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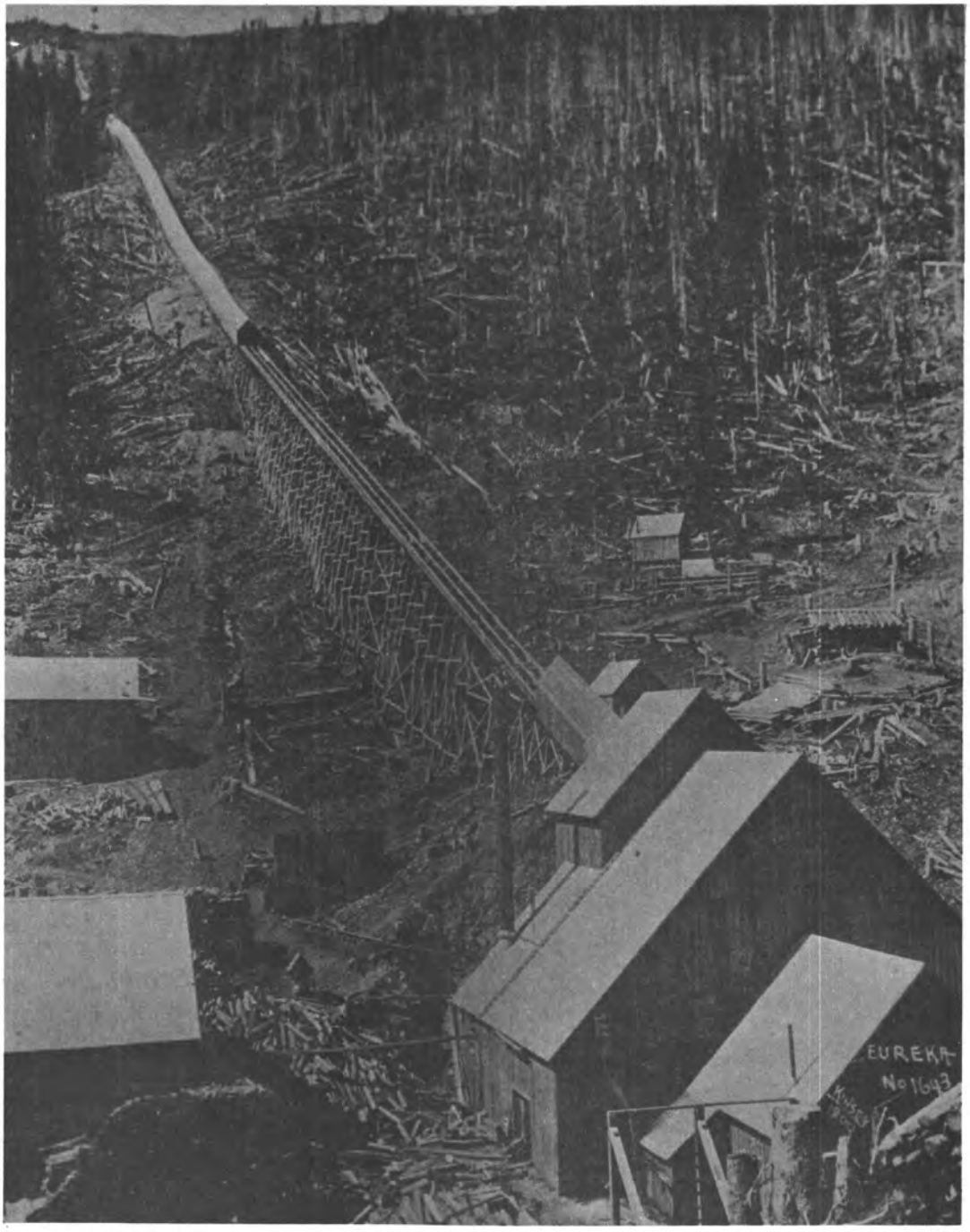
WASHINGTON GEOLOGIC NEWSLETTER



New Light mine and mill in the Slate Creek District of Whatcom County in 1900. Mill in foreground; glory hole in distance at end of railway. This mine is producing gold ore today

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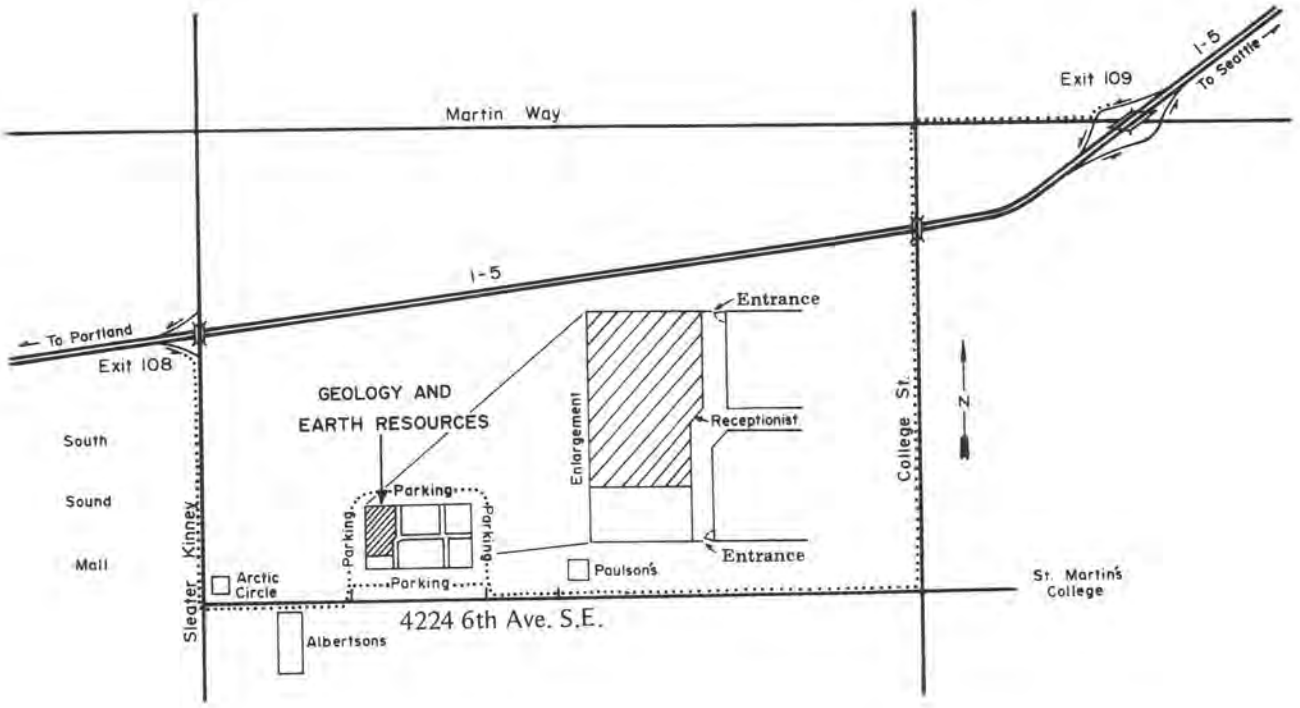

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The division also publishes bulletins, information circulars, and geologic maps. A list of these publications will be sent upon request.

THE MINERAL INDUSTRY OF WASHINGTON

HIGHLIGHTS OF ITS DEVELOPMENT

1853-1980

by

Wayne S. Moen

Part 2 is the second installment of a three-part series on the development of Washington's mineral industry. Part 1 in our July newsletter covered earliest coal mining, discovery of gold, the beginning of placer mining, and early lode mining. Part 2 has the peak years of metal-mining activity (1940-1970), recent metal-mining activity (1970-1980), and industrial minerals. Part 3, for our December issue, will discuss oil and gas development, statistics of recent and current production, and the future of Washington's mineral industry. The entire report has just been published as our Information Circular 74 (see "Recently Released Reports of the Division of Geology and Earth Resources Now Available" elsewhere in this newsletter).

Part 2

Peak Years of Metal-Mining Activity

From 1940 to 1970, some of the older mines and many more which were newly developed or discovered were particularly active, causing the metal output of the state to reach all-time highs. One of the later outstanding developments was the beginning of mining at the Holden property of the Howe Sound Co., Chelan Division, in 1938. This Chelan County operation was one of the largest in the state, producing a total of 10.6 million tons of copper-gold silver-zinc ore from 1938 through 1957 valued at $66.5 million. Outstanding, too, is the phenomenal development of the Metaline district of Pend Oreille County. The large zinc-lead deposits of this district not only placed it in a favored position among the mining areas of the state but gave it importance among the producing regions of the nation. The principal mines were the Pend Oreille, Grandview, and Bella May. Total production from these and other lead-zinc mines amounted to around $146 million between 1902 and 1969. The peak year for lead-zinc production in Pend Oreille County was 1957; 18 million pounds of lead and 22 million pounds of zinc, with a combined value of $7.5 million, was produced from mines of the Metaline district.

Figure 15. — Knob Hill gold mill at Republic, Ferry County, 1945. Since 1935 the mill has been used to recover gold and silver from ore of the Knob Hill mine, and currently the mine is Washington's only major gold producer.

Among the other important metal mines of the state during the peak metal-mining years was the Gold King, Chelan County, which produced $16 million in gold and silver from 1949 to 1967. In Okanogan County, between 1939 and 1953, gold--silver-copper-zinc ore valued at around $1 million came from the Alder mine; and from 1943 to 1951, the Kaaba Texas was the leading producer of silver-copper-lead-zinc ore in the county. In Stevens County, lead-zinc mining reached its peak in 1955, when the Van Stone produced 35 million pounds of zinc and 4 million pounds of lead, with a combined value of $5 million. In the years following 1955, mining of metals in the state declined, and by 1970, most mining operations had ceased. Of the major mines, only the Pend Oreille lead-zinc mine in Pend Oreille County and the Knob Hill gold mine in Ferry County continued to operate. Since 1955, uranium had been mined at several properties, the largest of which was the Midnite in Stevens County, but in 1966, a collapse of the uranium market resulted in the closure of the state's uranium mines. Total yearly metallic mineral production in Washington in 1970, stood at around $11 million, whereas in 1955, it had reached its peak of $14 million.

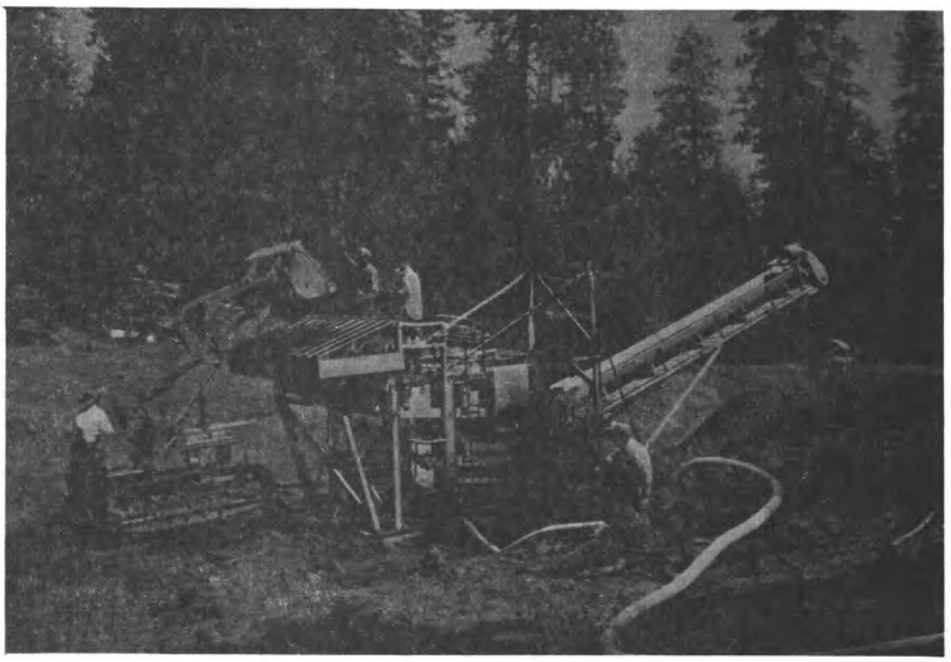

Figure 16. — Placer gold washing plant in Liberty district, Kittitas County, in 1960. Plant is typical of those being used currently to recover placer gold from the sands and gravels of gold-bearing streams.

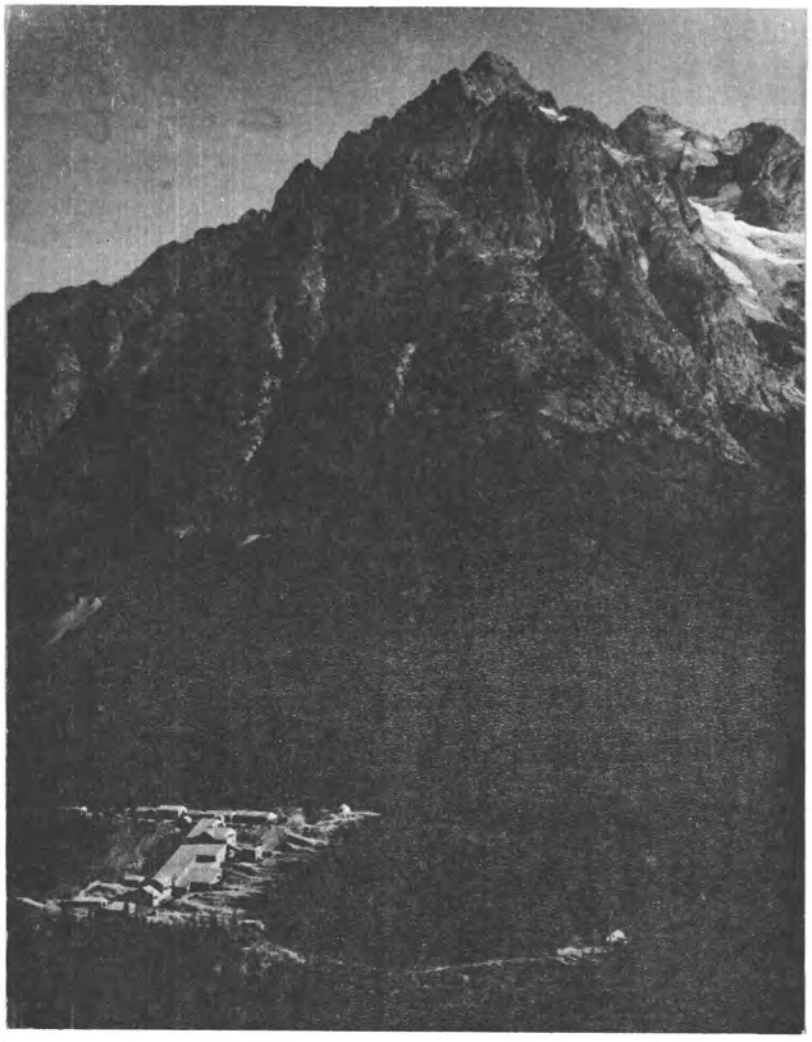

Figure 17. —Holden mine concentrating mill, Railroad Creek district, Chelan County, in 1950. This mine produced the bulk of copper, zinc, silver, and gold mined in Washington from 1938 to 1958.

Figure 18. —Pend Oreille Mines and Metals Co.'s concentrating mill at Metaline Falls, Pend Oreille County, in 1960, was the county's major producer of lead and zinc concentrates from 1929 to 1970.

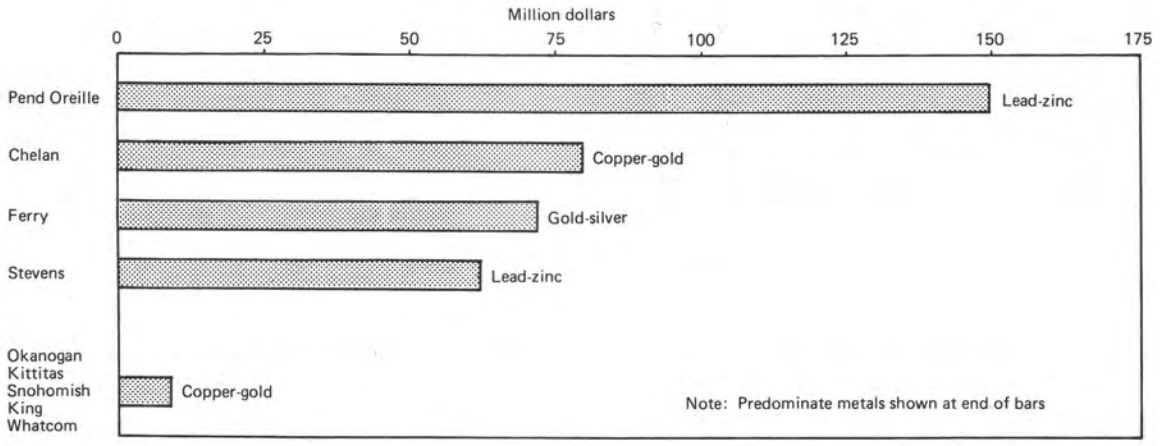

Figure 19. —Production of Washington's major metal-producing counties, 1903-1970 (includes gold, silver, copper, lead, and zinc).

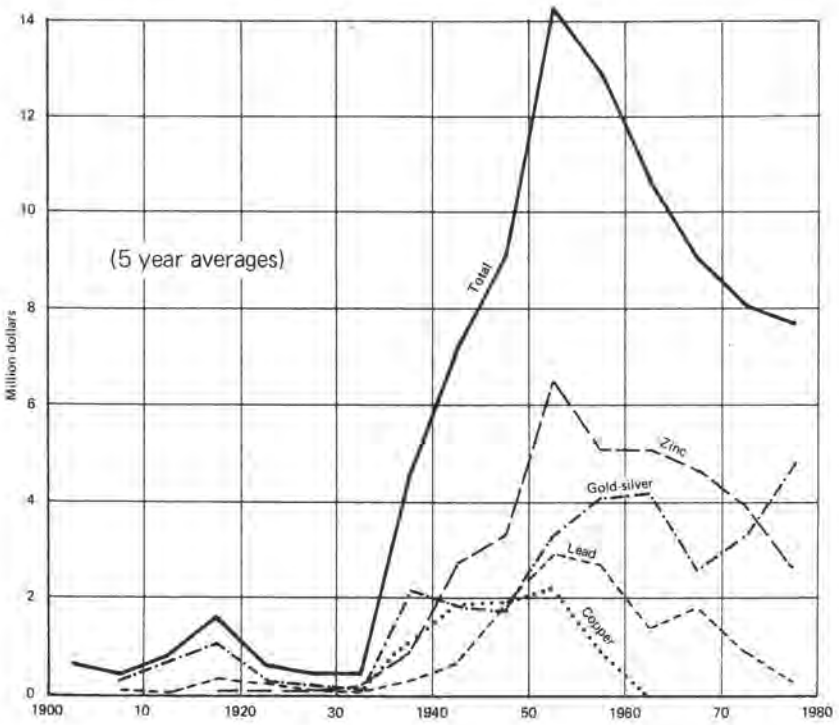

Figure 20. —Metal production of Washington, 1900-1980.

Recent Metal-Mining Activities (1970-1980)

Although metal mining had declined significantly by 1970, exploration and development of metallic mineral deposits by major mining companies increased considerably in the northern counties of the state and the Cascade Mountains. Known deposits of low-grade ore were being reexamined, and new mineral occurrences were being sought after. Extensive exploration and development work delineated several large copper-molybdenum mineral deposits. Work by Bear Creek Mining Company since the early 1950's established a very large deposit of copper in the Glacier Peak area of Snohomish County, in the north Cascades, and work by Duval International Corp. in the Spirit Lake district in the early 1970's disclosed an extensive low-grade copper deposit. In northeast Washington, Bear Creek Mining Company undertook exploratory work from 1964 to 1976 for copper and molybdenum in southwest Ferry County. This resulted in the discovery of the Mount Tolman deposit, which has been under development by Amax since 1978. Markets for uranium materialized in 1970, and the Midnite mine resumed production. In 1977, with the opening of Western Nuclear's Sherwood mine in Stevens County, the production of uranium in Washington reached an all-time high, with the current production being around $25 million per year.

It is not feasible in this summary account to list all the many proved or promising properties. Most of them contain the more usual ores of gold, silver, copper, lead, and zinc. However, to indicate the variety of available metals other resources deserve mention: these include ores of antimony, chromium, iron, manganese, mercury, and tungsten.

Industrial Mineral Development

As the state's metallic mineral resources were being developed, so were nonmetallic minerals. At the turn of the century clay from numerous pits throughout western Washington was mined for the manufacture of common building bricks used in the construction of buildings in rapidly growing towns. From sandstone quarries came building stone used in the construction of buildings as far south as San Francisco. And from limestone deposits on the San Juan Islands and the foothills of the Cascades came raw material used in the manufacture of lime and cement. In northeastern Washington, quarries in Stevens, Pend Oreille, and Spokane Counties produced marble and serpentine for monumental and architectural stone, as well as granite for paving blocks and curbing for the cities and towns of the region. In Pend Oreille County, limestone mined and processed in 1904, from a deposit near Metaline Falls, gave birth to the cement industry of Washington. In 1916, mining of magnesite began in Stevens County and "dead-burned magnesite" was shipped to steel mills of the East as a basic refractory. In 1916, about 700 tons of magnesite was mined, and by 1950, over 380,000 tons valued at almost $3 million was shipped yearly, which made Washington the foremost producer of magnesite in the country. In 1968, after 51 years of operation, mining of magnesite ceased. In Grant County of central Washington, mining of diatomite began in 1918, with a production of less than 1,000 tons. By 1980, many thousand tons were being mined primarily for use in filtration and as fillers in paint, rubber, and plastic products.

Figure 21. — U.S. Marble quarry at Valley, Stevens County, in 1900, was the largest stone quarry in Washington at that time. Workers shown drilling out large blocks of serpentine for use as monumental and building stone, utilizing steam-driven drills.

Figure 22. — Granger Clay Products Co. at Granger, Yakima County, in 1945. Beehive kilns were used to fire common brick and tile.

Figure 23. — Lehigh Portland Cement Co. plant at Metaline Falls, Pend Oreille County, in 1945 — site of the first cement plant in Washington (1904).

Figure 24. — Northwest Magnesite Co. at Chewelah, Stevens County, in 1949, was the leading producer of magnesite in the country. Crude magnesite from several outlying quarries was converted to "dead-burned magnesite" at reduction plant shown in photo.

In more recent years, the production of olivine began in Whatcom and Skagit Counties around 1946; barite mining began in Stevens County in 1940; and from 1933 to 1939, talc was produced from several mines in Skagit County. Although dolomite had been mined in Stevens County since the early 1900's for minor uses such as soil conditioners, refractory and building stone, and in 1943 and 1944 for the production of magnesium, it was not until 1976, that it became a major industrial mineral of eastern Washington. In 1976, Northwest Alloys placed into production a magnesium metal plant that utilizes around 450,000 tons of dolomite annually in the production of 25,000 tons of magnesium.

Adequate supplies of limestone, clay, and shale remain available for the production of Portland cement in areas where construction is at a maximum. Four large cement plants satisfy all market requirements; the dollar value of their output, which in 1980 was $83 million, led all other mineral substances. Sand, gravel, and common stone, all used in construction work, are in abundant supply in most areas where the need is greatest, and contribute many millions to the value of the state's mineral output.

Since 1930, when only around $2 million in sand and gravel was produced, production increased steadily to a maximum of $86 million in 1970. However, since 1970, due to slumps in the building industry, and completion of large projects such as freeway construction, production of sand and gravel has declined slightly. Because of near-future industrial and population growth in the Northwest, increased production of sand and gravel can be expected. Production of stone has also increased steadily since 1930, to an average of around $25 million since 1960.

Industrial minerals produced in 1980 include clay, diatomite, gypsum, olivine, peat, sand and gravel, stone, barite, limestone, dolomite, serpentine, silica sand, marble, talc, and granite. Ratios change from one year to another, but in recent years the various nonmetallic minerals and aggregates have accounted for about 90 percent of total mineral production. In 1980, the production of nonmetallic minerals had a value of about $275 million. Compared with our neighboring states, Washington's mineral production for 1980 was greater than Oregon's, but less than Idaho's. In 1979, Washington was 29th in rank in dollar value with 0.93 percent of the total mineral output of the United States. For comparison, Idaho was 18th in rank with 1.82 percent, and Oregon was 35th in rank with 0.68 percent.

Figure 25. — Northwest Alloys plant at Addy, Stevens County, in 1978, is one of the most modern metal-producing plants in Washington. As much as 400,000 tons of dolomite and 100,000 tons of quartzite are mined annually to produce magnesium and silicon metals.

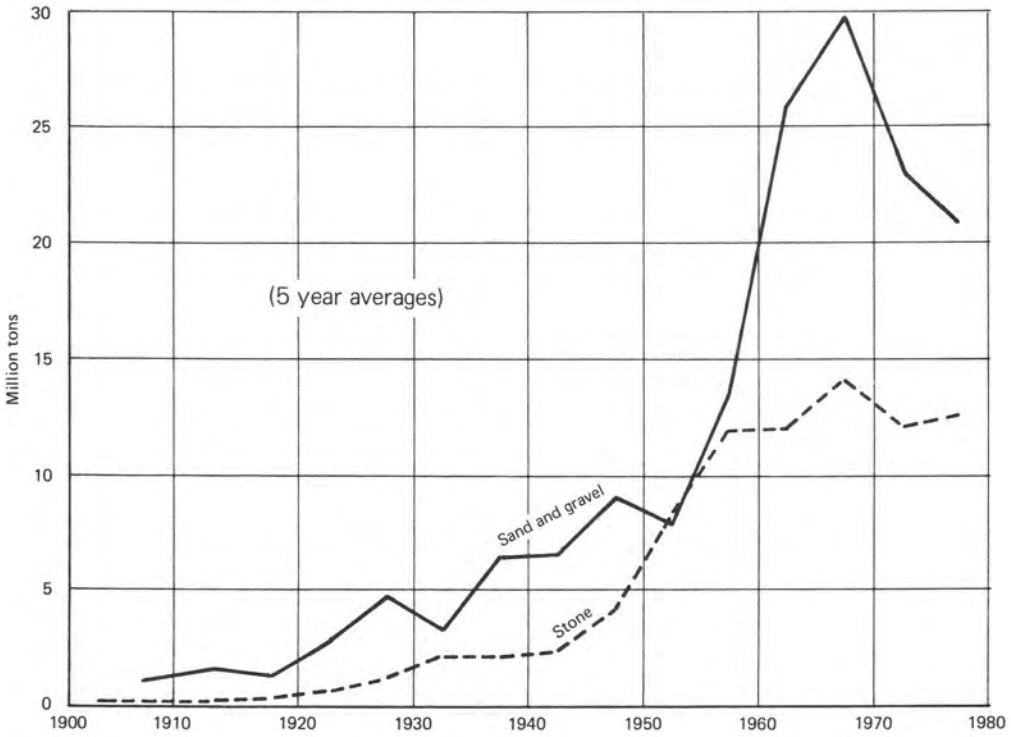

Figure 26. — Sand and gravel, and stone production of Washington, 1900-1980.

Figure 27. — Silica mining in Wenatchee district, Chelan County, in 1977, is typical of many nonmetallic mining operations in the state.

SUMMARY OF U.S. GEOLOGICAL SURVEY CURRENT ACTIVITIES IN WASHINGTON DURING 1982

These U.S. Geological Survey projects are in progress and the maps and reports mentioned are not yet available. This listing is only for information about the current work of the U.S. Geological Survey in our state.

Glacier Peak Wilderness Area. – Geologic mapping of the Glacier Peak Wilderness Area will be completed. Major bedrock units will be sampled for geochemical analysis to determine the mineral resource potential of the study area, which includes about 30 individual plutons and meta-igneous units for which little geochemical data presently exist. Isotope age determinations will be made and initial strontium isotopic ratios of major plutonic units will be determined. Analysis of major and minor-element compositions will be undertaken to geochemically characterize plutonic activity in the area. [Project chief: A. B. Ford.]

Mineral resources of Washington. – Mineral occurrence data for Clallam, Jefferson, and Mason Counties, Washington, will be entered in the Computerized Resources Information Bank (CRIB) of the U.S. Geological Survey. [Project Chief: Jocelyn Peterson.]

Western Cascade Range mapping. – Reconnaissance geologic mapping of the Western Cascade Range will continue. Several comprehensive reports on the Cenozoic geology of the Blue Mountains in Oregon, Idaho, and Washington will be prepared. [Project chief: G. W. Walker.]

Glacier View/Tatoosh. – Final reports on mineral resource appraisal for Glacier View and Tatoosh RARE II areas will be prepared. Geologic mapping and geochemical sampling of Long Swamp RARE II areas, which have been added to the project, will be completed. [Project chief: R. C. Evarts.]

Mount St. Helens basement rocks. – The immediate goal of this project is to characterize the pre-Holocene rocks on which Mount St. Helens is built. Intrusive rocks of probable Miocene age around and south of Mount St. Helens will be examined and sampled. Particular attention will be given to signs of mineralization in these rocks. [Project chief: R. P. Ashley.]

Basin-Range stratiform metals studies. – Metals and barite in Ordovician and Devonian rocks in northeastern Washington will be studied. [Project chief: F. G. Poole.]

Frontier Tertiary and Mesozoic hydrocarbon basins of the western United States. – Cores of Paleogene rocks from a gas storage area near Centralia, Washington, will be sampled in order to conduct paleontologic, sedimentologic, and geochemical analyses. A report on the reconnaissance petroleum geologic framework of an area from central Washington to northern Oregon will be in preparation. Analyses and descriptions of a core from the Shell Oil Co. exploration test well in eastern Washington will be initiated. [Project chief: T. D. Fouch.]

Petrology of organic matter in sedimentary rocks and formation of petroleum and natural gas. – A study of regional vitrinite reflectance will be underway in eastern Washington. [Project chief: N. H. Bostick.]

Borehole gravity studies and operations. – During 1981, the first field surveys were successfully run using the new "slimhole" borehole gravity meter. Seven wells are to be logged at the Hanford Water Works, Washington. This study is to determine the lateral distribution of densities within alluvial flood deposits in an attempt to determine, from surface gravity, the configuration of the top of the basalts that underlie the area. [Project chief: S. L. Robbins.]

Mount St. Helens pyroclastic flows and structural deformation. – Size analyses of 1980 pyroclastic-flow deposits will be completed in 1982. Laboratory studies on relative amounts of crystals, pumice, and lithic material in 1980 pyroclastic-flow deposits will continue. Fieldwork on 1980 pyroclastic-flow deposits will be completed, and a geoligic map of the deposits will be in preparation. [Project chief: R. D. Rowley.]

Puget Sound urban studies. – Maps of the Port Townsend quadrangle showing the bedrock geology, surficial geology, coastal erosion and sediment transport systems, physical properties of unconsolidated materials, and the thickness of unconsolidated deposits in the quadrangle will be completed at 1:100,000 scale. [Project chief: Fred Pessel.]

Tephrochronology, western United States. – The stratigraphy, erosion, transport, and redeposition of ash from Mount St. Helens eruptions of 1980-82 will continue to be monitored. [Project chief: A. M. Sarna-Wojcicki.]

Sandpoint 2-Degree quadrangle, Washington and Idaho. – Geologic maps, at 1:48,000-scale, will be prepared for Addy Mountain and Empey Mountain 7½-minute quadrangles, Washington. Compilation of 1:100,000-scale maps of the Sandpoint 2-degree quadrangle will be underway. Geochemical studies to locate tungsten, molybdenum, gold, and silver mineralization associated with a particular set of granitic plutons within the Sandpoint quadrangle are also planned. [Project chief: F. K. Miller.]

Seismo-tectonic analysis of Puget Sound province. – Mapping of surficial deposits in the Uncas, Center, Redmond, Kirkland, Issaquah, and Mercer Island 7½-minute quadrangles will be completed. Compilation of a surficial geologic map of the Seattle 1-degree quadrangle is in progress. Data collection in the study area will also be completed and the compilation of maps showing depth to bedrock, thickness of postglacial alluvium and fill, and depth to poorly consolidated Quaternary deposits in the Seattle quadrangle will be initiated.

Okanogan geologic map. – Fieldwork is underway in the Bossburg 7½-minute and the Brewster 15-minute quadrangles and an unpublished geologic quadrangle will be updated and revised. Plutonic rocks in the southeast quarter of the Republic 15-minute quadrangle will be subdivided, and a report prepared on the paleomagnetism of Eocene volcanic rocks. K-Ar and fission-track geochronology studies of plutonic and volcanic rocks will continue. [Project chief: K. F. Fox.]

Geologic map of the Colville Indian Reservation. – Geologic mapping of approximately 1,700 square km in parts of 7 15-minute quadrangles will be completed in 1982. The study of Pleistocene glacial deposits in the western half of the Reservation will continue, along with petrographic and chemical studies. [Project chief: C. D. Rinehart.]

West Wenatchee 1-degree quadrangle. – A geologic map of the Chelan 1-degree quadrangle will be completed and submitted for publication in 1982, along with an open-file map of the Skykomish River 1-degree quadrangle. Isotope dating, and fission track studies, petrography, and analysis of chemical data will continue. Field checking and sample collecting in the Skykomish River quadrangle will focus on locating conodonts in melange terranes and on collecting greenstone and amphibolite for chemical fingerprinting of the metamorphic terranes of the Cascade crystalline core. Mapping of late Tertiary volcanic rocks and their structures in the White River and Little Naches drainages in the Snoqualmie Pass 1-degree quadrangle will continue. Mapping of surficial deposits in both the Skykomish River and Snoqualmie Pass quadrangles is in progress. [Project chief: R. W. Tabor.]

Geology of the Doe Mountain quadrangle. – Collected samples will be prepared and submitted for modal, chemical, and isotopic analysis. A geologic map and explanatory text of Doe Mountain 15-minute quadrangle will be prepared for open-file release. Mapping and sampling in the Mazama 15-minute quadrangle and reconnaissance mapping in adjacent areas will be conducted. [V. R. Todd.]

Olympic Peninsula offshore-onshore geologic transect. – Detailed geologic studies in selected areas in the northwestern part of the Olympic Peninsula are underway to extend the structural and stratigraphic framework established by detailed geologic mapping in the Cape Flattery area eastward along the north-central flank of the Olympic Mountains and southward along coastal Washington; to establish the structural relationship between the accretionary wedge of Miocene melange and broken formations and the Eocene terrane that forms the core rocks of the Olympic Mountains; to perform detailed mapping and petrochemical studies to determine the provenance of the pre-Tertiary complex at the Point of the Arches; to interpret 24-channel and high-resolution seismic reflection profiles and tie the resulting offshore structural and stratigraphic framework with the adjacent onshore areas [Project chief: P. D. Snavely.]

Volcanic hazards. – Reports on pre- and post-1980 pyroclastic flows and lahars at Mount St. Helens and its pre-1980 stratigraphy will be prepared. Field studies of the volcanic hazards and deposits from 1980 blasts of Mount St. Helens will continue. Laboratory studies of paleomagnetic samples from Mount St. Helens will continue. Lahars from the southwest side of Mount Adams, Washington, will be field checked and a report prepared. [Project chief: D. R. Mullineaux.]

Tephra hazards from Cascade Range volcanoes. – New outcrops near Mount St. Helens will be examined to obtain data pertaining to prehistoric tephra eruptions. Preparation of a report on the stratigraphy and age of pre-1980 tephra layers on Mount St. Helens will be initiated. [Project chief: D. R. Mullineaux.]

Ground failure hazards in the Columbia River valley – A 1:100,000-scale strip map, augmented by a text and larger scale maps of selected areas showing the ground-failure hazards in the Columbia River valley, between Richland and Priest Rapids Dam will be completed in 1982. The study and mapping of landslides in the White Bluffs of the Columbia River, north of Pasco, will also be completed, except for long-term monitoring. Monitoring the activity of selected landslides by ground and aerial observation and photography and by use of surveyed stakes at selected localities in the study area, will continue, along with mapping and study of ground failures in the Columbia River valley, from Richland southward. [Project chief: W. H. Hays.]

Potential volcanic hazards to nuclear facilities. – Data on known volcanic activity at central-vent Cascade volcanoes and lava fields will be summarized and methods for estimating probabilities of volcanic and volcano-related hazards will be developed and evaluated. Criteria for assessing volcanic hazards relative to proposed nuclear powerplants will also be developed. [Project chief: M. H. Hait.]

Engineering implications of the Mount St. Helens eruption. – The study of the engineering aspects of Mount St. Helens eruptions will be completed and final reports prepared. The formation of "tributary" lakes by debris avalanche will be studied. [Project chief: R. L. Schuster.]

Radar Analysis–Mount St. Helens. – Mid-eruption radar data from Mount St. Helens that suggest partial blockage of main vent will be analyzed, and surface areas within the devastated area that exhibit strong radar characteristics will be field checked. [Project chief: H. H. Kieffer.]

Middle Tertiary chronostratigraphic framework, Pacific Northwest. – Field and laboratory work for the Washington transects, including analyses of samples previously collected in southwestern Washington, Knapp-

ton, and the northern Olympic Peninsula, as well as the type sections of the Twin River Group, will be completed. Reports detailing the results of the Washington transects study, proposing modifications of currently used fossil chronologies, and paleoecologic interpretations of the Knappton assemblages and their effect on the geohistory of the Pacific Northwest will be in preparation. [Project chief: K. A. McDougall.]

Genesis of basalt. – Petrogenetic studies of the Columbia River basalt will be completed. Detailed studies of Columbia River basalt will be initiated. These studies will include sampling of dikes exposed over a significant vertical distance to study volatile contents and processes of vesiculation and degassing; sampling of flows to study intra-flow chemical variation; electron microprobe study of alteration products; and one-atmosphere melting experiments for major chemical types. [Project chief: T. L. Wright.]

Regional volcanology. – Maps showing the distribution, composition, and age of late Cenozoic volcanic centers in Washington and other states are in press. The nature of the relationship between volcanism, geothermal resources, and ore deposits will continue to be studied, including investigations of systematic relationships among such parameters as magma volumes, composition (major and minor elements), longevities, and tectonic relations to different types of geothermal systems and ore deposits. [Project chief: R. L. Smith.]

Mount Adams RARE II area. – Alteration zones exposed around the margins of the Mount Adams summit icecap will be reexamined and the results integrated in the final reports on the mineral resource potential of the study area. [Project chief: E. W. Hildreth.]

Recent volcanic processes. – Mount St. Helens studies will be expanded to include the development of the May 18, 1980, mushroom cloud and associated fallout. [Project chief: J. G. Moore.]

Volcano monitoring. – The trilateration, tilt-level and gas geochemical measurements made at Mount Baker in 1981 will be repeated. A new trilateration network and new tilt level arrays will be established at Mount Rainier. At Mount St. Helens, all of the volcano monitor activities will continue, along with a review of monitoring techniques. [Project chief: D. W. Peterson.]

Cascade volcanoes observations. – All deposits resulting from Mount St. Helens eruptions of 1980, 1981, and 1982 will continue to be studied. One objective is to gain a better understanding of the complex processes that operated during the eruption of May 18, 1980, through continuing studies of the relations among the different kinds of deposits from that eruption. Erosion processes are gradually revealing new exposures of the deposits that must be documented and studied. The continuing activity of the volcano, including the products, the morphologic changes, and geochemical and geophysical characteristics will be documented. [Project chief: D. W. Peterson.]

Geophysics of the Cascade Range. – Gravity and aeromagnetic data from Mount St. Helens, both before and after its 1980 eruption, will be carefully analyzed. Gravity studies will be underway at Mount Adams. [Project chief: D. L. Williams.]

Magnetotelluric sounding for geothermal resource assessment. – The magnetotelluric studies of the Cascades will be extended to include the Mount St. Helens region. Interpretation of acquired data will continue, and a report on the results of these investigations will be in progress. [Project chief: W. D. Stanley.]

Element availability–Soils. – Data from a reevaluation of ash-fall effects on soil chemistry in eastern Washington will be analyzed and a report will be prepared. [Project chief: R. C. Severson.]

Colville Indian Reservation geophysical studies. – Compilation of regional aeromagnetic data of the Colville Reservation will be completed in 1982. Additional geophysical investigations aimed at locating and characterizing the airborne EM anomalies will be conducted. Audiomagnetotelluric measurements in the area of the porphyry system will be made to further delineate the mineralized system. [Project chief: V. J. Flanigan.]

Remote sensing studies of the Cascade Range. – Linear feature data mapped using computer-enhanced Landsat images of the Cascade Range will be statistically analyzed to determine prominent trend intervals. Linear feature maps and contour maps showing concentrations of linear features will be prepared for each important trend interval. These maps will be visually analyzed and compared to regional geological and geophysical data to define probable tectonic patterns for further study. [Project chief: D. H. Knepper.]

Infrared aerial surveillance of volcanoes of Cascade Range. – Aerial infrared surveys of fourteen volcanic sites and regions in California, Oregon, and Washington, using two different calibrated sensing systems will be conducted. USGS RS14A scanner, operating in 8 to 14-micrometer band, will be used at Mount St Helens, Washington; an EG&G Daedalus scanner operating in both 8 to 14- and 4.5 to 5.5-micrometer bands, will be used at Mount St. Helens, Mount Rainier, Mount Baker, and Glacier Peak. Infrared image prints will be prepared and data reduction will be undertaken. Possible detection of change and the radiant power emitted from thermal areas imaged will be investigated for these volcanoes. The physical and thermophysical properties of a sequence of Mount St. Helens' dome lobes of 1981-82 will be determined to ascertain more precisely the latent heat to fusion, specific heat, and bulk density for the successive lavas, and to provide heretofore unreported data on Cascade Range dacites and related volcanic rock types. These data will be used to determine the cumulative

thermal energy yield of the Mount St. Helens eruptions. [Project chief: J. D. Friedman.]

Benthic processes in west coast estuaries. – Analysis of data from a study of benthic invertebrates in Puget Sound, Washington, will continue, along with the collection and analysis of invertebrates in box cores as part of our study on continental-shelf sediment dynamics. [Project chief: F. H. Nichols.]

Geologic framework and resources assessment of Washington continental margins. – Preparation of a structure map for the continental margin off northern Washington is underway to tie this tectonic framework to that of the northwestern part of the Olympic Peninsula. [Project chief: P. D. Snavely.]

Juan de Fuca Ridge–Structure and metallogenic processes. – A cruise will attempt to photograph and sample an area of probable hydrothermal activity and obtain a long multichannel profile. Data acquired during this cruise will be used to compile a detailed bathymetric and structural map of the southern Juan de Fuca Ridge; for a photographic study of the axial zone of the ridge; and if possible, to study water and bottom samples in an area of hydrothermal activity. [Project chief: W. R. Normark.]

Volcanogenic manganese deposits. – Field investigations of large tonnage, low-grade stratiform manganese deposits in Washington and other states are in progress. This includes mine mapping, measuring stratigraphic sections, and sampling surface and underground mines and outcrops. [Project chief: R. A. Koski.]

Geothermal tectonic seismic studies. – Studies of the crustal structure of the Washington continental margin and the Olympic Peninsula for evaluating the earthquake hazards of western Washington should be nearly completed in 1982. Cascade Range studies will concentrate on determining the relation between horizontal compression, seismicity, and volcanism at Mount St. Helens, and testing the hypothesis that the stress of the Oregon Cascade Range (east-west extension) is different than that of the Washington Cascade Range (northeast compression), using both geologic and geophysical data. The hypothesis that the right-lateral motion between the Juan de Fuca and North American plates is occurring aseismically south of the Mount St. Helens seismic zone will also be tested by establishing several strain quadralaterals in the southern Washington Cascade Range. [Project chief: C. S. Weaver.]

Crustal strain. – Fieldwork for Washington is underway. A trilateration network near Seattle will be resurveyed, and initial measurements will be made on new trilateration networks on the Olympic peninsula and near Mount St. Helens. [Project chief: J. C. Savage.]

Pressurized fractures in hot rocks. – The study of volcanic rift zones and refining of techniques for estimating the shape of conduits and the ratio of magma driving pressure to host rock stiffness continued in 1982, using data acquired from Kilauea in Hawaii, and Mount St. Helens, Washington. New techniques for analyzing the heat and mass transfer aspects of the volcanic tremor model will be developed. [Project chief: D. D. Pollard.]

Magnetic field observations. – Installation, maintenance, and monitoring of magnetic and strain-measuring equipment continued. Models have been developed to explain magnetic and tilt changes observed during eruptions of Mount St. Helens. [Project chief: M. J. Johnston.]

Recent Geologic Division Reports

Reports on Washington geology released since last year's summary of USGS activities are listed below [some open-file reports that we have in our Division library were listed in previous newsletters and are not repeated here]:

Armstrong, F. C.; and others, 1981, Plate tectonics and uranium deposits in northeastern Washington and adjacent British Columbia [abstract]. *In* The last 100 million years (mid-Cretaceous to Holocene) of geology and mineral deposits in the Canadian cordillera – Symposium: Geological Association of Canada, Cordilleran Section, Feb. 13-14, 1981, p. 6.

Banks, N. G.; Hoblitt, R. P., 1981, Temperature studies of Mount St. Helens deposits, 1980 [abstract]. *In* Symposium on arc volcanism, Tokyo, 1981, Volume Abstracts: International Association of Volcanology and Chemistry of the Earth's Interior, p. 27.

Banks, N. G.; Cutter, E. B., 1981, Temperature estimates of the 1980 direct blast of Mount St. Helens, Washington, U.S.A., from thermal effects on trees and buried wood [abstract]. *In* Symposium on arc volcanism, Tokyo, 1981, Volume Abstracts: International Association of Volcanology and Chemistry of the Earth's Interior, p. 26.

Casadevall, T.; and others, 1981, Gas emissions from Mount St. Helens, Washington – Constraints on a model for behavior of magma in the near-surface environment [abstract]: Eos (American Geophysical Union Transactions), v. 62, no. 45, p. 1088.

Chin, J. L.; Hill, G. W., 1982, Vegetation of sandy intertidal flats, Willapa Bay, Washington – Summer, 1978: U.S. Geological Survey Open-File Report 82-425.

Christiansen, R. L.; Peterson, D. W., 1981, The 1980-81 activity and some results of monitoring and research at Mount St. Helens, U.S.A. [abstract]. *In* Symposium on arc volcanism, Tokyo, 1981, Volume Abstracts: International Association of Volcanology and Chemistry of the Earth's Interior, p. 27.

Clifton, H. E.; Phillips, R. L., 1980, Lateral trends and vertical sequences in estuarine sediments, Willapa Bay, Washington. *In* Field, M. E.; and others, editors, 1980, Quaternary depositional environments of the Pacific coast; Pacific Coast Paleogeography Symposium 4: Society of Economic Paleontologists and Mineralogists Pacific Section, p. 55-71.

Crandell, D. R.; and others, 1981, Radiocarbon dates from volcanic deposits at Mount St. Helens, Washington: U.S. Geological Survey Open-File Report 81-844.

Crosson, R. S., 1981, Earthquake hazard evaluation in the Pacific Northwest: U.S. Geological Survey Open-File Report 81-965.

Dethier, D. P.; Bethel, John, 1982, Chemical characteristics for 23 western Washington rivers, 1961-80: U.S. Geological Survey Open-File Report 82-185.

Duffield, W. A.; Guffanti, Marianne, 1981, The Geothermal Research Program of the U.S. Geological Survey: U.S. Geological Survey Open-File Report 81-564.

Dzurisin, Daniel; and others, 1981, Ground tilts during two recent eruptions of Mount St. Helens, Washington [abstract]: Eos (American Geophysical Union Transactions), v. 62, no. 45, p. 1089.

Eaby, J. S.; Clague, D. A., 1982, Preliminary description of basalt from the southern Juan de Fuca Ridge: U.S. Geological Survey Open-File Report 82-200-C.

Easterbrook, D. J.; and others, 1981, Fission-track and paleomagnetic dating of the Salmon Springs Glaciation in Washington: Geology, v. 9, p. 87-93.

Easterbrook, D. J.; and others, 1982, Pleistocene glacial and interglacial chronology in western Washington [abstract]: Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 161.

Frizzell, V. A., Jr.; and others, 1982, Mesozoic melanges in the western Cascades of Washington [abstract]: Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 161.

Grant, W. C.; and others, 1981, The February 14, 1981, Elk Lake, Washington earthquake and its aftershock sequence [abstract]: Eos (American Geophysical Union Transactions), v. 62, no. 45, p. 966.

Gresens, R. L.; and others, 1981, Stratigraphy and age of the Chumstick and Wenatchee Formations — Tertiary fluvial and lacustrine rocks, Chiwaukum graben, Washington: Geological Society of America Bulletin, Part II, v. 92, p. 841-876.

Hays, W. H.; and others, 1982, Active landslides on the White Bluffs of the Columbia River, south-central Washington [abstract]: Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 171-172.

Heller, P. L., 1981, Small landslide types and controls in glacial deposits — Lower Skagit River drainage, northern Cascade Range, Washington: Environmental Geology, v. 3, p. 221-228.

Hill, G. W., 1981, Facies characteristics and patterns in mid-estuary intertidal flat deposits, Willapa Bay, Washington: U.S. Geological Survey Open-File Report 81-162.

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Hill, G. W.; and others, 1982, Distribution of macrobenthic infauna in tidal flat deposits, Willapa Bay, Washington — Summer, 1978: U.S. Geological Survey Open-File Report 82-461.

Izett, G. A., 1981, Stratigraphic succession, isotopic ages, partial chemical analyses, and sources of certain silicic volcanic ash beds (4.0 to 0.1 m.y.) of the western United States: U.S. Geological Survey Open-File Report 81-763.

Johnston, M. J. S.; Dvorak, J. J., 1981, Implications of tilt and magnetometer measurements at Mount St. Helens, Washington, 1980-1981 [abstract]: Eos (American Geophysical Union Transactions), v. 62, no. 45, p. 1089.

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Kieffer, H. H., 1981, Radar observations at Mount St. Helens [abstract]: Eos (American Geophysical Union Transactions), v. 62, no. 45, p. 1089.

Kieffer, S. W., 1981, Mount St. Helens lateral blast — Explanation of acoustic observations [abstract]: Geological Society of America Abstracts with Programs, v. 13, no. 7, p. 487.

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Koski, R. A.; and others, 1982, Preliminary description of massive sulfide samples from the southern Juan de Fuca Ridge: U.S. Geological Survey Open-File Report 82-200-B.

Lipman, P. W.; Mullineaux, D. A., 1982, The 1980 eruptions of Mount St. Helens, Washington: U.S. Geological Survey Professional Paper 1250.

McKee, E. H.; and others, 1981, Age of Imnaha Basalt — Oldest basalt flows of the Columbia River Basalt Group, northwest United States: Isochron/West, no. 31, p. 31-33.

Michaelson, C. A.; Weaver, C. S., 1981, Teleseismic P-wave-residual studies in Washington and northern Oregon [abstract]: Eos (American Geophysical Union Transactions), v. 62, no. 45, p. 1089.

Miller, F. K., 1982, Geologic map of Salmo-Priest Wilderness Study Area (RARE E6-981 A1-981), Pend Oreille County, Washington, and Boundary County, Idaho: U.S. Geological Survey Map MF-1192-A, scale 1:48,000.

Miller, F. K.; Theodore, T. G., 1982, Molybdenum and tungsten mineralization associated with two stocks in the Harvey Creek area, northeastern Washington: U.S. Geological Survey Open-File Report 82-295.

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Newhall, C. G., 1982, A method for estimating intermediate- and long-term risks from volcanic activity, with an example from Mount St. Helens, Washington: U.S. Geological Survey Open-File Report 82-396.

Pessl, Fred, Jr.; and others, 1981, Sedimentary facies and depositional environments of Late Wisconsinan glacial-marine deposits in central Puget Lowland, Washington [abstract]: American Association of Petroleum Geologists Bulletin, v. 65, no. 5, p. 969-970.

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Ryan, M. P.; and others, 1981, Thermal structure of Mount St. Helens eruptive units — Restoration of the emplacement temperatures and in-situ thermal diffusivities [abstract]. *In* Symposium on arc volcanism, Tokyo, 1981, Volume Abstracts: International Association of Volcanology and Chemistry of the Earth's Interior, p. 27.

Savage, J. C.; and others, 1981, Geodetic strain measurements in Washington: Journal of Geophysical Research, v. 86, p. 4929-4940.

Savage, J. C.; and others, 1981, Dislocation model for strain accumulating along the Washington coast [abstract]: Eos (American Geophysical Union Transactions), v. 62, p. 404.

Snavely, P. D., Jr.; Wagner, H. C., 1982, Geophysical data collected on the southern Washington continental shelf along Line 12, USGS R/V S. P. LEE Cruise 3-76: U.S. Geological Survey Open-File Report 82-424.

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Tabor, R. W.; and others, 1982, Possible accreted terranes in the north Cascades crystalline core, Washington [abstract]: Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 239.

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Tilling, R. I., 1981, Overview of Mount St. Helens volcanic eruptions: Society of Photo-Optical Instrumentation Engineering, Annual Meeting, April 21-22, 1981, Washington, D.C., v. 278, p. 3-10.

Waitt, R. B., Jr., 1980, About forty last-glacial Lake Missoula jokulhaups through southern Washington: Journal of Geology, v. 88, p. 653-679.

Waitt, R. B., Jr., 1982, Revised limits of the cordilleran ice sheet and of multiple Lake Missoula jokulhaups in northern Idaho and northeastern Washington during the Fraser (Late Wisconsin) Glaciation [abstract]: Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 161.

Waitt, R. B., Jr.; and others, 1982, Regional significance of an early Holocene moraine in Enchantment Lakes basin, north Cascade Range, Washington: Quaternary Research, v. 17, p. 191-210.

Weaver, C. S.; Smith, S. W., 1981, The St. Helens seismic zone — A major crustal fault zone in western Washington [abstract]: Eos (American Geophysical Union Transactions), v. 62, no. 45, p. 966.

NWMA ANNOUNCES 88TH ANNUAL CONVENTION

The Northwest Mining Association will hold its 88th annual convention in Spokane on December 9, 10, and 11. The convention sessions will center around the 1982 theme, "Productivity — Prescription for Survival." The theme was selected to help members of the minerals industry cope with inflated costs and depressed markets.

A slate of experts from mining, smelting, commodity markets, banking, transportation, and foreign commerce specialties will assemble for the short course offered on December 6, 7, and 8. The specialists will present a practical workshop on marketing metallic minerals for decision-makers from the fields of exploration planning, mine planning and development, metallurgy, and mineral management.

Registration information for the convention and short course is available from the Northwest Mining Association, 633 Peyton Bldg., Spokane, WA 99201 (509) 624-1158.

DIVISION ADDS NEW CHARGE FOR DISTRIBUTION OF PUBLICATIONS

Because of increased costs in postage and handling, the Division of Geology and Earth Resources has had to start charging for distribution by mail of our publications. Each mail order will now have $1 added to the total cost of the order. This charge will apply even though the publication(s) may be free. Open-file reports are also included.

MINERAL REPORT AVAILABLE FROM OKANOGAN NATIONAL FOREST REQUIRES A HANDLING CHARGE

An article in our July Geologic Newsletter noted the release of the results of a geochemical and geologic study by Dr. A. R. Grant. A call from the Okanogan National Forest office asked us to please state that a distribution charge was necessary when ordering these reports. The mineral potential of the Okanogan National Forest study is available (text and plates) for $33.80, and the mineral potential of the Colville National Forest study (text and plates) sells for $40.25. Please add $10 ($16 in Canada) to your total order for these reports. They may be purchased from the Okanogan National Forest, P. O. Box 950, Okanogan, WA 98840 (509/422-2704). These reports are also available for inspection at our Division of Geology and Earth Resources library.

"SILVER OCCURRENCES OF WASHINGTON" REPRINTED

Bulletin 69, "Silver occurrences of Washington," by Wayne S. Moen, is now available for purchase for $4. This popular report was first issued in 1976, and by 1981 it was out of print. Repeated requests for the bulletin have resulted in its reprinting by the Division of Geology and Earth Resources. [If you request to have bulletin 69 mailed to you, please remember to include the $1 distribution charge per total order.]

RECENTLY RELEASED REPORTS BY THE DIVISION OF GEOLOGY AND EARTH RESOURCES NOW AVAILABLE

Copies of these reports may be obtained by writing to the Department of Natural Resources, Division of Geology and Earth Resources, Olympia, WA. Please add a $1 distribution charge to your total order.

Biggane, John, 1982, The low-temperature geothermal resource and stratigraphy of portions of Yakima County, Washington: Washington Division of Geology and Earth Resources Open-File Report 82-6, 136 p., 58 figs., 4 plates. Free.

Moen, W. S., 1982, The mineral industry of Washington — Highlights of its development, 1853-1980: Washington Division of Geology and Earth Resources Information Circular 74, 26 p. Free.

Phillips, W. M.; Walsh, T. J.; Schasse, H. W., 1982, Analyses of measured sections of Washington coals: Washington Division of Geology and Earth Resources Open-File Report 82-5, 181 p., 18 figs. Free.

Walsh, T. J.; Schasse, H. W.; Phillips, W. M., 1982, Directory of Washington mining operations, 1980-1981: Washington Division of Geology and Earth Resources Open-File Report 82-4, 71 p. Free.

THESES ADDED TO DIVISION LIBRARY

The following theses were recently added to our division library where they are now available for reference work:

Baichtal, J. F., 1982, The geology of Waldron, Bare, and Shipjack Islands, San Juan County, Washington: Washington State University Master of Science thesis, 222 p.

Brackett, M. H., 1966, Alderwood soil series: Washington State University Master of Science (Soils) thesis, 100 p.

Dainty, N. D., 1981, Petrology of the strata of Patos Island, San Juan County, Washington: Washington State University Master of Science thesis, 107 p.

Ellersick, D. K., 1967, An investigation of the shear strength of Palouse clay as a function of moisture content: Washington State University Master of Science (Civil Engineering) thesis, 41 p.

Jamieson, I. M., 1976, Heat flow in a geothermally active area – The Geysers, California: University of California at Riverside Doctor of Philosophy thesis, 143 p., 2 plates.

Lane, D. E., 1982, Sulfide mineralization in a sequence of metasedimentary and metavolcanic rocks, north fork Lone Ranch Creek area, Ferry County, Washington: Washington State University Master of Science thesis, 71 p., 1 plate.

Lillie, J. T., 1977, An analysis of selected gravity profiles on the Hanford Reservation, Richland, Washington: Wright State University Master of Science thesis, 88 p.

Mack, C. B., 1980, Postglacial tephrochronology of the Indian Heaven area, south Cascade Range, Washington: Washington State University Master of Science (Soils) thesis, 75 p.

McDonald, R. J., 1979, Chemical properties of, and crop production on, mine spoils in western Washington: Washington State University Master of Science (Soils) thesis, 37 p.

Mitchell, T. E., 1981, Uranium mineralization of the metamorphic aureole of the Spirit pluton, Stevens County, Washington: Oregon State University Master of Science thesis, 109 p., 2 plates.

Nordby, G. R., 1966, Time rate considerations in consolidation of Palouse loess: Washington State University Master of Science (Civil Engineering) thesis, 85 p.

Reiswig, K. N., 1982, Palynological differences between the Chuckanut and Huntingdon Formations, northwestern Washington: Western Washington University Master of Science thesis, 61 p.

Smith, B. L., 1982, Geology of the southeastern portion of the Inchelium quadrangle, Stevens County, Washington: Eastern Washington University Master of Science thesis, 60 p., 2 plates.

Wang, Kong, 1982, Emplacement analysis of the Starvation Flat quartz monzonite pluton, northeastern Washington, by using the anistropy of magnetic susceptibility method: Eastern Washington University Master of Science thesis, 34 p.

White, R. O., 1981, The geology of the Schminski molybdenum deposit (Colville Indian Reservation), Ferry County, Washington: Washington State University Master of Science thesis, 103 p., 2 plates.

Wilson, J. R., 1981, Structural development of the Kettle gneiss dome in the Boyds and Bangs Mountain quadrangles, northeastern Washington: Washington State University Doctor of Philosophy thesis, 156 p.

RECENT U.S. GEOLOGICAL SURVEY OPEN-FILE REPORTS ADDED TO OUR DIVISION LIBRARY

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

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

Church, S. E.; Mosier, E. L.; Frisken, J. G.; Arbogast, B. F.; McDouglas, C. M., 1982, Analytical results for stream sediments and panned concentrates from stream sediments collected from the Monte Cristo and Eagle Rocks study area, Washington: U.S. Geological Survey Open-File Report 82-303, 83 p., 1 plate.

Dethier, D. P., 1982, Chemical characteristics for 23 western Washington rivers, 1961-1980: U.S. Geological Survey Open-File Report 82-185, 46 p.

Mariner, R. H.; Presser, T. S.; Evans, W.C., 1982, Chemical and isotopic composition of water from thermal and mineral springs of Washington: U.S. Geological Survey Open-File Report 82-98, 18 p.

Normark, W. R.; Koski, R. A., 1982, Juan de Fuca Ridge massive sulfide samples – Sample distribution policy: U.S. Geological Survey Open-File Report 82-721, 2 p.

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