland, Eugene, and Corvallis reported rocking and rolling motions.

USGS Photo

Mount Rainier has 23 major glaciers that are among the nation's most accessible to the public. The volcano's ice and snow cover more than 35 square miles of land surface, and the thickest ice is 705 feet thick on Carbon Glacier.

VAST AMOUNTS OF ICE AND SNOW ARE ATOP CASCADE VOLCANOES

More than one cubic mile of snow and glacier ice lies on the summit and slopes of Mount Rainier volcano in the state of Washington, according to a new United States Geological Survey (USGS) study announced by a press release from the Public Affairs office of the USGS on March 21, 1985.

The study reports that if melted, the 156 billion cubic feet of snow and ice on Mount Rainier would be equivalent to more than 24 days of average flow of the Columbia River at The Dalles, Oregon, during January 1985, or equal to more than 85 percent of the amount of water stored in Franklin D. Roosevelt Lake behind Grand Coulee Dam on the Columbia River in January.

The survey of the ice and snow volume on Mount Rainier and on three other Cascade volcanoes in the Pacific Northwest is part of a continuing assessment of long-term geologic and hydrologic hazards presented by the Cascades.

The USGS study also found the following estimated amounts of ice and snow stored on the other three Cascade volcanoes that were surveyed:

* Mount Hood, 12.2 billion cubic feet, which is equal to more than half the water normally in Lake Bonneville behind Bonneville Dam on the Columbia River.

* Three Sisters, 5.6 billion cubic feet, which is equal to almost one-fourth of the water normally in Lake Bonneville.

* Mount Shasta, 4.7 billion cubic feet, which is equal to more than 3 percent of the water stored in Lake Shasta in January 1985.

The study of the four volcanoes was undertaken in part because the catastrophic eruption of Mount St. Helens in 1980 melted an estimated 4.6 billion cubic feet of that volcano's snow and glacier ice, which helped form large mudflows and floods that caused havoc and devastation in valleys for many miles downstream.

USGS scientists emphasized that, except for Mount St. Helens, no specific forecasts of eruptions have been issued for any of the 14 Cascades volcanoes in the United States, although none of them are extinct. Several of the mountains – including Lassen Peak, Mount Baker, Mount

Rainier and Mount Hood – have erupted during the past 200 years, however. Since 1975, as a result of increased gas emissions from its summit, Mount Baker has produced steam or meltwater – a reminder of possible deep-seated but still present volcanic heat sources.

The new USGS study showed that Rainier, Hood, Shasta, and the Three Sisters have potential snow and ice hazards similar to those that existed on Mount St. Helens. Most of the other Cascade volcanoes also have ice and snow covers.

Carolyn L. Driedger, a hydrologist at the USGS glacier-studies office in Tacoma, Washington, and Paul Kennard, formerly a geophysicist in the same office and now in private industry, said the slopes and craters of the four volcanoes that were studied hold more than 40 major glaciers, plus extensive snow fields. Twenty-three of the glaciers are on Mount Rainier, the largest of the Cascade volcanoes which extend from northern California into Canada.

"Floods and mudflows are common during eruptions of Cascade volcanoes because the snow and ice melt and often mix with soil and volcanic eruption debris," said Driedger, the principal author of the USGS report. "Studies of deposits around Cascade volcanoes show there have been numerous mudflows during eruptions in the geologic past."

"During the May 18, 1980, eruption of Mount St. Helens, the floods and mudflows that carried down the Toutle and Cowlitz Rivers and into the Columbia River demonstrated the need for predicting similar water-hazard events during possible future eruptions of other Cascade volcanoes," she added. "A basic requirement for such predictive analysis is information about the volumes and distribution of snow and ice on these volcanoes."

During the USGS study that began in 1981, aerial photographs were taken to map the areas covered by each volcano's snow and glacier ice. A backpack radar unit was used on the ground to measure the thickness of ice at representative locations, thus permitting ice volumes to be estimated.

Here are summaries from the USGS report for each of the four volcanoes:

* MOUNT RAINIER located southeast of Tacoma and Seattle, Washington, rises to 14,410 feet, has 23 major glaciers that are among the nation's most accessible to the public. The volcano has an estimated 156 billion cubic feet of ice and snow covering more than 35 square miles of land surface. The thickest ice is 705 feet thick on Carbon Glacier, which has the largest volume of ice of any Rainier glacier with 25.1 billion cubic feet. The Emmons Glacier has the largest surface, covering about 4.3 square miles.

Lahars (mudflows and volcanic debris flows) would be the major threat to people and property if a volcanic eruption of Mount Rainier should occur. In recent geologic times, melting of snow and ice has in part been responsible for mudflows that have moved as far as 70 miles downvalley beyond Auburn (about 6,000 years ago) and 30 miles to Orting (about 500 years ago). In historic times, mudflows have occurred most often in the valleys of the White, Nisqually, and Mowich Rivers and Tahoma and Kautz Creeks.

The area on Mount Rainier above 12,000 feet altitude is approximately the region of the old summit depression that contains two craters and has an ice volume of 8.7 billion cubic feet. If an eruption occurred on any side of the summit, this ice could be melted and released as water to drainages below.

* MOUNT HOOD near Portland, Oregon, with its summit at 11,245 feet, has an estimated 12.2 billion cubic feet of ice and snow covering an area of about 5.2 square miles. The volcano has nine major glaciers. Eliot Glacier has the largest volume of ice at 3.2 billion cubic feet and is thickest at 361 feet. The Coe-Ladd Glacier system covers the largest area with about eight-tenths of a square mile.

Much of the topography on the lower slopes of Mount Hood is the result of mudflows and pyroclastic flows during an eruptive period 12,000 to 15,000 years ago.

Earlier USGS studies indicated that a dome-building viscous lava eruption in the Crater Rock region might deposit debris on the White River, Palmer, Zig Zag and Reid Glaciers and affect about 2 billion cubic feet of ice and snow. An eruption outside the debris-fan region but near the summit might cause eruptive deposits on the remainder of the Mount Hood glaciers, which have an ice and snow volume of 10.5 billion cubic feet.

* THREE SISTERS (which includes North Sister, Middle Sister, and South Sister volcanic cones) west of Bend, Oregon, rising to a maximum of 10,358 feet, has five major glaciers. The volcanic complex has an estimated 5.6 billion cubic feet of ice and snow covering about 3.2 square miles.

Collier Glacier is the largest, with a surface area of more than four-tenths of a square mile, a volume of 700,000 cubic feet of ice and the greatest ice thickness at 300 feet.

There is no direct geologic evidence to indicate large-scale glacier melting during past eruptions, but there is evidence that some flank eruptions during the past 5,000 years were accompanied by small lahars, which probably were aided by rapid snowmelt. Regional eruptive patterns during that period indicate that future eruptions could occur on the south flank of South Sister. In this drainage basin are the Prouty and Lewis Glaciers, with a total volume of 800 million cubic feet of ice and snow. Eruptions north and south of the Three Sisters could pose an additonal hazard if erupted onto thick snowpack.

* MOUNT SHASTA located in northern California 40 miles south of the Oregon border, rises to 14,162

feet, has five major glaciers and has an ice and snow volume of 4.7 billion cubic feet covering an area of about 2.7 square miles. The main lobe of Hotlum Glacier has the largest area with seven-tenths of a square mile and the largest volume with 1.3 billion cubic feet, but Whitney Glacier has the thickest ice at 126 feet.

Past eruptions have included mudflows, and similar eruptions could occur in the future near the present summit or could form new vents as has happened in the past (such as the satellite cone of Shastina). But, unlike the valleys on Mount Rainier, those on Mount Shasta are not of great length, allowing mudflows, lava flows and pyroclastic flows to form deposits around the flanks of the mountain rather than many miles distant.

Mudflows, many of them unrelated to eruptions, have traveled more than 16 miles in the valleys of Mud, Ash, Whitney and Bolam Creeks and McCloud and Sacramento Rivers. About 80 percent of Mount Shasta's ice is at the tops of these drainages on the northern and eastern parts of the mountain.

The USGS report, titled "Ice Volumes on Cascade Volcanoes: Mount Rainier, Mount Hood, Three Sisters and Mount Shasta," by Carolyn Driedger and Paul Kennard, was released as USGS Open-File Report 84-581. Copies can be purchased from the Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, Box 25425, Federal Center, Denver, Colorado 80225. Prices are $33.75 for each paper copy and $8.50 for microfiche. Orders must include the report number (OFR 84-581) and checks or money orders payable to the Department of the Interior-USGS.

Copies of the report are available for inspection in the USGS Water Resources Division office in Tacoma, Washington (Suite 450, 1201 Pacific Ave.) and in the USGS Public Inquiries Offices in Spokane, Washington (678 U.S. Courthouse, West 920 Riverside Ave.), San Francisco, California (504 Custom House, 555 Battery St.), and Washington, D. C. (1028 General Services Administration Bldg., 19th and F Sts. NW).

LAURA BRAY RETIRES

After 25 years of dedicated service to the people of Washington State, Laura Bray started her well-deserved retirement on March 31, 1985.

Laura served the Division of Geology and Earth Resources, Department of Natural Resources, for the last 13 years, performing admirably as editor of the Division's technical reports, maps, and the quarterly newsletter.

One phrase expresses her philosophy: Strive for excellence. Her work won a number of awards, the most prestigeous of which was a national "Award of Distinguished Technical Communication" given by the Society of Technical Communication at their 28th annual meeting in Pittsburgh in 1981. At the state level, Division publications received recognition and awards every year.

Not all authors readily accept editorial changes. Laura's success was due not only to her professional editorial skills but also to her diplomacy, her pleasant and warm personality, and her ability to work well with a team of geologists, cartographers, and clerical staff.

We wish Laura well in her new endeavors.

BULLETIN 75 MAPS FOR SALE

Plates from Division of Geology and Earth Resources' Bulletin 75, Geology of the Wenatchee and Monitor quadrangles, Chelan and Douglas Counties, Washington, by Randall L. Gresens, 1983 are available as flat separates.

Plate 1 – Geologic map of the Wenatchee quadrangle
Plate 2 – Geologic map of the Monitor quadrangle
Plate 3 – Geologic cross sections of the Wenatchee, Monitor, Wenatchee Heights, and Malaga quadrangles

The cost of the set of three plates is $1.00 plus $1.00 handling.

BUREAU OF LAND MANAGEMENT AND FOREST SERVICE HONOR MINERS

A news release by the Bureau of Land Management, dated March 27, 1985 announced that three Pacific Northwest mining firms were honored by the Bureau of Land Management and the Forest Service for their environmentally sensitive, safe, and efficient operations on publicly owned lands, according to William G. Leavell, Bureau of Land Management Oregon-Washington State Director and Jeff Sirmon, Regional Forester.

The three who received agency awards were: Central Oregon Pumice Co., Bend, Oregon; Teague Mineral Products, Adrian, Oregon; and Vulcan Mountain, Inc., Lamona, Washington.

Leavell said, "These operators exemplify Federal policy to develop public land resources in a manner that satisfies national and local needs and provides for economically and environmentally sound exploration, extraction, and reclamation practices."

Central Oregon Pumice's surface pits on the Deschutes National Forest, produce a range of construction materials. The company actively reclaims the ground as it goes, restoring disturbed areas to agricultural and grazing land.

Teague Mineral Products has produced bentonite since 1972 from its open-cut mine. The firm routinely stockpiles the topsoil from areas to be mined in a way that maximizes moisture retention, and reclaims the ground concurrently for quality grazing. Some areas produce more forage for livestock and wildlife after mining than they did before mining.

The Gold Dike Mine operated by Vulcan Mountain, Inc., is in the active development stage, but it already shows the care and attention to site stabilization, and containment of leaching operations to prevent impacts on surrounding land.

Leavell said, "In all cases, these operators have also distinguished themselves by their attention to regulations and permit requirements, willingness to cooperate with the public, and to mitigate the effects of mining."

"Selecting this year's recipients was not an easy task. We who work with mineral explorers and developers on the public lands have been impressed with the willingness and cooperation of many operators who go beyond merely meeting requirements. To help narrow the field, we sought nominations from both BLM and Forest Service mineral specialists, state mineral resource management agencies, county commissioners, and from several Oregon and Washington mining associations," Leavell and Sirmon concluded.

MOUNT ST. HELENS FIVE YEARS LATER MAY 16-18, 1985

A symposium will be held at Eastern Washington University on the physical and social consequences of Mount St. Helens' eruptive activity and its ramifications for volcanology.

The preliminary program includes a field trip covering the eastern Washington ash fallout area. Technical sessions on Friday and Saturday include papers on soils, effects on biota and recovery, historic activity, long-term social effects, and planning.

A proceedings volume, *Mount St. Helens: Five Years Later*, will be published following the symposium. This will be a companion volume to *Mount St. Helens: One Year Later* (1982).

For futher information, contact: Michael M. Folsom or Sarah A.C. Keller, Department of Geography and Anthropology, Eastern Washington University, Cheney, Washington 99004, (509) 359-2433.

GEOLOGIC RESEARCH PROJECTS

Geological research activities conducted by colleges and universities on the geology of Washington State during 1984 are listed below:

CENTRAL WASHINGTON UNIVERSITY

Faculty Research Projects

Bedrock and economic geology mapping in the Big Maria and Little Maria Mountains, Mojave Desert, California [with Field Geology students] (Robert Bentley).

Classification and comparison of Tertiary flora of Central Washington with that of northern Europe (Edward Klucking).

Microprobe study of plagioclase phenocrysts in the Frenchman Springs Basalt flows, Washington and Oregon (James Hinthorne).

Quadrangle mapping of bedrock geology, central Washington, including portions of the Yakima Firing Range (Robert Bentley).

Sedimentary petrography and sedimentology of the Swauk Formation (Steven Farkas).

Tectonic interpretation of bedrock structures in western Columbia River basalts and underlying sedimentary strata (Robert Bentley).

Trace element and light element analysis of high-grade Be and B- containing silicate minerals (James Hinthorne).

EASTERN WASHINGTON UNIVERSITY

Faculty Research Projects

Compilation of computer data base of whole-rock chemical analyses of alkaline igneous rocks from gold deposits (Felix E. Mutschler).

Geochemistry of platinum-group elements (Mohammed Ikramuddin).

Geochemistry of the Sanpoil Volcanics and its relationship to gold-silver mineralization (Mohammed Ikramuddin).

Geologic map of the Inchelium quadrangle, Washington (James R. Snook).

Hydrogeochemical methods of exploration for gold and silver (Mohammed Ikramuddin).

Major and trace element chemistry of alkaline rock-related precious metal deposits (Felix E. Mutschler).

Major and trace element chemistry of "porphyry" molybdenum, tin-tungsten systems (Felix E. Mutschler).

Mineralogy of alkalic plutonic rocks including the Golden Horn batholith, northern Cascades, Washington (Russell C. Boggs).

Nitrate contamination of groundwater in Deer Park vicinity northeastern Washington (John P. Buchanan).

Permian bryozoans of the carbonate units of the Mission Argillite, northeastern Washington (Ernest H. Gilmour).

Quaternary geology of the northeastern Columbia Plateau (Eugene P. Kiver and Dale F. Stradling).

Rare earth elements in granitic and volcanic rocks associated with mineralization in northeastern Washington (Mohammed Ikramuddin).

Sedimentation in sand-bed braided rivers (John P. Buchanan).

Significance of stylolites in ore deposits (James R. Snook).

Surficial geologic maps and Quaternary history in the Grand Coulee, Wilbur, Lincoln, Turtle Lake, Little Falls, Wilmont Creek, Hunters, Inchelium, Bangs Mountain, Kettle Falls, Marcus, Boyds, Orient, Bossburg, and Laurier quadrangles, northeastern Washington (Eugene P. Kiver and Dale F. Stradling).

Use of remanent magnetization in correlating eastern Washington tephra deposits (William K. Steele).

Use of thallium as a potential guide to mineral deposits (Mohammed Ikramuddin).

Student Research Projects

A mineralogical and chemical study of manganese-bearing and associated rocks of the Crescent Formation, Olympic Peninsula, Washington (Eric R. Ridgway).

Biogeochemical methods of exploration for base-metal sulfides (Rick B. Lestina).

Correlation of bromine and iodine with gold in carbonaceous-type deposits using ppb detection for bromine and iodine (Linda Besse).

Depositional model of catastrophic flood bars in the Pine Creek channel, eastern Washington (Robert A. Pinotti).

Economic geology of the Sherman molybdenum prospect, Okanogan County, Washington (Grant R. Newport).

FERROS — a computerized data base for Precambrian auriferous banded iron-formations and related rocks (Glen R. Carter).

Fluid inclusions and trace element geochemistry of the Acme-Dora mining claim, Stevens County, Washington (Raimund J.C. Hahn).

Geochemical characteristics of tin-bearing granites (Fred T. Langston).

Geochemistry and petrology of the Sanpoil Volcanics and associated granitic rocks of a part of the Colville Indian Reservation, Washington (Sharon J.M. Digby).

Geochemistry and petrography of veins and wall rocks associated with gold-silver mineralization in the Republic district, Ferry County, Washington (Walter M. Martin).

Geochemistry of granitic rocks from the Newport quadrangle, northeastern Washington (Abebe Kassaye).

Gold deposits associated with alkaline plutons and volcanics — selected trace element geochemistry (Robbin M. Finch).

Granite molybdenite systems — North American Cordillera (Curtis A. Hughes).

Induced polarization-direct current resistivity methods in exploration for pre-Miocene paleo-drainage channels in eastern Washington (John S. McBeth).

Paleoenvironment reconstruction of the upper member of the Roslyn Formation of Kittitas County, Washington, with emphasis on coal exploration (D. Brent Barnett).

Paleomagnetic characteristics of the Touchet beds of the Walla Walla Valley of southeastern Washington (Donald R. Kietzman).

Paleomagnetism of Lake Missoula flood deposits in the Sanpoil River Valley of northeastern Washington (Russell G. Mitchell).

Pegmatites in northeastern Washington (John W. Aiken).

Petrography of Carboniferous dolomites, Springdale area,

Washington (Mehemed S. Gheddida).

Reconnaissance trace element geochemistry of the Loon Lake batholith, northeastern Washington (Adolphus A. Afemari).

Sedimentology of the Harts Pass Formation, north-central Washington (Robert L. Rau).

Sedimentology of the Puget Group, western Washington (Charles C. Cacek).

The geochemistry of precious metal mineralization in post-emplacement ophiolitic terrains, Ingall's ophiolite complex, Washington (Phillip C. Nisbet).

Vertical geochemical variations in granodiorites associated with porphyry molybdenum-copper deposits at Mount Tolman, Ferry County, Washington (Danelle D. Elder).

X-ray exploration for talc (Brian H. McHugh).

GRAYS HARBOR COLLEGE

Faculty Research Projects

Identification of Washington coastal dune systems and associated wetlands (James B. Phipps and Louis W. Messmer).

PACIFIC LUTHERAN UNIVERSITY

Faculty Research Projects

Geology of the Indian Creek gneiss and related rocks, Rimrock Lake area, Yakima County (Brian Lowes).

Groundwater resources of the south portion of Kitsap County [beginning phase] (Steven Benham).

Origin of vivianite in Pleistocene sediments of the Olympic coastal strip (Steven Benham).

Pleistocene stratigraphy of the Olympic coastal strip (Steven Benham).

TACOMA COMMUNITY COLLEGE

Faculty Research Projects

Guide to the roadside geology of Mount Rainier National Park, Washington (Jack H. Hyde).

Roadguide to the geology of the Mount Baker area (Jack H. Hyde).

UNIVERSITY OF WASHINGTON

Faculty Research Projects

Early Tertiary strike-slip faulting in the Washington Cascades (Joe Vance).

Fission-track dating of detrital zircon in Eocene sedimentary rocks in western Washington (Joe Vance).

Geochronology of Paleogene magmatism in the Cascades (Joe Vance).

Kettle and Okanogan Domes, northeast Washington and southern British Columbia (Kris Orr and Eric Cheney).

Metasomatic metamorphism of peridotites in Skagit Suite (Peter Misch).

Petrology and structure of the Chiwaukaum Schist and related granitic and ultramafic rocks, central Washington (Bernard Evans).

Processes and rates of erosion in sediments released by the eruption of Mount St. Helens (Tom Dunne).

Quaternary geology and geomorphology of the Puget lowland, Washington (Stan Chernicoff).

Stratigraphy and structural framework of the middle Cretaceous San Juan thrust system (Darrel Cowan, Joe Vance, and Mark Brandon).

Tectonic evolution and metamorphic history of north Cascades (Peter Misch).

Titanaugites in north Cascade greenstones (Peter Misch).

Student Research Projects

Compositional and textural variations in the Vashon till and underlying drifts in the northern and central Puget lowlands (Kathy Vanderwal).

Conditions at the base of the Puget glacial lobe inferred from till deformation, magnetic fabric and calculated sliding velocity (Nancy Brown).

Genesis of gold mineralization in the southern part of the Chiwaukum graben, Washington (Jacob Margolis).

Geology of the Island Mountain area, Okanogan County, Washington (Patricia White).

Hydrothermal activity and alteration at Mount Rainier (David Frank).

Petrogenesis of blueschist facies ironstones in the Shuksan and Easton schists, Washington (Claudia Owen).

Petrology and structure of the Easton schist, central Cascades, Washington (Robert Buchanan).

Petrology and structure of the Wenatchee Ridge area, north Cascades, Washington (Jerry Magloughlin).

Petrology of the Chilliwack composite batholith, Mt. Sefrit area, north Cascades, Washington (Jeffrey Tepper).

Sedimentological and tectonic significance of the Tithonian-Neocomian clastic sequence of the Decatur terrane, San Juan Islands, Washington (John Garver).

Sedimentology, depositional history and tectonic significance of the Eocene Chumstick Formation, central Cascade Range, Washington (Jim Evans).

Sedimentology and tectonic significance of the Cenomanian Ventura Member, Midnight Peak Formation, north-central Washington (David Mohrig).

Structural features along the margin of Kettle and Okanogan Domes, northeastern Washington (Kris Orr).

WASHINGTON STATE UNIVERSITY

Faculty Research Projects

Analysis of published geophysical maps of the southeastern Columbia Plateau and tectonic implications (R.L. Thiessen).

Columbia River Basalt in the Lewiston Basin/Anatone area (P.R. Hooper).

Comparison of lineaments picked off a single band Landsat Thematic Mapper image for the Richland area and previous multi-platform lineament studies (R.L. Thiessen).

Continuing work on the post-basalt studies in southeast Washington (G.D. Webster).

Eocene lacustrine sedimentation in the Republic graben, north-central Washington (David Gaylord).

Geologic mapping in southeast Washington (G.D. Webster).

Lineament orientations for the southeastern Columbia Plateau and tectonic implications for crustal structure (R.L. Thiessen).

Northeastward extension of the Hite fault as shown on gravity data and profile modeling (R.L. Thiessen).

Sedimentology and diagenesis of allochthonous Permian limestones, northeastern Washington (S.L. Dorobek).

Strain analysis and kinematic interpretation of the Kootenay arc in Washington (A.J. Watkinson and M. Ellis).

Student Research Projects

Characterization of fractures within the Museum and Rocky Coulee flows of the Columbia River basalts (Joyce Meints).

Computer analysis of western Washington seismicity — Are there any planar structures defined by alinement of the earthquakes? (Eric Rieken and R.L. Thiessen).

Definition of the cratonic margin in southwest Washington using gravity and magnetic surveys (Greg Mohl and R.L. Thiessen).

Finite strain determinations and relation to structure on the west side of the Okanogan dome, Washington (Jeff Volk).

Fission-track dating of the Palouse loess (Kevin Nelstead).

Geology and petrology of the Eocene plutonic suite east of the Republic graben, Republic quadrangle, Ferry County, Washington (Grace Holder).

Gold vein and porphyry copper mineralization in the McCoy Creek district, Skamania County, Washington (John Link).

Origin and emplacement of Colville batholith, with reference to exposures in the Seventeenmile Mountain and Bald Knob quadrangles (Wade Holder).

Paleomagnetic and structural analysis of a portion of the Umtanum Ridge (Andy Bartotti).

Paleomagnetic rotations of the Pomona intercanyon flow from Kahlotus eastward (Jose B. Lim and R.L. Thiessen).

Sedimentology and stratigraphy of the interbed overlying the Wanapum Formation in the Lewiston Basin, Washington-Idaho (John Lundquist).

Stratigraphy and depositional setting of the Lower Cambrian Addy and Gypsy Quartzites, northeastern Washington (Kevin Lindsey).

Stratigraphy and sedimentology of the Lower Cambrian Addy Quartzite, Pend Oreille County, Washington (Lou Groffman).

Structural analysis in the Metaline Falls area, Washington (Glenn Wiedenhoeft).

The mineralogy/chemistry of the Adaville No. 1 coal seam (Robert Eves).

WESTERN WASHINGTON UNIVERSITY

Faculty Research Projects

Correlations between plate interactions and the geologic record: Alaska to California (David C. Engebretson).

Debris torrents in the Cascade foothills (Don J. Easterbrook).

Geochemistry of Tertiary volcanic and plutonic rocks of the Cascades Range (R. Scott Babcock).

Net shore-drift along the Pacific coast of Washington State (Maurice L. Schwartz).

Paleomagnetism and tectonics of late Mesozoic and early Tertiary rocks in and east of the north Cascades (Russell F. Burmester).

Paleomagnetism, fission-track, amino-acid, and tephra studies in the Quaternary of the Puget lowland and Columbia Plateau (Don J. Easterbrook).

Paleomagnetism, structure, and accretionary history of the Olympic Peninsula and Puget Sound region (David C. Engebretson).

Petrology and geochemistry of the crystalline core of the north Cascades Range (R. Scott Babcock).

Quaternary glacial history of Mt. Baker (Don J. Easterbrook).

Recent Pacific-North American Plate interactions (David C. Engebretson).

Revision of pre-Wisconsin Quaternary chronology of the Puget lowland (Don J. Easterbrook).

Sedimentary and tectonic history of Washington west of the Cascades (Christopher A. Suczek).

Structure and petrology of the north Cascades (E.H. "Ned" Brown).

Student Research Projects

Biostratigraphy and paleoecology of the Lincoln Creek Formation, Grays River quadrangle, southwestern Washington (Gary Jones).

Depositional environment and provenance of the Hoko River Formation, northern Olympic Peninsula, Washington (Jennifer DeChant).

Economic geology of the Fifteenmile Creek area, Stevens County, northeast Washington – A volcanogenic massive sulfide deposit? (Bert Hyde).

Geology, petrochemistry and paleomagnetism of the Fifes Peak Formation in the Cliffdell area, central Cascades, Washington (Brad Carkin).

Geomorphology of the Wishkah river valley, Grays Harbor County, Washington (Steve Bubnick).

Glacial geology of the Tonasket-Spectacle Lake area, Okanogan County, Washington (Keith Pine).

Hydrothermal alteration and Ni-Au mineralization associated with the Devils Mountain fault zone, Skagit County, Washington (Don Graham).

Net shore-drift and coastal geomorphology of Jefferson and Clallam Counties, Washington (Jim Mahala).

Paleomagnetic and structural analysis of the Twin River Group, northern Olympic Peninsula, Washington (Ron Moyer).

Paleomagnetism of the Kitsap Peninsula (Joel Purdy).

Paleomagnetism of the Methow area (Julian Granirer).

Sedimentary petrology, depositional environment and tectonic implications of the Quimper Sandstone and Marrowstone Shale, northeastern Olympic Peninsula, Washington (Bill Rauch).

Structure and mineralization of the Lone Jack Mine area, north Cascades, Washington (Lief Christenson).

Structure and petrology of the Little Deer Creek area, Skagit County, Washington (Greg Reller).

Structure and petrology of the Shuksan Suite and associated rocks in the Whitechuck Mountain-Mt. Pugh area, north Cascades, Washington (David Silverberg).

Structure and stratigraphy of the Grandy Ridge/Baker Dam area, north Cascades, Washington (Mo Smith).

The geochemistry of silver in groundwater (Jeff Hess).

WHITMAN COLLEGE

Research Projects
(partial listing)

Depositional environments of the Miocene Wilkes Formation; mode of occurrence of pseudo-coprolites (P.K. Spencer).

Quaternary and environmental geology of the eastern Olympic Peninsula (R.J. Carson).

Trace-fossil paleoecology, northern and northeastern Olympic Peninsula (P.K. Spencer).

YAKIMA VALLEY COLLEGE

Faculty Research Projects

Geologic mapping of the Yakima East 15-minute quadrangle (Newell Campbell with Robert Bentley of Central Washington University).

Hydrocarbon potential of the Columbia Basin (Newell Campbell).

Structural geology along the Columbia River Basalt margin, northwest Columbia Basin (Newell Campbell).

DIVISION OF GEOLOGY AND EARTH RESOURCES RELEASES OPEN-FILE REPORTS

The following open-file reports may be purchased from the Department of Natural Resources, Division of Geology and Earth Resources, Olympia, WA 98504; they are also available for inspection in our Division library. ***Note the Handling and Distribution charge at the end of the listing.**

LaSalata, Frank V.; Menard, Mark C.; Walsh, Timothy J.; Schasse, Henry W., 1985, Inventory of abandoned coal mines in the State of Washington: Washington Division of Geology and Earth Resources Open-File Report 84-6, 42 p., 4 appendices. Price $3.25 plus .25 tax.

Lewellen, Dennis G.; Walker, Charles W.; Cushman, Curtis D., 1985, Geology and coal potential of the Taneum-Manastash area, Kittitas County, Washington: Washington Division of Geology and Earth Resources Open-File Report 83-9, 84 p., 2 plates. Price $3.71 plus .29 tax.

*** Please add $1.00 to cover a Handling and Distribution charge for your total publication order.**

RECENT U.S. GEOLOGICAL SURVEY PUBLICATIONS ADDED TO OUR DIVISION LIBRARY

The following reports are now available for inspection in our Division library. If you wish to purchase any of these published reports, please contact the U.S. Geological Survey, Public Inquiries Office, Room 678, U.S. Courthouse, 1020 Riverside, Spokane, WA 99201; (509) 456-2524.

Church, S. E.; Ford, A. B.; Flanigan, V. J.; Stotelmeyer, R. B., 1984, Mineral resource potential map of the Glacier Peak Wilderness and adjacent areas, Chelan, Skagit and Snohomish Counties, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-1652-A, 1 sheet, scale 1:100,000, 33 p. text.

Luedke, R. G.; Smith, R. L., 1984, Map showing distribution, composition, and age of late Cenozoic volcanic centers in the western conterminous United

States: U.S. Geological Survey Miscellaneous Investigations Series Map I-1523, 1 sheet, scale 1:2,500,000.

The following U.S. Geological Survey Open-File Reports are now available for inspection in our Division library. However, if you wish to purchase any of these reports, please write or call:

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Prepayment is required. Open-File reports are announced, with price, in the monthly list, "New Publications of the Geological Survey." A free subscription to the list may be obtained on application to: Mailing List Unit, U.S. Geological Survey, 329 National Center, Reston, VA 22092.

Fountain, A. G.; Fulk, M. A., 1984, South Cascade Glacier bibliography: U.S. Geological Survey Open-File Report 84-441, 14 p.

Meyer, William; Sabol, M. A.; Glicken, H. X.; Voight, Barry, 1984, The effects of ground water, slope stability, and seismic hazard on the stability of the south fork Castle Creek blockage in the Mount St. Helens area, Washington: U.S. Geological Survey Open-File Report 84-624, 72 p.

Prescott, W. R.; Savage, J. C., 1984, Crustal deformation near Hanford, Washington: U.S. Geological Survey Open-File Report 84-797, 247 p.

Waitt, R. B., Jr., 1984, Deposits and effects of devastating lithic pyroclastic density current from Mount St. Helens on 18 May 1980 – Field guide for northeast radial: U.S. Geological Survey Open-File Report 84-839, 10 p.

REPORTS OF CURRENT INTEREST

These reports have been acquired by our Division library where they are available for reference work.

Baird, Brian; Earle, Christopher, 1983, High level nuclear waste disposal at Hanford – A geologic critique: Washington Public Interest Research Group, 36 p.

Blake, Wilson, 1984, Assessment of the rock burst potential in basalt at the Hanford site: Rockwell Hanford Operations SD-BWI-ER-010, REV 0, 83 p.

Berkman, Ernest, 1983, Reprocessing and interpretation, seismic reflection data, Hanford site, Pasco Basin, south-central Washington: Rockwell Hanford Operations SD-BWI-TI-177, 74 p., 29 plates. (NOTE: Plates are on file at Nuclear Waste Board.)

Dischler, S. A., 1984, Hydraulic fracturing using a modified borehole deformation gage in the test interval: Rockwell Hanford Operations RHO-BS-SA-403 P, 219 p.

Hooper, P. R.; Reidel, S. P.; Brown, J. C.; Holden, G. S.; Kleck, W. D.; Sundstrom, C. E.; Taylor, T. L., 1976, revised 1981, Major element analyses of Columbia River Basalt, Part I: Washington State University [Geology Department] Basalt Research Group, 59 p.

Makhijani, Arjun; Tucker, K. M., 1985, Heat, high water, and rock instability at Hanford – A preliminary assessment of the suitability of the Hanford, Washington site for a high-level nuclear waste repository; with a supplement by Donald E. White: Health and Energy Institute [Washington, D. C.], 74 p., with 29 p. supplement. (Supplement is: White, D. E.,, 1983, reprinted 1985, Background paper for assessment of basalt lava flows (BWIP), Washington.)

Reidel, S. P.; Camp, V. E.; Ross, M. E., 1981, Major element analyses of Columbia River Basalt, Part II: Washington State University [Geology Department] Basalt Research Group, 90 p.

U.S. Department of Energy, 1984, Draft environmental assessment, reference repository location, Hanford Site, Washington: U.S. National Technical Information Service, 1 v.

COAL MINE REPORTS

The following reports are now available in our Division library.

Morrison-Knudson Company, Inc., 1985, Engineering investigation for the Renton, Washington area; prepared for U.S. Office of Surface Mining: Morrison-Knudson Company, Inc., 87 p., 8 plates.

Skelly and Loy, 1985, Abandoned coal mine survey, Coal Creek, King County, Washington; final report; prepared for U.S. Office of Surface Mining: Skelly and Loy, 3 vol., 2 plates.

U.S. Office of Surface Mining Reclamation and Enforcement, 1985, Proposed John Henry no. I mine, King County, Washington; final environmental impact

statement: U.S. Office of Surface Mining Reclamation and Enforcement OSM-EIS-13, 2 vol.

THESES ADDED TO OUR DIVISION LIBRARY

We have recently acquired the following theses in our Division library where they are now available for reference work.

Blunt, D. J., 1982, Geochemistry of amino acids in mollusks and wood, Pacific Northwest, United States: California State University Master of Science thesis, 183 p.

Brown, E. C., 1984, Tiltmeter analysis of Mount St. Helens, Skamania County, Washington: Portland State University Master of Science thesis, 153 p.

Burnham, R. J., 1984, Foliar morphological analysis of the Ulmoideae (Ulmaceae) from the early Tertiary of western North America: Univeristy of Washington Master of Science thesis, 109 p.

Collins, B. D., 1984, Erosion of tephra from the 1980 eruption of Mount St. Helens: University of Washington Master of Science thesis, 181 p.

Ellis, M. A., 1984, Structural morphology and associated strain within parts of the U.S. section of the Kootenay arc, N.E. Washington: Washington State University Doctor of Philosophy thesis, 254 p., 1 plate.

Graham, M. J., 1983, Hydrogeochemical and mathematical analyses of aquifer intercommunication, Hanford site, Washington State: Indiana University Doctor of Philosophy thesis, 204 p.

Heliker, C. C., 1984, Inclusions in the 1980-83 dacite of Mount St. Helens, Washington: Western Washington University Master of Science thesis, 185 p.

Hoeffner, S. L., 1983, Laboratory simulation of radionuclide migration through basalt – Applications to the proposed radioactive waste repository near Richland, Washington: University of Missouri Doctor of Philosophy thesis, 227 p.

Merzbacher, C., 1983, Water-saturated and -undersaturated phase relations of the Mount St. Helens dacite dome magma erupted on May 18, 1980, and an estimate of the pre-eruptive water content: Pennsylvania State University Master of Science thesis, 56 p.

Peterson, C. D., 1983, Sedimentation in small active-margin estuaries of the northwestern United States: Oregon State University Doctor of Philosophy thesis, 158 p.

Ralston, J. K., 1984, A study of the diatomites from a portion of the type area of the Ellensburg Formation of south-central Washington: University of Washington Master of Science thesis, 112 p.

Siebenmann, K. F., 1982, Potential for groundwater contamination by phenols and PAH adsorbed onto Mount St. Helens ash/sediments: Washington State University Master of Science thesis, 36 p.

Tepper, J. H., 1985, Petrology of the Chilliwack composite batholith, Mt. Sefrit area, north Cascades, Washington: University of Washington Master of Science thesis, 102 p., 1 plate.

Trexler, J. H., Jr., 1984, Stratigraphy, sedimentology, and tectonic significance of the Upper Cretaceous Virginian Ridge Formation, Methow Basin, Washington – Implications for tectonic history of the north Cascades: University of Washington Doctor of Philosophy thesis, 172 p.

RECENT PERMITS FOR OIL AND GAS DRILLING

Operator	Permit no.	County	Well name	Location	Ground elevation (feet)	Estimated total depth (feet)	Spud date	Date permit issued
Well completed since January, 1985								
AMOCO Prod. Co.	386	Grays Harbor	AMOCO-Weyerhaeuser No. 1-29	2,601 ft FWL, 2,377 ft FSL, sec. 29 (19-8W)	390	12,000[1]	6-26-84	5-31-84
Wells permitted since January, 1985								
AMOCO Prod. Co.	395	Pacific	Weyerhaeuser D No. 1	1939 ft FNL, 1346 ft FEL, sec. 18 (14-7W)	307	9,000		4-10-85
AMOCO Prod. Co.	396	Mason	Weyerhaeuser C No. 1	1200 ft FWL, 2100 ft FSL, sec. 3 (19-6W)	330	2,500		4-10-85
AMOCO Prod. Co.	397	Mason	Weyerhaeuser C No. 2	1854 ft FWL, 749 ft FSL, sec. 9 (19-6W)	317	2,800		4-10-85

[1] Plugged and abandoned 1-29-85, total depth 12,293 ft.

Department of Natural Resources
Division of Geology and Earth Resources
Olympia, WA 98504

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