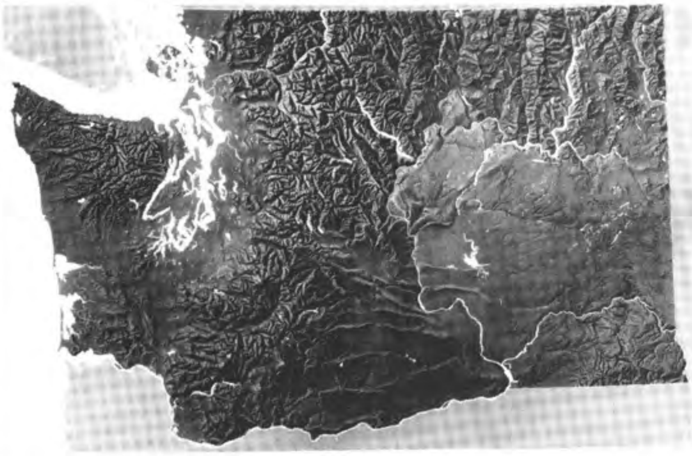


# WASHINGTON GEOLOGIC NEWSLETTER

Volume 17 Number 3 August 1989

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


Gully erosion near Fancher Field, East Wenatchee. (See article, p. 3)

## IN THIS ISSUE

# WASHINGTON GEOLOGIC NEWSLETTER

The Washington Geologic Newsletter is published quarterly by the Division of Geology and Earth Resources, Department of Natural Resources. The newsletter is free upon request. The Division also publishes bulletins, information circulars, reports of investigations, geologic maps, and open-file reports. A list of these publications will be sent upon request.




# Mineral Industry in 1935—Predictions and Reflections

by Raymond Lasmanis

Fifty-four years ago Washington was recovering from the Great Depression. There was optimism in the air. Great predictions were being made for the future of the state's mineral industry.

In 1935, a panel of experts presented their views through "A Popular Radio Story of Mineral Resources", the script of which was subsequently published by Secretary of State Ernest N. Hutchinson (Banker and Showalter, 1935). The panel consisted of:

H. J. Gille, President of the West Coast Mineral Association; E. F. Banker, Director of the Department of Conservation and Development; Milnor Roberts, Dean of the College of Mines, University of Washington; Joseph Daniels, Professor of Mining, University of Washington; and Henry K. Benson, Professor of Chemistry, University of Washington.

The statements made about Washington's coal resources in this script are particularly interesting in light of modern information and nonrenewable resource use. At that time the U.S. Geological Survey credited Washington with containing 64 billion tons of coal, and according to Gille, that was enough coal to last until the year 31,953 - or for 30,000 years. Daniels covered the topic in the radio interview, and a summary titled "Sparks" noted that Washington's reserves were three times as great as those of Alaska.

Although the reserves were overstated in 1935, currently coal mining is a significant industry in Washington. Washington Irrigation and Development Company operates the 24th largest coal mine in the U.S. It produces about 5 million tons of subbituminous coal annually (1988) (Schasse, 1989). The Pacific Coast Coal Co. in King County is producing approximately 110,000 tons of coal a year (1988) from its John Henry No. 1 mine (Schasse, 1989). However, in contrast to 1935, underground mining is no longer practiced in the state.

(Continued on Page 14)


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DIVISION LOCATION (OLYMPIA)

# Geologic Hazard Investigation near East Wenatchee, Washington

By Robert L. Logan

Last spring the Division of Geology and Earth Resources responded to a landslide- and flood-related disaster affecting a four-county area in eastern Washington. In response to a presidential disaster declaration (see related article in this issue), a Hazard Mitigation Survey Team was assembled. Division geologists were asked to contribute technical input. Although there were many individual sites in the disaster area, most were affected by floods and did not require investigation of geologic features. Our study was limited to the Canyon B area located just north of East Wenatchee in Douglas County.

During the second week in March 1989, flood waters charged with sand, mud, and rocks flowed from Canyon B, plugging culverts, covering roads, and flooding basements in an adjacent residential area. In order to determine the cause of the flood and possibilities of continued problems, Canyon B was examined from near Fancher Field to State Route 28 (Fig. 1). Evidence obtained during this study supports a conclusion that a combination of geology, weather, and land modification was responsible for the changes in the canyon and damage on its alluvial fan.

Canyon B is a deeply incised V-shaped canyon occupied by an ephemeral stream that has cut through several lithologic units. Most of these units have been displaced by landslides that began in the Pliocene and have continued sporadically to the present (Gresens, 1983; Tabor and others, 1982).

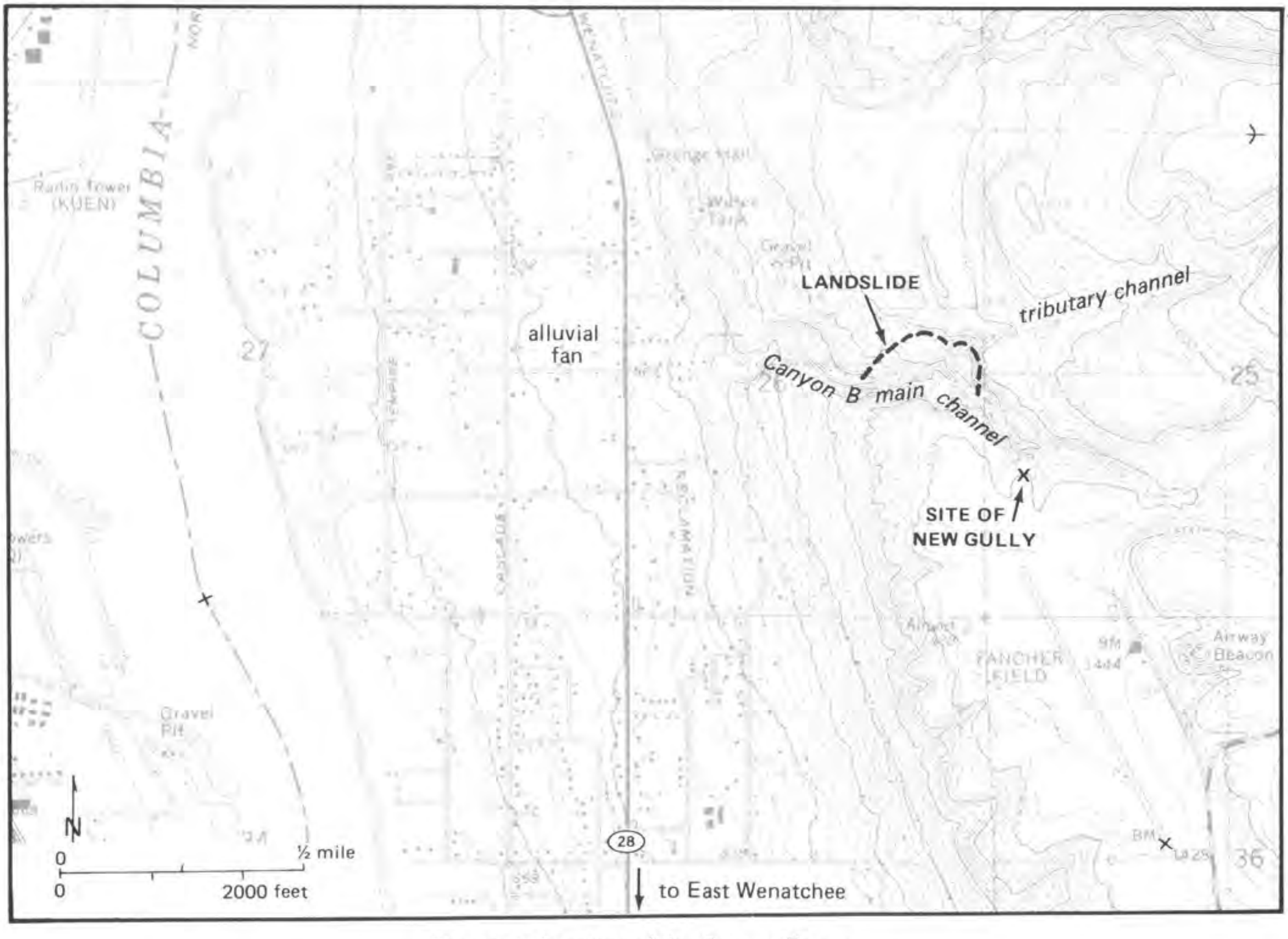


**Figure 1**. Location of the Canyon B area.

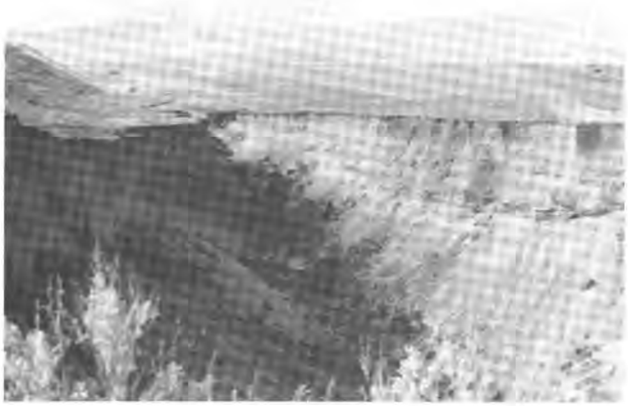

**Figure 2**. Gully formed during March 1989 event. A recently constructed berm is to the left of the gully. Note the undermined chain-link fence on the right. View is toward the south.

**Figure 3**. Sand-covered canyon floor at the base of a minor slope failure. The terrace on the left was deposited during flood stage. The 55-gal drum provides scale.

**Figure 4.** A typical shallow slope failure in the main channel canyon walls.

The oldest rock unit, Eocene sandstone of the Chumstick Formation, is exposed only in the lower reaches of the canyon. The overlying Oligocene Wenatchee Formation is composed of tuffaceous shale, siltstone, and sandstone with thin interbedded coal seams. Yakima Basalt and interbedded sandstone of Miocene age overlie the Wenatchee Formation. Breaching of these rocks during the Pliocene by the Columbia River caused loss of lateral support and resulted in slumping of the valley walls. Pleistocene catastrophic floods mantled these landslide materials with poorly consolidated sand and gravel bar deposits that form a terrace at about 1,400 feet elevation.

The surface of the terrace has been modified in recent years. A berm several hundred feet long was constructed between Fancher Field and the adjacent property to the east (Fig. 2). The ground surface was graded so that it sloped toward the berm, creating an artificial channel on the terrace. Under normal conditions, these modifications probably would not have affected the stability of the main canyon walls. However, the weather conditions during February and March set the stage for disaster.

A cold spell in February froze the exposed ground surface in much of eastern Washington. Before the ground could thaw, an insulating layer of

**Figure 5**. Confluence of a tributary and the main channel. Note the contrast between the well-armored tributary channel floor and the sand-choked main channel. Bushes are about 2 feet tall.

**Figure 6.** Reactivated portion of the deep-seated failure. View is to the northwest.

snow was deposited in early March. Rain fell on the snow during the second week of March. The combination of rain and melting snow could not penetrate the frozen ground. The resulting runoff was channeled by the berm and the sloped surface to the canyon rim just east of Fancher Field where a new gully was formed between two older gullies. Erosion must have been rapid in the essentially cohesionless Pleistocene flood sands that make up the angle-of-repose canyon walls in this area. Several sections of chain-link fence were undermined during the flood event, providing evidence of how much erosion has occurred.

A large quantity of sand was introduced into the main canyon (Fig. 3), choking the channel, covering the normal channel cobble and boulder armor, and causing the water to rise to a level where it began to undercut the unprotected canyon walls. As a result, many small canyon-wall failures occurred (Fig. 4), adding to the sediment load of the flood stream and increasing the amount of erosion.

The confluence of the main canyon stream and a tributary from the north is shown in Figure 5. Sand covers the main channel floor, but lag gravel and cobbles pave the channel of the tributary. No significant failures occurred along the tributary walls, but small landslides are common in the main channel from the new gully to the canyon mouth.

The tributary channel crosses a large deep-seated ground failure on the north side of the main channel. Part of this landslide was reactivated during the storm event, probably by breaching and undercutting of the slide toe (Fig. 6). Movement of the landslide into the main channel caused a temporary impoundment of runoff (Fig. 7). Breaching of the slide toe probably caused the surge of flood water and debris that aggravated canyon wall erosion downstream and moved through the residential area

**Figure 7**. An alluvial terrace in the canyon at the toe of the deep-seated failure. The present canyon floor is several feet below the terrace (at hammer level), indicating that the landslide toe dammed the canyon and was subsequently breached.

**Figure 8**. Stream-bank erosion in the residential area located on the Canyon B alluvial fan. Note the unsupported pipe in the bank on the left, slope failures on the right.

on the alluvial fan (Figs. 8 and 9). Movement has continued on this landslide (Fig. 10), setting the stage for a repeat performance, possibly during the next storm event.

Based on the preliminary findings of team members, efforts to design mitigation measures for this drainage are already in progress. These may include catchment basins, flood channels, and erosion control techniques. A private consulting firm has been hired to design and implement the final mitigation plan.

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**Figure 9.** Erosion along a street on the Canyon B alluvial fan. State Highway 28 is in the background. Floodwaters were nearly 3 feet deep at the lower end of this street.

**Figure 10**. Landslide dam in Canyon B. The toe of the landslide is on right, scoured bedrock on the left; a tire is being crushed between the two masses, indicating continued instability.

# Mitigation Planning for Disaster Areas

By Robert L. Logan

Storm-related floods, washouts, and landslides in Douglas, Okanogan, Stevens, and Whitman Counties in early March precipitated the April 14, 1989, presidential declaration of a Major Disaster area. Under Public Law 93-288, also known as the "Robert T. Stafford Disaster Relief and Emergency Assistance Act", federal funds may be made available for specific types of disaster relief. Funds are distributed according to criteria stipulated in the law for disaster repair, restoration, and mitigation. Also, a Hazard Mitigation Survey Team can be formed to address disaster damage issues by providing mitigation recommendations and funding. The Washington Division of Geology and Earth Resources (DGER) was asked to participate as a Team member and attended a mitigation meeting on April 26 and 27, 1989, in East Wenatchee.

The meeting was conducted jointly by Lora Murphy of the Washington Department of Community Development's Division of Emergency Management (DEM) and by Bob Freitag of the Federal Emergency Management Agency (FEMA). Other team members included representatives from the Washington Departments of Ecology (DOE), Wildlife, and Transportation; the U.S. Soil Conservation Service (SCS); private consultants; and local government officials.

The primary role of DGER was to provide technical input for site-specific mitigation issues. The major goals of other state and federal agencies in attendance were to recommend short- and long-term mitigation projects and identify funding sources for local governments. A variety of funding sources was described at the meeting. These include:

- DOE Flood Control Assistance Account Program (FCAAP)
- Clean Water Act funds
- Federal Highway Administration Title 23 ER monies
- SCS assistance
- PL 93-288 funds (public entity disaster assistance and mitigation)
- Local government funds.

Funds from these sources were matched with damages according to such criteria as location and property ownership. These funds were specified for both short-term damage repair and long-term preventive measures.

The long-term solutions included training, site design, storm-water management strategies, and development of subdivision design guidelines. They have been summarized in a draft Hazard Mitigation Survey Report written by DEM and FEMA participants.

According to the draft, a private consultant to the U.S. Army Corps of Engineers (USACE) will conduct a 4-hour workshop concerning flood warning and preparedness for rural, eastern Washington communities. The USACE will also conduct a 4- to 6-hour session on sandbagging techniques and the organization and implementation of a flood fight.

Additional long-term solutions include development of guidelines to add to the current Douglas County subdivision regulations. These guidelines address floodproofing of all new subdivisions, requiring design considerations to mitigate damages for a 50-year or greater event. Mitigation alternatives are to include, but not be limited to:

- Floodproofing
- Home orientation
- Street alignment for street access
- Floodway open spaces
- Streets for overflow corridors
- Overflow routes from onsite retention areas.

Public safety and future damage reduction must be addressed in designs for spring runoff and summer flash floods greater than a 10-year event. These recommendations are to be implemented by the county.

Also recommended were improving drainage in the Rosalia area in Whitman County and developing a stormwater strategy for Colville in Stevens County. A funding source was not immediately identified for the Rosalia project, although Title 23 ER money might be available. The culvert under State Route 195 directed storm water onto and thereby damaged two city roads. Several mitigation recommendations were made, but none has been adopted. A comprehensive strategy was recommended for the Colville area in which city and county officials will research available drainage information. They will identify existing and potential problems, decide how drainage should be handled, and then work with DEM to assemble appropriate agencies to establish sources of technical and financial assistance. Suggested possible funding sources include FCAAP, SCS, Section 404 PL 93-288, and the Clean Water Act.

Several other mitigation measures, all for sites in Douglas County, were recommended and funded through a similar process. These include:

- Preparing a comprehensive flood plain management plan for the city of Bridgeport
- Restoring the Foster Creek bridge

- Elevating and relocating portions of the road in the Palisades area
- Relocating a portion of the Jameson Lake Road
- Controlling debris flows and related drainage through the Canyon B area north of East Wenatchee.

DGER's main contribution to the hazard mitigation team effort was to provide a site inspection in the Canyon B area to identify the cause, assess risks, and help recommend mitigation techniques. The results of this inspection are presented in an article on page 3 of this issue.

Further information about hazard prevention and mitigation is available from FEMA, DEM, and DOE. These agencies offer publications on natural hazards, and they can be contacted at the following addresses:

- Washington Department of Community Development
  Division of Emergency Management
  Mail Stop PT-11
  Olympia, WA 98504
  (206) 459-9191
- Federal Emergency Management Agency, Region X
  130 228th Ave. SW
  Bothell, WA 98021
  (206) 487-4694
- Washington Department of Ecology
  Shorelands and Coastal Zone Management Program
  Mail Stop PV-11
  Olympia, WA 98504
  (206) 459-6000

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# Oil and Gas Wells Permitted in 1988 and 1989

| Company; Well name | Legal Description | Ground Elevation | Estimated Total Depth | Spud Date | Status |
|---|---|---|---|---|---|
| American Hunter Exploration Ltd.; Hunter Birch Bay #1 | 2,310' FSL, 660' FWL, Sec. 32, T. 40 N., R. 1 E., Whatcom County | 85' | 7,000' | 2-22-88 | Suspended |
| Twin River Oil & Gas, Inc.; Merrill & Ring Co. #25-1 | 975' FNL, 111' FEL, Sec. 25, T. 31 N., R. 10 W. Clallam County | 375' | 3,500' | 4-14-89 | Drilling |
| Shell Western E&P Inc. Quincy No. 1 | 2,532' FNL, 1,176'FEL, Sec. 22, T. 18 N., R. 25 E. Grant County (Federal Land) | 1,158' | 15,000' | 5-11-88 | P&A 2-8-89 TD 13,200' |
| Meridian Oil Inc.; Plum Creek 23-2 | 2,050' FSL, 1,650' FWL, Sec. 2, T. 18 N., R. 6 E. Pierce County | 1,679' | 4,000' | 8-5-88 | P&A 8-23-88 TD 4,600' |
| Meridian Oil, Inc.; 23-35 BN | 2,000' FWL, 1,800' FSL, Sec. 35, T. 17 N., R. 20 E., Kittitas County | 2,840' | 13,000' | 12-16-88 | P&A 5-4-89 TD 12,584' |
| Meridian Oil, Inc.; 42-14 State | 1,750' FNL, 650' FEL, Sec. 14, T. 13 N., R. 6 E., Lewis County | 2,950' | 6,000' | | |

P&A, plugged and abandoned; TD, total depth

# Knob Hill No. 2 Shaft at the Republic Unit Produces 2 Millionth Ounce of Gold

By Raymond Lasmanis

On June 24, 1989, Hecla Mining Company, operator of the Republic Unit, celebrated the production of 2 million ounces of gold from a single shaft. This milestone was achieved by the Knob Hill No. 2 shaft on May 24, 1989. Only six other shafts in the United States have that distinction. Dignitaries, invited guests, Hecla employees, and townspeople helped mark the event with speeches, surface tours of the mine, and a barbecue. More than 350 people attended the celebration.

The history of the Knob Hill mine can be traced to February 21, 1896, when the northern portion of the Colville Indian Reservation was opened to mineral entry. The mineralized outcrops were known prior to that date, so L. H. Long, C. P. Robbins, and James Clark of Spokane were able to grubstake a team of prospectors (Philip Creaser and Thomas Ryan) to stake claims in the area. Within two weeks all the important future producers were staked, including Knob Hill. James Clark and his brother Patrick visited the new district and provided initial development capital. Within a few years three mills had been built, and by 1903 the camp was served by two railroads.

The first recorded production from the Knob Hill claim was in 1904 when a pocket of rich direct shipping surface ore was mined. By June 1910 Knob Hill Co. leased the property and the adjacent


Cheryl Stewart with a representation of the volume of 2 million ounces of gold. A cube of gold this size would weigh 68.57 tons or 137,143 pounds.

Mud Lake claim from Oregon Senator Jonathan Bourne. Knob Hill started production in earnest on August 1, 1910, and the property has experienced continuous production to this day except for the period 1927 through 1929 and in 1936. From August 1, 1910, to January 1, 1912, the Knob Hill claim produced 7,142 tons of ore, from which was recovered 10,850 ounces of gold and 31,914 ounces of silver. By 1914 there were 700 feet of

The Knob Hill No. 2 shaft in 1976.


U.S. Senator Slade Gorton addressing guests. Other dignitaries, from the left, are Ralph Noyes, Vice President of Hecla; State Senator Scott Barr; Ferry County Commissioner Marie Bremner; Republic Mayor Jim Hall, and Joseph Suveg, Republic Unit Manager.

adits on Knob Hill, and to the north, the Mud Lake claim had a 60-foot-deep shaft in which a crosscut showed a 63-foot-thick quartz "vein". Since there was no concentrator on the property, raw ore was shipped to custom mills or smelters.

In the 1930s, a group of California mining men formed Knob Hill Mines, Inc. to exploit large near-surface ore deposits consisting of silicified breccia and stockworks on the north side of Knob Hill and on the Mud Lake claim. They commissioned Western-Knapp Engineering Company of San Francisco to construct a 400-ton-per-day (tpd) cyanide mill on the south slope of Knob Hill. The mill started processing ore on May 10, 1937, and within a year had reached monthly production rates as high as 539 tpd. At that time the mill was the largest in Washing-ton and the most modern in the U.S. Flotation cells were added to the mill in 1940 to expand the design capacity to 500 tpd. The contractor for this work was Western Machinery Co. of Spokane. Start-up of the flotation section was on November 7, 1940.

The Knob Hill mill has been operating for 52 years and achieves recoveries at 95 percent of the gold and 88 percent of the silver. Even during World War II, when the War Production Board shut down all except three of the nation's gold mines by Preference Rating Order P-56 and the Limitation Order L-208, the Knob Hill mine and mill were allowed to operate.

In 1937 initial mill feed came from the Stewart pit on the northeast side of Knob Hill and the adjacent Mud Lake pit. By 1938 the Mountain Lion pit (½ mile northwest of Knob Hill) started shipping ore to the Knob Hill mill, and as the Stewart and Mud Lake pits were depleted, production in 1941 from the Mountain Lion increased to 325 tpd. The Stewart pit eventually produced 499,000 tons of ore averaging 0.11 ounces of gold per ton.

It was recognized in 1938 that surface ore would eventually be depleted, so Knob Hill Mines, Inc. made plans to develop underground ore. A vertical shaft and an adit on the south slope were completed as the Knob Hill No. 1 mine. It eventually produced 81,000 tons of ore. The adit is located behind the present mine office, and the shaft, now backfilled, was situated under the present parking lot.

In 1939 shaft sinking started just south of the Stewart pit for the Knob Hill No. 2 mine. During 1941 the 250-foot-deep shaft was deepened an additional 150 feet. The first recorded production from the Knob Hill No. 2 shaft came in 1941. During 1954, the 8th level was under development, and in 1955 the old headframe was replaced. In 1957, the 9th and 10th levels were developed, and during 1958 the shaft was deepened another 300 feet to establish a new 12th level. This level produced ore from 1958 through 1987.

On February 28, 1978, all operations of Knob Hill Mines, Inc. were acquired by Day Mines. In turn, Hecla Mining Company merged with Day Mines during 1981. Hecla continues to operate the Republic Unit.

The Knob Hill No. 2 shaft is collared at an elevation of 3,129 feet above sea level and consists of three compartments, two used for hoisting ore and one for services. The inclined shaft has a 52.5° dip to 950 feet, where it steepens to 65° for a total depth of 2,072 feet (14th level). The bottom of the shaft is at 1,355 feet above sea level. The entire shaft is lined with 414 sets of timbers and has a total of 13 working levels. Hoisting of ore takes place with counterbalanced 2½-ton skips, and it takes 7 minutes (at 750 feet per minute) for a round trip from the main 1100 haulage level. To produce 2 million ounces of gold, more than 3 million trips had to be made up and down the shaft.

Twice during the history of the Knob Hill No. 2 mine, closure was imminent. In 1978 the mine was

Guests lining up for food and refreshments. The assay office and Bailey shaft are in the background.

Republic Unit concentrator. Built in 1937, the mill combines flotation and cyanidation methods to recover precious metals from the ore.

within one day of shutting down, when new reserves were located. And then again in 1983, as the ore reserves were dwindling, Hecla announced closure within 6 months. However, in the interim, the Bailey vein was discovered, and that extended the mine life an additional two years. During 1984 recognition of geologic controls and an aggressive exploration program outlined the large and rich Golden Promise vein system southeast of Knob Hill.

The new vein system was first accessed from the Knob Hill No. 2 shaft by a 7,000-foot crosscut driven on the 1100 level. The Golden Promise shaft was then developed by drilling a vertical pilot hole from the surface to a depth of 1,300 feet to intersect the crosscut; this was followed by upreaming to a finished 7-foot diameter on November 30, 1986. The Golden Promise portion of the Republic Unit was dedicated in January of 1987.

The Golden Promise shaft provides access for miners and for lowering supplies. All ore from the Golden Promise veins is trammed on the 1100-level drift to the Knob Hill No. 2 shaft and hoisted to the surface.

Under Knob Hill, veins which contributed ore to the 2-million-ounce record for the Knob Hill No. 2 shaft are: Stewart, South Cross, Knob Hill No. 3, Knob Hill No. 5, Alpine, and the Bailey. Since 1986, ore hoisted from the Knob Hill No. 2 shaft has come from the Golden Promise No. 2 vein (80% of the total) with smaller amounts from the Golden Promise Nos. 1, 4 and 6. During 1988, milling of 79,210 tons produced 80,301 ounces of gold and 354,077 ounces of silver at a cost of $94 per ounce of gold produced.

Through 1987, the Republic District in Ferry County has produced 4.4 million short tons of ore with an average grade of 0.577 ounce of gold per ton and 3.23 ounces of silver per ton.

Diluted, in place, proven and probable reserves (in short tons) for Hecla's Republic Unit for 1989 stand at:

| | |
|---|---|
| Golden Promise No. 2 vein | — 400,490 |
| Golden Promise No. 1 vein | — 52,336 |
| Knob Hill | — 39,844 |
| Minor veins | — 33,982 |
| Total | 526,652 |

The average grade is given at 0.80 ounce of gold per ton and 1.87 ounces of silver per ton. There is an additional indicated 1.2 million short tons of ore with an approximate grade of 0.50 ounce of gold per ton of ore.

The success of the Knob Hill No. 2 mine is a tribute to the operators, geologists, miners, and the community of Republic. The new Golden Promise vein system will make it possible for the mine to set new production records in future years.

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# Geothermal Resource Exploration Target Area Defined by Division Drilling Projects

By Michael Korosec and D. Brent Barnett

The Cascade Range of southern Washington, with its numerous Quaternary volcanic centers, tectonic setting, complex structure, easy access, and relatively favorable land ownership (outside of the parks and wilderness areas), represents Washington's best province for the exploration of high-temperature geothermal resources. Through a federal-state assessment program, the Washington Department of Natural Resources, Division of Geology and Earth Resources has conducted preliminary surveys of this Cascade province.

During the late summer and early fall of 1988, DGER completed drilling eight shallow geothermal gradient test wells in the southern Washington Cascade Range. The 1988 project was the sixth of its kind undertaken by DGER since 1975. Most of the funding for the 1988 and four of the earlier projects was provided by the U.S. Department of Energy, with subordinate cost sharing by the State of Washington. Forty-five holes have been drilled since 1975.

In the previous issue of the Washington Geologic Newsletter, preliminary results of the 1988 Geothermal Drilling Project were described. Final temperature gradient information is presented in Table 1, and preliminary heat flow values are given in Table 2. Terrain corrections have not been applied to the data. DGER Open File Report 89-2 (Barnett and Korosec, 1989a) has recently been released; it presents further details of the drilling operations, observations, and results. In addition, a summation of this and past geothermal drilling projects was presented at the Cordilleran Section meeting of the Geological Society of America in Spokane, May 9, 1989 (Barnett and Korosec, 1989b).

**Table 1**. Data summary for 1988 drill holes

| Hole name | Location | Date completed | Date of last temperature logging | Total depth (meters) | Gradient (°C/km)* / Interval of measurement (meters) | Bottom-hole temperature (°C) |
|---|---|---|---|---|---|---|
| Carlton Creek (DNR 88-1) | T.14N.,R.10E. sec. 11, AAC | 9-16-88 | 11-9-88 | 152.2 | 51.7 / 25.0-152.2 | 13.4 |
| Snyder Mountain (DNR 88-2) | T.13N.,R.9E. sec. 24, ADD | 9-27-88 | 9-30-88 | 152.4 | ** | 4.5 |
| Chambers Creek (DNR 88-3) | T.11N.,R.10E. sec. 35, BCD | 10-4-88 | 11-9-88 | 152.3 | 58.9 / 45.0-152.3 | 13.3 |
| Table Mountain (DNR 88-4) | T.9N.,R.9E. sec. 5, ADC | 10-11-88 | 11-9-88 | 152.3 | 56.9 / 35.0-152.3 | 12.8 |
| Babyshoe Ridge (DNR 88-5) | T.9N.,R.10E. sec.18, BCD | 10-18-88 | 10-24-88 | 152.6 | ** | 5.1 |
| Pin Creek (DNR 88-6) | T.9N.,R.9E. sec. 34, ADD | 10-25-88 | 11-9-88 | 152.5 | 49.7 / 35.0-152.5 | 11.8 |
| Quartz Creek (DNR 88-7) | T.8N.,R.8E. sec. 8, BBC | 10-31-88 | 11-9-88 | 152.5 | 31.2 / 30.0-152.5; 35.1 / 100.00-152.5 | 10.1 |
| Shingle Mountain (DNR 88-8) | T.4N.,R.9E. sec. 27, CBB | 11-8-88 | 11-17-88 | 152.6 | 35.3 / 55.0-152.6 | 12.9 |

*Derived from best-fit line of linear regression analysis

**Disturbed gradient or isothermal

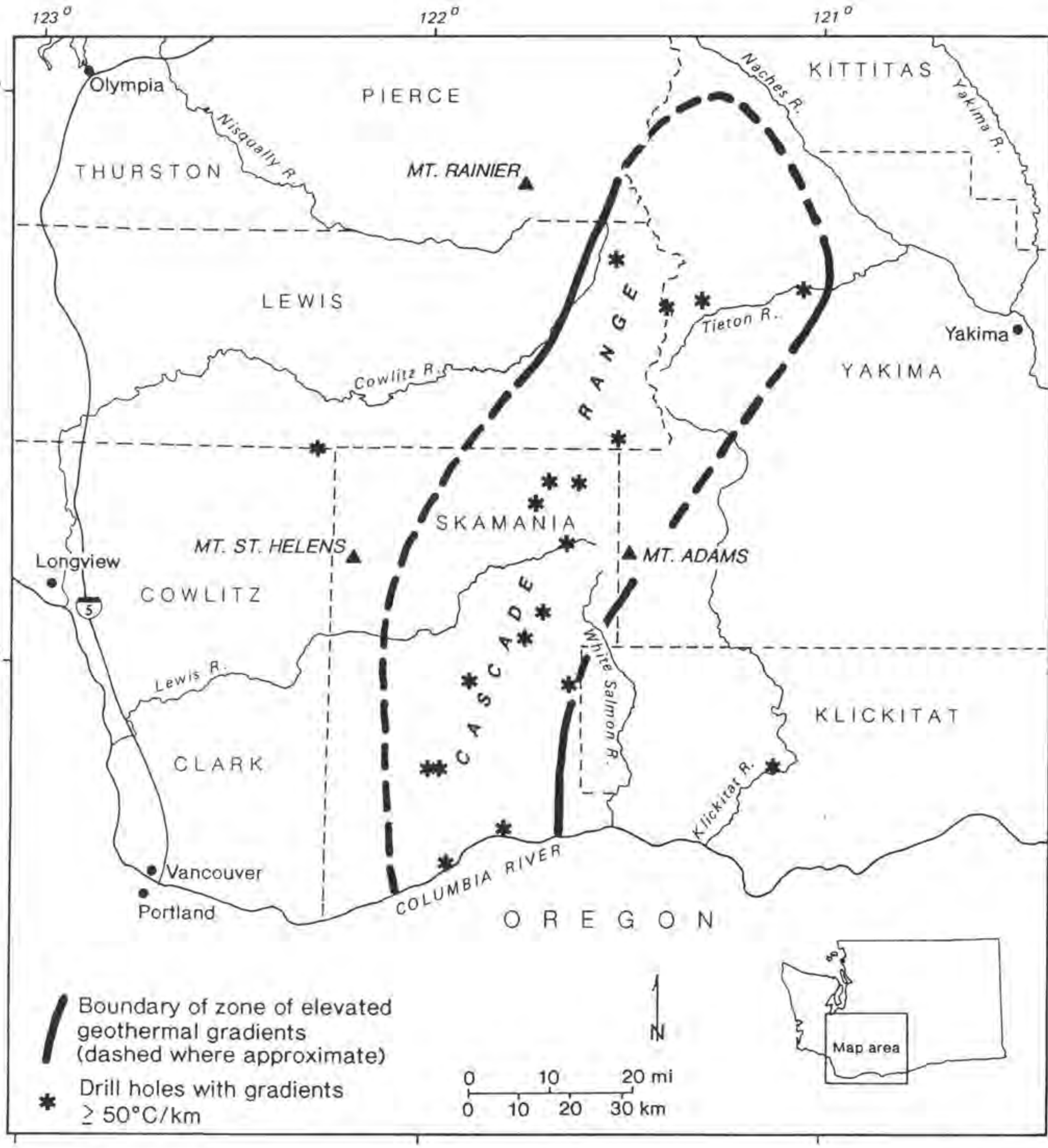


**Figure 1**. Zone of high temperature gradients in the southern Washington Cascade Range. Also shown are the locations of drill holes with gradients of 50°C/km or greater.

From the past and latest projects, we believe we have identified a large zone of high temperature gradients and high heat flow which can serve as a primary target of future explorations for high-temperature geothermal energy resources. When the best 1988 results are plotted with results from past projects, a concentration of gradients in excess of 50°C/km forms a north-northeast-trending zone through the southern Washington Cascade Range (Fig. 1), extending from the Columbia River north nearly to the Naches River.

Within this zone, most temperature gradients range from 50° to 60°C/km, and five holes have produced gradients of 70° to 90°C/km. Most of the heat flow values from the zone range from 80 to 120

**Table 2.** Calculated heat flow values

| Hole | Gradient (°C/km) | Thermal conductivity harmonic mean (W/m°C) | Porosity-corrected thermal conductivity (W/m°C) | Calculated heat flow (mW/m²) |
|---|---|---|---|---|
| Carlton Creek (DNR 88-1) | 52 | 3.08 | 2.8-3.01 | 146-156 |
| Chambers Creek (DNR 88-3) | 58 | 2.60 | 2.2-2.5 | 127-145 |
| Table Mountain (DNR 88-4) | 57 | 1.46 | 1.3-1.4 | 74-80 |
| Pin Creek (DNR 88-6) | 50 | 1.70 | 1.5-1.7 | 75-85 |
| Quartz Creek (DNR 88-7) | 31 | 2.25 | 1.9-2.2 | 59-68 |
| Shingle Mountain (DNR 88-8) | 35 | 1.60 | 1.4-1.5 | 49-52 |

milliWatts per square meter ($mW/m^2$) with several values between 120 and 160 $mW/m^2$. Average gradients outside of the zone are typically 35° to 45°C/km, with heat flow values of 40 to 55 $mW/m^2$.

Many of the known hydrothermal systems within this zone are indicated by the occurrence of thermal and mineral springs. These hydrothermal systems are, in part, responsible for several of the high gradients. However, many of the highest gradients, those ranging from 70° to 90°C/km, have been measured in areas with no surface hydrothermal manifestations. The nature and extent of these geothermal systems are not known, but they are strongly suspected to be related to (a) the active volcanic arc, (b) plutonism associated with the volcanic arc, and (c) hydrothermal systems controlled by the plutonism and regional structure. Most of the Quaternary volcanic centers of the Cascade Range of Washington occur within the zone.

Large areas of the Cascade Range, both within and outside of the projected high-gradient area, have not yet been tested by shallow drilling. Future test drilling of these areas will be necessary to refine the areal bounds of this zone, and significant understanding of the nature and potential of this geothermal resource will come about with deeper drilling.

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## Minerals (continued from Page 2)

The panel's predictions concerning copper have not been realized. The speakers noted (Banker and Showalter, 1935, p. 18), "Given another few years of development, we're going to be another Montana." It was felt that the future looked particularly good because "there is no substitute known for copper." The Tacoma smelter was going to be the keystone to a great copper mining industry in Washington.

Echoing these predictions, the status of Washington's—as well as the nation's—copper industry was described by the U.S. Bureau of Mines (1936, p. 125) in these hopeful terms:

> "United States imports and exports of copper constitute a well-balanced trade through which the smelting, refining, and manufacturing facilities of this country are used to treat foreign raw materials and to return refined copper and manufactures of copper abroad."

In 1935 the U.S. imported 233,264 metric tons of copper, of which 14.7 percent consisted of raw ore and mineral concentrates. Our refineries and smelters, including the Tacoma smelter, were producing finished products that were then exported. In 1935 exports totalled 274,706 metric tons of copper, of which 97.5 percent consisted of pipe, wire, bars, and other refined products. Our exports exceeded our imports.

By 1987, the domestic copper industry had become a net importer. Not only that, but 99.6 percent of the imports (535,574 metric tons) consisted of refined copper products. Of the 370,066 metric tons of copper exported by the U.S. in 1987, 35.3 percent consisted of raw ore and concentrates. In contrast, when the 1935 radio interview was conducted, only 2.5 percent of the total copper exports consisted of raw ores or concentrates. This comparison clearly shows that the U.S. has switched from being a producer of finished metal products to being an exporter of raw materials.

Washington did not become a major copper-producing state. Currently, no copper is produced in the state, and with the closure of the Tacoma smelter in March 1985, we no longer have a role to play in the copper industry. It is interesting to note that in 1935 the strongest market was for copper wire. This market is now being eroded by fibre optics and miniaturization technologies.

Although the base metal mining industry is currently depressed in comparison with its condition in 1935, the mining of precious metals, particularly gold and silver, is at record levels for Washington. In 1935, the state produced 9,682 ounces of gold and 52,320 ounces of silver. In 1988, more than 225,000 ounces of gold and 540,000 ounces of silver came out of Chelan and Ferry Counties (Joseph, 1989).

The panel was correct in stating that Stevens County contains important magnesium deposits. During 1988, Aluminum Company of America mined 760,000 tons of dolomite from their Addy property and had the ability to produce from 15 to 25 percent of the world plant capacity for magnesium metal production (Joseph, 1989).

Dean Roberts spoke about the utilization of Washington mineral resources. He mentioned that the Tacoma smelter had a plant for roasting arsenical ores to produce white arsenic for commercial uses. He also noted (Banker and Showalter, 1936, p. 27): "Arsenic combined with lead in the form of arsenate of lead is the material used to spray the millions of apple trees in Washington to kill the worms from the coddling moth." The panel of experts did not anticipate the environmental and health movements that have swept the nation since the publication of Rachel Carson's book, *Silent Spring*.

The radio script is nothing but optimistic about Washington's position in mineral industries. We have come a long way since 1935, and only some of those hopes have been realized. Some sectors of our mineral industry are healthy, and some have faded into history. With the changes in mineral use being brought about by new technologies and the political influences on raw material availability, it's probably safe to predict that the next 55 years will see changes as great as those I have touched on.

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## Staff Notes

**Nancy Eberle** is the Division's new lead cartographer. Her promotion to Cartographer 3, a new position, was effective July 10. Nancy, who earned her B.A. degree in geology from the University of California at Davis, came to the Olympia area in 1971 and has worked in DGER cartography since January 1981 as Nancy Eberle Herman. **Don Hiller**, a former member of the Division's cartographic staff, joined the Cartographic Unit of the DNR Engineering Division in Olympia as Cartographer 3 in January.

**David Norman** has been hired as the Regional Geologist for the Department's Central and Southwest Region offices. Dave will work out of Castle Rock. His responsibilities include administration of the Surface Mined Land Reclamation Act, assistance with the Timber, Fish, and Wildlife accord, and general geological research. He received a Bachelor of Earth Science degree in 1981 from Portland State University and a Master of Science degree in Geology from the University of Utah in 1983. Formerly, Dave was employed as manager of the Geosciences Group for Corelabs, Inc., in Calgary; as an exploration geologist with Union Oil Company; and as a geologist with Amoco Minerals in Denver. He has published on fractured reservoirs and the petrophysics of glauconite.

# 1989 Geological Projects, Washington Colleges and Universities

The following list is taken from material submitted, as of press time, by the geology departments of the state's colleges and universities. Names in parentheses with the faculty projects are student collaborators. Some projects involve areas outside Washington.

### University of Washington, Geophysics Program

#### *Faculty Projects*

Experimental and theoretical mineral and rock physics—*J. Michael Brown*

Seismology and geophysical inverse theory—*Kenneth C. Creager*

Seismology, structure and tectonics, earthquake hazards—*Robert S. Crosson*

Processes of lithosphere generation and consumption using seismology, gravity, and magnetics—*Brian T. R. Lewis*

Seismicity of Mount St. Helens, the Cascade volcanoes, and eastern Washington; computer applications in seismic network analysis—*Stephen D. Malone*

Geomagnetism, geophysics of solids, rock magnetism—*Ronald T. Merrill*

Earthquakes associated with volcanoes and glaciers, earth structure, and earthquake hazards—*Anthony Qamar*

Fluid dynamics, sediment transport mechanics, estuarine and coastal oceanography—*J. Dungan Smith*

Seismology, earthquake risk, seismotectonics—*Stewart W. Smith*

High-pressure experiments in geophysics, physics and chemistry of minerals—*Yosiko Sato Sorensen*

### University of Washington, Washington Mining and Mineral Resources Institute

Limestone derived CaO metallurgical refractories—*R. C. Bradt*

Effects of coal composition and minerals content in coal gasification and pyrolysis—*Barbara Krieger-Brockett*

Evolution of ore fluids in the Colville igneous complex, north-central Washington—*Bruce Nelson*

The distribution and behavior of cesium in rocks associated with gold, silver, molybdenum, and uranium deposits from northeastern Washington—*Mohammed Ikramuddin*

### Washington State University

#### *Faculty Projects*

Determination of crustal fractures in northeastern Washington using Geologic Spatial Analysis and their correlation to mineralization sites—*R. L. Thiessen*

Geologic and geohydrologic site characterization studies, Hanford site, Washington—*D. R. Gaylord*

Geophysical investigations of the cratonic margin in the Pacific Northwest—*R. L. Thiessen (G. B. Mohl)*

Regional stratigraphy and sedimentology of the upper Sanpoil Volcanics and Klondike Mountain Formation in the Republic, First Thought, and Toroda Creek grabens, Washington and southern British Columbia—*D. R. Gaylord (J. D. Suydam)*

Sedimentology and stratigraphy of upper Sanpoil Volcanics and the Klondike Mountain Formation, Republic Mining District—*D. R. Gaylord (S. M. Price)*

Structural analysis of the central Columbia Plateau utilizing radar, Landsat, digital topography, and magnetic data bases—*R. L. Thiessen*

A three-dimensional computer analysis of modelling system for remote sensing-structural geologic problems—*J. R. Eliason*

Application of Geologic Spatial Analysis to gas exploration in West Virginia—*D. E. Beaver (at Battelle Pacific Northwest Laboratory, working in conjunction with WSU faculty)*

Refold geometrics observed in the Loch Monar region, Scotland—*A. J. Watkinson*

#### *Student Projects*

Gold skarn mineralization at the Buckhorn Prospect, Okanogan County, Washington—*Robert Hickey*

Gravity studies of an island arc-continental suture in west-central Idaho and adjacent Washington—*G. B. Mohl*

Correlation of fractures observed using a televiewer in the Cajon Pass DOSSEC drill hole with ones determined from Geologic Spatial Analysis applied to topographic data bases—*Mark Ader*

Determination of the three-dimensional orientation and location of faults using earthquake foci—*E. R. Rieken*

Distribution of gold in skarns of the Phoenix-Greenwood district, British Columbia—*David Still*

Geologic analysis of a portion of the Weatherbee Formation, northeastern Oregon—*Rebecca Myers*

Geology and geochemistry of gold skarn mineralization in the McCoy mining district, Lander County, Nevada—*Jeff Brooks*

Geology of the Tillicum gold skarn camp, British Columbia—*Dean Peterson*

Gold mineralization in skarn and carbonate replacement bodies, New World mining district, Park County, Montana—*Todd Johnson*

Gold skarn mineralization in the Fortitude deposit, Lander County, Nevada—*Greg Myers*

Gold-enriched skarns of British Columbia with emphasis on the Hedley district—*Art Ettlinger*

Refold geometrics at the Richmond Hill Mine, northern Black Hills, South Dakota—*Erik Weberg*

Regional gravity modelling of the northern Black Hills, South Dakota—*Erik Weberg*

Sediment-hosted base metal mineralization in the Atlas Mine, Coeur d'Alene District, Idaho—*Brion Theriault*

Structural analysis of the West Idaho suture zone in the Salmon River gorge, Riggins region, west-central Idaho—*D. E. Blake*

### Grays Harbor College

#### *Faculty Projects*

Seismic stratigraphy of the Holocene sediments in Grays Harbor—*James B. Phipps*

Holocene sea level rise at Grays Harbor—*James B. Phipps*

### Eastern Washington University

#### *Faculty Projects*

Mineralogy of the Golden Horn batholith, North Cascades—*Russell C. Boggs*

Structural states of feldspars as an indicator of sedimentary provenance—*Russell C. Boggs*

Mineralogy of the Sawtooth batholith, Idaho—*Russell C. Boggs*

Geomorphic mapping of Chamokane Creek to evaluate the potential for enhancing fish habitat—*John P. Buchanan*

Geomorphic study of Cee Cee Ah Creek, Pend Oreille County, Washington—*John P. Buchanan*

Hydrogeology of Deer Lake, Stevens County, Washington—*John P. Buchanan*

Radon gas distribution in cave systems in the Pacific Northwest—*John P. Buchanan*

Mineral inventory of Jewel Cave, Black Hills, South Dakota—*John P. Buchanan*

Permian bryozoans of the carbonate units of the Mission Argillite, northeastern Washington—*Ernest H. Gilmour*

Biostratigraphic studies of Pennsylvanian and Permian bryozoans in North America and Pakistan—*Ernest H. Gilmour*

Carbonate petrology and paleoecology of the Antler Peak Limestone, northeastern Nevada—*Ernest H. Gilmour*

Rare earth element geochemistry of gold deposits—*Mohammed Ikramuddin*

Distribution of immobile trace elements in hydrothermally altered rocks associated with various types of gold deposits—*Mohammed Ikramuddin*

Thallium – a potential guide to mineral deposits—*Mohammed Ikramuddin*

Geochemistry of sediment-hosted precious metals deposits—*Mohammed Ikramuddin*

Development of new analytical methods by inductively coupled argon plasma and electrothermal atomic absorption—*Mohammed Ikramuddin*

Chemical composition of sediments from archaeological sites in central Washington—*Mohammed Ikramuddin*

Geochemistry of granitic rocks of northeastern Washington—*Mohammed Ikramuddin*

Hydrogeochemical and biogeochemical methods of exploration for gold and silver—*Mohammed Ikramuddin*

Geochemistry of platinum group elements—*Mohammed Ikramuddin*

Geochemistry of volcanic rocks and its relationship to gold-silver mineralization—*Mohammed Ikramuddin*

Use of cesium as a guide to mineral deposits—*Mohammed Ikramuddin*

The use of boron in gold exploration—*Mohammed Ikramuddin*

Reconnaissance lithogeochemical survey of Northwest Pakistan—*Mohammed Ikramuddin*

Study of toxic elements in environmental samples—*Mohammed Ikramuddin*

Chemical analysis of ultrapure electronic materials—*Mohammed Ikramuddin*

Glacial and catastrophic flood history of eastern Washington—*Eugene P. Kiver*

Quaternary map of northeastern Washington east of the Okanogan River—*Eugene P. Kiver*

Geology of national parks—*Eugene P. Kiver*

Structure and stratigraphy of the Middle Paleozoic Antler orogen in northwestern Nevada—*Linda B. McCollum*

Stratigraphy, sedimentology, and paleontology of the Cambrian System of the Great Basin—*Linda B. McCollum*

Paleozoic continental margin sedimentation in western U.S.—*Linda B. McCollum*

Transcurrent faulting and suspect terranes in the Great Basin—*Linda B. McCollum*

Alkaline igneous rocks and related precious metal deposits—*Felix E. Mutschler*

Compilation of computer data base of whole-rock chemical analyses of igneous rocks—*Felix E. Mutschler*

Laramide and younger tectonics and magmatism in the eastern Rocky Mountains—*Felix E. Mutschler*

Styolites in igneous rocks—*James R. Snook*

Geologic map of the Inchelium quadrangle, Washington—*James R. Snook*

Petrology of the Quartz Hill molybdenum deposit, Alaska—*James R. Snook*

Paleomagnetic investigation of glacial Lake Missoula flood deposits—*William K. Steele*

Use of remanent magnetization direction to correlate airfall ash deposits from Cascade volcanoes—*William K. Steele*

Mechanism of acquisition of remanent magnetization by airfall ash—*William K. Steele*

***Student Projects***

Gold deposits associated with alkaline igneous rocks; Selected trace element geochemistry—*Robbin W. Finch*

Biostratigraphy and lithostratigraphy of the late Devonian-early Mississippian Pilot Shale of eastern Nevada and western Utah—*Mark E. Jones*

The petrology and paleoecology of the Toroweap Formation, southeastern Nevada—*Laleh Mansoury*

FERROS – a computerized data base for Precambrian auriferous banded iron-formation and related rocks—*Glen R. Carter*

Gold deposits in the alkaline rock igneous centers of Colorado—*Daniel W. Fears*

Vertical geochemical variations in granodiorite associated with the molybdenum-copper porphyry deposit at Mount Tolman, Ferry County, Washington—*Danelle D. Elder*

Biogeochemical methods of exploration for Archean gold deposits—*Richard B. Lestina*

Geology of the McCullough Creek area, Douglas County, Oregon—*Allen V. Ambrose*

Bryozoan biostratigraphy of the Phosphoria Formation, southeastern Idaho—*Robert C. Walker*

Sedimentation and mineralogical composition of the Latah Formation (Miocene), eastern Washington—*John D. Robinson*

Geochemistry of igneous rocks from Newport and adjacent areas, northeastern Washington—*L. Christine Russell*

Upper Cambrian carboniferous section in the Toano Range near Wendover, Nevada—*Joseph Drumheller*

Depositional setting of quartzite beds in the middle part of the Precambrian Prichard Formation, Coeur d'Alene mining district, Idaho—*Eugene N. J. St. Godard*

Microfacies study of the Antler Peak limestone, northern Nevada—*D. Chad Johnson*

Saturated zone chemistry down-gradient from mine tailings ponds near Twisp, Washington—*Robert H. Lambeth*

Hillslope recharge to the Spokane aquifer system, Washington—*Tammy L. Hall*

The behavior of immobile elements in volcanic-hosted epithermal gold deposits—*Jianzhong Fan*

Abundance and behavior of cesium and selected trace elements in rock, soil, and water samples from the Republic area northeast Washington—*Wilfred H. Little*

Abundance of Pd and Pt in selected gold deposits from western United States—*Mohammad Zafar*

Rare earth element geochemistry of granite and volcanic rocks from northeastern Pakistan—*Ghulam M. Abbasi*

Granite molybdenite systems—North American cordillera—*Curtis A. Hughes*

Groundwater chemistry down-gradient from a uranium mill tailings pond—*Ronald A. Stone*

Origin and mineralization of Colorado Plateau uranium-copper-bearing breccia pipes—*J. Michael Faurote*

Fluvial geomorphology of Chamokane Creek, Washington—*Daniel J. Howard*

Water budget analysis of the Deer Lake basin, Stevens County, Washington—*Bruce L. Siegmund*

Reconnaissance lithogeochemical survey of Chitral area, northwestern Pakistan—*Abdul G. Afridi*

Mineralogy and geology of tungsten, molybdenum vein systems in northeastern Washington—*Dean G. Heitt*

### Central Washington University

***Faculty Project***

Omineca crystalline belt to western Basin and Range geoscience transect—*S. E. Farkas (R. R. Owens, J. L. Thompson)*

### Pacific Lutheran University

***Faculty Projects***

Stratigraphy, sedimentation, and palynology of the Pleistocene deposits in the Kalaloch area, Olympic National Park—*Steven R. Benham*

Zeolite mineralization at Kitsap quarry, Kitsap County, Washington—*Steven R. Benham*

# Selected Additions to the Division of Geology and Earth Resources Library

## April 1989 through June 30, 1989

### THESES

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Carlin, Rachel Ann, 1988, A geochemical study of the Eagle Creek Formation in the Columbia River Gorge, Oregon: Portland State University Master of Science thesis, 90 p., 1 plate.

Clark, K. P., 1989, The stratigraphy and geochemistry of the Crescent Formation basalts and the bedrock geology of associated igneous rocks near Bremerton, Washing-

ton: Western Washington University Master of Science thesis, 171 p., 1 plate.

Criswell, C. W., 1986, Chronology and pyroclastic stratigraphy of the May 18, 1980 eruption of Mount Saint Helens, Washington: University of New Mexico Master of Science thesis, 76 p.

Davis, Steven Allen, 1988, An analysis of the eastern margin of the Portland Basin using gravity surveys: Portland State University Master of Science thesis, 147 p.

Einarsen, J. M., 1987, The petrography and tectonic significance of the Blue Mountain unit, Olympic Peninsula, Washington: Western Washington University Master of Science thesis, 175 p.

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Hickson, Cathie J., 1981, Vector analysis of grain orientation in the May 18, 1980 'lateral blast' deposits at Mount St. Helens, with implications for the mechanism of flow: University of British Columbia Bachelor of Science thesis, 99 p.

Hoover, K. A., 1987, Holocene paleohydrology and paleohydraulics of the Okanogan River, Washington: University of Washington Master of Science thesis, 128 p.

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Scheidt, R. C., 1975, Relation between natural radioactivity in sediment and potential heavy mineral enrichment on the Washington continental shelf: Oregon State University Master of Science thesis, 64 p.

Wade, W. M., 1988, Geology of the northern part of the Cooper Mountain batholith, north-central Cascades, Washington: San Jose State University Master of Science thesis, 88 p., 1 plate.

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Ficklin, W. H.; Frank, D. G.; Briggs, P. K.; Tucker, R. E., 1989, Analytical results for water, soil, and rocks collected near Granite Falls, Washington, as part of an arsenic-in-groundwater study: U.S. Geological Survey Open-File Report 89-148, 9 p.

Hammond, S. E., 1989, Comparison of sediment transport formulas and computation of sediment discharges for the North Fork Toutle and Toutle Rivers, near Mount St. Helens, Washington – A preliminary report: U.S. Geological Survey Open-File Report 88-463, 18 p.

Muffler, L. J. P.; Weaver, C. S.; Blackwell, D. D., editors, 1989, Proceedings of workshop XLIV – Geological, geophysical, and tectonic setting of the Cascade Range: U.S. Geological Survey Open-File Report 89-178, 706 p.

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## WASHINGTON STATE AGENCIES

Juul, S. T. J., 1989, A study of the water quality of Curlew Lake, Washington [supplement]: Washington Water Research Center Report 70, Supplement, 13 p.

Kasperson, R. E.; Golding, Dominic; Tuler, Seth, 1989, Toward a conceptual framework for guiding future OCS research – Workshop report, Port Ludlow, Washington, 10-12 January 1989: University of Washington, Washington Sea Grant Program, Washington State and Offshore Oil and Gas, 38 p.

University of Washington Geophysics Program, 1989, Quarterly network report 89-A on seismicity of Washington and northern Oregon, January 1 through March 31, 1989: University of Washington Geophysics Program, 22 p.

## OTHER REPORTS OF INTEREST

Chambers, Frank, compiler, 1988, Hayden and his men – Being a selection of 108 photographs by William Henry Jackson of the United States Geological and Geographical Survey of the Territories for the years 1870-1878, Ferdinand V. Hayden, Geologist in Charge: Francis Paul Geoscience Literature, 120 p.

McClelland, Lindsay; Simkin, Tom; Summers, Marjorie; Nielsen, Elizabeth; Stein, T. C., editors, 1989, Global volcanism 1975-1985 – The first decade of reports from the Smithsonian Institution's Scientific Event Alert Network (SEAN): Prentice Hall, 655 p.

U.S. Bureau of Mines, 1989, Minerals yearbook 1987; Volume I – Metals and minerals: U.S. Bureau of Mines, 990 p.

U.S. Department of Energy, 1989, Draft environmental impact statement – Decommissioning of eight surplus production reactors at the Hanford site, Richland, Washington: U.S. Department of Energy DOE/EIS-0119D, 1 v.

# New Division Releases

**Bulletin 78: Engineering Geology in Washington**, with contents coordinated by Richard W. Galster, chairman of the Centennial Volume Committee of the Washington State Section, Association of Engineering Geologists. This is a publication of 1,234 pages in two volumes prepared as a Washington centennial commemoration project, and includes a series of generic papers relating to engineering geology and its practice in the state. Also included are engineering case histories of more than 100 Washington projects. These are divided into chapters on dams, the Columbia Basin Reclamation Project, nuclear and coal-fired power plants, urban geology, transportation routes, rural development, ground water, waste disposal, coastal and marine engineering geology, and the engineering geology aspects of the 1980 eruptions of Mount St. Helens. The two volumes will be sold as a set at a cost of $27.83 + $2.17 (tax) = $30.00. Add $1 to mail orders for postage and handling.

**Open File Report 89-2: Results of the 1988 Geothermal Gradient Test Drilling Project for the State of Washington**, by D. B. Barnett and Michael A. Korosec. The price is $1.87 + .13 (tax) = $2.00. Add $1 to each order for postage and handling.

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