LOCATION MAP
DIVISION OF GEOLOGY AND EARTH RESOURCES

STAFF

Regulations (Surface Mined Land Reclamation and Oil and Gas Conservation Act):
Donald M. Ford
Ralph H. Kimmel

Minerals and Energy:
J. Eric Schuster
Weldon W. Rau
Wayne S. Moen
Ellis R. Vonheeder
John M. Lucas

Environmental geology:
Gerald W. Thorsen
Ernest R. Artim
Mackey Smith
Allen J. Fiksdal
Kurt L. Othberg
Pamela P. Ferguson

Library
William H. Reichert

Mailing address: Department of Natural Resources
Division of Geology and Earth Resources
Olympia, WA 98504
(206) 753-6183

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 loading. 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

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 $80,99 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:

<table>
<thead>
<tr>
<th>Product</th>
<th>Tons (millions)</th>
<th>Value (millions of dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand and gravel</td>
<td>17.7</td>
<td>35.11</td>
</tr>
<tr>
<td>Stone</td>
<td>7.7</td>
<td>13.49</td>
</tr>
<tr>
<td>Coal</td>
<td>3.9</td>
<td>*25.00</td>
</tr>
<tr>
<td>Cement</td>
<td>1.42</td>
<td>53.47</td>
</tr>
</tbody>
</table>

*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.

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

Average value $1.93 per ton

<table>
<thead>
<tr>
<th>Unprocessed sand and gravel</th>
<th>Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill</td>
<td>2,347,275</td>
</tr>
<tr>
<td>Road base</td>
<td>1,351,109</td>
</tr>
<tr>
<td>Other</td>
<td>43,601</td>
</tr>
<tr>
<td>Total</td>
<td>3,741,994</td>
</tr>
</tbody>
</table>

Average value $1.20 per ton

<table>
<thead>
<tr>
<th>Industrial sand</th>
<th>Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>31,000</td>
</tr>
<tr>
<td>Blast, engine, etc.</td>
<td>26,745</td>
</tr>
<tr>
<td>Total</td>
<td>57,745</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Method of transportation</th>
<th>Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck</td>
<td>14,457,859</td>
</tr>
<tr>
<td>Water</td>
<td>3,251,294</td>
</tr>
<tr>
<td>Rail</td>
<td>371,385</td>
</tr>
<tr>
<td>Unspecified</td>
<td>20,048</td>
</tr>
<tr>
<td>Not shipped, used at site</td>
<td>968,021</td>
</tr>
<tr>
<td>Total</td>
<td>19,068,607</td>
</tr>
</tbody>
</table>

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 3½ 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, nonglaciated 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 Nisqually 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 contains 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 Kechelus 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 Washultna 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.

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. Forkas.
Glacial geology of the Waterville Plateau area. Don Ringe.

Eastern Washington State College
- Faculty Research Projects -
Fumarole and geothermal ice cave monitoring, Mounts Rainier and Baker. E. P. Kiver.

- 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 Laszczynowski.

University of Puget Sound
- Faculty Research Projects -
Magnetic depth estimates in the Puget Sound area. Z. F. Danes.
Tectonic pattern in the State of Washington. Z. F. Danes.

- Student Research Projects -
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
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
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-
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
Petrology of ultramafic hornfelses, Icicle Creek,
Stratigraphy and structural geology of the Wenatchee
formation. Randall L. Gresens.
Marblemount 15' quad. Geology by Peter Misch
Mount Baker 15' quad., being compiled by Peter
Misch from 1949-1975 field data.
Mount Shuksan 15' quad., compilation under prepara-
tion. 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 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 Arvilla, Washington Pass, Silver Star
Mountain, 7 1/2 quads., etc. Peter Misch.
Outline of the petrology of the Yellow Aster Complex
(the pre-Devonian basement of the North-
western 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

- Graduate Program -
Contact metamorphism of marbles, Cave Ridge,
Snoqualmie batholith. David Magk.
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,
Geology of the McClure Mts. area, Okanogan
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.


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

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


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


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. Stilling.

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.


Western Washington State College

- Recently Completed Master's Theses -


- Master's Theses Proposals -


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


The tectonic environment of the Fidalgo ophiolite. Daryl Gusey.

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

The role of shoal drift 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  

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

- Faculty Research Projects -  

Paleomagnetism and tectonics of southwestern Washing- 
ton.  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 aphiolite in the San Juan Islands.  
Edwin H. Brown.

Semiahmoo Bay tidal currents, Whatcom County,  

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 com- 
posite batholith, north Cascades, Washington.  
R. S. Babcock.

Petrology and geochemistry of crystalline rocks on  
southern Fidalgo Island and northern Whidbey  

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 Wash- 
ington, 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 ground- 
water basin, Whitman County, Washington,  
Latah County, Idaho.  James W. Crosby III.

Structural analysis of the Nancy Creek metamorphic  
terrace, Ferry County, northeastern Washing- 
ton.  Brion 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.


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


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.


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

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

Yakima Valley College


IN MEMORIAM

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, American Institute of Mining and Metallurgical Engineers, American Men of Science, American Geophysical Society, Sigma Gamma Epsilon, and Kappa Epsilon Pt.

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)

<table>
<thead>
<tr>
<th>Name</th>
<th>New edition</th>
<th>Photo revised</th>
<th>Latitude (indicates southeast corner)</th>
<th>Longitude (indicates southeast corner)</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deming</td>
<td>1972</td>
<td></td>
<td>48°45'00&quot;</td>
<td>122°07'00&quot;</td>
<td>Whatcom</td>
</tr>
<tr>
<td>Enumclaw</td>
<td>1968;1973</td>
<td></td>
<td>47°07'30&quot;</td>
<td>121°52'30&quot;</td>
<td>King; Pierce</td>
</tr>
<tr>
<td>Grayland</td>
<td>1973</td>
<td></td>
<td>46°45'00&quot;</td>
<td>124°00'00&quot;</td>
<td>Grays Harbor; Pacific</td>
</tr>
<tr>
<td>Knappston</td>
<td>1973</td>
<td></td>
<td>46°15'00&quot;</td>
<td>123°45'00&quot;</td>
<td>Pacific</td>
</tr>
<tr>
<td>La Conner</td>
<td>1968;1973</td>
<td></td>
<td>48°22'30&quot;</td>
<td>122°22'30&quot;</td>
<td>Skagit</td>
</tr>
<tr>
<td>Maple Falls</td>
<td>1972</td>
<td></td>
<td>48°52'30&quot;</td>
<td>122°00'00&quot;</td>
<td>Whatcom</td>
</tr>
<tr>
<td>Marysville</td>
<td>1968;1973</td>
<td></td>
<td>48°00'00&quot;</td>
<td>122°07'30&quot;</td>
<td>Snohomish</td>
</tr>
<tr>
<td>Reardon West</td>
<td>1973</td>
<td></td>
<td>47°37'30&quot;</td>
<td>117°52'30&quot;</td>
<td>Lincoln</td>
</tr>
<tr>
<td>Wellpinit</td>
<td>1973</td>
<td></td>
<td>46°52'30&quot;</td>
<td>117°52'30&quot;</td>
<td>Stevens</td>
</tr>
<tr>
<td>Westport</td>
<td>1973</td>
<td></td>
<td>46°52'30&quot;</td>
<td>124°00'00&quot;</td>
<td>Grays Harbor</td>
</tr>
<tr>
<td>Yakima West</td>
<td>1974</td>
<td></td>
<td>46°30'00&quot;</td>
<td>120°30'00&quot;</td>
<td>Yakima</td>
</tr>
</tbody>
</table>

15-MINUTE TOPOGRAPHIC QUADRANGLES

<table>
<thead>
<tr>
<th>Name</th>
<th>New edition</th>
<th>Latitude (indicates southeast corner)</th>
<th>Longitude (indicates southeast corner)</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ayer</td>
<td>1948</td>
<td>46°30'00&quot;</td>
<td>118°15'00&quot;</td>
<td>Franklin; Walla Walla</td>
</tr>
</tbody>
</table>

(formerly Haas, reprinted in 1976)