**Division Publications**

Geologic maps of part of the Yakima Fold Belt, northeastern Yakima County, Washington, Open File Report 93-3, by Robert D. Bentley, Newell P. Campbell, and John E. Powell. Contains maps of the Yakima East, Harrash, Toppenish, and Granger 15-minute quadrangles, scale 1:31,680, and a set of associated cross sections. 5 folded sheets and a 13-page pamphlet that includes a table of major element analyses of basalt in the area. $8.33 + $0.67 tax (WA residents only) = $9.00

Roadside geology of Mount St. Helens National Volcanic Monument and vicinity, Information Circular 88, by Patrick T. Pringle has gone into its second printing! This 120-page book explains the geologic history of the Mount St. Helens area and provides mile-by-mile geologic road guides for seven routes of approach to the mountain. A geologic primer and glossary are included. (It is also available at Mount St. Helens National Volcanic Monument visitor centers.) $3.24 + $0.26 tax (WA residents only) = $3.50.

Please include $1.00 with all publications orders to cover postage and handling.

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**DGER Spokane Field Office Has Moved**

The Division of Geology and Earth Resources Spokane Field Office has moved to the old Post Office Building in downtown Spokane. Bob Derkey and Chuck Gulick are now in Room 209 on the same floor as the USGS geologists.

The new address is:

Department of Natural Resources
Division of Geology and Earth Resources
904 W. Riverside, Room 209
Spokane, WA 99201-1011

Phone: 509/456-3255
Fax: 509/456-6115

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**Publications of the Association of American State Geologists**


- The State Geologists Journal disseminates information about the organization, facilities, activities, accomplishments, and publications of state surveys and mining bureaus. It is $10 for the single issue per year.

- The AASG Fact Book, updated annually, offers information about the programs of each of the state surveys and lists program managers and telephone numbers. It’s available for $10.

Orders may be sent to Dr. Thomas M. Berg, Ohio Geological Survey, Dept. of Natural Resources, 4383 Fountain Square Drive, Bldg. B, Columbus, OH 43224-1362.

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**Directory of Geoscience Libraries, United States and Canada**

4th edition, 1993

Geologists - Hydrologists - Engineers!

Find sources for those elusive, site-specific geologic reports, open-file reports, theses, and maps. This book describes the collections, accessibility and services of 591 corporate, governmental, academic, and private geoscience libraries in the U.S. and Canada. It also lists addresses, e-mail, fax, and phone numbers. $35 per copy (prepaid, U.S. dollars). Order from: Publications Manager, Geoscience Information Society, c/o American Geological Institute, 4220 King Street, Alexandria, VA 22302.
National Geologic Mapping Act Update

by Raymond Lamann

In fiscal year 1993, Congress appropriated $21,982,000 for the National Geologic Mapping Program. The funds for federal FY 93 were divided by program components as follows:

<table>
<thead>
<tr>
<th>Program</th>
<th>Authorization</th>
<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal mapping</td>
<td>$12,500,000</td>
<td>$10,852,000</td>
</tr>
<tr>
<td>Federal support</td>
<td>9,500,000</td>
<td>9,791,000</td>
</tr>
<tr>
<td>State mapping</td>
<td>15,000,000</td>
<td>1,339,000</td>
</tr>
<tr>
<td>Education support</td>
<td>500,000</td>
<td>0</td>
</tr>
</tbody>
</table>

Note that the U.S. Geological Survey (USGS) mapping program received 87 percent of authorization, USGS mapping support received 103 percent of authorization, education was not supported, and state mapping was supported at 9 percent of authorization.

Forty-four states submitted proposals to receive a portion of the $1,339,000. Our original request to the USGS was for field mapping and analytical support and for the cost of printing the 1:250,000-scale maps of the southeast quadrant. This grant request for $5,100 was rejected.

On September 3, 1993, we submitted a modified request for $25,000. The scope of this proposal is to acquire geologic data in the Roche Harbor and Bellingham 1:100,000-scale quadrangles. Radiostratigraphic dating, geochemistry, and travel costs were included in the proposal, which was approved by the USGS on September 30.

The National Geologic Mapping Act authorization for state mapping support in FY 94 is $18,000,000. The American Association of State Geologists (AASG) continues to support full funding for the National Geologic Mapping Program. However, AASG believes it is imperative that the program receive an increase of at least $10 million over the President’s budget for FY 94. Also, AASG has taken the position that the allocation of the budget be made among the four program elements in proportion to the authorization in the National Geologic Mapping Act of 1992.

The rationale for the proposed increase above the President’s budget for FY 94 is to maintain the federal mapping program element at their FY 93 level, to increase support of the state mapping program element to a more reasonable level, and to begin funding the educational program.

If the increase is obtained and the allocation is made in proportion to authorization levels for FY 94, then the FY 94 program would be as follows:

- Federal mapping: $11,112,000
- Federal support: 7,952,000
- State mapping: 13,306,000
- Education support: 612,000
- Total: $33,982,000

The state of Washington would benefit from full funding of the act for FY 94, but we must recognize that the federal budget deficit will make it extremely difficult to achieve that goal.

REGULATORY INFORMATION

Information Packages
- Geothermal Resources Act and accompanying rules and regulations
- Oil and Gas Conservation Act and accompanying rules and regulations
- Surface Mining Land Reclamation Act and accompanying rules and regulations
- Underground Gas Storage Act

These items are free unless otherwise noted. Send your order, with a check for the required amount made out to the Department of Natural Resources, plus $1.00 for postage and handling, to:

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Fax: 206-902-1785

Please include $1.00 with all publications orders to cover postage and handling.

HOW TO FIND OUR MAIN OFFICE

DGER Staff Changes

STAFF TRANSFERS

Venice Goetz (Geologist 2) has transferred to the Division of Forest Practices and has been promoted to Natural Resource Scientist 2. She will be doing watershed analysis and slope stability assessment for timber harvest.

Rex Hapala (Research Technician) has transferred to the Southwest Region, based in Castle Rock, and has been promoted to Geologist 2. He will be working as a surface mine reclaimed manager.

Naomi “Ninee” Hall (Clark Typist 3) has transferred to the Division of Forest Land Management.

Shelley Reicher (Clark Typist 2) is now a Fiscal Technician for the Division of Aquatic Lands.

Joan Castaneda (Clark Typist 2) has also transferred to the Division of Aquatic Lands.

NEW STAFF

Angela Stanton (Clark Typist 3) is a transfer from the North-West Region in Sedro-Woolley, where she worked for six years with the surface mining, service forestry, and forest practices programs. Before that she was at the Southeast Region in Ellensburg for four years—two in Lands and two in the Radio Room. Angela plans to continue working toward a degree in business administration.

Karin Lang (Clark Typist 2) is another new addition to our staff. Her early work experience is as a photographer. For the last three years, since her arrival in Olympia, she has spent the summers as a PBD Operator with the Division of Fire Control and winters as a staff photographer for the State Legislature. She is also a published poet. Karin plans to continue working toward a degree at Puget Sound Community College.

Winners Named in SME "Outstanding Student Paper Contest"
The North Pacific Section of the Society of Mining Engineers distributed awards to winners of the section’s Outstanding Student Paper Contest at its monthly meeting in May. Lynne Holland, Western Washington University, won first place in the Graduate Division for her paper titled "Fourier transform infrared spectroscopy quantitative analysis of leached copings over porphyry copper deposits"; she received a $400 scholarship. Richard Chaney, also of Western Washington University, won second place in the Graduate Division for his paper, "A study of gold mineralization at the Boundary Red Mountain deposit, Whatcom County, Washington" and received a $300 scholarship.

First place winner in the Undergraduate Division was Michelle Robinson, University of British Columbia; her paper is titled "Genesis of the "Blonde" carbonate-hosted Zn-Pb-Ag deposit, north-central Yukon Territory—Geologic, fluid inclusion, and isotopic constraints." She won a $400 scholarship.

Sponsors of the contest were Golder Associates, Inc., of Redmond, WA; Inglima Ltd. of Vancouver, BC; Robbins Company of Kent, WA; ASARCO of Tacoma, WA; and Corby Smith, Jr., of Bellingham, WA.

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Washington Geology, ISSN 0585-2134, is published four times a year by the Washington Department of Natural Resources, Division of Geology and Earth Resources. This publication is free upon request. The Division also publishes bulletins, information circulars, reports of investigations, geological maps, and specific reports. A list of these publications will be sent upon request.

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Russian Geologists to Speak at Northwest Mining Convention

For decades, world leaders and people in the mining industry have been dealing with endless supply of minerals that lay hidden in the former Soviet Union. Some of the mystery surrounding Russian mineral resources will be lifted this December in Spokane at the 99th annual meeting of the Northwest Mining Association.

A half-dozen experts from throughout Russia will share their knowledge of Russian geology and related mineral sciences at the NWMA short course “Global Business Opportuni- ties—Emerging Economies” from Nov. 29–30 and the NWMA convention “International—Pros and Cons” from Nov. 30–Dec. 3.

The invited speakers include Dr. Anatoly Sidenov and Dr. Leonid Parfenov of the Russian Academy of Sciences who will discuss opportunities and problems for joint mining ventures in the Russian Far East.

Parfenov, who is chief for the Laboratory on Regional Geology and Tectonics at Vostok in northern Siberia, will also open the convention on the luncheon speaker on December 1. His address will be “The Life of a Russian Geologist in Siberia.” Before his appointment to Siberia about 10 years ago, he was chief of a similar laboratory at the Institute of Tectonics and Geophysics at Khabarovsk in the central Russian Far East.

Other Russian scientists will discuss the geology and minerals of their country on December 2 and 3.

Northwest Mining Association
CONVENTION, SHORT COURSES, AND TRADE SHOW
Spokane, November 28–December 3, 1993

Convention (Nov. 30–Dec. 3)

The theme of the convention is “International—Pros and Cons.” Development, discoveries, and opportunities in the Americas and the former Soviet Union will be examined.

Trade Show (Dec. 1–3)
The trade show will again have 300 or more displays of products and services available to the minerals industry.

Short Courses (Nov. 28–30)

- Global Business Opportunities—Examining the Differences. Regions to be emphasized are Russia, the Pacific Rim, Latin America, and Asia. Topics will include: financial and legal considerations; environmental protection requirements and awareness of how local customs and culture affect business practices.
- Applied Biochemical Prospecting in Forested Terrain. Course will cover basic principles of bio-chemical prospecting and lead participants through “state-of-the-art” knowledge, leaning heavily on the experience of Russian scientists in the Pacific Northwest, British Columbia, and the boreal forests of Canada.

For More Information
Contact the Northwest Mining Association, 10 N. Post, Suite 414, Spokane, WA 99201-0772; Phone: 509/624-1158; Fax: 509/623-1241.

Prospectors & Developers Association of Canada
INTERNATIONAL CONVENTION
AND TRADE SHOW
Typee, March 5–6, 1994

PDAC Convention 94 will offer the latest information and news on investment, business, and technological aspects of worldwide natural resource development. These three days of technical sessions, a one-day short course, a special session for adjudicated papers, a trade show with over 250 exhibitors, and social events will provide an excellent opportunity for delegates to learn, inform, and update their knowledge on the mineral industry in Canada and abroad.

Technical Program

The technical program is under development and areas already defined include papers, presented by leading experts on:

- Alternative methods of financing exploration projects
- The global search for diamonds and the economics of diamond mining
- Gold projects in developing countries
- International discoveries and developments

There will be a strong focus on international exploration and development in special sessions where government or industry representatives will be able to discuss investment opportunities and the state of the mineral industry in their home country.

Short Course

A full-day short course on Saturday, March 5, entitled “Prospecting in Tropical Terrains”, will take a close look at the unique geological, biological, and social aspects of tropical and sub-tropical countries.

Call for Papers

The Open Forum is a special session of adjudicated papers that runs parallel to the main technical program. Typically, the forum covers a wide variety of exploration and development-related topics, including financing, geophysical and geochemical techniques, deposit descriptions, case histories, applications of new technologies, geological practice of various countries, and software applications. Please send an abstract of no more than 200 words by January 7, 1994, to Mrs. Salley Lowton in the PDAC office.

Mine Tours

There are tentative plans to offer delegates the opportunity for an overview of mineral districts and their relative importance on the world scene, financing, legal considerations, environmental protection requirements and awareness of how local customs and culture affect business practices.

- Applied Biogehemical Prospecting in Forested Terrain. Course will cover basic principles of bio-chemical prospecting and lead participants through “state-of-the-art” knowledge, leaning heavily on the experience of Russian scientists in the Pacific Northwest, British Columbia, and the boreal forests of Canada.

The ‘Geology’ of Papermaking

Joerg A. Bleek and Reed L. Sherar
Washington River Rivers P.O. Box 3, 300 N. Pelikan Road Woodland, WA 98674

INTRODUCTION

You have probably come across old books and newspapers that were irreparably damaged when watered with age and crumbled when you turn the pages. This deterioration is due to the acidic nature of the most common commercial papermaking process which makes paper weak and brittle for libraries and archives that must keep these materials available for users—restoration and preservation are expensive activities. Changes in the chemistry of papermaking (and to some extent ink) over the last 30 years have improved the life span of today’s papers by making it possible to produce acid-free paper at a much lower cost. This means that many of the books printed in 1993 will look just as good as they do in the year 2093—in fact, for hundreds of years to come.

HOW PAPER IS MADE

Paper is a thin mass of cellulose fibers made from some kind of vegetable fiber, usually wood fiber. In the most common commercial papermaking process, wood is ground up and the fibers are then treated and bleached to produce paper “pulp.” Wood fibers contain a high percentage of lignin and other impurities that, if left in the paper, eventually decay and produce acid that attacks the cellulose, turning the paper brown and brittle. Wood pulp requires extensive treatment before it’s suitable for ordinary papermaking and even more treatment before its properly bleached, sized, and made into “printable” paper. Resin and alum (aluminum sulfate) have commonly been added to “size” the paper. This process is done under acidic conditions (pH<5.7), and releases explosive fillers and coatings that do not dissolve in acid (commonly kaolin clay from Georgia and more fiber) must be used.

CALCIUM CARBONATE AND THE FILLER AGENT

As manufacturers searched for economical methods of producing paper, they began to replace resin and alum with an “inert” filler agent known as calcium carbonate or “synthetic” or precipitated calcium carbonate. Natural calcium carbonate is mined from high-grade calcite deposits and then finely ground. It is referred to as “filler” or “GCC,” or GCC, in the paper industry. Chemically precipitated calcium carbonate is also used on paper and is known as GCC. Calcium carbonate used for filler is referred to as “filler,” whereas calcium carbonate used for coating is referred to as “coating grade.” The two grades differ in particle size, the ratio of water to solids in the GCC slurry, and other characteristics.

The mineral is not only an inexpensive whitening pigment for filler and coating, but, in the case of GCC, the raw material is readily available worldwide, although deposits of limestone or marble that have suitable brightness and purity are limited. GCC, on the other hand, is produced by chemical processes (Fig. 1) and has some limitations, particularly in regard to how much can be added as filler.

In Europe, the use of ground calcium carbonate is the more widely used type of filler. Limestone or marble of high purity is ultra-fine ground by a sophisticated “water-grinding” method. Ninety percent of the particles are less than 2 microns (1 micron = 1 millionth of a meter) in diameter (Fig. 1). The particles are suspended in a slurry that consists of about 75 percent solids (cover photo). In the U.S., GCC – 3 – Washington Geology, vol. 21, no. 3
PRECIPITATED CALCITE CARBONATE

<table>
<thead>
<tr>
<th>raw rock</th>
<th>heating</th>
<th>crushing</th>
<th>grinding</th>
<th>floatation</th>
<th>GGC</th>
</tr>
</thead>
</table>
| marble, limestone, or chalk | heat | quicklime | carbon dioxide | | | CaCO₃
| quicklime plus water (slaking) | alkali | slaked lime | | | | Ca(OH)₂
| slaked lime plus water (carbonization) | | carbonization | | | | CO₂

Positive Rhombohedral Calcite

Ground Calcium Carbonate

<table>
<thead>
<tr>
<th>raw rock</th>
<th>grinding</th>
<th>floatation</th>
<th>GGC</th>
</tr>
</thead>
</table>
| limestone | | | | CaCO₃

Figure 1. Comparison of the properties for producing pre- precipitated calcium carbonate (GCC) and ground calcium carbonate (GCC). GCC is a natural chemical reaction, while GCC is manufactured through a series of physical processes. The colors in this table may indicate floatation for coating grade GCC to improve appearance and coating quality. The blue color indicates GCC that is APP or APP-like, while the yellow color indicates GCC that is not APP or APP-like.

Figure 2. Scalenohedral crystal, typical of precipitated calcite carbonate, and a rhombohedral crystal, typical of natural calcium carbonate, or calcite.

Characteristics of GCC

As filler, GCC offers these advantages:

- if on an on-site satellite, none, no dispersant chemicals are needed to keep the slurry from settling during transportation, thus reducing the cost of chemicals.
- Higher opacity, brightness, and bulk result from the scalenohedral morphology of GCC particles.
- There is less abrasion during the processing stages; abrasion is detrimental to the expensive machine paper and parts.
- The electric kinetic surface charge (electrostatic potential) is enhanced, which makes for better particle distribution on the sheet.

Disadvantages are:

- It has a large surface area of the particles decreases the efficiency of sizing.
- Small voids interfere with fiber bonding and consequently reduce the strength of the paper sheet.
- PCC retains more water than does GCC, which means that the speed of paper production is reduced; associated drainage problems affect the way paper behaves on a press (termed "runnability").
- Production problems increase dramatically when the load of GCC is very high, as in heavy paper making.
- Unrelated sizing (ARDD) that is attached to GCC particles remains as residue that is detrimental to paper production.
- Traces of quicklime that have not been neutralized in production adversely affect paper quality and runnability.

Characteristics of GCC

Use of GCC offers these advantages:

- Substantially higher filler levels are possible, thereby maximizing savings and improving profitability for papermakers.


Washington Geology, vol. 21, no. 3, p. 4. 21-22.


Figure 5. General, the Wauconda marble deposit (4 miles northeast of the town of Wauconda) and the Columbia River Carbonates plant at Woodland, WA, which is centrally located to served the needs of the Pacific Northwest paper industry.

CO2 gas precipitated CaCO3 crystals + H2O, the total PCC process, including the energy required for quicklime production, releases nearly 12 times more CO2 than making GCC (Fig. 4). As air-quality standards are tightened and energy taxes loom, paper manufacturers in the U.S. may find it economically advantageous to use more GCC.

SOURCES OF CaCO3 FOR GCC
Chemical and brightness characteristics for the ideal GCC supply are easy to define. The calcium carbonate, whether limestone or its metamorphic equivalent, marble, should be as close as possible to the Pacific Northwest—information and change to the NEFPEC Working Group on the Cascadia subduction zone. Appendix F. Somcvest, P. G., 1993, Predicting strong ground motion. Appen
dy F.

Walsh, T. J., 1993, Washington framework for seismic risk reduc
tion. Appendix E.

Hemphill-Haley, Elise, 1993, Occurrences of recent and Holocene Intertidal deposits in northwestern Willapa Bay, Washi

Hemphill-Haley, Elise, 1993, Taxonomy of recent and fossil (Holocene) deposits (Beckleraphia) from northern Willapa Bay, Washi


ngton Department of Transportation, 1 p.

ngton Department of General Administration. 4 p., 1 plate.

Cope, V., 1993, The Oregon earthquake handbook—An easy-to-
understand information and survival manual (Privately published by the author, Portland, Ore., 143 p., 1 plate.

serving Service. 417 p., 76 maps.

mary report of 208 water quality results and cause and effect relationships for water quality in the Spokane-Rathdrum aquifer. Spokane County Engineers Office, 1 v.


Goldin, Alan, 1992, Soil survey of Whatcom County area, Washi

Gray Harbor College Research, and others, 1990, Physical, chemi


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Open-File Reports

Fritzel, V. A., Jr., 1993, Proceedings of the National Earthquake Pre
diction Evaluation Council, May 7 and 8, 1992, Portland, Ore
.


Includes:

Malone, S. D., 1993, Pacific Northwest earthquake hazards based on historical seismicity. Appendix B.

dix D.

National Earthquake Prediction Evaluation Council, 1993, Earthquake hazards and special needs population—An assessment of spe
cial needs populations in areas of Seattle with residential buildings susceptible to earthquake damage. Battelle Human Affairs Re
sources Search Centers 900/6040, 1 v.


Walsh, T. J., 1993, Washington framework for seismic risk reduc
tion. Appendix E.

Hemphill-Haley, Elise, 1993, Occurrences of recent and Holocene Intertidal deposits in northwestern Willapa Bay, Washi

Hemphill-Haley, Elise, 1993, Taxonomy of recent and fossil (Holocene) deposits (Beckleraphia) from northern Willapa Bay, Washi


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Gray Harbor College Research, and others, 1990, Physical, chemi


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

June 1 through September 30, 1993

THESES


U.S. GEOLOGICAL SURVEY

Preliminary Reports


Includes:


Includes:

Figure 7. Six-inch-diameter pieces of high-purity and high-brightness marble are temporarily stockpiled at the data railroad siding south of Tonasket. The rock is transported in bottom-dumping railroad cars to the Columbia River Carbonates OCC plant at Woodland in southwest Washington.

Figure 8. The Columbia River Carbonates building in which the marble is processed.

Figure 9. Raw material is stockpiled at the Woodland plant. On the right are tanks that store the finished slurry.
Wauconda was one of many districts in the Northwest and Canada that were studied in the search for marble of whiting (pigment) potential. Other sources of suitable rock were found but are not plentiful. Considerations of purity and brightness, transportation, and the small market for GCC that developed while the use of GCC was rapidly increasing hampered development of other high-quality carbonate deposits in Washington, Alberta, and Canada. Small parts of the vast high-calcium limestone resources on Texada Island, British Columbia, have high brightness, but this stone is now largely used for making portland cement. Former marble-producing districts in Washington, such as Northport and others in the western part of the state, generally contain too much dolomite or quartz (1%) or are simply too dark for use in fine white papermaking.

Information Available for Regulated Activities

Governor Mike Lowry recently issued Executive Order #93-06 on Improving State Regulatory Activities. The Division of Geology and Earth Resources regulates surface-mining reclamation, oil and gas exploration, geothermal exploration, and underground gas storage in Washington. To assist state and local governments, businesses, and private citizens in understanding the regulations and in fulfilling their regulatory obligations, the Division provides a wealth of articles and handouts.

Since passage of the amendments to the Surface Mining Act, the Division has prepared new forms and guidelines, which we hope will be easier to understand, to assist applicants for reclamation permits in preparing the detailed reclamation plans that are required by law.

Information on regulated activities that is available from the Olympia office is given below:

Articles in Washington Geology


County Bibliographies

Bibliographies of the geology and mineral resources of selected counties (listed below) have been prepared in support of the Growth Management Act and updated through 1992. These are available free as paper copies or on disk. To order disk copies, send the number of kilobytes in the file desired (indicated below) and send us the appropriate number of formatted 3.5-in. or 5.25-in. disks. Specify whether you want the file in WordPerfect 5.0 or 5.1 or ASCII. ASCII file users may wish to order a paper copy of each file; these copies will show text formatting lost in the conversion to ASCII. We will copy the required files and return the disks to you.

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- Chelan County (190K) Lewis County (133K)
- Clallam County (1120K) Mason County (546K)
- Clark County (546K) Okanogan County (198K)
- Cowlitz County (1290K) Pierce County (758K)
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- Isand County (54K) Spokane County (51T)
- Jefferson County (1129K) Thurston County (91K)
- King County (313K) Walla Walla County (408K)
- Kittitas County (121K) Whatcom County (202K)
- Klickitat County (139K) Yakima County (139K)

Continued on Page 27
Landslide Inventory and Analysis of Tilton Creek-Mineral Ridge Area, Lewis County, Washington

Introduction

Because much of Washington's commercial forest land is in mountainous terrain, it is susceptible to slope instability of various types and scales. Some forest practices (principally road building associated with roads and timber harvest) can increase mass wasting on slopes of marginal stability. Since implementation of the Timber/Fish/Wildlife Agreement in 1987, the Cooperative Monitoring, Evaluation, and Research committee, the Sediment, Hydrology, and Mass Wasting technical steering committee, and the Department of Natural Resources (DNR) have been engaged in cooperative interdisciplinary efforts to study mass erosion on forest lands, improve methods by which it is addressed, and generally reduce the adverse effects of forest practices on slope stability and downstream resources. As one means of addressing these goals, a Slope-Stability Hazard Zonation Pilot Project was designed and completed using the resources and personnel of both the Forest Practices Division and the Division of Geology and Earth Resources (DGER) of DNR. The project's broad purposes were to (1) complete a landslide inventory of a selected pilot area, (2) collect topographic, geologic, soils, climatic, and vegetation data relevant to the landslides, and (3) compare the inventory with the state soil survey slope hazard ratings and other hazard zonation strategies to assess their utility. We present an overview of our results in this part and the new landslide Inventory of Washington Geology. In this issue, we present information pertaining to the relations among terrain features (landslide elevation and aspect), geologic materials and landforms, slope gradient, and incidence of landsliding.

Pilot Study Area

The pilot study area, 199 m², lies at the intersection of the southern part of the Cascade Range in Washington and a prominent mountain range, generally termed the Northcreek mountains. Rugged terrain and a variety of geomorphic features result from factors that include glacial erosion and deposition, high yearly precipitation (60-100 in.), and mass wasting of folded and faulted Tertiary volcanic and sedimentary rock. The variation in land use, ownership, topography, geologic and soils characteristics, climate, landforms, and mass-movement features in the study area allow the application of many other forested areas that have similar characteristics.

For the pilot project, we divided the general (whole) study area into a focus area, which we examined in detail using aerial photos and field verification of landslides, and a perimeter area, which was investigated using aerial photos and only field reconnaissance (Fig. 1). The focus study area of 61,061 acres (95.4 m²) contains 1,021 mapped landslides, of which 467 were field-verified. The perimeter area is 60,949 acres (95.7 m²) and contains 651 mapped landslides, 31 of them field-verified.

Methods

We used a modification of the landslide classification scheme of Varnes (1978), which is in turn an outgrowth of previous work by Varnes (1958) and Sharpe (1938). We combined the Varnes landslide classes into three groups: deep-seated, shallow, and cliff (rock-slope) failure types; and we defined road-related failures as a fourth type (Table 1). Deep-seated landslides such as debris slides, avalanches, and torrents (including debris flows and hyperconcentrated floods) typically start as rapid translational failures of the soil mantle (Figs. 2 and 3). Shallow slides also include road-related landslides that emanate from road fill, sideslopes, cutbanks, or landslides (Figs. 4 and 5). Deep-seated rotational landslides such as debris slumps, rock slumps and slump-earthflows are generally much less frequent (Fig. 6). For completeness, we inventoried prominent cliffs where rock fall, rock topples, and rock sliding are the primary processes of mass wasting.

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Tri-State Agreement on Mining

by David K. Norman

Officials of Washington, Idaho, and Oregon signed an agreement in 1993 to share technical information about mine regulation and training opportunities. The Washington Department of Natural Resources, Division of Geology and Earth Resources received a 2-year, $70,000 grant from the U.S. Environmental Protection Agency to fund this agreement; Idaho and Oregon received similar amounts. Ultimately, this agreement will lead to wiser resource development and protection.

Mine regulators in these three states now face more complex issues than in the past, and in order to be effective, they must keep abreast of the latest technology. Earlier this year, a team of regulators, represented mainly by Allen Throop (Oregon), Bruce Schuld and Jerry West (Idaho), and David Norman (Washington), visited several mines in Washington, British Columbia, and Idaho. The emphasis of their investigation was on water quality, chemical mining methods, and reclamation techniques at recently reclaimed and operating mines. A short summary of their visits follows.

Asxamera Minerals Inc.’s Cannon Mine

During their visits in Washington, the team observed underground operations, tailings impoundments, and surface reclamation at the Cannon gold mine in Wenatchee. The mine, operated by Asxamera Minerals Inc., uses a flotation method to concentrate gold. Concentrated ore is shipped to Japan for smelting. Asxamera is nearing completion of mining and has finished earthwork on some of the upper roads, drainage systems and dike construction (Fig. 1). Underripe stopes are backfilled with concrete made with locally mined sand and gravel, and ore is then removed from the adjacent stope. This method allows for more recovery of ore and ultimate subsidence.

The tailings are to be treated with a synthetic geotextile liner placed below the tailings impoundment, but natural clays below the dam act as a liner and have very low permeability. Four wells in the valley below the impoundment are used for water quality monitoring. The well that is being used to determine the background quality of water entering the tailings impoundment is upstream of the facility, and the elevation of the well bottom is higher than the final maximum elevation of tailings.

Battle Mountain Gold’s Crown Jewel Project

Battle Mountain Gold (BMG) proposes to develop an open-pit gold mine on Buckhorn Mountain near Chewelah in north-central Washington. BMG plans to treat the ore with a cyanide leach process that uses a carbon recovery system and an activated carbon process (PCG) patented sulfur dioxide (SO2) cyanide destruction process. The BMG’s proposal calls for a tailings impoundment lined with clay compacted to a very low permeability (1×10⁻⁸ cm/sec or less) and synthetic geomembrane liners. Nine groundwater-monitoring wells and 17 surface-water monitoring sites in and from four adits are being used to gather baseline data for the environmental impact statement that is being prepared.

Homestake Mining Co.’s Nickel Plate Mine

The Homestake Mining Company proposes a nickel-copper deposit in southern British Columbia because it is geologically similar to the proposed Crown Jewel Project. It uses ore processing techniques like those proposed for the Crown Jewel, as well as the SO2 cyanide destruction method. However, due to the nature of the ore deposit at Nickel Plate, several open pits have been mined rather than a single open pit as proposed for the Crown Jewel Project. Homestake backfills mine out-pits with waste rock, which necessitates leaving the last pit as a series of benches and highwalls. In contrast, requirements in the state of Washington call for benches and highwalls to be selectively blasted to form scenic slopes and a natural appearance. Waste-rock dump slopes at the Nickel Plate mine are generally 3 feet horizontal for each 1 foot vertical (or 3:1); there is a maximum height of 80 feet between terraces or breaks in slope on the dumps. Topsoil is placed on waste-rock slopes that are gentler than 3:1 to speed revegetation. Clays and silts salvaged from nearby glacial till supplement these soils. Created wheat, rye, and clovers are the first ground cover plantings used here to stabilize the soils on dump slopes. The mine reclamationist then plans to plant more native species as revegetation proceeds.

The tailings impoundment is dammed but unlined, and leakage through the underlying glacial till has been a problem. Homestake installed collection trenches and a buried collection piping system about 3 ft below the level of the adjacent Canty Creek and between the creek and the tailings impoundment. The system apparently removes most of the remaining cyanide, which is then pumped back to the tailings impoundment.
REFERENCES CITED

The number of landslides of any given analyzed factor (for example, number of landslides per slope gradient class) was normalized into a ratio of the number of landslides per unit area, or landslide density, in order to remove the variations in area from our statistics and to facilitate comparisons. The unit of area chosen was 160 acres, or one-quarter of a square-mile section. A geographical information system (GIS) and digital elevation model (DEM) data were used to determine the distribution by area of slope-gradient, elevation, and aspect classes. Areas of geologic map units were calculated in the GIS from a digitized version of the Centralia quadrangle 1:100,000-scale geologic map (Schaefer, 1987) of the area. In our analyses (that is, we did not eliminate questionable landslides). The assumption is that our screening process, field verification procedures, and knowledge of local geologic conditions have satisfactorily removed the majority of misidentified landslides. Also, the main advantage of a large database is that the small proportion of misidentified landslides is within the error limits of the large data set and will not significantly skew the data.

STUDY FINDINGS
Landslide Types
Most landslides can be accurately identified by detailed examination and interpretation of aerial photos. In the field, only 2.3 percent of presumed landslides detected on aerial photos were observed to be other geomorphic features—for example, a probable glacial cirque mistaken for a deep-seated landfall.

Table 1. Varnes’ (1978) slope movement types. Abbreviations correspond to the column and row symbols on the Varnes’ (1978) classification chart. Road landslides are shallow landslides originating from road fills, sidecast, landings and cutbacks.

<table>
<thead>
<tr>
<th>Varnes (1978) Landslide Types</th>
<th>Abbreviations</th>
<th>General landslide types used in this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debris slump</td>
<td>IBAl</td>
<td>Deep-seated</td>
</tr>
<tr>
<td>Rock slump</td>
<td>IBAg</td>
<td>Deep-seated</td>
</tr>
<tr>
<td>Skimp-earthflow</td>
<td>VBa3</td>
<td>Deep-seated</td>
</tr>
<tr>
<td>Debris slide</td>
<td>SKB</td>
<td>Shallow1</td>
</tr>
<tr>
<td>Debris avalanche</td>
<td>VBb3</td>
<td>Shallow1</td>
</tr>
<tr>
<td>Debris torrent</td>
<td>VBb71</td>
<td>Shallow1</td>
</tr>
<tr>
<td>Debris flow</td>
<td>VBb73</td>
<td>Shallow1</td>
</tr>
<tr>
<td>Rock fall, rock topple</td>
<td>lb-2l-2l</td>
<td>Cliffs</td>
</tr>
</tbody>
</table>

Figure 2. A debris torrent on a ridge on Storm Ring Mountain west of the main stem of the Tilton River. The landslide originates in colluvium below a rock outcrop and adjacent to a hollow. The soil along the fresh scarp is not thick. We observed many shallow failures in this rocky area. This landslide probably was initiated during the winter storms of 1990-1991, after the 1988 aerial-photo set and recent enough to have minimal revegetation.

Figure 13. Numbers of landslides versus slope types for the general study area. Dip-slope failures are commonly attributed to chemical or hydrologic processes that result in strongly bedded or foliated rocks. Scarp slopes generally parallel a master joint set that is systematically related to fold axes. The specific slip-plane geometry of dip-slope landslides contrasts with the many slip planes possible in scarp- and cross-slope landslides. Dip slopes are less common than the more general scarp and cross slopes, but the density of landslides on these slopes is relatively greater. Rock units in which bedding is moderately to well developed fail on dip slopes more commonly than do massive to poorly bedded intertonguene or volcanic rock units. Shallow landslides are slightly more sensitive to bedrock structure (such as bedding and joints) than are road-related or deep-seated landslides. Note the slightly lower proportion of cross-slope shallow landslides. We infer that road failures are least sensitive to bedrock orientation with the exception that there is a higher proportion (51.7%) of road cross-slope failures and low proportion of dip-slope failures in the general area. Road failures are more directly related to road material and construction techniques.
Figure 3. Shallow landslide along the East Fork Tish River. This debris slide occurs on the toe of a debris slump, similar to that in Figure 6. Mechanically disrupted or sheared materials along toes of deep-seated landslides have lowered strength and cohesion and are subject to stream undercutting. Debris slides in this type of setting are detrimental to stream quality. Note the person (lower left) for scale.

Figure 4. Debris slide in sidecut along a tributary to Mineral Creek, probably the result of stream undercutting and seepage pressures through the road prism during the storms of 1990–1991. This failure was assigned certainty and activity categories of definite and recent, respectively, and was probably accompanied by significant surficial erosion. This type of landslide degrades stream water quality.

Table 4. Rock units in the pilot study area. Units whose symbols begin with Q are of Quaternary age (1.6 million years old or younger), and those beginning with T are of Tertiary age (6.6 to 67 million years old).

<table>
<thead>
<tr>
<th>Unit</th>
<th>Lithologic description</th>
<th>Unit</th>
<th>Lithologic description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2h</td>
<td>Hayden Creek drift, unidivided</td>
<td>T0h</td>
<td>Churupewan Formation: anodite to basaltic breccias, conglomerates, (volcaniclastic) sandstones, and lava flows (including rare dacitic to rhyolitic compositions), locally interbedded with shale</td>
</tr>
<tr>
<td>Gls</td>
<td>Landslides, including the scarp, main body and deposit (as compiled by Schass, 1983), on the geologic map of the Central States published in 1984</td>
<td>Tva</td>
<td>Basaltic anodeite and anodeite flows, with lesser dacite flows, flow breccias, and thin, rare interbeds of shale, tuff, volcanic sandstone, and conglomerate</td>
</tr>
<tr>
<td>Goo</td>
<td>Evans Creek outwashed deposits</td>
<td>Tvc</td>
<td>Volcaniclastic lapilli and ash-pumice lithic tuff, volcanic sandstone and conglomerate, or breccia, interbedded locally with unit Tuv basaltic anodeite and anodeite flows</td>
</tr>
<tr>
<td>Q2d</td>
<td>Hayden Creek till</td>
<td>Tvn</td>
<td>Northeaster Formation: basaltic anodeite, anodeite, basalt, with silts and interbedded flow breccias</td>
</tr>
<tr>
<td>Q2g</td>
<td>Wingate Hill drift, unidentifiable</td>
<td>Tvo</td>
<td>Basaltic and basaltic flows, with minor interbedded volcanioclastic breccia</td>
</tr>
<tr>
<td>tvs</td>
<td>Anodeite flows, with subordinate breccia</td>
<td>Tvp</td>
<td>Puget Group: continental floodplain sandstone interbedded with siltite, shale, claystone, and coal, locally interbedded with lava flows, tuffs, volcanioclastic breccias, pebble conglomerates, and braided-water deposits</td>
</tr>
<tr>
<td>tvp</td>
<td>Basaltic flows locally with tuff, Lahars, and minor sedimentary rocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tfr</td>
<td>Rhyolite dikes (Kiona Creek area)</td>
<td>Trt</td>
<td>Rhyolite dikes, silts, or slugs</td>
</tr>
<tr>
<td>Td 3</td>
<td>Dacite dikes, silts, or slugs</td>
<td>Tvd</td>
<td>Anodeite dikes, silts, or slugs, anodeite grades locally into anodeite pinch and dikes</td>
</tr>
<tr>
<td>Tsd</td>
<td>Anodeite flows, with minor interbedded volcanoclastic breccia and conglomerate (Kiona Creek area)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

shows a slightly higher incidence of landsliding along bedding planes in the strongly bedded rock types, such as the Puget Group.

Part 2 of this article will appear in the next issue. It will discuss soils and timber-harvest history and their effect on slope stability in the study area. We will also summarize the study’s conclusions.

ACKNOWLEDGMENTS
We thank field assistants Bryn Thombs and Kim Farley, cartographers Carl Harris, Jeaneen Carlton, Nancy Eberle, Shu Smith, Liz Thompson, Dale Roberts, and Keith Ikard, and geologists Tim Walsh, Josh Logan, Hank Schass, Pat Pringle, Bill Lingley, Eric Schuster, and Dave Norman for their help with this project.
fairly high quartz and low ferromagnesian mineral (biotite and hornblende) contents and a high to very high incidence of land sliding (Fig. 11; unit T). Without biotite and hornblende, which weather to clay, siliceous rocks produce coarse, clay-poor soils. Such materials have low cohesion and are susceptible to shallow soil mantle failures on oversteepened (in this case, glaciotectonically) slopes.

"Weak" rock interlayers exist in otherwise mostly stable geologic units. For example, overall, the continental sedimentary rocks of the Puget Group (Table 4) have a moderate landslidel density (Fig. 11). However, the mechanically weak and relatively impermeable shale beds in this unit exhibit a very high landslide density. The same condition is observed for volcanic breccia or volcaniclastic lithologies within the volcanic rocks unit. Knowing where the weaker lithologies are improves the reliability of stability analyses. Detailed geologic mapping (approximately 1:5,000 or larger scale) is commonly required in site-specific slope-stability assessments. Using mapping that was both incomplete and at a range of scales in western Washington, Fidalgo and Brunseng (1980, 1981) observed only fair (and locally poor) correlation between landslide incidence and geologic units. DGEB's open-file geologic map compilations at 1:100,000 currently provide the most complete coverage.

Landslides and Geologic Structures

Landslides are controlled by geologic structures (such as joints and bedding) as well as by materials. Rock layers have various compositional, permeabilities, and degrees of alteration. Bed contacts, as well as joints, serve as boundaries to subsurface water movement or restrict penetration and development of root systems. They are typically discontinuities in strength, therefore potential failure surfaces.

Folding of rocks creates dip and scarps. The control that these slopes have over location of landsliding is indicated by the fact that a little more than half of shallow failures in the focus study area occur on dip slopes and scarps. Major joint sets in folded rocks commonly parallel fold axes. Joint influence landsliding in the same way as bedding—for example, by serving as physical discontinuities. We also found a high incidence of landslides along mapped faults.

For each landslide, we differentiated dip-slope, scarp-slope and cross-slope failure types (Fig. 12). Dip slopes are parallel to bedding and can allow soil or rock layers to slide down-slope along bedding planes. Scarp slopes are roughly perpendicular to dip slopes; bedding dips into the slope, and failures cut across bedding, typically along joints. Cross slopes are defined as those slopes that are oblique to both dip slopes and scarps slopes.

The planimetric areas of dip, scarp, and cross slopes were not measured, so the numbers for these landforms could not be normalized into landslide densities. However, as the more general case, cross slopes may represent a higher proportion of the area. We found that cross-slope failures are indeed the more common failure type for all rock and landslide types (Figs. 12 and 13). Cross-slope failures are probably controlled more by joints than by bedding planes, emphasizing the importance of joints to slope stability.

The significant role of bedding permeability and strength anisotropy across dip slopes is implied by (1) the number of dip-slope failures (Fig. 13); (2) the likelihood that the total area of dip slopes is relatively small and thus landslide density is probably high on these landforms, and (3) the magnitude and importance of slope factors that are unrelated to slope type or bedding orientation. These factors taken together indicate that the incidence of dip-slope failures is significant in the study area, and that dip slopes are inherently less stable under many circumstances. Comparison of rock type to slope type

<table>
<thead>
<tr>
<th>Landslide type</th>
<th>data type</th>
<th>Avg.</th>
<th>Mode</th>
<th>Dominant range</th>
<th>Std. dev.</th>
<th>Max.</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep/FG</td>
<td>25.3</td>
<td>26-30</td>
<td>16-45</td>
<td>8.6</td>
<td>75</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Deep/CL</td>
<td>33.0</td>
<td>36-40</td>
<td>11-55</td>
<td>8.6</td>
<td>52</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>Shallow/FG</td>
<td>34.2</td>
<td>36-40</td>
<td>21-50</td>
<td>10.3</td>
<td>67</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Shallow/CL</td>
<td>44.4</td>
<td>41-45</td>
<td>26-55</td>
<td>7.3</td>
<td>70</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Road/FG</td>
<td>35.0</td>
<td>36-40</td>
<td>21-45</td>
<td>9.2</td>
<td>58</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>Road/CL</td>
<td>40.9</td>
<td>36-40</td>
<td>31-50</td>
<td>5.0</td>
<td>57</td>
<td>37.0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. Road failure along the West Fork Tilton River caused by a blocked cobble. The blockage and resultant seepage of through the road prism elevated pore pressures that led to failure of the road, probably as a debris flow with significant surficial erosion.

(4) projection of deep-seated land- slides to steep streams and resultant undercutting and shallow landslides.

Other factors remaining constant, the incidence of shallow on deep landslides should be greater as the activity of shallow slope failures increases. However, old deep slides also contain a higher number of superimposed shallow slides, which implies that even though deep-seated failures are probably not directly triggered by forest practices, they are affected by the results of such activities, i.e., delay of root strength and (or) reduced evapotranspiration after tree harvest. The documented higher incidence of shallow failure on these landforms, combined with the sensitivity of shallow failure to tree removal, warrant caution and appropriate hazard evaluation on these common landforms.

We observed that undercutting of slopes is an important failure mechanism in the area, particularly in narrow inner gorges where streamflow is concentrated by hillslopes that impinge directly on the streams (Figs. 3, 5, and 6). Removal of slope buttresses and resultant landsliding by undercutting occurred on 7 percent of the deep-seated landslides, 18 percent of the shallow landslides, and 12 percent of the road-related landslides in the focus area. Master slides from hillslopes are numerically the most common form of landslides in the study area (Fig. 7, Table 2). Shallow slides usually result from the build-up of pore water pressure in soil mantles on steep slopes, thus common in hollows where ground-water convergence results in buoyant uplift on the soil particles and loss of shear strength. Soil-mantle failures in these hollows are often associated with cushion and resealation in about 30 to 60 years. Generally, shallow hillslope and road failures that were able to identify tend to be young (active or recent) and thus easy to identify, whereas...
the geometrically persistent deep-seated failures tend to be much older (thousands of years in some cases) and less active (Fig. 7).

Most road-related failures originated in sidescap, primarily as debris avalanches and secondarily as debris slides. Overloading and artificial steepening of slopes with sidescap and fill materials are the most significant causes of road-related failures. Off-road activity, road side-cuts, and landings overlaid constitute 82% of the road landslides in the focus area. These may be more detrimental to water quality than cut-slope failures (18% of road failures) because they may more easily exit the road area, enter tributaries, become water-laden, and affect major streams.

Landslides and Geologic Materials

Using previous map compilations and our field observations, we identified the parent material and rock and soil characteristics of the slopes. The composition of the parent material (rock and unconsolidated sediments such as glacial deposits) strongly influences mechanical strength and permeability, and thus slope stability. Indirectly controls soil properties such as mineral composition, texture, particle angularity and sphericity, and permeability. Therefore, we examined our field observations for the presence of such factors, including the bedrock, the gravelly sand, and the till. We also used the regional geologic map to identify the underlying geology of the area. The geology of the area includes a variety of rock types, including granite, gneiss, and metamorphic rocks. These rocks are deeply weathered and have developed a thick layer of weathered material on their surface. The weathered material is composed of clay, silt, sand, and gravel, and is highly susceptible to slope failure.
the geometrically persistent deep-seated failures tend to be much older (thousands of years in some cases) and less active (Fig. 7).

Most road-related landslides originated in sideslope, primarily as debris avalanches and secondarily as debris slides. Overloading and artificial steepening of slopes with sideslope and fill materials are the most significant causes of road-related landslides. Road fill, sideslopes, and loading contributed 82% of the road-related landslides in the focus area. These may be more detrimental to water quality than cut-slope failures (18% of road failures) because they may more easily exit the road area, enter tributaries, become water-laden, and affect major streams.

**Table 2. Landslide statistics for the focus area**

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Deep</th>
<th>Shallow</th>
<th>Road</th>
<th>Cliff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of land slides</td>
<td>315</td>
<td>533</td>
<td>147</td>
<td>32</td>
</tr>
<tr>
<td>Total area (acres)</td>
<td>5894</td>
<td>130</td>
<td>19</td>
<td>43</td>
</tr>
<tr>
<td>Proportion of study area (%)</td>
<td>10</td>
<td>0.2</td>
<td>0.03</td>
<td>0.07</td>
</tr>
<tr>
<td>Total area (ft²)</td>
<td>256,750,000</td>
<td>5,680,000</td>
<td>827,300</td>
<td>1,877,000</td>
</tr>
<tr>
<td>Minimum area (ft²)</td>
<td>25,000</td>
<td>320,500</td>
<td>69,160</td>
<td>219,000</td>
</tr>
<tr>
<td>Average area (ft²)</td>
<td>815,100</td>
<td>10,640</td>
<td>5,630</td>
<td>58,660</td>
</tr>
<tr>
<td>Area standard deviation (ft²)</td>
<td>1,625,332</td>
<td>32,490</td>
<td>10,400</td>
<td>57,100</td>
</tr>
<tr>
<td>Number of land slides/160 acres</td>
<td>0.83</td>
<td>1.4</td>
<td>0.39</td>
<td>0.08</td>
</tr>
</tbody>
</table>

**Landslides and Geologic Materials**

Using previous map compilations and our field observations, we identified the parent material (rock and unconsolidated sediments such as gravel deposits) strongly influences mechanical strength and permeability, and thus slope stability. Indirectly controls soil properties such as mineral composition, fabric, particle angularity and sphericity, and permeability. For example, we document a very high incidence of landsliding on the Hayden Creek till (Fig. 11), until 1960's. This may be the result of several factors, including: (1) the permeability of this soil imparted by (1) its compactness and lack of penetrative joints; (2) its valley-bottom position and resultant susceptibility to southward drainage and undercutting; (3) minimal penetration of roots into the dense till; and (4) a smooth glide surface along the soil-till interface.

Another example of the interactions of parent material and landslide can be found in the shallow landslides off of the area. Medium-grained andesitic (and particularly) rhyolitic parent materials have...
fairly high quartz and low ferromagnesian mineral (biotite and hornblende) contents and a high to very high incidence of landsliding (Fig. 11; unit T). Without biotite and hornblende, which weather to clay, siliceous rocks produce coarse, clay-poor soils. Such materials have low cohesion and are susceptible to shallow soil mantle failures on oversteepened (in this case glacially scoured) slopes.

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The planimetric areas of dip, scarp, and cross slopes were not measured, so the numbers for these landforms could not be normalized into landslide densities. However, as the more general case, cross slopes may represent a higher proportion of the area. We found that cross-slope failures are indeed the more common failure type for all rock and landslide types (Figs. 12 and 13). Cross-slope failures are probably controlled more by joints than by bedding planes, emphasizing the importance of joints to slope stability.

The significant role of bedding permeability and strength anisotropy along dip slopes is implied by the (1) number of dip-slope failures (Fig. 13), (2) the likelihood that the total area of dip slopes is relatively small and thus landslide density is probably high on these landforms, and (3) the multiplicity and importance of slope factors that are unrelated to slope type or bedding orientation. These factors taken together indicate that the incidence of dip-slope failures is significant in the study area, and that dip slopes are inherently less stable under many circumstances. Comparison of rock type to slope type

Figure 5. Road failure along the West Fork Tilton River caused by a blocked culvert. The blockage and resultant seepage of through the road prism elevated pore pressures that led to failure of the road, probably as a debris flow with significant surficial erosion.

(4) projection of deep-seated landslide axes into streams and resultant undercutting and shallow failures.

Other factors remaining constant, the incidence of shallow on deep landslides should be greater as the activity of individual landslide types increases. However, old deep slides also contain a higher number of superimposed shallow slides, which implies that even though deep-seated failures are probably not directly triggered by forest practices, they are affected by the results of such activities (i.e., delay of road strength and/or reduced exoatranspiration after tree harvest). The documented higher incidence of shallow failure on these landforms, combined with the sensitivity of shallow failure to tree removal, warrant caution and appropriate hazard evaluation on these common landforms.

We observed that undercutting of slopes is an important failure mechanism in the area, particularly in narrow inner gorge where streamflow is constrained by hilltops that impinge directly on the streams (Figs. 3, 5, and 6). Removal of slope buttresses and resultant landsliding by undercutting constitute about 17 percent of the deep-seated landslides, 28 percent of the shallow landslides, and 12 percent of the road-related landslides in the focus area.

Landslides from hilltops are numerically the most common form of landslides in the study area (Fig. 7, Table 2). Shallow slides usually result from the build-up of pore pressure in soil mantles on steep slopes, thus causing them to fail and move under the influence of gravity. As such, they are common in gullies where ground-water convergence results in buoyant uplift on the soil particles and loss of shear strength. Soil-mantle failures in these hollows are the result of slumping and recharge in about 30 to 60 years. Generally, shallow hillside and road failures that were able to identify tend to be young (active or recent) and thus easy to identify, whereas

Figure 6. Deep-seated landslide (center of photo) along the East Fork Tilton River. The stream has cut into the valley-bottom till deposit and, by removing the base of the slope, has caused debris sliding along this part of the river. Notice the accumulation of debris at the downstream end of the slide. The area immediately below the slide is prone to debris flow and debris avalanche.

Figure 7. Number of landslides by type per category of land area (in S. class) compared with percent of the study area for each category. The number of landslides can be approximately normalized by noting the percent area (black line) obtained by GIS for each slope class in the study area. (Note the axis on the right.) The GIS-generated slope ranges show that areas of slope classes decrease significantly on slopes steeper than 25°. Hill slopes and road-related failures are the most common landslides are typified at slopes steeper than 25° and are very common on slopes greater than 35°. The reduced area of slopes greeter than 25° demonstrates that steep slopes have higher landslide densities because of the increased incidence of landsliding. Deep-seated landslides are observed on slopes as gentle as 11 and are generally identified on gentle slopes than are shallow failures. The lack of slope class percent (black [n] for slopes steeper than 50° is a side effect of the way GIS measures slopes, i.e., the areas occupied by these steep slopes is so small that they are not accurately recorded by GIS at this scale.

Figure 8. Number of landslides by type per category of land area (in S. class) compared with percent of the study area for each category. The number of landslides can be approximately normalized by noting the percent area (black line) obtained by GIS for each slope class in the study area. (Note the axis on the right.) The GIS-generated slope ranges show that areas of slope classes decrease significantly on slopes steeper than 25°. Hill slopes and road-related failures are the most common landslides are typified at slopes steeper than 25° and are very common on slopes greater than 35°. The reduced area of slopes greater than 25° demonstrates that steep slopes have higher landslide densities because of the increased incidence of landsliding. Deep-seated landslides are observed on slopes as gentle as 11° and are generally identified on gentler slopes than are shallow failures. The lack of slope class percent (black [n] for slopes steeper than 50° is a side effect of the way GIS measures slopes, i.e., the areas occupied by these steep slopes is so small that they are not accurately recorded by GIS at this scale.
slide. We deleted these non-landscape features from the inventory. The overall similarity of the final numbers and distribution of landslides in the focus area (largely field-verified) and the perimeter area (chiefly mapped from aerial photos) was a source of confidence in our aerial-photo interpretations.

Two methods of communicating the rates of landslide incidence in an area are by landslides numbers or by planimetric area of rupture. Our data show that old, slow-moving, deep-seated landslides, most of which are hundreds to thousands of years old, are numerically the second most common landslide type in our general study area (Fig. 7, Table 2). However, the surface of rupture (failed area) of deep-seated failures covers about 10 percent of the focus area and is the primary mass-wasting feature. The rupture area of all other failure types sums to less than 1 percent of the focus area. More important, 44 percent of the shallow landslides from roads and slopes occur on deep-seated landslides that cover only approximately 20 percent of the focus study area (10 percent total surface of rupture area and an estimated 10 percent total deposit area below the rupture area). These shallow landslides typically originate on scarp, flank, or toe of deep-seated failures; fewer were found on the main slide bodies.

We conclude that the increased incidence of shallow landsliding on large deep-seated failures results from:

1. Over-steepened soil or rocks on the scarps, flanks, and toes (Fig. 2);
2. Discontinuous macropermeation, disrupted drainage, closed depressions, or perched ground water which may cause positive pore-water pressure;
3. Sheared rock and soil that have lower residual strength and cohesion; and

...
REFERENCES CITED

Figure 12. Diagram showing slope types relative to building orientation.

Figure 13. Numbers of landslides versus slope type for the general study area. Dip-slope failures are commonly attributed to mechanical or hydrologic instabilities in strongly bedded or foliated rocks. Scarp slopes generally parallel a master joint set that is systematically related to fold axes. The specific slip-plane geometry of dip-slope landslides contrasts with the many slip planes possible in scarp- and cross-slope landslides. Dip slopes are less common than the more general scarp and cross slopes, but the density of landslides on these slopes is relatively greater. Rock units in which bedding is moderately to well developed fail on dip slopes more commonly than do massive to poorly bedded intrusives or volcanic rock units. Shallow landslides are slightly more sensitive to bedrock structures (such as bedding and joints) than are road-related or deep-seated landslides, note the slightly lower proportion of cross-slope shallow landslides. We refer that road failures are least sensitive to bedding orientation because they are less common than the more general scarp and cross slopes. The dip slope failures in the general area. Road failures are more directly related to road material and construction techniques.

Seismology Resources for Teachers
Help for science teachers (K-12) whose curriculum includes earthquakes, earthquake preparedness, and related earth science topics is available from the Seismological Society of America. Resources listed include reference information (books, pamphlets, scientific papers), videotapes, computer hardware and software, and databases. For a copy of "Seismology: Resources for Teachers," send a self-addressed, stamped envelope to SSA, 201 Plaza Professional Building, El Cerrito, CA 94530-4003.

Foreign Minerals
The United States depends on foreign sources for 50 percent or more of 23 strategic and critical minerals. We import all of our arsenic, bauxite and alumina, columbium, graphite, manganese, mica, strontium, and thallium. In addition, 90 percent or more of asbestos, platinum-group metals, and industrial diamonds come from other countries. Reduced production in the U.S. of vital minerals increases dependence on offshore sources.

From U.S. Bureau of Mines

The number of landslides of any given analyzed factor (for example, number of landslides per slope gradient class) was normalized into a ratio of the number of landslides per unit area, or landslide density, in order to remove the variations in area from our statistics and to facilitate comparisons. The unit of area chosen was 160 acres, or one-quarter of a square-mile section. A geographical information system (GIS) and digital elevation model (DEM) data were used to determine the distribution by area of slope gradient, elevation, and aspect classes. Areas of geologic map units were calculated in the GIS from a digitized version of the Centrals quadrangle 1:100,000-scale geologic map (Schasse, 1987). In our analyses (that is, we did not eliminate questionable landslides). The assumption is that our screening process, field verification procedures, and knowledge of local geologic conditions have satisfactorily removed the majority of misidentified landslides. Also, the main advantage of a large database is that the small proportion of misidentified landslides is within the error limits of the large data set and will not significantly skew the data.

STUDY FINDINGS
Landslide Types
Most landslides can be accurately identified by detailed examination and interpretation of aerial photos. In the field, only 2.3 percent of presumed landslides detected on aerial photos were observed to be other geomorphic features—for example, a probable glacial cirque mistaken for a deep-seated land

Figure 2. A debris flow on a ridge on Storm King Mountain west of the main stem of the Tilton River. The landslide originates in colluvium below a rock outcrop and adjacent to a hollow. The soil along the fresh scarp is not thick. We observed many shallow failures in this rocky slope. This landslide probably was initiated during the winter storms of 1990-1991, after the 1988 aerial-photo set and recent enough to have minimal revegetation.

Table 1. "Varnes" (1978) slope movement types. Abbreviations correspond to the column in the Varnes (1978) classification chart. Road landslides are shallow landslides originating from road fills, sidecast, landslides and cutbacks.

<table>
<thead>
<tr>
<th>Varnes (1978) Landslide types</th>
<th>Abbreviations</th>
<th>General landslide types used in this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debris slump</td>
<td>BBA</td>
<td>Deep-seated</td>
</tr>
<tr>
<td>Rock slump</td>
<td>IBA</td>
<td>Deep-seated</td>
</tr>
<tr>
<td>Skirmish-earthflow</td>
<td>VBA</td>
<td>Deep-seated</td>
</tr>
<tr>
<td>Debris slide</td>
<td>IBB</td>
<td>Shallow1</td>
</tr>
<tr>
<td>Debris avalanche</td>
<td>VB3</td>
<td>Shallow2</td>
</tr>
<tr>
<td>Debris torrent</td>
<td>VB3</td>
<td>Shallow2</td>
</tr>
<tr>
<td>Debris flow</td>
<td>VB3</td>
<td>Shallow2</td>
</tr>
<tr>
<td>Rock fall, rock topple</td>
<td>&quot;</td>
<td>Cliff</td>
</tr>
</tbody>
</table>

1Road landslides are shallow slides originating from road landslides, cutbacks, sidecast, fills, or running surfaces
2Debris flows and hyperconcentrated flows are included with debris torrents in the inventory.
3Category includes Varnes' rock slide and rock block slide.
Officials of Washington, Idaho, and Oregon signed an agreement in 1993 to share technical information about mine reclamation and training opportunities. The Washington Department of Natural Resources, Division of Geology and Earth Resources received a 2-year, $70,000 grant from the U.S. Environmental Protection Agency to fund this agreement; Idaho and Oregon received similar amounts. Ultimately, this agreement will lead to wiser resource development and protection.

Mine regulators in these three states now face more complex issues than in the past, and in order to be effective, they must keep abreast of the latest technology. Earlier this year, a team of regulators, represented mainly by Allen Throop (Oregon), Bruce Schuld and Jerry West (Idaho), and David Norman (Washington), visited several mines in Washington, British Columbia, and Idaho. The emphasis of their investigation was on water quality, chemical mining methods, and reclamation techniques at recently reclaimed and operating mines. A short summary of visits follows.

Asamera Minerals Inc.'s Cannon Mine

During their visits in Washington, the team observed underground operations, tailings impoundments, and surface reclamation at the Cannon gold mine in Wenatchee. The mine, operated by Asamera Minerals Inc., uses a flotation method to concentrate gold. Concentrated ore is shipped to Japan for smelting. Asamera is nearing completion of mining and has finished earthwork on some of the upper roads (Fig. 1), drainage ditches, and pits (Fig. 2). Underground stopes are backfilled with concrete made with locally mined sand and gravel, and ore is then removed from the adjacent stope. This method allows for more recovery of ore and eliminates subsidence.

The tailings are too finely ground to be used as backfill, so they must be handled in an impoundment that was constructed across the valley. The impoundment has no synthetic geotextile liner placed below the tailings impoundment, but natural clay is used to stabilize the dam. The tailings impoundment is only 3 feet high, and the water level remains below the surface, eliminating any potential for seepage or downstream contamination. The impoundment is 80 feet below the water table.

Battle Mountain Gold's Crown Jewel Project

Battle Mountain Gold (BMG) proposes to develop an open-pit gold mine on Buckhorn Mountain near Chewelah in north-central Washington. BMG plans to treat the ore with a cyanide leach process that uses a carbon recovery system and an International Nickel Company (INCO) patented sulfur dioxide (SO₂) cyanide destruction process. The BMG's proposal calls for tailings impoundment lined with clay compacted to a very low permeability (10⁻⁸ cm/sec or less) and synthetic geosynthetic membranes. Nine groundwater monitoring wells and 17 surface-water monitoring sites from four adits are being used to gather baseline data for the environmental impact statement that is being prepared.

Homestake Mining Co.'s Nickel Plate Mine

The tri-state group visited the Nickel Plate mine in southern British Columbia because it is geologically similar to the proposed Crown Jewel Project. It uses ore processing techniques similar to those proposed for the Crown Jewel, as well as the INCO SO₂ cyanide destruction method. However, due to the nature of the ore deposit at Nickel Plate, several open pits have been milled rather than sluiced as proposed for the Crown Jewel Project. Homestake backfills mined-out pits with waste rock, which necessitates leaving the last pit as a series of benches and highwalls. In contrast, requirements in the state of Washington call for benches and highwalls to be selectively blasted to form smooth slopes and a natural appearance.

Waste-rock dump slopes at the Nickel Plate mine are generally 3 feet horizontal for each 1 foot vertical (or 3:1); there is a maximum height of 8 feet between terraces or breaks in slope on the dumps. Topsoil is placed on waste-rock slopes that are gentler than 3:1 to speed revegetation. Clay and silts salvaged from nearby glacial till supplement these soils. Crested wheat, rye, and clovers are the first ground cover plants used here to stabilize the soils on dump slopes. The mine reclamation plan is to plant more native species as revegetation proceeds.

The tailings impoundment is dammed but unlined, and leakage through the underlying glacial till has been a problem. Homestake installed collection trenches and a buried collection piping system about 3 feet below the level of the adjacent Cnty Creek and between the creek and the tailings impoundment. The system appears to stop the generation of cyanide, which is then pumped back to the tailings impoundment.
INTRODUCTION

Because much of Washington’s commercial forest land is in mountainous terrain, it is susceptible to slope instability of various types and rates. Some forest practices (particularly road building associated with roads and timber harvest) can increase mass wasting on slopes of marginal stability. Since implementation of the Timber/Fish/Wildlife Agreement in 1987, the Coordinated Monitoring, Evaluation, and Research committee (CMER), the Sediment, Hydrology, and Mass Wasting technical steering committee, and the Department of Natural Resources (DNR) have been engaged in cooperative interdisciplinary efforts to study mass erosion on forest lands, improve methods by which it is addressed, and generally reduce the adverse effects of forest practices on slope stability and downstream resources.

As one means of addressing these goals, a Slope-Stability Hazard Zonation Pilot Project was designed and completed using the resources and personnel of both the Forest Practice Division and the Division of Geology and Earth Resources (DGGER) of DNR. The project’s broad purposes were to (1) complete a landslide inventory of a selected pilot area, (2) collect topographic, geologic, soils, climatic, and vegetation data relevant to the landslides, and (3) compare the inventory with the state soil survey slope hazard ratings (and other hazard zonation strategies) to assess their utility. We present an overview of our results in the next section of Washington Geology. In this issue, we present information pertaining to the relations among terrain features (landslip elevation and aspect), geologic materials and landforms, slope gradient, and incidence of landsliding.

Pilot Study Area

The pilot study area, 199 m², lies at the intersection of the southern part of the Cascade Range in Washington and a prominent third-order range, generally termed the Northcrat mountains. Rugged terrain and a variety of geomorphic features result from factors that include glacial erosion and deposition, high yearly precipitation (60–100 in.), and mass wasting of folded and faulted Tertiary volcanic and sedimentary rocks. The variation in land use, ownership, topography, geologic and soils characteristics, climate, landforms, and mass-movement features in the study area allow the common application to many other forested areas that have similar characteristics.

For the pilot project, we divided the general (whole) study area into a focus area, which we examine in detail using aerial photos and field verification of landslides, and a perimeter area, which was investigated using aerial photos and only field confirmations (Fig. 1). The focus study area of 61,061 acres (95.4 m²) contains 1,021 mapped landslides, of which 567 were field-verified. The perimeter area is 60,949 acres (95.7 m²) and contains 651 mapped landslides, 31 of them field-verified.

Materials

We used a modification of the landslide classification scheme of Varnes (1978), which is in turn an outgrowth of previous work by Varnes (1958) and Sharpe (1938). We combined the Varnes landslide classes into three groups: deep-seated, shallow, and cliff (rock-slope) failure types; and we defined road-related failures as a separate type (Table 1). Shallow landslides such as debris slides, avalanches, and torrents (including debris flows and hyperconcentrated flows) typically start as rapid translational failures of the soil mantle (Figs. 2 and 3). Shallow slides also include road-related landslides that emanate from road fill, sideslopes, cutbacks, or landings (Figs. 4 and 5). Deep-seated rotational landslides such as debris slumps, rock slumps and slump-to-earthflows are generally much larger failures (Fig. 6). For completeness, we inventoried prominent cliffs where rock fall, rock topple, and rock sliding are the primary processes of mass wasting.

We used Digital Chart of the United States National Topographic System vector maps in the general study area prior to field verification in the summer of 1991. These are a black and white 1:14,000-scale map (1988) and a color 1:24,000-scale map set (1978). Lewis County soil map orthophotographs (1976) supplemented our aerial photo interpretations. The landslides were traced on mylar overlays of the aerial photos; polygons were transferred to U.S. Geologival Survey 7.5-minute topographic maps and digitized using AutoCAD. We imported our aerial-photo mapping after the field season to calibrate our field observations and photo interpretations.

For each landslide, we recorded data on a spreadsheet for documentation and analysis. The features recorded include elevation of the landslide crown; azimuthal direction (aspect) of movement; type and extent of affected, geologic and soil units underlying the disturbed area (that is, beneath the landslide rupture surface); geometric structure orientations, movement direction, shape, and scarp-slope, and cross-slope failure modes; and geomorphic characteristics (for example, hummocky topography). We also measured hillslope gradients adjacent to the failure from topographic maps and in the field. Using the aerial photos and field observations, we measured the rupture surface width, length, and depth to derive a landslide area and volume.

We classified each landslide by activity level (active, recent, dormant, or ancient) and by our certainty (definite, highly probable, probable, or questionable) that it is a landslide. Assignment of activity or certainty was based on the clarity and number of observed landslide features (such as head scarp, flanks, toes, as well as their morphologic freshness). These landslide data and observations were documented on field forms, which we filed with a photograph of the landslide.
Wauconda was one of many districts in the Northwest and Canada that were studied in the search for marble of whiting (pigment) potential. Other sources of suitable rock were found but are not plentiful. Considerations of purity and brightness, transportation, and the small market for GCC that developed while the use of PCC was rapidly increasing hampered development of other high-quality carbonate deposits in Washington, Alaska, and Canada. Small parts of the vast high-calcium limestone resources on Texada Island, British Columbia, have high brightness, but this stone is now largely used for making portland cement. Former marble-producing districts in Washington, such as Northport and others in the western part of the state, generally contain too much dolomite or quartz (1%) or are simply too dark for use in fine white papermaking.

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**Information Available for Regulated Activities**

Governor Mike Lowry recently issued Executive Order #93-06 on Improving State Regulatory Activities. The Division of Geology and Earth Resources regulates surface mine reclamation, oil and gas exploration, geothermal exploration, and underground gas storage in Washington. To assist state and local governments, businesses, and private citizens in understanding the regulations and in fulfilling their regulatory obligations, the Division provides a wealth of articles and handouts. Since passage of the amendments to the Surface Mining Act, the Division has prepared new forms and guidelines, which we hope will be easier to understand, to assist applicants for reclamation permits in preparing the detailed reclamation plans that are required by law.

Information on regulated activities that is available from the Olympia office is given below:

**Articles in Washington Geology**


(From Rocks & Minerals)

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**Information Circulars**


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**Open File Reports**


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**County Bibliographies**

Bibliographies of the geology and mineral resources of selected counties (listed below) have been prepared in support of the Growth Management Act and updated through 1992. These are available free as paper copies or on disk. To order disk copies, please include the number of kilobytes in the file desired (indicated below) and send us the appropriate number of formatted 3.5-in. or 5.25-in. disks. Specify whether you want the file in WordPerfect 5.0 or 5.1 or ASCII. ASCII files users may wish to order a paper copy of each file; these copies will show text formatting lost in the conversion to ASCII. We will copy the required files and return the disks to you.

- Benton County (340K)  Klickitat County (44K)
- Chelan County (190K)  Lewis County (133K)
- Clark County (120K)  Mason County (54K)
- Clallam County (54K)  Okanogan County (198K)
- Cowlitz County (104K)  Pierce County (96K)
- Douglas County (46K)  San Juan County (158K)
- Franklin County (73K)  Skagit County (144K)
- Grays Harbor County (112K)  Snohomish County (165K)
- Island County (54K)  Spokane County (101K)
- Jefferson County (119K)  Thurston County (91K)
- King County (313K)  Walla Walla County (40K)
- Kittitas County (121K)  Whitman County (202K)
- Klickitat County (139K)  Yakima County (139K)

Continued on Page 27
Selected Additions to the Library of the Division of Geology and Earth Resources
June 1 through September 30, 1993

THESES


Wuoreo, Marc A., 1993, Late-Quaternary vegetation and climate history of the central Coast Range, Oregon—A record of the last ca. 45,000 years from Little Lake: Oregon State University Master of Science thesis, 83 p.

U.S. GEOLOGICAL SURVEY Published Reports

Includes:

Includes:

Figure 7. Six-inch-diameter pieces of high-purity and high-brightness marble are temporarily stacked at the data railroad siding south of Tonasket. The rock is transported in bottom-dumping railcars to the Columbia River Carbonates ODC plant at Woodland in southeast Washington.

Figure 8. The Columbia River Carbonates building in which the marble is processed.

Figure 9. Raw material is stacked at the Woodland plant. On the right are tanks that store the finished slurry.

of 1984 when members of a joint venture team, Columbia River Carbonates and Genstar Stone Products, identified a previously unrecognized, large-tonnage deposit of fairly pure white marble in Okanogan County (Fig. 5). The deposit (Fig. 6), located 6 miles north of the town of Wauconda, is an elliptical podiform body that was delineated by the study of outcrop and drill cores. The deposit is nested in a group of hornsfels, amphibolites and carbonate rocks of the Permian Spectacle Formation that lies east of the Okanogan meta-morphic core complex and just west of the Tonado Creek graben. Geologists theorize that the marble and associated rocks in the Wauconda district are parts of Paleozoic exogenic terrane that were formed elsewhere and accreted to the edge of North America as the Pacific ocean plate passed under the continental plate. The complex geologic history and setting of the Wauconda district marbles account for some of the impurities.

Columbia River Carbonates keeps the purity and brightness of the Wauconda marble at acceptable levels through several processes that are broadly termed "beneficiation". Small dolomite zones and dikes or slits of lamprophyre and altered porphyritic rocks are removed during quarrying through selective mining and band sorting. After trucking to a facility at the data railroad siding (Fig. 7), south of Tonasket, six-inch fragments of quarry-run marble are passed across a vibrating screen that shakes off the fines (clay and dirt) before being loaded into railroad cars for shipment to the Columbia River Carbonates mill at Woodland. The fine particles, such as carbonized at A, are then sifted to color the stone and reduce brightness. This screening is enough to meet user specifications for grade and purity, but not ground products, which have less stringent criteria than coatings.

At the mill (Figs. 8 and 9), the part of the marble that will become coating is refined by flotation. Flotation removes minor amounts of pyrite, quartz, and graphite and results in a product that has a brightness of 95 to 96. Columbia River Carbonates is the only manufacturer west of the Mississippi to produce coating grade marble (Fig. 9). They are marketed throughout the Pacific Northwest (Fig. 10) and ship to a centrally located Woodlands plant.
Figure 5. General view of the Wasco marble deposit (4 miles northeast of the town of Wauconda) and the Columbia River Carbonates plant at Woodland, WA, which is centrally located to served the needs of the Pacific Northwest paper industry.

CO2 gas → precipitated CaCO3 crystals + H2O, the total PCC process, including the energy required for quicklime production, releases nearly 3 times more CO2 than making GCC (Fig. 4). As air-quality standards are tightened and emissions have to be very low because both are abrasive and can damage the fine screens on which paper slurry is laid as the paper is formed.

Brightness is defined on a scale of 0 to 100. Values from the mid-90s to 100, measured with a GE Ebreco testing equipment, are considered acceptable. High brightness normally means a very low concentration of iron in the raw rock.

There are other considerations: the GCC source has to be close to the market so transportation costs will be low; there has to be enough volume to assure a long-term supply; and of course, there has to be a market for the product.

During the early and mid-1980s, as use of CaCO3 in paper was beginning in the U.S., there was a large disparity for raw rock sources for GCC products was extensive. Many of these sources were racing to identify and develop exceptionally pure deposits of CaCO3 for high-quality production (Boise Cascade) or for outside GCC sales (Cominco American Resources). Just one good discovery could satisfy the projected GCC demand.

The WAUCONDA DEPOSIT

Reconnaissance for suitable raw CaCO3 resources culminated in the fall of

Open-File Reports


Includes:

Malone, S. D., 1993, Pacific Northwest earthquake hazards based on historical seismicity. Appendix B.


National Earthquake Prediction Evaluation Council, 1993, Earthquake hazards and special needs population—Assessment of special needs populations in areas of Seattle with residential buildings susceptible to earthquake damage. Battelle Human Affairs Research Services Center, 900-4040, 1 v.


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facing economic and environmental challenges akin to those the European producers have dealt with for decades. Timber suppliers continue to drop dramatically as we deal with ecological challenges, and there will be a commensurate increase in fiber costs. Every year, the average American consumes paper and wood products equivalent to a 100-foot, 16-inch-diameter tree. The demand for higher quality printing paper and intensified competition stemming from increased production capacity worldwide will compel U.S. producers to make paper at lower costs. In this decade, U.S. fiber levels, primarily calcium carbonate, will match those now commonplace in Europe. The current worldwide average for filler usage is about 20 percent. We can probably expect increases in the use of minerals for both fillers and coatings in the coming decade and beyond (Fig. 3).

ENVIRONMENTAL CONSIDERATIONS
Calcium carbonate is a mineral that has virtually no adverse impact on nature. Paper containing calcium carbonate is also superior postcycled for recycling. Pulp fibers can be recycled as many as five times before they become too short to be used again (without addition of longer fibers). Online-based manufacturing environments one that is CaCO3-rich, is less damaging to the fibers. Acid-based chemistry tend to weaken fiber properties, whereas CaCO3 made this way cannot be recycled as many times before breaking down. While there are clear advantages to having a CaCO3 source on site, there is a caveat with respect to energy consumption. Pulp plants in North America, of which 34 are operated by Mineral Technologies, Inc., typically purchase quicklime “touched prime manufactured” CaCO3 produced by adding heat to CaCO3, which produces CaO (quicklime). Another drawback is the byproduct of the reaction is the smokestack as CO2. Despite the similar energy expenditure required to mine the raw limestone for the production of either CaCO3 or quicklime, it has been estimated that CaCO3 production takes about 8 times more energy to produce PCC as opposed to making GCC. Furthermore, in spite of the fact that somewhat lower energy process gas from pulping mills can be captured in the carbonization process Ca(OH)2 slaked lime +
Figure 2. Scaevohordal crystal, typical of precipitated calcium carbonate, and a rhombohedral crystal, typical of natural calcium carbonate, or calcite.

Characteristics of PCC

As filler, PCC offers these advantages:

- If there is an on-site satellite plant, no dispersant chemicals are needed to keep the slurry from settling during transportation, thus reducing the cost of chemicals.
- Higher opacity, brightness, and bulk result from the scalenohedral morphology of PCC crystals.
- There is less abrasion during the production process; abrasion is detrimental to the expensive paper machine engine and parts.
- The electric kinetic surface charge (zeta potential) is enhanced, which makes for better particle distribution on the sheet.

Disadvantages are:

- The large surface area of the particles decreases the efficiency of sizing.
- Small voids interfere with fiber bonding and consequently reduce the strength of the paper sheet.
- PCC retains more water than does GCC, which means that the speed of paper production is reduced; associated drainage costs can be significant.
- Unreacted size (ADR) that is attached to PCC particles remains as residue that is detrimental to paper production.
- Trace elements that have not been neutralized in production adversely affect paper quality and runnability.

Characteristics of GCC

Use of GCC offers these advantages:

- Substantially higher filler levels are possible, thereby maximizing savings and profitability for papermakers.
Russian Geologists to Speak at Northwest Mining Convention

For decades, world leaders and people in the mining industry have been looking to Russia for endless supplies of minerals that lay hidden in the former Soviet Union. Some of the mystery surrounding Russian mineral resources will be lifted this December in a three-day international meeting of the Northwest Mining Association.

A half-dozen experts from throughout Russia will share their knowledge of Russian geology and related mineral sciences at the NWMA short course "Global Business Opportunities—East European Resources" from Nov. 28–30 and the NWMA convention "International Mining—Pros and Cons" from Nov. 30–Dec. 3. The Russian experts include Dr. Anatoly Sidoren and Dr. Leonid Parfenov of the Russian Academy of Sciences who will discuss problems and opportunities for joint mining ventures in Siberia. Parfenov, who is chief for the Laboratory for Regional Geology and Tectonics at Vokos in northern Siberia, will also open the convention as the luncheon speaker on Dec. 1. His address will be "The Life of a Russian Geologist in Siberia." Before his appointment to Siberia about 10 years ago, he was chief of a similar laboratory at the Institute of Tectonics and Geophysics at Khabarovsk in the central Russian Far East.

Other Russian scientists will discuss the geology and minerals of their country on December 2 and 3.

The theme of the conference is "International Mining—Pros and Cons". Development, discoveries, and opportunities in the Americas and the former Soviet Union will be examined.

Trade Show (Dec. 1–3)

The trade show will again have 500 or more displays of products and services available to the minerals industry.

Short Courses (Nov. 28–30)

- Global Business Opportunities—Examining the Differences: Regions to be emphasized are Russia, the Pacific Rim, Latin America, and Asia. Topics will include metals, energy and environmental issues.
- Applied Biogeochemical Prospecting in Forested Terrain. Course will cover basic principles of biochemical prospecting and lead participants through to "state-of-the-art" knowledge, learning heavily on the Pacific Northwest. Co-sponsored by Pacific Northwest British Columbia and the boreal forests of Canada.

Contact

more information

Contact the Northwest Mining Association, 10 N. Post, Suite 414, Spokane, WA 99201-0772. Phone: 509-624-1158; Fax: 509-626-1241.

Prospectors & Developers Association of Canada

INTERNATIONAL CONVENTION AND TRADE SHOW

March 5–9, 1994

PDAC Convention 94 will offer the latest information and news on investment, business, and technological aspects of worldwide mineral exploration and development. Three
tdays of technical sessions, a one-day short course, a special session for adjudicated papers, a trade show with over 200 exhibits, and social events will provide an excellent opportunity for delegates to learn, inform, and update their knowledge on the mineral industry in Canada and abroad.

Technical Program

The technical program is under development and areas already defined include papers, presented by leading experts, on:
- Alternative methods of financing exploration projects
- Global search for diamonds and the economics of diamond mining
- Gold projects in developing countries
- International discoveries and developments

There will be a strong focus on international exploration and development in special sessions where government or industry representatives will be able to discuss investment opportunities and the state of the mineral industry in their country.

Short Course

A full-day short course on Saturday, March 5, entitled "Prospecting in Tropical Terrain", will take a close look at the unique geologic, hydrologic and social aspects of mineral exploration in tropical and subtropical countries.

Call for Papers

The Open Forum is a special session of adjudicated papers that runs parallel to the main technical program. Typically, the forum offers a wide variety of exploration and development-related topics, including financing, geophysical and geotechnical techniques, deposit descriptions, case histories, applications of new technologies, geological problems of various countries, and software applications. Please send an abstract of no more than 200 words by Jan. 7, 1994, to Mrs. Gayle Lowsen in the PDAC office.

Mine Tours

There are tentative plans to offer delegates the opportunity to visit working mining operations located in the Canadian Ancestral Shield, including:
- Hemlo gold camp
- Jeffrey nickel and copper mines
- Timmins base metal deposits
- Base and precious metal mines in the Quebec Abitibi
- Industrial mineral, dimension stone, and aggregate operations

For More Information


The ‘Geology’ of Papermaking

You have probably come across old books and newspapers that are held together with age and crumble when you turn the pages. This deterioration is due to the acidic nature of the most common commercial papermaking process (acid papermaking). Problems for libraries and archives that must keep these materials available for users—restoration and preservation are expensive activities. Changes in the chemistry of papermaking (and to some extent ink) over the last 30 years have improved the life span of today’s papers by making it possible to produce acid-free paper at a much lower cost. This means that many of the books printed in 1939 will look just as good as they do now in the year 2093—in fact, for hundreds of years to come.

HOW PAPER IS MADE

Paper is a thin mixture of cellulose derived from some kind of vegetable fiber, usually wood fiber. In the most common commercial papermaking process, wood is ground up and the fibers are then treated and bleached to produce paper "pulp." Wood fibers contain a high percentage of lignin and other impurities that, if left in the paper, eventually decay and produce acid that attacks the cellulose, turning the paper brown and brittle. Wood pulp requires extensive treatment before it’s suitable for ordinary papermaking and even more treatment before it’s properly sized for high quality, permanent papers.

The pulp is used to make up the basic structure of a sheet of paper, which is supplied as a web of fibers that adhere to each other and form a seamless sheet similar in appearance to cloth fabric. Paper for printing also has to repel water and bestow the "beauty" of writing. This is achieved as "printing." Rosin and alum (aluminum sulfate) have commonly been added to "size" the paper. This process is done under acidic conditions [ph (pH)] ranging from 4.0 to 4.5. Sizing agents are required to make the paper hold ink and to prevent the paper from excessive "bleed through" of ink from one side to the other. The quality and quantity of "size" in the final paper may vary widely.

CAUCALM CARBONATE AND THE PAPERMAKING PROCESS

As manufacturers searched for economical methods of producing paper, they began to replace resin and alum with ACP (a synthetic organic chemical), forming a process known as "synthetic" or precipitated CaCO₃. Natural CaCO₃ is mined from high-grade calcite deposits and then finely ground. It is referred to as "calcrete," "grounding," or "GCC," in the paper industry. Chemically precipitated CaCO₃ is also used on paper and is known as PCC. CaCO₃ used for filler is referred to as "filler" and is used to provide coating for "coating grade." The two grades differ in particle size, the ratio of water to solids in the CaCO₃ slurry, and other characteristics.

Papermakers have found there are significant advantages to using precipitated CaCO₃. It is much cheaper to produce, and since the mineral is not only an inexpensive whitening pigment for filler and coating, but in the case of GCC, the raw material is readily available worldwide, whereas deposits of limestone or marble that have suitable brightness and purity are limited. PCC, on the other hand, is produced by chemical processes (Fig. 1) and has some limitations, particularly in regard to how much can be added as filler.

In Europe, precipitated ground calcium carbonate is the most widely used type of filler. Limestone or marble of high purity is ultra-fine ground by a sophisticated "wet-grinding" method to produce the particles. The effective size of these particles is less than 2 microns (1 micron = 1 millionth of a meter) in diameter (Fig. 1). The particles are suspended in a slurry that consists of about 75 percent solids (cover photo). In the U.S., GCC is excellent, and until recently, a ready supply of fiber for pulp (particularly Douglas fir and hemlock trees, which produce strong fibers) was available. However, as paper producers start producing more and more recycled fiber, many of these same problems are starting. As the supply of natural sources of GCC are running low, new sources for GCC are being investigated. In the U.S., GCC is being produced in the Midwest and in the Gulf Coast region. GCC is being used in a variety of applications, including coatings, inks, and adhesives. GCC is also being used in the production of a new type of paper called "recycled paper." Recycled paper is made from recycled paper fiber, which is ground up and mixed with GCC to improve the brightness and whiteness of the finished product. GCC is also being used in the production of paperboard, which is used for packaging and printing.GCC is also being used in the production of paperboard, which is used for packaging and printing.
National Geologic Information Mapping Act Update

by Raymond Lawanski

In fiscal year 1993, Congress appropriated $21,982,000 for the National Geologic Mapping Program. The funds for federal FY 93 were divided by program components as follows:

- **Program**
  - Authorization: $12,500,000
  - Funding: $10,852,000
- **Federal funding**
  - Federal support: $9,500,000
  - State funding: $1,399,000
  - Education funding: $500,000

Note that the U.S. Geological Survey (USGS) mapping program received 87 percent of authorization, USGS mapping support received 103 percent of authorization, education was not supported, and state mapping was supported at 9 percent of authorization.

Forty-four states submitted proposals to receive a portion of the $1,339,000. Our original request to the USGS was for field mapping and analytical support and for the cost of printing the 1:250,000-scale maps of the southeast quadrant. This grant request for $51,000 was rejected.

On September 3, 1993, we submitted a modified request for $25,000. The scope of this proposal is to acquire geologic data in the Roche Harbor and Bellingham 1:100,000-scale quadrangles. Radiometric dating, geochemistry, and travel costs were included in the proposal, which was approved by the USGS on September 30.

The National Geologic Information Mapping Act funding for state mapping support in FY 94 is $18,000,000. The American Association of State Geologists (AASG) continues to support full funding for the National Geologic Mapping Program. However, AASG believes that the program receive an increase of at least $10 million over the President's budget of $94. Also, AASG has taken the position that the allocation of the budget be made among the four program elements in proportion to the authorization in the National Geologic Mapping Act of 1992.

For the proposed increase above the President's budget for FY 94 to maintain the federal mapping program elements at their FY 93 level, to increase support of the state mapping program element to a more reasonable level, and to begin funding the educational program.

If the increase is obtained and the allocation is made in proportion to authorization levels for FY 94, then the FY 94 program would be as follows:

- Federal mapping: $11,112,000
- Federal support: $7,952,000
- State mapping: $13,306,000
- Education funding: $612,000
- Total: $33,982,000

The state of Washington would benefit from full funding of the act for FY 94, but we must recognize that the federal budget deficit will make it extremely difficult to achieve that goal.

REGULATORY INFORMATION

Information Packages
- Geothermal Resources Act and accompanying rules and regulations
- Oil and Gas Conservation Act and accompanying rules and regulations
- Surface Mining Land Reclamation Act and accompanying rules and regulations
- Underground Gas Storage Act

These items are free unless otherwise noted. Send your order, with a check for the required amount made out to the Department of Natural Resources, plus $1.00 for postage and handling, to:

- **Washington Department of Natural Resources**
  - Division of Geology and Earth Resources
  - PO Box 47007
  - Olympia, WA 98504-7007
  - Phone: 206/992-1450
  - Fax: 206/992-1785
  - Please include $1.00 with all publications orders to cover postage and handling.

年报 Named in SME "Outstanding Student Paper Contest"
The North Pacific Section of the Society of Mining Engineers distributed awards to winners of the section's Outstanding Student Paper Contest at its meeting in May. Lynn Holland, Western Washington University, won first place in the Graduate Division for her paper titled "Fourier transform infrared spectroscopy quantitative analysis of teach pulpings on perthopy copper deposits"; she received a $400 scholarship. Richard Chaney, also of Western Washington University, won second place in the Graduate Division for his paper, "A study of gold mineralization at the Boundary Red Mountain mine, Whatcom County, Washington" and received a $300 scholarship.

First place winner in the Undergraduate Division was Michelle Robinson, University of British Columbia; her paper is titled "Genesis of the Blythe carbonate-hosted Zn-Pb-Ag deposit, north-central Yukon Territory—Geologic, fluid inclusion, and isotopic constraints." She won a $400 scholarship.

Sponsors of the contest were Golder Associates, Inc., of Redmond, WA; Inco Ltd. of Toronto, Ont.; and CH2M Hill, all of Seattle, WA; Borden Cligg of Vancouver, BC, Robbins Company of Kent, WA; ASARCO of Tacoma, WA; and Corby Smith, Jr., of Bellingham, WA.

HOW TO FIND OUR MAIN OFFICE

DGER Staff Changes

STAFF TRANSFERS
- Venice Goets (Geologist 2) has transferred to the Division of Forest Practices and has been promoted to Natural Resource Scientist 2. She will be doing watershed analysis and slope stability assessment for timber harvest.
- Rex Hopala (Research Technician) has transferred to the Southwest Region, based in Castle Rock, and has been promoted to Geologist 2. He will be working as a surface mine reclamation inspector.

Naomi "Nonie" Hall (Clerk Typist 3) has transferred to the Division of Forest Land Management.
- Shelley Reicherl (Clerk Typist 2) has now a Fiscal Technician for the Division of Aquatic Lands.
- Joan Castaneda (Clerk Typist 2) has also transferred to the Division of Aquatic Lands.

NEW STAFF
- Angela Stanton (Clerk Typist 3) is a transfer from the Northwest Region in Sedro-Woolley, where she worked for six years with the surface mining, service forestry, and forest practices programs. Before that she was at the Southeast Region in Ellensburg for four years—two in Lands and two in the Radio Room. Angela plans to continue working toward a degree in business administration.
- Karin Lang (Clerk Typist 2) is another new addition to our staff. Her early work experience is as a photographer. For the last three years, since her arrival in Olympia, she has spent the summers as a PBD Operator with the Division of Fire Control and her winters as a staff photographer for the State Legislature. She is also a published poet. Karin plans to continue working toward a degree at Puget Sound Community College.
Division Publications
Geologic maps of part of the Yakima Fold Belt, north-eastern Yakima County, Washington, Open File Report 93-3, by Robert D. Bentley, Newell P. Campbell, and John E. Powell. Contains maps of the Yakima East, Hannah, Toppenish, and Granger 15-minute quadrangles, scale 1:31,680, and a set of associated cross sections. 5 folded sheets and a 13-page pamphlet that includes a table of major element analyses of basalt in the area. $8.33 + .67 tax (WA residents only) = $9.00

Roadside geology of Mount St. Helens National Volcanic Monument and vicinity, Information Circular 88, by Patrick T. Pringle has gone into its second printing! This 120-page book explains the geologic history of the Mount St. Helens area and provides mile-by-mile geologic road guides for seven routes of approach to the mountain. A geologic primer and glossary are included. (It is also available at Mount St. Helens National Volcanic Monument visitor centers.) $3.24 + .26 tax (WA residents only) = $3.50.

Please include $1.00 with all publications orders to cover postage and handling.

Directory of Geoscience Libraries, United States and Canada
4th edition, 1993
Geologists - Hydrologists - Engineers!
Find sources for those elusive, site-specific geologic reports, open-file reports, theses, and maps. This book describes the collections, accessibility and services of 591 corporate, government, academic, and private geoscience libraries in the U.S. and Canada. It also lists addresses, e-mail, fax, and phone numbers. $35 per copy (prepaid, U.S. dollars). Order from: Publications Manager, Geoscience Information Society, c/o American Geological Institute, 4220 King Street, Alexandria, VA 22302.

DGER Spokane Field Office Has Moved
The Division of Geology and Earth Resources Spokane Field Office has moved to the old Post Office Building in downtown Spokane. Bob Derkey and Chuck Gulick are now in Room 209 on the same floor as the USGS geologists.
The new address is:
Department of Natural Resources
Division of Geology and Earth Resources
904 W. Riverside, Room 209
Spokane, WA 99201-1011
Phone: 509/456-3255
Fax: 509/456-6115

Publications of the Association of American State Geologists
The State Geologists Journal disseminates information about the organization, facilities, activities, accomplishments, and publications of state surveys and mining bureaus. The price is $10 for the single issue per year.
The AASG Fact Book, updated annually, offers information about the programs of each of the state surveys and lists program managers and telephone numbers. It is available for $10.
Orders may be sent to Dr. Thomas M. Berg, Ohio Geological Survey, Dept. of Natural Resources, 4383 Fountain Square Drive, Bldg. B, Columbus, OH 43224-1362.

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