OREGON GEOLOGY

published by the
Oregon Department of Geology and Mineral Industries

VOLUME 57, NUMBER 3 MAY 1995

IN THIS ISSUE:

OREGON GEOLOGY

(ISSN 0164-3304)

VOLUME 57, NUMBER 3 **MAY 1995**

Published bimonthly in January, March, May, July, September, and November by the Oregon Department of Geology and Mineral Industries. (Volumes 1 through 40 were entitled *The Ore Bin*.)

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Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted. If manuscript was prepared on common word-processing equipment, a file copy on diskette should be submitted in place of one paper copy (from Macintosh systems, high-density diskette only). Graphics should be camera ready; photographs should be black-and-white glossies. All figures should be clearly marked; figure captions should be together at the end of the text.

Style is generally that of U.S. Geological Survey publications. (See USGS *Suggestions to Authors*, 7th ed., 1991, or recent issues of *Oregon Geology*.) Bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Include names of reviewers in the acknowledgments.

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, letters, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office (address above).

Cover photo

"With eyes only a few feet above the ground the observer today must travel back and forth repeatedly and must record his observations mentally, photographically, by sketch and by map before he can form anything approaching a complete picture. Yet long before the paper bearing these words has yellowed, the average observer, looking down from the air as he crosses the region, will see almost at a glance the picture here drawn by piecing together the ground-level observations of months of work. The region is unique: let the observer take the wings of the morning to the uttermost parts of the earth: he will nowhere find its likeness." —*J Harlen Bretz, 1928.*

This somewhat whimsical photo of Bretz was taken some time around 1940. His work opened the way to our understanding of the cataclysmic Missoula floods that created the Channeled Scabland. A field trip guide to Missoula flood features begins on the next page and will be continued in subsequent issues.

In memoriam: Volunteer Martha Carlson

Martha Carlson, volunteer with the Oregon Department of Geology and Mineral Industries (DOGAMI) since 1992, died at her home on March 9, 1995, of cancer. Born in Denver, Colorado, Martha and her husband Lennert were longtime residents of Oregon. They loved the out-of-doors, and both were Mazamas.

After her family was raised and Lennart died, Martha expanded her interest in travel to places outside Oregon, visiting other parts of the United States, Canada, England, Russia, Greece, Switzerland, Mexico, and Egypt. Her interest in art and history enabled her to serve as a docent for the Portland Art Museum and the Oregon Historical Society.

As a DOGAMI volunteer in the Nature of the Northwest Information Center, Martha was able to share her knowledge of Oregon and the out-of-doors with the public. More than that, she worked hard at marking and filing maps, helping to maintain the inventory of brochures, dusting and arranging stock on shelves, and even assembling publications so they could be available to the public when they were needed in a hurry.

Always cheerful and interested in what was going on around her, Martha made a real contribution to the lives of all of those of us who worked with her. She gave 461 hours of service to DOGAMI, but she also gave us much more—friendship, warmth, and encouragement. We miss her in many ways. She is survived by her daughter Eleanor, son David, both of their spouses, and five grandchildren whom she loved dearly. □

Policy Working Group presents final report on coastal natural hazards

The Oregon Coastal Natural Hazards Policy Working Group (PWG) has published its findings and recommendations in a book recently released by the Oregon Sea Grant program of Oregon State University. The 128-page book is entitled *Improving Natural Hazards Management on the Oregon Coast*. The report outlines 23 issues along with 78 recommendations, dealing with hazard assessment, beach and shore protection, land use planning, and earthquake and tsunami disaster preparedness.

The book is available for $12 from the publisher, Sea Grant Communications of OSU, phone (503) 737-2716, or the DOGAMI offices in Baker City, Grants Pass, and Portland. See information on this page and on page 72. □

Beyond the Channeled Scabland

A field trip to Missoula flood features in the Columbia, Yakima, and Walla Walla valleys of Washington and Oregon—Part 1

by James E. O'Connor and Richard B. Waitt, U.S. Geological Survey, David A. Johnston Cascades Volcano Observatory, 5400 MacArthur Blvd., Vancouver, Washington 98661. With contributions by Gerardo Benito, Centro de Ciencias Medioambientales, Serrano, 115 dpdo, Madrid, Spain 28006; and David Cordero and Scott Burns, Department of Geology, Portland State University, P.O. Box 751, Portland, Oregon 97207*

A preliminary version of this field trip guide was prepared for the first annual field conference of the Friends of the Pleistocene, Pacific Northwest Cell, May 13–15, 1994. This first part includes the introductory discussion and the list of references. The guide for the three-day trip will begin in the next issue. —ed.

INTRODUCTION

Field trip route

This trip along the Columbia, Walla Walla, and Yakima River valleys highlights Missoula flood features southwest of the classic Channeled Scabland of eastern Washington. The road log for each day begins at Deschutes River Recreation Area, an Oregon State Parks facility with camping and picnicking areas at the mouth of the Deschutes River, 3.4 mi west of Biggs and 12 mi east of The Dalles. Day 1 focuses on features on the Oregon side of the Columbia River between The Dalles and Arlington. Day 2 is a high-mileage loop up the Columbia River valley, through Wallula Gap and the lower Walla Walla valley, and up the lower Yakima valley, returning via Satus Pass. Day 3 concludes the trip by traveling downstream through the Columbia River Gorge to the Bonneville Landslide near Cascade Locks and Bonneville Dam (Figure 1).

Field trip guide organization and units

The guidebook includes introductory and background material, which is then followed by descriptions of each day's stops and discussions of features viewed while traveling between stops. A detailed road log for each day is at the end of the field-trip guide. The metric system is used for all scientific aspects of the guidebook except for altitudes, which are given in meters and in feet. Travel distances and mileages in the road log are given in miles.

Guide responsibility

The introductory material was written mainly by O'Connor, except for the last section by Waitt. The material for Day 1 is mostly from work by O'Connor and Benito, influenced by discussions and field visits with Waitt. Day 2 is mostly the work of Waitt, except for the discussion of the hydrology at Wallula Gap by O'Connor. Day 3 was compiled by O'Connor, based on work by O'Connor, Benito, Cordero, and Burns and previously published accounts of Columbia River Gorge geology.

THE MISSOULA FLOODS

Floods from cataclysmic releases of glacially dammed Lake Missoula produced a suite of spectacular flood features along multiple flowpaths between western Montana and the Pacific Ocean (Figure 2). In northern Idaho and eastern Washington, flow exiting glacial Lake Missoula overwhelmed the normal drainage routes, resulting in a plexus of flowpaths as the water spread out over the vast loess-covered basaltic plains. As the Missoula floods crossed eastern Washington, they eroded large and anastomosing coulee tracts into the basalt surfaces and left immense gravel bars. Far-travelled crystalline rocks, first picked up and carried by the Cordilleran ice sheet, were floated downstream by huge icebergs borne by the floods, and finally deposited in valleys and stranded on high hillslopes to define a "bathtub ring" of maximum flood stages. Tributary valleys like the Snake, Yakima, Walla Walla, Tucannon, John Day, Klickitat, and Willamette Rivers were mantled with sand and silt carried by water backflooding up these valleys and then receding from them again.

In south-central Washington, the myriad flow routes from the east and north converged onto the Pasco basin before funneling through Wallula Gap. Downstream, the Missoula floods continued, filling the valley of the Columbia River to depths greater than 275 m and leaving spectacular erosional and depositional features that dominate many parts of the present landscape between Wallula Gap and Portland.

Weaving together a story that linked the bizarre topography, the far-travelled exotic rocks, the immense and rippled gravel bars, and the valley-mantling bedded sand and silt has tested the creative abilities of countless scientists since the first decades of this century. Famous is J Harlen Bretz for his efforts during the 1920s and into the 1950s to persuade a skeptical geologic community of the merits of his "outrageous hypothesis" of cataclysmic flooding for genesis of what he named the "Channeled Scabland." More recent debate has centered on the number of floods, especially the idea that scores of colossal floods may have coursed through the Channeled Scabland (Waitt, 1980a, 1985b), rather than just one or a few envisioned by Bretz and other earlier workers. Discussion has also extended to the role that such multiple flows may have had in creating the flood features that we see today. Recent reports that review and

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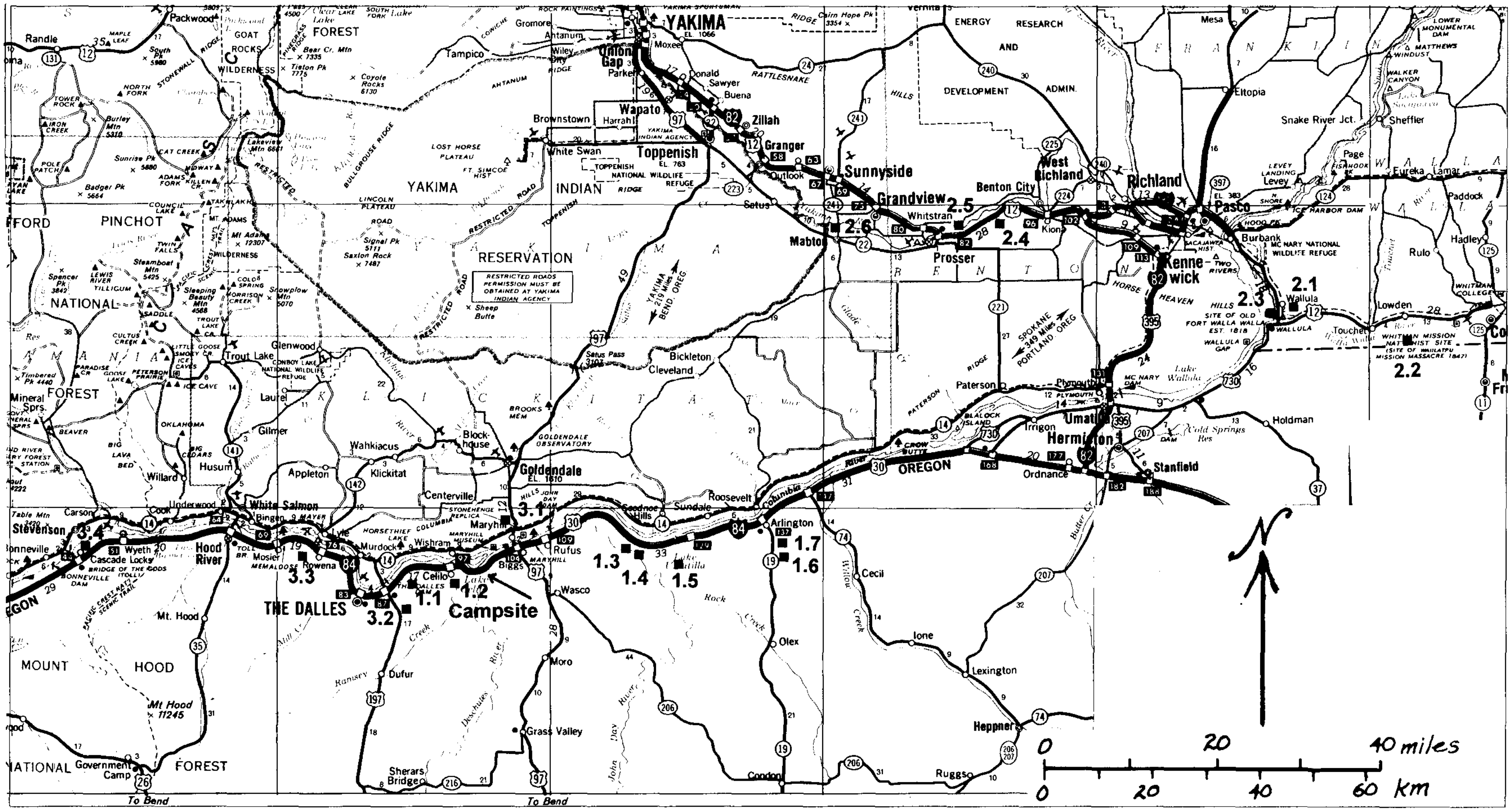

Figure 1. Road map showing approximate locations of field trip stops.

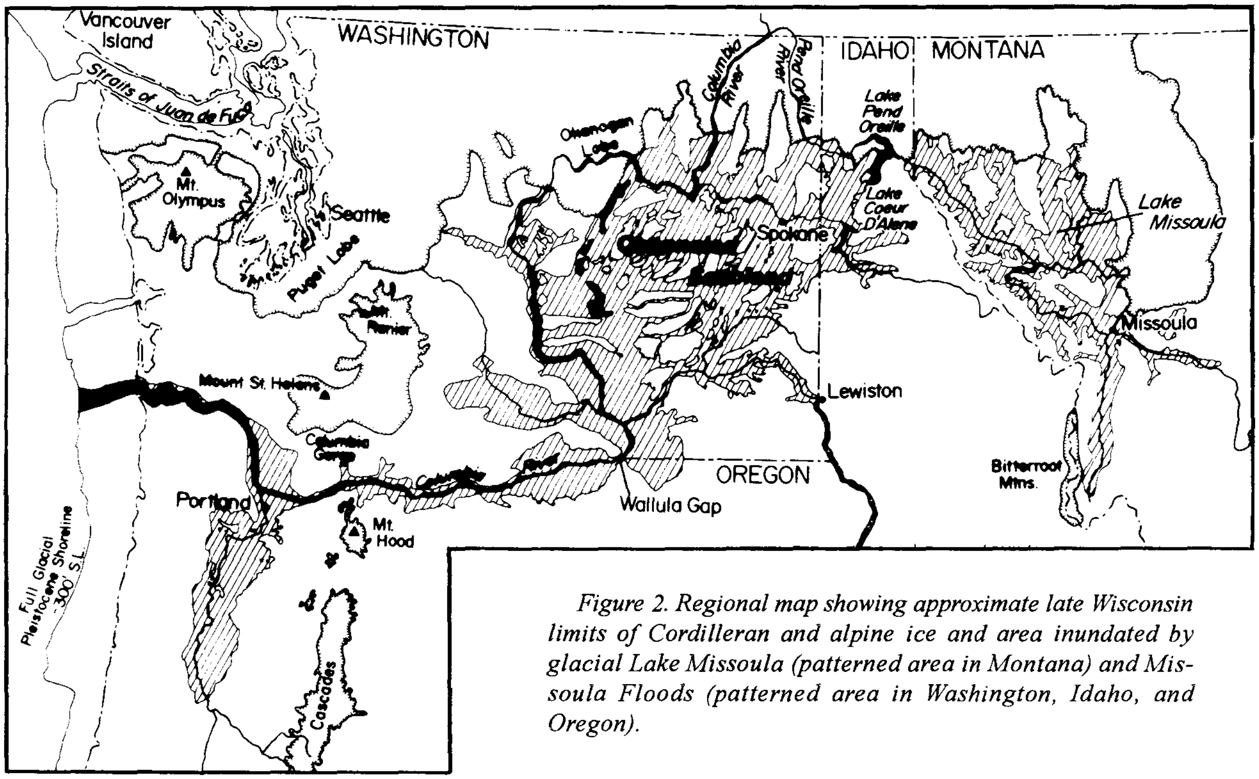

Figure 2. Regional map showing approximate late Wisconsin limits of Cordilleran and alpine ice and area inundated by glacial Lake Missoula (patterned area in Montana) and Missoula Floods (patterned area in Washington, Idaho, and Oregon).

touch on debated aspects of the Missoula floods include Waitt (1985a,b; 1994), Baker and Bunker (1985), Atwater (1986), O'Connor and Baker (1992), and Smith (1993).

BEYOND THE CHANNELED SCABLAND

Early studies of the Columbia River valley

Geomorphic features relevant to Missoula flooding in the Columbia River valley downstream from Wallula Gap were studied by Bretz (1924, 1925, 1928), Hodge (1931, 1938), and Allison (1933, 1941). These papers presented classic descriptions and discussions of features and ideas regarding the genesis of the extraordinary landscape of the valley of the Columbia River between Wallula Gap and Portland. Bretz described the bars and eroded scabland topography, arguing that they were the product of huge discharges from a then-unknown source, pointing out with clear descriptions and logic that many of these features resulted from channel processes at a valley scale. Gravel deposits with smooth and rounded forms flanking the valley were not terraces, but flood bars of immense height deposited in reaches of slacker currents or in zones of recirculation. The scabland and eroded rock benches were the result of plucking and erosion in channels beneath deep, vigorous currents that covered the entire valley bottom and sides to depths of hundreds of meters. Bretz's ideas were strongly disputed, but he responded with prose that remains relevant today:

> "Geology is plagued with extravagant ideas which spring from faulty observation and misinterpretation. They are worse than 'outrageous hypotheses,' for they lead nowhere. The writer's Spokane Flood hypothesis may belong to the latter class, but it can not be placed there unless errors of observation and direct inference are demonstrated. The writer insists that until then it should not be judged by the principles applicable to valley formation, for the scabland phenomena are the product of river channel mechanics. If this is in error, inherent disharmonies should establish the fact, and without adequate acquaintance with the region, this is the logical field for critics." (Bretz, 1928, p. 701)

E.T. Hodge (1931, 1938) suggested that the high gravel deposits, ice-rafted erratics, and divide crossings flanking the Columbia River valley recorded not a brief cataclysm, but the gradual entrenchment of the Columbia River through the Cascade Range since the middle Pliocene, stating:

> "The Columbia in its down-cutting was often choked by icebergs, which caused temporary or permanent local diversions. Many rock benches, chasms, and pot holes were cut, and stranded deposits were left at the successive levels of entrenchment. The river is not yet graded, and the methods by which it produces these curious, but by no means exceptional, features may still be observed." (Hodge, 1938, p. 836)

Ira S. Allison (1933) examined in some detail field relations between Portland and Wallula Gap and recognized the indisputable evidence for extremely high water levels. He clearly, however, struggled with the notion of catastrophic floods, and proposed a "new version" of the Spokane Flood, believing,

> "that the ponding was produced by a blockade of ice in the Columbia River Gorge through the Cascade Mountains; that the rise of the Columbia River to abnormally high levels began at the gorge and not on the plateau of

eastern Washington; the blockade gradually grew headward until it extended into eastern Washington; that, as the waters were dammed to progressively higher levels, they were diverted by the ice into a succession of routes across secondary drainage divides at increasing altitudes, producing scablands and perched gravel deposits along the diversion routes, distributing iceberg-rafted erratics far and wide, and depositing pebbly silts in slack-water areas. This interpretation of the flood does not require a short-lived catastrophic flood but explains the scablands, the gravel deposits, diversion channels, and divide crossings as the effects of a moderate flow of water, now here and now there, over an extended period of time. It thus removes the flood from the 'impossible' category." (Allison, 1933, p. 676–677)

Recent work in the Columbia River Gorge

Since the mid-1950s, J Harlen Bretz's "impossible" story has become widely accepted by the scientific community. In recent decades, research has focused on understanding details of the Missoula floods, mostly from work in eastern Washington—where stratigraphic, glacial, and hydraulic studies have refined our understanding of the chronology, magnitude, and sequence of events. Nevertheless, many questions linger, and our work between Portland and Wallula Gap has focused on these. For example, it is clear from backflooded sites all along the flood path that there were tens of late Wisconsin flows, perhaps as many as 90 (Waitt, 1980a,b, 1984, 1985a,b; Atwater, 1986). But are these flows, mostly recorded by deposits at low-elevation sites, correlative with the high gravel deposits and evidence of maximum flood stages? How many flows got how high? Were all of these flows triggered by subglacial releases from the ice dam (gigantic jökulhlaups)? Were some perhaps due to catastrophic mechanical failure of the ice dam? What was the late-glacial flood chronology? Within the Columbia River valley, some additional questions include: What were the hydraulic characteristics of the floods and their relation to resultant flood features? Is there a record of pre-late Wisconsin floods like that in eastern Washington? How did the Missoula floods affect the Columbia River Gorge? The Columbia River valley is a good place to ask such questions: the features are dramatic and commonly well exposed, and all floods followed the same route downstream from Wallula Gap, thereby avoiding the possible hydraulic and stratigraphic complexity in eastern Washington that could have resulted from the anastomosing and evolving channel patterns of the Channeled Scabland in eastern Washington.

Flood hydraulics and hydrology

We have compiled evidence of maximum flood stages between Portland and Wallula Gap from previous workers and our own observations and have used this information to estimate the peak discharge of the largest flow(s). Good evidence of maximum flood stages comes from the altitudes of ice-rafted erratics, divides crossed and divides not crossed, and loess scarps. The compiled high-water evidence indicates that the water-surface profile dropped substantially—almost 200 m—in the Columbia River Gorge between The Dalles and Portland (Figure 3). This was one of the steepest drops along the entire flood route, and hydraulic ponding behind the constricted gorge probably affected flow at maximum stages as far upstream as the Pasco basin. We have calculated water-surface profiles, using the step-backwater method (U.S. Army Corps of Engineers, 1990), for a 200-km reach between Arlington and Portland. A water-surface profile for a ten million m^3/s discharge is consistent with the highest evidence of flooding along the entire flood route (Figure 3a). This value is similar to results from earlier studies that estimated the peak discharge at Wallula Gap (O'Connor and Baker, 1992). By comparison, ten million m^3/s is about 300 times the flows of the 1993 Mississippi River flood as well as the largest historic Columbia River flood of 1894. The calculated water-surface profile for the largest Missoula flood indicates that flow was critical to supercritical in the lower part of the Columbia River Gorge, near Crown Point, with substantial hydraulic ponding upstream. Other constrictions that were apparently important in controlling the water-surface profile were near Mitchell Point, downstream from Hood River, and at Rowena Gap downstream from The Dalles, where the Columbia River flows through the Ortley anticline.

Using the results from these flow calculations, we have attempted to evaluate a couple of different questions. One research avenue has been trying to estimate discharges at sites where deposits of multiple floods are preserved, with the aim of answering the question: "How many floods were how big?" Another question we have evaluated is the relation of the calculated flood hydraulics with erosional features left by the floods.

Radiocarbon dating and flood chronology in the Columbia River valley

While examining exposures between Wallula Gap and Hood River, we found various organic materials incorporated within and below Missoula flood deposits. Most of these samples were from gravel deposits or backflood deposits at high altitudes, which, we hoped, would help determine the chronologic relation of the larger floods to the lower-elevation rhythmites. The sampled material included charcoal, soil-organic material, dung, bones, and clasts of organic-rich silt of unknown origin. We obtained results on 25 samples from various sites, yielding dates spanning quite a large range of time—from >40,000 to 13,700 ^{14}C yr B.P. (Figure 4). Because all of these dates are from clasts in or below deposits, they are maximum limiting ages for the deposits, and their wide range is not totally unexpected considering the diversity of the samples collected. Because of the common occurrence of very different age determinations from (1) different samples collected from within the same deposits, (2) analyses of parts of individual samples subject to different pretreatments, and (3) analyses of subsamples of individual samples, we infer that there was abundant old carbon existing on the landscape and that only the very youngest age determinations (those dates <20 ka [20,000 years]) are helpful in determining the ages of the floods. Some of the "charcoal" samples that gave >40-ka ages are probably pre-Quaternary coal. Other very old charcoal samples, including one friable charcoal sample that cleaved along growth rings, were probably from sites where they had been protected from decay for many thousands of years. The many samples between 20 and 30 ka were probably entrained from sites of sediment accumulation and soil formation prior to the floods, and their dates reflect carbon photosynthesized during several thousands of years prior to the floods. Consistent with this, humate extracts and plant fragments, isolated from larger bulk samples, gave substantially younger dates than the ages of the bulk samples; thus they more closely limit the age of the floods. We emphasize that many of the older dates came from horizons above or at the same stratigraphic level of those that contained materials yielding <15-ka ages, indicating that there was a lot of old organic material being transported by the floods. Consequently, we doubt that radiocarbon dating of these types of transported materials can be considered reliable evidence of

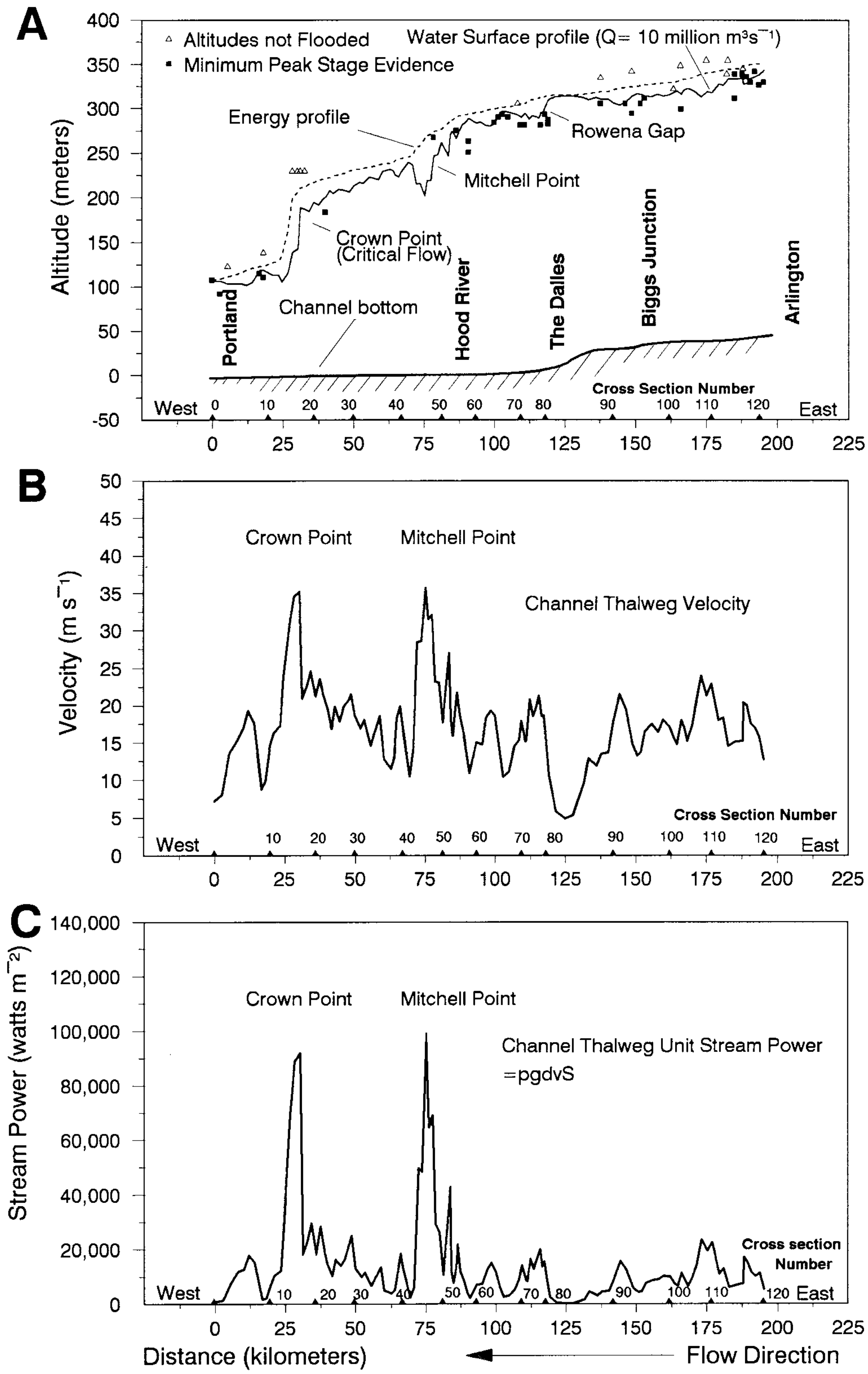

Figure 3. Profiles of calculated hydraulic conditions between Portland and Arlington. All profiles determined on the basis of step-backwater calculations for a 10 million m^3/s discharge for 120 cross sections. A: Water-surface and energy-surface profiles (and field evidence of maximum flood stages). B: Channel velocity. C: Unit area stream power.

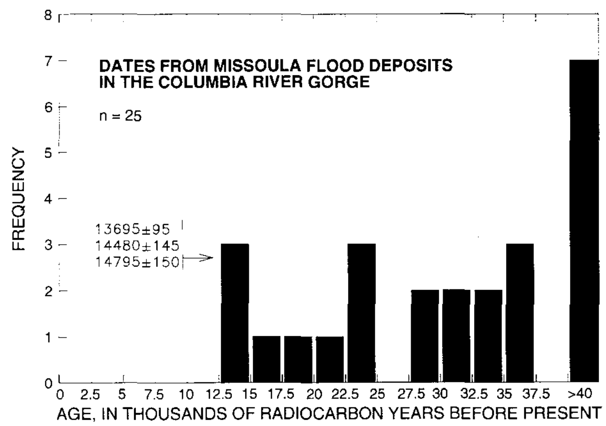

Figure 4. Histogram of radiocarbon ages from samples collected (by Benito and O'Connor) from within or below Missoula flood deposits. All samples were collected between Hood River and Arlington, and most were from high-altitude gravel bars. We emphasize that all of these ages are maximum limiting ages for the deposits that contain or overlie the samples.

middle Wisconsin flooding, as some have suggested (e.g., Kiver and others, 1991).

Weak soils cap the high gravel bars. This evidence, coupled with the radiocarbon dates, indicates that most, if not all, the coarse Missoula flood deposits in the Columbia River valley date from the last glacial (late Wisconsin) period of flooding, postulated earlier (Waitt, 1980a, 1985b; Atwater, 1986; Waitt and Atwater, 1989) to have been between 12.7 and 15 ka on the basis of radiocarbon dates, varve counts between flood deposits, and tephra relations in eastern Washington. We have not yet found any coarse deposits that have soils or radiocarbon results that indicate deposition during earlier periods of flooding. The question of pre-late Wisconsin floods through the Columbia River Gorge will be further addressed at Stop 3.4.

A key stratigraphic marker that can be seen at several sites along the trip is the Mount St. Helens "set S" tephra. Exposed in various places as a singlet, couplet, or triplet, the age of this tephra has been bracketed between radiocarbon dates of 12,120±120 and 13,650±120 ^{14}C yr B.P. (Mullineaux and others, 1978). Dates of 13,130±350 and 12,910±160 ^{14}C yr B.P. from samples within the tephra units and associated volcanic units near Mount St. Helens indicate that the tephra was probably erupted near 13 ka (Crandell and others, 1981). Another important stratigraphic relation, outside the field trip area near Lewiston, is that about 21 Missoula flood rhythmite layers overlie Bonneville flood deposits (Waitt, 1985b). The overflow of Pleistocene Lake Bonneville was some time between 14.3 and 15.3 ka (Oviatt and others, 1992).

THE QUESTION OF REPEATED GIANT LATE-WISCONSIN FLOODS

In a justly famous report that forever vindicated Bretz's controversial 1920s' great-flood theory of the Channeled Scabland, Bretz and others (1956) announced that as many as seven great late Wisconsin floods had occurred. The evidence was geomorphic and mostly from the Quincy basin and environs. For instance, the Quincy basin gravel plain, deposited by large floods, was channeled by lesser floodflow to form a sinuous depression occupied by Moses Lake. Yet such geomorphic relations could be accomplished by just one colossal flood and its waning flow. Wielding Occam's proverbial razor, V.R. Baker in the Quincy basin and R.B. Waitt along the adjacent Columbia River valley shaved off several of Bretz's floods, explaining almost all late Wisconsin features by one or two great floods and their waning flows (Waitt, 1972, 1977a,b; Baker, 1973, 1977, 1978).

Just beyond the Channeled Scabland, rhythmic flood beds of gravel, sand, and silt in southern Washington had been briefly described and photographed over the years (Bretz, 1929; Allison, 1933, 1941; Flint, 1938; Lupher, 1944; Glenn, 1965), but their significance remained obscure. It had been suggested (Bretz, 1969; Baker, 1973) that perhaps these beds bespoke some sort of pulsation in the supply of a flood, or that perhaps transient hydraulic surges during a flood were responsible. And perhaps these beds were repeated turbidites into continuously ponded water.

When rhythmic stacks of sand-silt beds in the Walla Walla valley were revisited in late 1977, the Mount St. Helens "set-S" ash couplet was found within the sequence, atop one particular bed that was not substantially different from any other bed in the section. Yet how could this be, if all beds were deposited by just one great flood? By June 1978, several features observed while measuring sections at Burlingame Canyon suggested that long subaerial pauses had intervened after deposition of each bed, that each graded bed there thus represented a separate flood, and that therefore at least 40 separate gigantic Missoula floods had backflooded the Walla Walla valley from the Columbia valley (Waitt, 1979). Burlingame Canyon thus became the "Rosetta stone" for deciphering similar beds all over the region. Within a few years, many side valleys scattered all across the north, west, southeast, and southwest parts of the flooded region were found to reveal similar evidence for scores of separate great floods (Waitt, 1980a,b, 1983a,b, 1984, 1985a,b; Atwater, 1984, 1986). The widely dispersed locations of these sites—nearly surrounding the Channeled Scabland—seemed to reveal that dozens of floods swept not only up the several valleys harboring these deposits but also through the entire Channeled Scabland itself (Waitt, 1980a, 1983b, 1985b).

These conclusions are affirmed by records of flooding in proglacial lakes in northern Washington, where varved lake sediment of glacial lakes separates successive flood-laid beds at many localities. The number of varves between successive flood beds indicates durations of six decades to a few years, generally becoming fewer upsection (Figure 5) (Waitt and Thorson, 1983; Atwater, 1984, 1986, 1987; Waitt, 1984, 1985a,b, 1987). The bottom sediment of glacial Lake Missoula is also varved; it constitutes dozens of fining-upward sequences, each the record of a gradually deepening then swiftly emptying lake (Chambers, 1971, 1984; Waitt, 1980a). Figure 6 shows the inferred relation of Lake Missoula's bottom deposits to the interbedded lake and catastrophic-flood deposits in northern Idaho and Washington and to the flood-laid beds in southern Washington. The behavior of repeated discharge every few decades or years suggests that glacial Lake Missoula emptied due to the same type of hydraulic instability that causes relatively small glacier-outburst floods (jökulhlaups) from present-day glaciers in Iceland and elsewhere (Waitt, 1980a, 1985b).

One differing interpretation is that the rhythmites may reflect numerous floods—but only late, fairly small ones, confined to low courses like Grand Coulee and the Columbia valley. Baker (1991), for instance, bases his objection on what he styles low-energy rhythmites:

> "The physical evidence of a low-energy flood deposit is linked by a chain of reasoning to a hypothesized cataclysmic event. Baker and Bunker (1985) reject this argument as proof of the 40 or more cataclysmic floods, noting that high-energy flood facies must be found to prove the existence of multiple cataclysms." (Baker, 1991, p. 250)

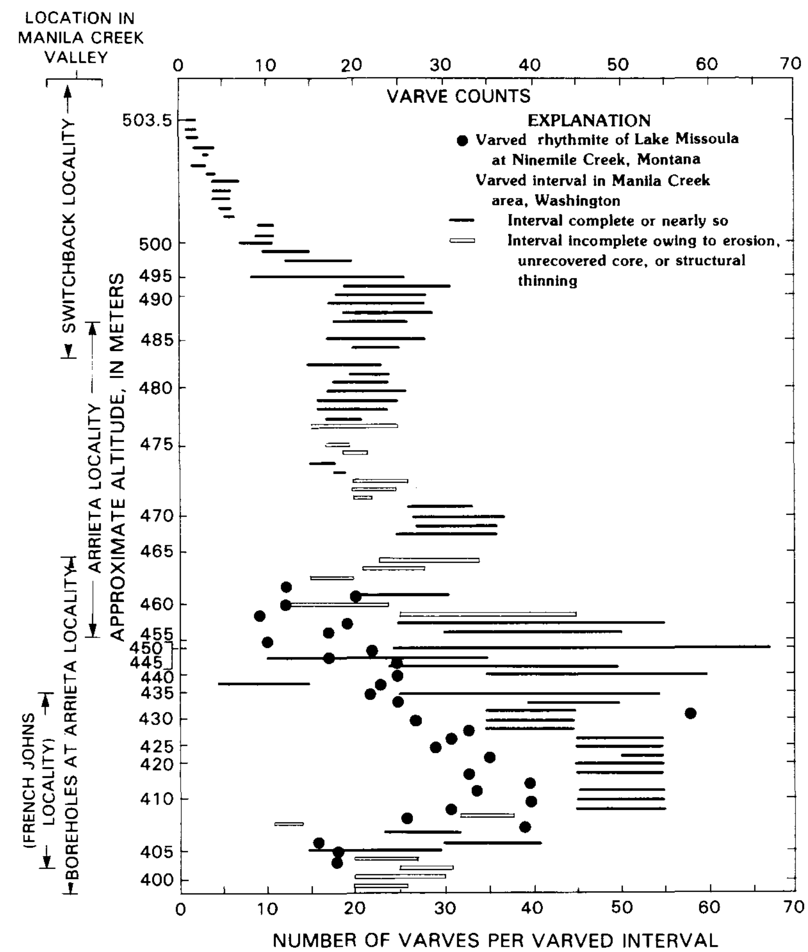

Figure 5. Data on varves (of glacial Lake Columbia) interbedded between 89 beds laid by Missoula floods, at the composite section at Manila Creek, Sanpoil valley, northern Washington (from Atwater, 1986, Figure 17). The bar range of a varve bed reflects the difference between a stingy count (dubious ones ignored) and a generous count (everything possibly a varve included).

To this statement and analogous ones (e.g., Baker, 1989b, p. 54, 1989c, p. 63; Busacca and others, 1989, p. 62; Kiver and others, 1991) it must be said that some identified rhythmite sections lie at fairly high altitude (e.g., Priest valley, Pine valley at Malden, Snake valley at Lewiston, Yakima valley at Union Gap), that some include high-energy (gravel) flood facies (e.g., Touchet, Mabton, Latah Creek, lower Tucannon valley [backflooded Snake tributary]), and that some rhythmic deposits (Malden, Tucannon valley, Snake valley near Lewiston) could not even exist except by general flooding of the Cheney-Palouse and other high scabland tracts. Nor does the claim of "linked by a chain of reasoning" fairly characterize the scores-of-cataclysms thesis, for it is firmly rooted in regionally distributed field evidence, and the paths from field deposit to giant-flood inference are fairly direct.

A second critical claim is that some multiple major rhythmites are products of intraflood surging (Baker and Bunker, 1985; Bjornstad and others, 1991, p. 237; Kiver and others, 1991, p. 241). These reports and cited supporting works in fact offer no new evidence—field or otherwise—but merely reiterate earlier opinion (Baker, 1973, 1978; Bjornstad, 1980; Bunker, 1982; Rigby, 1982) that has been refuted by field evidence (Waitt, 1985b).

A third recurrent claim (Moody, 1987; Baker, 1989b; Busacca and others, 1989, p. 62; Kiver and others, 1991, p. 238, 241–243) is that radiocarbon dates between about 32,600 and 41,300 yr B.P. and observations of "smectite" capping soils are evidence that many flood bars and rhythmically bedded backflood deposits—including sections at Latah Creek, Malden, the Tucannon valley, and others on which the scores-of-cataclysms theory has relied—are of middle Wisconsin age and thus irrelevant to Waitt's thesis of repeated colossal late Wisconsin floods. And yet, (1) the radiocarbon dates are from clasts and therefore are but

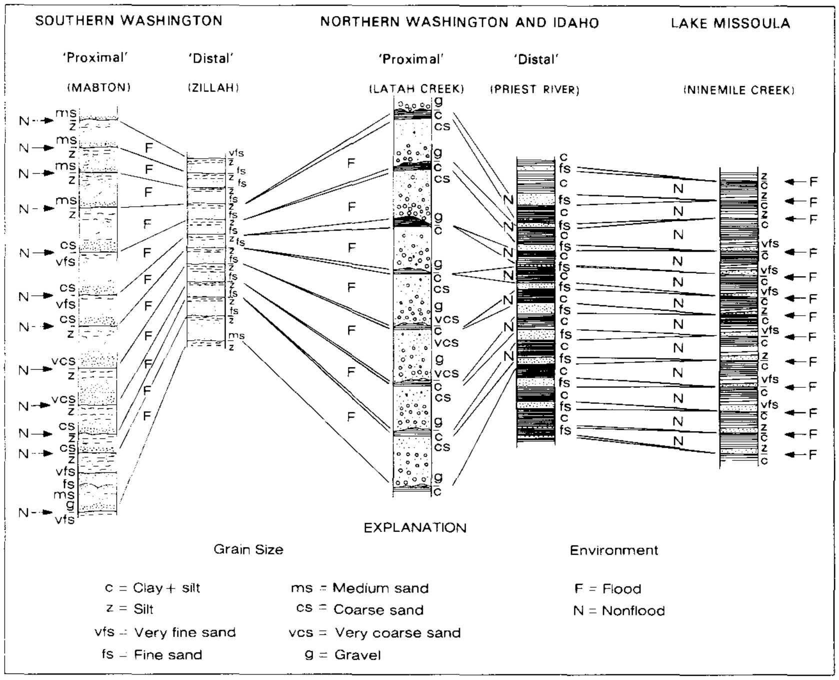

Figure 6. Inferred relations between flood rhythmites in southern Washington, flood rhythmites interbedded with varved glacial-lake deposits in northern Washington and Idaho, and rhythmic and varved glacial Lake Missoula sediments in western Montana. From Waitt (1985b, Figure 17).

maximum-limiting ages; (2) the "charcoal" of the 41,300-yr-B.P. date has been found to be Eocene lignite, while the "wood" of a 37,000-yr-B.P. date has been found to be petrified and devoid of carbon (P.E. Carrara, U.S. Geological Survey, personal communication, 1993); (3) the identification of "smectite" soil has not been confirmed by anyone else; (4) rhythmites in the Tucannon valley that were dated as middle Wisconsin contain the Mount St. Helens "set-S" tephra (e.g., Smith, 1993), confirming their late Wisconsin contemporaneity with those in the Walla Walla, Yakima, and other valleys; and (5) several dozen radiocarbon dates in continuous stratigraphic context in south-central British Columbia reveal continuously nonglacial conditions there from 19,000 ^{14}C yr B.P. back to 44,000 ^{14}C yr B.P. (Clague, 1980, Table 2; 1981, p. 6–8) and even 59,000 ^{14}C yr B.P. (Clague, 1989, Figure 1.17 and p. 57): At a time when southern British Columbia was unglaciated, there could have been no glacial Lake Missoula, and therefore no Missoula floods.

Over the last decade, scores of high-level and (or) high-energy flood bars have been examined in exposures scattered about the Channeled Scabland, its high-discharge intakes and outlets, the Columbia Gorge, and the vast Portland-Vancouver composite delta-bar. Where exposures are at least several meters deep, most pebble- and cobble-gravel bars show intercalated fine beds, ripup clasts of these fine beds in overlying gravel, and other evidence that they were composited by at least several separate floods. Such evidence seen in two pits in the Columbia Gorge (Stops 1.1 and 3.1) is typical of the internal stratigraphy of gravel bars distributed throughout the region including the Cheney-Palouse scabland tract (Waitt, 1994 and unpublished data).

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!!! And try to see the article "The floods that carved the West" in the April 1995 issue of the *Smithsonian* (p. 48–59), written by Michael Parfit and impressively illustrated with photos by Ted Wood. —*ed.* □

To be continued with Day 1 field trip in next (July) issue

We regret!

A slight computer "glitch" around the end of 1994 caused us to lose temporarily some of your addresses. We apologize sincerely!
If you missed your January issue of *Oregon Geology*, please let us know. We shall be glad to send you the missing copy.

DOGAMI PUBLICATIONS

Released March 28, 1995:

Inventory of Critical and Essential Facilities Vulnerable to Earthquake or Tsunami Hazards on the Oregon Coast was published as Open-File Report O–95–2. It can be purchased for $9.

The study was prepared by James W. Charland and George R. Priest and consists of a 52-page text and a 3½-inch diskette containing the collected data both as dBase (.dbf) files and in spreadsheet format for Microsoft Excel (.xls files).

The inventory covers 47 communities on shorelines within about nine miles of the open coast. It includes such critical and essential facilities as hospitals, schools, fire and police stations, emergency shelters and communication centers, hazardous sites, and major structures—all as they are defined in Oregon law and the Uniform Building Code. Tables show summary estimates of risk from ground shaking and tsunami inundation for individual counties and major communities and comparisons of total existing facilities with those at risk. Also included is a table showing preliminary estimates of tsunami runup elevations. These data are presented in greater detail in digital databases on the diskette.

Because of limited funding and time, the study is preliminary in nature, and its results are intended as a general guide to potential problems that need more detailed study. Still, the authors state, "It is apparent that over half of the critical and essential facilities on the coast could possibly be vulnerable to collapse during shaking. This is particularly worrisome with respect to schools. Should a great earthquake occur during class time, children in as many as 64 of the 117 schools might find themselves in collapsing buildings. When the additional hazard of tsunami inundation is added to the earthquake threat, 86 of the 117 schools (74 percent) may be vulnerable." As the "good news," the authors point out that, fortunately, "Current estimates of the likelihood of a great earthquake and locally generated tsunami are on the order of 10-20 percent in the next 50 years. This means that there is an 80- to 90-percent chance that we have those 50 years to prepare" by taking action now.

Chronic Geologic Hazard Maps of Coastal Lincoln County, Oregon is a pilot report by DOGAMI geologists George R. Priest, Ingmar Saul, and Julie Diebenow and describes coastal erosion rates and landslide hazards for 31 miles of the Lincoln County coast, from Salmon River to Seal Rocks, and for about 1½ miles inland from the shore. The data are published in the form of maps, text, and a computer database. They serve as basic resources for land-use planning decisions, emergency management planning, and insurance purposes.

The results of the study are printed on 19 photo maps, each of them covering a small stretch of coastline. Explanations and an abbreviated erosion-rate table are published in

*(Continued on page 68, **Publications**)*

Mineral industry in Oregon, 1993–1994

by Ronald P. Geitgey, Industrial Minerals Geologist, Oregon Department of Geology and Mineral Industries

INTRODUCTION

Nonfuel mineral production has continued to increase in both quantity and value, due primarily to increasing consumption of aggregate materials as the result of population and construction growth. Oregon continues to be a leader in pumice production, and increasing amounts of gemstones, principally sunstones, are being produced. Metal production was minimal, with no major metal mines operating at the end of 1994. Gold production was almost exclusively from small seasonal and recreational placer operations.

Exploration and development programs continued for perlite, soda ash, silica sand, and heavy-mineral sands. Metal exploration was moribund, reflecting several factors including the general flight of exploration funds out of the U.S. in recent years, changes in the U.S. Bureau of Land Management requirements for claim staking and maintenance, and the threat from a ballot measure of more stringent requirements on bulk metal mining, processing, and reclamation.

PRODUCTION STATISTICS

The U.S. Bureau of Mines reported a nonfuel mineral production value of $226 million in 1993 and a preliminary estimate of $254 million in 1994. These data have been collected from producers on a voluntary basis for many years and include some manufactured material such as cement and lime. They are based on producer responses and estimates made by U.S. Bureau of Mines commodity experts. Unlike for oil, gas, coal, and certain other leasable minerals, there is no federal or state statutory requirement to report production amounts for most mineral operations. The past 20 years of these statistics as well as the natural gas production for Oregon are summarized in Table 1.

In order to refine mineral production data for Oregon for 1993 and gauge its economic impact, the Oregon Department of Geology and Mineral Industries (DOGAMI) conducted a canvass by mail and by telephone of all mineral producers. This survey, done by DOGAMI Minerals Economist Robert Whelan, was published as Open-File Report O–94–31. Over 84 percent of all mineral producers responded, representing approximately 85 percent of the total value of production. Total value was about $240 million. Data were collected in groups by county, but to protect the confidentiality of individual companies in counties with a limited number of producers, values were summarized in groups by 11 regions. Total value of mineral production by these regions is summarized in Figure 1.

Production was measured as raw material at its point of removal: that is, before processing other than crushing, screening, or cleaning. For example, the value reported for limestone does not include its value as cement—a manufactured product. Neither does the value for diatomite include processing as a filter aid, nor is the final value of cut or faceted gems included. While these data cannot be compared directly with the U.S. Bureau of Mines data, they do represent a much more detailed approach to collecting production statistics, and they suggest that surveys by the federal government have underestimated the total value of mineral production from Oregon.

PRODUCTION HIGHLIGHTS

As noted earlier, mineral production in Oregon is primarily aggregate materials. Demand and production continue to increase as do competing land uses. Concrete-

Table 1. Summary of mineral production value (in millions of dollars) in Oregon for the last 21 years. Data for 1994 derived from U.S. Bureau of Mines annual preliminary mineral-industry survey and DOGAMI statistics are based on voluntary reporting and should be considered as minimums.

Year	Rock materials[1]	Metals and industrial minerals[2]	Natural gas	Total
1974	75	29	0	104
1975	73	33	0	106
1976	77	35	0	112
1977	74	35	0	109
1978	84	44	0	128
1979	111	54	<1	165
1980	95	65	12	172
1981	85	65	13	163
1982	73	37	10	120
1983	82	41	10	133
1984	75	46	8	129
1985	91	39	10	140
1986	96	30	9	135
1987	102	52	6	160
1988	130	48	6	184
1989	131	55	4	190
1990	148	85	4	237
1991	139	131	4	274
1992	130	111	4	245
1993	160	66	7	254
1994	181	73	6	260

[1] Includes sand, gravel, and stone.
[2] For 1992–1994 this includes cement, clays including bentonite, copper-zinc, diatomite, gemstones including Oregon sunstone, gold-silver, nickel, perlite, pumice, quarts, silica sand, talc including soapstone, and zeolites.

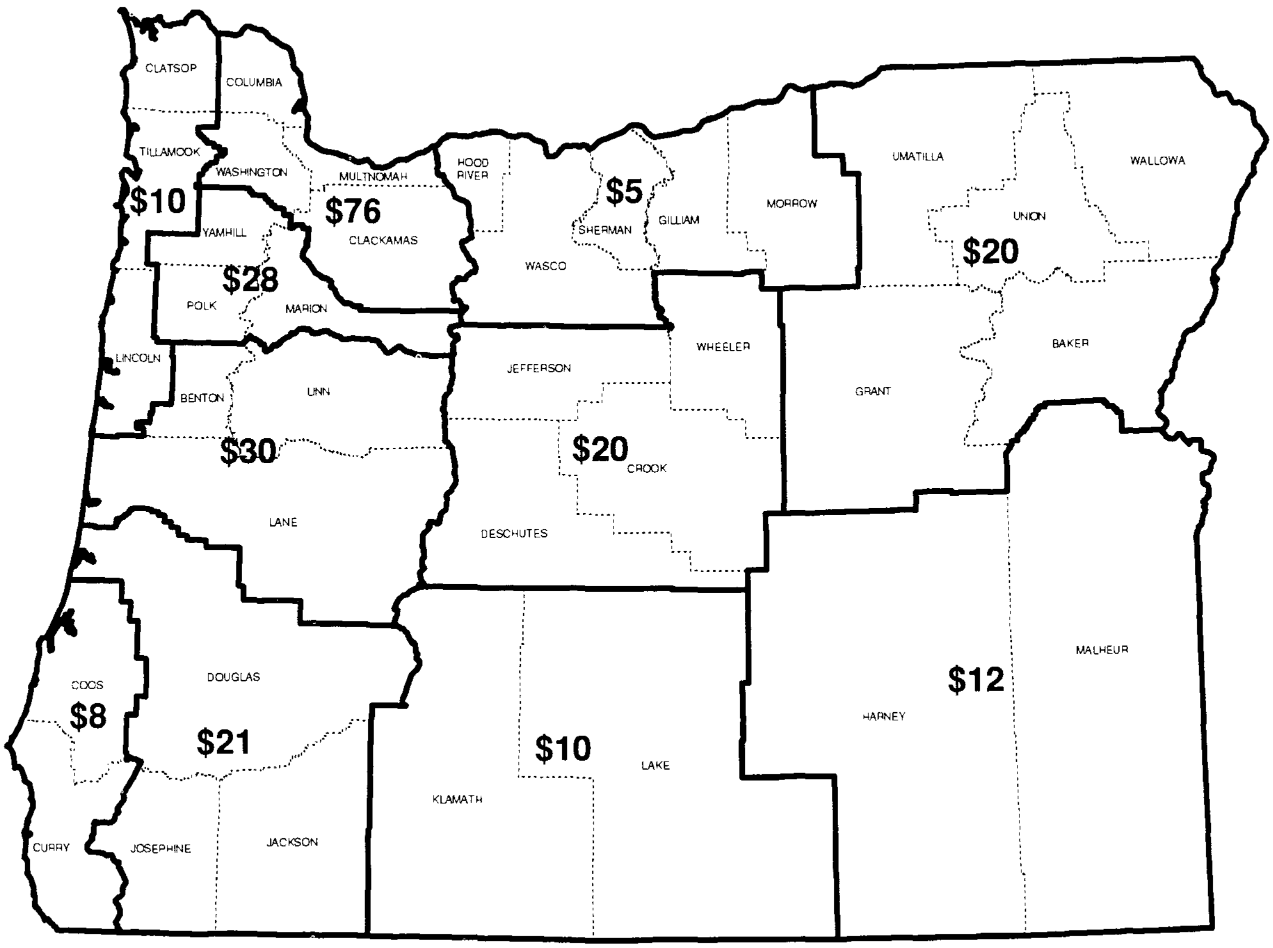


Figure 1. Total value in millions of dollars of mineral production (excluding natural gas) in Oregon in 1993, summarized by multiple-county regions.

quality sand and gravel sources are increasingly difficult to develop, and many crushed rock resources are being overtaken by urban growth.

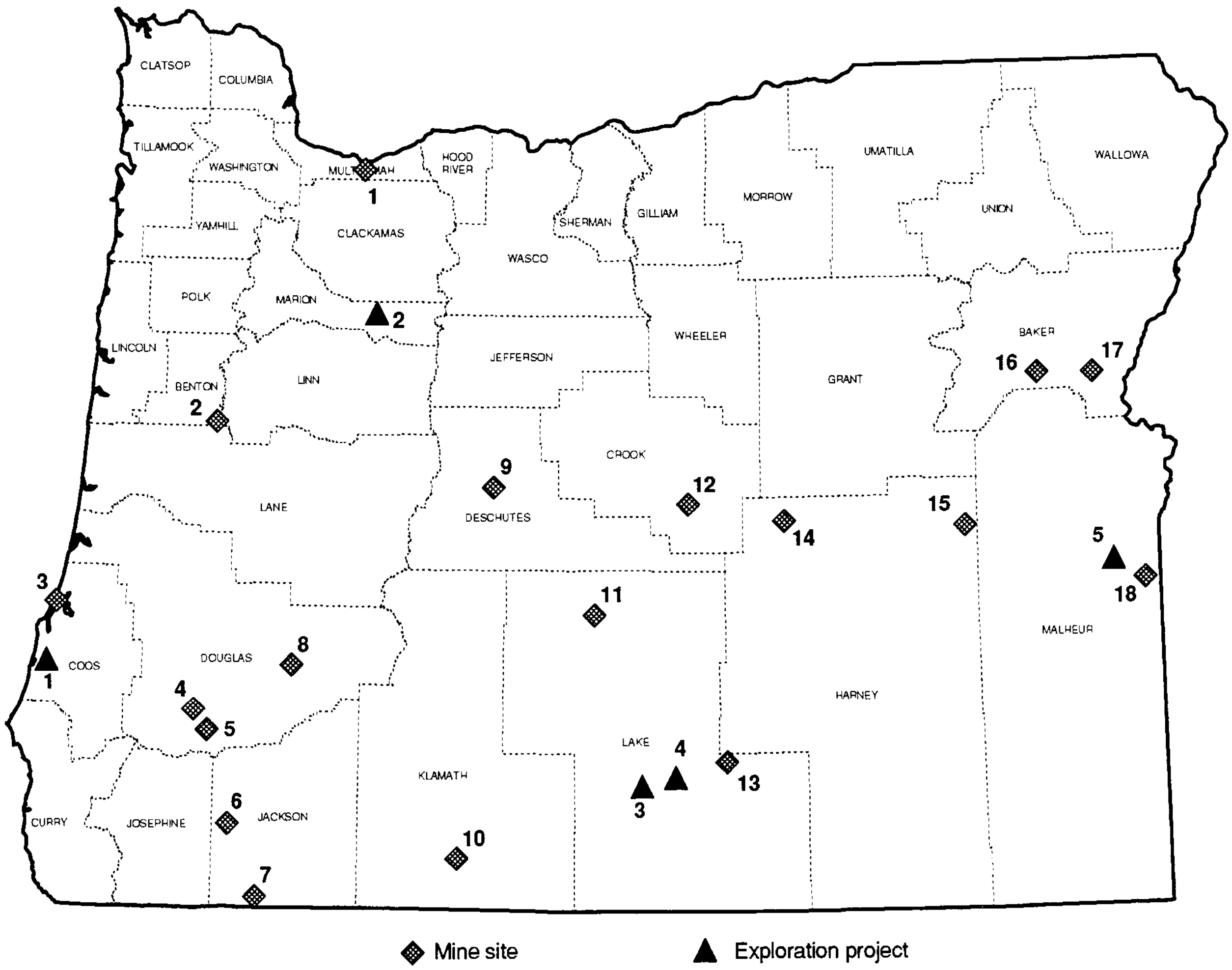
During the last two years, Karban Rock, Inc., of Hillsboro tried a novel approach to supplying the metropolitan Portland area with crushed rock. The company developed a quarry on a rail line in the far northwestern corner of Washington County and brought pit run material into its Hillsboro crushing plant by unit trains carrying three thousand tons, often on a daily basis. The project demonstrated the technical feasibility of aggregate importation by rail, which will become a necessity in the future, but in the short term the operation did not remain profitable and has been closed.

Major producers other than for aggregate are indicated on Figure 2. There has been no major metal production in Oregon for the last two years. Gold production is estimated to be about 2,000 oz annually; almost all of it from recreational placer operations. Formosa Exploration's Silver Peak mine in Douglas County has been closed, the mill dismantled, and the site reclaimed.

Glenbrook Nickel at Riddle in Douglas County has been operating on only a care and maintenance basis but has announced plans to reactivate the smelter in the spring of 1995, initially using ore mined at Nickel Mountain and later also ore imported from New Caledonia through the port of Coos Bay. Full operating work force will be about 300 employees, as well as company and contract truckers. During this idle period, the Green Diamond subsidiary of Glenbrook has continued to produce air blast abrasives and roofing granules from nickel slag. These abrasive products meet or exceed requirements for respirable silica and leachable metals, and reserves are sufficient for many years at current production levels.

Brick production has continued, although with several changes. Columbia Brick Works of Gresham was purchased by Mutual Materials of Bellevue, Washington, the major brick producer in the Pacific Northwest. Klamath Falls Brick and Tile in Klamath Falls, a producer of a wide range of brick colors for over 70 years, ceased operation. Monroe Brick in Benton County has been reopened after many years and is again producing red brick.

Steatite of Southern Oregon continues to produce carv-



EXPLANATION

MINE SITES

1. Mutual Materials (formerly Columbia Brick Works)
2. Monroe Brick
3. CooSand Corporation (glass sand)
4. Glenbrook Nickel, Green Diamond (abrasives, roofing granules)
5. Formosa Exploration Silver Peak Mine (copper, zinc, gold, silver; closed)
6. Bristol Silica (quartz)
7. Steatite of Southern Oregon (soapstone)
8. Quartz Mountain (quartz; idle)
9. Cascade Pumice and Central Oregon Pumice
10. Klamath Falls Brick and Tile (closed)
11. Oil-Dri Production (diatomite)
12. Central Oregon Bentonite (bentonite clay)
13. Rabbit Hills area (sunstones)
14. Ponderosa Mines (sunstones)
15. Eagle-Picher Minerals (diatomite)
16. Supreme Perlite Dooley Mountain mine (perlite)
17. Ash Grove Cement Company (portland cement, limestone)
18. Teague Mineral Products (bentonite clay, zeolite)

EXPLORATION PROJECTS

1. Oregon Resources, Oregon Mineral Sands Project (garnet, chromite)
2. Kinross Copper Corporation, Bournite Project copper, gold, silver)
3. Atlas Corporation, Tucker Hill Project (perlite)
4. Canadian Occidental Chemical, Lake Abert Project (sodium salts; terminated)
5. Newmont Mining, Grassy Mountain Project (gold)

Figure 2. Mine sites and major exploration projects in Oregon, 1993-1994, excluding sand, gravel, and crushed stone.

ing and sculptural-grade soapstone from its quarries in Jackson County. Bristol Silica, also in Jackson County, produces decorative material and filter media from a quartz replacement body, and the Quartz Mountain deposit in Douglas County remains idle. CooSand Corporation produces container-grade glass sand from dunes north of Coos Bay.

Oregon remains the leading domestic producer of pumice. Cascade Pumice and Central Oregon Pumice produce lightweight aggregate and horticultural materials from mines in the Bend area. Neither was ever a major supplier of pumice for stone-washing garments, so neither has suffered from the collapse of that market.

Oil-Dri Production Company produces pet litter and absorbent products from its Christmas Valley diatomite operation in Lake County, and Eagle-Picher Minerals produces diatomite filter aids from mines near Juntura and a plant near Vale. Bentonite, primarily for civil engineering purposes, is produced by Central Oregon Bentonite in Crook County and Teague Minerals in Malheur County. Teague Minerals also produces the zeolite mineral clinoptilolite for odor control and heavy-metal absorption applications.

Gemstone production has increased significantly. Opals and various forms of silica (jasper, agate, thundereggs) are produced from small-scale operations, and sunstones (calcic feldspar) are increasingly being mined on a commercial basis by Ponderosa Mines in Harney County and several operators in the Rabbit Hills area in Lake County. Sunstones have long been mined and cut on a small scale, but during the last few years Ponderosa has developed wider markets. The rare, highly colored varieties have always had a specialty market, but now the more common yellows are being successfully marketed by Ponderosa, encouraging more Lake County producers to operate on a commercial scale.

Ash Grove Cement Company continues as a major employer in Baker County. In addition to portland cement, the company supplies lump limestone to sugar refineries in Oregon and Idaho.

MINING CLAIMS

In the fall of 1993, the U.S. Bureau of Land Management (BLM) initiated new policies on mining claim filing and maintenance. A total of $235 is now charged for filing each new claim. The Bureau now charges an annual maintenance fee of $100 per claim rather than accepting labor on the claim as qualifying for assessment work. However, anyone owning 10 or fewer claims can apply for a waiver allowing performance of labor in lieu of the maintenance fee. There has been a sharp drop in the number of active mining claims. BLM does not maintain records by individual states, so statistics for Oregon and Washington are compiled together. Early in 1993, the agency had 36,852 claims recorded in the two states. After September 1, 1993, the number fell to 14,683, and after September 1, 1994, rose to about 16,400.

EXPLORATION HIGHLIGHTS

No new major metal exploration programs were initiated in 1993 or 1994. Many large claim blocks were abandoned or greatly reduced, and many holders of smaller blocks also chose not to pay the new fees. At the end of 1994, drilling permits were in effect for 15 projects (down from 44 in 1991), but the writer is aware of no project, other than Grassy Mountain, on which drilling was actually done in 1994.

Newmont Mining continued investigations at its Grassy Mountain gold project in Malheur County to further define the ore body and engineering and environmental requirements. Announced reserves include 1.5 million oz of gold and 2.5 million oz of silver. The company diverted its attention was from the project itself during 1994 to present its views on a ballot measure that would have created additional environmental and reclamation requirements. The ballot measure was subsequently defeated, and at year's end Newmont was evaluating and planning its future permitting requirement.

Kinross Copper Corporation continues to maintain its Bornite copper, gold, and silver project in eastern Marion County. Engineering and environmental operating plans for an underground mine have been completed for more than a year and approved by all but one state agency. The project has generated both strong support and opposition, and at this writing its future remains uncertain.

Oregon Resources Corporation has brought its mineral sands project in Coos County partially through the required permitting process and is preparing for a final feasibility study. Heavy-mineral sands (black sands) containing ilmenite, chromite, garnet, and small amounts of rutile and zircon occur as thin, elongate deposits covered by dune sand on elevated beach terraces. The various minerals would be separated from the sands by magnetic and gravity methods. Garnet would be marketed for water-jet cutting abrasive, and chromite for metallurgical or chemical uses.

Atlas Corporation continued drilling and bulk testing of the Tucker Hill perlite deposit near Paisley in Lake County. The perlite has expanded satisfactorily in both bench and bulk testing, and the company has begun the permitting process with the hope of starting production during 1995. Pit run material will be trucked to Lakeview for crushing and screening and shipped from Lakeview by rail. A total work force, including contractors, of 10–15 workers will be employed at the mine and mill. Supreme Perlite has produced small amounts of ore from its Dooley Mountain deposit in Baker County for its own use for many years. The Atlas Corporation Tucker Hill property will be the only operation in the Pacific Northwest states supplying the open market.

For the last four years, Canadian Occidental Chemical Group, Ltd., has been evaluating Lake Abert in central Lake County as a possible sodium salt source, but the company has now withdrawn its lease applications and has terminated the project. The lake water is approximately three times more saline than sea water, and has a very high proportion of sodium and bicarbonate. Either soda ash (sodium carbonate) or caustic soda (sodium hydroxide) could be produced from this re-

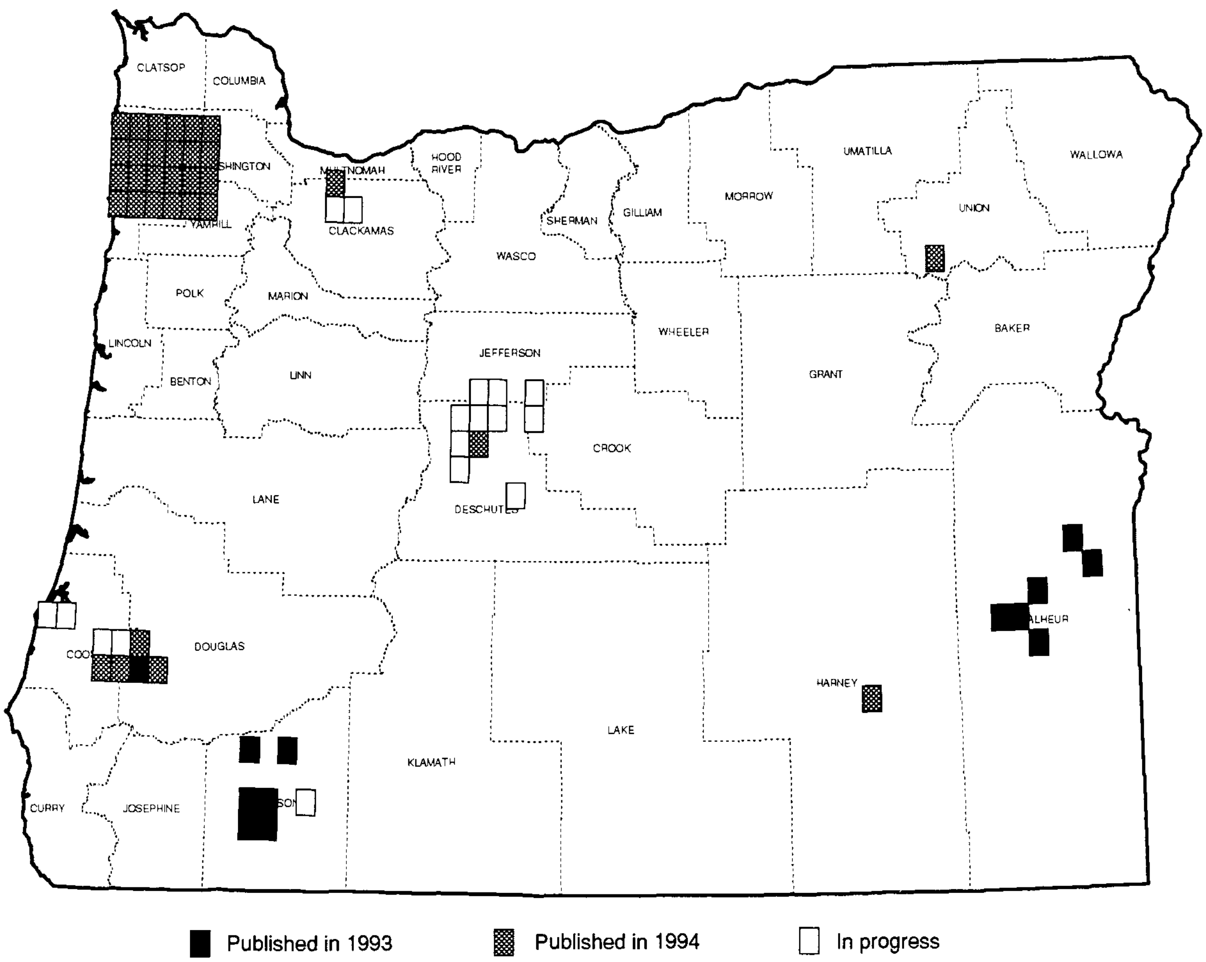


Figure 3. Statewide overview of geologic maps published in 1993 and 1994 by DOGAMI and other agencies.

source. Both compounds are widely used in the chemical and paper industries and are currently supplied from saline lakes in California and from the huge bedded deposits in the Green River basin of southwestern Wyoming. Canadian Occidental concluded that it was not economically feasible at this time to develop the Lake Abert resource.

OTHER DOGAMI ACTIVITIES

DOGAMI's statewide survey of pumice resources was presented to the public in 1993 with the publication of Special Paper 25, *Pumice in Oregon*. Updated versions of the Mineral Information Layer of Oregon by County (MILOC) and the Directory of Mineral Producers were also published in 1993.

DOGAMI has continued its earthquake hazard, coastal hazard, and geologic mapping programs. Geologic mapping of the gold region in Malheur County has resulted in the release of 28 maps of 7½-minute quadrangles (scale 1:24,000), partly as GMS-series maps, partly as open-file reports, and partly for library inspection only. The project concluded with the publication of two 1:100,000-scale full-color compilation maps—of the Vale (GMS-77) and Mahogany Mountain (GMS-78) 30×60-minute quadrangles—that cover the entire Oregon portion of the Boise 1°×2° sheet. Other geologic and mineral-resource mapping has produced maps of 14 quadrangles, mostly in the Medford and Roseburg areas in southwestern Oregon but also in Deschutes and Union Counties.

Various types of studies, databases, and maps have been published as open-file reports and as GMS-series maps, and many of them are listed on the back cover of this publication. Some studies are available for purchase; others are on file in various department offices as well as other public offices in the state. Databases include mineral occurrences, low-temperature geothermal occurrences, a beach-shoreline database, and earthquakes in Oregon. A relative hazard earthquake map has been published for the Portland 1:24,000 quadrangle, and a series of maps depicting chronic geologic hazards of coastal Lincoln County has been released. Geologic mapping on a scale of 1:24,000 published in 1993 and 1994 is shown on Figure 3. Mapping in progress is also shown. A current list of publications (1995) is now available from the Nature of the Northwest Information Center (see order form on back cover). ☐

Summary of major DOGAMI activities in 1995

The mission of the Oregon Department of Geology and Mineral Industries (DOGAMI) is to serve as the cost-effective centralized source of geologic information in Oregon for the public and for government. Its mission is also to serve as a cost-effective steward of mineral production with attention paid to environmental, reclamation, conservation, engineering, and technical issues.

With regard to geologic information, emphasis is placed on geologic mapping, cost-effective earthquake mitigation, geologic hazards, and mineral resources. With regard to mineral stewardship, authorities are in place for the exploration, production, and reclamation of oil, gas, geothermal, aggregate, and nonaggregate mineral resource activities. The emphasis in DOGAMI activities is placed on the prevention of hazards and waste, the benefits of long-range planning, and the efficiency of using land and mineral knowledge in policy decision making in government and the private sector.

GEOLOGIC MAPPING

Statemap program: In contractual relationship with the U.S. Geological Survey, DOGAMI develops geologic maps of priority areas of the state for problem solving, guided by an advisory group of users in the public and private sectors. Major areas of effort are focused on three 1:100,000-scale quadrangles, the Bend, Medford, and Roseburg sheets. The three-year program for each sheet includes a mix of complete mapping, reconnaissance mapping, and compilation. Current focus is on mapping of the 7½-minute quadrangles Dora and Sitkum in the Roseburg area, Lakecreek and Grizzly Peak in the Medford area, and O'Neil and Gray Butte in the Bend-Prineville area.

Contact person: John Beaulieu.

Coastal mapping: With funding from the U.S. Minerals Management Service through a contract with the University of Texas, DOGAMI participates in developing needed geologic data bases in coastal zones. The specific current project is mapping the Coos Bay 7½-minute quadrangle.

Contact person: Jerry Black.

Geologic map index: This is an effort to create and maintain an index of geologic maps for the state. The goal is to provide current information about all geologic maps and their availability at sale counters and to develop database resources that provide various types of access to such information. For 1995, a first product has been released as Open-File Report O–95–4, an index of mapping through 1994 by topographic quadrangle name.

Contact person: Beverly Vogt.

EARTHQUAKE STUDIES

ODOE power-plant siting: This program involves the responsibility of DOGAMI to provide peer review of the seismic-hazard portions of siting documents for power plants, whenever such documents are submitted to the Oregon Department of Energy (ODOE). Peer review generally involves early meeting with the applicant, followed by review of the application document to assure true site-specific analysis, proper attention to site-specific data collection, and proper attention to preexisting information on seismic risk. Also included is the need for clear definition of acceptable seismic risk. Consequently, this also involves DOGAMI in any development of rules in this area that is initiated by the Energy Facility Siting Council.

Contact person: Dan Wermiel.

Oregon City quadrangle: Robert Yeats of Oregon State University and Scott Burns of Portland State University are providing maps and data to produce a generalized display of earthquake-related information for the west half of the Oregon City 1:100,000-scale quadrangle. Key elements include earthquake epicenters, fault identification, surficial geologic units, depth to bedrock, and other information considered of interest to the general public.

Contact person: Beverly Vogt.

Metro maps: The Federal Emergency Management Administration (FEMA) and Metro (Portland) are supporting efforts to develop ground response data that will lead to the publication of relative earthquake-hazard maps for the Mount Tabor, Gladstone, Lake Oswego, and Beaverton 7½-minute quadrangles, which surround the already completed downtown-area Portland quadrangle on the east, south, and southwest. These maps will each include smaller maps of the individual hazards (amplification, liquefaction, and landslides) that are combined to produce the main relative-hazard maps. The Mount Tabor quadrangle map has just been published as map GMS–89. In addition, procedures and methods are being developed to make digital files of these data available to a technical audience.

Similar projects are to cover all quadrangles within the urban growth boundaries of the metropolitan area. It is planned to match the collected ground-response data with Metro's building-inventory data, so that, for instance, loss evaluation can be performed.

Contact person: Matthew Mabey.

PSU studies: Portland State University is the partner in two earthquake hazard studies. The first is to develop recommendations for retrofitting buildings. It is coordinated with the Portland School District and is to benefit particularly Portland's public schools. The second effort is the organization of a series of seminars presented by distinguished lecturers on selected engineering topics that are relevant to earthquake mitigation.

Contact person: John Beaulieu.

The joint effort to combine the expertise gained in current field work with the educational needs of the technical community dealing with earthquake hazards is continuing with the shared DOGAMI/PSU support for the position of Matthew Mabey, who devotes one-third of his time to teaching earthquake-engineering classes at PSU.

Seismograph net: DOGAMI is working with the Department of Higher Education to expand the seismograph net by upgrading selected recording stations in the state. In this context, the three major universities will cooperatively develop research focused on hazard mitigation.

Contact person: John Beaulieu.

Salem area: Similar to the efforts in the Portland area, this project aims at modeling ground response for, initially, two 7½-minute quadrangles in the Salem area (Salem West and Salem East). It may be expanded eventually to include the entire area within the Salem urban growth boundary. The published products will be similar to those for the Portland metropolitan area, with regard to both maps and digital data.

Contact person: Mei Mei Wang.

Liquefaction study: DOGAMI staff is joining geologists from Alaska and Washington in a training program for the study of earthquake-related liquefaction features that occurred in the 1964 Alaska earthquake. This expertise is needed for technology transfer and sharing of earthquake data between Oregon, Washington, and Alaska in cooperation with the U.S. Geological Survey.

Contact person: Jerry Black.

Scotts Mills earthquake follow-up: In the survey conducted by DOGAMI on observed effects of the Scotts Mills earthquake in 1994, over 4,000 responses were returned. These responses are being analyzed now for the production of a felt-intensity map that can be compared to ground response models developed in the ongoing studies of the Portland and Salem projects.

Contact person: Jerry Black.

Regional maps: DOGAMI is involved in the development of three Northwest area maps that are focused on earthquake hazards. Two, a geologic map of the Damascus quadrangle in the Portland area and a relative earthquake hazard map of the Vancouver urban area, have been released. A geologic map of the Charleston quadrangle in the Coos Bay region is to conclude these efforts during the current year.

Contact person: Ian Madin.

COASTAL HAZARD STUDIES

Coast research is focused on two categories of hazards: chronic hazards, such as landslides and coastal erosion, and catastrophic hazards, such as earthquake and tsunami damage. DOGAMI is involved in four pilot projects for the central Oregon coast. This work involves cooperation with the Oregon Department of Land Conservation and Development and FEMA.

Lincoln City/Siletz Bay is the center of an area for which full delineation of all hazards is intended and will be made available to the public in published maps and digital data.

A pilot project for the use of imagery (taken from the air and from space) and computer tools attempts to evaluate chronic hazards for closely spaced transects along a 50-km stretch of the central Oregon coast. It will produce preliminary maps showing landslide hazards and erosion rates. However, the complex terrain and geology of the Oregon coast required extensive observation and geologic interpretation in the field. Open-File Reports O–94–11 through O–94–30 are the most recent products that have been released in conjunction with this project.

Modeling of ground response to earthquakes in the Siletz Spit area of the central coast stretch will be used to produce maps at a scale of 1:12,000 for separate ground response types and relative earthquake hazard.

A joint project with Portland State University and the Oregon Graduate Institute is designed to link information on the modeling of tsunami inundation with the physical evidence of (paleo-) tsunami inundation in Oregon and to develop maps of tsunami inundation in the future. Given the record of past inundations in the coastal area, Oregon's geology provides a unique opportunity for calibration of inundation models.

Contact person for these projects: George Priest.

MINERAL RESOURCES

Demand for aggregate: An economic-demand model is being developed for the use of aggregate in Oregon. This model focuses on end use of the commodities, so that it can be used to forecast demand for specific market regions of the state.

Contact person: Robert Whelan.

Geothermal resources: The geothermal potential of southeastern Oregon is being investigated with a focus on geologic parameters such as lineaments and faults, after the completion of data-collecting from wells. This largely computer-driven modeling project will integrate geologic information more fully and will also use data on terrain factors and satellite imagery.

Contact person: Ian Madin.

State agency assistance: DOGAMI is providing technical information to the State Forestry Department to help in the evaluation of land transactions. In a similar manner, the Department provides technical review and assistance to the Department of State Lands on transactions that involve mineral rights. DOGAMI's assistance toward making the most prudent decisions for the State of Oregon and the school fund focuses specifically on the two goals of maximizing revenue and of protecting the environment.

Contact person: Ron Geitgey.

Tyee Basin: The investigation of the Tyee Basin in the southern Coast Range is being concluded with an analysis of its natural gas potential.

Contact person: Alan Niem, Oregon State University.

Data bases: Two mineral-resource databases are being developed: One, developed in cooperation with the Oregon offices of the U.S. Bureau of Land Management and the USDA Forest Service, includes all information from earlier federal and other data collections and combines it with the data DOGAMI published earlier as the Mineral Layer of Oregon by County (MILOC). The result is a database called "MILO," which can be linked to digital maps and includes data from DOGAMI's Mined Land Reclamation Program.

Contact person: Ron Geitgey.

The second database will follow the same structural and application principles for a collection of data on drilling activity for hydrocarbons and geothermal resources.

Contact person: Dennis Olmstead.

OUTREACH EFFORTS

Together with other state and federal offices, DOGAMI is involved in three major efforts to convey earth-science knowledge and experience to government staff in other fields of specialization and to the Oregon citizens.

Mine regulation training: The first program is aimed at providing seminars and on-the-ground training opportunities for mine regulators from various states and regulatory agencies. This multi-state training effort is spearheaded by the Environmental Protection Agency and is administered by DOGAMI.

Contact person: Gary Lynch.

Tsunami historic signs: Along the coast, historic signs are being placed in cooperation with the Oregon Department of Transportation, selected communities, and the Oregon Travel Information Council. DOGAMI's involvement extends to the media and political outreach as well as to technical assistance.

Contact person: Angie Karel.

Earthquake outreach: This is an effort to bring the results of ground-response studies and related technical activities to the attention and within reach of a broader public audience. This involves, for instance, providing guidance in broader efforts for open-space planning, lifeline routes and other emergency response strategies, evaluations prior to any construction, or retrofitting existing structures. Damage scenarios will be developed to guide budget decisions related to earthquake hazard reduction and emergency response.

Contact persons: Beverly Vogt and Angie Karel. □

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*(**Publications**, continued from page 60)*

a 45-page text, titled *Explanation of Chronic Geologic Hazard Maps and Erosion Rate Database, Coastal Lincoln County, Oregon: Salmon River to Seal Rocks*. All data are stored on a 3½-inch diskette in two DOS formats, for Lotus 1–2–3 (.WK1 file) and for dBase III+ or higher (.DBF file). Text and diskette have been released as DOGAMI Open-File Report O–94–11. The maps have been released individually as Open-File Reports O–94–12 through O–94–30.

Chronic geologic hazards are mass movement hazards such as landslides, slumps, rock toppling, and soils or rock flows. These, along with shoreline geology and shoreline erosion rates, are shown on the maps. The database contains estimated erosion rates and other information for a series of transect points spaced approximately 150 feet apart along the shoreline. The transect points are also marked on the maps.

The report was funded in part by the Federal Emergency Management Agency (FEMA) and the Oregon Department of Land Conservation and Development (DLCD) with support from the National Oceanographic and Atmospheric Administration (NOAA). The project is to serve as a pilot for the entire Oregon coast.

Complete sets of Open-File Reports O–94–11 through O–94–30 have been made available by DOGAMI in public libraries of Lincoln City, Newport, and the Lincoln County Library District, the libraries of the Hatfield Marine Science Center, and the Oregon Coast Community College in Newport. Other libraries that have complete sets are the State Library in Salem, the Multnomah County Library in Portland, and the academic libraries of the University of Oregon, Eugene; Oregon State University, Corvallis; Portland State University, Portland; Southern Oregon State College, Ashland; and Eastern Oregon State College, La Grande. Partial sets including the maps appropriate for the region are in the city planning offices of Lincoln City, Depoe Bay, and Newport.

The open-file report numbers of individual maps are as follows:

Salmon River area	O-94-12
Roads End area	O-94-13
Lincoln City-Wecoma Beach area	O-94-14
Lincoln City-D River area	O-94-15
Taft-Siletz Spit area	O-94-16
Gleneden Beach-Siletz Spit area	O-94-17
Fogarty Creek-Lincoln Beach area	O-94-18
Boiler Bay area	O-94-19
Depoe Bay area	O-94-20
Cape Foulweather-Whale Cove area	O-94-21
Otter Crest area	O-94-22
Beverly Beach area	O-94-23
Moolack Beach area	O-94-24
Moolack-Agate Beach area	O-94-25
Newport area	O-94-26
South Beach area	O-94-27
Newport Airport area	O-94-28
Lost Creek area	O-94-29
Seal Rock area	O-94-30

All reports can be purchased. Report O-94-11, containing the explanations and the database diskette, costs $9 and should always be purchased together with any maps. Maps cost $6 each. The complete set of maps, database, and explanatory text costs $109. The maps must be ordered in Portland and will be printed on demand.

*(Continued on page 70, **Publications**)*

An overview of seismic analysis and retrofit recommendations for Portland Public School buildings

by Franz Rad, Department of Civil Engineering, Portland State University, Portland, Oregon

BACKGROUND

Little was known about design and construction to resist seismic forces during the first part of the century. In particular, unreinforced masonry (URM) buildings have come under criticism in recent years due to their poor structural performance in earthquakes. Additionally, URM structures often exhibit hazards that may be nonstructural or cosmetic in nature.

The problem has become more acute in Oregon now that geologic evidence has shown that the Pacific Northwest region has probably experienced much larger earthquakes than can be gleaned from the historic record. Quite a large number of unreinforced masonry structures now must be investigated as to whether they could withstand a major earthquake.

Many old unreinforced masonry structures, while seemingly sturdy and well built, are heavy and often poorly tied together. The floors and roofs are either wood framing or concrete slab-and-joist systems with a fractional inset connection to the masonry exterior walls. The construction of the masonry walls varies in design and quality; often the exterior layer of bricks, or wythe, is tied to the rest of the wall by the vertical collar joint only, which may be of poor quality.

School buildings with an H- or U-shaped floor plan were popular in the 1910s and 1920s. The H- or U- shaped plans tend to perform poorly in earthquakes, because they provide poor torsional resistance to the earthquake forces. The wings tend to displace in a direction perpendicular to the displacement of the center of the building. The result of this action is that large stresses and consequent distress are concentrated at the intersections.

DOGAMI/PSU 1994 STUDY

As a joint venture project between Portland State University (PSU) and the Oregon Department of Geology and Mineral Industries (DOGAMI), a study was undertaken in 1994 to estimate potential seismic hazards in four existing URM public school buildings in Portland and to suggest possible upgrade strategies for each of the four buildings. The four buildings analyzed were Rose City Park Elementary School, Fernwood Middle School, Franklin High School, and Roosevelt High School. [*The complete report from this project is available for inspection in the DOGAMI Portland library. —ed.*]

The scope of the study was to investigate the buildings to establish the general configuration and construction type, to analyze the magnitude and distribution of seismic forces on each structure according to 1994 Uniform Building Code (UBC), to calculate the degree of overstress induced by the seismic forces in the URM walls and roof/floor diaphragms, to suggest a possible structural upgrade strategy for the four buildings, and to determine potential nonstructural hazards. The buildings selected for this study were chosen as representative of a number of old URM buildings in the city of Portland. These four buildings are not necessarily any more or less dangerous than many other public and private URM buildings in the city.

The seismic hazards in the existing structures were analyzed by UBC Static Lateral Force Procedure, UBC Dynamic Lateral Force Procedure, and UCBC analysis of URM walls and piers. The Uniform Building Code, the legal building code for the State of Oregon, was used as a general reference for developing the required seismic design forces for the static and dynamic procedures.

The Uniform Code for Building Conservation (UCBC), Appendix Chapter 1: Seismic Strengthening Provisions for Unreinforced Masonry Bearing Wall Buildings, was used to analyze the stresses in the unreinforced masonry walls and piers. The UCBC is the latest compilation of provisions developed by the Structural Engineers Association of California and California Building Officials (SEAOC/CALBO). These provisions have been developed in the last five years by engineers in the Los Angeles area for the required upgrade of unreinforced masonry structures.

Another reference used is the National Earthquake Hazards Reduction Program (NEHRP) Handbook for the Seismic Evaluation of Existing Buildings, published by the Federal Emergency Management Agency (FEMA). The section of the manual that covers the evaluation of unreinforced masonry buildings is very similar to the UCBC guidelines, having originated from the same document. The NEHRP design forces coincide more with the design forces found in the UBC.

A finite element response spectrum analysis (computer analysis technique) was made of two of the schools: Rose City Park Elementary and Franklin High School. This was done to verify the base shear and force distribution obtained in the static analyses and to study the effects of the irregular H- and U-shaped floor plans

SUMMARY OF RESULTS

Nonstructural hazards

The buildings analyzed generally have three significant nonstructural seismic hazards: tall parapet walls, chimneys, and clay tile partitions. Generally the parapet height-to-thickness ratios exceed the UCBC limit, requiring parapets to be braced.

Clay tile partitions in various locations in the buildings pose an out-of-plane wall-failure hazard. For example, a 12-ft wall of 4-in. clay tile has a height-to-thickness ratio of 36. The UCBC recommends a maximum height-to-thickness ratio between 14 and 18 (depending on the wall location) in seismic zone 3. All these partitions should be either strengthened or removed and replaced.

At Fernwood Middle School, the exterior wythe (unit thickness of material) of bricks is a veneer course and is most likely unanchored or poorly anchored. Veneer failure is similar to an out-of-plane wall failure; when the acceleration on the veneer causes excessive deflections, the wall will fail. The 1994 UBC requires that veneer be anchored every 2 ft^2, or about 16 in. each way.

URM wall and pier analysis

In the UBC Static Lateral Force Analysis, seismic story forces were distributed to the shear walls (walls acting as the structural members that resist horizontal forces, such as earthquake shaking, that tend to cause shear deformation in the structure) assuming rigid diaphragm action. A UCBC-type analysis was used to calculate the pier capacities. This analysis showed all the piers to be overstressed. The piers with the highest overstress values were located on the first floor. Considering all buildings, the range of values was from a few hundred percent to several hundred percent overstress for the first floor piers.

Diaphragms

Because U- and H-shaped buildings have modes of vibration where the wing motion opposes the center motion, large tension and shear forces were anticipated in the slabs in the areas where the wings connect to the center of the main building. Complicating the situation were the stairwell openings, which pinched these areas even further. Generally the calculated stresses are significantly higher than allowed by UBC.

Upgrade strategy

The upgrade recommendations for the various structures include the following:

1. Provide the structure with shear walls in both directions to provide the most direct path for the earthquake forces to follow.
2. Provide tie elements to minimize the stress in the floor diaphragms (horizontal structural members, such as floors and roofs, that can transfer stresses between and to beams and columns), and to provide a force path along the walls.
3. Provide shear walls at the extremities of the wings to minimize the effects of the torsional modes of vibration. Sections of buildings should also have torsional stability, with good connections between the segments.
4. Brace parapets, chimneys, hung ceilings, mechanical equipment, and tall bookshelves.
5. Strengthen or remove clay tile partitions.

OBSERVATIONS AND CONCLUSIONS

The four schools investigated show that critical weaknesses in earthquake resistance exist in the buildings. The investigators assume that these four schools would be typical of the unreinforced masonry school buildings found in Portland. We strongly recommend that all school buildings built or retrofitted prior to about one or two decades ago be given high priority to be investigated for seismic strength. □

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*(**Publications**, continued from page 68)*

Released April 28, 1995

Geothermal Gradients in Oregon, 1985-1994 contains previously unpublished geothermal temperature-depth data from wells in southeastern Oregon that complete the currently available information for geothermal energy research for the state. Released as DOGAMI Open-File Report O–95–3, the report contains, for each well, location maps; depth, temperature, and gradient of each measurement; and graphic plots of the gradients. The report can be purchased for $7.

The dates of the title place this report in the continuous series of nine similar DOGAMI open-file reports for geothermal gradient data since 1970. The complete list now includes the following:

1970–1974	O–75–3
Oct. 1974 through June 1975	O–75–4
Sept. 1975 through Dec. 1976	O–77–2
Dec. 1976 through Dec. 1977	O–78–4
1978, 1979, and 1980	O–81–3A,B,C
1981	O–82–4
1982 through 1984	O–86–2
1985–1994	O–95–3.

The 132-page report is comprised of three groups of data. The first is a set of data logs from seven wells in the central and southern parts of Lake, Harney, and Malheur Counties. These wells were logged during 1993. The second set of data comes from a group of 18 wells in the vicinity of Vale, Malheur County, drilled and logged during 1986 for a study of the Oregon Water Resources Department. The third set of data presents results of an exploration project conducted by Hunt Energy Corporation in the general area of the Lake Owyhee thermal area in Malheur County. This data set was collected during 1980 and 1981 and covers 16 wells.

For all publications listed above, purchases can be made over the counter, by mail, FAX, or phone at the Nature of the Northwest Information Center, Suite 177, State Office Building, 800 NE Oregon Street #5, Portland, Oregon 97232-2109, phone (503) 872-2750, FAX (503) 731-4066; and the DOGAMI field offices: 1831 First Street, Baker City, OR 97814, phone (503) 523-3133, FAX (503) 523-9088; and 5375 Monument Drive, Grants Pass, OR 97526, phone (503) 476-2496, FAX (503) 474-3158. Orders may be charged to Visa or Mastercard. Orders under $50 require prepayment except for credit-card orders. □

AVAILABLE PUBLICATIONS
OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

GEOLOGICAL MAP SERIES

	Price ☑
GMS-5 Powers 15' quadrangle, Coos and Curry Counties. 1971	4.00
GMS-6 Part of Snake River canyon. 1974	8.00
GMS-8 Complete Bouguer gravity anomaly map, central Cascades. 1978	4.00
GMS-9 Total-field aeromagnetic anomaly map, central Cascades. 1978	4.00
GMS-10 Low- to intermediate-temperature thermal springs and wells. 1978	4.00
GMS-12 Oregon part, Mineral 15' quadrangle, Baker County. 1978	4.00
GMS-13 Huntington/Olds Ferry 15' quads., Baker/Malheur Counties. 1979	4.00
GMS-14 Index to published geologic mapping in Oregon, 1898-1979. 1981	8.00
GMS-15 Gravity anomaly maps, north Cascades. 1981	4.00
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