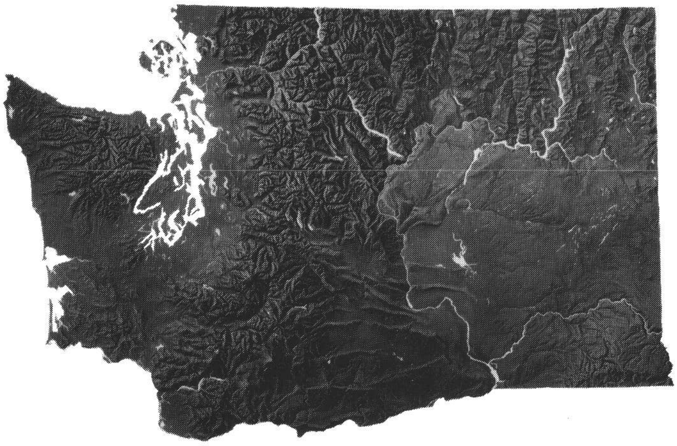

WASHINGTON GEOLOGIC NEWSLETTER

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Mount St. Helens ash and gas emission, May 16, 1983. Crater diameter is about 1.9 km. Height of plume in photo is ~1.2 km, dome height = 227 m (current height = 267 m). Photo by Patrick Pringle from ~ 6 km away.

IN THIS ISSUE

WASHINGTON GEOLOGIC NEWSLETTER

The Washington Geologic Newsletter is published quarterly 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, geologic maps, and open-file reports. A list of these publications will be sent upon request.

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Earthquake preparedness in Washington

By Raymond Lasmanis

On February 14, 1990, Governor Booth Gardner, Senator Brock Adams, and Senator Slade Gorton sponsored a conference "Earthquakes in Washington: Are we ready?" The more than 1,200 participants attending heard background papers, followed by a presentation of the City of Seattle's earthquake preparedness plan, twelve speakers addressing lifeline subjects, and a session devoted to state and local government issues. The Mayor of Seattle, Norm Rice, was a speaker, as was Mayor Art Agnos of San Francisco.

Clearly, leaders in the private and public sectors have a heightened awareness that now is the time to embark on proactive mitigation programs to reduce losses from earthquakes in Washington State. Although there is still much research to be done on the causes of various types of earthquakes in the Northwest, the consensus among scientists is that engineers, planners, and public leaders are now fully justified in proceeding with accelerated mitigation programs.

As part of our involvement in earthquake preparedness issues, the Division was proud to co-sponsor, with the Federal Emergency Management Agency and the U.S. Geological Survey, the fourth annual National Earthquake Hazards Reduction Program (NEHRP) workshop for the Puget Sound - Portland area held on April 17-19 (photos, page 20). The program was designed to reflect the shift in emphasis from seismological research to application and mitigation. Speakers addressed such issues as ground response, lifelines, and loss estimation. The field trip in downtown Seattle featured older buildings that have been retrofitted for seismic safety.

As we approach the fifth year of the federally funded NEHRP program in the Puget Sound-Portland area, the time is ripe for the private sector and local and state government agencies to prepare to assume their roles in mitigation and preparedness.

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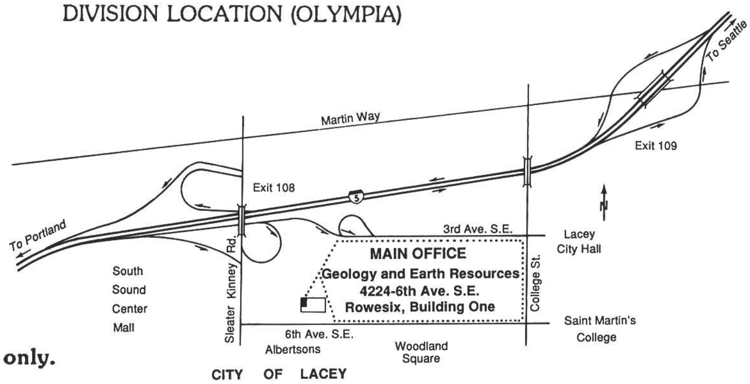

Mount St. Helens—A Ten-Year Summary

By Patrick Pringle

Ten years ago, on May 18, 1980, Mount St. Helens volcano erupted cataclysmically, producing a huge debris avalanche, an explosive, laterally directed "blast", lahars, and a Plinian eruption column. This powerful eruption had a profound impact on the Pacific Northwest—and on volcano studies as well. This article briefly reviews the effects of that eruption and subsequent eruptive activity and discusses some of the implications of the eruption for volcanology. For those seeking greater details, the 1980 volcanic activity and many of its impacts are richly documented (see Manson and others, 1987).

Studies by the U.S. Geological Survey (Crandell and others, 1975) described Mount St. Helens as the youngest and most active volcano in the Cascade Range and documented the eruptive history of this 40,000-year-old volcano. Although the mountain had been quiet since about 1857, the authors warned of the likelihood of future eruptions on the basis of the frequency of its past eruptions. The mountain erupted only 2 years after publication of their report (Crandell and Mullineaux, 1978).

Earthquake-swarm precursors to the May 18 eruption began under the volcano on March 20, 1980. On March 27 a phreatic (steam) eruption created a small summit crater, making Mount St. Helens the first Cascade Range volcano to erupt since Lassen Peak in 1921. The phreatic activity occurred intermittently until May 18; nevertheless, earthquakes, swelling, and disruption of the mountain continued.

On May 18, at 08:32 PDT the catastrophic eruption began, apparently triggered by a magnitude 5.1 earthquake. A large bulge that had formed on the north flank of the mountain in response to the intrusion of magma failed retrogressively in a series of three huge block slides. This debris avalanche, the largest landslide in recorded history (about 2.5 km^3 or 0.67 mi^3), traveled northward into Spirit Lake, over a 350-m (1,150-ft) ridge into the Coldwater Creek drainage, and westward 25 km (15.5 mi) down the North Fork Toutle River (Voight and others, 1981).

The sudden removal of this immense volume of material from the mountain unloaded the hydrothermal and magmatic system and released the laterally directed blast, which leveled all vegetation within 18 km (11.2 mi) in a 180° sector north of the volcano (about 600 km^2 or 230 mi^2). Major lahars, generated by snowmelt caused by the explosion, flowed down the South Fork Toutle and Muddy Rivers, carrying logs, trucks, and even bridges with them. The largest and most destructive lahar occurred in the North Fork Toutle River later in the day when the saturated debris-avalanche deposit began to dewater. The lahar flowed slowly to the Columbia River and deposited as much as 30 million m^3 (39 million yd^3) of sediment, blocking the shipping channel to ocean-going vessels.

A Plinian column (vertical eruption of ash) rose to more than 20 km (12.4 mi) within 10 minutes of the eruption's onset. An eruption column was maintained for more than 9 hours (Christiansen and Peterson, 1981). Fallout, including ash-sized particles, from the eruption amounted to more than 1 km^3 (≈0.24 mi^3) (Sarna-Wojcicki and others, 1981) and spread across Washington and Idaho and into Montana, disrupting human activities and transportation facilities and damaging civil works such as sewage- and water-treatment facilities.

In the aftermath, about 60 people had died as a result of the eruption, most from ash asphyxiation. More than 200 miles (320 km) of roads, 15 miles (25 km) of railways, at least 43 bridges, and about 200 homes were destroyed or severely damaged (Schuster, 1981). Mount St. Helens was reduced volumetrically by about 2.5 km^3 (0.67 mi^3).

Five smaller explosive eruptions occurred during 1980, and were accompanied by pyroclastic flows and tephra. Small dacite lava domes were emplaced at the end of three of these episodes. From October 1980 until 1990, 19 episodes of dome growth constructed a composite lava dome 267 m (876 ft) high (Fig. 1; see also cover photo). Minor explosions accompanied several of these episodes, generating lahars that flowed at least 15 km (≈9 mi) from the crater on two occasions (March 19, 1982, and May 14, 1984). The most recent lahar was generated by a hot avalanche on May 8, 1986 (Cameron and Pringle, 1990). After the most recent dome-growth event (October 1986), the volume of the dome had reached 74 million m^3 (≈97 million yd^3) (Swanson and Holcomb, 1990), more than 40 times the volume of the Seattle Kingdome. Although this figure seems impressive, it amounts to only about 3 percent of what the mountain lost in the May 18 eruption.

SECONDARY EFFECTS OF THE MAY 18, 1980 ERUPTION

Serious secondary effects of the Mount St. Helens eruption have lingered long after the initial volcanic activity. The dramatic post-eruption erosion and sedimentation rates and the ongoing hazards of potential breakouts from lakes impounded by the debris avalanche have presented costly problems around the volcano.

Erosion and Sedimentation

Erosion of tephra from hillsides by sheetwash and rills was intense in the first year after the eruption. For example, 8 million tons of sediment were washed into the Toutle River system (Collins and others, 1983). However, erosion of the debris ava-

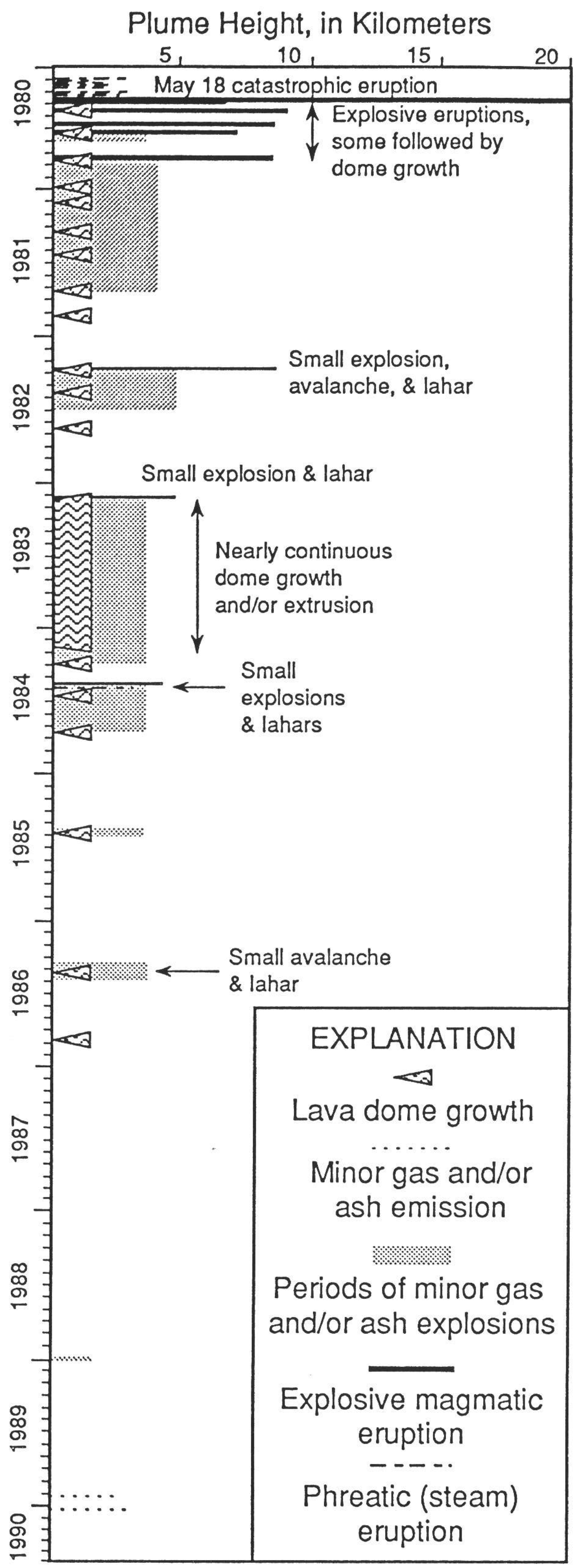

Figure 1. Diagrammatic summary of Mount St. Helens eruptive activity, 1980-90.

lanche by development of a stream network and subsequent channel widening resulted in a much larger sediment discharge to the same system, averaging 20 million to 30 million tons of sediment annually for the first 6 years (Lehre and others, 1983; Janda and others, 1985), a load that is about an order of magnitude greater than that contributed by tephra erosion in the same drainage basin. The post-eruption Toutle River had become one of the most sediment-laden rivers in the world.

The impacts of this sediment load were devastating, severely affecting water quality and aquatic habitat, as well as increasing flood potential downstream and jeopardizing homes and roads built on the floodplain and adjacent terraces of the Toutle River. As the lower Toutle and Cowlitz Rivers filled with sediment, their in-channel flow capacity during flood events was dramatically reduced. In addition, extreme sediment concentrations magnified flood volumes for given amounts of precipitation. Early mitigation efforts included dredging the Cowlitz River and construction of temporary sediment dams in the upper North Fork Toutle River. Fortunately, all rainstorms during the 1980s were less than those typically associated with a "10-year" flood.

Unlike the tephra erosion rates, which decreased dramatically during the first several years, sediment discharge rates for the Toutle River remained fairly

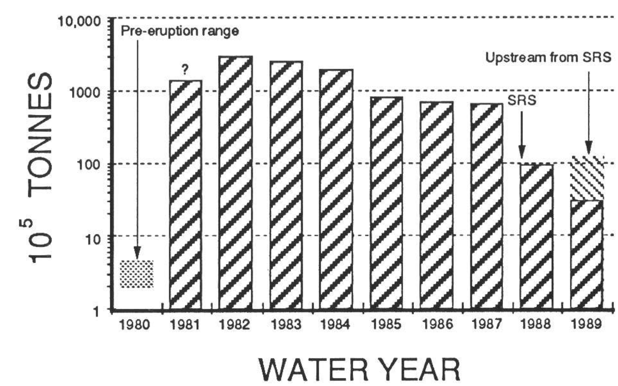

Figure 2. Histogram showing log-normal distribution of suspended-sediment load in the Toutle River near Kid Valley for water years 1981-89. (A water year begins on October 1 of the previous calendar year.) Kid Valley is about 45 km (27 mi) downstream from the crater and only 4 km (2.4 mi) downstream from the Sediment Retention Structure (SRS). Range of annual, average pre-eruption sediment loads is estimated from Collins and Dunne (1988). Figure for water year 1981 (queried) calculated from data in Lehre and others (1983). To show the sediment-trapping effects of the SRS during 1989, an estimate of the annual suspended-sediment load upstream from the SRS (John Pitlick, Cascades Volcano Observatory, oral commun., 1989) is superimposed on the 1989 Kid Valley data. All other data are from USGS Water Data reports (1982-89). Estimates do not include bed load, which could increase values by 15 to 40 percent. One tonne = 1 megagram = 0.9 ton.

high until 1988, when sediment-trapping effects of a preliminary cofferdam at the new sediment-retention structure were first observed (Fig. 2).

Hazards from Debris-Avalanche Dams

Numerous natural dams were created by the debris-avalanche deposit in the North Fork Toutle River drainage. On at least five occasions during 1980-82, breaches of small lakes or ponds on or adjacent to the debris avalanche caused relatively minor (<500 m^3 or 650 yd^3) floods (D. F. Meyer and others, 1986). But most public concern about breakout floods has been focused on Spirit, Coldwater, and Castle lakes, the three largest lakes impounded by the debris avalanche. Early concerns were amplified by the discovery that several thick, ancient lahar deposits had originated as breakouts of lakes (Scott, 1988). Scott reconstructed hydrographs of the flood surges created by these ancient breakouts on the basis of deposit thickness and cross-sectional area of the valley. He determined that one of these lahars had had an instantaneous discharge (sudden peak flow wave that was not sustained) of more than 300,000 m^3/sec (390,000 yd^3/sec), equivalent to that of the Amazon River at flood. The Coldwater and Castle Lake blockages were temporarily stabilized in 1981. Initial pumping of Spirit Lake via a floating barge and outlet pipe began in November 1982, and a more permanent outlet tunnel was completed by the Army Corps of Engineers in 1985 (Sager and Chambers, 1986). According to a U.S. Geological Survey report (W. Meyer and others, 1986), all three blockages are apparently stable with respect to liquefaction, gravitationally induced slope failure, and piping; the possible exception is Castle Lake, where the dam may be only marginally stable against piping. Studies and monitoring of the Castle Lake blockage continue.

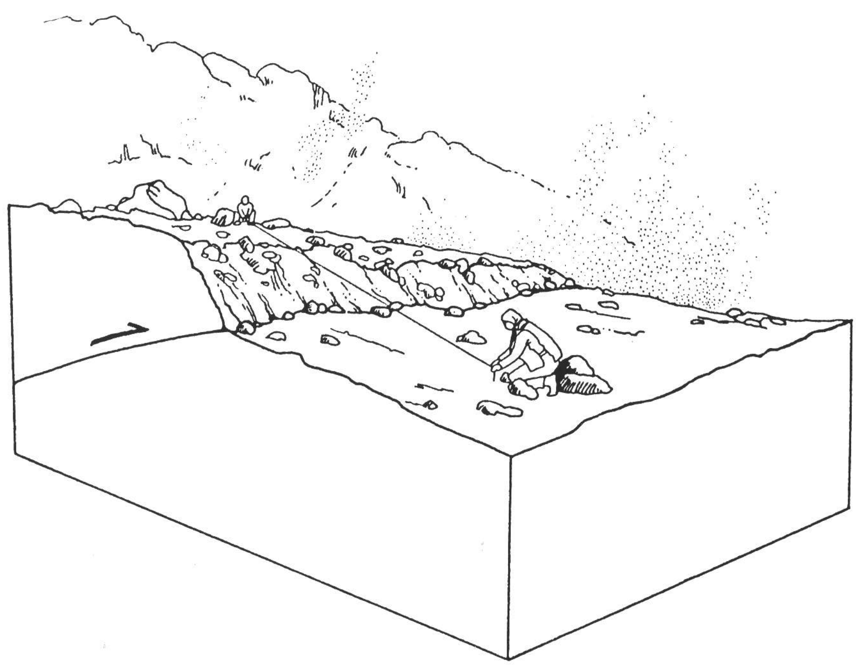

Figure 3. Measuring thrust-fault motion on the crater floor adjacent to the lava dome. During 1980-82, thrust faults were observed in the crater floor. The upper block material (hanging wall, or the left part of the diagram) is pushed over the lower block (foot wall) in response to magma intrusion into the dome. By measuring the distance between reference points on the two blocks with a steel tape, the slope distance can be determined, and a rate of fault motion can be calculated from changes in that distance. An eruption can be heralded by accelerated shortening of the slope distance. (Sketch by Bobbie Meyers, Cascades Volcano Observatory, from Brantley and Topinka, 1984).

ADVANCES IN VOLCANO MONITORING RELATED TO 1980-90 STUDIES OF MOUNT ST. HELENS

Mount St. Helens has been the most closely studied stratovolcano in history, and as a result, new understanding of volcanic processes and deposits has surged, as has public interest in volcanoes and volcanology. Volcano monitoring techniques have been devised or refined to predict with confidence eruptive events at Mount St. Helens. Furthermore, these techniques have been effectively applied to the monitoring of other volcanoes.

Refinement of volcano monitoring techniques has included combined use of non-seismic deformation and tilt measurement techniques for predicting dome growth. Early efforts at the U.S. Geological Survey Cascades Volcano Observatory in Vancouver, Washington, focused on measuring movement of thrust faults and radial cracks in the crater floor with a carpenter's steel tape (Fig. 3) (Chadwick and others, 1983; Swanson and others, 1983). Increasing displacement rates for these features indicated rising magma and allowed the early onsets of dome building to be predicted.

Monitoring of the lava dome with electronic distance meters and theodolites began in 1981 and made possible more accurate plotting of deformation trends and more reliable prediction of eruptions. Geoscientists observed that movement of the lava dome systematically increased before an extrusion of lava, reaching rates as high as 53 m/day (≈175 ft/day) (Swanson, 1986). As the swelling rates increased beyond a given threshold, a "window" of time was predicted during which the eruption could be expected (Fig. 4).

Strainmeters and electronic tiltmeters (in essence a sensitive bubble level) placed on the lava dome now telemeter deformation data to a remote base. These provide measurements during bad weather and/or at night and have supplemented the surveys. The combined use of these prediction techniques was effec-

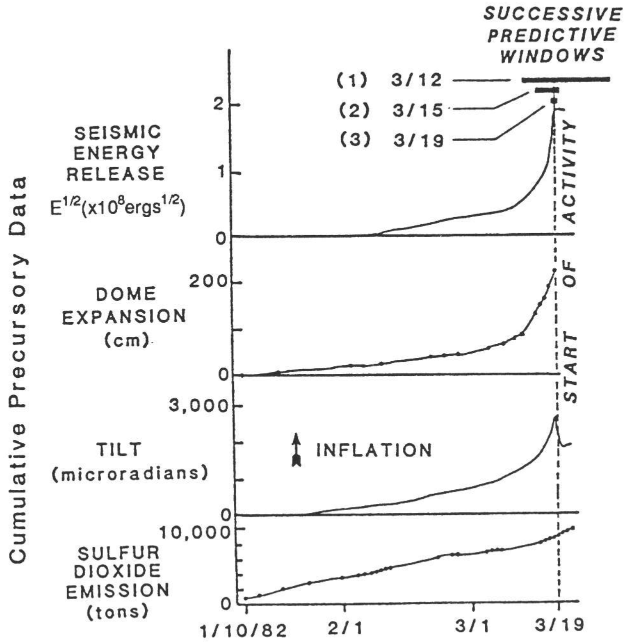

Figure 4. Increases in the rate of precursory activity with time for the eruptive episode of March 19, 1982. Information from several kinds of instrumentation showed simultaneous increases in precursory activity in the weeks preceeding March 19; by studying the relation of the timing and rates of increase, scientists were able to shorten the length of the predictive windows. A predictive window is a time during which onset of an erutpive event would most probably occur. Dome expansion was measured by EDM (electronic distance meter) for measurements of horizontal displacement; tilt changes were measured by electronic tiltmeter; and sulfur dioxide was measured by correlation spectrometer. (Diagram modified from Swanson and others, 1985.)

tive in all except two instances during the 1980-90 dome-growth episodes. Only the explosions that occurred in February 1983 and May 1984 and that were followed by lava extrusions were not predicted.

A real-time seismic-amplitude measurement system (RSAM) was developed at Cascades Volcano Observatory to provide inexpensive, continuous measurements (Murray and Endo, 1987). A laptop computer controls an analog-to-digital recording system for eight seismic stations. Seismic-amplitude information is telemetered to the observatory from Mount St. Helens, processed, and added to a file in a multi-user computer system. A chief advantage of this system is that data can be plotted against other available monitoring information on a common time base; for example, volcanic gas discharge, earthquake energy, surveyed deformation measurements, tilt, and ground temperature changes can be plotted together. The information then is accessed easily for graphical analysis at the base or remotely by modem. Changes in the seismic activity, atmospheric conditions, and/or instrument difficulties can be distinguished as distinct patterns in the data.

RSAM has been a useful tool in successfully predicting the three latest dome-building episodes at Mount St. Helens, recent eruptions at Redoubt volcano in Alaska, and at Nevado del Ruiz in Colombia. It was recently installed at Long Valley caldera in California because of ongoing seismic activity in that area.

Studies by the Geophysics Program at the University of Washington have made substantial progress in interpreting the wide variety of earthquakes that have occurred at Mount St. Helens. Malone (1983) classified Mount St. Helens earthquakes using frequency content, amplitude density spectra, and the nature of first-arrival signals. Plots of the changing of occurrence and cumulative energy of the various types of earthquakes have been used to make predictions of eruptive activity in a manner similar to, and in concert with plots of similar rate changes reflecting deformation.

Other University of Washington researchers have used seismic frequency content and relative amplitudes and durations to detect and locate debris flows at Mount Rainier and Mount Adams (Jonientz-Trisler and Qamar, 1989). Much of their experience in interpretation of the signals was gained from the study of Mount St. Helens earthquakes.

ADVANCES IN VOLCANIC HAZARDS ANALYSIS

Volcanic Stratigraphy: "The Present is the Key to the Past"

New insights about volcanic processes and their deposits at Mount St. Helens have been applied to the re-interpretation of deposits at other volcanoes around the world. The quality of volcanic hazards analyses has improved greatly because of new criteria for recognizing types of deposits.

Major contributions to volcanic studies that are directly associated with study of the 1980 debris avalanche are: (1) correlation of the debris avalanche with triggering of the May 18 explosive lateral blast; (2) understanding that generation of the relatively clay-rich North Fork Toutle lahar was caused by dewatering of the avalanche deposit (Janda and others, 1981) and liquefaction during the harmonic tremor of May 18 (Fairchild, 1986); (3) observation of the unusual characteristics of the debris-avalanche deposit (for example, hummocky surface with no integrated drainage system, enclosed blocks of rock with relatively intact geologic structures, and associated horseshoe-shaped crater) (Siebert, 1984; Glicken, 1986); and (4) confident recognition of similar deposits, processes, and related hazards on other volcanoes.

As one example of the relevance of Mount St. Helens studies, hummocky deposits similar to those of the Mount St. Helens debris avalanche have now been identified at Mount Shasta (Crandell and others, 1984) and at numerous volcanoes around the world.

Lee Siebert of the Smithsonian Institution in Washington, D.C. has compiled a list of more than 150 Quaternary debris-avalanche deposits (Siebert, 1984). Other studies suggest that not all debris avalanches have been caused by eruptions. Some, like a debris avalanche at Ontake volcano in Japan, may have been triggered by regional or local earthquakes (Nagaoka, 1987). The collected evidence indicates that debris avalanches (including "sector collapses" in which large portions of a volcano slide away) occur more frequently than previously thought and deserve serious consideration in future volcanic hazards studies.

Relatively thin deposits locally found in association with the hummocky deposits at other volcanoes may be analogous to the deposits of the St. Helens lateral blast. Using observations of blast deposits at Mount St. Helens (Hoblitt and others, 1981; Waitt, 1981; Fisher, 1987), geologists have created criteria for the recognition of these units and for the establishment of hazard zones where these lateral blasts are a potential hazard and/or have occurred in the past (Crandell and Hoblitt, 1986).

Studies at Mount St. Helens also have led to advances in the understanding of lahars and lahar-related flows and their deposits. On one occasion, for example, geologists were able to witness a lahar generated by a volcanic explosion (May 14, 1984), sample the flow at a downstream locality as it passed (Fig. 5), observe the lahar's impact on the stream channel immediately after the event, and then study the deposits of the lahar as they became exposed over the next year (Pringle and Cameron, 1986). Such opportunities are truly rare for geologists, and they provide excellent criteria for the evaluation of debris-flow deposits on other volcanoes and even for deposits from similar processes in non-volcanic landscapes.

Outgrowths of the study of Mount St. Helens lahars include: (1) a classification system for lahar types and their behavior, derived on the basis of clay content and method of generation; (2) a new model of flow behavior for certain clay-poor lahars which shows that they can become larger and more concentrated by incorporating large amounts of solid debris and then, by depositing this debris, transform into a flood; (3) more confident estimates of flow parameters (particularly velocity and discharge) based on calibration of stratigraphic evidence at Mount St. Helens with eyewitness accounts and photographic evidence; (4) previously undescribed flow features, sedimentary features, and facies for lahars; and (5) application of the above knowledge to the interpretation of other debris-flow deposits.

These advances in our understanding of lahars have helped in the interpretation of the causes of ancient lahars; in recognizing deposits not previously correlated with lahars; and in more accurate reconstructions of the behavior, size, and extent of ancient flows. The improved classification scheme also has had important implications for design criteria for structures and civil works in river valleys surrounding volcanoes, and it has been derived from anticipated hazards for the various types of lahars.

Figure 5. Sampling the May 14, 1984, laharic flood on the North Fork Toutle River near Elk Rock (27 km or 16 mi from the crater). The channel is 400 m (1,300 ft) wide at this location. A velocity of 2.3 m/sec (7.5 ft/sec) was calculated from flow run-up on the sampler's leg. Trees on the opposite valley wall were blown down by the 1980 eruption. (Photo by K. A Cameron, formerly USGS.)

Dendrochronology

Dating techniques such as dendrochronology (tree-ring dating) recently have been used to precisely date prehistoric lahars, eruptions, and lava flows at Mount St. Helens (Brantley and others, 1986; Yamaguchi, 1983, 1985). This technique not only provides a more detailed chronology of relatively recent events for individual volcanoes but can allow better characterization of petrologic trends as well because of more precise dates for specific volcanic events (Cameron and Pringle, 1987; Yamaguchi and others, in press).

Volcanic Hazards: Preparedness and Mitigation

The scope and philosophy of volcanic hazards analysis have evolved worldwide as a result of the scale of 1980 events at Mount St. Helens. In particular, those events produced the general recognition that steep-sided volcanoes are hazardous features and that unusual events like the Mount St. Helens blast are possible and must be included in a volcanic-hazards inventory.

In New Zealand, within five months of the Mount St. Helens' eruption, the National Civil Defense Planning Committee on Volcanic Hazards was formed. Citing the increasing importance (and cost) of problems created by volcanic hazards in an industrialized society (as exemplified at Mount St. Helens), the committee solicited reports, risk analyses, and precautionary measures for the volcanic areas of the North Island, New Zealand (Dibble and others, 1985). Similar investigations were already in progress in the United States and resulted in general hazards assessments for most Washington volcanoes and neighboring Mount Hood by 1982 (Beget, 1982; Crandell, 1973, 1980; Hyde and Crandell, 1978; and Hoblitt and others, 1987).

The three most important aspects of preparedness and mitigation with respect to volcanic hazards are: (1) communication of volcano monitoring and volcanic hazards information by geoscientists to the public, the media, and responsible agencies and officials, (2) emergency preparedness by responsible agencies and officials, and (3) the status of community and regional planning and land-use designations. All three aspects are interrelated insofar as they depend on the communication of understandable scientific information about, first, the current state and expected behavior of a volcano, and, second, the nature, extent, implications, and likelihood of impacts from a variety of volcanic processes near that volcano.

The communication of scientific information about the status of a volcano has improved mainly because geoscientists have an improved ability to predict eruptions at Mount St. Helens. Public demand for prompt and more understandable technical information and, for scientists, the experience of working with an accessible volcano such as Mount St. Helens, have helped to "fine tune" the communication process. Improvements in communications have taken place both in electronic media and newspapers and in geoscience literature (such as explanatory journal articles, books, and training manuals; see Tilling, 1989).

As an impetus for the transformation in communications, Swanson and others (1985) defined factual statements, predictions, and forecasts as these terms are used in public statements about volcanic activity at Mount St. Helens. *Factual statements* provide information but do not anticipate future events. *Predictions* are relatively precise statements about the time, place, nature and size of impending activity (usually on the basis of measurements at the volcano), whereas *forecasts* are comparatively imprecise statements about the nature of expected activity (typically based on the past history and potential of a volcano and geologic mapping). These and other terms have been incorporated into the lexicon of public statements about Mount St. Helens and have been accepted by the media and the public because they have provided a means to define and translate scientific information and to clarify public expectations and understanding of volcanic events and hazards.

Newhall (1982) devised a method for quantifying long-term hazards and risks at a volcano on the basis of sizes and types of eruptions, time intervals between eruptive episodes, and the effects at various distances from the volcano. He used a similar technique for short-term hazards based on work at Mount St. Helens (1984). In a more site-specific study, Hoblitt and others (1987) published frequency, order-of-magnitude, and probability information for a wide range of volcanic events, using as a model those recorded in the geologic history of individual Cascade Range volcanoes.

Details about improvements in emergency response and land-use planning as they relate to the learning experience of Mount St. Helens are beyond the scope of this article. However, as noted above, these two subjects are significantly dependent on technical information about volcanic hazards.

In the Pacific Northwest, debris flows and debris avalanches constitute some of the greatest volcanic hazards. However, detailed information on probabilities of flow types of varying magnitudes and frequencies are not yet published for specific drainages (although several such studies are in progress). This information is critical for planning purposes because urban/suburban growth typically occurs along river valleys; those valleys near volcanoes could be vulnerable to future flows.

Eisbacher and Clague (1984) discuss a range of active and passive hazards-management measures for flows of various sizes. Their techniques range from forestry practices, control works, protective works, and planning and zoning. They note that decisions about these debris-flow and avalanche hazards must be founded on the recurrence and magnitude information and a broad-based socio-economic consensus relating to the hazards and acceptance of risk. As growth continues in the Pacific Northwest, hazards management and emergency response decisions will no doubt be influenced by similar factors.

Despite the destruction it caused, Mount St. Helens provides a laboratory for many kinds of research that are now beginning to effectively prepare us for living with the hazards this volcano and others still pose.

Acknowledgments

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Substitute House Bill No. 1597

AN ACT Relating to the practice of geology; creating new sections; and providing an expiration date.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF WASHINGTON:

NEW SECTION. Sec. 1. The legislature finds that it may be in the public interest to establish qualifications for geologists and for the practice of professional geological work.

NEW SECTION. Sec. 2. The department of licensing shall conduct an evaluation of the practice of professional geological work and make recommendations to the legislature as to whether and to what extent it is in the public interest to regulate the practice of geological work. In conducting the evaluations and preparing recommendations, the department shall consult and work with state geologists and professional geological organizations. The department's findings and recommendations shall be submitted to the legislature by December 1, 1990.

NEW SECTION. Sec. 3. In the event the department finds that regulation of geological work is in the public interest, the department shall prepare a legislative proposal to implement such recommendations. The proposal may include, but shall not be limited to, the following items:

(1) Definitions and criteria for qualification and practice as a professional geologist in Washington state;

(2) The composition of a professional geologist board, including provisions for terms of office, rotation of members, and method of appointment;

(3) Powers and responsibilities of the board;

(4) Maintenance of a roster of professional geologists; and

(5) A system of reciprocity with other states.

NEW SECTION. Sec. 4. This act shall expire June 30, 1991.

Senate passed as amended March 2, 1990
House concurred March 5, 1990
Gov. Booth Gardner signed into law March 27, 1990

From the Office of the Governor

To Raymond Lasmanis, State Geologist
April 12, 1990

Dear Mr. Lasmanis:

I am pleased to hear that the 1991 "Rocks and Minerals" magazine, published by Heldref Publications (a division of the Helen Dwight Reid Educational Foundation), will feature the state of Washington. The efforts of the authors under the auspices of the Pacific Northwest Chapter of the Friends of Mineralogy deserve to be complimented.

Such an issue will certainly help promote Washington state as a visitor destination. I fully support your efforts to raise contributions for the Helen Dwight Reid Education Foundation so that the natural beauty of the state and its minerals, gems, and fossils can be pictured in full color.

Sincerely,

BOOTH GARDNER
Governor s/s

[Ray Lasmanis is Secretary of the Pacific Northwest Chapter of the Friends of Mineralogy and is contributing two articles to the issue. With Mike Groben of Coos Bay, Oregon, he is helping coordinate articles, providing back-up resources for the authors, and assisting with raising money to permit wide use of color. Fifteen articles are planned. The Division is providing some graphics assistance.]

Earthquakes in Washington and Oregon 1980-89: A Decade of Discovery

By Anthony Qamar
Geophysics Program, University of Washington

The decade 1980-89 was a significant milestone on the path to understanding earthquake hazards in Washington and Oregon. It was the second decade during which the University of Washington (UW) Geophysics Program has monitored earthquakes using a statewide network of seismographs centrally recorded at the university, and it was the first decade in which computers were used to detect earthquakes and permanently record and process the earthquake seismograms. This monitoring system now permits us to automatically calculate preliminary locations and magnitudes of earthquakes anywhere in the world within minutes of recording the seismic waves. We are cautiously using this capability to provide timely earthquake information to key state and local organizations. The UW network now includes 121 seismograph stations in Washington and northern Oregon. Their distribution is shown in figure 3 of Noson and others (1988).

The computer techniques we use to detect and process the seismic data were rapidly developed in 1980. By coincidence, Mount St. Helens began to rumble and swell in March 1980 just as the UW Geophysics Program was fine-tuning a newly acquired digital data acquisition system. UW geophysicists worked long hours to install additional seismographs around the volcano and, at the same time, to develop computer software to process the newly acquired digital data (Malone and others, 1981). During this time the UW worked closely with scientists from the U.S. Geological Suvey (USGS), a relationship that continues to this day.

In some ways the earthquakes between 1980 and 1989 (Fig. 1) were similar to those in the previous decade. Scattered earthquakes, both shallow and very deep, occurred mainly in the greater Puget Sound region, and shallow ones were recorded in eastern Washington, particularly in a wide zone near the western margin of the Columbia Plateau. There were some surprises, too. For one thing, most of the seismic energy was released in southwest Washington, not in the Puget Sound area. The major contributors to this seismic energy were the earthquakes of magnitude 5 or greater (Table 1) that occurred at Mount St. Helens (May 1980), Elk Lake (February 1981), and in the Goat Rocks Wilderness (May 1981), and a magnitude 4.9 earthquake that occurred a few kilometers west of Mount Rainier in December 1989. The foci of all of these were in the upper part of the Earth's crust at depths of 2 to 18 kilometers.

These earthquakes have strengthened seismologists' interest in the possibility of large shallow earthquakes in Washington. Until recently, most seismologists focused on the hazards of future earthquakes that would be repeats of the magnitude 7.1 earthquake in 1949 or the magnitude 6.5 earthquake in 1965. Both of these occurred in the subducting Juan de Fuca plate at depths of 50 to 80 kilometers, not in the shallow crust. However, the focus of the shallow magnitude 5.5 earthquake of 1981 lies on an active north-south seismic zone (called the Mount St. Helens seismic zone) that may be capable of even larger shallow earthquakes. Given two earthquakes of the same magnitude, a shallow one is potentially more damaging than a deep one because, in the former, the earthquake focus is closer to the Earth's surface. Washington has had moderately large shallow earthquakes in the past. In fact, the 1872 North Cascades earthquake, possibly Washington's largest earthquake in recent history (magnitude estimated to be 7.5), is presently believed to have occurred in the shallow crust.

Another surprise of the 1980s is the recently discovered geologic evidence that a third and more serious type of earthquake is possible in Washington

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Figure 1 (on facing page). Epicenters of earthquakes of magnitude 3.0 and greater, 1980-89. The location of the deep, magnitude 6.5 earthquake of 1965 also is shown for reference. Epicenters of shallow earthquakes are shown as circles; epicenters of earthquakes having foci deeper than 30 km are shown as squares. Star symbols indicate prominent volcanoes. The Cascadia subduction zone boundary is shown to the west, offshore of Washington and Oregon. This is the junction between the Juan de Fuca plate (west) and the North American plate (east). The deep earthquakes in Washington actually occur within the part of the Juan de Fuca plate that lies beneath the North American plate. The seismic quiescence of the shallow part of the Cascadia subduction zone is evident from the absence of earthquake epicenters just east of the subduction zone boundary.

A vertical east-west cross section showing depths of earthquakes from 1980 to 1989 also is shown at the right. The cross section is centered on Seattle and extends for 200 km to the west and east; the scale is the same as the map scale, with no vertical exaggeration. Note the clear spatial separation between the deep earthquakes that occur in the subducting Juan de Fuca plate and the shallow ones in the North American plate. The location of the 1965 earthquake is shown again for reference.

and Oregon (Atwater, 1987). This is the so-called subduction-style earthquake of magnitude 8 or greater, similar to the ones that occurred in Chile in 1960 and in Alaska in 1964. Because of the steady convergence of North America and the offshore Juan de Fuca plate over the past several million years, geophysicists have known that there was, in principle, the possibility of a subduction-style earthquake if the two plates jerked past each other suddenly. However, an alternate hypothesis was that the convergence is accommodated by slow, steady slip without earthquakes. After all, there are no known written records of a great subduction-style earthquake on the coast of Washington or Oregon. However, the pioneering work by USGS geologist Brian Atwater and additional geologic studies by others suggest that many such earthquakes have occurred in the last few thousand years, the most recent one about 300 years ago.

From the seismologist's point of view, the virtual absence of even small thrust earthquakes on the shallow part of the boundary between the North American and the Juan de Fuca plates (called the Cascadia subduction zone) is perplexing. This observation has led some geophysicists to believe the "big one" would never occur. The recent geologic evidence suggests another explanation for today's seismic quiescence on the Cascadia subduction zone. Just as in California, where the seismically inactive segments of the San Andreas fault are precisely the segments where

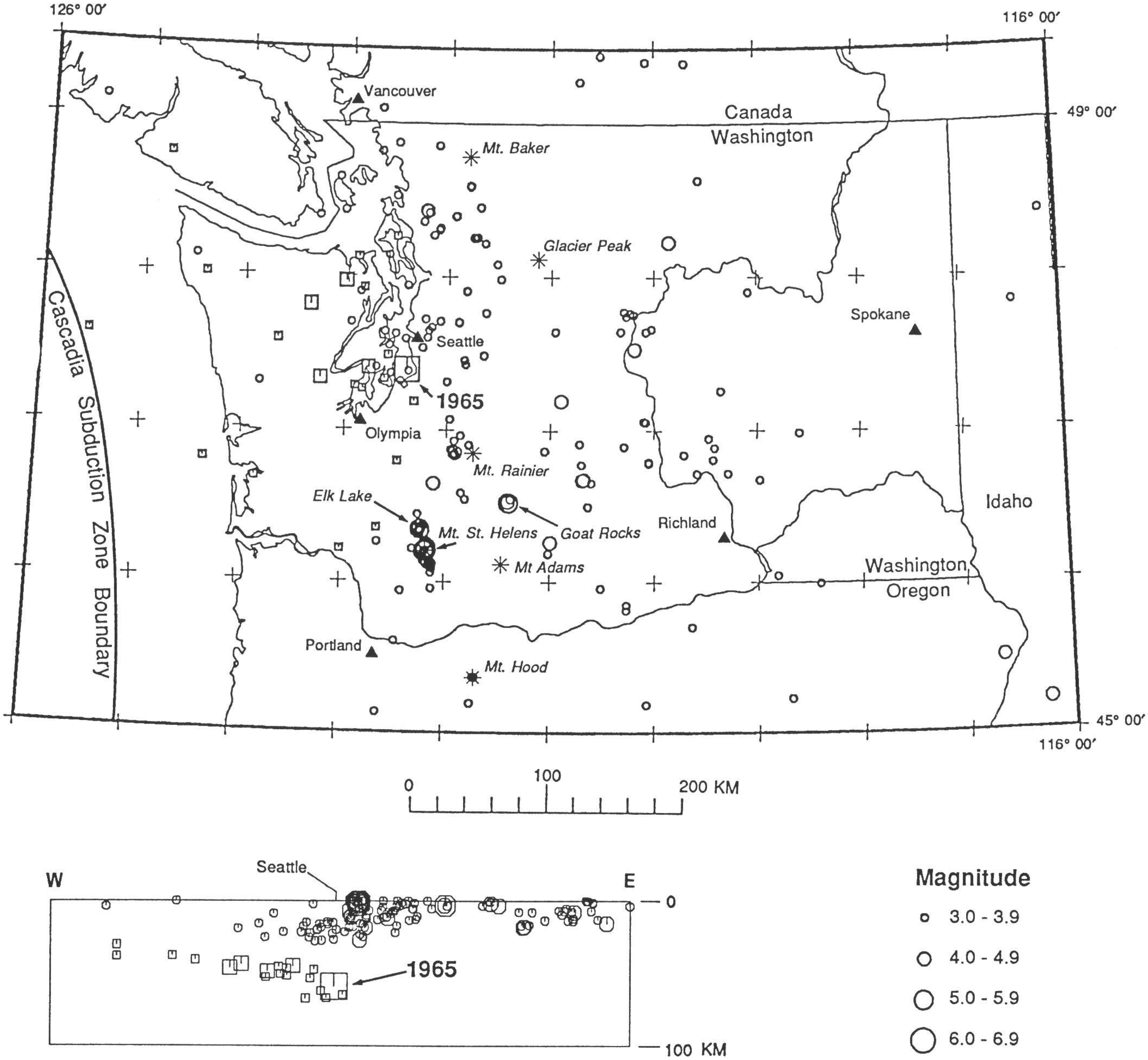

Table 1. Earthquakes, coda-wave magnitudes 4.5 or greater, 1960-1989 (Day: year/month/day; universal time [subtract 8 hr for Pacific Standard Time]; depth in kilometers; M, magnitude)

DAY	TIME	LAT	LON	DEPTH	M
60/09/10	15:06:34.00	47 42.00	123 09.00	40	4.7
60/11/08	11:36:23.10	45 02.40	125 23.39		5.6
61/02/02	05:50:13.40	47 00.00	121 30.00		4.5
61/09/16	03:24:56.05	46 00.80	122 06.70		4.8
61/09/17	15:55:56.26	46 01.50	122 06.00	21	5.1
61/11/07	01:29:08.40	45 42.00	122 52.00		4.7
62/11/06	03:36:43.00	45 36.48	122 35.87	18	5.2
62/12/31	20:49:30.80	47 15.00	122 04.80	2	4.7
63/01/24	21:43:09.80	47 34.20	122 01.80		4.6
63/03/07	23:53:27.40	44 50.40	123 25.20	50	4.6
63/12/27	02:36:22.50	45 46.80	123 21.00		4.5
64/07/14	15:50:03.30	48 54.00	122 30.00		4.6
65/04/29	15:28:43.30	47 24.00	122 24.00	59	6.5
68/05/30	00:35:58.80	42 19.80	119 50.99	22	5.1
68/06/03	13:27:39.70	42 15.00	119 48.00	20	5.0
68/06/04	02:34:14.50	42 14.40	119 52.20	25	4.6
68/06/05	04:51:56.30	42 13.79	119 59.39	25	4.6
69/11/10	07:38:44.70	48 33.00	121 30.60		4.6
73/12/20	01:08:28.24	46 52.08	119 21.17	2	4.8
74/04/20	03:00:10.36	46 46.43	121 34.02		4.9
75/04/23	01:03:42.72	47 04.92	122 40.31	45	4.5
75/11/30	10:48:21.00	49 13.79	123 37.20	10	4.9
76/04/13	00:47:15.00	45 09.23	120 51.66	15	4.8
76/05/16	08:35:15.06	48 47.99	123 21.05	60	5.1
76/09/02	13:36:11.48	48 11.58	122 46.07	20	4.5
76/09/08	08:21:02.03	47 22.74	123 05.87	46	4.5
77/11/27	09:25:55.51	44 31.20	116 21.23	10	4.8
78/03/11	15:52:11.61	47 25.32	122 43.08	24	4.8
80/05/18	15:32:11.43	46 12.44	122 11.28	2	5.7[a]
81/02/14	06:09:27.21	46 20.96	122 14.16	7	5.2[b]
81/05/13	05:00:36.18	46 21.77	122 14.89	10	4.5
81/05/28	08:56:02.54	46 31.80	121 23.91	2	4.6
81/05/28	09:10:45.90	46 31.52	121 23.64	3	5.0
89/03/05	06:42:00.66	47 48.77	123 21.41	46	4.5
89/05/09	18:28:45.50	48 13.83	119 51.23	15	4.5
89/12/24	08:45:58.90	46 39.00	122 06.97	18	4.9

a. Only the earthquake accompanying the cataclysmic eruption of Mount St. Helens on May 18, 1980, is listed. Between March 27 and May 18, 1980, there were 88 additional earthquakes at Mount St. Helens having M≥4.5. Since May 18, 1980, earthquakes at Mount St. Helens have been much smaller.

b. The Elk Lake earthquake of February 14, 1981, was the largest in Washington from 1980 to 1989 that was not associated with a volcano. It had several foreshocks and more than a thousand aftershocks that could be located. Only one of these had a magnitude of 4.5 or greater, the event of May 13, 1981, that appears in the table.

the largest earthquakes are expected in the future, the apparently inactive shallow boundary between the converging plates in the Pacific Northwest may be the eventual source of Washington's and Oregon's largest earthquakes.

In summary, the past decade has given earth scientists a new perspective on earthquake hazards in the Northwest. Although our estimates of the frequency of damaging earthquakes has not changed significantly, we now understand earthquake processes and the potential geographical locations of future earthquakes in the Northwest better than previously. The bottom line is that the potential hazard is somewhat greater than formerly believed.

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Seismic Activity Brief at Mount Hood

Thirty minor earthquakes were recorded by a Mount Hood station during a 4½-hr period the evening of February 15. Six of those were located in the Timberline area, where earthquakes have been previously located. The events with the best quality seismic records were at depths of 4 to 5 km. The magnitude of the largest event was 1.3.

Seismic activity at Mount Hood remained quiet over the following weekend, but was recorded again the morning of February 20 for 3 hours. At least 28 events were recorded at Flag Point and Tom, Dick and Harry Mountain. The largest magnitudes were much smaller than those recorded the previous Thursday.

Past seismic episodes at Mount Hood generally have been followed by several months or more of quiescence.

Evidence of Liquefaction in the Puyallup Valley

By John A. Shulene
Earth Science Teacher (retired), Puyallup Public Schools; Volunteer, U.S. Geological Survey
Puyallup, Washington

The city of Puyallup, about 30 miles south of Seattle, is situated on the broad floodplain of the Puyallup River. The floodplain surface is only a few feet above sea level. During the earthquake that struck Washington in 1949 (magnitude 7.1 on the Richter scale; see Fig. 1 for location), Puyallup experienced considerable sandblow activity.

The valley's soil profiles are varied, but generally the surface layer consists of a foot or more of cohesionless sandy loam. A layer of fairly clean sand has been widely found directly under the loam in many excavations, borings, and wells. A high water table causes this sand to be saturated, thus making an ideal situation for liquefaction of the sand during ground shaking, as in an earthquake. The release of pore pressure from the liquefied sand causes venting of water and sand through the overlying materials, which may result in small mounds of sand, termed sandblows, on the soil surface.

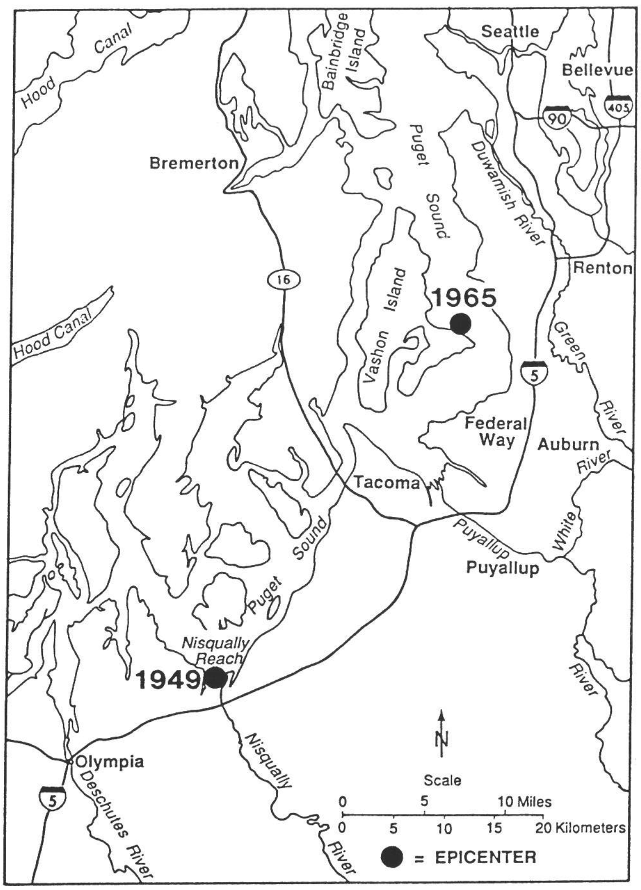


Figure 1. The location of Puyallup in relation to the epicenters of the 1949 and 1965 Puget Sound earthquakes. The hypocentral distance from the two quakes to the city is 65 ± 2 km.

In May 1989, I placed a notice in the valley newspaper, *The Pierce County Herald*, asking for information from persons who had witnessed sandblows or "gushers" during the 1949 or 1965 earthquakes. I received 27 phone calls from persons who saw these phenomena.

The pictures accompanying this article were taken immediately after the 1949 earthquake by Richard Six, who was then a Tacoma police officer. The street flooding (Fig. 2a) is on 4th Avenue NW, just west of the Puyallup school-bus garages. The day of the earthquake, April 13, was sunny and dry. Six stated that although there were some broken water mains after the earthquake, he was unaware of ruptured mains in the area of the flooding. The flooding was a product of the "gushers". A heavy layer of sand that erupted from the blows was deposited on lawns (Figs. 2b-d).

Memories of many events may dim after 40 years, but an earthquake tends to remain imprinted in the mind. I received some vivid and detailed descriptions from those with whom I spoke. One person told me of a crack in a basement floor that allowed liquefied sand to fill the basement to a depth of about 4 ft. Another said sand filled the basement and floated a furnace. There were descriptions of "gushers" in gardens, in front and back yards, and in crawl spaces, as well as of sandy water venting upward to heights of 6 ft or more. Others told of simple bubbling or small spurts of sandy water.

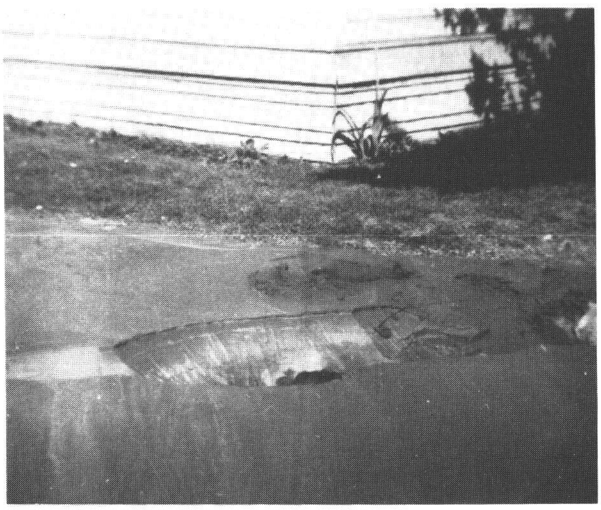
There were many stories of small hills of sand, 7 to 9 in. in diameter and as much as 9 in. high. Clusters of as many as 20 such hills appeared on front and back lawns or open fields. One woman described the block where the Puyallup High School gymnasium now stands as a site of active sandblows. A single sandblow north of the Puyallup River in the Firwood area was reported to cover an area of 15 to 20 ft^2. The owner of the property states that he can grow nothing on that spot.

Most of the reported sites of sandblows are in the northwest part of the city (Fig. 3) on both sides of the railroad tracks and in the farm lands north of the river toward the city of Fife. I received only one report of a sighting near the fairgrounds in Puyallup, but there were many open fields near that site at the time – and few observers. There was one report from Sumner, and a call from a woman in Orting who reported a "gusher" that seemed a bit "oily". An oily sandblow would not be typical.

The 1965 earthquake (Richter magnitude 6.5) evidently caused little sandblow activity. The only report I received concerning this earthquake involved a considerable amount of sand and water on the Aylen Junior High School playing field. This field is

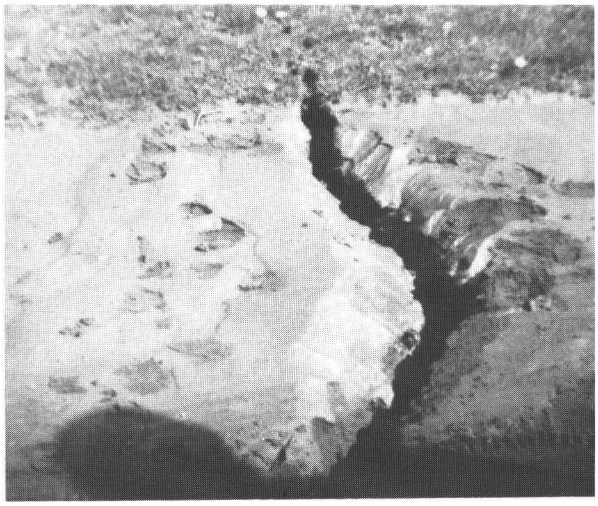
a

b



c

Figure 2a. Street flooding on 4th Ave. NW in Puyallup, apparently caused by water released from subsurface liquefaction. **Figures 2b, c, d**. Three separate sandblows on the lawn of a residence on 4th Ave. NW. (Reproduced from photographs by Richard Six.)



d

about 150 yd from the site where the photographs accompanying this article were taken.

The pace of development and population increase continues to rise in the Puyallup area. Buildings will not be properly supported if founded in liquefiable sand layers, and damage to roadways and underground utilities is commonly the result of liquefaction of the underlying or surrounding soil. Information about the locations of liquefied sand will be helpful in planning safe construction.

EDITOR'S NOTE – A companion article covering the geotechnical aspects of the shallow sand layer will appear in the next issue.

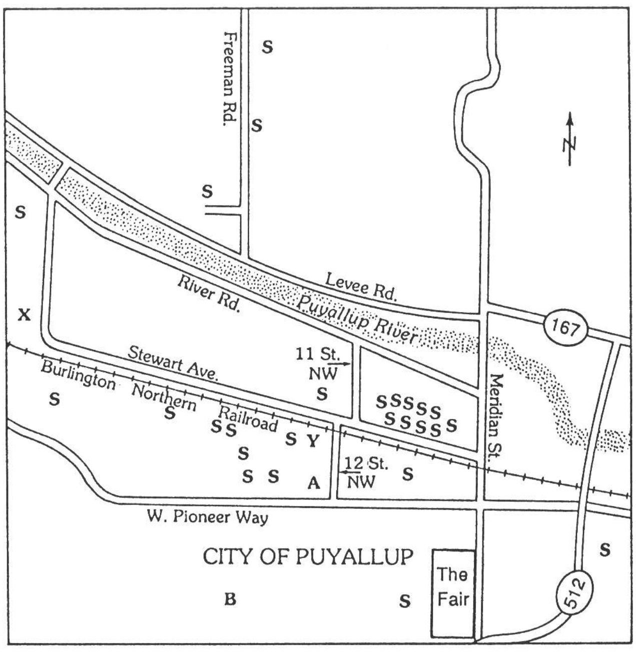


Figure 3. Central Puyallup: S, sandblows reported for the 1949 earthquake; Y, 4th Ave. NW site where photos on this page were taken; X, house that turned on its foundation; A, only sandblow reported for the 1965 earthquake; B, currently active "sand boils" in DeCoursey Park swamp.

George A. Bethune: First State Geologist

By Angus Young Bethune

EDITOR'S NOTE — Angus Young Bethune, living in retirement in Spokane, is the son of George Angus Bethune.

George Angus Bethune was born June 1, 1857, the sixth child of second-generation Canadian parents originally of Scottish-English ancestry. His birthplace was on the family holdings fronting on the north bank of the St. Lawrence River in eastern Canada.

He was trained for the Presbyterian ministry, which probably accounts for his good command of the English language. However, his training must have included instruction in chemistry, physics, geology, and mathematics, all of which seemed to capture his interest, and which he subsequently put to good use in his chosen profession. He forsook a possible career in the church to follow the expanding mineral industry growing along with the burgeoning population of western North America.

George A. Bethune, first Washington State Geologist, in his uniform as lieutenant colonel, Quartermaster Corps, Washington State National Guard, circa 1890, age about 33 years. Photograph taken in Tacoma.

The exact date of his migration to the United States is not known, but the year 1878 (following his formal schooling) may be assumed without serious error. He first worked in the mines and reduction plants in Colorado, then moved to western Montana to engage in similar work. With the Pacific Coast as his ultimate destination, his next activity was to join the railroad survey party establishing the new route from the Bitterroot Range in Montana, through Idaho, then across the eastern Washington desert to link up with the tunnel at Stampede Pass in the Cascades. The time and place of the survey suggests strongly that it was for the then partially completed Northern Pacific Railway, which terminated in Tacoma.

By 1888 he was established in Tacoma as a member of a mining partnership, had become known as a chemist-assayer, and was a naturalized American citizen.

The circumstances that culminated in his appointment as first State Geologist of Washington are not known. However, two major factors must have contributed to this end. First, he was associated with the Republican Party, then led by Elisha P. Ferry, which became the dominant political force of the new state in 1889. Second, experienced men with technical knowledge dealing with the earth sciences, having the requisite physical stamina for the job, and residing in the area, were comparatively scarce. Qualified men were hard to find on the raw frontier. When the state was admitted to the Union in 1889, Bethune was awarded a commission of lieutenant colonel in the Quartermaster Corps of the newly formed National Guard.

The Washington legislature, for political reasons, failed to fund the office of State Geologist in 1892. At that point Bethune, after submitting his second annual report, moved to San Francisco to follow the mining industry. He maintained his headquarters there for many years.

In 1894 he married Helena Amie Young of San Francisco. Two children were born of this union: Beatrice Amie Bethune in 1898 and Angus Young Bethune in 1907.

George A. Bethune pursued a successful business of scouting mining properties for possible development and sale, and he operated independent assay offices in both California and Arizona until his retirement.

He died in Los Angeles in 1937.

How the Washington State "Geological Survey" Got Its Start in 1890

By J. Eric Schuster

EDITOR'S NOTE: The position of the State Geologist began its second century February 28, 1990. This article covers the first year of the operation of that office. Subsequent articles will follow the establishment of the state's "geological survey" and events of the earliest years.

The need for systematic investigation and advertising of Washington's mineral resources was recognized by the first state legislature in 1890 and resulted, on February 25, in the approval of a bill creating a state Mining Bureau. The Mining Bureau was composed of the Governor, Lieutenant Governor, and State Treasurer, who were to serve without compensation except for traveling expenses.

The Mining Bureau was directed to: collect reliable statistical information concerning the production and processing of minerals in the state; examine different ore treatment processes used in the state; inquire into the merits of processes and machines used elsewhere for mining and metallurgical purposes; correspond with corporations, individuals, and schools of mines in other states in reference to mining and metallurgy; keep such correspondence and reports on file for viewing or for publication from time to time; make an annual report to the legislature; and house a cabinet of metallurgical exhibits. To fund the first year of operation the legislature provided $250 to rent a room for the exhibits and $1,500 for traveling expenses (Weir, 1890, p. 249-251).

Figure 1. G. A. Bethune had his office and laboratory in this building at 1111 Pacific Avenue in Tacoma. (Photograph courtesy of the Tacoma Public Library.)

Three days later a companion bill was approved, creating the office of State Geologist. The Mining Bureau was to appoint the State Geologist, with the advice and consent of the senate. The State Geologist was to be a person of known competence, theoretically and practically acquainted with the mining and treatment of ores.

The State Geologist was to: collect reliable statistical information on the production and reduction of all precious or useful minerals in the state; keep all reports, correspondence, and papers on the production and reduction of minerals, to be submitted to the Mining Bureau as they required; collect, analyze, classify, mark, catalog, and describe mineral and geological specimens found in the state and assume charge of them under the supervision of the Mining Bureau; analyze, on request, samples of ores, minerals, metals, coals, and mineral waters under a fee schedule provided by the legislature; solicit contributions of ores, minerals, rocks, fossils, and specimens of natural history and be curator of the state museum under the direction of the Mining Bureau; visit each mining county at least once a year and examine as many of the mines as practicable; visit, examine, and determine the safety of any mine upon receipt of a written complaint of dangerous conditions from five or more of the mine's employees, direct the mine owner or operator to make the necessary changes, and institute legal proceedings if needed; and make an annual report to the Mining Bureau. For the first year's activities of the State Geologist, the legislature appropriated $1,200 for salary, $300 for chemicals and apparatus for the State Geologist's office, $1,500 for contingent and traveling expenses, and $300 for rent of office and laboratory (Weir, 1890, p. 647-651).

Both the Mining Bureau and the State Geologist were to concern themselves with the state's mineral resources, and on a first reading their duties seem to overlap. But the list of their duties makes it clear that the Mining Bureau was to be an executive organization intended to accumulate samples and literature pertinent to the state's mineral industry and to make such information available. The State Geologist, on the other hand, was given extensive field and laboratory responsibilities.

Note that the Mining Bureau and State Geologist's office were created for a rather narrowly defined purpose—to collect and disseminate information that would further the development of the state's mineral industry. The need for a broader charge to the State Geologist and Mining Bureau was partially recognized by the legislature as early as 1891, when it made an appropriation to fund a state mineralogical and geological survey. But an enduring state geological survey with a broader charge would not be formed until 1901.

Shortly after the passage of the act creating the office of State Geologist, the Mining Bureau met and appointed George A. Bethune as State Geologist. (See related article, this issue.) Bethune rented quarters in Tacoma and set up his office and laboratory (Bethune, 1891, p. 3) in two rooms on the sixth floor of a new 6-story building (the Barlow-Catlin or Washington block) at 1111 Pacific Avenue that boasted the only passenger elevator in the city (Fig. 1). He resided at 722 D Street and later at the Tacoma Hotel, now Stadium High School (Hunt, 1916, v. 1, p. 539; City of Tacoma, 1890, 1891).

Bethune apparently wasted little time in setting about to accomplish his assigned tasks. By June 21, 1890, he was in Spokane with Lieutenant Governor and Mining Bureau President Charles E. Laughton and Olympia Mayor John F. Gowey; the three were making a tour of mining districts in the state. By this date Bethune had also been appointed the official assayer of the Spokane and Seattle mining exchanges, and he expected his office to be moved to Spokane in the near future (*Spokane Falls Review*,1890). He evidently spent much time in the field in 1890, for by the time his first annual report was printed in January 1891, Bethune (1891, p. 4) could say,

"During the past year, or rather that part of it intervening between the date of my formal taking of office and the present time, I have visited, inspected, and now report on every mining district, every mine of promise or prospective worth, every industrial and commercial enterprise born of the mineral development of the country, and all geological formations indicative of the existence of merchantable metal in Washington, as far as known."

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Mineral Industry News Notes

By Nancy L. Joseph

Metals

Chelan County

A total of 150,420 oz of gold and 302,731 oz of silver were produced and shipped in 1989 from the Cannon mine, a joint venture between Asamera Minerals Inc. (operator) and Breakwater Resources Ltd. Production from the epithermal deposit was from 520,993 tons of ore having an average grade of 0.305 oz gold per ton. The Cannon is the second largest underground gold mine in the nation. Asamera Minerals is owned by Asamera, Inc., which is 91 percent owned by Gulf Canada Resources Ltd. Negotiations with Corona Corp. to acquire the assets of Asamera Minerals, which owns 51 percent of the mine, from the parent company have been terminated. Another company is presently considering raising the necessary capital to purchase Asamera's non-petroleum interests.

Ferry County

Hecla Mining Company has begun to drive the 6,500 ft of new decline and development drifts at the Republic Unit, the second largest gold mine in the state. The $6.6 million decline will provide access to mineralized areas discovered by underground drilling from the Golden Promise area, expand underground exploration, and permit the use of rubber-tire vehicles in the mine. The mine produced 74,335 oz of gold and 301,432 oz of silver in 1989 from 82,961 tons of ore that has an average grade of 0.90 oz gold per ton. Proven and probable reserves at the mine at the end of 1989 totaled 412,324 tons averaging 0.81 oz of gold per ton and 3.3 oz of silver per ton. The company also announced the retirement at the end of April of Josef Suveg, manager of the Republic Unit. Joseph M. Maher has been appointed as the new manager.

The first gold-silver dore bar was poured at the Kettle River Project, a joint venture of Echo Bay Exploration Inc. (majority owner and operator) and Crown Resources Corp. The dore represents ore from two new mines, the Kettle mine, west of Curlew, and the Overlook, 12 mi north of Republic, both of which began limited production in late 1989. Echo Bay anticipates producing 110,000 oz of gold during the first year of production.

Okanogan County

Battle Mountain Gold Co. (BMG) purchased (for $5 million) an option to acquire a 51 percent interest in the gold exploration project near Chesaw held by Crown Resources Corp. This includes the Crown Jewel deposit (formerly known as the Buckhorn Mountain) that is reported to contain uncut, open-pit minable reserves of approximately 5.5 million tons containing 580,000 oz of gold at a grade of 0.106 oz of gold per ton. The option on the skarn deposit runs through January 1991, when BMG would pay an additional $5 million to exercise the option. In addition, BMG, which will assume responsibility for exploration and development of the property, is committed to exploration expenditures during 1990.

Stevens County

Equinox Resources Ltd. announced in mid-April that it will purchase the Van Stone mine from Callahan Mining Co., U.S. Borax & Chemical Corp., and Consolidated Brinco Ltd. for $1,050,000. An underground operation is planned at the mine 15 mi north of Colville. The mine, with reserves of 2.4 million tons containing 5.4 percent zinc and 1.1 percent lead, was last active in 1971 when ASARCO operated an open pit mine there. Although ASARCO conducted underground exploration, no underground mining took place. Development is expected to cost $8.8 million; the infrastructure is in place, and only upgrading will be necessary. The company hopes to have the mine in production by the end of the year.

Industrial Minerals

Pend Oreille County

Lafarge Corp. announced in late March that they would close and demolish the portland cement plant in Metaline Falls that they acquired from Lehigh Portland Cement Co. in mid-1989. The plant, which produces about 200,000 tons of cement annually, is one of the smallest in the country, but it was the only cement plant in the state to mine stone in Washington. Lafarge cited higher than anticipated costs to update the 80-year-old, dry process facility as reasons for the closure. The plant employs 60 workers and is one of the main employers in the northern part of the county.

Earthquake hazards workshop

The Division hosted the Fourth Annual Workshop on Earthquake Hazards in the Puget Sound and Portland Regions April 17-19 in Seattle. Prof. Bekhzad Yulgashev (second from left, above), a particle physicist, and Prof. Tursun Rashidov (second from right), a seismic engineer, representing the Uzbek Academy of Sciences (USSR), were distinguished guests. During the meeting, Ray Lasmanis (right) and Tim Walsh (left) were made honorary Uzbeks.

A field trip to Restoration Point on Bainbridge Island gave Bob Bucknam, U.S. Geological Survey (center, photo below), an opportunity to show evidence of 7 m of uplift (perhaps in one event) within the last 1,500 yr.

Source of Minerals Information in Spokane

By Kathleen M. Johnson
U.S. Geological Survey, Spokane

The U.S. Geological Survey has opened a Minerals Information Office (MIO) in the U.S. Courthouse in downtown Spokane to serve the public in the Pacific and inland Northwest. The MIO was established to respond to questions on minerals and mining, as well as to provide information on the activities and programs of the U.S. Geological Survey in the area of mineral resources. Another goal of the MIO is to improve the exchange of information among federal and state agencies and other generators and users of minerals data.

The Minerals Information Office features the Resource Oriented Computer System (ROCS), a graphically oriented program for displaying mineral resource and related earth science data on a Macintosh computer. It operates in stand-alone mode, using a laser printer and pen plotter to generate output. ROCS uses the USGS's Mineral Resources Data System (MRDS) as its source of mineral-deposit data. MRDS has more than 80,000 records describing mines and prospects around the world. ROCS produces maps (on the screen, the laser printer, or the plotter) showing mineral deposits and political boundaries for any geographic area; additional thematic data (geology, wilderness boundaries, drainage basins) are available for some areas. Descriptive data for mines and prospects include information on location, commodities, exploration/development, geology, production, reserves, resources, and references.

Data on a variety of commodities are available; information, whether from ROCS or other sources, is customized to meet the requester's specific needs. The MIO provides the following services:

- searches of USGS mineral-resource data bases;
- access to reports on USGS minerals-related studies;
- contact with USGS mineral-resource specialists (geologists, geophysicists, and geochemists); and
- assistance with specialized research on mineral-resource topics. (Most information and computer searches are free; a nominal charge may apply to extensive searches.)

The MIO is located in Room 651 of the U.S. Courthouse, at West 920 Riverside Avenue, Spokane and is open Monday through Friday, 9:00 a.m. to 4:00 p.m. The office is near the USGS Earth Science Information Center, where USGS publications and maps are available for over-the-counter purchase.

Requests for information can be made by visiting the office, by calling (509) 353-2649 or (509) 353-3113, or by FAX to (509) 747-8980. Demonstrations of ROCS are given on request. If you think we might be able to answer a question, or you're just curious to see what we're about, please stop in to visit or give us a call.

BLM Implements Policy to Prevent Deaths of Small Wildlife

The Bureau of Land Management (BLM) issued on February 9, 1990, a national policy that would limit the use of plastic or metal pipe for mining-claim markers on BLM-administered lands because the pipes may present hazards for small birds and reptiles.

BLM wildlife biologists believe that the pipes pose a hazard because some species have a tendency to enter these pipes to escape predators or to find shelter or nesting areas. Once they get into a pipe, either through a hole (in perforated pipe) or through the open end of hollow, uncapped pipes, they can be trapped.

The American Mining Congress, with 500 corporate members including mineral producers and mining equipment manufacturers, has informed BLM that they are equally concerned about this potential hazard to small wildlife. They have pledged to alert their membership about this problem and to work with miners, BLM, and state mining associations to come up with appropriate solutions.

(From a Department of the Interior news release)

Selected Additions to the Division of Geology and Earth Resources Library

February 1990 through April 1990

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New Division Releases

Bulletin 79: Bibliography and index of the geology and mineral resources of Washington, 1981-1985, compiled by C. J. Manson. This 484-page publication supersedes Open File Report 86-5. The price is $11.53 + .97 tax = $12.50.

Open File Report 90-8: Preliminary bibliography and index of the geology and mineral resources of Washington, 1986-1989, compiled by C. J. Manson. 322 pages. The price is $5.53 + .47 = $6.00.

The bibliography and index of Washington geology and mineral resources is brought up to date with the two releases above.

Open File Report 90-6: Geologic map of the Banks Lake 1:100,000 quadrangle, Washington, compiled by C. W. Gulick and M. A. Korosec. This 20-page publication, which includes 1 plate, is priced at $1.38 + .12 = $1.50.

Open File Report 90-7: Geologic map of the Rosalia 1:100,000 quadrangle, Washington-Idaho, compiled by S. Z. Waggoner. This 20-page publication includes 1 plate. It is priced at $1.38 + .12 = $1.50.

Open File Report 90-9: Geologic map of the east half of the Twisp 1:100,000 quadrangle, Washington, compiled by B. B. Bunning. This 51-page report, including 1 plate, costs $2.78 + .22 = $3.00.

Open File Report 90-10: Geologic map of the Republic 1:100,000 quadrangle, compiled by K. L. Stoffel. This 62-page report includes 1 plate. The price is $2.78 + .22 = $3.00.

Open File Report 90-11: Geologic map of the Oroville 1:100,000 quadrangle, Washington, compiled by K. L. Stoffel. This 58-page report includes 1 plate. The price is $2.78 + .22 = $3.00.

The five Open File Reports above are additional releases, bringing to eight the total released to date in the series of maps that will be used to prepare a 1:250,000-scale geologic map of the northeast quadrant of Washington.

Open File Reports 90-1 (Geologic map of the Moses Lake 1:100,000 quadrangle) and 90-2 (Ritzville quadrangle) were incorrectly numbered in the last issue of the Washington Geologic Newsletter.

Add $1 to each order for postage and handling. Orders should be sent to the address on page 2.

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