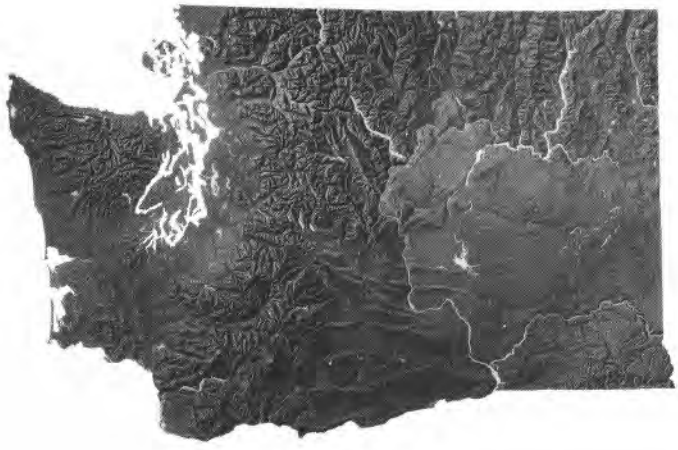

WASHINGTON GEOLOGIC NEWSLETTER

Volume 18, Number 4 December 1990

Washington State Department of Natural Resources Division of Geology and Earth Resources

The K M Mountain landslide, February 1990. See article, p. 3. Photo by Washington State Dept. of Transportation.

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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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Art Stearns, *Supervisor*

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Raymond Lasmanis, *State Geologist*
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Growth Management Act of 1990 and Mineral Resource Lands

by Raymond Lasmanis

A Growth Management Act, Substitute House Bill 2929, was passed by the 51st session of the state legislature. The act became effective July 1, 1990. Section 5 of the act requires various state agencies to provide guidelines to counties and local government for classification of agricultural, forestry, and mineral resource lands, as well as critical areas. Section 17 of this act stipulates that counties and local governments have until Sept. 1, 1991, to designate such natural resource lands and critical areas.

The Washington Department of Natural Resources was required by the act to provide guidelines regarding forest and mineral resource lands. The State Geologist, working in conjunction with the Technical Advisory Committee of the Department of Community Development, developed a set of guidelines and procedures pertaining to mineral resource lands. These guidelines are provided in order to comply with Emergency Rule IV, Section D, which became effective Sept. 1, 1990. The rule states:

"D. Mineral Resource Lands

1. Classification Criteria

Areas shall be classified into Mineral Resource Lands based on geologic, environmental and economic factors, existing land uses and land ownership. The areas to be studied and their order of study shall be specified by counties and cities.

a: Counties and cities must classify the following minerals: sand, gravel, and valuable metallic substances.

b. In classifying these areas, counties and cities shall use maps and information on location and extent of mineral deposits provided by the Washington State Department of Natural Resources (DNR). Additionally, DNR has a detailed minerals classification system counties and cities may choose to use.

"2. Source of Data

Counties and cities may seek additional information from private land owners to supplement information from DNR."

A Mineral Resource Land Classification System is presented starting on page 21. The system has been adapted from that used in California. After review by the mineral resource industry of the state and revisions based on their comments, copies of the Mineral Resource Land Classification System have been sent to all the counties.

(For additional copies of the text, please contact Raymond Lasmanis, State Geologist.)

MAILING ADDRESSES

Main Office
Department of Natural Resources
Division of Geology and Earth Resources
Mail Stop PY-12
Olympia, WA 98504
Phone: (206) 459-6372
FAX: (206) 459-6380

Field Office
Department of Natural Resources
Division of Geology and Earth Resources
Spokane County Agricultural Center
N. 222 Havana
Spokane, WA 99202
Phone: (509) 456-3255

NOTE: Publications available from the Olympia address only.

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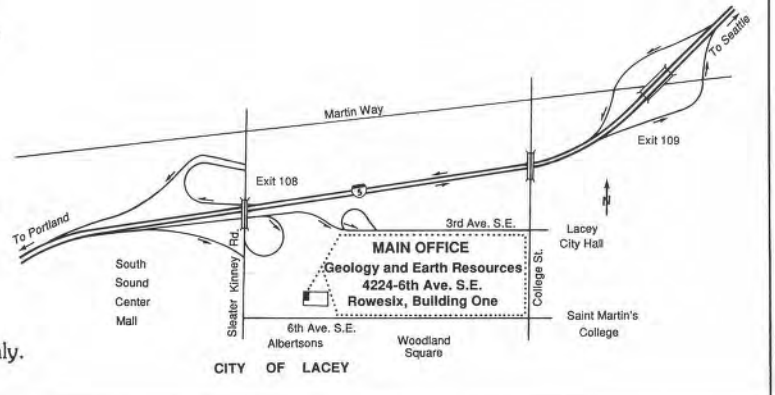

The K M Mountain Landslide near Skamokawa

by
Steve M. Lowell
Chief Engineering Geologist
Washington State Department of Transportation

INTRODUCTION

On February 10, 1990, at approximately 5:00 PM, a massive landslide occurred at milepost 24.5 along State Route 4 (SR4), approximately 5 mi west of Skamokawa, Washington (Fig. 1). The landslide involved an estimated 1.5 million to 2.0 million yd^3 of material and destroyed approximately 700 feet of SR4, a critical transportation link between the Interstate 5 corridor and the southwest Washington coast. (See cover photo.)

Within 2 days of the landslide, a detailed field reconnaissance was conducted by Washington State Department of Transportation (WSDOT) engineering geologists to determine the nature of the landslide and to identify potential options for re-establishing this transportation link. The conceptual alternatives identified were:

(1) Regrade the landslide using excavated material from upslope to construct a downslope counterweight berm.

(2) Regrade the landslide upslope of the former highway and construct a mechanically stabilized embankment buttress at the former centerline.

(3) Relocate the highway.

On the basis of preliminary geotechnical data, WSDOT decided to investigate the technical feasibility of rebuilding the SR4 alignment across this landslide at the location of the former highway.

The investigation of the landslide consisted of two phases of geotechnical investigation and analysis. The first phase involved (a) initial field exploration to determine site conditions, subsurface geology, and groundwater conditions, (b) development of a landslide model and preliminary computer evaluation of landslide stability, and (c) development of conceptual landslide corrections and determination of their feasibility. The second phase work, based on the conclusions drawn from the first phase, would allow WSDOT geotechnical engineers to make detailed recommendations for the landslide correction and re-establishing the highway.

The first phase of the geotechnical investigation has been completed, and the second phase is near completion.

LANDSLIDE DESCRIPTION

The SR4 alignment near the landslide traverses the southwest flank of a knob that reaches an elevation of 520 ft, referred to in this article as the elevation 520 knob. The part of the former highway alignment that was destroyed by the landslide was approximately 600 ft downslope of the knob at an approximate elevation of 320 ft. Seven hundred feet downslope of the highway is Eggman Creek. The landslide involved an overall length of approximately 1,100 ft and a width that averaged 800 ft.

Field reviews indicate that the failure mechanism for the landslide was complex and involved several stages. Landslide movement was initiated as a slow creep downslope of the existing highway. This movement was expressed on the highway alignment as pavement settlement, and it was apparently occurring as much as 2 weeks prior to the failure on February 10. On the afternoon of February 10, the movement began to accelerate, with as much as 1 ft of pavement settlement occurring in 1½ hours. In addition, other areas of the highway alignment began to crack and buckle at the same time.

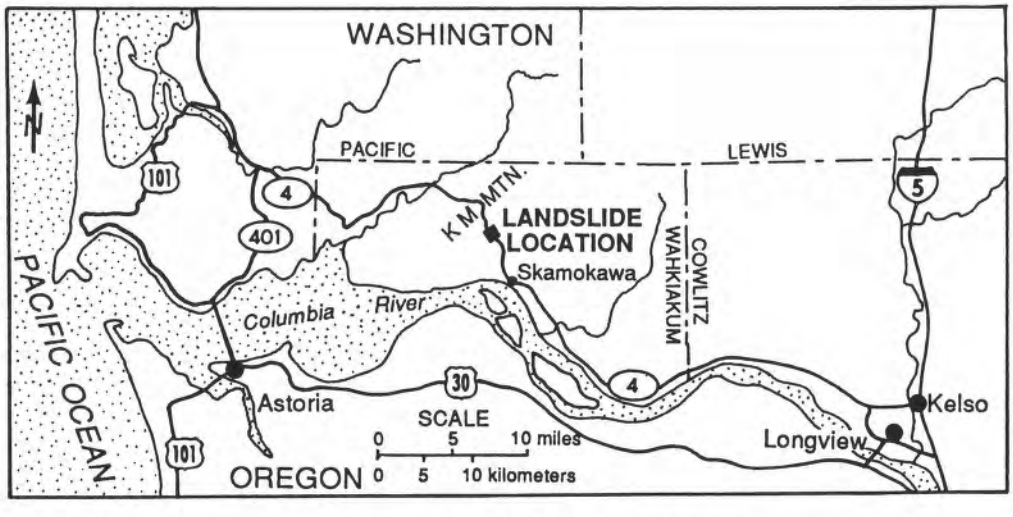

Figure 1. Location of K M Mountain landslide.

With the downslope portion of the landslide having moved, the stability upslope of the highway was highly compromised. This area began to fail as a massive block of siltstone and rotated as much as 20 degrees.

Almost simultaneously with the failure of the upslope mass, a tremendous amount of ground water was released in the toe area of the landslide. This release resulted in debris flows in the two pre-existing drainages on the west and east edges of the landslide. These de-

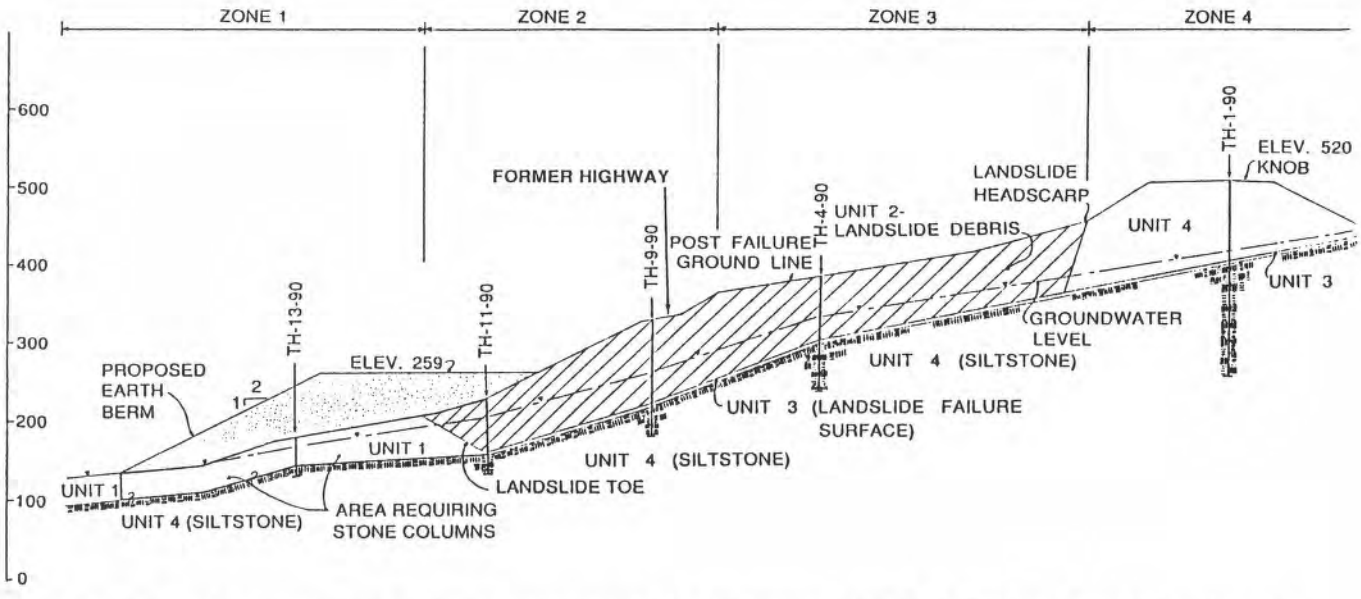

Figure 2. Schematic cross section (northeast end to the right) of the K M Mountain landslide, showing the zones and geologic units determined by WSDOT geotechnical investigations and location of proposed stabilizing features.

bris flows travelled rapidly downslope toward Eggman Creek.

Descriptions obtained from WSDOT maintenance personnel, who were on the landslide at the time of failure, indicated that once catastrophic failure of the area was initiated, the landslide took only a matter of minutes to occur.

GEOTECHNICAL INVESTIGATION

The geotechnical investigation consisted of:

- Extensive use of vertical and oblique aerial photography to interpret the site and its associated landforms and geology.
- Surficial geologic mapping to confirm the airphoto interpretation, to locate geologic features not evident on the airphotos, to delineate undisturbed and disturbed soil and rock units, and to locate springs and seeps.
- A total of 18 deep test borings drilled to determine the subsurface conditions in the landslide. Continuous sampling of the test borings consisted of both standard penetration tests and sampling of undisturbed materials to determine soil/rock stratigraphy and for laboratory testing. Standard diamond core drilling techniques were used to recover representative samples of the bedrock. Slope inclinometers were installed in twelve of the test borings to provide data on movement in the landslide mass. At 14 locations piezometers were installed to monitor groundwater levels. Twenty-one electronic cone penetrometer probes were made to provide *in situ* measurements of shear strength and pore pressure.
- A laboratory testing program for this phase of the project consisting of a series of tests on representative soil and rock samples obtained to determine soil/rock strength parameters. Those tests included soil gradations (with Atterberg limits), unconsolidated undrained triaxial tests, consolidated undrained triaxial tests, remolded direct shear tests, and unconfined compression tests.

Four distinct zones (Fig. 2) were identified in the landslide. Those zones are described as follows:

Zone 1: This zone is located downslope of the former highway alignment and above Eggman Creek. The zone is approximately 600 ft wide and 500 ft long. In this zone the primary post-failure features are two distinct debris flows separated by a 250-ft-wide topographic high that is partially intact. Field review of this ridge-like feature revealed a landslide toe lobe (Fig. 3) located approximately 300 ft downslope of the former highway. The toe lobe is approximately 15 to 20 ft high and has overridden downslope trees to a height of approximately 5 to 10 ft. The west debris flow is approximately 200 ft wide and extends downslope to the edge of Eggman Creek. The east debris flow is approximately 150 ft wide and has stopped short of Eggman Creek by approximately 200 ft. Review of airphotos taken in 1981 indicates that both debris flow areas correspond to well-defined drainages that were present prior to the landslide.

Zone 2: This zone is located directly upslope of Zone I and includes the former location of the highway (Fig. 4). The width of this zone is approximately 700 ft; its length is approximately 200 ft. Vertical relief is about 100 ft. In this zone the slopes are steep and consist of large, broken, and jumbled blocks of siltstone that have been rotated 40 to 45 degrees. (See cover photo.) This zone represents the toe area of the massive upslope landslide, as discussed below.

Figure 3. Toe zone of the K M Mountain landslide, about 300 ft downslope of the former highway location. (Photo by S. M. Lowell)

Zone 3: This zone is located directly upslope of Zone 2. This zone is approximately 700 to 900 ft wide and 250 to 400 ft long. Blocks in parts of the zone have rotated as much as 20 degrees, and it contains large, broken blocks of siltstone. In the upper part of this zone is a large headscarp/graben feature (Fig. 5). The headscarp/graben exhibits as much as 100 ft of vertical displacement and 100 to 150 ft of horizontal movement. Landslide movement in this zone involved deep-seated failure in the siltstone bedrock to depths in excess of 100 ft.

Zone 4: This zone is located directly upslope of Zone 3 and is composed of the elevation 520 knob. Shortly after the landslide, extensive cracking developed in the eastern 550 ft of this zone; it extended back from the headscarp area for approximately 100 to 200 ft. In addition, a field review of this area revealed a detached block approximately 200 ft wide and 75 ft long in the central portion of this zone. The estimated volume of this detached block is as much as 55,000 yd^3. At the present time, the movement detected in this zone has been attributed to stress relief in the headscarp.

LANDSLIDE ANALYSIS

The field exploration and laboratory analysis allowed WSDOT engineering geologists to determine the distribution of the geologic units and the strength parameters of those units. The four units (Fig. 2) are described below:

Unit 1: The majority of the downslope area in Zone 1 consists primarily of debris flow and fluvially deposited soils composed of gray, soft to stiff, fine, silty, clayey sands.

Unit 2: Landslide debris in Zones 2 and 3 consists of a gray, very loose to medium dense, silty sand intermixed with large blocks of siltstone rubble.

Unit 3: Failure zone material at the base of Unit 2, and thought to be present in the elevation 520 knob, consists of a gray, very soft to stiff, sandy clay to very silty clayey sand.

Unit 4: Intact siltstone bedrock underlies Units 1, 2, and 3 and most of the elevation 520 knob.

Information about the subsurface geology in the landslide area led WSDOT engineering geologists and geotechnical engineers to conclude that the counterweight earth berm concept and a partial regrade upslope had the highest potential to improve the stability of the landslide. Therefore, this alternative was evaluated in detail.

Figure 4. Former location of State Route 4 on the K M Mountain landslide. Note the large, jumbled blocks of siltstone (bedrock). View to the southwest. (Photo by S. M. Lowell)

Figure 5. Headscarp area of the K M Mountain landslide. The headscarp is about 100 ft high. A WSDOT drill access road can be seen in the center of the photo. View to the southwest. (Photo by S. M. Lowell)

An extensive series of sliding block stability analyses incorporating the subsurface geology and soil strength parameters was performed using a two-dimensional, limiting equilibrium, slope stability computer program (PCSTABL 4). The results of these computer-aided analyses indicate that a counterweight earth berm with a partial regrade upslope will provide *upslope stability* at an acceptable factor of safety (F.S. = 1.25 min.).

A stability analysis of the berm and the foundation soils underneath the berm indicates that some form of ground improvement would be required to provide *overall stability* for the landslide. Possible methods of achieving overall stability and conclusions reached by WSDOT engineers were:

(1) *Major Regrade Upslope*: Analyses showed that removing additional material from Zone 3 provided no major increase in overall stability.

(2) *Lower the Groundwater*: Analyses of lowering of the ground-water level in Zone 3 by constructing a subsurface drainage gallery indicated that only minimal improvements in overall stability were attainable.

(3) *Shear Key Below Berm*: Potential construction of a shear key installed beneath the counterweight berm and founded on the intact bedrock below the Unit 1 soils was analyzed in detail. Because of the low soil strength and thickness of saturated soil in the area of the shear key, WSDOT engineers concluded that a standard open-excavated shear key could not be constructed. A non-standard cofferdam shear key (50 ft wide and 700 ft long) was then evaluated. Although this offered substantial improvements in terms of the overall stability, WSDOT engineers felt that design issues of a braced cofferdam system that accounted for landslide forces and the high cost of construction made this concept unattractive.

(4) *Lime Columns*: This method of ground improvement entails the *in situ* mixing of lime with the foundation soils to improve the soil strength. Although this method holds some technical merit, WSDOT engineers saw this option as environmentally unacceptable due to the potential for leaching of the chemical constituents into Eggman Creek, an anadromous fish stream.

(5) *Stone Columns*: Installation of high-strength columns of rock by the vibroreplacement method would improve the overall strength of the foundation soils and promote drainage. Analysis indicates that this method of ground improvement should provide adequate support for the proposed berm and would raise the factor of safety for overall stability to within acceptable limits.

On the basis of present field information, laboratory test data, and stability analyses, WSDOT engineers found that, at least conceptually, a counter-weight earth berm with stone column ground improvement is technically feasible to correct this landslide.

The following design considerations (based on the Phase I geotechnical investigation and analyses) were used for conceptual estimating purposes.

Earth Berm Recommendations:

- Top Elevation of Berm: 259 feet (minimum)
- Width of Berm: 270 feet (minimum) as measured at the 259-foot contour
- Berm Embankment Slopes: 2:1 (maximum)
- Drainage Blanket: A minimum 5-foot-thick rock drainage blanket beneath the earth berm to limit the build-up of groundwater.
- Source of Earth Berm Material: Landslide debris from Zone 3, and bedrock from Zone 4 may be usable for constructing the earth berm. Due to the slaking nature of this material, heavy compaction was recommended to promote breakdown of the material. Construction of the earth berm should take place during the drier parts of the year.
- Source of Rock Drainage Blanket: Material for this blanket will have to be obtained from sources outside the project limits. This rock must be free draining and have the quality/size characteristics of light, loose rip-rap.

Stone Columns:

- Spacing of the Stone Columns: 7 feet (maximum)
- Spacing Pattern: Equilateral triangle
- Stone Column Diameter: 4 feet (minimum)

Figure 6. Geotechnical exploration drilling with Mobil B-61 in progress, spring 1990. The purpose of this exploratory drilling (Phases I and II) was to define subsurface conditions and obtain samples for laboratory testing. (Photo by S. M. Lowell)

- Estimated Depth of Stone Columns: 40 to 50 feet
- Stone Column Coverage: Full width and total length of the earth berm.
- Source of Stone Column Material: Outside the project area limits.
- Cost of the Stone Columns: Estimated at approximately $25.00 per linear foot of column.

CURRENT ACTIVITIES

To provide final geotechnical design recommendations for landslide correction, a Phase II geotechnical investigation is presently nearing completion. (See Fig. 6.) This investigation has concentrated primarily on the detailed characterization of the footprint area underneath the proposed earth berm.

The majority of the investigation was accomplished by a 20-ton Electronic Cone Penetrometer to provide *in situ* measurements of shear strength, pore pressure, and pore pressure dissipation on a continuous downhole basis. Conventional test holes were also drilled in critical areas to provide for additional undisturbed samples for laboratory triaxial testing.

Assuming satisfactory results are obtained from this investigation, construction of the berm might begin in early 1991.

Regional Mineral Officer to be based in Spokane

Rodney J. Minarik will work out of the Western Field Operations Center in Spokane as the new State Mineral Officer for Washington, Idaho, Montana, Oregon, and Wyoming.

Minarik was recently appointed Mineral Officer for the five states by the U.S. Department of the Interior Bureau of Mines. His duties will include extensive travel throughout the region. He will meet and work with people in the mining industry, state and other federal agencies, academic institutions, and civic groups.

Minarik also will be responsible for collecting, analyzing, and reporting on mineral-related issues, problems, and for their possible solutions within each of the five states.

Minarik has a strong background in ferroalloys and base metals and has done extensive work with precious metals. He is a native of western Pennsylvania. He was graduated from Indiana University of Pennsylvania, and he earned a Master of Science degree in mineral economics from Pennsylvania State University.

AGI Minority Scholarships Available

The American Geological Institute (AGI) announces an increase in funding for minority geoscience scholarships for the next academic year. The value of awards to be given to Black, Hispanic, and Native American undergraduate and graduate students will total $221,000. The increase is due largely to a grant from the National Science Foundation (NSF). Geoscience professional societies, industries, and individuals have also contributed funds.

Scholarship recipients are judged on academic achievement, financial need, and their potential for future success in the geoscience profession. The NSF grants will be renewed each year for 3 years on the basis of merit and availability of funds.

The deadline for application materials is February 1, 1991. For more information about the Minority Participation Program scholarships and related programs, contact:

Marilyn Suiter, Director
AGI, Minority Participation Program
4220 King Street
Alexandria, VA 22302.

Industrial Minerals in Washington—Production and Potential

by
Nancy L. Joseph

Industrial mineral products in Washington include uncommon materials such as olivine and diatomite and more common materials such as limestone, silica, dolomite, and clay (Table 1; Fig. 1). The state also has the only plant in the nation to produce magnesium metal from dolomite. Two plants have produced portland cement, and eleven plants produce lime, calcium chloride, precipitated calcium carbonate (PCC), ground limestone, or silicon (Table 2, Fig. 2). In addition, in excess of 900 pits and quarries were under permit to mine sand and gravel and crushed stone in 1989.

The value of nonfuel mineral production in Washington state was approximately $450 million in 1989, according to figures compiled primarily by the U.S. Bureau of Mines (USBM) (Fig. 3). Industrial minerals accounted for nearly 80 percent of this figure; sand and gravel and crushed stone production together accounted for 40 percent of the total value. The large production volume and the value added to mined dolomite makes the production of magnesium metal the highest value mineral operation in the state.

DOLOMITE

More than 800,000 tons of dolomite were extracted in Washington in 1989. A majority of the rock is quarried in Stevens County, in the northeastern part of the state. Most of the stone is used in the production of magnesium metal, with the remainder crushed for decorative rock and for agricultural applications.

Dolomite for Magnesium Metal

Dolomite is used in the production of magnesium metal by Northwest Alloys, Inc., a wholly owned subsidiary of Aluminum Company of America (Alcoa). The company is the largest producer of dolomite in the state, extracting in 1989 approximately 760,000 tons of the Cambrian-Ordovician Metaline Formation from the Addy Dolomite quarry. Chemical analyses of the stone mined at the quarry have indicated that the rock averages 30.3 percent CaO, 21.3 percent MgO, and less than 1 percent insoluble residues (Bennett, 1944).

The magnetherm process is used to produce magnesium metal from dolomite. In this process, pelletized

Table 1. Industrial minerals (exclusive of sand and gravel) mined in Washington in 1989 and operating companies. See Figure 1 for the locations of these operations.

Commodity	Map symbol	Property	Owner and/or operator	County	1989 production and developent
Clay	HI	Twin River quarry	Holnam Ideal, Inc.	Clallam	Mined 100,000 tons
Clay	MM1	Mica mine, plant, and Pottratz pit	Mutual Material Co.	Spokane	Mined 35,000 tons
Clay	MM2	Elk pit	Mutual Materials Co.	King	Mined 5,000 yd^3
Clay	MM3	Sec. 31 pit	Mutual Materials Co.	King	Mined 90,000 yd^3
Diatomite	W 7, 8	Sec. 7 and 8 pits	Witco Corp.	Grant	Mined 150,000 tons
Diatomite	W 17	Sec. 17 pit	Witco Corp.	Grant	Hauled 15,000 tons
Diatomite	W 3, 10	Sec. 3 and 10 pit	Witco Corp.	Grant	Permitted in 1989
Dolomite	AM	Gehrke quarry	Allied Minerals Inc.	Stevens	Mining and milling
Dolomite	BS	Crystal City mine	Blue Silver Mining	Lincoln	Crushing
Dolomite	NA	several quarries	Nanome Aggregates, Inc.	Stevens	Mining from several locations
Dolomite	NWA	Dolomite quarry	Northwest Alloys, Inc.	Stevens	Mined 760,000 tons
Dolomite	NWM	White quarry	Northwest Marble Products	Stevens	Mining
Limestone	CL	Bear Mountain pit	Clauson Lime Company	Whatcom	Mining
Limestone	CRC	Wauconda quarry	Columbia River Carbonates	Okanogan	Mined 60,000 tons
Limestone	LC	Champane Placer	Lafarge Corp.	Pend Oreille	Mined 240,000 tons
Limestone	NL	Northport Limestone	Northport Limestone Co. (Hemphill Brothers, Inc.)	Stevens	Mined 42,000 tons
Limestone	PC	Tonasket Limestone quarry	Pacific Calcium, Inc.	Okanogan	Mining and milling
Olivine	OC	Swen Larsen quarry	Olivine Corp.	Whatcom	Mined 80,000 tons
Silica	ACW	Superior quarry	Ash Grove Cement West, Inc.	King	Mined 100,000 tons
Silica	LB	Ravensdale pit	L-Bar Products, Inc.	King	Mined 100,000 tons
Silica	LM	Lane Mountain Silica	Lane Mountain Silica Co. (Hemphill Brothers, Inc.)	Stevens	Mined 300,000 tons
Silica	NWA	Blue Creek mine	Northwest Alloys, Inc.	Stevens	Mined 12,000 tons

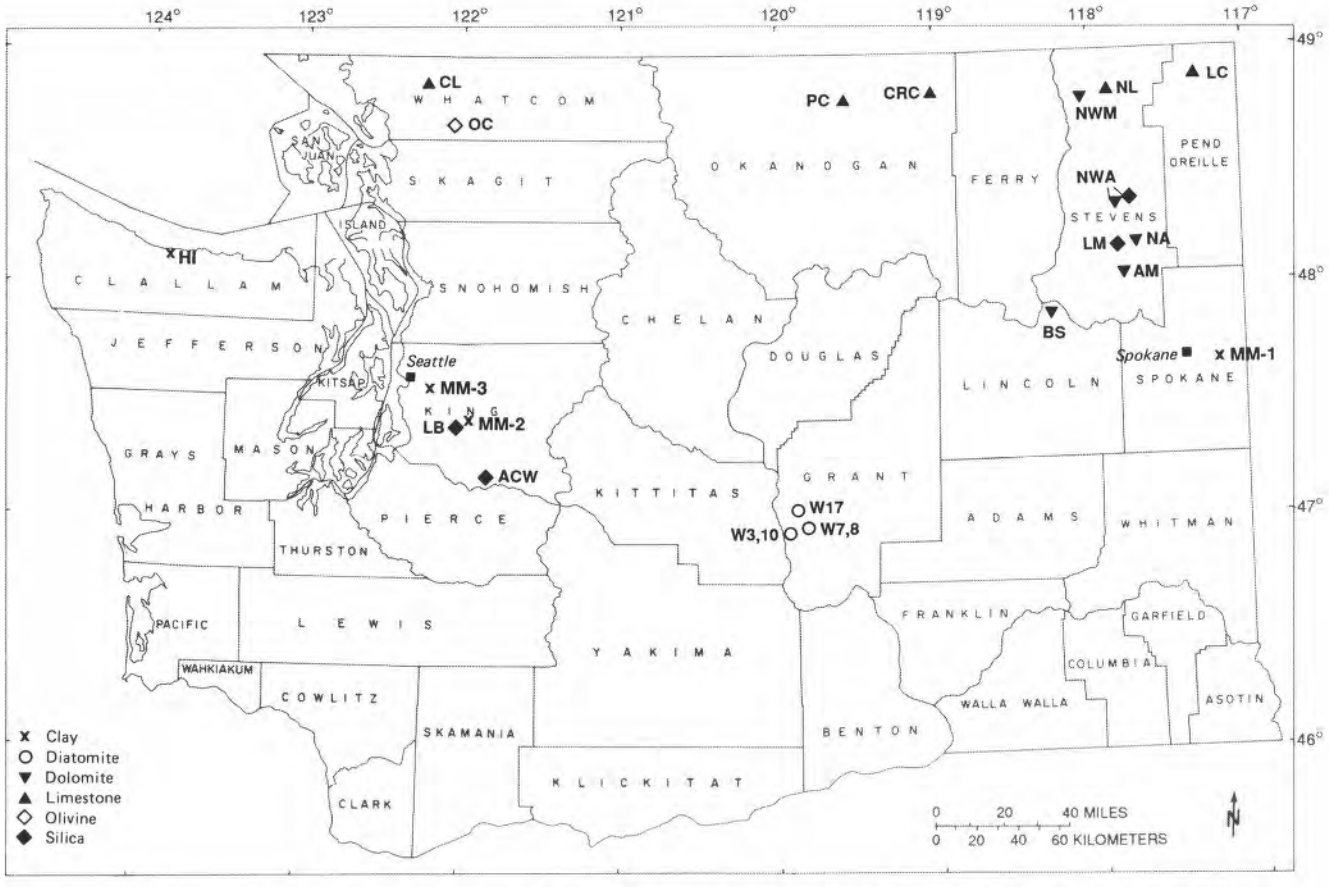

Figure 1. Companies mining industrial minerals in Washington. Refer to Table 1 for company names represented by initials on this map.

dolomite, alumina flux, and ferrosilicon are mixed and heated to 1,600°C. This is done in nine resistive electrical furnaces at the Stevens County plant. Magnesia in the calcined dolomite is reduced by the silicon; the magnesium vapor condenses externally and is remelted under flux. Ten tons of dolomite are needed to produce one ton of magnesium metal by this method (O'Driscoll, 1989a).

The 14-year-old Addy plant has the capacity to produce more than 80 million pounds of magnesium per year, and it accounted for 16 percent of the world's production of the metal in 1988. Northwest Alloys is one of three producers of magnesium metal in the U.S. and the only company at present using the magnetherm process. Northwest Alloys enjoys a strong market for the metal, which has been selling for approximately $1.60 per pound (99.8% pure ingots; American Metal Market). The value of annual sales was reported to be more than $100 million in 1988 (Spokane Journal of Business, March 30, 1989). The market for the metal is cyclic and is dependent on the health of the regional aluminum industry. Two-thirds of the production from the Stevens County plant is used by the parent company as an alloy of aluminum in the manufacture of aluminum cans and aircraft-grade aluminum. The remainder is sold on long-term contract for uses that include de-sulfurizing steel (Spokane Journal of Business, March 30, 1989). A magnesium metal plant in southern Alberta, Canada, began limited production in 1989. This facilitiy is being built in stages by Magnesium Company of Canada Ltd. and will increase competition for non-captive sales of the metal (O'Driscoll, 1989b).

Northwest Alloys reports a 15- to 20-year supply of dolomite at the quarry it now mines and a nearly 100-year supply at a nearby site. The plant operates 24 hours a day, seven days a week. The company has an annual payroll of more than $18 million and, with nearly 500 workers, is the largest employer in Stevens County (Spokane Journal of Business, March 30, 1989).

Crushed and Ground Dolomite

Dolomite quarried by the other producers in the state is used as an agricultural additive, architectural aggregate, and mineral filler.

Allied Minerals Inc. extracts dolomite from the Late Proterozoic Stensgar Dolomite at the Gehrke quarry in Stevens County. The rock is crushed, ground, dried, and bagged at a plant near Springdale. The dolomite is used as a filler in fertilizer and as decorative garden rock.

Nanome Aggregates, Inc., selectively mines dolomite from several quarries in Stevens County to produce white and various colors of architectural

Table 2. Producers of selected industrial mineral products in Washington in 1989. Figure 2 shows locations of producers.

Commodity	Map symbol	Owner and/or operator	County
Portland cement	HI	Holnam Ideal, Inc.	King
Portland cement	LC	Lafarge Corp.	Pend Oreille
Lime	CL	Continental Lime, Inc.	Pierce
Lime	NWA	Northwest Alloys, Inc.	Stevens
Precipitated calcium carbonate	PI	Pfizer, Inc.	Cowlitz
Precipitated calcium carbonate	PIW	Pfizer, Inc.	Walla Walla
Precipitated calcium carbonate	CL	Continental Lime, Inc.	Pierce
Calcium chloride	OC	Occidental Chemical Corp.	Pierce
Ground limestone	H	Hueber Corp.	King
Ground limestone	CRC	Columbia River Carbonates	Cowlitz
Crushed limestone	HB	J. A. Jack and Sons, Inc. (Hemphill Brothers, Inc.)	King
Ground, crushed dolomite	NA	Nanome Aggregates, Inc.	Stevens
Ground dolomite and limestone	PC	Pacific Calcium, Inc.	Okanogan
Ground dolomite	AM	Allied Minerals Inc.	Stevens
Crushed dolomite	NWM	Northwest Marble Products Co.	Stevens
Ground olivine	AC	AIMCOR	Skagit
Refractory olivine	OC	Olivine Corp.	Whatcom
Silicon	SM	Silicon Metaltech, Inc.	Chelan
Silicon	NWA	Northwest Alloys, Inc.	Stevens

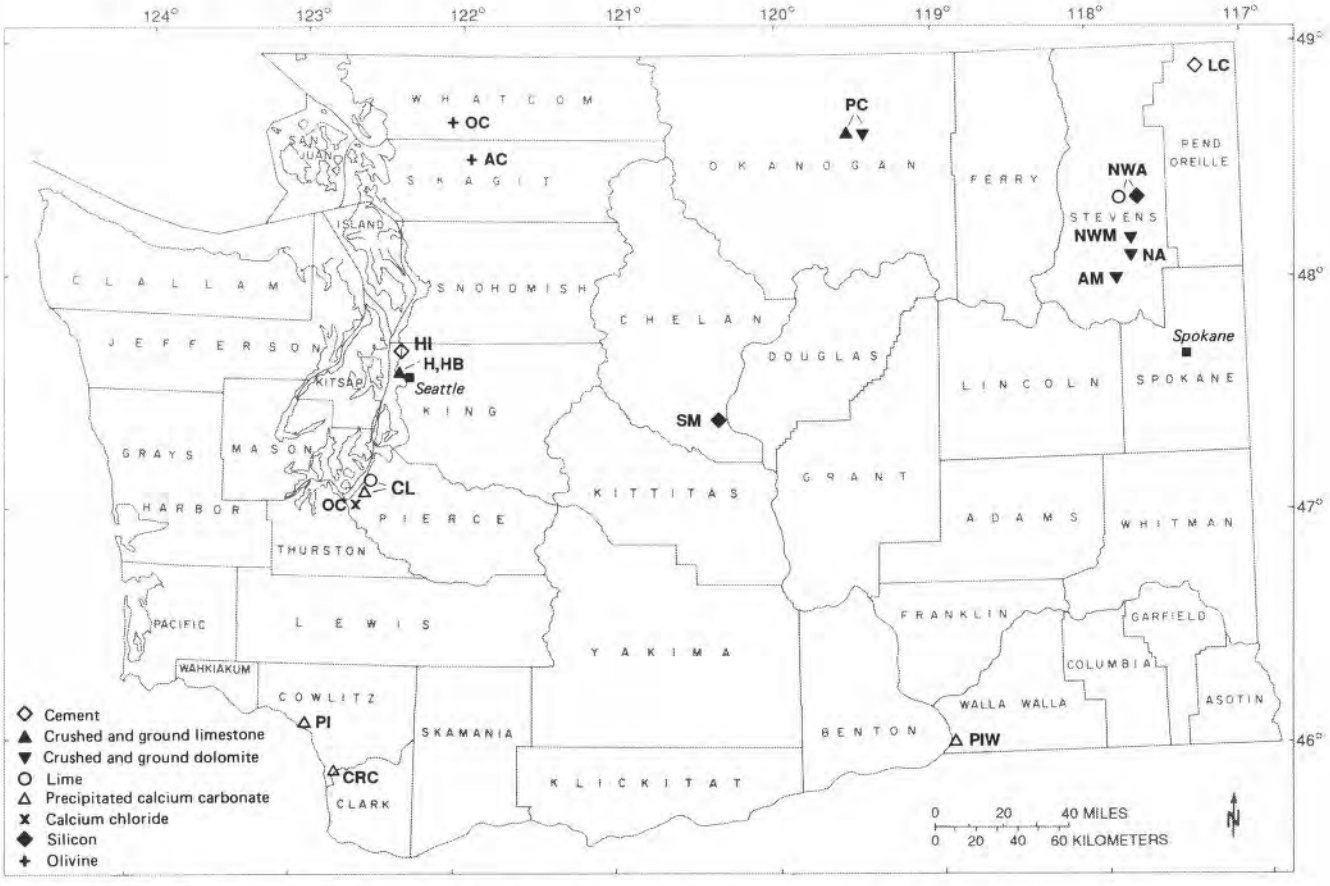

Figure 2. Producers of selected industrial mineral products. Refer to Table 2 for company names represented by initials on this map.

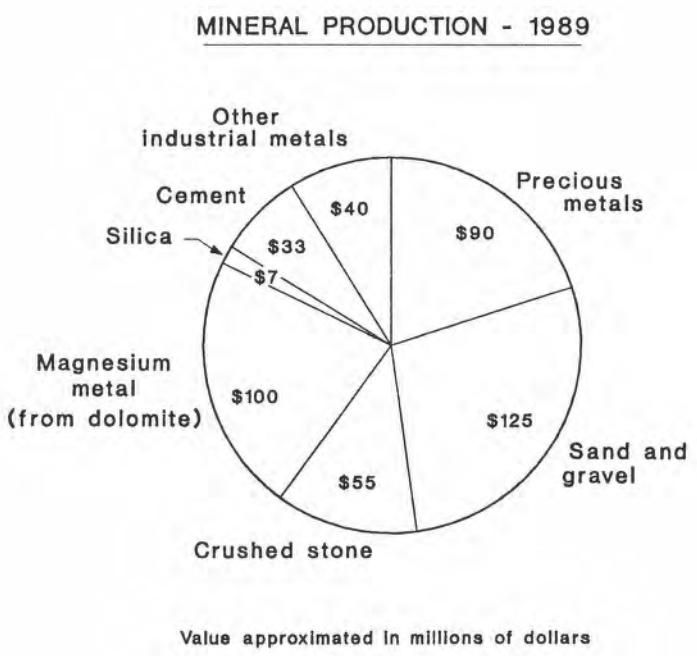

Figure 3. Value of nonfuel minerals (includes value-added processing for some minerals) in Washington in 1989. From data compiled by the U.S. Bureau of Mines and the Washington Division of Geology and Earth Resources.

aggregate. White dolomite is finely ground in a Raymond mill at the plant and is used in highway paint and in agricultural products. The company was purchased by Meridian Minerals Co. in mid-1990. Meridian plans to improve the quality of the raw materials used and upgrade the plant.

Northwest Marble Products produces white dolomite from the White quarry for use in the ceramic industry. Primary crushing is done at the quarry on Kelly Hill in Stevens County, and further processing is completed at their plant at the railhead near Chewelah.

Blue Silver Mining has produced small quantities of dolomite from their quarry near Miles on the south side of the Spokane River in Lincoln County. The stone is reported to contain as much as 31.5 percent CaO and 21 percent MgO (Bennett, 1944). The Crystal City quarry is in white marble formed by contact metasomatism of the Metaline Formation.

Pacific Calcium, Inc., produces crushed limestone and dolomite for agricultural uses from two quarries in Okanogan County. The rock is crushed at the company's plant near Tonasket.

LIMESTONE

In excess of 352,000 tons of limestone were mined in Washington in 1989. Limestone production decreased significantly in 1990 with the cessation of production of portland cement in Pend Oreille County. Producers of carbonate products on the east side of the state generally use limestone extracted near the site of beneficiation. In contrast, most of the limestone used in the Puget Sound area is imported from Texada Island in British Columbia, which is less than 200 miles by barge from Seattle.

Crushed and Ground Limestone

Columbia River Carbonates, a joint venture between Bleeck Management, Inc., and Genstar Carbonates, Inc., mines white marble in Okanogan County and produces fine- and ultrafine-ground calcium carbonate at their plant near Vancouver, Washington (Fig. 4). As much as 60,000 tons of the Permian Spectacle Formation were extracted from the Wauconda quarry in 1989. Reserves at the site are reported to be in excess of 10 million tons averaging 98 percent $CaCO_3$, 1 percent MgO, and 1 percent acid insolubles (O'Driscoll, 1989a). The rock is crushed to approximately 6 inches and then screened.

The limestone is trucked 64 miles to near Tonasket and then shipped by rail to the grinding plant near Woodland in Cowlitz County. To reduce any contamination that may affect the quality of the ground product, the company has constructed a covered area in which to transfer the stone from the hopper cars to the plant. The rock is fed into vibratory pan feeders, then transferred by enclosed conveyors to the mill. The ore is gravity fed to a hammer mill, screened, and transferred to a fine-grinding tube mill. Following grinding, it is air-classified, creating one class of material averaging 7 microns in diameter and another class averaging 3 microns (O'Driscoll, 1989a). The coarser material produced by the dry grinding method is characterized by mean particle sizes ranging from 3 to 10 microns, an average brightness of 93 ± 1 (measured

Figure 4. Columbia River Carbonates produces fine- and ultrafine ground calcium carbonate at this plant in Cowlitz County. The enclosed conveyor system at the plant reduces contamination of the white rock. (Photo courtesy of Columbia River Carbonates).

by the Elrepho process), and a purity of 98 percent $CaCO_3$. The dry ground material is mainly used in paints and plastics. The finer class of material can be ground still finer by the company's proprietary wet grinding system. The products include two filler grades averaging 1.8 microns and a coating grade for paper. In the coating grade, which is the finest of the slurry products, 99 percent of the particles are less than 5 microns, 90 percent less than 2 microns, and 65 percent less than 1 micron; the $CaCO_3$ content is 98.9 percent, and the brightness is 96 ± 1 (Elrepho measurement).

Columbia River Carbonates is in competition with both Contential Lime and Pfizer, Inc., producers of PCC, to provide coating and filler-grade, white, calcium carbonate to the paper industry in the Pacific Northwest. Markets for these products will increase if more manufacturers of white paper switch from the acid papermaking process to alkaline sizing, which is popular in Europe and produces longer lasting paper.

Northport Limestone Division of Hemphill Brothers, Inc., extracts limestone from the Metaline Formation near Northport in Stevens County. The stone is used as a flux at the Cominco Ltd. smelter at Trail, British Columbia, 15 miles due north of the quarry.

Producers of calcium carbonate products in the Puget Sound area import limestone from British Columbia; most of the stone comes from Texada Island. Hemphill Brothers, Inc., barges limestone from the island to their Seattle plant, where the stone is crushed and ground to produce various grades of calcium carbonate; agricultural applications are among the major uses of the rock. The finer, white fraction of the crushed rock is sent through a Raymond mill owned by Hueber Corp. and operated by Hemphill Brothers, Inc., to produce several grades of fine-ground calcium carbonate for paint, plastics, and wallboard.

Lime

Washington was 17th largest producer of lime in the country in 1989, according to the USBM. Two companies in the state produce lime products, including quicklime and hydrated lime.

Quicklime and hydrated lime are produced in Tacoma by Continental Lime, Inc., which was the ninth largest lime producer in the nation in 1989. The lime operations of Continental Lime were purchased by Graymont Ltd., a Canadian producer of lime, in 1989. Crushed limestone is purchased from the Ash Grove Cement, Inc., quarry on Texada Island, and the stone is barged to the plant on tidewater in Tacoma. The lime is used in the steel and the pulp and paper industries and for pollution control in the Pacific Northwest. Twenty-five percent of the company's quicklime production is used to make PCC.

Quicklime is also produced by Northwest Alloys at their plant in Addy. Lime is a byproduct of the production of magnesium metal from dolomite.

Precipitated Calcium Carbonate

Continental Lime, Inc., operates one of the few free-standing PCC plants in the country. The company sold its PCC plants, except for the plant in Tacoma, to G K Carbonate in 1989. The plant, which was brought on line in 1987, is designed to produce 42,000 tons of PCC per year, although the plant is not currently running at capacity. Approximately 25 percent of the company's quicklime production is combined with recycled waste carbon dioxide from the lime plant to manufacture a high-grade calcium carbonate product. The PCC plant is designed to produce 1- to 2-micron particles for use by the local paper industry.

Pfizer, Inc., has installed satellite PCC plants at the Weyerhaeuser Paper Co. paper plant in Longview and at the Boise Cascade Corp. paper plant at Wallula. These are the first satellite PCC plants to be built in Washington and follow a growing national trend toward building these plants at or near paper mills. The trend has been spurred by the increase in demand for high-quality, acid-free, white paper. The PCC plants convert recovered carbon dioxide, lime, and water from the lime kilns at the paper plant to a fine calcium carbonate product that is used in premium-quality white coated and uncoated paper. The PCC is pumped in slurry form directly to the adjacent plant (O'Driscoll, 1989a).

Cement

Approximately 670,000 tons of portland cement worth more than $32 million were produced by two plants in Washington in 1989. This is half the amount that was produced in 1987 when three cement plants were in operation. As of mid-1990, only one portland cement plant was operating in the state. However, a new state-of-the-art plant in Seattle is due to come on line in mid-1992. At present no limestone is mined in the state for the production of cement.

Manufacturers of portland cement in Washington face continuing competition from imports. However, demand for portland cement in the state presently exceeds internal production. More than 0.8 million tons of cement and clinker were shipped into ports on the west side of the state in 1989. According to the USBM, 67 percent of the imported cement and clinker was from Canada; most of the remainder came from Japan, and a very small amount was from China. Lafarge Corp., CBR Cement, Holderbank, Lone Star Industries, and Onoda Cement Co. are among the foreign companies that import portland cement and clinker and that own cement terminals in the state (Ullman, 1989). Lafarge is constructing a new 6,000-ton-capacity terminal in Seattle to be supplied from its Richmond, British Columbia, cement plant (Grancher, 1990).

In August of 1989, Lafarge Corp. purchased the portland cement plant in Metaline Falls and three distribution terminals from Lehigh Portland Cement Co. for nearly $7.5 million. Lafarge, the second largest cement manufacturer in the country in 1989, then closed the plant in June 1990, citing higher than expected capital costs to modernize the 80-year-old facility.

More than 240,000 tons of limestone were mined from the Champane Placer (quarry) in 1989, resulting in 171,820 tons of portland cement being produced at the Metaline Falls site. The rock was mined from the Metaline Formation and transported by aerial tram to the 185,000-ton-per-year, coal-fired, dry-process facility. In order to produce types I, II, and III portalnd cement, the company adds crushed quartzite, alumina-

rich material, slag, and gypsum to the limestone; a minor amount of mortar is produced. The operation employed 59 workers in 1989.

Ideal Basic Industries, Inc., merged with the U.S. subsidiary of Holderbank Financiere Glaris Ltd. in 1990 to become Holnam Ideal Inc.; Holnam Inc., the parent company, through recent mergers, is the largest producer of portland cement in the country. Holnam Ideal produces 490,000 tons of portland cement annually at the wet-process, electric-powered facility in Seattle. Limestone from Texada Island and clay from their Twin River quarry in Clallam County are barged to the plant site. Although it is unusual for a cement plant to be offsite from the limestone quarry, the proximity of the plant to tidewater, rail, and the market in the Puget Sound area helps the operation stay competitive.

Ash Grove Cement West, Inc., a wholly owned subsidiary of Ash Grove Cement Co., broke ground in late August for a new state-of-the-art portland cement plant on tidewater in Seattle. The planned $65 million, 750,000-ton-per-year plant, which is scheduled to begin operation in mid-1992, will replace the 200,000-ton-per-year portland cement plant previously at the site. The new, energy-efficient plant will burn locally mined coal and produce types I and II portland cement. The plant location will permit shipments to customers by rail, truck, and barge. The company currently sells cement from other Ash Grove plants in the northwest and processes imported clinker for its customers in the Puget Sound area. Limestone mined by the company on Texada Island will be used at the new plant. Ash Grove Cement Co., a domestic company, was the fifth largest producer of portland cement in the country in 1989.

Tilbury Cement (CBR) purchased Columbia Northwest Cement Corp., formerly the largest producer of portland cement to mine limestone in the state, in mid-1987. The Bellingham plant is now used to grind clinker imported from CBR's plant near Vancouver, British Columbia, and Columbia Northwest's Kendall quarry, 20 miles east of Bellingham, is essentially idle.

SILICA AND SILICON

As much as 450,000 tons of silica were produced at four quarries in 1989. Lane Mountain Silica Co., a division of Hemphill Brothers, Inc., is the largest producer of silica in the state and produces some of the highest quality silica products in the Pacific Northwest. In 1989, the company mined 300,000 tons of quartzite from the Lane Mountain quarry in Stevens County. The quarry is in an area of friable, thick-bedded, white quartzite in the lower part of the Upper Proterozoic-Cambrian Addy Quartzite. The rock is crushed, ground, floated, dried, and screened at the plant in Valley to produce a silica flour that is 99+ percent SiO_2. Uses for the silica include plate glass, glass bottles, foundry sand, blasting sand, and roofing granules.

In western Washington, L-Bar Products, Inc. continues to mine silica sand from rocks of the Eocene Puget Group. This rock at the Ravensdale pit is reported to average between 60 and 70 percent quartz, between 15 and 20 percent feldspar, and between 10 and 20 percent kaolinite (McLucas, 1982). Sandstone from the pit is mined, washed, screened, and dried to produce silica for colored glass bottles, fiberglass, and cement.

In competition with L-Bar for cement-grade silica on the west side of the state is Ash Grove Cement West, Inc., which has been mining silica from the Superior quarry in southern King County since 1987. This deposit is unique in that it is part of a silica cap resulting from hydrothermal alteration associated with Miocene volcanic rocks at the margin of a caldera (McCulla, 1986). The silica cap, which is 3.5 miles long and as much as 1 mile wide, is also being explored by others for gold. The rock is composed of 94 percent silica and less than 0.1 percent alkalis. The material is generally crushed to 1 inch, and most is sold for cement, but it is suitable for other uses. Ash Grove originally explored and developed the site as a silica source for its new cement plant in Seattle, which will come on line in 1992.

Approximately 17,000 tons of silicon and 75 percent ferrosilicon (75% SiO_2) are produced annually at the Rock Island plant near Wenatchee. The plant, previously owned by M. A. Hanna Co., was purchased by a Seattle-based partnership, Silicon Metaltech, Inc., in 1988. Since purchasing the plant the company has built a new chemical laboratory and relined one of the three furnaces. Depressed prices for the metal due to lower priced imports has affected the profits of the company.

Production of 75 percent ferrosilicon by Northwest Alloys, Inc., at their plant at Addy has been sporadic and dependent on the price for the material, which is used in the production of magnesium metal from dolomite. The furnaces at the 50,000-ton-per-year facility were shut down in 1986 when it was less expensive to purchase the material than to produce it, and then restarted in 1988 when the price of ferrosilicon increased. The plant was shut down again in mid-1989 when foreign competition drove down the price of ferrosilicon.

OLIVINE

Washington is one of two states in the country to produce olivine. Olivine Corp. mines approximately 85,000 tons of the mineral annually from the Swen Larsen quarry in Whatcom County. Here, the company obtains the fresh, unaltered olivine from the Twin Sisters dunite, which is reported to be the largest body of olivine in the country (Teague, 1983). Olivine Corp. has concentrated on the development of modular olivine slabs for both wood and municipal waste incinerators (Fig. 5). The incinerator units, which use from 20 to 100 tons of olivine each, account for 95 percent of the company's revenues and are marketed throughout the country and to Pacific Rim countries.

Applied Industrial Materials Corp. (AIMCOR) formerly mined an olivine-bearing till at the depleted Twin Sisters quarry. It now purchases olivine from Olivine Corp. Because of the superior quality of the olivine, only dry crushing and processing is required. AIMCOR produces 10 grades of olivine for blast furnaces, refractory uses, foundry and blasting sands, and other applications at their plant near Hamilton. The products are sold domestically and to Pacific Rim countries

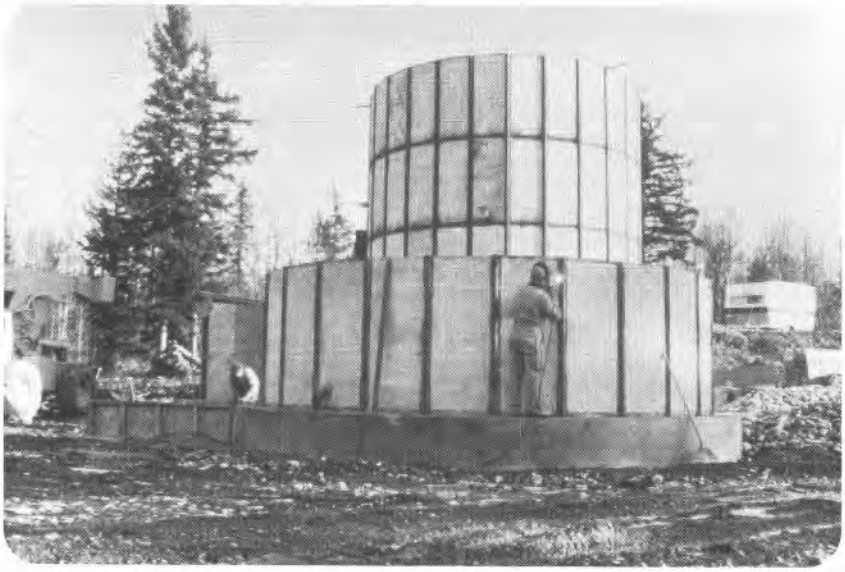

Figure 5. A wood incinerator made by Olivine Corp. using modular olivine slabs. (Photo courtesy of Olivine Corp).

(O'Driscoll, 1989a). The use of olivine in sand blasting eliminates the hazard of silicosis, which makes it an attractive alternative to silica sand (Teague, 1983).

DIATOMITE

Witco Corp. is the sole producer of diatomite in Washington. In 1989 the company mined more than 160,000 tons of diatomaceous material from three pits in Grant County. Of these, the Section 7 pit was the most active. The Section 3 and 10 pit was permitted in early 1989, but use of this pit will not increase total production.

The deposits consist of freshwater diatom tests deposited in lakes that formed on flows of the Miocene Columbia River Basalt Group. Ore consists of almost 100 percent diatoms and only minor amounts of clay. The average thickness of the diatom-bearing unit is 25 feet; the deposits pinch and swell and taper at the edges. Two grades (based on size of the diatoms) are recognized in mining.

Diatoms are processed and calcined in Quincy. The company has two plants at the site, which have a combined production capacity of 90,000 tons per year (O'Driscoll, 1989a). Only minor crushing is necessary because the sediments are poorly consolidated. Diatoms are air-separated from waste material in a tower at the site. In order to control both the pore size in the diatom skeletons and product brightness, diatoms are fired and fluxed in a kiln. They are then air classified. The diatoms are used for filters, including those for high-fructose sugars and juices. Smaller particles are used as filler in paint, such as highway paint.

CLAY

Major uses of clay minerals in the state are structural brick and cement. Most of the state's clay comes from King and Clallam Counties; lesser amounts are mined in Spokane County.

Mutual Materials Co. mined and hauled more than 95,000 yd^3 of clay and shale from two pits in King County in 1989. The clay is used for red-fired structural bricks. The company also has clay pits in Pierce, Thurston, Cowlitz, and Chelan Counties.

Structural bricks have been produced near Mica in Spokane County since 1893. Mutual Materials Co. purchased the plant and mine from Interpace Industries Inc. of Kirkland in mid-1990. The company employs 80 people and processes 15 to 20 tons of clay per day, resulting in the production of nearly 50 million off-white and colored structural and decorative bricks a year. The unique charactertistics of the clay at Mica make it possible to produce light-colored bricks that are sold nationwide. The gas-fired, computer-controlled kiln and the plant were updated in 1987, after the project was partially funded by bonds issued by the Washington State Community Economic Revitalization Board (Journal of Business, Nov. 25, 1987).

The clay at Mica is mined from laterized lakebed sediments of the Miocene Latah Formation. The 20-foot-thick sediments both conformably overlie basalt saprolite of the Columbia River Basalt Group and unconformably overlie saprolitic Precambrian gneiss. The deposit consists of yellowish-orange to white clay and sand, which is composed of quartz, muscovite, and feldspar; it is silty in places. Thirty percent of the deposit is clay, which contains kaolinite as the major clay mineral and lesser amounts of illite (Hosterman, 1960). The Al_2O_3 content of the clay is in the range of 25 to 32 percent; alkalis generally constitute less than ½ percent. Saprolitic Precambrian gneiss and pre-Tertiary intrusive rocks in the area also contain reserves of residual clay.

Holnam Ideal, Inc., quarries approximately 100,000 tons of clay annually from its Twin River quarry west of Port Angeles. The Oligocene mudstone is barged to the Holnam Ideal cement plant in Seattle, where it is used to make portland cement.

SAND AND GRAVEL

Washington was the ninth largest producer of sand and gravel in the country in 1989. Sand and gravel and crushed stone production resulted in more than $180 million in revenues during 1989 (Fig. 3), according to the USBM. This figure represents nearly 40 percent of the value of the nonfuel mineral production in the state. Figures published by the USBM indicate that tonnage of sand and gravel produced in 1989 increased 43 percent over that produced in 1986. This increase was spurred by increased population growth and several large construction projects in the Puget Sound region. Clark, King, Pierce, and Snohomish were the major producing counties (Rice and Joseph, 1988). A majority of this production comes from aggregate-rich, ice-margin deposits in the Puget Sound region and from late Wisconsin Lake Missoula flood deposits near Spokane.

Lone Star Northwest's facility in Steilacoom is the fifth largest sand and gravel operation in the nation and one of two plants on the list of the top ten pro-

ducers in 1989 not located in California. Approximately 3.9 million tons of sand and gravel were produced in 1989 from the operation in Pierce County (Mencacci, 1990).

While older mines in the Puget Sound area are being depleted, only a few new deposits are being permitted. The lack of new permits is the result of zoning pressures resulting from the spread of urban developement.

EXPLORATION

Exploration for industrial minerals is currently concentrated on the search for lump silica, talc, and clay. Exploration for high-brightness, high-purity calcium carbonate, which was very active from 1984 to 1986, has tapered off. That boom in exploration, however, resulted in the discovery of the Wauconda deposit, now mined by Columbia River Carbonates.

United Catalyst Inc., in joint venture with First Mississippi Gold Corp., has been exploring for talc in a shear zone in the Precambrian Monk Formation in Pend Oreille County. Results from several years of drilling have been encouraging, and a plan of operation has been submitted to the U.S. Forest Service for evaluation.

Basic Resources Corp. continues to explore the Rock Top property in Grant County. The company is testing deposits of non-swelling bentonite clays that formed in lakes that developed on the flow surfaces of the Columbia River basalts.

POTENTIAL RESOURCES

The potential for discovery and exploitation of barite, clay, dimension stone, dolomite, graphite, limestone, magnesite, pumice, silica, and talc deposits in Washington is encouraging. The excellent road and rail systems, increased industrial growth in the Pacific Northwest, and the reduced shipping time (in relation to other U.S. ports) from the port of Seattle to the Pacific Rim countries enhance the marketability of Washington's industrial minerals. The following is a brief description of a few areas of potential for barite, graphite, limestone and dolomite, magnesite, and talc.

Barite

Approximately 2.1 million tons of barite that has a specific gravity of 3.9 to 4.01 and contains 80 percent $BaSO_4$ have been developed at the Flagstaff Mountain barite deposit in Stevens County. The open-pit, syngenetic deposit in Devonian metasedimentary rock was drilled out and permitted, and some initial mining was done by C.E. Combustibles before the downturn in the oil industry resulted in the termination of the operation. Other smaller barite deposits also are located in Stevens County, north of Colville, in similar rocks.

Graphite

Flake graphite is present in schist, marble, and gneiss in Okanogan and Ferry Counties. The Boulder Creek deposit (sec. 2, T. 38 N., R. 36 E.) in Ferry County is in coarse-grained marble in the Kettle metamorphic core complex. The large-tonnage deposit is reported to contain as much as 10 percent flake graphite (Valentine, 1960). The nearby Renner Lake deposit (sec. 24, T. 38 N., R. 36 E.), in similar rock, is reported to contain as much as 7.57 percent disseminated flake graphite (Valentine, 1960). In Okanogan County, 18 miles east of Omak (sec. 27, T. 34 N., R. 29 E., graphitic schist and gneiss are present as roof pendants in Eocene granitic rocks (Atwater and others, 1984); they were sources of limited production by American Graphite and Metal Corp in the 1940s). A mill at the property ground the graphite to 20 mesh and finer. According to Valentine (1960), a marble lens with disseminated graphite has also been reported in Haden Creek near this site. Additional occurrences of flake graphite in schists are present in Skagit and Chelan Counties; high-quality amorphous graphite is reported to occur in Yakima County (Valentine, 1960).

Limestone and Dolomite

Potential for the discovery of high-purity calcium carbonate deposits is good in the northern tier of counties in Washington. Large-tonnage deposits of high-calcium limestone are present in the northeastern part of the state in Ordovician to Cambrian rocks and in Permian rocks along the Columbia River from Northport to Marcus, near Cedar Lake, and north of Metaline Falls. Large, high-grade (95% $CaCO_3$) deposits occur in Permian limestones in Okanogan County west of Ellisforde and near Chesaw. Many of these deposits are suitable for uses that include chemical, metallurgical, pulp and paper, filler and coating for paper, glass, and cement (Mills, 1962). Large bodies of generally fossiliferous, Devonian to Permian limestone are present in the western part of the state in Whatcom, Skagit, and San Juan Counties. Deposits on the west side of the Cascade Range contain more argillaceous material, chert, and other impurities than limestone in the eastern part of the state. These deposits have been mainly mined for cement, pulp rock, and riprap; however, selective mining has made possible other uses of high-grade parts of many of these deposits (Danner, 1960).

High-purity, high-brightness, white dolomitic marble is present throughout the northern part of the state (Mills, 1962; Danner, 1966). Deposits include large-tonnage, high-purity, coarse-grained dolomites that formed from contact metamorphism and range in age from Late Proterozoic to Permian. These include deposits in the Riverside district in Okanogan County, near Old Fort Spokane in Lincoln County (Bennett, 1944), along the Columbia River north of Flat Creek in Stevens County, and on Jim Creek in Pend Oreille County.

Magnesite

Quarries in Stevens County were major producers of magnesite from 1917 until the cessation of production at the Red Marble quarry in 1968. The deposits, which occur in the northeast-trending, 25-mile-long magnesite belt, are in the Upper Proterozoic Stensgar Dolomite of the Deer Trail Group. Campbell and Loofbourow (1962) have estimated that more than 5 million tons of magnesite were quarried from this belt. The rock was originally mined to produce high-grade, dead-burned magnesite for use in the steel industry.

Although many of the deposits in the magnesite belt have been mined out, several contain minable reserves. For example, the Turk deposit in the southwest part of the belt has not been commercially exploited

and is reported to contain more than 2 million tons of reserves averaging 40 percent magnesia (Bennett, 1943).

Talc

Minor production of talc in Washington has come from Skagit, Stevens, and Lincoln Counties. Potential for deposits of talc also is present in Chelan, Ferry, and Pend Oreille Counties.

Most of the deposits in Skagit County are near Marblemount and include soapstone and high-grade talc deposits resulting from the alteration of serpentine and other basic rocks.

The G. W. Capps talc deposit (sec. 34, T. 27 N., R. 38 E.) in Lincoln County is reported to be in a shear zone in calcareous schist and dolomitic limestone in contact with dioritic intrusive rock. Talc from the mine was used in the paper industry.

In Stevens County, limited production was reported from a zone of high-grade talc in Precambrian quartzite and dolomite cut by basic dikes at the Springdale deposit (sec. 15, T. 30 N., R. 38 E.) (Glover, 1936).

In Chelan County several talc properties are reported near Wenatchee Lake; talc is also reported west of Entiat in Cretaceous gneiss (Valentine, 1960). Talc deposits of reported cosmetic grade are currently being explored in Totem Gulch (sec. 26, T. 39 N., R. 44 E.) in northeastern Pend Oreille County. The deposit is in a sheared dolomite in the Precambrian Z Monk Formation.

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Washington Division of Geology and Earth Resources Report Wins John C. Frye Award

The John C. Frye Memorial Award in Environmental Geology for 1990 was awarded to the Division's Information Circular 85, **Washington State Earthquake Hazards**, by Linda L. Noson, Anthony Qamar, and Gerald W. Thorsen.

J. C. Frye served as state geologist, first for the Kansas Geological Survey, and later for the Illinois State Geological Survey; he was long active in the American Association of State Geologists (AASG). He also was Director of the Geological Society of America (GSA). After his retirement, he continued his life-long interest in Quaternary and environmental geology.

Only articles and reports on environmental geology published by state surveys or by GSA are eligible for this award. A committee of the AASG reviewed 31 nominated reports.

The award was presented October 29 at the midyear AASG meeting during the GSA meeting in Dallas, Texas.

Information Circular 85 was a product of a cooperative program, the National Earthquake Hazards Reduction Program, with the U.S. Geological Survey. To date, nearly 9,000 copies of this report have been distributed. The report is available free on request, but $1 for postage and handling should be added to each order. Our mailing address is given on page 2.

Early Efforts of the Washington Mining Bureau

by J. Eric Schuster

EDITOR'S NOTE: This is the third in a series about the earliest years of operation of the office of the State Geologist.

By the time his first annual report was printed in January 1891, State Geologist George A. Bethune (1891, p. 4) could say:

"During the past year...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."

In this first annual report Bethune gives a history of mining in Washington, reports assays of coal, coke, and iron ores, describes metallic mining properties in Okanogan, Stevens, Snohomish, King, Kittitas, and Skagit Counties, and briefly surveys building stone, limestone and marble, clay, and cement resources. The metallic mineral properties of Okanogan County are described at greater length than those of any other county.

"I reiterate," he wrote, "our iron ore fields are filled with an inexhaustible supply of ores of nearly all the known varieties, and I feel that others acquainted as I am with the vast extent and value of these deposits will not think my prophecy extravagant when I say that the near future will find our state wearing the sobriquet of the Pennsylvania of the West."

Bethune (1892) went on to produce a second annual report, similar to the first, but somewhat more extensive in the numbers and types of mineral deposits described.

Meanwhile, the Mining Bureau had met in the spring of 1890 to appoint Bethune State Geologist (Bethune, 1891, p. 3), but they appear not to have met later in 1890. At least they did not issue a formal report for the April 1, 1890, to March 31, 1891, fiscal year for their report of the following fiscal year (Laughton and Lindsley, 1892) is titled First Annual Report of the Mining Bureau of the State of Washington. In the spring of 1891, however, the legislature not only passed a general appropriation act that included $9,600 to fund the usual activities of the Mining Bureau and the State Geologist for the April 1, 1891, to March 31, 1893, biennium, but it also appropriated $50,000 for a geological and mineralogical survey of the state. This was the equivalent of at least $577,000 in 1987 dollars. The pertinent part of this appropriation act, which was approved on March 7, 1891, (Weir, 1891, p. 221-222) follows:

"Mining bureau and state geologist: For salary of state geologist at twelve hundred dollars ($1,200) per year, two thousand four hundred dollars ($2,400); for chemicals at two hundred and fifty dollars per year ($250), five hundred dollars ($500); for contingent and traveling expenses at one thousand dollars per year ($1,000), two thousand dollars ($2,000); for rent of office six hundred dollars per year ($600), twelve hundred dollars ($1,200); for rent of cabinet room for mining bureau, five hundred dollars ($500); for traveling and incidental expenses, three thousand dollars ($3,000); for making geological and mineralogical survey of state, and making and publishing maps and reports of the same, fifty thousand dollars ($50,000)."

This appropriation spurred the Mining Bureau to action, and they met April 9, 1891, "...to consider the systematic organization of such a survey" (Laughton and Lindsley, 1892, p. 5). They considered the applications of several people and decided to place three surveying parties in the field under Eugene Ricksecker, Paul F. Riecker, and H. E. Parrish as engineers in charge, to be known as assistant state geologists. Ricksecker and Riecker had performed similar work for the U.S. Army Corps of Engineers, and Parrish had many years' experience in the coal measures of Pennsylvania and other states (Laughton and Lindsley, 1892, p. 5). Laughton and Lindsley (1892, p. 5-6) describe their duties as follows:

"These three surveying parties were allotted stations as follows:

Mr. Ricksecker was instructed to proceed with his work in Okanogan County, from a point to be selected by him as the most advantageous for the prosecution of the work in the mineral belt of that county. Mr. Riecker was instructed to make his base of operations from a point in the vicinity of Colville, Stevens county, and Mr. Parrish was instructed to begin his work on the coal measures of the State of Washington at a point on the Carbon river, near Carbonado, it being the policy of the Mining Bureau to begin its geological and mineralogical surveys in those sections of the mineral belts which had been most actively prospected and developed; proceeding thence, as the work progressed, to make a thorough and comprehensive survey of the mineral belts of the entire state. The assistant geologists in charge were instructed to make weekly reports to the Mining Bureau, of the progress of their work and, also, reports at the end of each month or upon the completion of the work in any one mineral district; to transmit maps to the Bureau, showing the work done during the month or in that district. They were instructed to make thorough topographical, geographical, geological and mineralogical surveys; to note carefully the character of the country, as to its timber, water, water ways and fords, quality of soil, number and names of rivers and streams, its adaptability for settlement and for agricultural purposes; to collect specimens, securing samples of the ores produced by the various mines in the respective districts; to secure specimens of fossils, petrefactions, etc.; and, generally, specimens of interest of whatever nature, and forward same fully classified to the Mining Bureau for the state cabinet."

Between April 10 and April 26, 1891, Ricksecker assembled materials for camp and field and traveled to

his area of operations near Conconully. He brought H. S. Heitzeberg and George H. Ricketson with him from Seattle as assistants and hired another assistant, C. S. Baldwin, either in Spokane or Conconully. In the following weeks the party laid out a base line on a bench between Conconully and Mineral Hill to the northwest of the town, surveyed in triangulation stations and other points for horizontal and vertical control, determined their camp's elevation through barometric observations at a Northern Pacific Railway bench mark on the Columbia River and at their Conconully camp, and gathered enough data to make a topographic map of an area of at least 8 mi^2 northwest, west, and southwest of Conconully. In addition to topographic mapping, the men surveyed the boundaries of all mining claims. Ricksecker reported his progress in letters and

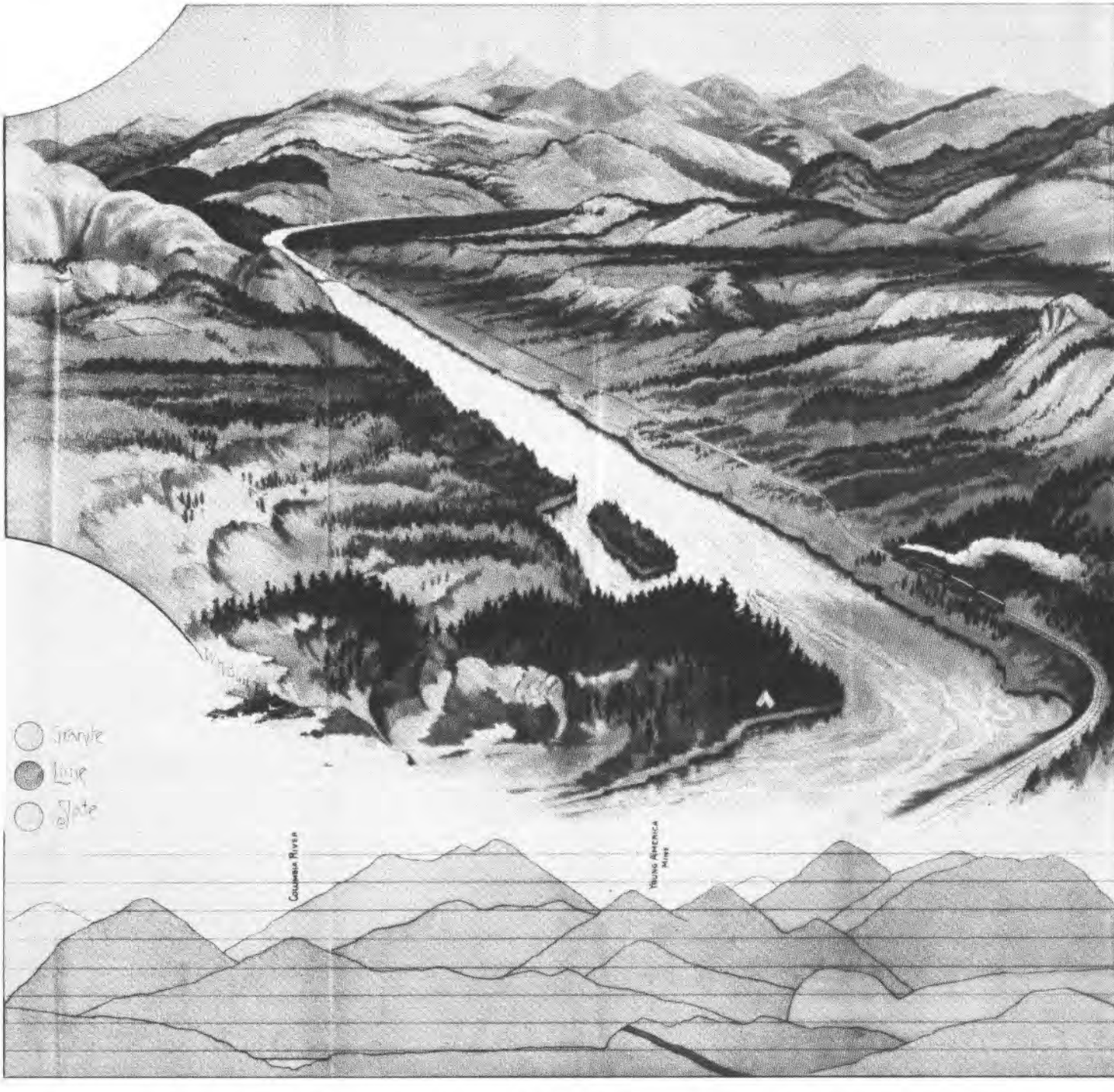

Figure 1. Perspective view of Bonanza-Young America mines area by Wm. H. Bull.

reports to the Mining Bureau dated May 1, June 1, June 7, July 1, and July 7, 1891 (Laughton and Lindsley, 1892, p. 9-13).*

Riecker left Spokane on May 4, 1891, with a party of five men and a cook and established camp just north of Colville, Stevens County. He decided to make Dominion Hill (Old Dominion Mountain), about 8 mi ENE of Colville, the starting point of his survey and moved camp to the Old Dominion mine, on the south side of the mountain, on May 5. From then to May 23 the party made topographic surveys on Old Dominion Mountain, especially near the Old Dominion mine, mapped surface and underground workings, collected rock and ore samples for transmission to Olympia, and made other observations on the nature of the country, flora and fauna, and the prospects for development. On May 22 Riecker wrote (Laughton and Lindsley, 1892, p. 20):

"I have the honor to transmit herewith by express, tracings of maps of Dominion Hill mining district, as surveyed under my direction, showing topography, mineral locations, geological and mineralogical features, together with a perspective view taken from a position near Colville and facing westerly slope of hill, with geological section of the country."

On May 24 Riecker's party moved camp, by wagon, about 20 miles to the Clugston Creek mining district, about 12 miles north of Colville. They worked in the Clugston Creek and nearby Bruce Creek mining districts until June 13, at which time Riecker submitted his report on the two districts, including perspective views, geological sections, and topographic maps.

On June 13 they moved near the Bonanza mine, about 12 mi NNW of Colville, where, until July 4, they surveyed the mines in that area and near the Young America mine 3 mi to the northwest. During this time Riecker sent a party to examine the Silver Crown mine at Northport, about 25 mi to the northeast. On July 4 he sent another report to Olympia, including a description of the surrounding country and another perspective view and geological cross section, which is reproduced here as Figure 1. He decided to go next to the Chewelah area.

Riecker sent word of his progress to Olympia in letters and reports dated May 10, about May 16, May 22, May 30, June 13, June 17, and July 4, 1891. He names P. Stixrud and Mr. Soderburg as the expedition's topographers, and Wm. H. Bull as the artist.

H. E. Parrish and his crew arrived in Carbonado, Pierce County, on April 27 to begin gathering data on the coal seams and mines of that area. Parrish remarked early that the country was the worst he had ever seen regarding roughness of the terrain and thickness of underbrush, but the section of coal-bearing strata exposed along the canyon of the Carbon River was the finest he had ever seen. Parrish and his party had trouble with the cold, wet weather, illness, and a close call when one of the crew was almost knocked over a precipice by a rolling stone. Parrish's team persisted and completed a topographic map of the area and at least two detailed drawings of the coal processing plant of the Carbon Hill Coal Co. This plant impressed Par-

* After leaving the Mining Bureau, Ricksecker returned to service as an engineer with the War Department and participated in many well-known projects in western Washington, including early work on the Lake Washington ship canal, preliminary surveys of Forts Flagler, Worden, and Casey, construction of gun emplacements at Fort Flagler, dredging of Tacoma harbor, and locating and constructing the road from Longmire's Park to Paradise Park on Mount Rainier. A prominent viewpoint along this road is now named Ricksecker Point in his honor (Hunt, 1916, v. 2, p. 102, 505-508).

rish because of its modern design and the way its architect, a Mr. Davis, had taken advantage of local water power and topography to improve the plant's efficiency and lower the coal processing cost. Parrish's idea was to make detailed drawings of the best plants he found in his travels so that anyone who wished to build a new coal processing plant could study these drawings and draw on their best features for the design of new ones. Parrish reported back to the Mining Bureau in letters and reports dated May 1, May 3, May 6, May 8, May 17, June 15, June 29, and July 7, 1891 (Laughton and Lindsley, 1892, p. 35-41).

The three parties had successfully launched a progressive, even daring, enterprise that the Mining Bureau was convinced would pay off by making Washington a leading mineral-producing state. In one sense, their activities were prescient—they made topographic maps of the areas they studied. Good topographic maps are the foundation for all geologic field studies. Theirs were probably the first topographic maps made in Washington; the first topographic map made by the U.S. Geological Survey in this state, of the Seattle area (Snohomish 30′ quadrangle), was not surveyed until 1893-1895 (Glover, 1935, p. 4).

Although their efforts were weak by today's standards, the science of geology had only recently developed to the point that geologic maps of quadrangle-size areas were being made routinely. None had yet been made in Washington, and none would be until later in the 1890s. Likewise, the recognition that knowledge of the geology of an area could enhance the search for mineral deposits by identifying those geologic factors important in the genesis of mineral deposits and concentrating the search for deposits in areas where such geologic factors had been identified, was only then beginning to develop.

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Earth Science Teacher from Forks Given Presidential Award

The White House invited 215 of the nation's finest science and mathematics teachers for a week of ceremonies and special events highlighted by the presentation of Presidential Awards for Excellence in Science and Mathematics Teaching. One of the national awardees is **Sheryl L. Schaaf**, who teaches earth science at the Forks Middle School in Forks, Washington.

The awards program was initiated 8 years ago and has become the premier recognition for middle/junior or senior high school mathematics and science teachers. It has consistently identified the highest quality teachers. Each awardee receives a grant of $7500 from the National Science Foundation to spend at his or her school and many useful teaching tools as gifts from the private sector.

While in Washington, the winners of these awards attended briefings on Capitol Hill, went to receptions at the National Academy of Sciences and the National Geographic Society, and took in an event at the Kennedy Center. They exchanged ideas at "discipline breakfasts" and other events and were able to interact with guest speakers.

Eligible teachers have spent at least 5 years teaching science or mathematics halftime or more in a public or private school in a state or territory or in a Department of Defense Dependents school. In 1990, for the first time, elementary school teachers were added to this awards program. Elementary school teachers were in the nation's capitol from October 1 to 6, the secondary school teachers from October 15 to 20.

The Presidential Awards program is managed for the National Science Foundation by the National Science Teachers Association. Nominations are made by colleagues, administrators, students, parents, and others who are familiar with the teacher's skills. Statewide nomination and selection procedures in science are directed by the Council of State Science Supervisors and in mathematics by the National Council of Teachers of Mathematics. Other cooperating organizations are the American Association for the Advancement of Science, American Association of Physics Teachers, American Chemical Society, National Association of Geology Teachers, and National Earth Science Teachers Association, among many others. A panel of scientists, mathematicians, and science and math educators select the Presidential Awardees from a slate of teachers previously selected.

Mineral Resource Land Classification System

SECTION I. CLASSIFICATION

1. Classification Criteria

a. Areas will be classified into Mineral Resource Areas (MRA) and Scientific Resource Sites (SRS), as defined in this section, and this classification shall be based on geologic and economic factors without regard to existing land use and land ownership. The areas to be studied and their order of study shall be specified by local government.

b. To be considered significant for the purpose of the classification of mineral lands, a mineral deposit or a group of deposits that can be mined as a unit must meet the following criteria of marketability and threshold value. In these guidelines the term *mineral deposits* denotes natural occurrences of rock or mineral materials in or on the Earth's crust that are known to be economically minable and such rock or mineral materials that are not minable at present but which may come into such demand as to become economically minable in the foreseeable future. The term *mineral resources* is used herein as a collective term for all mineral deposits of a particular kind or for mineral deposits in general. For the purpose of evaluating marketability and threshold value, the size of mineral deposits shall include the amounts of naturally occurring rock or mineral material, of known or potential economic interest, that can be measured, indicated, or inferred by using available geologic and geophysical evidence in commonly accepted fashion. The terms *measured*, *indicated*, and *inferred* are to be used as defined by the U.S. Bureau of Mines and the U.S. Geological Survey in U.S. Geological Survey Bulletins 1450-A and 1450-B.

(1) *Marketability*--In determining marketability, mineral deposits shall be divided into two categories: those containing non-strategic and those containing strategic mineral commodities. Unique or rare occurrences of rocks, minerals, or fossils that are of outstanding scientific significance are not required to meet marketability criteria.

(i) *Non-strategic mineral commodities* are those which are available domestically and of which the United States imports less than 50 percent of its needs as reported annually by the U.S. Bureau of Mines. Deposits of mineral commodities in this category must be minable, recoverable, and marketable under the technologic and economic conditions that exist at present or which can be estimated to exist in the foreseeable future. The amount of mineral resources needed for periods of the foreseeable future (50 years) shall be projected using past consumption figures, with appropriate adjustments based upon anticipated changes in market conditions and mining technology.

(ii) *Strategic mineral commodities* are those that are in short domestic supply and important for national defense or the well-being of the domestic economy. For the purposes of these guidelines, they are those mineral commodities of which the United States imports more than 50 percent of its needs, as reported annually by the U.S. Bureau of Mines, and that are judged to be minable, recoverable, and marketable in the foreseeable future if non-domestic sources of supply are cut off.

(iii) *Foreseeable future*, as used in this paragraph and elsewhere in the guidelines, is a time span of approximately 50 years. Because some of the conditions affecting extraction and marketability cannot be accurately projected 50 years into the future, conservative estimates shall be made in assessing whether a particular mineral resource can be mined, processed, and marketed within the next 50 years.

(2) *Threshold value* is the projected value (gross selling price) of the first marketable product from an individual mineral deposit, or from a group of deposits that can be operated as a unit, upon completion of extraction and any required mineral separation and processing. For those deposits which meet the marketability criteria, only those estimated to exceed the following threshold values in 1990-equivalent dollars shall be considered significant. These threshold values are intended to indicate in a general way the approximate minimum size of a mineral deposit that will be considered significant for classification and designation. The values are not intended, nor in practice could they be, for use as precise cut-off values. For some deposits in some areas, larger or smaller values than those specified would be required for a marketable deposit. If for technological or other reasons one or more parts of a mineral deposit cannot meet the marketability criteria, those parts shall not be considered in estimating whether the deposit exceeds the threshold value.

(i) *Construction materials* (minimum value $5,000,000)--Mineral materials capable of being used in construction, such as sand and gravel or crushed rocks, that normally receive minimal processing (commonly washing and grading) and for which the ratio of transportation costs to value of the processed material at the mine is high.

(ii) *Industrial and chemical mineral materials* (minimum value $1,000,000)--Non-metallic mineral materials that normally receive extensive processing, such as heat or chemical treatment or fine sizing, and for which the ratio of transportation costs to value of the material at the mine is moderate or low. Examples of this category include:

Limestone, dolomite, and marble, except where used as construction aggregate
Specialty sands
Clays
Diatomite

Phosphate
Coal, lignite, or peat mined primarily as raw materials for chemicals such as montan wax
Salines and evaporites such as borates and gypsum
Feldspar
Talc
Building and dimension stone
Rock varieties producible into granules, rock flour, mineral wool, expanded shale, pozzolans and other similar commodities

(iii) *Metallic and rare minerals* (minimum value $500,000)--Metallic elements and minerals, gemstones, and minerals that possess special properties valuable to science or industry. The ratio of transportation costs to the value of the material at the mine for this category is low. Examples include ores, deposits, or crystals of:

Precious metals (gold, silver, platinum)
Iron and other ferro-alloy metals (iron, tungsten, chromium, manganese)
Base metals (copper, lead, zinc)
Mercury
Uranium and thorium except syngenetic deposits in shale
Rare earths
Minor metals, including rubidium and cesium
Gemstones and semi-precious materials
Niobium, tantalum
Optical-grade calcite

(iv) *Non-fluid mineral fuels* (minimum value $1,000,000)--Non-hydrothermal mineral fuels occurring in sedimentary rocks. Examples include:

Coal and coal bed methane
Lignite
Peat
Organic shale
Tar sand
Uranium and thorium (syngenetic deposits in shale)

(v) *Unique or rare occurrences of rocks, minerals, or fossils* that are of outstanding scientific significance (no threshold value).

2. Mineral Resource Areas (MRA) and Scientific Resources Sites (SRS)

The following MRA and SRS categories shall be used in classifying lands. The geologic and economic data and the arguments upon which each unit MRA or SRS assignment is based shall be presented in the land classification information transmitted to a local government body such as a Zoning Board or the County Commissioners.

a. *MRA-1*—Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that there is little likelihood for their presence. This area shall be applied where well-developed lines of reasoning, based upon economic geologic principles and adequate data, demonstrate that the likelihood for occurrence of significant mineral deposits is nil or slight.

b. *MRA-2*—Areas where adequate information indicates that significant mineral deposits are present or where it is judged that there is a high likelihood for their presence. This area shall be applied to known mineral deposits or where well-developed lines of reasoning, based upon economic geologic principles and adequate data, demonstrate that the likelihood for occurrence of significant mineral deposits is high.

c MRA-3—Areas containing mineral deposits the significance of which cannot be evaluated from available data.

d. *MRA-4*—Areas where available information is inadequate for assignment to any other MRA.

e. *SRS* containing unique or rare occurrences of rocks, minerals, or fossils that are of outstanding scientific significance.

3. Documentation and Transmittal of Mineral Lands Classification Data

a. Areas assigned to mineral resource lands shall be delineated on suitable maps of a scale adequate for use on lead agency general plan maps. These maps shall also show the boundaries of each permitting authority in the report area.

b. A map at a convenient scale and a summary report showing the mineral lands classification for an entire county or, at the direction of the Board or Commissioners, major subdivisions of a county, or a major mineral district that includes portions of two or more counties, shall be prepared after classification is complete. Each map and report shall be submitted to the Board or Commissioners which, after review and approval, shall transmit it to the appropriate lead agencies and shall make it available to other interested parties.

c. Mineral land classification reports of regions containing *Construction Materials* classified *MRA-2* shall include the following additional information for each such mineral commodity:

(1) The location and an estimate of the total quantity of each such construction material that is geologically available for mining in the report region. The limits of the region shall be considered to be the consumption areas for each potentially producible construction mineral commodity under consideration.

(2) An estimate of the total quantity of each such construction material that will be needed to supply the requirements of both the county and the marketing region in which it occurs for the next 50 years. The marketing region is defined as the area within which such material is usually mined and marketed. The amount of each construction material mineral resource needed for the next 50 years shall be projected using past consumption rates adjusted for anticipated changes in market conditions and mining technology. These estimates shall be periodically reviewed.

4. Classification Priorities

Potential mineral lands that are most likely to be converted to uses that are incompatible with mining or which would preclude mining shall be classified first. Where the potential risk of conversion to incompatible land uses exists, those areas with mineral deposits of greatest statewide or regional significance containing strategic mineral commodities or non-fluid mineral fuels shall be classified first. The potential for loss may be through the process of urbanization or through other irreversible uses of the mineral lands, or of ad-

joining lands, with which mineral extraction would be incompatible.

5. Petitions for Mineral Lands Classification

a. Petitions may be brought before the Board or Commissioners by any individual or organization to classify mineral lands that are claimed to contain significant mineral deposits and which are claimed to be threatened by land uses incompatible with mining. Classification is a prerequisite to designation of regional or statewide significance.

SECTION II. DESIGNATION

1. Designation Criteria

Areas to be considered for designation by the Board or Commissioners will contain one or more mineral deposits of statewide or regional significance. Ordinarily, classification of an area as MRA-2 by a qualified geologist will constitute adequate evidence that an area contains significant mineral deposits, but other data, including the intent of beneficial mineral owners, shall be considered by the Board or Commissioners in determining the significance of specific mineral deposits and the desirability of designation.

2. Designation Procedures

a. Upon receipt from a qualified geologist of a mineral lands classification map and report delineating one or more areas classified as MRA-2 or SRS, the Board or Commissioners shall:

(1) Review the map and report to determine the sufficiency of the submitted data as a basis for designation and request such additional information as may be required.

(2) Determine the need for, and the priority of, designating the MRA-2 and SRS areas, taking into consideration the importance of the mineral deposits to the State or region thereof and the imminence of any threatened land-use changes that would be incompatible with mineral extraction.

(3) Notify the appropriate lead agencies of the decision to consider designation of one or more mineral resource areas within their jurisdiction.

(4) Set a date and place for a public hearing to consider the areas which the Board or Commissioners propose to designate as containing mineral deposits of statewide or regional significance. If practicable, the public hearing shall be held in or near the area proposed for designation.

(5) Notify all affected agencies and parties having an interest in the lands considered for designation.

b. At the public hearing to consider proposed designations, the Board or Commissioners shall seek the recommendations of concerned federal, state, and local agencies, educational institutions, civic and public interest organizations, and private organizations and individuals in the identification of mineral deposits of statewide or of regional significance. Such review and comment should address:

(1) The adequacy of the mineral land classification data transmitted by a qualified geologist and of any additional data transmitted by the Board or Commissioners, which together will constitute the principal basis for designation.

(2) Additional data bearing on the presence and marketability of mineral deposits proposed to be of statewide or of regional significance in the area under consideration including the interest of beneficial mineral owners.

(3) The need, amount and location of mineral deposits of regional significance, namely *Construction Materials* as defined in Section 1, Subsection 1b of these guidelines, that should be designated to provide for the needs of the region.

(4) The need for the proposed designation of each mineral deposit of statewide significance, namely, *Industrial and Chemical Mineral Materials, Metallic and Rare Minerals, Nonfluid Mineral Fuels, and Rocks, Minerals, and Fossils of Outstanding Scientific Significance*, as defined in Section 1, Subsection 1b of these guidelines. Ordinarily, such deposits are uncommon or rare, and economically significant occurrences warrant designation. However, some types, such as low-grade limestone, low-grade clays and other rock varieties that may be processed into valuable mineral products are commonly present in such large quantities that designation would be warranted only where special circumstances exist. Such circumstances might include proximity of a mineral deposit to markets, transportation, or energy sources or to other raw materials with which they could be combined to produce more valuable products.

(5) The existing uses of the areas proposed for designation and the future uses of these areas as determined by local agencies.

(6) Values relating to recreation, watershed, wildlife, range, and other special considerations, such as critical areas.

c. Following the public hearing, the Board or Commissioners may designate to be of statewide or regional significance all or part of the areas classified as MRA-2 or SRS. The designation shall specify the following:

(1) The boundaries of the designated area.

(2) The mineral deposits of statewide or of regional significance contained in each designated area and an estimate of the amount of each mineral commodity that is available for mining under present or foreseeable technologic, economic, and land-use conditions, for MRA-2 areas or a description of the materials of scientific value in the SRS area.

(3) The reason that each designated area is of significance to the Sate or region, the advantages to the State or region that might be achieved from the extraction of the minerals of the area, and the adverse effects that might result from premature development to land uses that would preclude mining.

(4) The specific goals and policies to protect the areas containing mineral deposits designated to be of statewide or regional significance from

premature development to uses that would preclude mining, or to uses with which mining would be incompatible.

(5) Lead agencies having jurisdiction over the area.

3. Petitions for Designation

a. Prior to permitting a use which would threaten the potential to extract minerals classified as MRA-2 or SRS but not yet designated, the lead agency may petition the Board or Commissioners for a designation hearing.

b. Petitions for a designation hearing may also be brought before the Board or Commissioners by any other party, provided that the Board or Commissioners have received and approved land classification information that indicates that the area in question is classified MRA-2 or SRS and that the Board or Commissioners have not yet considered designation. Petitions submitted to the Board or Commissioners shall include the following information.

(1) The petitioner's name, mailing address, and interest (beneficial, jurisdictional, or other) in the area to be considered for designation.

(2) A map (USGS 7½′ quadrangle or other appropriate map) showing the boundaries of the MRA-2 or SRS area the petitioner wishes to be designated.

(3) The reasons for requesting designation.

(4) The name and mailing address of each recorded land owner and each recorded lessee in and adjoining the area described. The Board or Commissioners shall then evaluate the data submitted in the petition as to their accuracy and sufficiency. If the Board or Commissioners find that the petition contains sufficient information and arguments to require a public hearing, then the Board or Commissioners shall schedule such a hearing and proceed as outlined in this section.

4. Termination of Designation Status

a. The status of mineral lands previously designated to be of statewide or regional significance may be terminated, either partially or wholly, by the Board or Commissioners on a finding that the protection afforded by designation is no longer necessary. In making this finding, the Board or Commissioners shall consult with affected lead agencies and beneficial owners of mineral resources as to the desirability of terminating designation. Such a finding may result from, but not be limited to, the following reasons:

(1) Depletion of the mineral deposit or deposits within the designated area.

(2) Demonstration that the mineral deposit or deposits within the designated area are in excess of quantities required for present or foreseeable future statewide or regional needs.

(3) Ending of the time limit, if any, for the designation to be in force.

b. Prior to making such a finding, the Board or Commissioners shall notify the beneficial owners of mineral resources and hold a public hearing. If practicable, it shall be held in or near the area in which the designated areas occur.

c. Petitions may be brought before the Board or Commissioners to terminate the designated status of mineral lands. Petitions submitted to the Board or Commissioners shall include the following information:

(1) The petitioner's name, mailing address, and interest (beneficial, jurisdictional or other) in the petitioned area.

(2) A map (USGS 7½′ quadrangle or other appropriate map) and legal description of the petitioned area.

(3) Reference to the specific action of the Board or Commissioners which designated the area.

(4) The reasons and supporting data as to why direct Board or Commissioners involvement is no longer necessary.

d. The Board or Commissioners shall then evaluate the data submitted in the petition as to their accuracy and sufficiency. If the Board or Commissioners find that the petition contains sufficient information and arguments to require a public hearing on termination, then the Board or Commissioners shall schedule such a hearing and proceed as outlined in this section.

SECTION III. COMPATIBILITY/INCOMPATIBILITY

The following land-use categories are to serve as examples to local government in assisting designation of MRA-2 lands. Compatible vs. incompatible categories will vary from one jurisdiction to another.

1. *Incompatible*—Land uses inherently incompatible with mining and/or which require a high public or private investment in structures, land improvements and landscaping and which would prevent mining because of the higher economic value of the land and its improvements. Examples of such uses include:

High-density residential
Low-density residential with high unit value
Public facilities

2. *Compatible*—Land uses inherently compatible with mining and/or which require a low public or private investment in structures, land improvements, and landscaping and which would allow mining because of the low economic value of the land and its improvements. Examples of such uses include:

Very low density residential (for example: 1 unit per 10 acres)
Extensive industrial
Recreational (public/commercial)
Agricultural
Silvicultural
Grazing
Open space

[For more information about these guidelines. refer to the article on page 2 or contact Raymond Lasmanis, State Geologist)

State Geologic Map Progress

by
J. Eric Schuster

I last reported state geologic map progress in the October 1988 issue of this newsletter (Schuster, 1988), and I last reported on support for student and faculty mappers in the December 1989 newsletter (Schuster, 1989). Since then, we have made great progress on the northeast quadrant of the state geologic map, we have realigned compilation assignments for 1:100,000-scale quadrangles in the northwest quadrant, we have decided how to accomplish geologic compilation of the southeast quadrant, and we have selected mapping or map-related graduate student or faculty projects for support in fiscal year 1991 (July 1, 1990, to June 30, 1991).

Thirteen mapping proposals were chosen for support in fiscal year 1991. The investigators, their universities, and the titles of their projects are listed in Table 1. As shown in Table 2, the Division has now supported a total of 67 student and faculty mapping and map-related projects in the 7 years of the state geologic map mapping support program, for a total of $112,712. Table 2 also shows that the numbers of proposals submitted and supported in the last 2 years have returned to the numbers experienced during the first 2 years of the program, a healthy trend.

We have finished preparation of open file 1:100,000-scale geologic maps for the northeast quadrant of the state. Fourteen quadrangles have been released; they are marked by asterisks in the references listed at the end of this article. Division geologists did not re-compile the Chelan (Tabor and others, 1987) and Wenatchee (Tabor and others, 1982b) quadrangles because recent geologic maps at 1:100,000-scale are available from the U.S. Geological Survey. Division geologists have prepared reduced-scale, simplified geologic maps for each northeast-quadrant 1:100,000 quadrangle. These reductions, at 1:250,000 scale, serve as linework masters for Division cartographers as they prepare the map materials for publication. The Division cartographic staff is now scribing the geology plate for the northeast quadrant geologic map.

The design of the northeast quadrant map publication is also finished, and preliminary decisions about

Table 1. Proposals funded under state geologic map, mapping support program, fiscal year 1991 (f, faculty)

Investigator	University	Project Title
Randy C. Blomquist	San Jose State University	Geology of the Ruby Creek and Canyon Creek area, North Cascades, Washington
Eric S. Cheney (f)	University of Washington	Extent and age of the Chesaw thrust, Okanogan County, Washington
Ralph L. Dawes	University of Washington	Geochemistry and crystallization of Late Cretaceous granitoid plutons, North Cascades, Washington
Kathleen M. Duggan	Western Washington University	Petrology and geochronology of the Tonga Formation, Tonga Ridge-Blanca Lake area, North Cascades, Washington
David C. Engebretson (f)	Western Washington University	Structure, age, and geochemical characteristics of the Crescent Formation: Comparison of the eastern and northern Olympic Peninsula, Washington
James E. Evans (f)	Bowling Green State University (Ohio)	Sedimentology and stratigraphic relationships of Tertiary sedimentary units within the Sauk River 1:100,000 quadrangle, Washington (Awarded in FY 1990)
Steven M. Fluke	Western Washington University	Geology of the Mount Buckindy area, North Cascades, Washington
Hugh A. Hurlow	University of Washington	U-Pb geochemistry of the Okanogan Range batholith and High Pass pluton, Robinson Mountain and Twisp 1:100,000 quadrangles, Washington
Dan McShane	Western Washington University	Structure and geology of the Eldorado Peak area, North Cascades, Washington
Lynda S. Nicholson	San Jose State University	Structure and petrology of portions of the Stehekin, Sun Mountain, McAlester Mountain, and McGregor Mountain quadrangles northeast of the Stehekin River, Chelan County, Washington (Awarded but not accomplished in FY 1989. Resubmitted for FY 1991)
Michael G. Rasmussen	University of Washington	Geology of the Overlook gold deposit, Republic mining district, Ferry County, Washington
Joseph A. Vance (f)	University of Washington	Fission-track dating of zircons from the Olympic core, Olympic Peninsula, Washington
Andrew C. Warnock	Western Washington University	Paleogeographic reconstruction of the Crescent terrane on the Olympic Peninsula, Washington

Table 2. Summary of mapping support program, FY 1985-FY 1991

Fiscal Year	No. of contracts	Support level
1985	14	$26,000
1986	10	17,500
1987	6	12,476
1988	6	11,388
1989	7	11,695
1990	11	12,686
1991	13	20,967
Totals	67	$112,712

the colors and patterns to use for northeast-quadrant geologic units are being"tested" by printing a color-pattern proof sheet. The publication will consist of three sheets and a pamphlet. The first sheet will present the geologic map and a simple matrix-style key to geologic units. This key will be similar to that published on sheet one of the Geologic map of Washington--Southwest quadrant (Walsh and others, 1987), but it will be larger because there will be 188 geologic units on the northeast quadrant geologic map as compared to 118 on the southwest. Sheet two will consist of descriptions of geologic units and a list of named geologic units. Sheet three will contain a generalized bedrock geologic map, a table summarizing the geologic history, figures illustrating geologic history, and a diagram showing correlation of geologic units. The pamphlet will include general introductory and explanatory material, acknowledgments, maps showing sources of data, notes on the ages assigned to geologic map units, and references. Geologists in our Spokane office are well advanced in the preparation of drafts of all the above materials. Our intent is to be ready to go to press with the northeast quadrant by May 1991.

As noted in the introductory paragraph, we have decided how the compilation of the southeast quadrant geology will be done. While the majority of the Division staff geologists with state geologic map assignments will continue to work on the compilation of the northwest quadrant, two geologists, one from the Olympia office and one from the Spokane office, will take on the compilation of the southeast quadrant. Although this approach at first seems understaffed, we have judged it a practical approach in light of the fact that the southeast quadrant includes the equivalent of about nine 1:100,000-scale quadrangles, fewer than any other quadrant. In addition, the northern tier (equivalent to 1.75 1:100,000 quadrangles) is already available as 1:100,000-scale geologic compilation maps (Waggoner, 1990c; Gulick, 1990a, 1990b; Tabor and others, 1982b). Two full quadrangles and part of a third are scheduled to be compiled by S. P. Reidel and K. R. Fecht of Westinghouse Hanford Corp. The geology of the southeast quadrant is considerably simpler than that of the other quadrants, which should greatly speed and simplify the compilation effort. Following the relatively rapid compilation effort, the southeast quadrant is targeted for publication in 1993.

Work is continuing on the collection and compilation of geologic data in the northwest quadrant. Compilation assignments remain largely as reported 2 years ago (Schuster, 1988) except as affected by staff changes. Current quadrangle compilation assignments are shown in Table 3. The geology of several of the northwest quadrant 1:100,000-scale quadrangles has been mapped in recent years by the U.S. Geological Survey, and for these quadrangles the Division will not release new open-file maps. Rather, the Division geologist responsible for that quadrangle will add pertinent information from more recent references and "translate" the map's geologic units to those used in our geologic map series. These quadrangles are noted in Table 3 and listed in the References section.

Two other projects will have significant influence on the northwest state geologic map quadrant. One is the continuing COGEOMAP (Co-Operative GEOlogic MAPping) project wherein R. W. Tabor and R. A. Haugerud of the U.S. Geological Survey are preparing geologic maps of the Mount Baker and Robinson Mountain 1:100,000-scale quadrangles; the Division is supplying a small fraction of the funding for the project. The other project, supported by funding to the Division from the U.S. Minerals Management Service,

Table 3. Compilation assignments for the northwest quadrant of the state geologic map. References are to published 1:100,000-scale quadrangles; these will not be re-compiled but rather "translated" into the Division's system for representing the geology and augmented with more recent geologic data. The basic geology of all or parts of the Cape Flattery, Forks, Mount Olympus, Port Angeles, Port Townsend, and Shelton 1:100,000 quadrangles is available in Tabor and Cady (1978)

1:100,000-scale quadrangle	Compiler(s)
Bellingham	Pat Pringle
Cape Flattery	Bill Phillips
Chelan (Tabor and others, 1987)	Unassigned
Copalis Beach	Josh Logan
Forks	Bill Phillips, Josh Logan
Mount Baker	Unassigned
Mount Olympus	Bill Phillips
Port Angeles	Hank Schasse
Port Townsend (Pessl and others, 1989)	Hank Schasse
Robinson Mountain	Unassigned
Roche Harbor	Josh Logan
Sauk River (Tabor and others, 1988)	Hank Schasse
Seattle	Tim Walsh, Josh Logan
Shelton	Josh Logan
Skykomish River (Tabor and others, 1982a)	Bob Derkey
Snoqualmie Pass (Frizzell and others, 1984)	Bob Derkey
Tacoma	Tim Walsh, Josh Logan
Twisp	Unassigned
Wenatchee (Tabor and others, 1982b)	Tim Walsh

is a study of the regional stratigraphic and structural framework of the western Olympic Peninsula being undertaken by R. J. Stewart, a professor at the University of Washington under contract to the Division.

Because Division staff geologists and others have produced so many compilation geologic maps in the last several years, it has become possible for me to compile a page-sized geologic map of Washington. This map is to be published, in black and white, in the July/August 1991 issue of "Rocks and Minerals" magazine, which will be devoted to the State of Washington. The Division is also preparing a colored version that will be released as a single-sheet, 1:2,250,000-scale map; major sources of data will be listed on the back.

The state geologic map data are not now available in digital form. One of the Division's long-term goals is to make the 1:100,000-scale geology a data layer on the Department's geographic information system.

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The Nisqually Landslide of September 1990

by Patrick T. Pringle

At about 7:00 A.M. on September 16, debris of a large landslide blocked the Nisqually River for several hours about 8 km (5 mi) downstream from La Grande Dam (Figs. 1 and 2). The landslide was a large slump (rotational slip) caused by undercutting of the steep south bank by the Nisqually River. More than 200,000 m^3 of debris now partially dams the river. The Nisqually River flows around the toe of the slide through a forested area on low alluvial terraces north of, and adjacent to the pre-landslide channel (Fig. 2).

Site Description and Geology

The Nisqually valley in this reach is incised about 75 m, and the flood plain averages 500 m wide. The valley walls are composed mainly of sands and silts of the Mashel Formation, an upper Miocene fluvial and lacustrine sequence that contains clayey silt, lignite,

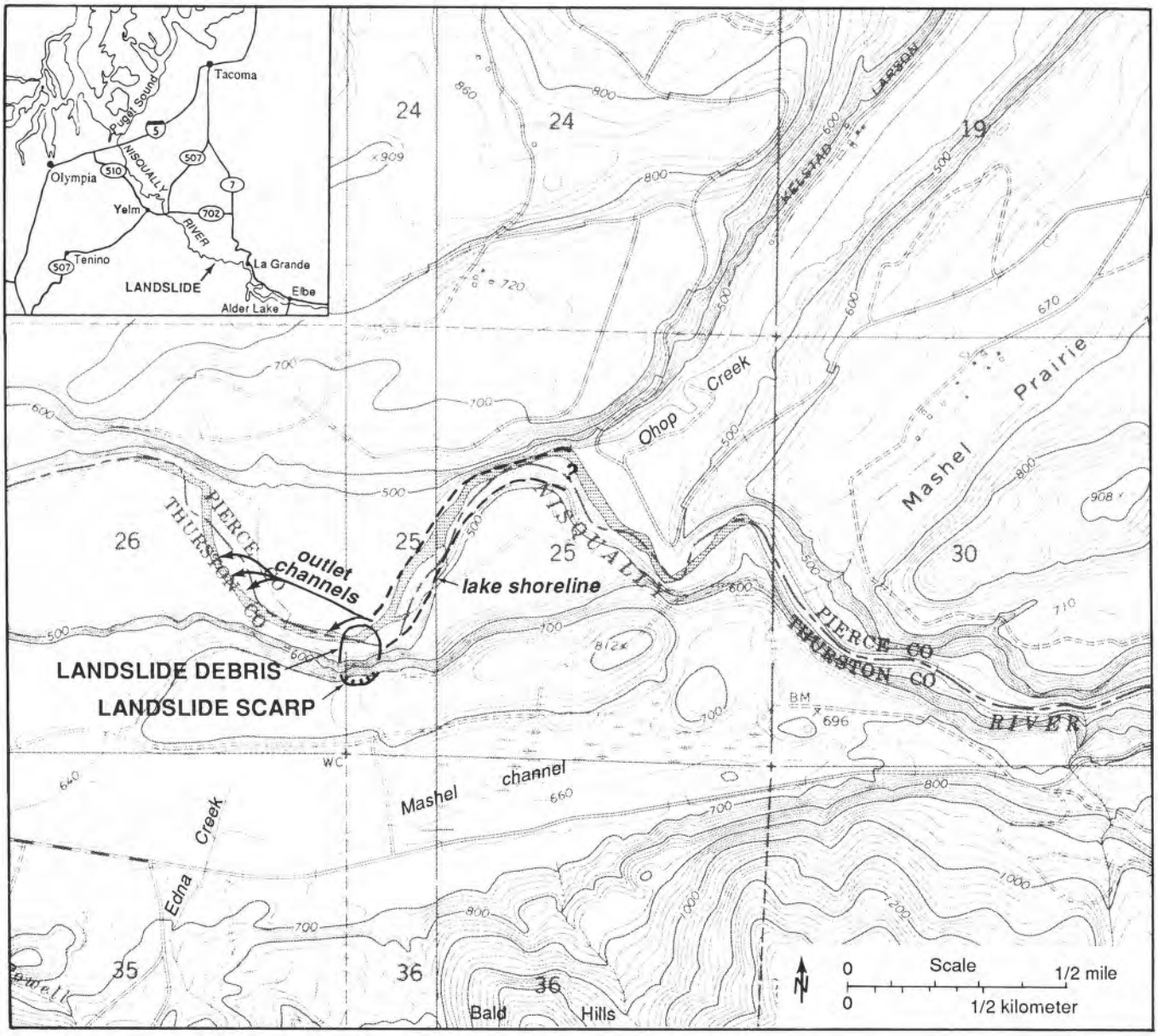

Figure 1. Location map of the Nisqually River valley north of the Bald Hills showing location of the September 16 landslide, approximate extent of ponding of the Nisqually River, and outflow from the lake. The Mashel glacial outwash channel and wetland caused by the internal drainage pattern of Edna Creek and an unnamed tributary to the east are also shown.

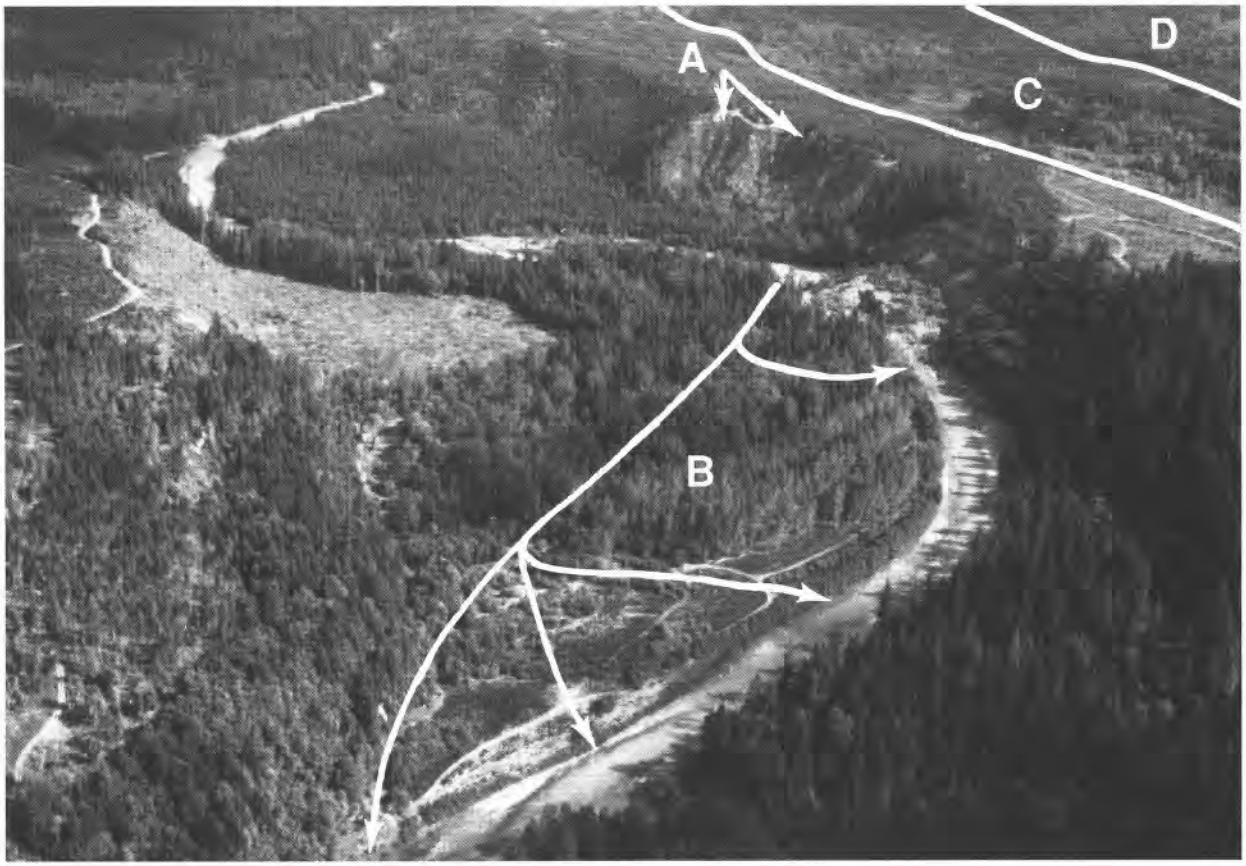

Figure 2. Oblique aerial photograph of the Nisqually River taken on September 17. The landslide of September 16 is visible in the upper right. Scallops in the valley wall from previous landslides are visible upstream of the landslide in the top center of the photograph (A). Arrows (B) show current drainage of the Nisqually through the forested alluvial terraces on the north bank of the river. Mashel glacial outwash channel and wetlands are outlined at upper right corner (C). D indicates the extreme northern tip of the Bald Hills. (Photo courtesy of Patrick Neary of the Olympian)

pumice, volcanic ash, and tuffaceous sand (Walters and Kimmel, 1968). The Mashel sediments are unconformably overlain by about 10 m of Vashon (15,000 yr B.P.) glacial drift that consists of a lower discontinuous till(?) and overlying outwash sands and gravels.

Beds of the Mashel formation dip gently to the west at the site. As determined from well logs, the eroded upper surface of the formation dips to the north and is covered by younger formations near McKenna, about 18 km to the northwest (Walters and Kimmel, 1968). The exact thickness of the Mashel Formation underlying the Nisqually River at the landslide site is unknown, but a well located about 3 km north-northwest of the site (580 ft elev.) was still in the formation at a depth of 426 ft (130 m).

Upper units of the Mashel exposed in the landslide escarpment consist of 10 m of tuffaceous sands overlain by a 0.5-m-thick opalized lapilli tuff containing hornblende- and plagioclase-phyric pumice. These beds are fairly permeable, but they overlie poorly permeable clayey silt units that cause the water table to be perched and seepage and springs to flow along at least two horizons on the valley wall escarpment.

Although the Nisqually landslide occurred during a dry period of the year, moist conditions predominate at the site because of drainage characteristics that resulted from its glacial history (described below) and the locally impervious nature of the Mashel Formation. The site is only about 1 or 2 km north of the maximum southern extent of the Yelm lobe of the Vashon Cordilleran ice sheet. The Bald Hills, a complex of indurated Eocene volcanic rocks south of the area, provided an obstacle to the southward-advancing ice sheet. When melting and retreat of the ice formed glacial Lake Yelm, the lake initially drained through an ice-marginal meltwater channel that occupied a position slightly south of the present Nisqually River. (See Fig. 1.) This channel, which here will be called the Mashel channel because the area is an apparent extension of Mashel Prairie, drained westward along the ice front and probably joined the Johnson Creek-Skookumchuck

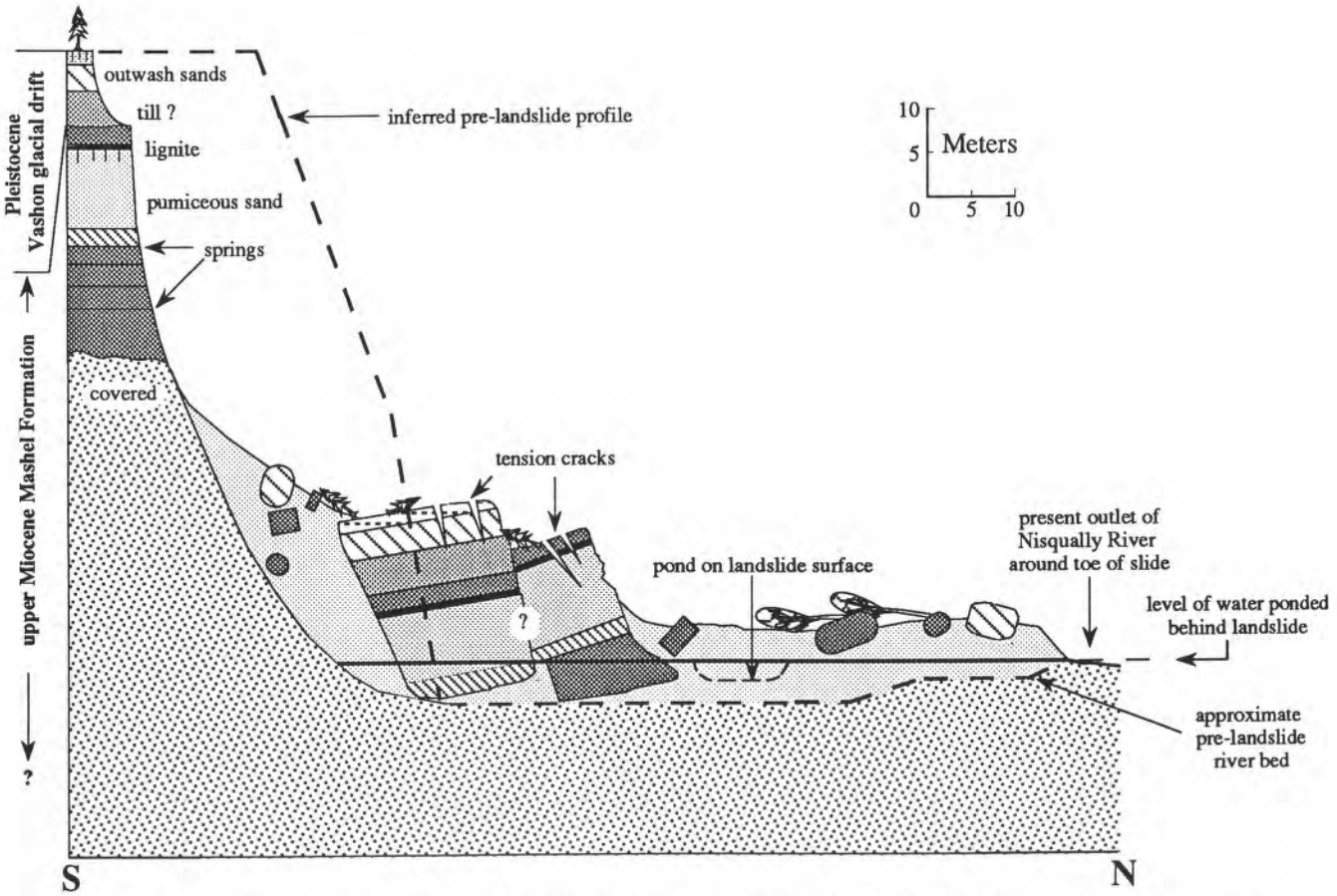

Figure 3. Diagrammatic north-south cross section of the September 16 Nisqually landslide showing the structure of the slide and a stratigraphic section of deposits composing the valley wall. Note the level of the pond on the landslide surface.

River-Chehalis River outwash route described by Noble and Wallace (1966).

Edna Creek and an unnamed tributary to the east now drain northward from the Bald Hills volcanic highland into a wetland in the Mashel channel (Fig. 1). This 12.7-km^2 (4.9 mi^2) catchment area has an internal drainage system (no outlet) and thus recharges the ground-water table. Therefore, a perched water table exists in this area even during the relatively dry conditions of late summer. This perched water saturates the clayey silts and decreases slope stability along the valley walls.

The steep and locally scalloped walls along the Nisqually River valley near the landslide suggest that slumping has been a common agent of landscape change along this reach (Fig. 2). Slump blocks of the Mashel Formation that were observed in the river during earlier geologic investigations can be distinguished on previous (1960) aerial photographs. These provide evidence that slumps similar to that of September 16 have temporarily blocked the Nisqually River in the past.

Nature and Effects of the September 16 Landslide

Investigators had noted minor active landslides at the site about a year ago (James Ward, Weyerhaeuser Centralia Research Center, written commun., 1989). Progressive undercutting by the river apparently removed the base of the valley wall and caused the wall to fail as blocks that slid into the river on September 16. The landslide probably formed a blockage immediately, forcing the river to find an outlet at least 100 m farther north around the toe of the slide mass.

Currently, a small lake is ponded upstream of the landslide. The lake extends upstream nearly to the mouth of Ohop Creek (about 1 km). This lake averages about 100 m wide and, during normal river flow (27 m^3/s or 950 cfs), has a maximum depth of about 5 m. The highest parts of the landslide deposit are the tops of slump blocks; these are situated about 18-20 m above the level of the water impounded by the blockage (Fig. 3). The lowest part of the blockage is a small plug of sediment located north of, and adjacent to the northernmost slump block. The top of this plug is only about 3 m above the level of the ponded water at normal flow. The bottom of a pond on the slide surface located about 30 m downstream of this plug, however, is 2 m below the surface of the lake (Figs. 3 and 4).

Investigations now being planned will evaluate the stability of the landslide and the downstream effects of a potential breakout of the lake. These studies should

←**Figure 4.** Upstream view of depressions and the pond on the landslide surface (left foreground), north face of the northernmost slump block (right foreground), and impounded Nisqually River (background). The largest sediment block in the pond is 2 m in height. The pond surface is 2 m lower than the level of the impounded lake during normal stream flow. (Photo by the author)

include a survey of the dimensions of the blockage and the lake ponded behind it and a determination of the engineering properties of the materials composing the blockage. Saturated conditions caused by the local perched water table will undoubtedly contribute to future slope-stability problems along this reach of the Nisqually River.

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A (Re)Discovery in the Library

We have about 75 unfolded copies of each of the maps that make up our Geologic Map GM-22 (1978, reprinted 1986), **Mineral Resource Maps of Washington**: Metallic mineral resources, non-metallic mineral resources, sand and gravel pits and stone quarries, and energy resources. Normally the maps are folded and placed in an envelope with the text. If you wish to purchase this report, you can request unfolded copies of the maps; the text and maps will then be mailed in a tube. GM-22 costs $1.86 + .14 tax (Washington residents) = $2.00. See the back page of this newsletter for ordering instructions.

SME NW Section to Meet

An interim Executive Committee has been formed to reactivate the Society for Mining, Metallurgy, and Exploration's North Pacific Section. The first meeting of the section will be held in Seattle, Thursday, January 24, at 6:30 p.m. (social hour), with dinner at 7:00. The speaker will be Donald E. Ranta, one of the Society's Henry Krumb lecturers. Ranta is manager of North American Exploration, Phelps Dodge Corporation. He will speak on "Geological considerations in the transition from exploration to production". For more information or to make reservations, contact Grant Foster at (206) 622-4900.

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Pasco Mining Group Lauded

THC, Incorporated, of Pasco is one of two Northwest mining companies to receive special recognition from the Bureau of Land Management.

THC and Hecla Mining Company of Coeur d'Alene, Idaho, were recognized by the BLM for their exceptional stewardship and cooperation during exploration drilling operations within the Oregon Trail Area of Critical Environmental Concern near Baker, Oregon.

Both companies were commended for completing their operation with minimal surface disturbance and for their reclamation of the site when the project was completed.

Meetings

National Western Mining Conference
SME/CMA Joint Exhibit
February 24-27, 1991
Colorado Convention Center
Denver, Colorado
Information:
Shirley Hunter
Colorado Mining Association
1600 Broadway, Suite 1340
Denver, CO 80202
(303) 894-0536

Smithsonian Research Fellowships in Science

The Smithsonian Institution announces its research fellowships for 1991-1992. These fellowships are awarded to support independent research in residence at the Smithsonian in association with the research staff and using the Institution's resources. Predoctoral and postdoctoral fellowships for 6 to 12 months, and graduate student appointments for 10 weeks are awarded. Proposals in earth sciences may be made in these areas: meteorics, mineralogy, paleobiology, petrology, planetary geology, sedimentology, and volcanology.

Application are due January 15, 1991. Annual stipends supporting awards are $26,000 plus allowances for senior postdoctoral fellows, $21,000 plus allowances for postdoctoral fellows, and $13,000 plus allowances for predoctoral fellows; stipends are prorated on a monthly basis for periods less than 12 months. A sum of $3,000 is given graduate students for the 10-week tenure period.

Smithsonian fellowships are open to all qualified individuals without reference to race, color, religion, sex, national origin, age, or condition of handicap. For more information and applications write to the Smithsonian Institution, Office of Fellowships and Grants,Suite 7300, 955 L'Enfant Plaza,Washington, DC 20560.

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JOURNAL SUBSCRIPTIONS ADDED TO THE LIBRARY

American Journal of Botany
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Status of Division Publications

A recent inventory turned up 10 copies of **Information Circular 32, Early man in Washington** (1959) and 45 copies of **Report of Investigations 24, Mount St. Helens ash—Properties and possible uses** (1981). These are available, first come, first served, at $1.85 + .15 tax (Washington residents only) = $2.00 each.

Our supply of reprints of **Bulletin 37, Part II, Metallic minerals**, has been exhausted. Our recently released Open File Report 90-18, Metal Mines of Washington - Preliminary Report, is the current update of the older report.

Mima Mounds—An evaluation of proposed origins with special reference to the Puget Lowland, Report of Investigations 29, by A. L. Washburn, has been reprinted. The price is still $1.85 + .15 tax = $2.00.

Geologic Hazard Slides Available

The National Geophysical Data Center has 17 sets of slides that depict geologic hazards throughout the world and that are of use to engineers, architects, planners, disaster preparedness teams, and educators. Twelve sets address earthquakes, among them the Armenian earthquake of December 1988 and the Loma Prieta (California) earthquake of October 1989.

The price of each set is $25.00, and there is a $10.00 handling fee per order.

For more information, contact:

National Geophysical Data Center
NOAA/NESDID E/GC4
325 Broadway, Dept. 730
Boulder, CO 80303
(303) 497-6958

Staff Notes

David P. Clark, who is studying computer graphics at South Puget Sound Community College, joined us October 29 as a Natural Resource Aide. He will be assisting our cartographers for several months.

Rebecca Christie, the Division's new Library Technician 2, is a transplanted Easterner. Rebecca has a B.A in Art Studio from the University of California at Davis and a M.L.S. from the University of Alabama. Her background includes typographic design and book arts, materials conservation, and working with special collections.

Gwendolyn Crain, our Library Technician since October 1987, has moved on. Gwen had extensive library experience, primarily as a library technician in military libraries in the U.S. and overseas. She and her family have moved to Chicago, where her husband was transferred. We miss her good humor and that famous Texas chili.

Joe Dragovich joined the Division as a project geologist on November 26. A native of northwestern Washington, Joe received his Bachelor's degree (in geology) from Washington State University in 1984. After working for the Department's Conservation Corps in Sedro Woolley, he returned to school at Western Washington University, where he completed his master's thesis on the Cascade River Schist of the North Cascades in 1989. Since then he has been employed in geologic mapping for the Idaho Geological Survey and in engineering geology for a consulting firm in Bellingham. At the Division, Joe will be assisting Matt Brunengo with the Slope Hazard Zonation Project, which is funded by the research committee of Timber/Fish/Wildlife cooperators.

Rex Hapala joined the Division on September 4 as our Natural Resource Research Technician 2. He fills a position vacated by the retirement of Arnold Bowman. Rex recently graduated from Pacific Lutheran University in Tacoma with a B.S. degree in Earth Sciences. He brings with him a variety of laboratory skills acquired while he was a student.

Dave Norman has been promoted from Geologist II in the Department's Southwest and Central regions to Chief Reclamationist, Geologist III, in the Division's Olympia office. His duties will consist of managing the Surface-Mined Lands Reclamation program. Dave received his Bachelor's degree from Portland State University and a Master of Science degree from the University of Utah. Previously, he was employed by Union Geothermal Company, by Amoco Minerals, Inc., and most recently by Corelab, Inc., in Calgary where he managed the Geology Section. Dave moves to Olympia after remarkable success with the surface mining program in our Central and Southwest regions.

Jack Sareault left us in August for a position with the Washington State Patrol, where he will be developing and writing newsletters. Jack came to the Division in 1988 from a long career in journalism; his specialty was sports writing. He soon took on the chores of Editorial Assistant and helped us devise some new formats. We appreciated his knowledge of Washington geography and his steady hand.

Stephanie Waggoner has transferred from the Spokane Field Office to the Department's Southwest and Central region offices in Castle Rock and Centralia. Stephanie has compiled three of the open-file reports for and is a co-author of the new 1:250,000-scale geologic map of Washington's northeast quadrant, to be released in mid-1991. In her new job, she will be the surface-mined lands reclamation specialist.

Tim Walsh has been selected to participate in the State's Career Executive Program.

New Division Releases

Open File Report 90-12, Geologic map of the Omak 1:100,000 quadrangle, Washington, compiled by C. W. Gulick and M. A. Korosec. 52 pages with 1 plate. The price is $2.78 + .22 tax (Washington residents only) = $3.00.

Open File Report 90-13, Geologic map of the Colville 1:100,000 quadrangle, Washington-Idaho, compiled by N. L. Joseph. 78 pages with 1 plate. Priced at $3.25 + .25 = $3.50.

Open File Report 90-14, Geologic map of the Chewelah 1:100,000 quadrangle, Washington-Idaho, compiled by S. Z. Waggoner. 63 pages with 1 plate. Priced at $3.25 + .25 tax = $3.50.

Open File Report 90-15, Geologic map of the Coulee Dam 1:100,000 quadrangle, Washington, compiled by S. Z. Waggoner. 40 pages with 1 plate. Priced at $2.30 + .20 = $2.50.

Open File Report 90-16, Geologic map of the Nespelem 1:100,000 quadrangle, Washington, compiled by N. L. Joseph. 47 pages with 1 plate. Priced at $2.30 + .20 = $2.50.

Open File Report 90-17, Geologic map of the Spokane 1:100,000 quadrangle, Washington-Idaho, compiled by N. L. Joseph. 29 pages with 1 plate. Priced at $1.86 + .14 = $2.00.

The six open-file reports above bring to fourteen the releases to date and complete the series of maps that are being used to prepare a 1:250,000-scale geologic map of the northeast quadrant of Washington.

Open File Report 90-18, Metal Mines of Washington — Preliminary Report, by R. E. Derkey. This report is a revision of Part II of Bulletin 37 and presents information about 541 mines. 587 pages (punched for three-ring binders). Priced at $13.81 + 1.19 = $15.00.

Washington State Surface Mining Permit File: The Division maintains a computerized file of all surface mining operations in the state. The file lists information by product, county, and permit number. A printout can be ordered from the Division; the price is $9.28 + .72 tax (Washington residents only) = $10.00.

Mail orders for any of the above reports must be prepaid. Add $1.00 to each order for postage and handling. Please make checks available to the Department of Natural Resources. See address information on page 2.

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