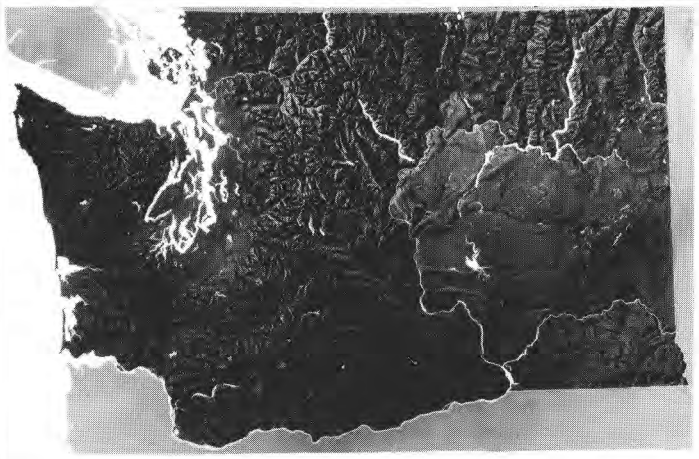
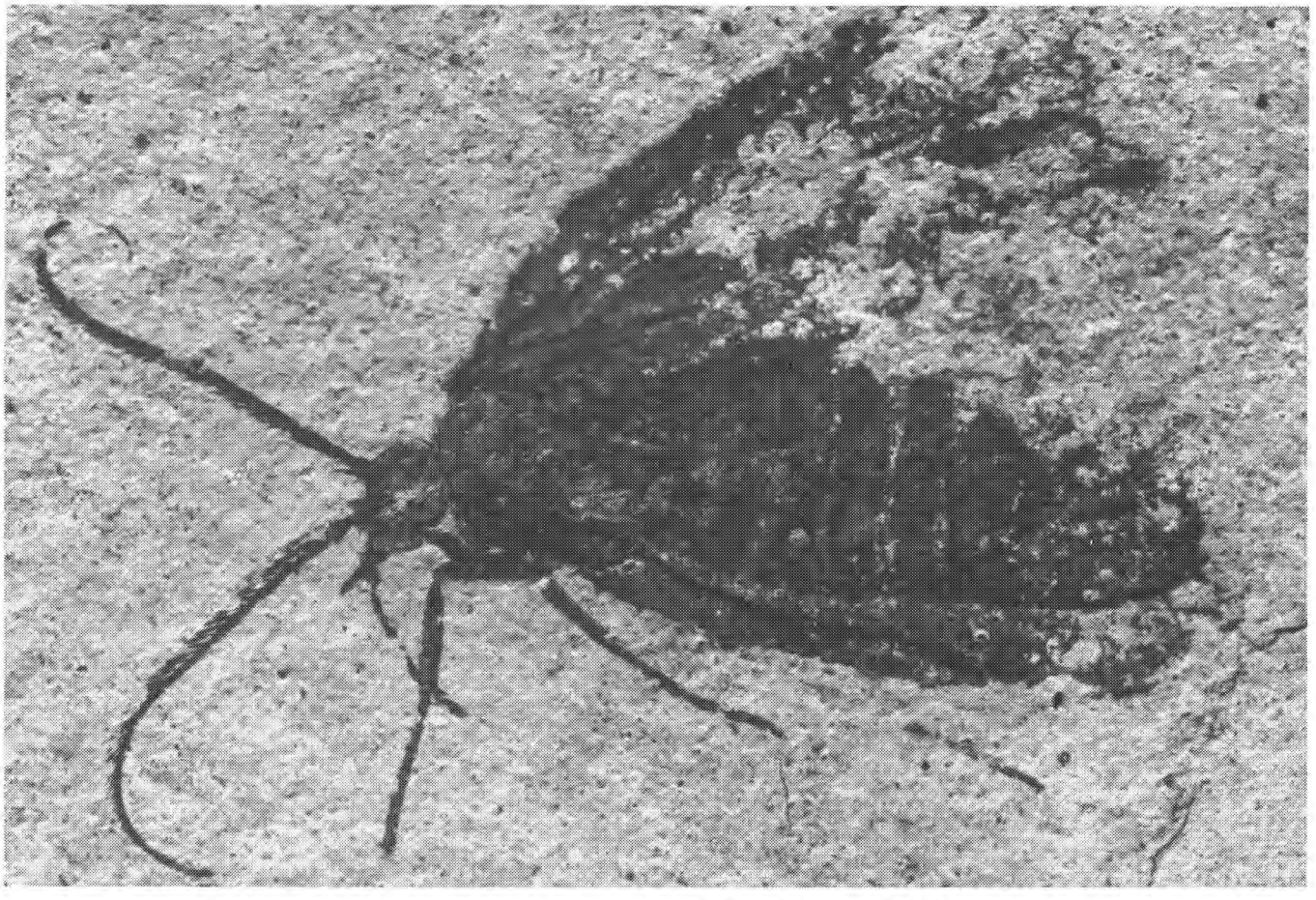


WASHINGTON GEOLOGIC NEWSLETTER

Volume 14 Number 4 October 1986

Washington State Department of Natural Resources

Division of Geology and Earth Resources



A middle Eocene fossil moth from Republic, Washington. This is one of the oldest and most complete specimens found in North America. Original specimen is about 2 cm long.

(Photo by Paul Schwartz)

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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, and geologic maps. A list of these publications will be sent upon request.

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MINERALS IN FRACTURED BASALT-- AN ISSUE

by
Raymond Lasmanis, State Geologist

The Cohassett Flow of the Columbia River Basalt Group has been selected by the U.S. Department of Energy (USDOE) as a potential storage site for the nation's high-level nuclear waste. A recurring issue raised by the public and earth scientists is the highly fractured nature of basalt flows. After all, most of the numerous basalt outcrops throughout eastern Washington are cliffs of basalt below which are large talus slopes of fractured and jointed rock. Some concerns about effects on fracture-filling minerals and the effectiveness of waste containment under the conditions created by the proposed repository were addressed in the Division's response to the USDOE draft Environmental Assessment and are described briefly in the paragraphs that follow.

USDOE claims that at a repository depth of 3,000 feet, the fractures are infilled and healed by minerals, thus effectively sealing adjacent aquifers from the repository. They state in the Environmental Assessment (USDOE, 1986) that fractures at depth in the Cohassett basalt flow are filled with clay minerals (89 percent), zeolites (7 percent), and silica (4 percent). In a USDOE-sponsored report (Ames, 1980), it is noted that sodium-containing nuclear wastes, if escaping from a canister, would come in contact with calcium-bearing nontronite clay, causing an exchange in the nontronite of calcium for sodium. (In nontronite, aluminum can be replaced by magnesium, which, in turn, can

(Continued on p. 11)

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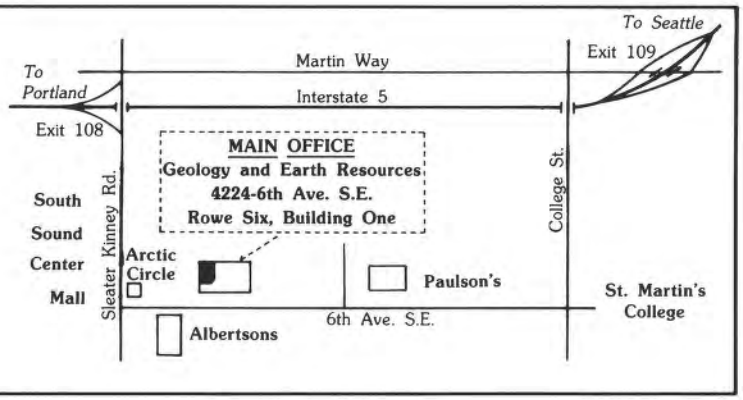

EOCENE FLORA AND FAUNA UNEARTHED AT REPUBLIC

by

Nancy L. Joseph

Gold was not the only treasure being dug from the Earth on October 6 in Republic, home of the State's second largest gold mine. Republic's "Town Dig" ceremony initiated an effort to preserve for educational and scientific studies an impressive diversity of early middle Eocene plant, fish, and insect fossils. A large slab of fossil-bearing rock was cleaned off to symbolize the work ahead.

Although some similar fossils are present in rocks units of the same age elsewhere in northeastern Washington and southern British Columbia, this site is important because it is one of the very few localities from which fossils representing an early middle Eocene upland community have been obtained in North America. Its diverse assemblage will help paleontologists understand the succession of ancestor to descendant forms.

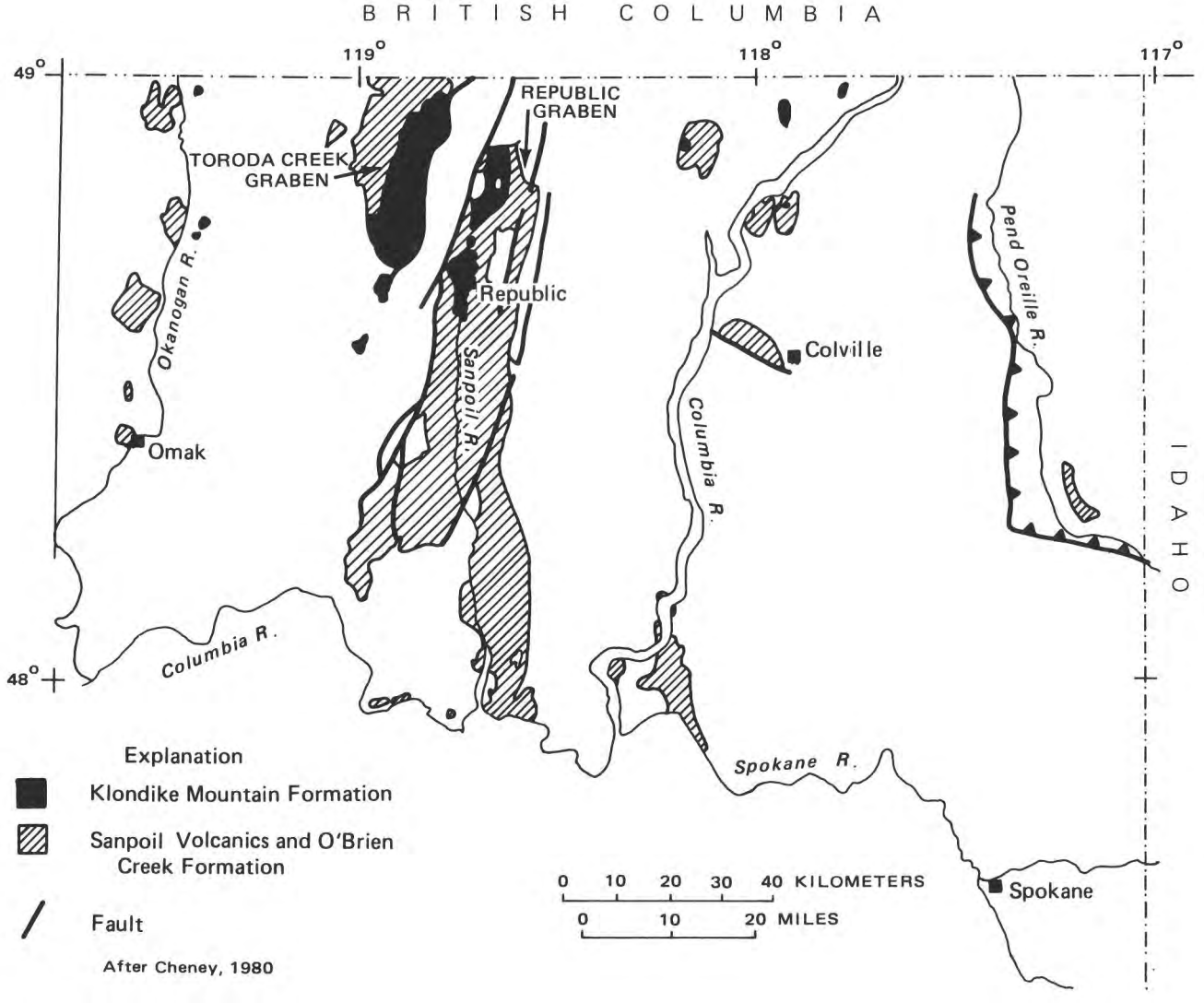

Figure 1. Simplified geologic map of northeastern Washington showing locations of major outcrops of Eocene volcanic, volcaniclastic, and clastic units and selected faults.

The fossils are in the Tom Thumb Tuff Member of the Klondike Mountain Formation, which lies unconformably above the Sanpoil Volcanics. The Klondike Mountain is part of a sequence of Eocene volcanic, volcaniclastic, and clastic rocks that are well preserved in the Republic and Toroda Creek grabens (Fig. 1). Exposures of similar rocks elsewhere throughout northeastern Washington and to the north suggest that these volcanic units were originally more widespread (Pearson and Obradovich, 1977). The Tom Thumb Tuff Member typically has a basal unit of volcanic breccia, conglomerate, and tuff. Above this unit are fossil-bearing tuff beds, which were deposited in a lake environment. An ancient lava flow in the Toroda Creek graben approximately 300 m above a fossiliferous horizon similar to that at the Republic site has yielded a mean K-Ar age of 47 m.y. (Pearson and Obradovich, 1977). This age is consistent with a K-Ar date of 50 m.y. from the underlying Sanpoil Volcanics.

Fossils in the Republic area represent an upland conifer forest and include species of pine and earliest macroscopic records for hemlock, fir, spruce, and Thuja (red cedar). The oldest known fossils of the rose family (Fig. 2) have also been found there.

Insects (cover photo) and fish, such as trout, perch, and suckers, and the earliest record of salmonids were also discovered in the area. Even a crayfish has been found at Republic.

The fossil conifer assemblage suggests that the Republic area had a mean annual temperature of 12-13° C (about 55° F) and a mean annual temperature range of about 5° C (9° F) during the early middle Eocene (Wolfe and Wehr, in press). These conditions are similar to those in the mesic (moderate rainfall) and humid regions of North America, such as along the northern coast of California. Geologic evidence suggests that the altitude of the site was about 900 m, or 2,800 ft.

At the end of the Eocene, a worldwide decline of mean annual temperature led to regional (and for some forms, total) extinction of many woody, broad-leaved evergreen and deciduous species that could not tolerate prolonged winters (Wolfe and Wehr, in press). The distribution of many plant forms was significantly altered by this

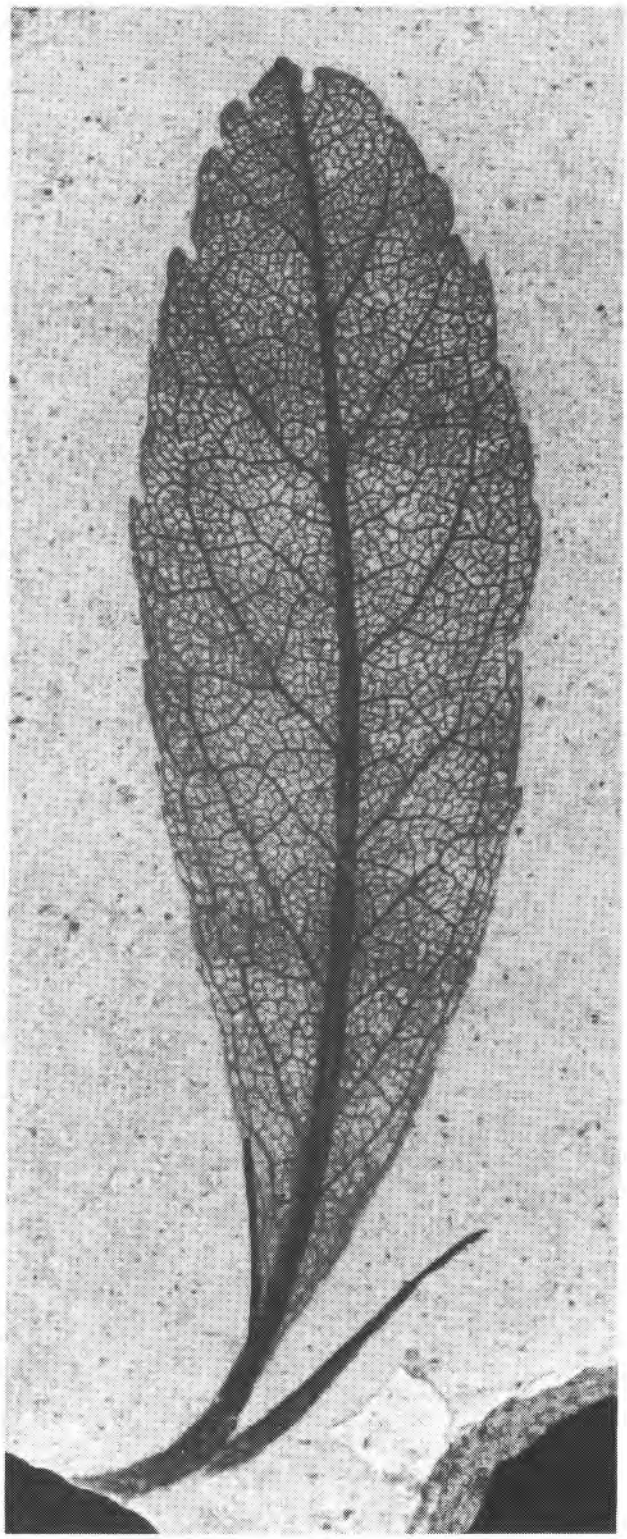

Figure 2. A fossil leaf of an extinct genus of the rose family, ancestral to Spiraea, a modern shrub. Original specimen is about 4.5 cm long. (Photo by Paul Schwartz)

Figure 3. Wesley Wehr, of the Thomas Burke Museum, and Steve Erickson, of Langley, WA, examine fossils at the Republic site.

climatic change. For example, although species of Gingko and Metasequoia are included in the flora at the Republic site and were widespread during the Eocene, only one species of each survives today. The modern forms have natural ranges only in forests in Japan and China. About 40 percent of the genera of flowering plants at Republic are now extinct, but these fossils provide clues to the evolution of many common families.

Wesley Wehr has been collecting fossils (Fig. 3) at the Republic site since 1977. He has been assisted by Kirk Johnson and Michael Spitz. The Thomas Burke Memorial Washington State Museum on the University of Washington's Seattle campus contains the best collection of Republic fossils. Wehr is affiliate curator of paleobotany for the museum. J. A. Wolfe of the U.S. Geological Survey (Denver) and Wehr have named several new genera in honor of the site and local residents.

The fossil beds are near Republic's town hall, at the south end of town. The city first became involved with the site when City Councilman Bert Chadick became aware of Wehr's work and brought the significance of the site to the attention of the council. The city has purchased the site and an adjacent house. The council plans to have the fossil lake bed exposed back 20 to 30 ft into the hill behind it and to build a shelter over the working area. An interpretive center and guides for the site are in planning stages. The house will become a museum to display the fossils.

Following the ceremony, the fossil beds were covered with soil to protect them and the slab until it can be appropriately displayed and to prevent unauthorized fossil collection or vandalism. Work on the site is to resume in the spring of 1987.

Photos and descriptions of many common fossils in the area are in preparation for use in local schools and the interpretive center. Their purpose is twofold: to enable school children to recognize the region's common fossils, and to help identify small evolutionary changes that may assist in taxonomic and eocological studies.

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THE SILICA INDUSTRY IN WASHINGTON

by
Nancy L. Joseph

Silicon (Si) is the second most abundant element in the Earth's crust. Silicon does not occur naturally but is found in nature in its purest form as silica (SiO_2), generally as the mineral quartz (SiO_2). High-purity quartz sands and crystalline quartz are mined for silica.

Silica is an important industrial mineral. The hardness, high melting point, ability to alloy, and the glassmaking properties of quartz make it useful in numerous applications. Most raw silica is used in glass and foundry sands. In addition, silica goes into the manufacture of hundreds of other products, including silicon, fiberglass, paint, and ceramics (Table 1).

Exploration for deposits of both silica sand and coarse silica has been active in Washington for more than 60 years. Silica in the state has been mined from quartzite and sandstone for silica sand, and from quartz veins, pegmatites, and quartzite for lump or coarse silica. Currently, four silica mines are operating in the state (Table 2, Fig. 1).

In evaluating a property's potential as a silica mine, the deposit's size, its chemical purity, markets, end-product use, as well as beneficiation and transportation costs, must be considered. As with most industrial mineral production, suppliers of silica must maintain constant chemical and physical characteristics of their product. Most silica plants maintain a laboratory to control product quality. Depending on the end use of the silica, the ore must be crushed, washed and sized; for some uses the ore must be ground, and its excess iron must be removed.

The following paragraphs discuss some uses of silica and silica deposits in the State of Washington. Figure 1 shows the general locations of silica sources and manufacturers.

Uses of Silica Sand

Glass

Virtually all glass produced in the United States is of three types: container, pressed and blown, and flat (window) glass. Container-glass manufacturers are the largest users of silica sand. Glass is produced by fluxing silica (SiO_2) with soda (Na_2O) and lime (CaO) as stabilizers. Various other oxides, such as alumina (Al_2O_3), may be added to impart the desired properties to the finished products. Silica sand of high purity

Table 1. Selected common uses of silica. Washington manufacturers make only some of these products. Sand sources may have properties suitable for more applications.

Sand		Coarse silica
Flat glass	Asphalt fillers	Silicon
Containers	Decorative rock	Semiconductors
Metal casting (foundry)	Fillers and extenders (paint)	Photovoltaic power
Fiber optics	Portland cement	Silicon carbide
Blasting sand	Flux	Ferrosilicon
Golf course sand	Filtration	Decorative rock
Construction	Hydraulic fracturing	Sand and gravel
Fiberglass	Ceramics	
Abrasive	Silica brick	
Tile	Coal washing	
Roofing granules	Traction sand	
Sand and gravel		

Table 2. Present producers of silica in Washington State (Exclusive of product used for sand and gravel)

Name	Location	Operator	Source (age)
Lane Mountain silica quarry	Valley	Hemphill Brothers	Addy quartzite (Cambrian)
Wenatchee silica sand quarry	Wenatchee	Wenatchee Silica Products Inc. (Asamera Minerals (U.S.) Inc.)	Wenatchee Formation (Eocene)
Ravensdale sandpit	Ravensdale	L-Bar Products Inc.	Puget Group (Eocene)
Easy Street claims	Metaline Falls	Bockman Construction Company	alluvial materials

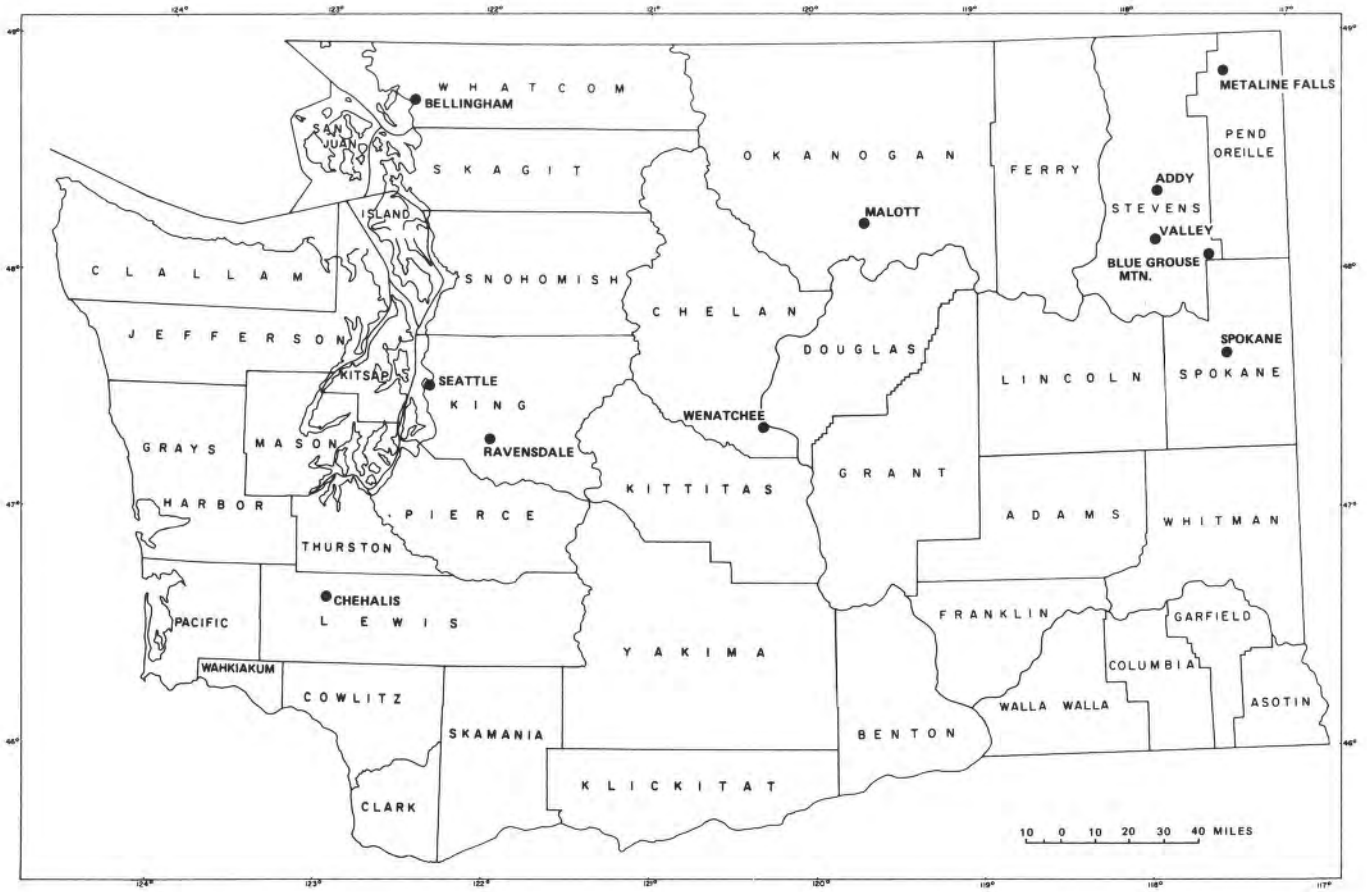

Figure 1. Locations of silica sources and manufacturing plants.

and having low iron-oxide content is the main constituent of glass. Typical chemical requirements for raw silica sand used in glass manufacture are given in Table 3.

There is no universally used formula for glass. Individual producers create their own formulas based on the composition of raw materials available within an affordable transportation distance and on the proposed end product. For example, in California, where impure sands are locally available, clear glass containers are manufactured from sands containing as much as 6 percent alumina and 0.08 percent iron oxide. In the eastern United States, where cleaner sands can be obtained, purity requirements are 0.2 percent alumina and 0.025 percent iron oxide for sand that goes to make clear containers. Specifications for raw materials required by a particular glass producer will therefore reflect the quality of sand from the current supplier and the current market trends, and may be subject to change.

Although the purity of the raw material required by the manufacturers of various glass products may vary, constancy of the chemical composition and physical properties of the materials produced by the suppliers is essential. The glass batchmaker must be able to rely on uniform raw materials to insure that proper amounts of non-silica oxides are added to the batch to insure the strength, clarity, and color of the final product. Once the sand batch has been mixed, the quality of the product has been determined. Inclusions of refractory minerals such as chromite, for example, may cause defects or remain as solid inclusions. An excess of iron may cause discoloration in certain clear glass products. Changes in the amount of iron in colored glass affect heat transmission during melting and molding. Physical properties, especially grain size of glassmaking materials, must also be consistent to insure a complete, homogeneous melt. Coarser fractions may be difficult to melt, and thereby increase energy costs, whereas very fine fractions may cause dusting and erosion of the furnace. Glass manufacturers generally require all source sands to pass through a 30-mesh screen, with less then 10 percent passing through a 100-mesh screen.

Prices for glass sands averaged about $13 per ton in 1985, f.o.b. mine plant site, depending on particle size, percent silica, and tonnage purchased. Prices for silica sand to all glassmakers increased 0.5 percent in 1985 over 1984 prices. This figure, however, includes sands for container glass, prices for which fell for the third straight year (Penfield, 1986). The cost of transportation, even over short distances, can

Table 3. Typical chemical requirements (in percent) for raw silica products in selected industrial uses; from Mills (1983) and Murphy and Henderson (1983)

	Clear Glass	Colored Glass (range)	Silicon
SiO_2 (min. purity)	99.00	95.00-99.00	99.50
Al_2O_3 (max. content)	0.20	2.50- 0.25	0.15
CaO (max. content)	0.05	0.05- 0.01	0.10
Fe_2O_3 (max. content)	0.03	0.15	0.10

more than double the f.o.b. plant price (Dickson, 1984); therefore, users of silica sand will generally give preference to the closest supplier, even if a more distant supplier has a product of higher quality.

The glass sand market is very competitive, and in the Northwest there are few glass manufacturers. Flint (clear) and colored containers for the food and beverage industry are produced in Seattle by Northwestern Glass, Inc., and by Owen-Illinois in Portland, Oregon. PPG Industries Inc. began startup of their float glass plant in Chehalis in mid-1986; the plant manufactures glass for the sash and door industry. New entries into the market will have to compete with established silica producers and with the growing use of cullet (recycled glass) by the container glass industry. In addition, the increased use of plastic containers may affect the industry.

Quartzite and sandstone have been mined for glass throughout the state. Present production in eastern Washington is from the Addy Quartzite of Cambrian age. In western Washington, sands of the Puget Group of Eocene age are being mined.

The Addy Quartzite, which crops out throughout Stevens and Pend Oreille Counties, has been explored for many years as a silica resource for the glass industry. However, exploitation has been successful only where the rock is friable, such as in the lower plate of the Lane Mountain thrust fault at the Lane Mountain silica mine. Elsewhere, the rock is too well cemented for easy crushing.

Eocene and younger, poorly consolidated units have also been of interest throughout Washington for glass sands. Although these sands may contain only 75 percent quartz, beneficiation (such as washing, sorting, and magnetic separation) can increase the percent-silica content of the final product so that it can be used for container glass. For example, the rock mined by L-Bar Products Inc. at the Ravensdale silica-sand quarry averages between 60 and 70 percent quartz, between 15 and 20 percent feldspar, and between 10 and 20 percent kaolinite. However, after washing and sorting, it is suitable for container glass, fiberglass, cement, and foundry sand (McLucas, 1982).

Foundry Sand

Foundry sand is the second largest use of silica sand. Molds are formed by binding the sand with clay and water, or with other minerals, such as bentonite, for casting iron, aluminum, and copper alloys. The molds are broken after use and remixed before reforming.

Foundry sands must withstand the high temperatures of molten metals, resist the weight of the metals, allow the release of vapors during cooling, and produce a smooth finish on the metal. Cohesion for molding is achieved by adding clay minerals to the sand (or by relying on the clay content of the raw sand) or by adding other binding agents.

Coarse through fine sands that contain 90-100 percent silica are utilized by foundries. High-quality medium foundry sands in the eastern United States, for example, contain more than 98 percent silica and have a fusion point above 1,682°C. Sands of different grain sizes are used for molding different metals. Medium sands are used to cast steel, whereas very fine sands are used for making precision castings and in aluminum or light copper-based alloy castings. Well-rounded grains are generally desirable because smooth grain surfaces require less of the expensive binding material. Uniformity of grain size is also important because it facilitates particle packing in creating the molds.

In recent years the demand for silica sand for foundry use has declined as the production of iron castings has fallen. Although an annual growth rate for foundry sands of 2.7 percent is forecast by the U.S. Bureau of Mines (Davis and Tepordei, 1985), foundry shipments declined 6 percent in 1985 relative to 1984 (Penfield, 1986). Sand reclamation facilities installed in foundries have also decreased the amount of new sand used. However, foundries using no-bake resin consume 20-30 percent more sand than those using uncured molding sands. Foundry sands recently sold for $10-$13 per ton f.o.b. shipping site on the West Coast (Wilborg and Henderson, 1983).

Small deposits of silica for use as foundry sands have been mined in Grays Harbor,

King, and Stevens Counties. Presently, Lane Mountain Silica Company produces foundry sands through beneficiation of the Addy Quartzite.

Portland Cement

Portland cement for most uses contains 20 percent silica. To produce Portland cement, silica, iron oxide, and calcium carbonate are burned in a furnace to form a calcium-silicate clinker, which is then ground. Although the necessary silica may be derived from the quarried carbonate rock or from slag, silica sand is often utilized.

Portland cement contains approximately 6 percent iron, and therefore silica sands having higher iron-oxide concentrations can be used in this industry. (Compare with requirements in Table 3.) The alumina content for sands used in Portland cement must generally be below 6 percent.

In 1984, 1,156,000 short tons of Portland cement were produced by four plants in Washington State: in Seattle by Ash Grove Cement West Inc. and Ideal Basic Industries Inc.; in Bellingham by Columbia Northwest Cement Corp.; and in Metaline Falls by Lehigh Portland Cement Co. Also in the western part of the state, L-Bar Products Inc. supplies silica for use in making Portland cement. In late 1986 Bockman Construction Inc. began producing silica for the Lehigh Portland Cement Co. from a site 8 miles east of Metaline Falls.

Paint

Both natural and synthetic silica are used as extenders in paints. Silica increases the "scrubability" and wear resistance and imparts the textures in textured paints and those used to make anti-slip surfaces. The shape and size of the silica particles help control paint gloss. Fine grinds of silica (silica flour) are used as wood fillers and to provide easier brushing in low-quality undercoats.

Paint may contain 25 to 250 pounds of 120-325-mesh silica per 100 gallons. Sand must be 98 percent pure silica for finer mesh products that are to be used in paint manufacture, while 80-98 percent pure silica sand can be utilized in coarser fraction applications.

Paint is manufactured in Washington by numerous companies in Benton, Clark, King, Pierce, and Spokane Counties.

Flux

Silica fluxes are used in metal smelting to facilitate the removal of waste material from the ores. Fluxes lower the melting temperature of the slag, increase slag fluidity, and remove many elements that are combined with ore minerals. Silica is one of the least expensive fluxing materials. Sandstone, quartzite, and quartz can be used for fluxing agents; however, silicates such as feldspar, mica, and hornblende are not acceptable in fluxes.

Uses of Coarse Silica

Coarse silica is quartzite or vein quartz utilized at 1-6-inch pieces. It is used to produce silicon (Si) and ferrosilicon. This form of silica is melted in an electric arc furnace, and periodically the molten material is drawn and cooled into ingots. The smelting process for silicon and ferrosilicon is the same except that various amounts of iron, generally scrap iron, is added before smelting to produce ferrosilicon.

Silicon manufactured in Washington is mainly used by the aluminum industry to strengthen and decrease the weight of the finished product. Silicon is also used as the starting material for semiconductor devices and silanes (SiH_4) from which silicon is produced. Ferrosilicon is used by the iron and steel industry for deoxidation of molten metal and as an alloying agent.

Silica purity requirements for the silicon industry are stringent. Because 1-6-inch pieces are used in the furnace, little beneficiation can be done; therefore the raw material must be extremely pure. Producers generally require a purity grade of 98 percent SiO_2 or greater for ferrosilicon and at least 99-percent-pure SiO_2 for silicon (Table 3). Small amounts of iron, aluminum, and other oxides can be tolerated in smelting; however, compounds of arsenic, phosphorus, or sulfur are objectionable because they emit toxic fumes during the smelting process.

Silicon and ferrosilicon are produced by one manufacturer in Washington; Hanna Mining

Co. operates the Rock Island plant at Wenatchee. Northwest Alloys Inc. (Aluminum Company of America) formerly produced ferrosilicon at their Addy plant; they now purchase ferrosilicon for use in their magnesium production.

The main sources of coarse silica in Washington have been vein quartz, quartz pegmatite, and quartzite. Until recently the Addy Quartzite was being mined by Northwest Alloys Inc. for use at their Addy plant. Historically, silica for the production of silicon has come from two sites in Spokane County. The Dennison property contained 97.9-99.4 percent pure silica in a quartz pegmatite in granitic rocks; that deposit is mined out. The second site, the Quartz Mountain silica deposit, is a quartz lens in Cretaceous biotite-muscovite quartz monzonite. The deposit, which was mined in the 1950s and 1960s, contains silica that is more than 99 percent pure.

The U.S. Bureau of Mines has investigated several Washington properties for massive or coarse silica. These include quartz lenses in granitic rock near Malott in Okanogan County and at Blue Grouse Mountain in Stevens County. Quartzitic deposits the agency has studied also include quartzites in the Covada Group in Ferry County and the Addy Quartzite in Stevens County (Carter and others, 1962).

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MINERALS IN FRACTURED BASALT

(Continued from p. 2)

be replaced by calcium, sodium, and potassium.) As a result of the substitution, the clay would expand to close off the fracture, and thus block further flow of water along joints and cracks.

The complex minerals contained in basalt fractures under the Hanford area are listed, with their chemical formulas, in Table 1 (page 12). These minerals were identified in drill core from five holes drilled by Atlantic Richfield Hanford Company between 1969 and 1972. Of the clays, nontronite was the most common, and heulandite and gmelinite were the most abundant zeolites.

The effect of fractures and the mineralogy of their fillings on containment and protection of groundwater from nuclear waste can not be dismissed by a simplistic analysis. Once a repository is operational, the minerals in the fractures will be exposed to heat, differential hydrostatic and lithostatic pressure, air, and humidity. It is conceivable that, in time, the local environment of the canister storage area will be exposed to nuclear waste as well, should canisters fail.

USDOE reports that after waste emplacement, the basalt in the emplacement rooms will reach a temperature of 131°C and that basalt surrounding the storage hole will reach a temperature of 224°C (USDOE, 1982). Clays of the smectite group can experience considerable water loss upon heating between 100° and 200°C. The illite clays can contain appreciable amounts of water as interlayers between silicate sheets of the molecular structure. This water is also released after heating above 100°C. Zeolites, too, will dehydrate and produce water in the fractures. The smectite-group clays experience contraction with initiation of heating, whereas the less abundant illite clays may expand.

The questions that need to be answered about clay and zeolite behavior in fractures require complex laboratory experiments. There is an urgent need to know the nature of fracture-filling materials and what they will produce after having been exposed to heat and air during the operation of the repository. It is possible that the purported integrity of the fractures will be compromised and that solutions resulting from dehydration of zeolites and clays could create new geotechnical and geochemical problems.

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Table 1. Minerals in basalt fractures at Hanford, Washington. Repository depth is 3,000 ft below the surface; clay formulas are simplified

Surface to 1,300-foot depth

Quartz
Calcite (up to 7.06% MnO)
Smectite group clays
  nontronite
  montmorillonite

From 1,300-to 8,000-foot depth

- Silica minerals (4%)
  - quartz SiO_2
  - opal (cristobalite) $SiO_2 \cdot nH_2O$
- Zeolites (7%)
  - heulandite $Ca_4[Al_8Si_{28}O_{72}] \cdot 24H_2O$
  - clinoptilolite $Na_6[Al_6Si_{30}O_{72}] \cdot 24H_2O$
  - mordenite $Na_8[Al_8Si_{40}O_{96}] \cdot 24H_2O$
  - gmelinite $Na_8[Al_8Si_{16}O_{48}] \cdot 24H_2O$
  - phillipsite $(Ca_{0.5},Na,K)_6[Al_6Si_{10}O_{32}] \cdot 12H_2O$
  - chabazite $Ca_2[Al_4Si_8O_{24}] \cdot 13H_2O$
  - harmotome $Ba_2[Al_4Si_{12}O_{32}] \cdot 12H_2O$
- Clay minerals (89%)
  - Smectite group
    - nontronite $(OH)_4(Si_{7.34} \cdot Al_{0.66})Fe_4^{3+}O_{20}$
    - beidellite $(OH)_4(Si_6 \cdot Al_2)Al_{4.44}O_{20}$
    - montmorillonite $(OH)_4Si_8(Al_{3.34}Mg_{0.66})O_{20}$
  - Illite - H_2O content 3.58-8.01%

U.S. GEOLOGICAL SURVEY PROJECTS ACTIVE IN WASHINGTON IN 1986

The following U.S. Geological Survey projects were authorized for Fiscal Year (FY) 1986. The work being done in Washington as part of these projects is emphasized; other areas may also be under investigation. Unless otherwise noted, project work is continuing from previous years. For more information, readers should contact the project chiefs, most of whom are stationed at the Survey's Menlo Park offices:

345 Middlefield Road
Menlo Park, CA 94025
tel. (415) 323-8111

Project Title: Side-looking airborne radar survey. On September 26, the USGS signed a contract with INTERA Radar Services Ltd. of Calgary, Alberta, to cover an area surrounding the Hanford Nuclear Reservation. Faults and fracture zones in the deep layered basalts in the area could provide pathways that short circuit the slow upward migration of water toward the shallow aquifers and the Columbia River. Composite maps that combine data from several kinds of studies may be used to select drill sites for confirmation, and, if faults or fracture zones are found, for hydrologic testing. Project chief is John Jones. The project commences in FY 1987.

Project Title: Geologic studies for seismic zonation of the Puget Lowland. Recent USGS seismic zonation studies have not included areas near Tacoma or Olympia. The mapping and topical studies aim to fill gaps in geologic knowledge and facilitate seismic zonation of this populated area. The project objectives include geologic maps of as many as 16 quadrangles (7 1/2-minute), maps to show predicted shaking intensity, susceptibility to slope failure, and other seismic hazards. Other topical studies may include estimations of vertical crustal movement, assessment of evidence for past earthquakes, examination of glacial drift sheets, and study of the boundary between oceanic rocks of the Olympic Mountains and the arc rocks of the Cascades. Project chief is B. F. Atwater, Menlo Park, CA; 1986 is the first year of the project's work.

Project Title: Depth to bedrock in the greater Tacoma area. The project seeks to reduce earthquake-related geologic hazards through identifying areas of thick sediment cover that could produce strong ground shaking and slope failures. The relevant data would be displayed on a map. Project chief is J. M. Buchanan-Banks, David A. Johnston Cascades Volcano Observatory, Vancouver, WA. The project started in 1986.

Project Title: Geologic maps of the French Butte-Stonewall Ridge area, southern Washington. Results of the project work will provide the first geologic maps across the southern Cascades of Washington. The mapping will permit construction of cross sections of the magmatic arc, evaluation of paleomagnetic rotation, and elucidation of the volcanic history. The change in petrologic character of volcanic rocks with time will also be studied. Geologic maps and related papers are expected products of the project. Project chief is D. A. Swanson, of the Volcano Observatory, Vancouver, WA. Project work began in 1986.

Project Title: Geothermal resource assessment of the Cascade Range. In the 1978 preliminary assessment of the area, it was postulated that significant geothermal resources remained undiscovered. This project has as its goal a quantitative assessment of hydrothermal and igneous-related geothermal energy regime of the volcanic arc. A major USGS publication and related topical articles are planned. Project chief is L. J. P. Muffler, Menlo Park, CA. Work on this two-year project began in 1986.

Project Title: Seismological investigation of magmatic injection in volcanic terranes. The aim of the project is to understand the nature and dynamics of the seismic sources associated with magmatic injection and transport in volcanic terranes from study of the elastic wave field radiated by such sources. Anticipated publications include theoretical analyses of elastic radiation and dynamics of an expanding fluid-filled crack.

Only a small percentage of the project's work will take place in Washington. Project chief is Bernard Chouet, Menlo Park, CA. Project work got under way in 1986.

Project Title: Morphology of submarine basaltic lava flows. The project will try to determine how currently available research tools can be used to identify long-term changes along submarine rift zones. Studies will focus on interpretation of submarine flow morphology, as well as application of information gathered by side-scan sonar and from interpretation of eruption history of a subaerial rift zone in Hawaii. About one-fifth of the project work will focus on Washington. USGS and journal reports of ALVIN dives on the Juan de Fuca ridge are anticipated. Project chief is R. T. Holcomb, Vancouver, WA. The project began in 1986, and fieldwork should be complete in 1989.

Project Title: Mesozoic radiolarian paleogeography for western Cordilleran accreted terranes. By correlating Triassic and Jurassic radiolarian faunas with megafaunas of known paleogeographic affinity, formation of an accurate scheme of paleogeographic faunal distribution may be possible. Several melanges in the project area have yielded Tethyan faunas in blocks adjacent to those containing faunas of boreal aspect. Radiolarians may prove useful in deciphering the origin of tectonic blocks in melange and olistostrome belts. Publications about taxonomy and paleogeography of high-paleolatitude radiolarians and faunas from areas from Baja California to Alaska are anticipated products. A small part of the project will be carried out in Washington. Project chief is C. D. Blome, Denver, CO. Two years of fieldwork are planned, beginning in 1986.

Project Title: Geologic map of the Cascade Range. Compilation of the Concrete, Yakima, Dalles, Hoquiam, and Vancouver 2-degree quadrangles at 1:250,000 was scheduled for completion in 1986, along with final editing of the Seattle and Wenatchee quadrangles at 1:500,000 scale. Project chief is J. G. Smith.

Project Title: Mount St. Helens basement rocks. In preparation are: a 1:62,500-scale map of the Mount St. Helens National Monument, 1:24,000-scale maps of the Vanson Peak, Cowlitz Falls, Spirit Lake East, and Spirit Lake West 7 1/2-minute quadrangles, and a 1:50,000-scale map of the Spirit Lake 15-minute quadrangle. Acquisition of fission-track and K-Ar dates from the Mount St. Helens area and geochemical, isotopic, and fluid-inclusion studies of the Spirit Lake pluton, Earl porphyry copper deposit, and Red Springs advanced argillic alteration zone continue. Geologic mapping in the Elk Rock 15-minute quadrangle is under way. Project chief is R. C. Evarts.

Project Title: Western Region mineral resource assessment. A report on mineral-resource data available through the USGS Mineral Resource Data System and a mineral-resource assessment map of Washington (scale 1:500,000) are in preparation. Project chief is M. G. Sherlock.

Project Title: Studies of chemical dispersion patterns in large, zoned mineral deposit systems and of their application to mineral exploration. On completion of chemical analyses for the Margaret deposit in Washington, evaluation of the data will be undertaken. Project chief is M. A. Chaffee.

Project Title: Modern massive sulfides. A report on the mineralogy (including two new minerals recently discovered) of samples collected from the Juan de Fuca Ridge during ALVIN dives is in preparation. Project chief is Robin Brett.

Project Title: Phase equilibria and petrogenesis of silicic igneous rocks. The project work involves a study of the uplift and thermal history of the Tenpeak region of north-central Washington (among other areas in the western states). Project chief is Priestley Toulmin.

Project Title: Massive sulfide deposits. Compilation maps showing deposit occurrences are being prepared for Washington, as well as Utah and Montana. Project chief is Robert Earhart.

Project Title: Peat resources. When available, analytical data from samples collected in

1985 in Washington will be evaluated. Project chief is C. C. Cameron.

Project Title: Geochemistry of stratabound sulfide deposits. Sulfur isotopic analyses of 50 samples of dissolved sulfide from hydrothermal vent fluids and chimney sulfide minerals from the Juan de Fuca Ridge have been completed; work on this area is scheduled for completion in FY 1987. Project chief is W. C. Shanks.

Project Title: Sulfides. Chemical analyses of zoned vent chimneys on the Juan de Fuca Ridge indicate that the minerals formed in a variety of environments. Among elements of possible economic interest: Zn (as much as 50 percent), Pb (0.1 to 0.2 percent), Cd (0.1 percent), and Ag (200-300 ppm). Analysis and refinement of analytical techniques continues. Project chief is J. A. Philpotts.

Project Title: Metal-organic interactions. Investigations of organic matter/uranium interactions in peats from the Flodelle Creek area were continuing. Ongoing studies in the laboratory are designed to show how humic acids are formed during early diagenesis. Project chief is P. G. Hatcher.

Project Title: Remote-sensing investigations of volcanoes. Compilation of Mount St. Helens magma-flow and discharge rates in order to plot specific-age eruption rate curves continues. Project chief is J. D. Friedman.

Project Title: Geophysics of the Cascade Range. Work on the Mount St. Helens study is scheduled for completion; preliminary results indicate a large sheeted dike complex beneath the mountain and a buried basaltic cone under the southwest flank of the mountain. A detailed structural model of the Juan de Fuca/North American plate boundary is being constructed, using gravity and magnetic data constrained by seismic-refraction, seismic-reflection, and magnetotelluric data, and geology. A magnetic model of a Cretaceous fore-arc basin as defined by magnetotelluric data for southern Washington was being planned. Project chief is D. L. Williams.

Project Title: Aeromagnetic surveys of San Fransisco volcanic field, Arizona, and the Cascade Range. Studies indicate that east-west-trending structures revealed by magnetic anomalies may underlie the volcanic chain and related features of the Cascade Range. These anomalies may be traces of a concealed basement connection between the Klamath Mountains and the Blue Mountains. Techniques used in this work are being applied in Nevada. Project chief is R. J. Blakely.

Project Title: Hazardous waste geophysics. Geophysical studies of the Yakima area were scheduled for 1986. Project chief is G. R. Olehoeft.

Project Title: Deep gas geophysics. Detailed studies of the Western Washington Conductive Anomaly (WWCA) and Methow trough regions were to be undertaken to complement previous COCORP seismic studies and establish the nature of the Pasayten fault on the east side of the trough. Additional soundings were to be made near Mount St. Helens to verify the suggested relationship of the edge of the WWCA to a linear strike-slip seismic belt. Project chief is W. D. Stanley.

Project Title: Pullman-Moscow basin magnetotelluric survey. One-dimensional modelling from 24 magnetotelluric stations in the Moscow-Pullman area provides a first-order quantitative estimate of the thickness of pre-Tertiary rocks. An open-file report about the results of these studies was in preparation. Project chief is D. P. Klein.

Project Title: Carbon cycle. A report on sediment trap studies at Soap and Merrill Lakes in Washington was being completed. Project work is ongoing in several other states. Project chief is W. E. Dean.

Project Title: Convergent margin characterization for deep source hydrocarbon potential. Interpretation of geochemical data from outcrop and subsurface samples collected to evaluate the hydrocarbon source potential of Eocene and middle Miocene melange wedges along the west coast of the Olympic Peninsula continued. A map showing outcrop, natural gas, and paleontologic sample locations, as

well as locations of test wells from which subsurface samples were taken and the distribution of coastal melange zones and inferred distribution of melange on the continental shelf (based on interpretation of seismic reflection profiles) was in preparation. Project chief is K. A. Kvenvolden.

Project Title: Development potential studies. The project studies engineering geology and subsidence processes and hazards in areas underlain by coal mines. Work in Washington was not funded for 1986, but may continue in future years. Project chief is C. R. Dunrud.

Project Title: Methane resources. Addition of data to a methane data base was under way so as to complete this project's work in Washington (and other states). Project chief is R. G. Hobbs.

Project Title: Uranium source rock studies--Volcanic rocks. Uraniferous organic-rich sediments, extracted pore waters, and sediment leachates from sites in northeastern Washington (and an area in Nevada) were to be processed to characterize contained organic matter and its association with uranium. Planned project activity included processing of soil and plant samples from a drainage containing surficial, organic-rich sediments to determine geobotanical signatures of locally uraniferous groundwater. Experimental leaching studies of uraniferous peats to determine the nature of uranium bonding continue. Project chief is R. A. Zielinski.

Project Title: Uranium in the surficial environment. For the north Flodelle Creek area in Washington, the project was undertaking radiogenic and biogenic gas analyses, a study of the biogeochemistry of the Douglas fir, and detailed petrologic and geochemical studies of bedrock samples from the creek drainage. Project chief is J. K. Otton.

Project Title: Formation, composition, and resources of sedimentary deposits. The study of the hydrocarbon geochemistry of a melange complex in Washington was to be completed in 1986. An atlas of GLORIA mosaics covering the Exclusive Economic Zone from Mexico to Canada was released. Project chief is K. A. Kvenvolden.

Project Title: Marine biogeology. Reports that contrast benthic community dynamics in San Fransisco Bay and Puget Sound and describe the difference in responses to human activity, that discuss the potential influence of the benthos on water-column particle concentrations during periods of low river flow, that describe a 10-year study of community dynamics in an intertidal mudflat exposed to routine habitat disturbances, and that summarize the history of human manipulation of the physics, geology, chemistry, and biology of an estuary have been submitted for publication. Measurement of the rate of removal of inorganic and organic particles from the water column by estuarine benthos is under way, and field programs to characterize natural and human-induced influences on estuarine benthos in offshore areas of California, Washington, and Alaska continued. Project chief is Paula Quinterno.

Project Title: Sediment transport and deformation. Analysis of GLORIA data previously acquired off the Pacific coast continues. Project chief is D. E. Drake.

Project Title: Geologic framework and resources assessment of Oregon-Washington continental margins. A final report on the petroleum potential of Eocene and Oligocene-Miocene accretionary melange terrane on the west side of the Olympic Peninsula and the adjacent continental shelf was in preparation for the Department of Energy. Geologic interpretation of reprocessed seismic-reflection profiles of the Oregon-Washington continental margin continues. A reconnaissance geologic map of the northern part of the Washington continental shelf, a geologic map of the western part of the Strait of Juan de Fuca, and geologic maps of five 7 1/2-minute quadrangles in the Cape Flattery area are being completed. Project chief is P.D. Snavely.

Project Title: Marine geology and resources of the western conterminous United

States. Geologic interpretation of sidescan sonar data from the GLORIA atlas of the West Coast Exclusive Economic Zone was being completed, along with work in other coastal states. Project chief is David McCulloch.

Project Title: Seafloor hydrothermal studies. Following several ALVIN dives on Juan de Fuca Ridge and studies of boiling seawater, the pressure-temperature composition of a vapor/liquid region of a brine system from 400° to 900°C was under study to understand the boiling behavior in seafloor geothermal systems. Reports on analyses of vent waters from Juan de Fuca and on the results of the quartz-solubility experiments were being prepared. Sampling and preliminary analysis of marine carbonates for uranium-series dating was planned for FY 1986. Project chief is J. L. Bischoff.

Project Title: Sandpoint 2° quadrangle, Washington and Idaho. This project seeks to constrain tectonic rotation by studies of paleomagnetism and to use magnetostratigraphy to establish a time line in the upper part of the Snowslip Formation across the Belt basin. Compilation of project work is scheduled for FY 1987. Project chief is R. F. Burmester.

Project Title: Okanogan 2° quadrangle. Work in the Boot Mountain 15-minute quadrangle is being emphasized. Compilation of field data and petrographic studies of samples from the Sherman Peak 15-minute quadrangle are under way. Preparation of the 1:250,000-scale map of the Okanaogan quadrangle continues. Project chief is K. F. Fox.

Project Title: Colville Indian Reservation. The geologic map of the reservation was scheduled to be submitted for review prior to publication; the interpretive report that includes quantitative data was in preparation. Project chief is C. D. Rinehart.

Project Title: Geology of the Twisp quadrangle. Modal analyses, petrographic studies, and report preparation of the Twisp 1:100,000-scale geologic map continue. About 50 samples have been submitted for XRF analysis, and about 40 samples have been sent for radiometric dating. Project chief is V. R. Todd.

Project Title: Olympic Peninsula offshore-onshore transect. Geologic maps of the Cape Flattery area were being completed in 1986. Progress was made on a reconnaissance map of the northern part of the Washington continental shelf. Project work coordinates with that of the project: Geologic framework and resources assessment of Oregon-Washington continental margins. Project chief is P. D. Snavely.

Project Title: Sauk River. Thin-section studies of the Sauk River rocks, as well as field checking and sample collection, dating by K-Ar, fission-track, and U-Pb methods, continue. A preliminary map of the Sauk River 2° quadrangle is being compiled. Project chief is R. W. Tabor.

Project Title: Tectonic framework of the Tillamook Volcanics, Oregon coast. Reports on the correlation of Eocene volcanic stratigraphy across the Columbia River, its constraints on the interpretation of the paleomagnetic and accretionary history of the Oregon Coast Range, and on the relative contribution of accretion and extension to tectonic rotations in the Pacific Northwest were in preparation. Project chief is R. E. Wells.

Project Title: Geology of interactions among volcanoes, glaciers, and water. A 1:50,000-scale surficial geology map and text for the Chelan area in Washington were being prepared. Work on reports describing the evolution of the Columbia River drainage basin and revisions of glacial and flood limits in northeastern Washington and northern Idaho was under way. Project chief is R. B. Waitt.

Project Title: Mount Baker (1°x ½°) quadrangle. This project aims to clarify the geologic history of accreted terranes, faulting (especially the Straight Creek, Entiat, and Ross Lake faults, and all probable transcurrent faults active in the Mesozoic and Tertiary), Tertiary intrusion and volcanism, and Quaternary deposits (both glacial and those from Mount Baker volcano). Project work focused on map compilation, literature search, evaluation of earlier mapping in the adjoining quadrangle, and reconnaissance work near Mount Baker. Field mapping in 1986 was

concentrated in the eastern part of the area. Project chief is R. W. Tabor.

Project Title: Geochronology. A report was being prepared on the variation of Sr initial ratios in northern Washington and Idaho, defining areas underlain by pre-Mesozoic sialic crust. Rb-Sr and oxygen isotopic studies of the Belt Series was expanded to define metamorphic hydrothermal areas north of the Idaho batholith. Project chief is R. J. Fleck.

Project Title: Paleozoic biostratigraphic framework of eastern Washington. Collection of additional Devonian and Permian material from northeastern Washington was under way. Completion of a report relating Carboniferous brachiopods of Washington, Oregon, and nearby areas in the Pacific Northwest to the terrane hypothesis that proposes microplates and their times of docking on the North American continent was under way. Preparation of reports describing the Ledbetter graptolites and trilobites continued. Project chief is J. T. Dutro, Jr.

Project Title: Spirit Lake hazard evaluation liquefaction studies. Monitoring with piezometers and accelerometers was to continue so as to measure the response of the debris dams in the Mount St. Helens area in case an earthquake occurs. New developments in the evaluation of the liquefaction resistance of gravelly soils are being reviewed to determine if current methods of assessing the safety of debris dams need reappraisal. Project chiefs are A. T. F. Chen and T. L. Youd.

Project Title: Seismological observatories. The Newport Observatory in Washington continued to telemeter real-time data to the NEIC for all large earthquakes. All observatories continued to work with Federal, local, and other agencies and academic institutions on all matters pertaining to geophysics and to respond to requests from the public regarding geophysical data and phenomena. Project chief is L. E. Kerry.

Project Title: Seismicity and tectonics. Reports on lithospheric stresses along the coasts of Washington and Oregon were being prepared. Project chief is William Spence.

Project Title: Geothermal tectonic seismic studies. Efforts in 1986 focused on completion of reports about Mount St. Helens and southwestern Washington and seismotectonic setting of Spirit Lake. Study of about 100 deep (3-12 km) earthquakes that occurred beneath Mount St. Helens prior to the major eruption in 1980, which may be evidence of magma transport, continued. Project chief is C. S. Weaver.

Project Title: Seismic waveform analysis. The initial focus of this project was to estimate the nature of seismic hazards due to shallow subduction earthquakes in the northwestern United States. This research was to be completed in 1986. Current emphasis of the project is on the analysis of waveforms recorded by regional short-period seismometer networks. Project chief is T. H. Heaton.

Project Title: Urban hazard seismic field investigations. Field strong motion instrumentation was scheduled to be deployed in the Seattle area. Tests have shown that this equipment can discern natural earthquake energy from background noise in urban areas. Explosive-induced motion is being recorded at these sites, and preliminary refraction-reflection velocity-geotechnical surveys are under way. The project seeks to reduce the time from field effort to the availability of a preliminary analysis report and improve the state-of-the-art in P- and S-wave high resolution shallow reflection methods. Project chief is K. W. King.

Project Title: Engineering implications of the Mount St. Helens eruptions. A report on debris-dammed lakes at Mount St. Helens was scheduled to be submitted for publication. Project chief is R. L. Schuster.

Project Title: Tilt, strain, and magnetic field observations. Implementation of a 16-bit satellite data collection system continued, along with analysis of strain, tilt, and magnetic data from Mount St. Helens and other areas in western states. Project chief is M. J. Johnston.

Project Title: Genesis of basalt. A report on the major oxides, trace element, and glass chemistry pertinent to regional correlation of the Grande Ronde basalt flows in Washington was being prepared. This project is active in Hawaii and Montana as well. Project chief is R. T. Helz.

Project Title: Hydrothermal fluids. Collection and analysis of thermal and river waters at Mount St. Helens continued in order to document the evolution of an apparently new hot-spring system in which thermal waters are leaching fresh lava. Project chief is R. O. Fournier.

Project Title: Volcanic hazards. A report reviewing methods of hazard zonation and a revision of hazard assessment at Mount St. Helens were in preparation. A report concerning the eruptive behavior of Mount St. Helens during the last 1,500 years and implications of past behavior for future volcanic hazards was being completed. Reassessment of volcanic hazards at Mount Rainier continues. Project chief is R. P. Hoblitt.

Project Title: Chemistry of mafic and ultramafic rock. A collaborative geochemical/ petrologic study of rocks of the Kalama eruptive period at Mount St. Helens has provided strong evidence of magma mixing. A report on this topic was begun in 1986. Project chief is J. S. Pallister.

Project Title: Tephra hazards from Cascade Range volcanoes. Major project focus was on the preparation of a comprehensive report on the pre-1980 tephra deposits of Mount St. Helens and on studies of the minor differences in ferromagnesian mineral content of the Mount St. Helens tephras erupted in 1980. Project chief is D. R. Mullineaux.

Project Title: Multiphase fluid flow in geothermal and volcanic systems. Fieldwork was scheduled at Mount St. Helens to study erosion surfaces under volcanic deposits. Project work continued in other western states as well. Project chief is S. W. Kieffer.

Project title: Geochemistry of gas-forming elements. Reports documenting accumulated data and correlation with other gas data, such as sulfur dioxide and carbon dioxide data from Mount St. Helens, and on remote gas sensing technology are in preparation. Project chief is Motoaki Sato.

Project Title: Recent volcanic processes. A report on the initial giant umbrella cloud of the May 18, 1980, explosive eruption of Mount St. Helens was being prepared. Most project work was in Hawaii. Project chief is J. G. Moore.

Project Title: Volcanology and petrology of late Cenozoic magmatic systems. Field mapping at Mount Adams was completed, and compilation of a geologic map of the area began. Project chief is R. L. Christiansen.

Project Title: Mount St. Helens volcano monitoring. Monitoring volcanic activity at Mount St. Helens and research on volcanic processes and products of eruptions continue. Aeromagnetic maps of the crater are in preparation. Changes in the magnetic field over the crater dome continue to be recorded, and thermal and magnetic properties of the dome rocks are being measured. Theoretical models are being constructed and tested to determine the rate of inward migration of the Curie-point surface and thus of the rate of dome cooling. These results, together with those from electrical self-potential and very low frequency electromagnetic induction surveys will provide a geophysical characterization of the shallow subsurface beneath the crater and dome. Calibration of the existing dome seismic network will facilitate locating the recorded earthquakes. Geodetic networks and dry tilt sites were to be reoccupied at Mount Baker and Mount Rainier and two volcanoes in Oregon. Also part of the project's work is construction of a data base for the Cascades that incorporates information on chemical composition of rocks and ages of deposits or eruptions, and amassing relevant literature. Project chief is N. S. MacLeod.

Project Title: Volcanic processes in California, Oregon, and Alaska. A paleomagnetic investigation of the Castle Creek eruptive period at Mount St. Helens was under way. Project chief is C. D. Miller.

Project Title: Mineralogy and geochemistry of active hydrothermal and fumarolic alteration processes. Laboratory studies of Mount St. Helens incrustations collected in 1985 are ongoing; the results will be compared and contrasted with information from 1980-81 crusts. The project is also active in Alaska and other western states. Project chief is T. E. C. Keith.

Project Title: Early and middle Cenozoic volcanic synthesis. Project work focused on collection and compilation of geologic, chemical, and age data on early and middle Cenozoic igneous rocks in several western states, including Washington. Project chief is R. G. Luedke.

UNIVERSITY OF WASHINGTON FACULTY AND STUDENT GEOLOGY PROJECTS

(This information reached us too late to be included in the previous newsletter)

Faculty Research Projects

Rates of stream incision in urbanized catchments, King County (Derek Booth)

Correlation of Seasat observations with oil basins (Robert Bostrom)

Sedimentology, stratigraphy, structure, and tectonic significance of Cretaceous Methow-Pasayten basin (Joanne Bourgeois, with M. McGroder, D. Mohrig, J. Garver)

Sedimentology and basin analysis of the Eocene "Chiwaukum Graben" (Chumstick Formation) (Joanne Bourgeois, with J. Evans)

Geology and ore deposits of metamorphic core complexes of northeastern Washington and tectonics of northern Puget lowland (Eric Cheney)

Kinematics of late Cretaceous thrust zones on San Juan Island and Lopez Island (Darrel Cowan)

Sediment budgets for forested drainage basins (Thomas Dunne)

Metamorphic history of the Chiwaukum Schist and related intrusives, Chelan County (Bernard Evans)

Sr and Nd isotopic studies of metasomatism in the Franciscan complex, California (Bruce Nelson)

Origin and ages of the European Variscan granites (Bruce Nelson)

Atmospheric ^{14}C activity and its relationship to solar variability and climatic change (Minze Stuiver)

Oxygen isotope analysis of Antarctic ice cores (Minze Stuiver)

Very precise dating of earthquakes at Pallett Creek, California, and their interpretation (Minze Stuiver)

Student Research Projects

Sedimentology, depositional environments, and basin evolution of the Eocene Chumstick Formation, Cascade Range, Washington (James Evans)

Stable carbon and oxygen isotope ratios of Holocene lake sediments from Okanogan County, Washington (Jeff Forbes)

Stratigraphy and depositional and tectonic environments of the upper Jurassic-lower Cretaceous clastic cover of the Fidalgo Ophiolite, San Juan Islands, Washington (John Garver)

Biostratigraphy of Oligocene-Miocene deposits in the Goshen Hole area, Wyoming (Bryan Goodrich)

Paleohydrology and paleohydraulics of the the Okanogan River, Washington (Karin Hoover)

Response of the Columbia River to Holocene climatic change (Karin Hoover)

History of downcutting and terrace development along the Columbia River, Washington--A model for aggradation and degradation in a semi-arid region (Karin Hoover)

Quantitative model of deposition of fine-grained sediment in the Okanogan River, Washington (Karin Hoover)

Ancient and modern storm and river-flood sedimentation on the Eel River shelf, northern California (Elana Leithold)

Hydrothermal alteration and structure associated with epithermal Au-Ag-Sb mineralization, Wenatchee Heights, Washington (Jacob Margolis)

CAMREX: Carbon in the Amazon River Experiment--Fluvial geomorphology and sediment transport of the river (Leal Mertes)

SIR-B: Space-Borne Imaging Radar-B--Radar imagery taken from the Space Shuttle of the Amazon River to study information on fluvial geomorphology, deforestation, and inundation patterns (Leal Mertes)

Multicomponent diffusion in silicate melts (William Minarik)

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

The petrogenesis of blueschist facies ironstones in the Shuksan and Easton Schists, North Cascades, Washington (Claudia Owen)

The upfreezing process and its function in sorted circles (Suzanne Prestrud)

Crystallization history of the Banks Pluton --Implications for mid-crustal evolution in Cordilleran batholitic terranes (Charles Russell)

Mineral detection in alluvial fan soils using reflectance spectra and remote sensing (Hugh Shipman)

Chemical weathering in arid environments (Hugh Shipman)

THE DEPARTMENT OF NATURAL RESOURCES AND COLVILLE TRIBES REACH AGREEMENT FOR REGULATING MINING OPERATIONS

The State of Washington and the Colville Federated Tribes have reached an agreement enabling the tribes to regulate all mining operations on the Colville Reservation.

Under the agreement, all mining operations within the Reservation's boundaries will be subject to regulation under the Colville Mining Practices Water Quality Act. In addition, the Colville Geology Department will also enforce State Department of Natural Resources regulations for any mines on fee (private) lands within the Reservation.

Prior to the agreement, the Tribes were responsible for primary enforcement on Reservation lands held in trust by the U.S. Government, and the state took direct responsibility for regulating any mining operations on private Reservation lands.

"Our cooperative agreement provides an arrangement whereby the Reservation environment is protected and mining regulations are uniformly enforced," said Colville Environemntal Quality Commission Chairman Lou Stone. "It will also eliminate confusion any mineral developer may have regarding mining practices on Reservation lands."

"The agreement provides for continued, effective regulation of all mining operations on the Colville Indian Reservation," said Commisssioner of Public Lands Brian Boyle. "It also demonstrates an important spirit of cooperation between the Colville Tribes and the State of Washington."

The new pact on mining regulations is really phase two of a more general agreement, which was signed by the Colville Confederated Tribes, the Department of Natural Resources, and the Department of Ecology in August 1985. The original agreement was reached to implement the Colville Water Quality Management Plan on the Reservation and to avoid unnecessary jurisdictional disputes between the Tribes and the state regulatory agencies.

Under the new agreement, all documents required by Washington, including State Environmental Policy Act checklists, bonding to the State, and surface-mined lands permit application, should be submitted to:

Colville Confederated Tribes
Geology Department
P. O. Box 50
Nespelem, Washington 99155

These documents will be reviewed by officials from the Confederated Tribes and the State of Washington. (From a DNR press release)

X-RAY COURSES ANNOUNCED

Two summer courses in x-ray techniques have been announced by the Department of Physics at State University of New York at Albany.

The course in x-ray powder diffraction will run from June 15 through June 26, 1987. The first week's study stresses fundamentals, the second emphasizes quantitative methods. According to the announcement,

mathematical and computer calculations and diffractometer automation are given significant attention. Registration can be made by payment of $1100 for each week.

The course in x-ray spectrometry runs for three weeks, in three sessions. The first session covers fundamentals, principles, practice, and instrumentation and will be held from June 1 to 5. The second session treats advances, latest developments, and mathematical methods; it will be held from June 8 through 12. These two sessions cost $1100 each. The third session covers mathematical and computer methods and runs from August 17 to 21. It costs $1200.

To register or for more information contact:

Prof. Henry Chessin
State University of New York
at Albany
Department of Physics
1400 Washington Avenue
Albany, NY 12222
(Tel. (518) 442-4512,4513)

PACIFIC COAST COAL COMPANY BEGINS PRODUCTION

by
Henry Schasse

Pacific Coast Coal Co. began breaking ground in late July 1986 at its John Henry No. 1 open-pit coal mine northeast of Black Diamond. The company recently shipped its first production tonnage to be tested at the University of Washington. Coal will initially come from two seams exposed in the mine: Franklin No. 9 and Franklin No. 10c (which occurs as a split of the Franklin No. 10 within the mine).

The coal is reported to have an average heating value of 12,500 Btu per pound, an average ash content of 10-15 percent, and an average sulfur content of 0.7 percent.

The opening of the mine represents a new supply of bituminous coal for users who have formerly had to depend on coal suppliers outside the state.

THE LYLE AND LELA JACKLIN COLLECTION

by
Raymond Lasmanis, State Geologist

A large collection of petrified wood, the state gem, is on display at the Geology Department of Washington State University in Pullman, Washington. More than 1,700 cut and polished slabs of silicified wood and other geologic materials can be viewed by the public Monday through Friday, 8:00 a.m. through 5:00 p.m., during the academic year. Summer hours are 7:30 a.m. to 4:00 p.m. Group tours on weekends are available with prior arrangement. The collection is located in the Harold E. Culver Memorial Room (Room 124) in the Physical Sciences Building, College Avenue Mall and Stadium Way, on the campus of Washington State University.

In terms of native Washington material, the numerous vertical display cases exhibit a wide variety of petrified wood of Miocene age from Saddle Mountains, as well as from Sunnyside and Asotin. Several cases contain red petrified wood of Triassic age from the Petrified Forest area in Arizona and numerous specimens from Oregon localities such as Stinking Water Mountains, Swartz Canyon, and Grassy Butte. Colorful Utah wood is also on display.

In addition to fossils and minerals, the Lyle and Lela Jacklin Collection contains outstanding geode specimens. A large case features material from Mexico. Oregon geodes from such classic localities as Succor Creek, Skull Springs, Burns, and near Heppner can also be seen. Another case displays cut and polished red dinosaur bone from Utah. For those interested in agate, specimens from Hampton Butte, Oregon, and Wiggins Fork, Wyoming, are also featured.

A visit to this public museum is highly recommended. For more information about the Lyle and Lela Jacklin Collection, contact:

Department of Geology
Washington State University
Pullman, WA 99164-2812
(tel: (509) 335-3009)

Richard B. Grabowski

BUREAU OF MINES NAMES NEW SPOKANE CHIEF

The U.S. Bureau of Mines recently appointed Richard B. Grabowski as chief of its Western Field Operations Center in Spokane.

Grabowski has spent most of his career in the western United States managing mineral exploration and development for several industrial firms. His most recent position was as chief geologist for Cabot Mineral Resources, a multinational firm based in New York.

In his new position, Grabowski will be responsible for a variety of programs that assess the nation's mineral resource potential and the adequacy of its mineral supply. The center's work includes examination of individual mines and mineral deposits, evaluation of the mineral potential of public lands, engineering and economic studies of mineral commodities and the industries that produce them, as well as activities related to environmental impact.

(Text and photo courtesy of the Northwest Mining Association)

SELECTED REPORTS ADDED TO THE LIBRARY, WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES AUGUST THROUGH OCTOBER, 1986

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OIL AND GAS DRILLING PERMITS ISSUED OR APPLIED FOR

FNL = from north line; FEL = from east line; FWL, from west line;
FSL = from south line; T.D., total depth

Well	Permit No.	Location	Ground Elevation & Estimated Total Depth (feet)	Status
L.B. Petroleum, Inc. Kerryn BN 34-11	398	2,030 FWL, 2,078 FSL, sec. 34, T. 19 N., R. 6 E., Pierce Co.	1,342/5,000	Plugged & Abandoned 2-5-86
Wilexco, Inc. #1-17	404	2,127 FNL, 1,200 FEL, sec. 17, T. 18 N., R. 6 E., Pierce Co.	1,680/2,500	T.D. 1,367
Twin River Oil & Gas Inc. State #1-30	410	1,109 FEL, 1,442 FNL, sec. 30, T. 31 N., R. 9 W., Clallam Co.	250/5,000	Testing T.D. 6,571
Shell Western E & P Inc. Boylston Mt. Unit No. 12	411	3,253 FNL, 1,445 FEL sec. 2, T. 16 N., R. 20 E., Kittitas Co.	3,300/15,000	Location
Carbon River Energy Partners Ship Carbon River #1-20	412	2,997 FNL, NESE Sec. 20, T. 18 N., R. 6 E. Pierce Co.	1,915/6,000	Pending
Carbon River Energy Partners Ship Carbon River #2-21	413	2,332 FEL, SWSW Sec. 21, T. 18 N., R. 6 E. Pierce Co.	1,920/6,000	Pending
Carbon River Energy Partners Ship Carbon River #3-20	414	3,871 FEL, SESE Sec. 20, T. 18 N., R. 6 E. Pierce Co.	2,005/6,000	Pending
Carbon River Energy Partners Ship Carbon River #4-29	415	4,234 FEL, NENE Sec. 29, T. 18 N., R. 6 E. Pierce Co.	2,060/6,000	Pending
Carbon River Energy Partners Ship Carbon River #5-20	416	1,526 FNL, SWSE Sec. 20, T. 18 N., R. 6 E. Pierce Co.	1,860/6,000	Pending

STAFF NOTES

Staff members of the Division of Geology and Earth Resources are involved with numerous geologic issues. Activities described below are some of our current ways of studying problems and needs and of providing information and services to Washington's residents.

During October, the State Geologist, **Ray Lasmanis**, presented a talk at a seminar held at Washington State University. His topic was "Geology--Past and future", a discussion of the need to solve geologic problems so as to improve social and economic conditions. As a member of the Advisory Board, Mr. Lasmanis also attended the October meeting of the Washington State Mining and Mineral Resources Research Institute, at which the institute's programs in geology and materials engineering were described. As a designee to the Nuclear Waste Board, he attended the October meeting; on the agenda were reviews of transportation and health, as well as a discussion of the proposed sites in Texas and Nevada and a side-looking radar survey of the Hanford site. Mr. Lasmanis also serves on the Socioeconomic Commitee of the Nuclear Waste Board. At the October meeting of the Pacific Northwest Chapter of the Friends of Mineralogy, Mr. Lasmanis, the national president, reviewed the results of the 12th annual symposium recently held in Tacoma. He also attended the western States' "cluster meeting" of U.S. Geological Survey scientists and State Geologists, at which he participated in a review of geologic and hydrologic aspects of toxic wastes.

Connie Manson, Senior Librarian, attended the Geoscience Information Society (GIS) annual meeting in San Antonio, Texas, November 10-13. She participated in various GIS symposia and meetings, and met with two U.S. Geological Survey (Reston) librarians with whom she is collaborating to produce the forthcoming comprehensive bibliography on Mount St. Helens. Connie is co-editor of the GIS national newsletter.

The Division has recently been funded through a U.S. Minerals Management Service grant to prepare a bibliography and index of the geology of offshore Washington. The bibliography will focus on the mineral resources of the Exclusive Economic Zone. **Virginia Taken**, former librarian with R. W. Beck and Associates and the U.S. Navy, began working, on contract, on this task. We expect the bibliography and index to be issued as an open-file report late in 1987.

William Lingley, Division oil and gas specialist, presented two talks on October 29. The first was a discussion of the oil and gas potential in the Hanford area for the Washington State Senate Energy Committee. (This issue was described in the August 1986 Washington Geologic Newsletter.) The second talk was given to the Seattle Municipal Engineering Department; its topic was the petroleum geology of the Eastgate landfill.

Nancy Joseph, of the Spokane office, visited elementary and middle schools to talk with students about identification of rocks and minerals and about mining and mineral exploration. She also worked with a 6th grade class at Camp Spalding, a nature study facility.

As the Division's representative, **Gerald Thorsen** attended the annual conference of the Western States Seismic Policy Council. The program covered topics such as earthquakes and dam safety, earthquake planning for rural populations, implementing earthquake safety programs in schools, and the status of the U.S. Geological Survey's National Earthquake Hazards Reduction Program.

NEW PUBLICATIONS OF THE DIVISION OF GEOLOGY AND EARTH RESOURCES

Theses on Washington Geology, 1901-1985, compiled by Connie J. Manson. Washington Division of Geology and Earth Resources Information Circular 80, 400 p., 5 pl. Price: $8.00.

This circular is a bibliography and index of all Bachelors, Masters, and Doctoral theses about geology and mineral resources of Washington known to have been written between 1901 and 1985. The bibliography is in five parts: The full bibliography, arranged alphabetically by author, with notes on published articles and abstracts derived from the thesis and notes on original thesis mapping; an index by subject and geographic area; an index by degree-granting institution, with addresses; a list of subject headings; five plates showing the locations of thesis mapping. The circular is a cumulated update of Information Circular 70, which included theses written through 1979.

The Puget Lowland earthquakes of 1949 and 1965--Reproductions of selected articles describing damage, compiled by Gerald W. Thorsen. Washington Division of Geology and Earth Resources Information Circular 81, 113 p. Price: $2.50

Because the Puget Lowland is now more densely populated than it was at the time of the 1949 and 1965 seismic events, and because of the probability of considerable property damage in future earthquakes, the articles and cover photographs were chosen to provide examples of some kinds of damage to homes, businesses, roads, and other facilities that can be expected. Some technical information about the area's seismicity is included. The articles reproduced in this circular were taken from journals or other sources that are now difficult to obtain.

Copies of these publications can be ordered from the Division of Geology and Earth Resources; the address is given on page 2 of this newsletter. Make checks payable to the Washington Department of Natural Resources and add $1 to each order to cover postage and handling.

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