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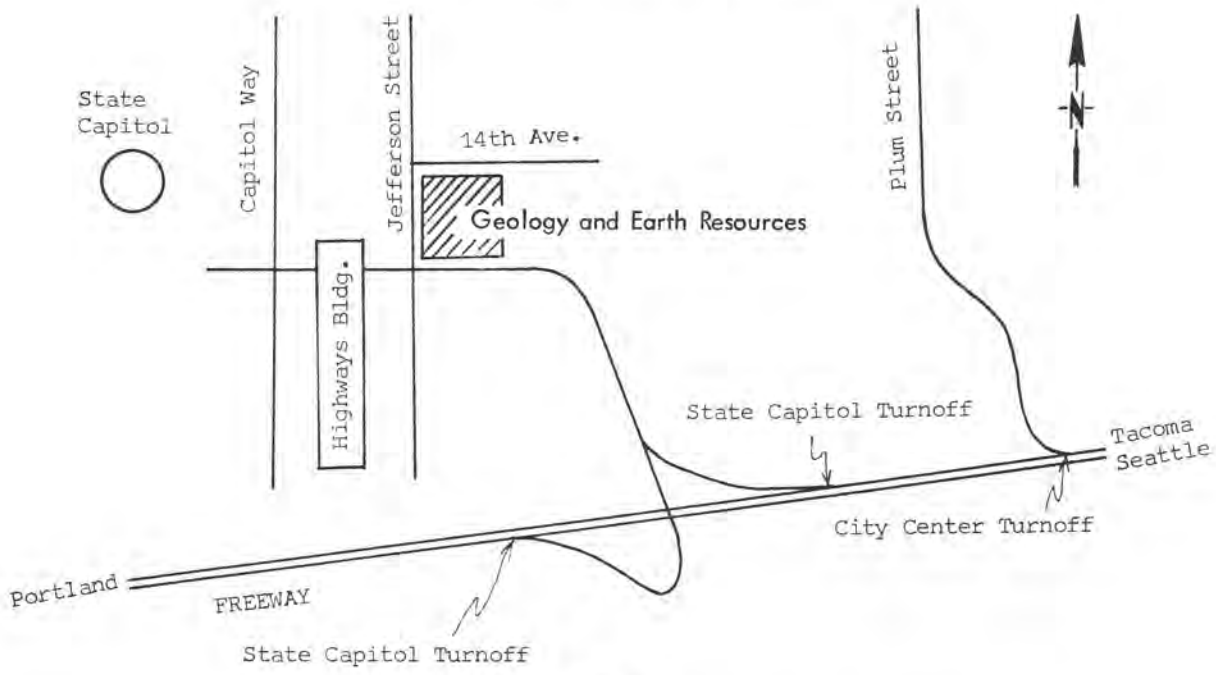
LOCATION MAP

DIVISION OF GEOLOGY AND EARTH RESOURCES



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COVER PHOTO

Sand and gravel plant of Lone Star Industries, Inc. at Steilacoom in Pierce County. It is the largest sand and gravel operation in the state and utilizes a fully automatic control system for excavating, processing, and loadout. Maximum output of the plant is rated at 1,800 tons per hour, with loading facilities for railcars, barges, and trucks.

SAND AND GRAVEL IN WASHINGTON

By Tom Zimmerman, Washington Department of Highways, and Wayne S. Moen, Washington Division of Geology and Earth Resources[1/]

Production and Uses

Few people think of sand and gravel as a valuable mineral product; however, the sand and gravel industry is the largest mineral industry in terms of tonnage and the second largest in terms of dollars, exceeded only by portland cement, in Washington. Preliminary mineral production figures for Washington for 1976 show an all-time high of $180.99 million, $35.11 million of which is assigned to sand and gravel. Production figures for sand and gravel, as well as for stone, coal, and cement follow:

Product	Tons (millions)	Value (millions of dollars)
Sand and gravel	17.7	35.11
Stone	7.7	18.49
Coal	3.9	*25.00
Cement	1.42	53.47

*Estimated value.

Although the dollar value of sand and gravel reached an all-time high in 1976, the tonnage value has been declining slowly. The dollar value of sand and gravel increased sharply from $1.08 per ton in 1973 to a high of $1.98 per ton in 1976 (fig. 1).

Salient sand and gravel statistics are not yet available for 1976; 1975 figures will be used to bring out pertinent facts relating to the sand and gravel industry in Washington.

In 1975, 186 operations in the state produced 19,069,000 tons of commercial sand and gravel. Although every county in the state produced these materials, 63 percent of the total was produced by 5 counties. The leading sand and gravel producing counties—most of which are in western Washington—are: Pierce, 25.17 percent; King, 17.98 percent; Snohomish, 9.30 percent; San Juan, 5.39 percent; and Spokane, 5.29 percent.

The use of sand and gravel is primarily related to construction. Almost every type of construction utilizes sand and gravel for purposes such as fill or aggregate in concrete. Heavy construction jobs (highways and dams, for instance) consume large amounts of sand and gravel. In the Grand Coulee Dam alone over 10 million cubic yards of sand and gravel was used in the concrete.

A breakdown by use for processed and unprocessed commercial sand and gravel sold in Washington in 1975 is listed below.

Processed sand and gravel	Tons
Nonresidential and residential construction	4,602,037
Highway and bridge construction	878,977
Dams, waterworks, airports, etc.	544,106
Cement blocks, bricks, pipe, etc.	905,430
Bituminous paving	1,198,608
Road base	1,136,063
Fill	464,001
Other	120,261
Total	9,848,483

Average value $1.93 per ton

Unprocessed sand and gravel	Tons
Fill	2,347,275
Road base	1,351,109
Other	43,601
Total	3,741,994

Average value $1.20 per ton

Industrial sand	Tons
Glass	31,000
Blast, engine, etc.	26,745
Total	57,745

Average value $5.76 per ton

[1/] This article is an updated modified version of "Sand and Gravel" that appears on pages 251 through 257, of Mineral and Water Resources of Washington, Washington Division of Geology and Earth Resources Reprint No. 9, 1966 (Out of print).

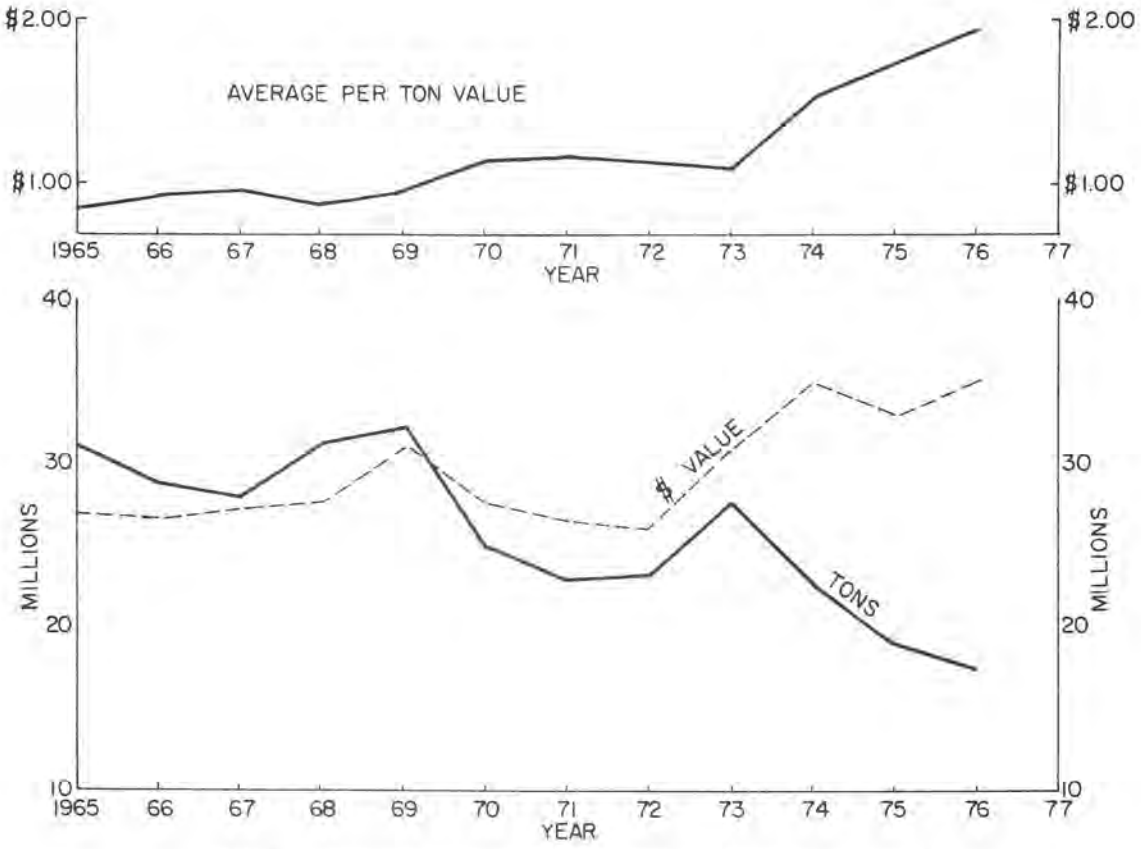

FIGURE 1.—Washington sand and gravel production, 1965-1976.

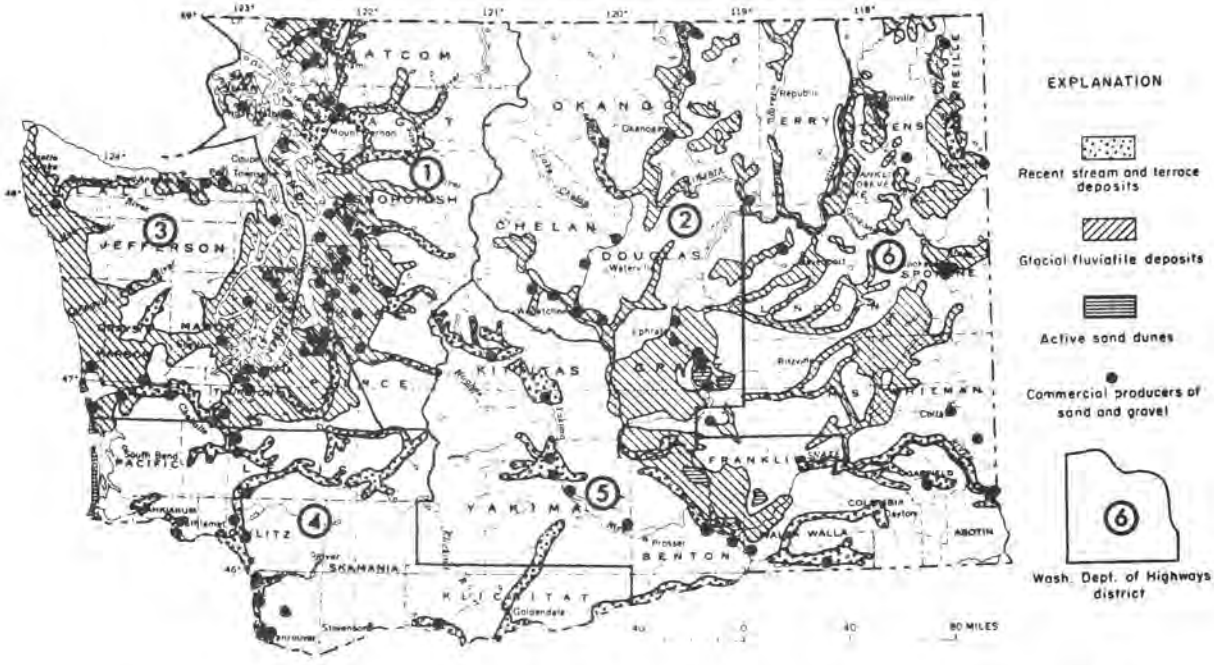

FIGURE 2.—Commercial producers of sand and gravel in Washington and boundaries of State highway districts.

At the source, washed and graded sand and gravel constitute low-cost commodities worth only around $1.20 a ton. Transportation is a major item in the marketing of these mineral products; consequently the producer locates his operation as close as possible to his market. Thus, sand and gravel producers are found in most of the cities of the state. Of the 186 sand and gravel operations active in 1975, 87, or 47 percent, of the total are in the heavily populated Puget Sound region. When local sand and gravel is not available, crushed rock is manufactured or, in coastal ports, the material is barged from deposits along the shores of Puget Sound, utilizing low-cost water transportation.

The volume of sand and gravel barged in Washington in 1975, as well as other methods of transportation, follows:

Method of transportation	Tons
Truck	14,457,859
Water	3,251,294
Rail	371,385
Unspecified	20,048
Not shipped, used at site	968,021
Total	19,068,607

There are several definitions for sand and gravel. The sand and gravel producers define sand as unconsolidated granular material coarser than 200 mesh (0.074 mm) and finer than one-fourth inch; gravel is unconsolidated granular material coarser than one-fourth inch and finer than $3\frac{1}{2}$ inches. In large concrete masses such as dams the maximum size of gravel may be 6 to 8 inches. The largest proportion of gravel is made up of rock fragments; only minor amounts of pure minerals are present. In most sands, minerals such as quartz, feldspar, chert, and mica predominate over rock fragments. Most sand and gravel deposits contain varying amounts of silt, clay, as well as rock fragments larger than desired. These undesired materials in many cases must be eliminated to meet certain specifications. The coarser material may be eliminated by screening or may be reduced to the proper size by crushing. Screening and washing equipment may be used to remove the silt or sticky clay. Many such plants are portable and moved from one job site to another.

Distribution of Deposits

Deposits of sand and gravel occur in every county of the state but vary both in quantity and quality. The general distribution of these deposits is shown in figure 2. Sand and gravel in Washington is mainly of glacial origin, having been formed as glacial moraines or as outwash material. The morainal material consists largely of heterogeneous accumulations of boulders, gravel, sand, silt, and clay that was carried along the base of the glacier or deposited along its margins. During the retreat and melting of the glacier, streams formed by melt water reworked much of the glacial debris and formed outwash deposits of sand and gravel. These fluvial glacial deposits are more homogeneous than the morainal deposits and are extensively worked for sand and gravel. In general, fluvial deposits occur in valleys where the valley is wide enough and has moderate to low grades that permit accumulation. In short narrow steep-graded valleys few significant deposits of sand and gravel accumulate. Terrace deposits left by streams as they cut their way to lower levels are fluvial deposits that are also sources of sand and gravel.

The discussion of sand and gravel deposits of Washington which follows is limited to the construction class and does not include industrial sand. As a matter of convenience the sand and gravel deposits of the state are separated into six districts that coincide with the Washington Department of Highways districts (fig. 2).

District 1.—Deposits in Whatcom and Skagit Counties are widely scattered and limited in quantity. Some granular materials are found north of Bellingham in a recessional glacial moraine. Scattered eskers in the vicinity of Blaine and a morainal ridge that parallels the Canadian border are the major producers.

Glacial till with high gravel content has been washed and crushed in this area to provide aggregate suitable for asphalt and concrete pavements. Gravel terraces, river bars, and deltaic deposits found along the Nooksack River are generally small and contain high percentages of the soft metamorphic rocks, thus making them unfit for use as mineral aggregate. However, they have been utilized for common borrow and gravel base.

Large deposits of sand and gravel derived from alpine glaciation are found along the upper reaches of the Skagit River. Particles of soft metamorphic rock also limit the use of these deposits as mineral aggregate. Continental glacial drift composed of hard subrounded gravel is present in the area of Sedro Woolley. Gravel sources south and east of Mount Vernon consist of small widely scattered alluvial deposits.

The Stillaguamish River in Snohomish County contains large gravel bars that replenish themselves during high water. These bars are west of Arlington and contain hard-rounded gravel. Large reserves of gravel are present in the terraces southwest of Arlington.

The heavy population in King County, growth of housing developments, and construction of highways has virtually depleted the available aggregate sources in the urban area of Seattle. Those sources remaining are largely confined to the north-south-trending ridge east of Issaquah, large deltaic gravels southeast of Auburn, and the glacial outwash gravels in the vicinity of Kent. Many gravel terraces are evident near the shoreline of Vashon Island, indicating good potential for development.

District 2.—District 2 encompasses parts of three diverse physiographic regions; the rugged youthful topography of the Cascade Mountains in the western part, the subdued older landforms of the Okanogan Highlands in the northern part, and the level Columbia Basin in the southeastern part. Both alpine and continental glaciers have affected the mountainous areas, and the continental ice sheet covered most of the area north and east of Waterville in Douglas County. The deposits left by the glaciers are the major sources of aggregate in the northern half of the district.

North of Okanogan and Omak the gravels are generally shallow in depth, and the size of the particles is small. Southward to the confluence of the Okanogan and the Columbia Rivers the deposits are somewhat thicker and the reserves are substantial. The gravel occurrences along the Columbia River in Okanogan County are large, of excellent quality, and well sorted. The deposits occur as low-level terraces or ancient river bars. Potential resources of this material are large but will be substantially diminished in the future as many of the areas will be inundated by the construction of large dams on the Columbia River. Rhyolite and dolomite talus deposits have been used as aggregate sources in the highland area between the towns of Omak and Conconully because of the lack of sand and gravel. Another highland area where little or no gravel is found is the basaltic plateau in T. 31 N., Rs. 26 and 27 E.; basalt from quarries is the most suitable material available in this area. In Ferry County the production of aggregate is primarily from gravel terrace deposits; however, the gravels occur as thin cappings on top of other glacial debris. Along the Columbia River boundary of Ferry County the sources are limited to the gravel topping the high terraces, as the deposits at lower elevations have been covered by Lake Roosevelt. Roadway materials and commercial aggregate production in Chelan County is from glacial outwash deposits limited to the lower elevations of the major drainages. Deposits in the Wenatchee and Entiat River Valleys and the Lake Wenatchee areas have all proven to be shallow in depth and incapable of large yield per unit area. Gravel deposits along the Columbia River in Chelan County are quite extensive and have good depth; however, many of the deposits have been inundated by the lake behind Rocky Reach Dam. Real estate developments and fruit production have made other

deposits unavailable. However, although limited, the reserves are adequate for many years at the present rate of production. Douglas County may be divided into three general regions; glaciated plateau, non-glaciated plateau, and channeled scabland. Aggregate production in all of these areas has been almost entirely from basalt quarries. However, excellent sand and gravel deposits are found along the Columbia River and lower Moses Coulee in Douglas County as terrace and river bar deposits.

Sand and gravel in Grant County occurs in huge quantities in the deltaic deposits of lower Grand Coulee and Dry Coulee; also the deposits along the Columbia River between Vantage and Vernita contain vast quantities of material. With the exception of the channeled coulee areas, the aggregate produced in eastern Grant County is entirely from basalt quarries.

District 3.—In District 3 sand and gravel deposits derived from continental glaciation are practically limitless in quantity and almost all of excellent quality. Such deposits are particularly common in the eastern one-third of the district. The Kitsap Peninsula and the area south of Bremerton to Tacoma contain vast deposits of sand. Coarse gravels are sparsely distributed, however, occurring mostly as deltaic deposits that were formed in ice-marginal bodies of water. These deltaic deposits are also well developed along the west side of Hood Canal. A glacial outwash channel extends from the southern point of Hood Canal southwestward to Shelton and on to the tributaries of the Satsop River. Gravel deposits of good quality may be obtained over most of the channel. The very large outwash plain extending south and west from Tacoma to Olympia contains excellent sand and gravel deposits of almost unlimited quantity. At Steilacoom, within this area, an exceptionally large delta deposit is located. It was deposited by escaping water from glacial Lake Puyallup as it emptied into glacial Lake Russell. The gravel came from the glacier as well as from the large channel cut between the lakes. These materials were all deposited as an enormous delta that has served as a source of high-quality aggregate for more than 50 years. The quality of this material is so high that the Washington State Highway Department has set the compressive strength of portland cement concrete made with this material as a statewide standard of quality to which all other aggregates are compared. Another vast glacial outwash plain extends south and westward from Olympia to the Chehalis River. The deposits found in this area vary from pure sand to typical gravel-bar deposits, all of which provide high-quality construction material. The terraces found along the Chehalis River valley downstream to a point approximately 6 miles west of Elma contain large quantities of sand and gravel. However, because silts and clays are intermixed, the quality of this material is limited. Although several large rivers are found on the west side of the Olympic Peninsula, the sand and gravel deposited by them is of marginal quality because it is composed largely of soft sedimentary and metamorphic rocks from the Olympic Mountains. Some scattered deposits of sand and gravel are found along the northern edge of the Olympic Peninsula from Cape Flattery to Port Angeles, but because they contain generally some soft rocks, they are used only as fill materials. Eastward from Port Angeles the aggregate quality is better because of a much higher percentage of rocks of glacial origin. Quarry rock in this district is of only minor importance for uses other than large riprap material for two reasons. First, available quantities of excellent gravels in the eastern one-third of the district encompass virtually the same area as the sound quarry rocks. Second, in the areas not richly endowed with good sand and gravel, the rock obtained from quarry sites is also of poor quality for use as any type of crushed aggregate.

District 4.—Sand and gravel deposits in District 4 may be divided into three groups: modern stream gravels, glacial outwash and terrace deposits, and older gravels which have undergone prolonged weathering.

Recent stream deposits in large quantities and of high enough quality for use in all crushed products and as concrete aggregate are confined to the channels, bars, and banks of only four rivers: the Tilton, East Fork of the Lewis, and the Columbia Rivers and the Cowlitz above the mouth of the Toutle River. Smaller deposits of good material are found along some of the smaller rivers, such as the lower Washougal, Nisqually, and many of the even smaller streams. Gravel deposits in the Toutle and Kalama Rivers, North Fork of the Lewis River and the Cowlitz below the mouth of the Toutle are composed of soft, lightweight, porous rock, and pumice sand suitable only for backfill and borrow materials. The Grays River gravel contain particles of soft shale; however, good quality gravel has been produced in areas of natural separation through an increase in the velocity of the river.

Deposits of glacial origin occur at various terrace levels along the Cowlitz and Columbia Rivers. Although these terraces contain huge quantities of sound gravel, many are very sandy or the gravel is coated with silt and clay, which necessitates washing. The use of dry scalping in strong dry winds is a very effective method of processing these materials from the terraces on the Columbia River in Klickitat County. Large deposits of outwash gravels derived from the Puget Sound glaciation are used in the vicinity of Centralia.

The usable older gravel deposits are confined to the Logan Hill Formation. This formation consists of rusty brown, well-rounded, iron-cemented, quartzite gravels with most of the sand and other fine material highly weathered. Remnants of this formation have been found in all counties of the district.

District 5.—Large quantities of high-quality sand and gravel as well as good quarry material are present in District 5. The major sources of alluvial gravels are the Yakima, Columbia, and Snake Rivers. Aggregate from these rivers is generally hard, well rounded, and of a mixed-rock type, with basic igneous rocks predominating. It is high-quality aggregate for all uses in construction.

Only one area in this district has shown any problem connected with the use of aggregate produced locally. The area from Keechelus Lake along the Yakima River to the town of Cle Elum has produced some materials of marginal quality, which contain metamorphic rocks and sandstones.

District 6.—North of the Spokane River, sand and gravel deposits are used almost exclusively for aggregate. These deposits are located along the Columbia, Kettle, Colville, and Pend Oreille Rivers, and through an area between Colville and Tiger. The deposits are very large recent river sediments that contain various rock types but do not include extrusive igneous rocks. There are, however, remnants of basalt in the Springdale Valley area of Stevens County that have been used as sources of road metal. The area roughly bounded by Sacheen Lake on the south, Tiger on the north, the Pend Oreille River on the east, and a point about 5 miles east of Colville on the west, produces poorly sorted gravel that contains a high percentage of partially altered granite that tends to break into its individual mineral particles upon crushing.

South of the Spokane River the sources for construction aggregates are basalt gravels and basalt from quarry sites. The areas of gravel are roughly in a strip running southwest from Spokane to Washtucna and along the Crab Creek drainage. These gravels vary in quality from very good to poor. In areas where the gravels are lacking or of poor quality the crushed basalt is used. The basalt is exposed in all major drainages where the silt overburden has been removed by erosion.

Summary

The sand and gravel resources of Washington are adequate for most present and near-future needs. State Highway Districts 2, 3, and 5 contain the largest reserves of high-quality sand and gravel, and in Districts 4 and 6 the deposits are scattered and of moderate size. The deposits of District 1 are scattered and limited in quantity.

In the metropolitan areas urban expansion is spreading into areas occupied by sand and gravel pits and aggregate plants. Zoning restrictions in these areas will force the closure of some operations, and relocation of these operations to rural areas will increase haulage costs. Large reserves of sand and gravel, especially in the Columbia Basin area, have been and are being depleted by flooding from hydroelectric developments and through the development of land by irrigation projects. Improved zoning regulations properly administered could be extremely helpful in conserving valuable sand and gravel resources for future use.

UNPATENTED MINING CLAIMS MUST BE RECORDED WITH BUREAU OF LAND MANAGEMENT

On October 21, 1976, the 94th Congress enacted Public Law 94-579—the Federal Land Policy and Management Act or "Organic Act." Section 314 of the act covers recordation of mining claims and abandonment, which will affect the owners of all unpatented mining claims on federal land. Specific questions about the recording of mining claims with the Bureau of Land Management may be directed to:

Bureau of Land Management
Branch of Records and Data Management
U.S. Department of the Interior
P. O. Box 2965
Portland, OR 97208
Phone (503) 234-3361, Ext. 5248

or

State of Washington
Department of Natural Resources
Division of Geology and Earth Resources
Olympia, WA 98504
Phone (206) 753-6183

The Washington Division of Geology and Earth Resources has prepared some material entitled "Questions and Answers—Recordation of Mining Claims and Abandonment." This information is available upon request.

METALS AND MINERALS CONFERENCE TO BE HELD IN SEATTLE IN MAY

The 1977 Pacific Northwest Metals and Minerals Conference will be held May 4, 5, and 6 at the Washington Plaza Hotel, 5th and Westlake, Seattle. Jointly hosted by the American Society of Metals (Puget Sound Chapter) and the American Institute of Mining Metallurgical and Petroleum Engineers (North Pacific Section), the session will be devoted to "Minerals, Material, and Energy—Their Reserves and Utilization."

For further information contact S. D. Schwarz, Shannon and Wilson, 1105 N. 38th, Seattle, WA 98103, phone (206) 632-8020.

U.S. GEOLOGICAL SURVEY OPEN-FILE MAP

The following map has recently been released by the U.S. Geological Survey and can now be inspected in our Division library:

Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho, by D. A. Swanson and others. Two plates; geologic map and explanation, consisting of cross sections and legend. Scale: 1:250,000.

U.S. BUREAU OF MINES BULLETIN 667 "MINERAL FACTS AND PROBLEMS" NOW AVAILABLE

The new "Mineral Facts and Problems," 1975 edition, is now available for a cost of $17 from the U.S. Government Printing Office in Washington, D.C. 20402. Its stock number is 024-004-01893-3. This comprehensive work (1,259 pages) discusses the industry structure, reserves, technology, supply and demand

relationships, byproducts, economic factors, operating problems, and outlook of the many mineral commodities used in our society. The report has been prepared by a group of Bureau commodity specialists and is one of the best reference books available on the mineral industry.

GEOLOGIC RESEARCH PROJECTS

Geologic research projects are a continuing process at our universities and colleges. The work now in progress within Washington State is listed below:

Central Washington State College

- Faculty Research Projects -

Structure and stratigraphy of the Columbia River Basalts. Robert D. Bentley.

Geology of the Parke Creek area, Kittitas County. Steven E. Farkas.

Glacial geology of the Waterville Plateau area. Don Ringe.

Eastern Washington State College

- Faculty Research Projects -

Paleomagnetic investigation of plutonic rocks of northeastern Washington. W. K. Steele.

Fumarole and geothermal ice cave monitoring, Mounts Rainier and Baker. E. P. Kiver.

Permian bryozoans of the carbonate units of the Mission Argillite, northeastern Washington. E. H. Gilmour.

Petrochemistry of Columbia River Basalts. F. E. Mutschler, W. L. Wilkerson, and D. F. Stradling.

- Student Research Projects -

Geologic hazards in the Spokane quadrangle. Tom Davis.

Patterned ground in the Spokane area. Lee Tallyn.

The Gillis lease on the Spokane Indian Reservation. Lee Nesbit.

Geochemistry and petrology of plutonic rocks in northeastern Washington. Walter Nijak.

Chemistry of Cascade volcanics (including Washington stratovolcanoes). Andy Leszcykowski.

Palynology of the Badger Lake area, Washington. Rudy Nickmann.

University of Puget Sound

- Faculty Research Projects -

Gravity survey of Mount Rainier area, Washington. Z. F. Danes.

Magnetic depth estimates in the Puget Sound area. Z. F. Danes.

Tectonic pattern in the State of Washington. Z. F. Danes.

- Student Research Projects -

Geophysical investigation of Mount Adams area, Washington. Steve Rowley.

Geophysical survey of Puyallup Valley area, Washington. Louis Lepp.

Crustal structure of Puget Sound from seismic data. Bob Bryce.

University of Washington

- Faculty Research Projects -

Structural and petrologic evolution of the San Juan

Islands and adjacent areas. Darrel S. Cowan and John T. Whetten.

Structure, stratigraphy, and sedimentology of the Chiwaukum graben. John T. Whetten.

Origin of chaotic rocks in the San Juan Islands. Darrel S. Cowan.

Stratigraphy, metamorphism, and tectonic evolution of the San Juan Islands. Joseph A. Vance.

Tertiary stratigraphy and structure of the area between Darrington and Skykomish. Joseph A. Vance.

Tertiary tectonic emplacement of ultramafic rocks in the Darrington area. Joseph A. Vance.

Fission track geochronology of the Tertiary volcanic rocks of the central Cascades (Mount Rainier-Darrington). Joseph A. Vance.

Chronology of neoglacial moraines at Mount Rainier. Stephen C. Porter.

Stream channel processes during aggradation, Big Beef Creek, Kitsap County. Thomas Dunne and Mary Ann Madej

Geologic hazards of the Skagit nuclear power site. Eric S. Cheney.

Stratigraphy and structure of the Okanogan Highlands. Eric S. Cheney.

Structure and origin of the Twin Sisters Dunite. Nikolas I. Christensen.

Physical properties of Olympic Peninsula graywackes. Nikolas I. Christensen.

The origin of Washington State ophiolites. Nikolas I. Christensen.

Gravity studies south and southwest of Mount Baker. Nikolas I. Christensen.

Review of geologic conditions at proposed nuclear plant sites in Washington. Howard A. Coombs.

Petrology of ultramafic hornfelses, Icicle Creek, central Cascades. B. R. Frost.

Stratigraphy and structural geology of the Wenatchee formation. Randall L. Gresens.

Marblemount 15' quad. Geology by Peter Misch 1949-1967. Peter Misch.

Mount Baker 15' quad., being compiled by Peter Misch from 1949-1975 field data.

Mount Shuksan 15' quad., compilation under preparation. Peter Misch.

Metamorphic facies and petrogenesis of Shuksan Greenschist. Peter Misch.

Petrology of Cascade River Schist and its associated metaplutonic rocks. Location: largely in Marblemount 15' quad., but includes part of Eldorado Peak, Cascade Pass and Sonnyboy Lakes $7\frac{1}{2}$' quads. Peter Misch.

Metasomatic progressive metamorphism of ultramafic rocks in Skagit Metamorphic Suite (Skagit Gneiss and Cascade River Schist). Peter Misch.

Geology, geochemistry and origin of the Golden Horn batholith. With R. T. Stull. Includes parts of Crater Mtn., Azurite Peak, Slate Peak, Mount Arriva, Washington Pass, Silver Star Mountain, $7\frac{1}{2}$' quads., etc. Peter Misch.

Outline of the petrology of the Yellow Aster Complex (the pre-Devonian basement of the Northwestern Cascades). Peter Misch.

Glacier Peak tephra in the eastern North Cascades. Stephen C. Porter.

Paleontology of the Ringold Formation. John M. Rensberger and Eric Gustafson.

Stratigraphy and structure of rocks in the Hoh River—Clearwater River area, western Olympic Peninsula. Richard J. Stewart.

- Graduate Program -

Contact metamorphism of marbles, Cave Ridge, Snoqualmie batholith. David Mogk.

Volcanic and glacial stratigraphy of the Goat Rocks area, central Cascade Mountains. Geoffrey Clayton.

Mechanics of river meanders, Sinlahekin River. William Dietrich.

Geology and petrology of the Chaval Mountain area, North Cascades, Washington. Jeremy Boak.

Geology of the McClure Mts. area, Okanogan County, Washington. F. William Burnet.

Factors affecting the geochemistry of Williamson Creek, Snohomish County, Washington. David Dethier.

Hydrothermal clay and thermal activity in source areas of debris avalanches at Mount Rainier and Mount Baker. David Frank.

A structural and petrologic study of the Chiwaukum schist north and east of Stevens Pass, Washington. Jennifer Getsinger.

Paleoecology of the sagebrush region of eastern Washington. Dennis Hibbert.

Late Quaternary evolution of western Washington coast. A. Dan Horn.

Stratalogic analysis of the Intra-Miocene Ochoco unconformity in Washington-Oregon. Sandra Leo.

Fossil vertebrates from the Clarendonian and Hemphillian of northern Oregon and Washington. James Martin.

Structure and petrology of the Ingalls Complex and associated pre-Tertiary rocks near Mount Stuart, central Cascades. Robert Miller.

Detailed structure of a segment of the Ross Lake Fault west of Ross Lake. Wesley Wallace.

Chemical alteration of Quaternary sediments, Puget Lowlands, Washington. Linton Wildrick.

Paleontology of the Skookumchuck Formation in the Central-Chehalis area, Washington. Bruce Wiley.

Geophysics Program

- Geophysical Research Projects -

Earthquake swarms at Wooded Island (on Columbia River by Richland). G. Rothe, S. W. Smith, J. Booker.

Seismicity and gravity changes at Mount Baker. S. Malone, S. W. Smith.

Gravity and magnetic investigation of the Skagit Valley. W. Foxall.

Gravity and seismic investigation of the Chiwaukum graben. R. Silling.

Methods of avalanche prediction and control. E. LaChapelle.

Investigation of the Blue Glacier, Mount Olympus. C. Raymond.

Seismicity in the Puget Sound region. R. Crosson.

Seismicity in the Lake Chelan-Grand Coulee region. S. W. Smith and S. Malone.

Seismicity in the Hanford region. N. Rasmussen.

Structure of the ocean-continent transition. B. Lewis.

Gravity and elevation changes in western Washington. N. Rasmussen and R. Bostrom.

Western Washington State College

- Recently Completed Master's Theses -

Ca-Al phase relations of the Shuksan metamorphic suite, north Cascades, Washington. Jami Fernette.

- Master's Theses Proposals -

Origin of landslides in the lower Skagit and Baker River valleys, Washington. Paul Heller.

Puget Sound bluff stability and shoreline changes in Skagit County, Washington. Ralph F. Keuler.

Seasonal ecology of Recent Benthic Foraminifera in Samish Bay, Washington. Garry Jones.

Structural analysis of the Shuksan metamorphic rocks near Gee Point, north Cascades, Washington. Michael Morrison.

The relationship between ultramafic rocks and Shuksan metamorphic rocks near Gee Point, north Cascades, Washington. Daniel Wilson.

Volcanic geology of a portion of the south flank of Mount Baker, Washington. Doug McKeever.

The tectonic environment of the Fidalgo ophiolite. Daryl Gusey.

The shape of the paleomagnetic field using directional data sets. David Engebretsen.

The role of shoredrift in the origin of beach cusps. John Spasari.

The relationship of geologic setting to coal petrography. Bob Crandall.

Paleomagnetic study of the Teanaway Basalts and Goble Volcanics, Washington. Cynthia Burr.

Stratigraphy and chronology of raised beach terraces, Bay View Ridge, Skagit County. Relative isostatic and eustatic changes since the Everson interstade. Bob Siegfried.

- Faculty Research Projects -

Paleomagnetism and tectonics of southwestern Washington. Myrl Beck.

Paleomagnetism of the Mount Stuart batholith. Myrl Beck.

Magnetic properties of basalt from the Cobb seamount. Myrl Beck.

Regional geophysics of northwestern Washington. Myrl Beck.

Petrology and structure of the Shuksan metamorphic unit, north Cascades, Washington. Edwin H. Brown.

Origin of ophiolite in the San Juan Islands. Edwin H. Brown.

Semiahmoo Bay tidal currents, Whatcom County, Washington. Maurice L. Schwartz.

Port Susan Bay tidal sedimentation. Maurice L. Schwartz, Geology and Thomas Terich, Geography.

Study of the Tertiary coals of western Washington. Charles A. Ross.

Back-calculations of soil strength parameters from simple measurements on landslides. Andre Lehre.

Petrology and geochemistry of intrusive rocks in the Illabot range, north Cascades, Washington. R. S. Babcock.

Petrology and geochemistry of the Chilliwack composite batholith, north Cascades, Washington. R. S. Babcock.

Petrology and geochemistry of crystalline rocks on southern Fidalgo Island and northern Whidbey Island, Washington. R. S. Babcock.

Paleomagnetism of Pleistocene sediments in the Puget Lowland. Don Easterbrook.

Slope stability of coastlines of Whatcom County. Don Easterbrook.

Chronology and correlation of Pleistocene sediments. Don Easterbrook.

Volcanic and glacial history of Mount Baker. Don Easterbrook.

Washington State University

Department of Geology

- Research Projects -

Geology of Squaw Creek prospect, Northport, Stevens County. Francis Beka and Joseph W. Mills.

Structural analysis of China Bend, northeastern Washington, Stevens County. Jason Bressler.

Copper-gold prospects, Kettle Falls, Stevens County. Michael Broch and Joseph W. Mills.

Geophysical investigation of Washington ground-water resources, eastern Washington. James W. Crosby III.

Geophysical investigation of physical properties of Ringold Formation, Hanford Reservation. James W. Crosby III.

Geophysical investigation of Pullman-Moscow groundwater basin, Whitman County, Washington, Latah County, Idaho. James W. Crosby III.

Structural analysis of the Nancy Creek metamorphic terrace, Ferry County, northeastern Washington. Brian Donnelly.

Petrology of the Metaline Limestone, Stevens and Pend Oreille Counties, Washington. Howard Fischer.

Columbia River Basalt stratigraphy, petrology and geochemistry in Asotin and Whitman Counties. Peter R. Hooper.

Metaline Limestone-Ledbetter Slate contact, Stevens County. Bruce Hurley and Joseph W. Mills.

Uranium concentration in the ground waters of the Pullman-Moscow basin, Latah County, Idaho

and Whitman County, Washington. Vernon Ichimura.

Mineralogy of the sediments of Wildcat Lake, Starbuck quadrangle, Whitman County. Clarence Johnson.

Friability of Addy Quartzite, Stevens County. Gale Knutsen and Joseph W. Mills.

Mineralogy of oxides and sulfide accessory minerals of Columbia River Basalt of southeastern Washington. David Korzendorfer and Joseph W. Mills.

Base metal sulfides and barite in middle to late Paleozoic clastic metasedimentary rocks of northeastern Washington. Joseph W. Mills.

Wall-rock alteration at the Rendezvous prospect, Methow Valley, Okanogan County. Donatus Orazulike.

Geochemistry of Wildcat Lake, Whitman County, Washington. Philip E. Rosenberg and Franklin F. Foit, Jr.

Beach erosion in the San Juan Islands, San Juan County, Washington. W. Frank Scott.

Cretaceous stratigraphy, San Juan Island, San Juan County. W. Frank Scott.

National geological natural landmarks program, U.S. National Parks Service, Columbia River Plateaus. W. Frank Scott.

Petrogenesis of Mount Baker, Washington, Whatcom County. Victor Swan.

Structural synthesis of Kootnay Arc, northeast Washington, Stevens County. A. John Watkinson.

Fluid inclusion thermometry, lead-zinc ores, Pend Oreille County. Nancy Wotruba and Joseph W. Mills.

Whitman College

Department of Geology

Landslides along Hood Canal. Jeff Gryta, North Carolina State U.; R. J. Carson.

Quaternary faults of southeastern Olympic Peninsula. Joe Wilson, Gardner-Webb College; R. J. Carson; M. J. Bartholomew, Longwood College.

Quaternary and environmental geology of eastern Jefferson County. R. J. Carson; Marty Gayer , North Carolina State University; Kathryn Hanson.

Slope stability in the southern Hood Canal area. Mackey Smith, Washington Division of Geology and Earth Resources; R. J. Carson.

Relative compressibility of earth materials in the southern Hood Canal area. R. J. Carson; Mackey Smith, Washington Division of Geology and Earth Resources.

Yakima Valley College

Geologic hazards of Yakima County, Washington. Newell Campbell.

Geohydrology and the Moxee Bog. Newell Campbell and Lynn Hendrix.

Mineral identification of the Cowan and Eustace collections, Yakima Valley Historical Museum. Newell Campbell.

IN MEMORIUM

W. A. G. (Ben) Bennett was born in Hickory County, Missouri in 1900. He died on February 8, 1977 in his home in Olympia. Surviving are his wife Maude, Olympia; a son Major William Glenn Bennett, stationed at Scott Air Force Base in Illinois; and three grandchildren.

Ben was a geologist with the Division of Geology and Earth Resources for many years before he retired in 1970. His degree in geology was obtained from Washington State in 1925 and his master's in 1928. He then worked for the Anaconda Copper Co. until 1930 when he returned to teach geology at Washington State until 1935. He returned to school

at the University of Chicago and received his doctorate in 1937.

Ben was a member of the Geological Society of America, America Institute of Mining and Metallurgical Engineers, American Men of Science, American Geophysical Society, Sigma Gamma Epsilon, and Kappa Epsilon Pi.

YOUR STATE GEOLOGIST REPORTS

My old friend W. A. G. Bennett passed on last month. As I sat at his funeral listening to the eulogy, two words were used that almost told Ben's (as he was known to his fellow workers) whole life. Those two words were "gentleman" and "unostentatious." I don't know that I have ever met a more gentlemanly, kindly person than Ben; there was not a pretentious bone in his body. I believe Ben epitomized what I would call a professional person. He was quiet, unassuming, perfectly honest, and I don't think I ever heard him say an unkind word about anyone. He lived for geology; whereas, most of us use geology as a means to an end, geology was the end to Ben. After he retired from our Division, he bought himself a petrographic microscope and continued to study a shonkinite intrusive that had intrigued him for years.

The world is poorer at Ben's passing, but it is also richer because of his life. To his dear wife Maude and son Bill the entire Division staff expresses their sympathy and regret. He was a good man, and we are better for having known him.

Ted Livingston

U.S. GEOLOGICAL SURVEY 7½-MINUTE TOPOGRAPHIC QUADRANGLES
(Maps received in the division library since July 1, 1976)

Name	New edition	Photo revised	Latitude (indicates southeast corner)	Longitude	County
Deming	1972		48°45'00"	122°07'00"	Whatcom
Enumclaw		1968;1973	47°07'30"	121°52'30"	King; Pierce
Grayland		1973	46°45'00"	124°00'00"	Grays Harbor; Pacific
Knappton		1973	46°15'00"	123°45'00"	Pacific
La Conner		1968;1973	48°22'30"	122°22'30"	Skagit
Maple Falls	1972		48°52'30"	122°00'00"	Whatcom
Marysville		1968;1973	48°00'00"	122°07'30"	Snohomish
Reardan West	1973		47°37'30"	117°52'30"	Lincoln
Wellpinit		1973	46°52'30"	117°52'30"	Stevens
Westport		1973	46°52'30"	124°00'00"	Grays Harbor
Yakima West		1974	46°30'00"	120°30'00"	Yakima

15-MINUTE TOPOGRAPHIC QUADRANGLES

Ayer (formerly Haas, reprinted in 1976)	1948		46°30'00"	118°15'00"	Franklin; Walla Walla

Department of Natural Resources
Division of Geology and Earth Resources
Olympia, WA 98504

April 1977

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