OREGON GEOLOGY

Oregon Department of Geology and Mineral Industries

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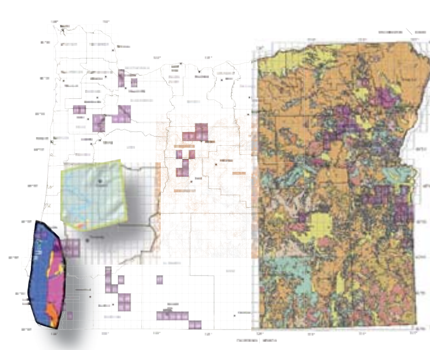
IN THIS ISSUE:



TO OUR READERS — Welcome back!

From the State Geologist:

In this issue of *Oregon Geology*, we play catch-up since our last issue of Fall 2004 by publishing a set of articles that have been languishing for some time and by summarizing recent agency activities. We want to continue to publish articles on Oregon's unique geology, but we can't do it without your submissions! See page 35 for contributor guidelines.

— Vicki S. McConnell

Agency News

Geologic Mapping Section

Our first priority remains completion of the statewide digital compilation map, now in its third year. To this end, we have completed and released the second version of the Oregon Geologic Data Compilation. OGDC-2 incorporates a digital and spatial database for northeast and southeast Oregon with the central portion of the state being added to the compilation in winter 2006. We anticipate this project and the final digital model to be our primary mapping product, with completion by 2010. A subset of the Oregon Geologic Data Compilation from the first two years is also now available to view on our website, http://www.oregongeology.com (Figure 1, page 13). Using data from OGDC-2, you can view online Oregon stratigraphy, rock type, and rock property theme maps on topographic and shaded relief backdrops.

The Oregon Geologic Map Advisory Committee has advised DOGAMI and its partners to complete mapping of the Southern portion of the state, including the Klamath Falls, Medford, and Cape Blanco 1:250,000 scale quadrangles. This compilation will incorporate new mapping by DOGAMI in the Klamath Basin and Grants Pass areas. The Southern Willamette Valley was previously defined by the Committee as a multi-year, multi-quadrangle project in 2004 but was only partially funded by USGS. We now propose to map up to four quads in the area. South coast urban areas were identified as high priority for mapping

(Continued on page 13)

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Cover photo

The White River Bridge on Oregon Route 35, east of Mount Hood, after the debris flow events of early November 2006. Note the blue-jacketed person standing in the channel near the center of the bridge span. The debris deposit is roughly 4–6 m high on the upslope side of the bridge. Debris completely filled the channel and overtopped the bridge deck, so total debris flow depth reached more than 6 m. [Route 35 was re-opened December 9, 2006.]

Photo contributed by William J. Burns, DOGAMI.

Recent geologic history of the upper White River valley, Oregon

by Thomas G. DeRoo, Mount Hood National Forest Headquarters, 16400 Champion Way, Sandy, OR 97055

About 12,000 years ago two major landscape-shaping processes were waning in the upper White River valley (Figures 1 and 2): a glacier from the last major ice age had either melted entirely or retreated substantially, and the Polallie eruptive period had ended. The White River was adjusting to the lahar deposits and pyroclastic-flow deposits that partially filled the valley. For most of the next 12,000 years the White River valley was probably free of major geologic changes. The river and slope processes developed a relatively stable valley that was forested up to at least 1675 m elevation (Scott, 1995) and probably resembled other major river valleys of the region.

About 220 years ago a remarkable change occurred. Lahars and pyroclastic flows from the Old Maid eruptive period partially filled the upper valley with large amounts of loose volcanic material, forming a depositional surface that extended roughly to the entrance to the narrow White River canyon, about 850 m in elevation. At least one lahar reached Tygh Valley and covered the valley floor there (Cameron and Pringle, 1987).

The loose material in the upper valley eroded rapidly. Runoff from intense rainstorms cut large gullies in the more steeply sloped fill material in the upper valley. Most of the sediment was transported by debris flows that deposited coarser-sized particles above 1030 m elevation. Subsequent flood events and debris flows continued building an alluvial fill or fan that

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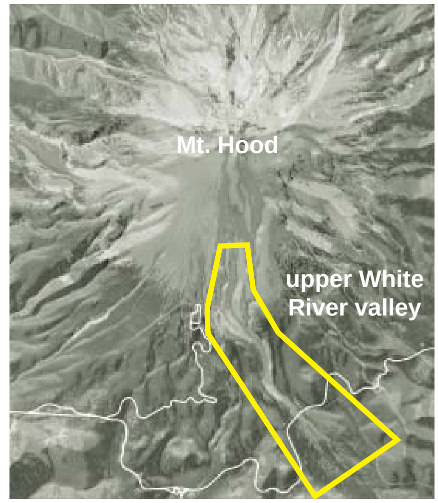

Figure 1. Study area location. The yellow polygon outlines the upper White River valley. The white line transecting the polygon is Oregon Route 35.

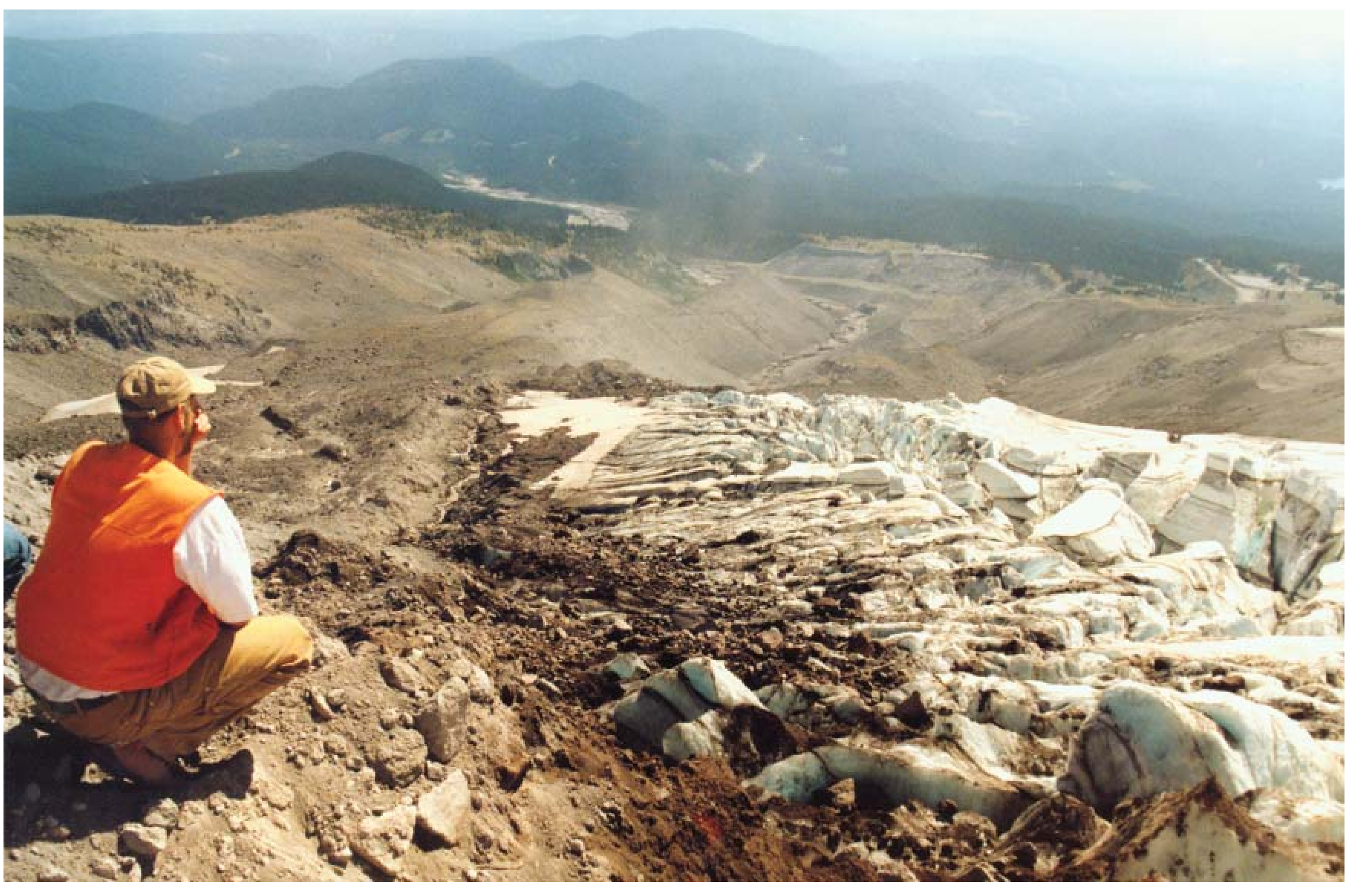

Figure 2. Looking down the White River Glacier from 2440 m elevation. Three subparallel drainages that converge at the head of the alluvial fan are visible in the upper half of the photo. (9-10-98 photo)

RECENT DOGAMI PUBLICATIONS

Publications are available from: Nature of the Northwest, 800 NE Oregon St., #5, Portland, OR 97232, info@naturenw.org, (503) 872-2750; or from the DOGAMI field offices in Baker City, 1510 Campbell Street, (541) 523-3133, and Grants Pass, 5375 Monument Drive, (541) 476-2496. For online purchasing, go to http://www.naturenw.org, select "Store" and "Maps and Reports" and use the short identification of the publication (e.g., RMS-1) for a search.

Look online (http://www.oregongeology.com) for:

- **All *Ore Bin* and *Oregon Geology* past issues–** http://www.oregongeology.com/sub/quarpub/OrGeo.htm
- **All Geologic Map Series (GMS) maps–** http://www.oregongeology.com/sub/publications/GMS/gms.htm
- **Oregon Geologic Data Compilation (OGDC) interactive map–** http://www.oregongeology.com/sub/ogdc/index.htm

Released February 17, 2006:

- **Geoanalytical information layer for Oregon (GILO) -- Release 1, northeast Oregon**, by Mark L. Ferns and Vicki S. McConnell. GILO rel. 1. 1 CD, $10.
- **Morphologies of beaches and dunes on the Oregon coast, with tests of the geometric dune-erosion model**, by Jonathan C. Allan and Paul Komar. Open-file report O-05-08. 1 CD, $10.
- **A geographical information (GIS) data set of beach morphodynamics derived from 1997, 1998, and 2002 LIDAR data for the central to northern Oregon coast**, by Jonathan C. Allan and Roger Hart. Open-file report O-05-09. 1 CD, $10.
- **Evaluation of coastal change and the potential for erosion during extreme storms at Crissey Field, southern Oregon coast**, by Jonathan C. Allan. Open-file report O-05-12. 1 CD, $10.

Released March 1, 2006:

- **The City of Seaside's tsunami awareness program: Outreach Assessment — How to implement an effective tsunami preparedness outreach program**, by Darci Connor. Open-file report O-05-10. 1 CD, $10.

Released March 3, 2006:

- **Dynamic revetments for coastal erosion stabilization: A feasibility analysis for application on the coast**, by Jonathan C. Allan, Ronald P. Geitgey, and Roger Hart. Special Paper 37. 1 CD, $10.

Released June 2, 2006:

- **Oregon geologic data compilation — version 2, southeast and northeast Oregon**, compiled by Margaret D. Jenks, Clark A. Niewendorp, Mark L. Ferns, Ian P. Madin, Paul E. Staub, Lina Ma, and Ronald P. Geitgey. OGDC-2. 1 CD, $25.

Released June 12, 2006:

- **Interim report: Johnson Creek landslide project, Lincoln County, Oregon**, by George R. Priest, Jonathan C. Allan, and Allan Niem. Open-file report O-06-02. 1 CD, $10.
- **Preliminary geologic and mineral resources map of the Mormon Basin 7.5 minute quadrangle, Baker and Malheur counties, Oregon**, by Howard C. Brooks. Open-file report O-06-25. 1 CD, $10.

Released July 14, 2006:

The following individually released publications comprise the USGS STATEMAP 2002 deliverable (originally bundled together as Open-file report O-03-11):

- **Preliminary geologic map of the Eugene East and Eugene West quadrangles, Lane county, Oregon**, by Ian P. Madin and Robert B. Murray. Open-file report O-06-17. 1 CD, $10.
- **Preliminary geologic map of the Gold Hill and Rogue River 7.5 minute quadrangles, Jackson and Josephine counties, Oregon**, by Thomas J. Wiley. Open-file report O-06-18. 1 CD, $10.
- **Geology of the Upper Grande Ronde River Basin, Union county, Oregon**, by Mark L. Ferns, Vicki S. McConnell, Ian P. Madin, and Jenda A. Johnson. Open-file report O-06-19. 1 CD, $10.
- **Preliminary geologic map of the Service Buttes, Echo, Nolin, Barnhart, and Pendleton 7.5 minute quadrangles (west to east), Umatilla County, Oregon** [map only; no text], by Vicki S. McConnell. Open-file report O-06-20. 1 CD, $10.

The following individually released publications comprise the USGS STATEMAP 2003 deliverable:

- **Oregon statewide geologic map data: A pilot project where digital techniques changed the geologic map compilation process and product**, by Mark L. Ferns, Ronald P. Geitgey, Margaret D. Jenks, Lina Ma, Ian P. Madin, Vicki S. McConnell, and Paul E. Staub. Open-file report O-06-03. 1 CD, $10. (Complete data set for northeast Oregon released as OGDC-1, July 12, 2005.)
- **Preliminary geologic map of the Wimer and McConville Peaks 7.5 minute quadrangles, Jackson and Josephine counties, Oregon**, by Thomas J. Wiley. Open-file report O-06-05. 1 CD, $10.
- **Preliminary geologic map of the Coburg 7.5 minute quadrangle, Lane and Linn counties, Oregon**, by Ian P. Madin, Robert B. Murray, and Frank R. Hladky. Open-file report O-06-06. 1 CD, $10.
- **Preliminary geologic map of the Springfield 7.5 minute quadrangle, Lane county, Oregon**, by Frank R. Hladky and Glenn R. McCaslin. Open-file report O-06-07. 1 CD, $10.
- **Preliminary geologic map of the Cayuse 7.5 minute quadrangle, Umatilla county, Oregon**, by Mark L. Ferns. Open-file report O-06-08. 1 CD, $10.
- **Preliminary geologic map of the Mission 7.5 minute quadrangle, Umatilla county, Oregon**, by Mark L. Ferns and Kate Ely. Open-file report O-06-09. 1 CD, $10.
- **Preliminary geologic map of the Thorn Hollow 7.5 minute quadrangle, Umatilla county, Oregon**, by Mark L. Ferns. Open-file report O-06-10. 1 CD, $10.

The following individually released publications comprise the USGS STATEMAP 2004 deliverable:

- **Oregon statewide geologic map data: Preliminary geologic compilation map of the southeast portion of Oregon**, by Margaret D. Jenks, Mark L. Ferns, Paul E. Staub, Ian P. Madin, Ronald P. Geitgey, and Clark Niewendorp. Open-file report O-06-04. 1 CD, $10. (Complete data set for northeast and southeast Oregon released as OGDC-2, June 2, 2006.)
- **Preliminary geologic map of the Sexton Mountain, Murphy, Applegate, and Mount Isabelle 7.5 minute quadrangles, Jackson and Josephine counties, Oregon**, by Thomas J. Wiley. Open-file report O-06-11. 1 CD, $10.
- **Preliminary geologic map of the Creswell 7.5 minute quadrangle, Lane county, Oregon**, by Robert B. Murray. Open-file report O-06-12. 1 CD, $10.
- **Preliminary geologic map of the Veneta 7.5 minute quadrangle, Lane county, Oregon**, by Robert B. Murray and Ian P. Madin. Open-file report O-06-13. 1 CD, $10.
- **Preliminary geologic map of the Cabbage Hill 7.5 minute quadrangle, Umatilla county, Oregon**, by Mark L. Ferns and Vicki S. McConnell. Open-file report O-06-14. 1 CD, $10.

(Continued on page 28)

(White River valley, continued from page 3)

covered the valley floor. Smaller flood events deposited material at the head of the fan; larger events transported coarse material further down the fan, but generally not below 1030 m. The evidence for this is a very thin and discontinuous soil horizon developing on the valley fill deposits beginning at about 1030 m (Scott, 1995). In addition, below this elevation, the channels of White River and Iron Creek are incised into the valley fill, indicating that they have been in these approximate positions for some time. In contrast, above 1030 m to the present head of the alluvial fan near 1525 m, there is little relief on the channel banks and the channels frequently migrate laterally in the manner of a braided stream.

Three subparallel drainages converge at the head of the fan to form the White River. The westernmost and central drainages originate at the White River glacier and are the source areas for present-day debris flows (Figure 3).

Erosional remnants of the 220-year-old surface are still clearly visible in the upper valley above 1370 m. Mesa Terrace, located between the westernmost and central drainages, is one of these remnant surfaces. Another surface of similar age is located between the central and easternmost drainages, further up valley than Mesa Terrace (Sherrod and Scott, 1995). The aggrading fan head has covered the down-valley end of Mesa Terrace.

These remnant Old-Maid-age surfaces allow the graphical reconstruction of the valley floor as it appeared 220 years ago following the eruption. From this, it is possible to estimate the total volume of sediment transported from the upper valley to the alluvial fan since that time. Assuming an equal volume of sediment was transported from one year to the next, the average sediment production per year for the last 220 years is about 500,000 tons. If the total volume of sediment from 220 years were spread evenly over the alluvial fan surface, the thickness would be about 8.5 m.

Because the original deposit was loose, over-steepened, and represented a change in river base-level, it eroded much more rapidly in the early years of the Old Maid eruptive period than it has since. Thus, 500,000 tons of sediment per year is probably an underestimate of the amount of sediment produced initially and an overestimate of that produced now. Nevertheless, it may be considered an upper limit to the current annual level of sediment production. Estimates made with the Universal Soil Loss equation suggest modern rates of sediment production to be about 200,000 tons per year.

It is important to make clear that these numbers refer to the amount of sediment transported from the headwater deposit to the fan below — not necessarily to the amount of sediment that has been delivered to White River itself below 1030 m eleva-

(Continued on page 6)

Figure 3. View of the upper White River valley showing both deposition and erosion. The reflective surface of the valley floor is recent deposition from debris flow surges. Glacial meltwater has carved steep-sided channels in the debris flow deposits. A large landslide is evident at the major outside bend of the valley where debris flow surges have undercut the valley wall. The low, flat-topped ridge between the two drainages is Mesa Terrace. (9-9-98 photo)

(White River valley, continued from page 5)

tion (i.e., the lower limit of the modern fan deposits). The thickness of the alluvial fan varies from zero near 1030 m to probably 15 m or more near the highway crossing (Scott, 1995). Deposits at the margins of the fan are thinner than at the center of the valley (Scott, 1995).

The steep slopes of loose deposits in the upper valley continue to function as sediment sources (Figure 3). Surface erosion and small mass-wasting events deliver sediment to the bottoms of the large gullies and periodic debris flows initiated by landslides, dam-break floods, intense rainstorms, or glacial outburst floods clean out the channels and transport the sediment to the alluvial fan (Figure 4). These large events probably scour part of the surface of the fan during main flow and deposit sediment as they wane. Later, near-normal runoff reestablishes a channel.

The White River glacier has diminished greatly since 1900. The removal of ice-support from the upper valley walls has created very unstable slopes. Melting blocks of ice buried in morainal deposits have caused local saturation and collapse of the overlying material and are thought to have initiated some recent debris flows (Driedger, 1995).

A non-comprehensive summary of recent water-flood and debris flow events on the upper White River comprises 14 separate events: August 1907, August 1926, October 1926, 1927, October 1930, mid-1930s, October 1947, 1949, September 1959, October 1959, January 1966, January 1967, September 1968, and fall of 1981 (Driedger, 1995). Notice that most of these events occurred in the late summer and fall.

With abundant and easily erodible sediment still available in the upper valley, periodic debris flows will continue to affect the alluvial fan. Much of the sediment will be deposited on the headward part of the fan, expanding the area of the fan and continuing an overall trend of aggradation.

Another Mount Hood eruptive period or a major change in the White River glacier would perturb the White River system once again.

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Cameron, K. A., and Pringle, P., 1987, A detailed chronology of the most recent major eruptive period at Mount Hood, Oregon: Geological Society of America Bulletin, v. 99, p. 845–851.

Driedger, C. L., 1995, verbal communication.

Scott, W. E., 1995, verbal communication.

Sherrod, D. R., and Scott, W. E., 1995, Preliminary geologic map of the Mount Hood 30- by 60-minute quadrangle, Northern Cascade Range, Oregon: U.S. Geological Survey Open-File Report 95-219, 35 p., 1 map sheet.

Figure 4. Looking up the White River valley from 1400 m elevation. Most of the valley floor is covered with recent deposits from debris flow surges. These deposits are 0.3 to 4.5 m deep and lie on top of older deposits. Glacial melt water has created new channels in these fresh deposits. The White River glacier is visible in the distance. (9-3-98 photo)

Response to 1998 debris flow in the upper White River valley, Oregon

by Douglas A. Anderson, Washington Department of Transportation, 1655 South Second Ave., Tumwater, WA 98504; Thomas G. DeRoo, Mount Hood National Forest Headquarters, 16400 Champion Way, Sandy, OR 97055; and Christopher D. Hedeen, Oregon City High School, 19761 S. Beavercreek Road, Oregon City, OR 97045.

How do agencies respond when a debris flow occurs? This account is based on an internal report written in mid-September 1998 to document the authors' observations of the September 3, 1998, White River debris flow event and to educate agency staff about the geologic hazard. At the time, this event was thought to be large and relatively unusual. Since then White River debris flows have occurred almost every other year, and the magnitude of the debris flow events of October 1, 2000, and November 7, 2006, have dwarfed the 1998 event.

On the morning of Thursday, September 3, 1998, a number of debris flow surges and/or small glacial outburst floods originated near the snout of the White River glacier at approximately 2200 m elevation. These debris surges had the consistency of a wet cement slurry, floating small boulders and pushing larger boulders down the channels of the braided White River valley bottom. Typically, a surge was 6–12 m wide and 1–2 m high at the snout, with a concentration of larger boulders at the front. Each surge deposited material at its flanks, while the center continued to move down channel at an estimated 15–25 km per hour. The net effect of the debris flow surges was to deposit material over the width of the valley bottom, raising the elevation of the valley bottom by 0.3 to 4.5 m. These boulder-rich surges increased in frequency due to the increased glacial melt from multiple days of hot weather and the extremely high freezing level. Late in the day the size of the debris surges increased and the valley bottom elevation raised enough to allow a surge to spill into the White River quarry, where an Oregon Department of Transportation (ODOT) contractor was excavating sand.[1] This particular debris surge covered the quarry floor and partially buried some equipment. On Friday morning ODOT shut down quarry operations until further notice.

(Continued on page 8)

Figure 1. Looking down the recently enlarged gully along the eastern edge of the White River glacier from about 2300 m elevation. The left wall of the gully is glacial moraine material; the right wall is sediment-laden glacier ice. (9-10-98 photo)

1 The White River quarry (or sand pit), located along the west side of the valley about 0.8 km above the Oregon Route 35 crossing, was used by ODOT for many years as a source of highway sand. The pit was closed in 1999.

Figure 2. (top) Close-up view of the recently enlarged gully from about 2250 m elevation, just above the glacier terminus. The gully is about 25 m deep and 20 m wide. Several blocks of ice can be seen in the foreground on the gully floor. (9-10-98 photo) (bottom) The eastern wall of the gully, just below the glacier terminus. Note the near vertical slopes and the melting seam of ice that is embedded in the morainal material in the gully wall and completely detached from the glacier. This is a likely site for a future landslide that could initiate another debris flow. (9-9-98 photo)

(1998 Debris Flow, continued from page 7)

Friday morning the United States Geologic Survey (USGS) in Vancouver, Washington, was notified of the processes occurring in the White River drainage. The debris surges continued to occur through Friday afternoon and Saturday. They began to dissipate in size and frequency by late Saturday and into Sunday. This was most likely a result of the cooler weather and the lower freezing level that began on Labor Day weekend and lasted through Thursday, September 10. The Route 35 bridge and the White River quarry approach road were in danger of being overtopped, undermined, and breached by Friday morning. At this time ODOT brought in a D-9 bulldozer to attempt to channel the White River under the center of the Route 35 bridge and to protect the approach road from further damage. The attempt on Friday was unsuccessful due to the unpredictable nature of the debris flow surges. On Saturday the human-created channel finally captured the White River; the river is currently flowing under the bridge and has been re-established to its approximate location prior to the debris surge events. On Monday, the stream continued to readjust to its new channels from the glacier to the bridge and beyond. The river water was a dark brown color as it continued to transport fine-grained material. No debris surges were observed on Monday.

On Tuesday, September 8, 1998, the USGS surveyed the White River glacier from the air and observed water ponding in some crevasses and minor ponding on top of the glacier. This is a sign that the internal glacial drainage system had been altered by glacial movement or that the drainage system could not handle the high runoff of the melting glacier from a number of record hot days in a row. This was enough evidence to convince the USGS glaciologist and the Mount Hood National Forest (NF) geologists and hydrologists that there was potential for a glacial outburst flood. A glacial outburst flood can occur when a glacier's "plumbing system" becomes blocked and water fills voids inside or underneath the glacier. At a critical point, increasing water pressure forces a blowout near the terminus of the glacier. On the basis of quick USGS calculations, the power of a glacial outburst flood in the White River valley would begin to wane at the Timberline Trail crossing of the White River and would most likely terminate near or just beyond the Route 35 crossing. ODOT allowed their contractor to begin work again in the White River quarry on Tuesday.

On Wednesday, two Mount Hood NF geologists surveyed the White River drainages[2] and located the drainage that was producing the debris surges. The west fork and east fork were normal, but the middle fork was noticeably downcut and freshly disturbed by the four days of frequent debris surges. The geologists climbed to the snout of the glacier and found a deeply eroded U-shaped drainage that was on average 20 m wide by 25 m deep. This new gully had developed along the lower eastern edge of the glacier. The west side wall of the drainage was glacial ice, and the east side wall was glacial moraine material (loose boulders, cobbles, pebbles, and sand). This drainage was constantly calving off glacial ice on the one side or spalling rock and sand from the other side as the small stream moved back and forth, undercutting the gully slopes until they failed (Figures 1–3). At this point it was apparent that the Hood River District Ranger would be faced with a decision on whether to close portions of the Timberline Trail and the White River Sno-Parks to public access.

On Thursday, September 10, the Hood River District Ranger, with support from the Mt. Hood NF Supervisor, decided that the prudent course was to issue a public closure and news release based on the information that was currently available. The only questions remaining were whether the glacier continued to pond or store water as the USGS glaciologist had witnessed on Tuesday's fly-over of the White River glacier and what the potential was for the middle fork to produce debris flow surges again when the predicted warm weather arrived on Friday.

The USGS was contacted to do some calculations on a worst case scenario glacial outburst flood from the White River glacier and its impact on the valley downstream. Simultaneously, a team of geologists, a hydrologist, and a public affairs officer ascended the mountain once again to confirm reports regarding the ponding water and to assess the condition of the middle fork drainage and its potential to initiate any more debris flow surges. After assessing the middle fork and climbing to viewpoints to examine the crevasses for ponded water, the team met to finalize their observations and hypotheses.

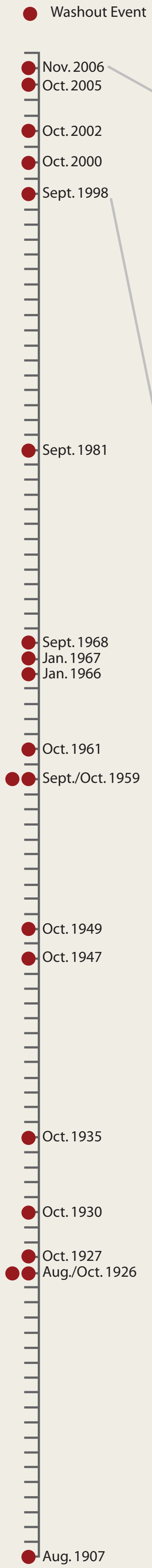
We believe that the middle fork drainage was the most likely cause of the debris flow surges that occurred late last week and through the weekend. We also believe that the significant downcutting in this small drainage has created a high susceptibility for moderate to large debris flow surges to originate during the next high runoff event during a warming trend or possibly during a thunderstorm. We saw no ponded water on the surface and very little to no water in the crevasses that we could see into. There was a clean portion of the glacier surface near the snout that appeared to be the area that was ponding the water a few days prior. For this reason we felt that the potential for a glacial outburst flood was fairly low for the next couple of days. However, the next warming trend or thunderstorm may result in more debris flow surges similar in size or larger than those of late last week and during the Labor Day weekend. We are unsure whether the glacier plumbing has cleared or if it was just cool enough to allow the glacier to finally catch up with draining some of its runoff. The USGS estimated 500,000 cubic meters of water and debris from the potential worst case scenario glacial outburst flood. This volume would dissipate near the Route 35 bridge or just below. These are the set of circumstances that led to the public closure of the upper White River area on Friday, September 11, 1998, until further notice.[3]

We would like to thank the USGS for their quick calculations and assessment, Mount Hood Meadows for offering ski lift rides to expedite our investigation, Mount Hood National Forest Headquarters for their support and specialist personnel, and ODOT for their continued communication with the Hood River Ranger District.

2 Three unnamed tributaries that converge near 1525 m at the head of the alluvial fan to form the White River are referred to here as the west fork, middle fork, and east fork.

3 The public closure of the upper White River area ended in mid-October 1998 when both the snow level and the debris flow hazard level dropped. Route 35 remained open throughout this time.

Figure 3. View of shallow landslides along the east slope of the middle fork of the White River valley near 1730 m elevation. These landslide scars are about 75 m high. (9-9-98 photo)



White River Washouts

White River washouts have closed the Oregon Route 35 bridge 20 times since 1907.

A. November 7, 2006

B. September 8, 1998

Images: Oregon Route 35 bridge crossing White River southeast of Mount Hood. (A) after November 7, 2006, debris flow (looking up river) and (b) after September 3, 1998 debris flow (looking down river). Also see issue cover photo. (2006 photo: Doug Jones, Mount Hood National Forest; 1998 photo: Thomas DeRoo, Mount Hood National Forest.)

Timeline source: *The Oregonian*, Mount Hood vs. ODOT, Nov. 26, 2006, p. C1.

Debris flow modeling

USGS debris flow flume at H. J. Andrews Experimental Forest

by William J. Burns, Oregon Department of Geology and Mineral Industries, 800 NE Oregon St., Portland, Oregon, 97232

Flume technical details are from U.S. Geological Survey Open-File Report 92-483, http://vulcan.wr.usgs.gov/Projects/MassMovement/Publications/OFR92-483/framework.html

One type of landslide common in Oregon is the channelized debris flow. Typically, a debris flow originates as a small, shallow landslide above a drainage channel and is triggered by intense rainfall, rapid snow or glacial melting, or volcanic eruption (lahar); the debris mixes with water already in the channel to become a slurry of water, rock, soil, and other organic material that can attain speeds greater than 10 m/s.

Debris flows can also initiate within a channel through erosion of channel sediment during times of increased water flow due to heavy rain or rapid snow or glacial melting. During rapid descent down the channel (commonly termed transport), debris flows can grow in size and speed. By the time a debris flow reaches the mouth of the channel, what started as a small shallow landslide may have grown into a potentially devastating, rapidly moving landslide that can cause major damage to structures and roads, change drainage patterns, and sometimes cause loss of human life (Figure 1) (Iverson and others, 1992).

Observations and measurements of naturally occurring debris flows are problematic. In 1991 the U.S. Geological Survey (USGS), motivated by Richard Iverson, constructed a flume (Figure 2) to conduct controlled experiments on debris flows. The flume is located about 72 km east of Eugene, Oregon, in the Cascades Range foothills in the Andrews Experimental Forest. USGS Cascades Volcanic Observatory (CVO) personnel, led by Iverson, perform experiments at the flume.

The flume is a reinforced concrete channel 95 m long, 2 m wide, and 1.2 m deep that slopes 31 degrees (60 percent), an angle typical of terrain where natural debris flows originate. Removable glass windows built into the side of the flume allow flows to be observed and photographed as they sweep past. Eighteen data-collection ports in the floor of the flume permit measurements of forces due to particles sliding and colliding at the base of flows.

To create a debris flow, up to 20 cubic meters (about 40 tons) of sediment are placed behind a steel gate at the head of the flume, saturated with water from subsurface channels and surface sprinklers, and released. Alternatively, a sloping mass of sediment is behind a retaining wall at the flume head and watered until slope failure occurs. The ensuing debris flow descends the flume and forms a deposit on a nearly flat runout surface at the flume base. The flume design thus accommodates research on all stages of the debris-flow process, from initiation through deposition. Experiments can be conducted using a variety of materials, from mixtures of well-sorted gravel and water to heterogeneous natural slope debris. Experimental materials are recycled by excavating deposits with a front-end loader, placing them in a dump truck, and hauling them back to the staging area at the head of the flume.

Experiments at the flume have expanded our understanding of debris flows and have increased development of computer models for interpreting and forecasting future debris flows in susceptible areas (Iverson and others, 1992). Some of these models were used to create lahar hazard zones for volcanic hazard maps (http://vulcan.wr.usgs.gov/Publications/hazards_reports.html). Experiments in September 2006 conducted at the flume through col-

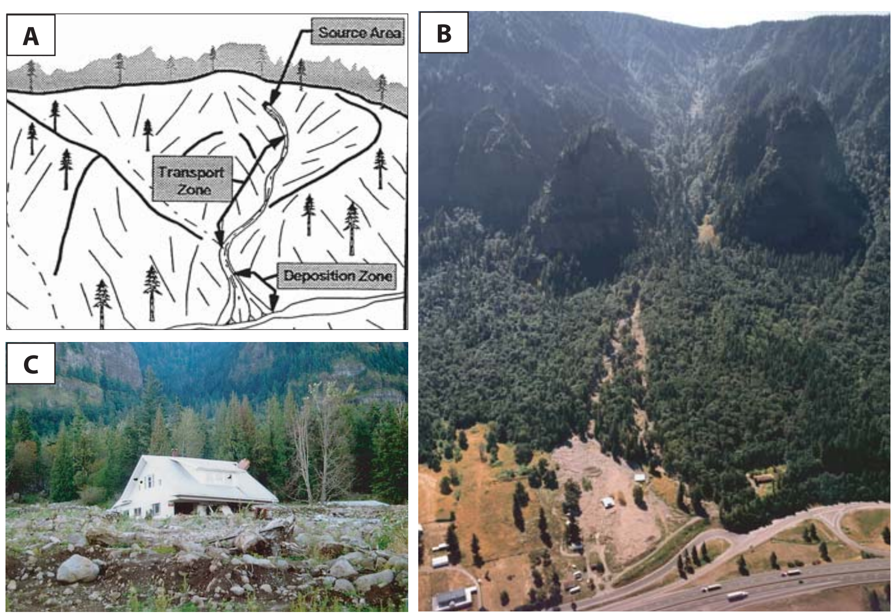


Figure 1. (A) Schematic diagram of debris flow zones including initiation (source area), transport zone, and deposition zone (Pyles and others, 1998). (B) Oblique aerial photograph of the Dodson, Oregon, debris flow of February 1996 in the Columbia River Gorge. (C) Photograph of a house buried by the Dodson debris flow (photograph courtesy of Kenneth Cruikshank, Portland State University).

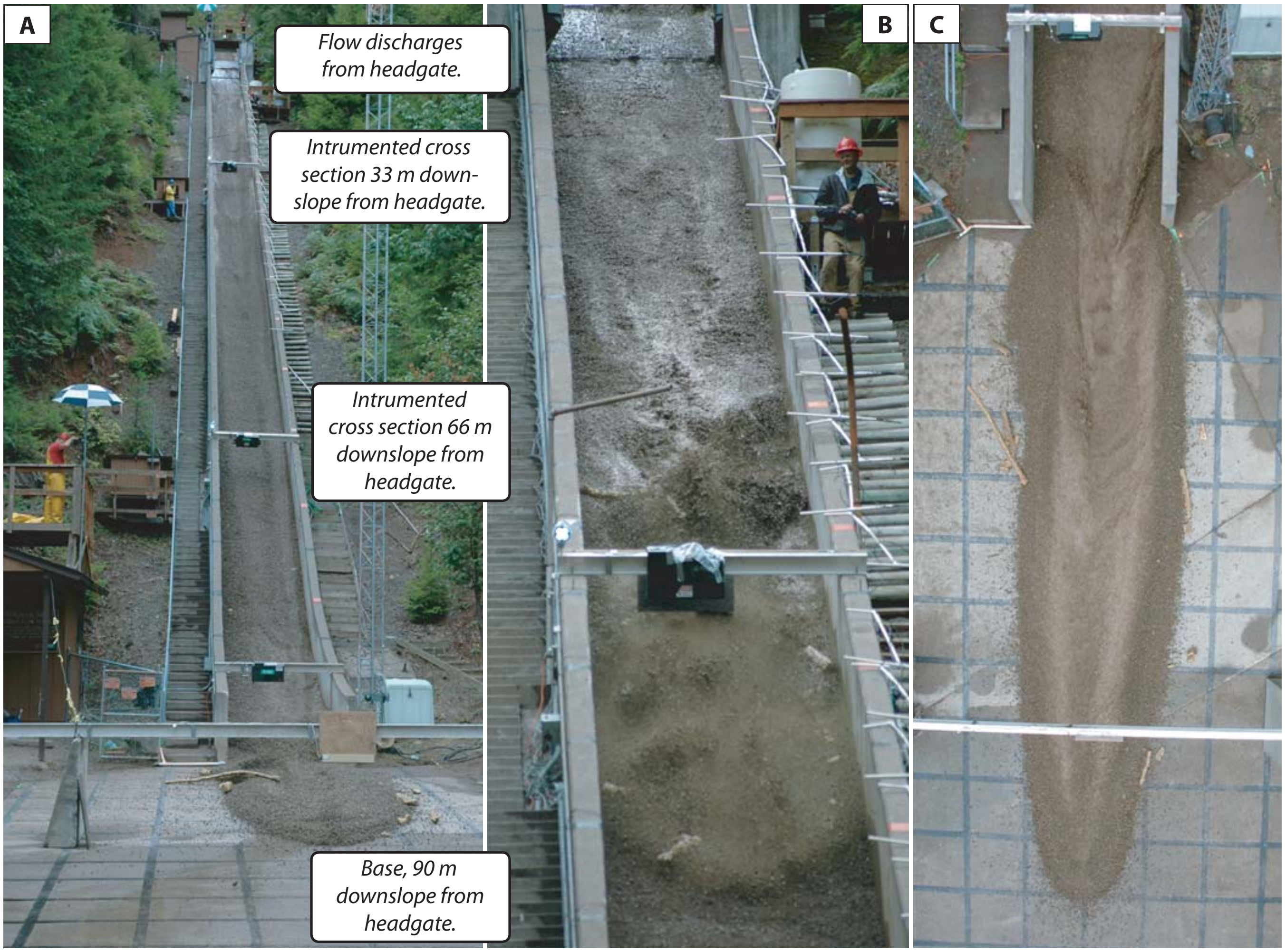


Figure 2. September 2006 debris flow flume experiment. (A) General flume setup and debris deposit, (B) flow front as it advances across the sediment-covered bed in the upper part of the flume, and (C) looking directly down at the deposit. (Photographs courtesy of Richard Iverson, USGS CVO.)

laborative research by the USGS Volcano Hazards Program and the USGS Landslide Hazard Program (LHP) were aimed at further understanding the entrainment phenomenon, or growth in size of debris flow, during transport. These experiments examined scour of wet sediment on the flume bed by an advancing debris flow. Sediment entrainment by debris flows, a common phenomenon in Oregon, creates larger flows. Entrainment processes are poorly understood but are critical to forecasting debris-flow impact velocities and inundation areas (Iverson and Reid, 2006).

The USGS LHP is working closely with Oregon state agencies in a 5-year program. The LHP is engaged in activities suggested in the National Landslide Hazard Mitigation Strategy and supports the Oregon Department of Geology and Mineral Industries (DOGAMI) to improve the level of landslide hazard mitigation in Oregon (USGS, 2006).

One of the goals of this partnership is to increase our understanding of debris flow hazards in Oregon and to reduce long-term losses from these hazards. One of the most successful regional ways communities in Oregon have begun to reduce future losses is through the creation of hazard maps tied to codes or ordinances requiring detailed site-specific studies and mitigation design prior to future development in hazard areas (Iverson and Reid, 2006).

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Pyles, M. R., Adams, P. W., Beschta, R. L., and Skaugset, A. E., 1998, Forest practices and landslides, A report prepared for Governor John A. Kitzhaber: Forest Engineering Dept., Oreg. State Univ., Corvallis, 49 p.

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(Agency News, continued from page 2)

and this includes all or parts of about 12 quadrangles that cover several coastal communities experiencing rapid growth. In central Oregon, the Lower Crooked River/Prineville area was also identified as a high mapping priority. This area includes two quadrangles north of Prineville that are important for fish habitat and an additional quadrangle to the south that is subject to rapid rural residential growth.

Our geologic and fault mapping of the Portland Urban Corridor is now in the fourth year of a 5-year program, funded by the National Earthquake Hazards Reduction Program (NEHRP). This aligns with ongoing USGS FEDMAP projects. We are collaborating with the USGS Advanced National Seismic System (ANSS) program and a consortium of state and local governments to acquire Light Detection and Ranging (LIDAR) imaging in the Portland Urban corridor, which will cover those portions that have not already been mapped with LIDAR. The 800 square miles of data we hope to acquire will increase our LIDAR data holdings sixfold. These LIDAR data are seen as essential for revealing faults buried by thick vegetation and for delineating landslide and debris-flow scars.

DOGAMI is focused on LIDAR data acquisition because it has revolutionized the identification of existing landslide complexes, earthquake fault zones, floodplains, and forest regions for wildfire management. We have proposed to the State Legislature a program that would allow DOGAMI and its partners to acquire LIDAR data in 10,000 square miles of survey area in western Oregon. With these data, we could avoid incorrect assessment of large areas that have low risk and sharpen the focus on truly dangerous locations with high risk.

Our fault-mapping program in the Portland area has identified numerous potentially active faults, but until recently, none had been shown to be active and little was known about slip rates or other fault characteristics. Characterizing local faults in the Portland area is the single greatest unknown in evaluating seismic hazards in Oregon.

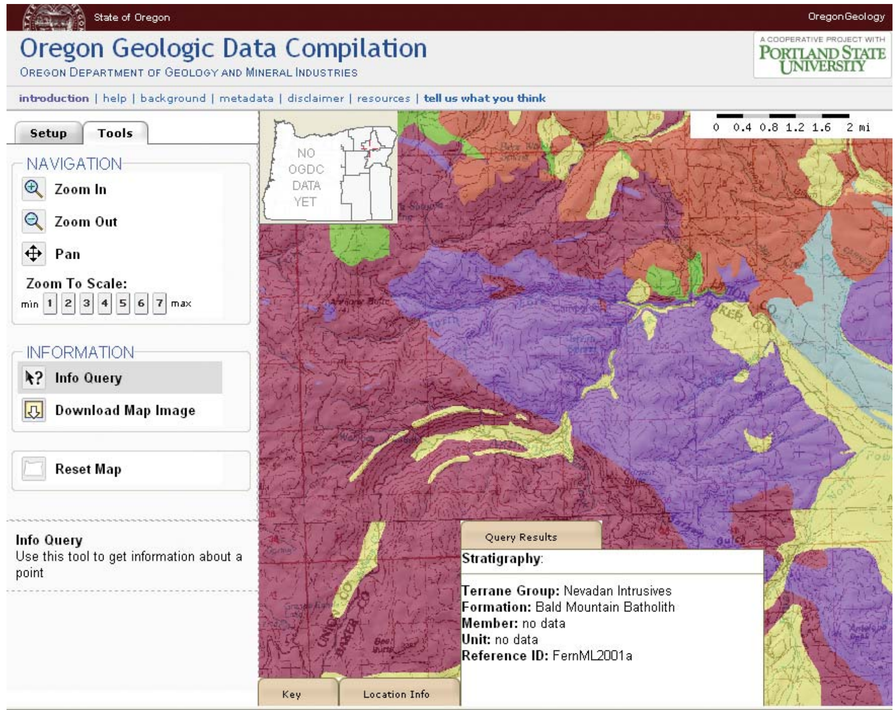


Figure 1. Screenshot of the online version of the Oregon Geologic Data Compilation, http://www.oregongeology.com/sub/ogdc/. The NE and SE area are online now; the central section will be online in February 2007.

Geologic mapping of the southeast end of the Portland Hills fault has been completed and has greatly improved our understanding of the extent and age of faulting. Geologic mapping of the northwest end of the fault has begun and is extending the fault through a complex area of large landslides. New proposals will complete the mapping at the northwest end of the fault and begin new mapping to connect the northwest end to published detailed mapping near downtown Portland. This will provide a complete, detailed map of the entire Portland Hills fault structure and should allow us to determine the style of faulting and help us better locate fault traces. In concert with our fault mapping we are also working to locate, interpret and digitally incorporate thousands of borehole logs available along the Portland Hills Fault.

We have also been awarded funding for a project that will establish a statewide database of geothermal systems in Oregon using a Geographic Information System (GIS).

Coastal Processes and Hazards Section

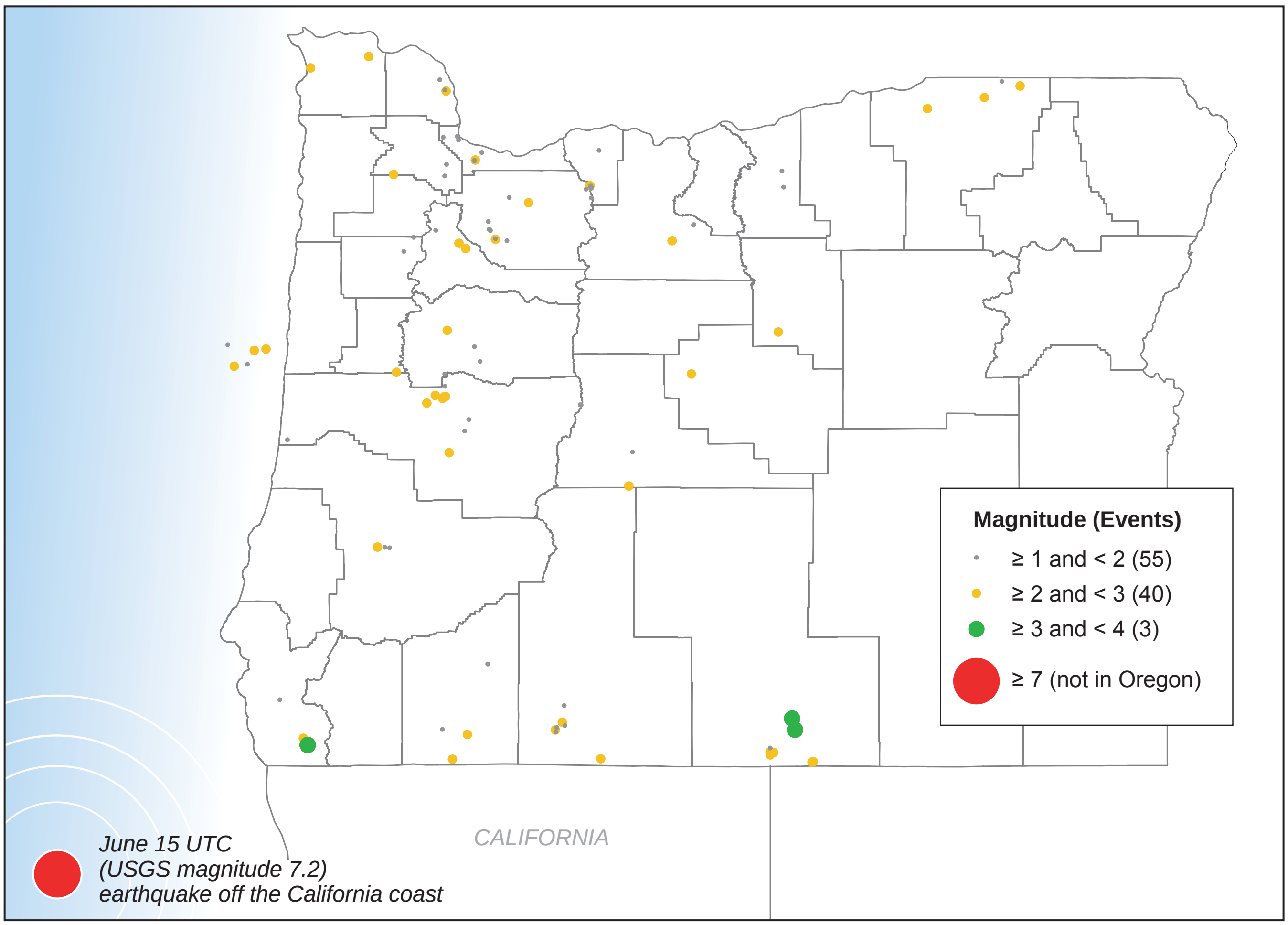
We continue overseeing a variety of projects and programs. We are an active partner with the Northwest Association of Networked Ocean Observing Systems (NANOOS), a cooperative venture to establish a pilot coastal ocean observatory for the estuaries and shores of Oregon and Washington. Other projects include analysis and monitoring of a unique dynamic revetment and artificial dune for shore protection at Cape Lookout State Park, monitoring an active landslide that impacts part of Coastal Highway 101 and coastal erosion hazard mapping for several counties. The Oregon Coastal Processes and Hazards Working Group continue to meet, chaired by the State Geologist.

(Continued on page 26)

OREGON SEISMICITY IN 2005

These data were generated from the Advanced National Seismic System (ANSS) Worldwide Earthquake Catalog (http://www.ncedc.org/anss/catalog-search.html). In 2005 the most significant earthquakes for Oregon were two sizable earthquakes that occurred offshore northern California on June 15 UTC (USGS magnitude 7.2) and June 17 UTC (USGS magnitude 6.4).

The June 15 UTC earthquake triggered a tsunami alert for the coasts of California, Oregon, and Washington. Because the dominant motion on the fault was strike-slip, no significant tsunami resulted. The alert was called off after an hour or so, but the event exposed a number of problems in notification systems and evacuation plans. Oregon Emergency Management (OEM) published an After Action Report (http://www.oregongeology.com/sub/news&events/OEMTsunamiWarningReport6-14.pdf) that provides an overview of the earthquake, the tsunami warning timeline, and recommendations for future response.



Field trip guide to the geology of the Lower Crooked River Basin, Redmond and Prineville areas, Oregon

by Jason D. McClaughry and Mark L. Ferns, Baker City Field Office, Oregon Department of Geology and Mineral Industries

The geologic record preserved in the Redmond and Prineville areas of central Oregon details a history of explosive volcanism and basalt lava flows that have intimately controlled the development of the Lower Crooked River Basin and geographic position of the Crooked River through time. This field trip provides an opportunity to stop at some of central Oregon's scenic treasures and to gain insight into the geologic conditions that influence society in the Lower Crooked River Basin.

The Lower Crooked River Basin area is located near the intersection of the High Cascades, High Lava Plains, and Blue Mountains geomorphic provinces. The region is dominated by juniper- and sage-covered high desert terrain with pine forested uplands in the Ochoco Mountains to the northeast. Topographic relief in the basin ranges from ~5841 ft (1779 m) along the Ochoco Divide on the northeast to ~2000 ft (610 m) at Lake Billy Chinook. The Lower Crooked River Basin is a traditional ranching and lumber-milling community that is rapidly transforming into a suburban residential area. Population growth and expansion of development into rural lands over the past decade have raised major issues in the Lower Crooked River Basin that include 1) geologic controls on surface and subsurface water, 2) geologic controls on landslides, and 3) distribution of trace metals and radioactive geochemical anomalies. Integrated geologic mapping (1:24,000 scale), lithologic descriptions, geochemical and petrographic analyses, and subsurface well log data provide information needed to erect a stratigraphic framework for the Lower Crooked River Basin and to refine the geologic relations with the eastern margin of the upper Deschutes Basin.

Recent detailed DOGAMI mapping in the core of the Lower Crooked River Basin has identified previously undocumented ancient volcanic centers of the John Day Formation, discerned the depositional controls and crude geometries of Neogene water bearing units, and has recognized potential controls on the distribution of landslide deposits. A synopsis of the stratigraphic framework erected by DOGAMI and major Tertiary geologic units in the field trip area is provided on the next page. A geologic time-scale is provided at the end of this guide for reference.

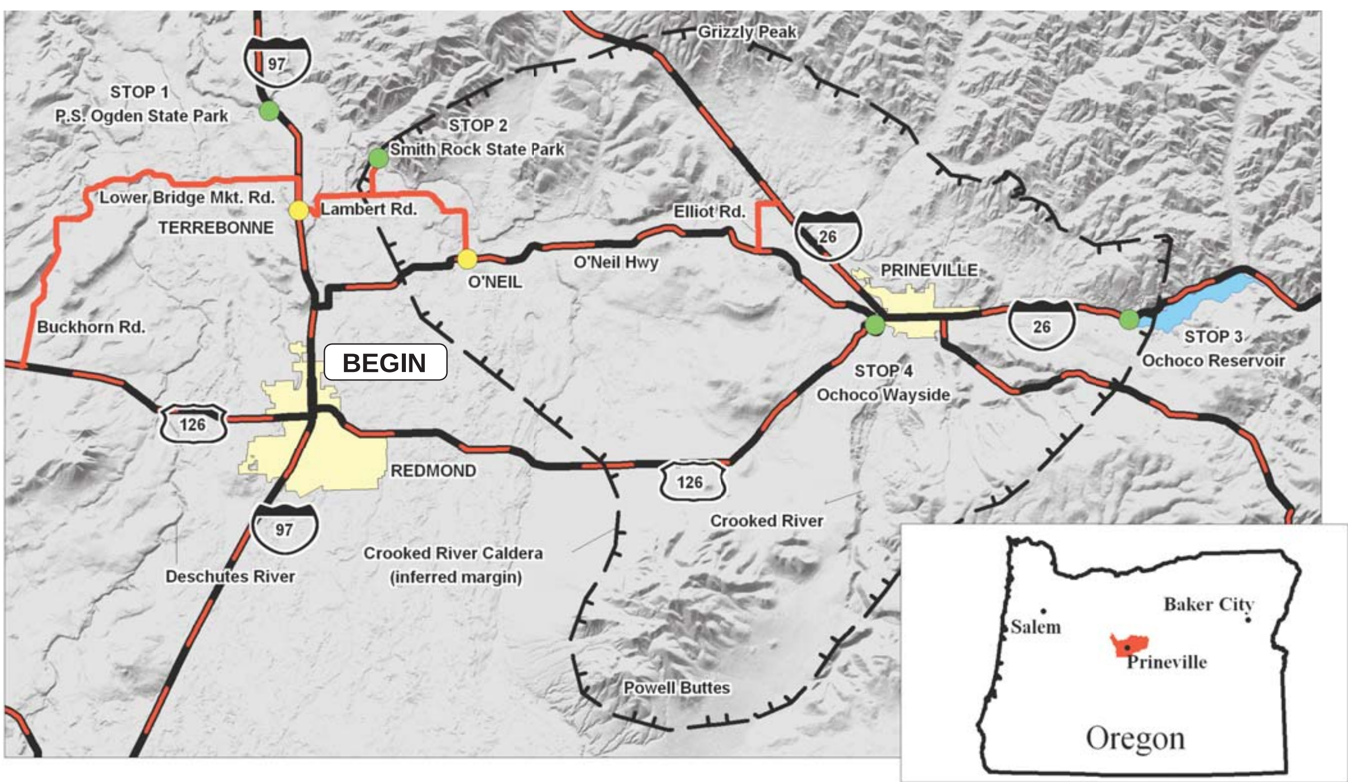


Figure 1. Field trip route for the Lower Crooked River Basin. Green points are field trip stops described in the text; yellow points are locations of smaller towns or important sites. Solid red lines are secondary roads off main highways shown in red and black. The geographic position of the inferred margin of the Oligocene Crooked River Caldera (dashed line) is shown for reference. Red-filled area in inset location diagram shows the extent of the Lower Crooked River Basin.

Major Tertiary Volcanic and Sedimentary Units of the Lower Crooked River Basin

Qbn Basalt of Newberry Volcano (Pleistocene)
Open-textured, vesicular basalt lava flows erupted from vents on the north flank of Newberry volcano (Sherrod and others, 2004).

Tpb Basalt of Dry River (Pliocene)
Open-textured olivine-phyric basalt flows that form the capping rimrock northwest of Powell Buttes. Sherrod and others (2004) consider the basalt of Dry River to be about the same age as the basalt of Redmond, which has an $^{40}Ar/^{39}Ar$ whole rock age of 3.56 + 0.30 Ma (Smith, 1986a).

Td Deschutes Formation (Pliocene and late Miocene)
Plateau-forming olivine-phyric basalt flows and interbedded sedimentary rocks that fill and cap channels incised into middle Miocene strata. Basalt flows are onlapped by loosely consolidated sand and gravel of unknown age. Olivine-phyric basalt flows (Tdb) were erupted from volcanic vents in the basin; sedimentary rocks (Tds) were derived from local sources. Equivalent to the Deschutes Formation as defined by Farooqui and others (1981) and Smith (1986a). A majority of the Deschutes Formation in the Lower Crooked River Basin is apparently older than 7.05 Ma on the basis of stratigraphic position beneath the Rattlesnake ash-flow tuff in the Crooked River Canyon. Includes the basalt of Cline Falls (Tdbc) and porphyritic basalt (Tdbp), the rhyolite of Cline Buttes (Tdrcb), the tuff of Deep Canyon (Tdtd), and the tuff of Lower Bridge (Tdtl) (Sherrod and others, 2004). Also includes the rhyolite of Steelhead Falls (Tdrsf) of Ferns and others (1996).

Tmr Rattlesnake Ash-flow Tuff (late Miocene)
Pumice-crystal-lithic tuff exposed between reversed polarity Deschutes Formation basalt flows in the Crooked River Canyon. Considered equivalent to the Rattlesnake Ash-Flow Tuff of Walker (1979). A late Miocene age is based on a 7.05 + 0.1 Ma $^{40}Ar/^{39}Ar$ age (Streck, 1994).

Tcp Prineville Basalt (middle Miocene)
Basalt and basaltic andesite lava flows exposed from Prineville Reservoir north to Lake Billy Chinook. The basalt flows are equivalent to the Prineville Basalt as defined by Tolan and others (1989) and Hooper and others (1993). A middle Miocene age is based on a radiometric date of 15.7 ± 0.1 Ma (Smith, 1986a) on the basal flow at Pelton Dam in the Deschutes Basin and intertonguing relationships between reversed magnetic polarity Bowman Dam type flows and R2 Grande Ronde Basalt flows north of the Deschutes Basin (Hooper and others, 1993).

Tmos Volcaniclastic sedimentary rocks (middle to early Miocene? and Oligocene?)
Moderately indurated deposits of brown to tan tuffaceous siltstone, volcaniclastic sandstone, diatomite, cobble conglomerate, and massively bedded white pumice-crystal-lithic tuff. A middle Miocene age for the upper part of the unit is based on conformable or intertonguing relationships with overlying flows of the Prineville basalt. Although previously considered to be the upper part of the John Day Formation (Swanson, 1969) Tmos is herein tentatively considered to be correlative to the Simtustus (Smith, 1986b) and Mascall (Merriam, 1901) Formations. The unit is discordant on the upper part John Day Formation, separated by a distinct angular unconformity.

Tj John Day Formation (Oligocene)
Succession of rhyolite lava flows, domes and plugs, ash-flow tuff, and tuffaceous sedimentary rocks exposed from Prineville Reservoir northwest to Gray Butte. Includes eruptive products of the Crooked River Caldera. Oligocene age is based on stratigraphic relations and radiometric age dates of rhyolite lava flows and domes between ~28 Ma and 25 Ma (Robinson and others, 1990; McClaughry and Ferns, 2006a; McClaughry and Ferns, 2006b; Ferns and McClaughry, 2006b). Equivalent to the John Day Formation of Marsh (1875), Merriam (1901), and Robinson and others (1990).

Tc Clarno Formation (Eocene)
Andesite to rhyolite lava flows, intrusions, and tuff exposed in the Ochoco Highlands northeast of Prineville and south of Prineville Reservoir. Volcaniclastic rocks are a minor component of the stratigraphy in the Lower Crooked River Basin. Equivalent to the Clarno Formation of Merriam (1901) and Walker and Robinson (1990).

Lower Crooked River Basin Road Log

Mile

0 ***BEGIN at the intersection of US 97 and OR 126*** *in the town of Redmond.* ***Travel WEST on OR 126****. Redmond is built on Pliocene flows of the basalt of Redmond (~3.56 My. old; Sherrod and others, 2004).*

1.9 *Crossing the contact between the basalt of Redmond and Quaternary basalt flows from Newberry Volcano (Qbn, ~ 0.78 My. Old). The Newberry flows are inset into the basalt of Redmond.*

4.3 *Cline Falls State Park and Deschutes River crossing. The Deschutes River here is cut into the Pliocene? and/or Miocene basalt of Cline Falls (Tdbc). The river is near the contact of Cline Butte flows on the west and Newberry flows on the east.*

5.4 *Between the Deschutes River and mile 5.4 the route crosses Pleistocene sand and gravel deposits (Qs) that rest on the surface of the basalt of Cline Falls. At mile 5.4 the route crosses the exposed tumuli-capped, olivine-phyric basalt of Cline Falls. To the left is emergent topography of the Miocene Cline Buttes rhyolite dome (Tdrcb) (6.14 ± 0.06 Ma; Sherrod and others, 2004).*

6.3 *Basalt flow breccia in road cut.*

8.2 ***Turn RIGHT on Buckhorn Road*** *– Typical landscape in central Oregon; irregular tumuli-capped basalt (Tdb) and Pleistocene sand and gravel (Qs).*

10 *Entering Buckhorn Canyon. Porphyritic basalt (Tdbp) overlying sand and gravel (Tds).*

11.2 *Tuff of Deep Canyon (Tdtd) (gray-brown weathering).*

12.5 ***Turn RIGHT*** *on Lower Bridge Road. Spoil pile of the Terrebonne Diatomite (Pleistocene-Qsd) mine on the left.*

13.3 *Tuff of Lower Bridge (Tdtl) (gray-brown weathering) on left.*

13.9 *Old Terrebonne diatomite plant.*

14.1 *Lower Bridge Crossing.*

14.3 *Deschutes Formation sand and gravel (Tds), Basalt of Newberry Volcano (Pleistocene-Qbn), to the NW is the Miocene Rhyolite of Steelhead Falls (Tdrsf) (6.74 ± 0.20 Ma; Sherrod and others, 2004; Ferns and others, 1996).*

15.4 *Left is a Pliocene? - Miocene basalt intrusion (Tbi).*

19.3 *To the front are spires of tuff (Tjt) at Smith Rock State Park. On the right are Pliocene and Miocene cinder deposits of the Deschutes Formation.*

20.2 ***Turn LEFT (north) onto US 97****.* **Two-way, high-speed traffic. Please use extreme caution when turning!!**

22.6 *Stop 1:* ***Turn LEFT*** *into Peter Skene Ogden State Park, and* ***PARK****.*

STOP 1: PETER SKENE OGDEN STATE PARK – CROOKED RIVER GORGE OVERLOOK

The Crooked River Gorge Overlook at Peter Skene Ogden State Park (PSOSP) provides a spectacular view of a deep canyon that has been partially filled by younger basalt lava flows (Figure 2). The highway bridge is anchored on a thick section of Quaternary basalt lava flows erupted from vents on the north flank of Newberry Volcano about 780,000 years ago (Sherrod and others, 2004). Newberry flows traveled from the south across a broad plain to points north of Redmond, where the flows entered canyons of the Deschutes and Crooked River. Miocene and Pliocene Deschutes Formation (~9.0-3.5 Ma) basalt lava flows formed the canyon walls at the time of Newberry eruptions. Deschutes Formation basalts in the vicinity of PSOSP were erupted from vents to the south and east within the Lower Crooked River Basin.

The geologic relations exposed in the Crooked River Gorge have a distinct impact on the connections between surface stream flow and subsurface groundwater flow in the Lower Crooked River Basin. In general, younger Neogene deposits, which include the Deschutes Formation (Td), Prineville basalt (Tcp), and Miocene to late Oligocene sedimentary rocks (Tmos) are relatively permeable. These geologic units tend to be the most productive aquifers. Older Paleogene units, such as the John Day and Clarno Formations, are relatively less permeable and are less likely to contain productive aquifers. Upstream of PSOSP, Paleogene "basement" rocks lie at or near the surface. Permeable Neogene units are generally thin and, on the basis of map patterns, are distributed in laterally discontinuous channel forms incised into Paleogene rocks. The channel-

Figure 2. The Crooked River Gorge looking west from the old US 97 Bridge at Peter Skene Ogden State Park. Note the spring system at the base of the canyon beyond the railroad bridge.

ized geometry of Neogene units in the Lower Crooked River Basin is in distinct contrast to the Deschutes Basin, where equivalent strata form a thick blanket that extends west to the High Cascades.

Stream flow data recorded along the Crooked River downstream of Bowman Dam, south of Prineville, give insight into the relations between Neogene geologic units, surface water volume, and the water table location in the Lower Crooked River Basin. In permeable units such as the Deschutes Formation, water table elevation is controlled by geomorphology. Where the stream base lies at an elevation above the regional water table, water flows from the stream bed into the groundwater system. This geomorphic relationship produces a losing reach, where surface flow volume in the stream is reduced. A stream base positioned at an elevation below the regional water table will pirate groundwater, producing a reach of stream flow gain. Table 1 shows the changes in the volume of water carried in the Crooked River between Prineville Reservoir and Lake Billy Chinook.

Between Prineville and Terrebonne the Crooked River is a losing stream reach; water is lost to heavy domestic and agricultural uses and may be transmitted to the regional water table. The incised canyon of the Crooked River intersects the regional groundwater table at PSOSP, resulting in numerous springs that surface at the base of the canyon west of the railroad trestle. The discharge of Cascade-derived groundwater into the Crooked River downstream of PSOSP accounts for an increased streamflow of ~1100 cfs (cubic feet per second) over that measured near Prineville. Groundwater is the most significant component of surface volume to the Lower Crooked River as there are no tributaries to the Crooked River downstream of Prineville.

Stop 1 is also an example of the landslide dangers that exist along the basalt-lined Crooked River Canyon. Landslides originate from oversteepened, tension-cracked cliff-faces that calve and topple or rotate listrically along fractured columnar joint margins in basalt flows. Older slide deposits have vegetated and soil-mantled upper surfaces; more recent deposits lack vegetation and soil and in places may be confused for tumuli-capped intracanyon lava flows. Large landslide deposits along the Crooked River Canyon have become popular development targets south of Prineville. However, the stability of these deposits remains unclear.

Table 1. Average streamflow gauge data in cubic feet per second, collected for the Crooked River, August 28 to September 8, 2006.

Gauge Location	Flowage (cfs)
Above Prineville Res.	~4.3
Prineville	~253
Terrebonne	~130
Below Opal Spring	~1300

Mile

22.6 ***EXIT*** *Peter Skene Odgen State Park.*

22.9 ***Turn RIGHT*** *on US 97 and travel south to Terrebonne.*

25.8 *In Terrebonne,* ***turn LEFT on B-avenue/Smith Rock Way****. Terrebonne sits on the Pliocene Basalt of Redmond (Tbr).*

26.5 ***Turn LEFT onto 1st Street****. Basalt of Newberry Volcano (Qbn) inset into the Basalt of Redmond (Tbr).*

28.5 ***Turn LEFT onto Crooked River Drive*** *to Smith Rock State Park.*

29.5 *Stop 2:* ***PARK*** *in parking area at Smith Rock State Park. Parking permits are required.*

STOP 2: SMITH ROCK STATE PARK

John Day Formation tuff and rhyolite exposed at Smith Rock State Park represent the local Paleogene "basement" into which Quaternary basalt flows of Newberry Volcano are incised (Figure 3).

The John Day Formation is a regionally extensive mass of ash-flow tuff, lava flows and domes, and sedimentary rocks exposed across central and eastern Oregon. Vent sources for the large ash flows have not been previously recognized and have been thought to be located in the west Cascade Range (Robinson and others, 1990). Mapping by DOGAMI in 2005 tentatively identified the spectacular spires of tuff and rhyolite at Smith Rock, now encircled by the tight meanders of the Crooked River, as remnants of one of the elusive John Day Formation vents. We speculate that explosive, caldera-forming eruption(s) that occurred here ~29 Ma created the Crooked River Caldera, a northeast trending depression measuring ~30 km long by ~20 km wide (McClaughry and Ferns, 2006a) (Figure 1). The eroded core of the caldera interior consists of a 300 m+ thick section of late Oligocene zeolitized pumice-lithic tuff that can be traced from Ochoco Reservoir on the southeast margin to the ~1.1-km-thick lithic-rich facies equivalent of Smith Rock on the northwest margin. The thickest accumulation of caldera-filling tuff corresponds to a prominent, closed, gravity low that is flanked on the northwest, northeast, and southwest margins by large (50–80 km^2) fields of late Oligocene rhyolite lava flows and domes. Smaller domes and masses of brecciated rhyolite and welded ash-flow tuff mark the caldera margin north of Prineville. The rhyolite of Ochoco Reservoir (Stop 3) flanks the southeast margin of the caldera. Smaller, sometimes perlitic rhyolite intrusions and domes, including the Barnes Butte dome, intrude the caldera-fill tuff near Prineville and at Smith Rock.

Robinson and others (1990) reported a 30.8 Ma K-Ar date for the Smith Rock Tuff; radiometric ages from post-collapse, rhyolite domes and flows at Gray Butte, Barnes

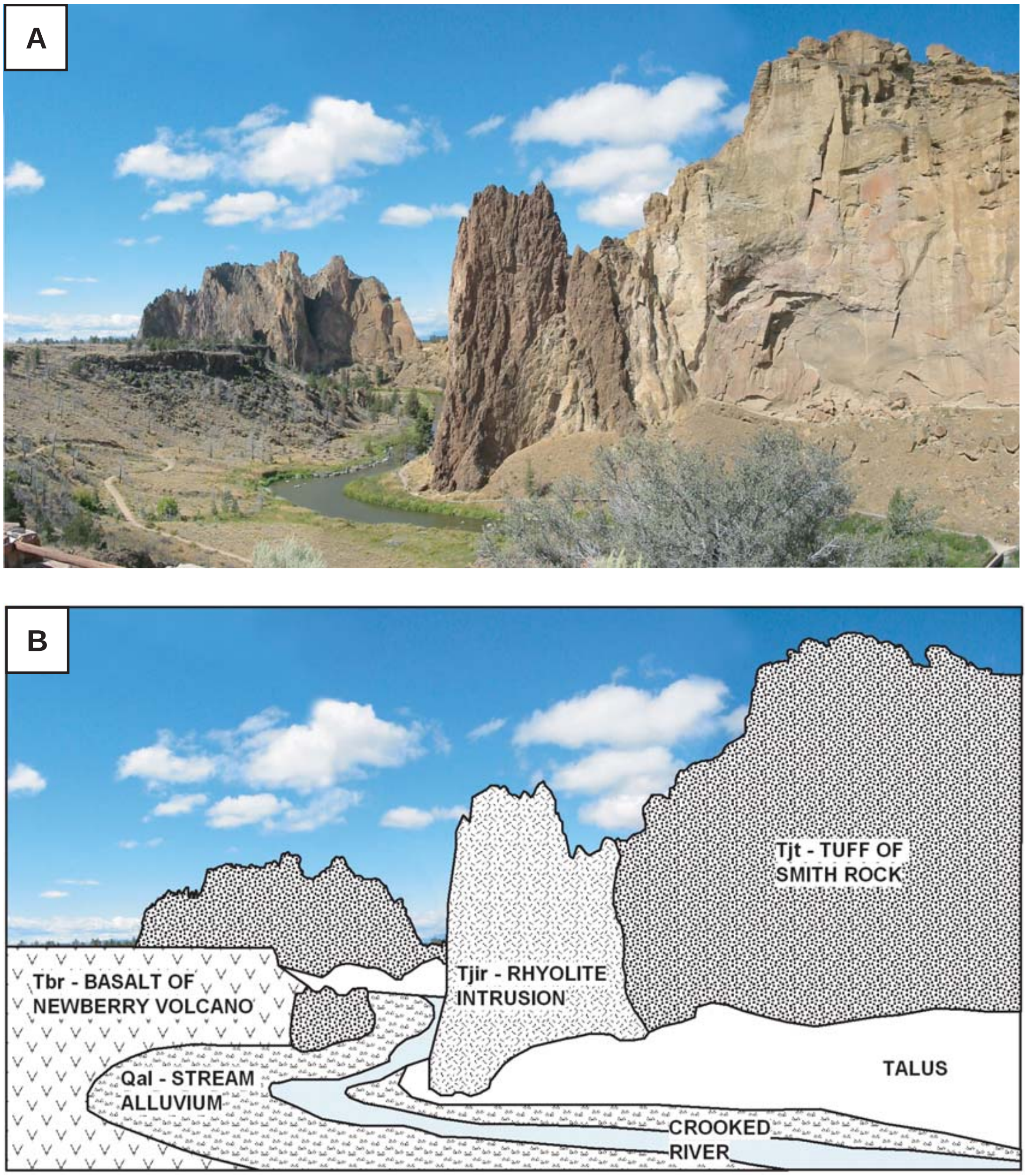


Figure 3. (a) Overlook at Smith Rock State Park. (b) Sketch explanation of geology at Smith Rock.

Butte, Powell Buttes, and Ochoco Reservoir range from 25.8 Ma to 28.8 Ma (Evans and Brown, 1981; Smith and others, 1998; McClaughry and Ferns, 2006a,b). Stratigraphic relations and radiometric age dates obtained on rhyolite domes, combined with a 30.1 Ma date on an alkaline basalt flow (Brown and Others, 1980) offset by the caldera margin on the SW flank of Powell Buttes, likely constrain the climactic caldera-forming eruption to ~29 Ma. This age is slightly younger than the 30.8 Ma date on the Smith Rock Tuff (caldera fill) reported by Robinson and others (1990).

Outflow tuff facies from the Crooked River Caldera can be stratigraphically and chemically traced south to Prineville Reservoir, but correlation elsewhere is premature pending further work. Smith and others (1998) correlate both the Gray Butte rhyolite and tuff of Smith rocks to member G of the John Day Formation. Those workers reported radiometric ages that range from 29.53 to 29.61 Ma for a welded-ash-flow tuff at the base of member G that is exposed a short distance north of Smith Rock. An age of 27.62 + 0.63 Ma is reported for a welded ash-flow tuff at the base of the member H (Smith and others, 1998). Additional field reconnaissance is needed to clarify the stratigraphic relations of caldera-fill facies and outflow tuff from the Crooked River Caldera to apparently coeval ash-flow tuff horizons interbedded elsewhere with sedimentary rocks of the John Day Formation.

Mile

29.5 ***EXIT*** *Smith Rock State Park.*

30.5 ***Turn LEFT on Wilcox Rd.*** *(Wilcox Road will become Lambert Rd.)*

32.2 *On basalt of Dry River (Tbdr) and Pleistocene sand and gravel (Qs). To the left is John Day Formation Rhyolite (Tjr). The John Day Formation rhyolite dome at Grizzly Mountain can be seen to the NE.*

32.7 ***Turn LEFT onto Smith Rock Way****. The intersection to Forest Crossing sits on the basalt of Newberry Volcano (Qbn). This flow has been interpreted to have dammed the Crooked River.*

33.3 ***Turn RIGHT onto Lone Pine Road****.* **Caution, watch for gravel trucks**. *Prineville basalt exposed beneath the Basalt of Dry River in the canyon wall to the east is the preferred rock source because of its closed, aphyric texture.*

34.6 ***Turn LEFT onto O'Neil Hwy****. Basalt of Dry River (Tbdr) overlying Deschutes Formation sediments (Tds) in the north and south canyon walls.*

37.2 *Mouth of Dry River on the right. Basalt of Dry River caps canyon wall to the south. High knob on the north is a south-dipping section of middle Miocene Prineville basalt (Tcp).*

39.1 *The Deschutes Formation basalt of Round Butte (Tdbr) is exposed to the left.*

40.1 *The basalt of Round Butte (Tdbr) overlies the Prineville basalt in the north canyon wall. A basalt intrusion cuts the Prineville basalt; it was a likely feeder for the basalt of Round Butte. The south canyon wall is capped by the upper basalt of Meyers Butte (Tdbm1); Landslide deposits (Qls) line the canyon wall.*

42 *On right, Prineville basalt sitting on sedimentary rocks in roadcut. Basalt of Round Butte sitting on Prineville basalt on island to the north.*

43.3 ***Turn LEFT onto Elliot Road****. Crossing stream alluvium of the Crooked River.*

43.6 ***Turn RIGHT onto Elliot Lane****.*

44.2 ***Turn RIGHT onto US 26****. Flat-topped terraces exposed here and to the NE are interpreted as the backwater deposits left when the Crooked River was dammed by the basalt of Newberry Volcano (Qbn). The Crooked River Canyon may have been 200 feet deeper than at present.*

48.5 ***YIELD*** *at junction of OR 126 and US 26,* ***then turn LEFT (east) to continue on US 26****.*

49.1 *Crook County Courthouse on right.*

51.3 *Barnes Butte welded tuff on left. Terrace gravel banks against tuff.*

52.8 *Rhyolite of Ochoco Reservoir (Tjor), flat-topped, south-dipping outcrop to east. Basalt of Combs Flat (Tdbc) to the south.*

54.3 *Landslide deposit on left.*

56.3 *Stop 3: Ochoco Dam,* ***PARK*** *in large pullout on the right.*

Figure 4. View east toward Ochoco dam and reservoir. The cliffs of the south-dipping rhyolite of Ochoco Reservoir (Tjro) and flanking landslide deposit (Qls) form the topography north of the reservoir. The basalt of Combs Flat (Tdbc) forms the plateau south of the reservoir.

STOP 3: OCHOCO RESERVOIR AND DAM

Ochoco Dam, located ~6 miles east of the city of Prineville was completed in 1920 for irrigation and flood control as part of the United States Bureau of Reclamation (USBR) Crooked River Project (Carter, 1998; Kunzer, 1998) (Figure 4). Since its completion, the dam has suffered from persistent seepage problems beneath the right abutment (north side); deteriorating site conditions since construction resulted in the temporary evacuation of the reservoir in 1993 (Carter, 1998). Water storage resumed in 1995 after modifications to increase embankment stability and decrease seepage along the right abutment had been completed. Additional flood protection was provided through modifications to the left abutment spillway (Carter, 1998; Kunzer, 1998). Operational problems at the Ochoco reservoir dam site are intimately linked to site geology (Carter, 1998), which consists of a dissected and locally altered Paleogene succession of dacite domes, lava flows, and volcanogenic sedimentary rocks of the Clarno Formation and Oligocene rhyolite, tuff, and sedimentary rocks associated with the Crooked River Caldera. Unaltered middle Miocene Prineville basalt and late Miocene to Pliocene lava flows of the Deschutes Formation are inset into and onlap the Paleogene section.

Quaternary landslide deposits line both margins of Ochoco Reservoir and form the foundations upon which the dam structure is built; the construction site was chosen where landslide deposits formed the greatest topographic restriction in the valley. The left abutment (south side) of the dam is constructed upon rock-fall and debris flow deposits derived from the 3.56 Ma basalt of Combs Flat of the Deschutes Formation (McClaughry and Ferns, 2006b). These deposits originate from oversteepened, tension-cracked cliff-faces in the basalt that calve and topple or rotate listrically along fractured columnar joint margins. The right abutment of the dam is founded upon landslide deposits composed of intermixed rhyolite and tuffaceous siltstone derived from tension-cracked, southerly dipping, cliff-forming outcrops of the rhyolite of Ochoco Reservoir (Tjor) and underlying sedimentary rocks (John Day Formation) (Figure 4). Persistent seepage beneath the right abutment is linked to sinkholes developed in poorly sorted landslide deposits that have variable hydraulic conductivity and material strength.

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56.3 *Leave Ochoco Dam pullout, and* ***turn LEFT onto US 26****. Head west past Prineville to Ochoco Wayside State Park.*

64.3 ***Turn RIGHT*** *into Ochoco Wayside State Park.*

64.6 *Stop 4:* ***PARK*** *at Ochoco Wayside State Park viewpoint.*

STOP 4: OCHOCO WAYSIDE STATE PARK

Stop 4 offers a panoramic vista of the Lower Crooked River Basin (Figure 5). The stop offers insight into the geologic relations that locally influence both the local groundwater resources and the geographic position of the Crooked River. The modern exhumed geomorphic expression of the Lower Crooked River Basin is the result of the complex interplay between caldera forming eruptions, basalt volcanism, fluvial aggradation, and erosion. The present basin

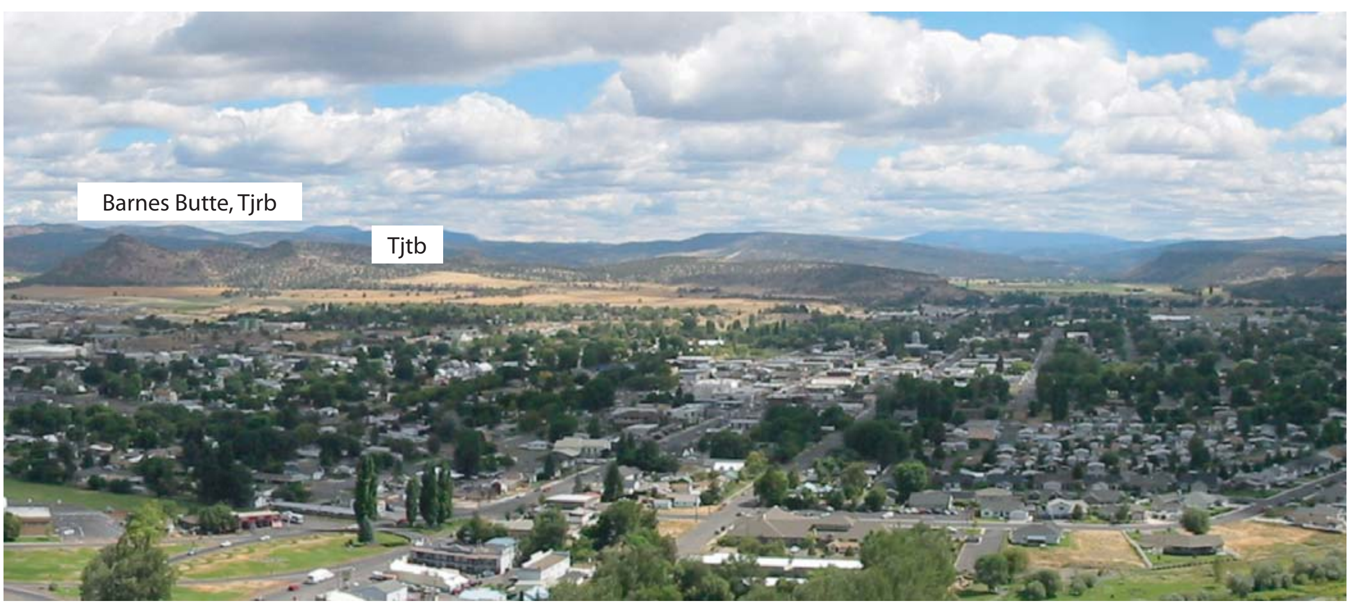

Figure 5. View east across the city Prineville from Ochoco Wayside State Park. The Oligocene rhyolite dome (Tjrb) of Barnes Butte is in the center-left of the photograph. Barnes Butte was the site of a ca. 1940s mercury mine developed in a heavily silicified rhyolite dome. The slope that grades off Barnes Butte to the right is the Tuff of Barnes Butte (Tjtb).

is centered on the ~29 Ma Crooked River Caldera and consists of a thick succession of intracaldera tuff fill, that is ringed and intruded by the post-collapse rhyolite domes of Powell Buttes (SW; 28–25 Ma), Grizzly Mountain (NNW; no age data), and Barnes Butte (E; 27 Ma). The intracaldera tuff fill reaches depths of at least 300 m near Prineville, is relatively impermeable, and is a poor regional aquifer. The tuff-fill instead acts as an aquitard or impermeable plug in the basin, restricting productive aquifers beneath Prineville to Neogene and Quaternary surface units. Rhyolite domes have been sites of past mineral exploration. Barnes Butte was the site of a ca. 1940s mercury mine developed in heavily silicified rhyolite (Brooks, 1963). Powell Buttes was variably explored as a potential uranium target in the 1940s and 1950s and geothermal potential was explored in the 1980s (Brown and others, 1980).

Caldera-related deposits are disconformably overlain by lower to middle Miocene sedimentary strata and locally interbedded lava flows of the middle Miocene Prineville Basalt. The Prineville basalt is chemically characterized by a range of silica values (SiO_2 from ~50.8 to 55.7 weight percent) and elevated concentrations of phosphorus (P_2O_5 from ~1.50 to 1.80 weight percent) and barium (Ba from ~1800 to 2800 ppm). Flows of the Prineville basalt reach a maximum composite thickness of 210 m in the Crooked River Canyon near Bowman Dam, south of the city of Prineville. The basalt section thins abruptly away from the Crooked River; flows exposed in highlands form thin, shoe-string exposures that are interbedded with and sow into coeval sedimentary rocks. Plateau-forming olivine-phyric basalt flows and interbedded sedimentary rocks of the Miocene-Pliocene Deschutes Formation fill and cap channels incised into middle Miocene strata. Deschutes Formation basalt flows were erupted from vents in the Lower Crooked River Basin and have been divided into 14 flow packages based on stratigraphic relations and chemical affinity. The thickest accumulation of Deschutes basalt is observed in the Crooked River Canyon south of Prineville where a majority of the section sits beneath the 7.05 Ma Rattlesnake ash-flow tuff. Flows younger than the Rattlesnake tuff form distinct equal elevation plateaus in the vicinity of Prineville. However, the apparent correlation of plateaus is deceptive. Chemical correlation of flow packages across canyons in conjunction with stratigraphic relations observed elsewhere in the field indicate that Deschutes lava flows were heavily influenced by channeled topography at the time of emplacement. The modern basalt plateaus are excellent examples of cut-and-fill topography and indicate that caution should be applied when interpreting and correlating basalt flows intimately associated with fluvial systems. Detailed mapping of field relations and chemical analysis of middle Miocene to Pliocene rocks has demonstrated: 1) a cut and fill nature between basalt flows and fluvial sedimentary rocks, 2) the Deschutes Formation section has not been structurally dismembered, and 3) the Crooked River has held the same general geographic position since the middle Miocene.

Mile

64.6 ***EXIT*** *Ochoco Wayside;* ***turn RIGHT (west) onto OR 126****, returning to Redmond.*

82 ***END*** *in Redmond*.

Geologic Time-Scale

Era or Erathem	Period or System		Epoch or Series	Age Estimates of Boundaries (in millions of years)
Cenozoic (Cz)	Quaternary (Q)		Holocene	0.010
			Pleistocene	2 (1.7-2.2)
	Tertiary (T)	Neogene Subperiod or Subsystem (N)	Pliocene	5 (4.9-5.3)
			Miocene	24 (23-26)
		Paleogene Subperiod or Subsystem (Pε)	Oligocene	38 (34-38)
			Eocene	55 (54-56)
			Paleocene	63 (63-66)

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RECENT DISSERTATIONS & THESES ON OREGON GEOLOGY

From time to time, we compile a list of recent dissertations and theses on Oregon geology that in our opinion are of general interest to our readers.

The Department maintains a collection of theses and dissertations on Oregon geology. While reserving the right to determine the desirability of each acquisition, the Department is interested in purchasing two copies of each accepted master's thesis or doctoral dissertation, bound, and complete, for the amount of $150 or $200, respectively, if such a thesis or dissertation concerns the geology of Oregon. Part of the acquisition will be the right to publish the abstract in Oregon Geology.

Ph.D. dissertations:

2004

Johnson, Joel E., ***Deformation, fluid venting, and slope failure at an active margin gas hydrate province, Hydrate Ridge Cascadia accretionary wedge*** (Ph.D., Oregon State University, 2004), 154 p..

2005

Kumar, Dhananjay, ***Analysis of multicomponent seismic data from the Hydrate Ridge, offshore Oregon*** (Ph.D., The University of Texas at Austin, 2005), 203 p., ISBN 0-542-12370-3.

O'Neal, Michael A., ***Late little ice age glacier fluctuations in the Cascade Range of Washington and northern Oregon*** (Ph.D., University of Washington, 2005), 116 p., ISBN 0-542-17730-7.

Petcovic, Heather L., ***Feeder dikes to the Columbia River flood basalts: underpinnings of a large igneous province*** (Ph.D., Oregon State University, 2005), 194 p.

Schoonmaker, Adam, ***Convergent and collisional tectonics in parts of Oregon, Maine, and the Vermont-Quebec border*** (Ph.D., State University of New York at Albany, 2005), 222 p., ISBN 0-542-17159-7.

Wampler, Peter J., ***Contrasting geomorphic responses to climatic, anthropogenic, and fluvial change across modern to millennial time scales, Clackamas River, Oregon*** (Ph.D., Oregon State University, 2005), 398 p.

Weinberger, Jill, ***Investigations of the structural and hydrologic context of gas hydrate deposits on Hydrate Ridge, Oregon*** (Ph.D., University of California, San Diego, 2005), 138 p., ISBN 0-542-19268-3.

Chaytor, Jason D., ***Diffuse deformation patterns along the North American plate boundary zone, offshore western United States*** (Ph.D., Oregon State University, 2006) 281 p.
Available online: http://hdl.handle.net/1957/3126.

2006

Jefferson, Anne J., ***Hydrology and geomorphic evolution of basaltic landscapes, High Cascades, Oregon*** (Ph.D., Oregon State University, 2006), 180 p. Available online: http://hdl.handle.net/1957/3140.

Punke, Michele Leigh, ***Paleoenvironmental reconstruction of an active margin coast from the Pleistocene to the present : examples from southwestern Oregon*** (Ph.D., Oregon State University, 2006), 171 p.

Rowe, Michael C., ***The role of subduction fluids in generating compositionally diverse basalts in the Cascadia subduction zone*** (Ph.D., Oregon State University, 2006), 441 p.
Available online: http://hdl.handle.net/1957/1947.

Schmidt, Mariek, ***Deep crustal and mantle inputs to North Sister Volcano, Oregon High Cascade Range*** (Ph.D., Oregon State University, 2006), 197 p.

Stewart, Gregory B., ***Patterns and processes of sediment transport following sediment-filled dam removal in gravel bed rivers*** (Ph.D., Oregon State University, 2006), 87 p.
Available online: http://hdl.handle.net/1957/1815.

M.S. theses:

2004

Bandow, Jeffrey R., ***Holocene alluvial history of the Middle Fork John Day River, Oregon*** (M.S., University of Oregon, 2004), 106 p.

Casebeer, Nathan E., ***Sediment storage in a headwater valley of the Oregon Coast Range : erosion rates and styles and valley-floor capacitance*** (M.S., Oregon State University, 2004) 48 p.

Chevallier, Johanna, ***Seismic sequence stratigraphy and tectonic evolution of southern hydrate ridge*** (M.S., Oregon State University, 2004), 117 p.

Griswold, Julia P., ***Mobility statistics and hazard mapping for non-volcanic debris flows and rock avalanches*** (M.S., Portland State University, 2004), 102 p.

Oestreicher, Zachery W. J., ***Geomicrobiology investigation of Mickey Hot Springs, Southeastern Oregon*** (M.S., Portland State University, 2004), 171 p.

2005

Arighi, Louis M., ***Quantification of the nitrate attenuation capacity of low-permeability Missoula Flood deposits in the Willamette Valley of Oregon*** (M.S., Oregon State University, 2005), 92 p.

Clough, Charles M., ***Geologic model and geotechnical properties of stratified paleodune deposits, Central Oregon Coast, Oregon*** (M.S., Portland State University, 2005) 264 p.

Easterly, Heather R., ***Characterization of iron-bearing films found on ephemeral pools, central coast, Oregon*** (M.S., Portland State University, 2005), 98 p.

Marcott, Shaun A., ***A tale of Three Sisters : reconstructing the Holocene glacial history and paleoclimate record at Three Sisters Volcanoes, Oregon, United States*** (M.S., Portland State University, 2005), 92 p.

Nielsen, Eric L., ***Hydrogeology and ground water--surface water interactions of the Clatsop Plains aquifer, Clatsop County, Oregon*** (M.S., Portland State University, 2005), 303 p.

Ninnemann, Jeffery J., ***A study of hyporheic characteristics along a longitudinal profile of Lookout Creek, Oregon*** (M.S., Oregon State University, 2005), 148 p.

Rapp, Elizabeth K., ***The Holocene stratigraphy of the Sandy River Delta, Oregon*** (M.S., Portland State University, 2005), 99 p.

Wallick, Jennifer R., ***Geology, flooding & human activities: establishing a hierarchy of influence for controls on historic channel change, Willamette River, Oregon*** (M.S., Oregon State University, 2005), 172 p.

2006

Craner, Jeremy D., ***Hydrogeologic field investigation and groundwater flow model of the southern Willamette Valley, Oregon*** (M.S., Oregon State University, 2006), 227 p.

Mutti, Jeffrey G., ***Temporal and spatial variability of groundwater nitrate in the southern Willamette Valley of Oregon*** (M.S., Oregon State University, 2006) 173 p. Available online: http://hdl.handle.net/1957/2268.

MLRR Program 2005 Mined Land Reclamation Awards

Creating a new park for the city of Lyons, making new neighborhoods from reclaimed gravel pits in Keizer, and creating new pasture lands in central Oregon are some of the highlights of the 2005 Mined Land Reclamation Awards presented by the Oregon Department of Geology and Mineral Industries (DOGAMI).

Each year the MLRR office, with an independent panel of experts, selects specific mine sites and operators to receive awards for outstanding reclamation and mine operation. The awards, based on an operator's performance during the previous year, were presented at the Oregon Concrete and Aggregate Producers Association (OCAPA) annual conference in June 2006.

"We consider these awards important recognition to those owners and operators that go beyond the basic requirements of rules and regulations," said Vicki S. McConnell, State Geologist. "By using innovative ideas and responsible techniques of reclamation they are working to improve the environment and be good neighbors."

Mining in Oregon creates important public benefits and, at times, deep public concerns. While population growth has increased demand for mined products, a variety of resource concerns have affected the location and operation of mine sites. In-stream gravel removal, for example, is decreasing as the need for protection of salmon increases. Available aggregate sources located within floodplains now require more stringent environmental regulation to protect adjacent resources such as wetlands and wildlife habitat and floodplain stability. Agricultural areas along rivers previously used for round rock aggregate production are being reduced to conserve prime farmlands. As the sizes of new and existing sites increase, groundwater is more frequently encountered; this in turn requires monitoring and protection. Quality of life issues and new environmental challenges must be addressed.

In recent years the Mineral Land Regulation and Reclamation Program (MLRR) has become the lead program for mine regulation in Oregon. The number one issue for the program is floodplain mining and its relationship to off-site resources including the potential for habitat restoration. The program has an effective field inspection program that is critical to maintaining compliance and maintaining a positive working relationship with the regulated community.

A residential community was developed after voluntary reclamation of the McNary gravel pit site in Keizer, Marion County.

Award Winners

Good Neighbor Award
Freres Lumber Company, Lyons, Linn County
Contact: Randy Silbernagel (503)-859-2121

Outstanding Reclamation, Government Agency
Oregon Department of Transportation (ODOT), Region 5, Burns, Harney County
Contact: Gary VanHouten, (541) 963-1334

Outstanding Small Operator
Sierra Cascade LLC, Chemult, Klamath County
Contact: Dana VanPelt (541) 365-2440

Outstanding Reclamation
PGE - Property Services, Madras, Jefferson County
Contact: Bruce Carroll (503) 464-8126

Outstanding Reclamation-Exploration
Malheur Mining Corporation LCC, Malheur County
Contact: Alan Glaser (775) 738-9531

Outstanding Operator
Windsor Rock Products Inc., Salem, Marion Country
Contact: Bill McCall (503) 393-8920

Outstanding Voluntary Reclamation
Staats Corporation, Salem, Marion County
Contact: Jay Compton (503) 363-9281

To learn more about each 2005 MLR award winner, visit: http://www.oregongeology.com/sub/mlr/2005MLRRAwards.htm

For more information on the MLRR Program, contact Ben Mundie, telephone (541) 967-2149; email: ben.a.mundie@mlrr.oregongeology.com.

(Agency News, continued from page 13)

Our Tsunami Hazards Mitigation Program, funded by NOAA, continues to work with Oregon Emergency Management and local cities and counties to provide mitigation and mapping programs for coastal communities. Completed and ongoing projects include tsunami hazard modeling and mapping of Alsea Bay, Waldport, Cannon Beach and Florence and tsunami evacuation mapping, signage, and brochure production for Brookings, Gold Beach, Port Orford, the Nestucca Fire District of Tillamook County, Newport, and Depoe Bay. 19 existing tsunami evacuation brochures were reprinted (approximately 10,000 copies each) to support a recently passed Senate bill to provide tsunami information to coastal lodging and tourist based locations. A pilot project to provide tsunami evacuation brochures to the many coastal Oregon State Parks is also underway at South Beach State Park on the central Oregon coast.

Geohazards Section

In August 2005, The Oregon State Legislature authorized DOGAMI to begin a systematic, statewide seismic needs assessment of critical emergency response buildings and public schools that, when finished, will suggest to local jurisdictions which facilities are more at risk and should be strengthened to withstand damaging earthquakes. Through on the ground rapid visual screenings and extensive data mining of existing seismic reports, we have to date assessed over 2,500 buildings statewide (Figure 2). Over the next several months the rapid visual screening evaluations will be combined with other vital information about the buildings, such as the type of soil and rock each building is built upon, to rank the facilities into risk categories based on need. The publication of this statewide database in the summer of 2007 can then be used by all state and local governments and will allow the Seismic Rehabilitation Grant Committee to administer grant programs for the disbursement of funds for seismic rehabilitation.

We continue our work with the Oregon University System (OUS), which is folding seismic rehabilitation of buildings into their deferred maintenance scheduling. OUS and DOGAMI were awarded $2.6 million in FEMA Earthquake Safety Grants to complete earthquake readiness upgrades on buildings at Oregon State University and Western Oregon University with DOGAMI as the administrator of this project. OUS and DOGAMI had already been the recipients of over $3 million from FEMA for similar work.

In February 2006, DOGAMI hosted a one-day Landslide Forum to mark the 10th Anniversary of what has been characterized as 100-year events for landslides in Oregon. The main objective of the forum was to review the flooding and landslide events of 1996 and Oregon's response specifically to the landslide hazard. We updated the 150 plus participants on state and local government activities to understand and mitigate the hazard, and all shared insights on how to improve our response capability.

This past year we collaborated with the USGS on a new landslide-mapping program using LIDAR. We compared landslide mapping using existing techniques (time-series air photo surveys and three other remote sensing types of data sets) to mapping with LIDAR in the Portland Hills (Figure 3). We found LIDAR to be outstanding in its spatially accurate delineation of slide boundaries. We are now using LIDAR to provide new information about potential landslide hazards in the Oregon City area of metropolitan Portland. Oregon City is the first Oregon community for which this kind of high-resolution landslide geomorphologic mapping is available and we hope it proves to be a model for use in many other cities.

With the success of our Oregon City mapping, we are now looking at a year 2 proposal with the USGS that will allow us to work with local jurisdictions to define an area of interest or the extent of proposed landslide hazard mapping. We will then be able to produce detailed maps of existing landslides for their communities using all available data, including LIDAR, and we could then work with local governments to implement mitigation measures based on the hazard maps we produce.

Figure 2. Rapid Visual Screening (RVS) team. Back row (from left): Nathan Wallace, Sam Jensen Augustine, Andy Tibbetts, Henry Pierce, Juan Hernandez, Bill Burns. Middle row (from left): Yumei Wang, Carol Hasenberg, Christine Theodopolus, Jeremy Mikkelsen. Front row (from left): Jared Fischer (student assistant), Natalie Richards, Tom Miller.

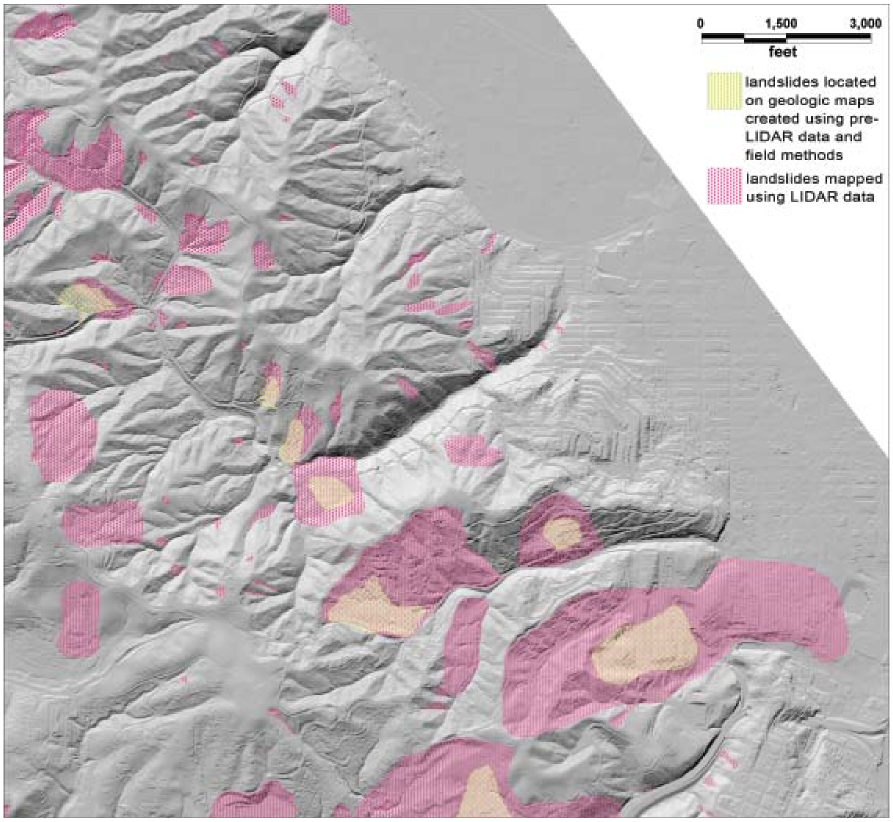


Figure 3. Landslides in Portland Hills, Oregon area. Highway 26 is in the southeast corner of the image. Slides from the 1990 geologic map of the Portland quadrangle are mapped in yellow hatch, slides identified largely by LIDAR in the pilot study are in magenta hatch.

Figure 4. DOGAMI Landslide Geotechnical Specialist Bill Burns answers questions at Springwater Environmental Sciences School during Earth Science Week 2006.

Publications and Education Outreach Section

We have added two GIS Specialists and a Publications Coordinator to our staff. These additions have, among other things, revitalized our publications agenda and online capabilities with a resultant increase in daily online users. In addition to our web-based interactive Oregon Geologic Data Compilation, we have also published our complete Oregon Geologic Map Series (117 7.5' quadrangle series maps) online. Additional resources on our website now include downloadable copies of our technical journal, *Oregon Geology,* and its predecessor, *The Ore Bin*, going back to 1939, plus over 50 geologic field trips and 56 tsunami inundation maps and 20 tsunami evacuation brochures for coastal Oregon. Our website (http://www.oregongeology.com) remains very popular with the geologically curious public. Hits increase to thousands per day when geologic events, such as small, local earthquakes, occur.

Outreach efforts have included dozens of presentations by our staff to both private and public organizations around the state, on topics ranging from tsunami preparedness to our role in seismic needs assessments of critical emergency response buildings and public schools. In November 2005, we oversaw the dedication of a Native American historical marker depicting the 1700 AD Cascadia earthquake and tsunami at the coast in partnership with the Confederated Tribes of Siletz Indians. In May, our Grants Pass Field Office hosted a 2-day workshop. October 9–15 was declared Earth Science Week in Oregon by Governor Kulongoski, and staff members traveled to teacher conferences and schools in support (Figure 4).

Our innovative, cooperative venture with the U.S. Forest Service, the Nature of the Northwest Information Center, continues to attract many people looking for information on Oregon and Washington outdoors. We

(Agency News, continued from page 27)

distribute maps and books about the Northwest, both through a "bricks and mortar store" in Portland and online (http://www.naturenw.org).

Mineral Lands Regulation and Reclamation

Our Mineral Land Regulation and Reclamation Program (MLRR) is the lead program for mine regulation in Oregon. MLRR administers a fee-based statewide program with authority to regulate all upland and underground mining on all lands. In addition, the program implements the federal Clean Water Act General Stormwater Permit and the state Water Pollution Control Facility Permit at aggregate mine sites in cooperation with the Oregon Department of Environmental Quality. MLRR works with the industry and the public to minimize the impacts of mining and optimize the opportunities for reclamation. The number one issue for the program is floodplain mining and its relationship to off-site resources including the potential for habitat restoration. Total annual aggregate production in Oregon is approximately 52,000,000 cubic yards. There is also significant diatomaceous earth production, an industrial mineral with a variety of commercial uses. There are no active commercial metal or coal mines in the state.

MLRR oversees 830 permits in Oregon and to date over 5,400 acres of mined land have been reclaimed and put to secondary, beneficial use. As part of our strategy to encourage best practices in mining, MLRR hosts an annual Awards Program for operators that recognize operation and reclamation above and beyond the requirements of regulation (see page 25). Following the success of the Rogue River Reclamation Project in southwest Oregon, DOGAMI is now leading a private-public stakeholders group hoping to restore river and floodplain functions on a 2-mile stretch of the Willamette River in northwest Oregon.

Statewide training and assistance for mine operators in mine site reclamation is an important aspect of the public education efforts. Regular workshops and the publication of a "Best Management Practices" manual by DOGAMI's reclamation specialists has been used by other states and the staff have received national honors for technical expertise and leadership in reclamation.

(DOGAMI Publications, continued from page 4)

- **Preliminary geologic map of the McKay Reservoir 7.5 minute quadrangle, Umatilla county, Oregon**, by Mark L. Ferns and Vicki S. McConnell. Open-file report O-06-15. 1 CD, $10.
- **Preliminary geologic map of the Table Rock 7.5 minute quadrangle, Umatilla county, Oregon**, by Mark L. Ferns and Vicki S. McConnell. Open-file report O-06-16. 1 CD, $10.

Released July 26, 2006:

The following individually released publications comprise the USGS STATEMAP 2005 deliverable:

- **Preliminary geologic map of the Huston Lake 7.5 minute quadrangle, Crook county, Oregon**, by Mark L. Ferns and Jason D. McClaughry. Open-file report O-06-21. 1 CD, $10.
- **Preliminary geologic map of the Prineville 7.5 minute quadrangle, Crook county, Oregon**, by Jason D. McClaughry and Mark L. Ferns. Open-file report O-06-22. 1 CD, $10.
- **Preliminary geologic map of the Ochoco Reservoir 7.5 minute quadrangle, Crook county, Oregon**, by Jason D. McClaughry and Mark L. Ferns. Open-file report O-06-23. 1 CD, $10.
- **Preliminary geologic map of the Powell Buttes 7.5 minute quadrangle, Crook county, Oregon**, by Mark L. Ferns and Jason D. McClaughry. Open-file report O-06-24. 1 CD, $10.
- **Preliminary geologic map of the Albany 7.5 minute quadrangle, Linn, Marion, and Benton counties, Oregon**, by Thomas J. Wiley. Open-file report O-06-26. 1 CD, $10.

Released October 12, 2006:

- **Map of landslide geomorphology of Oregon City, Oregon, and vicinity interpreted from LIDAR imagery and aerial photographs**, by Ian P. Madin and William J. Burns. Open-file report O-06-27, 1 CD, $10.

Released December 19, 2006:

- **Oregon geologic data compilation — version 3, southeast, northeast, and central Oregon**, compiled by Clark A. Niewendorp, Margaret D. Jenks, Mark L. Ferns, Ian P. Madin, Paul E. Staub, and Lina Ma. OGDC-3. 1 CD, $25.

TRUE GRIT

— a tribute to Jerry Gray by former State Geologist John Beaulieu (retired)

Jerry Gray, a dedicated employee at the Oregon Department of Geology and Mineral Industries in various capacities from 1973 until his retirement in 1992, passed away on November 29, 2006. I had the privilege of working with Jerry directly and indirectly throughout his career with the agency. I am pleased to be able to record some highlights here.

Jerry was born near Walkerville, Michigan. He graduated from Michigan State University in 1954 with a degree in geology. He was drafted into the army during the Korean War. Jerry spent his service growing quartz crystals for field radios. From 1956 to 1962 he was employed by Anaconda Copper Company and later as a geological engineer in a tungsten operation. Next he worked for the U.S. Bureau of Mines until the office closed and, later, as a consultant and an emery explorer with some unique deposits in the Oregon Cascades.

When I met Jerry in 1973 he was the first employee (as a contracted staffer) of the emerging Mined Land Reclamation Department with DOGAMI. To this task he brought passion and determination. Here and in all of his assignments Jerry liked to say that for him geology, any geology, was an avocation and a vocation.

He loved his work.

Around 1980 Jerry moved into a series of other positions in the agency, dealing with the exploratory side of various mineral commodities in the state. Regional specific gravel assessments were followed by a variety of other efforts with nonmetallic and metallic mineral commodities. The agency mission was properly constrained to "mineral assessments for public policy support." But ever lurking in Jerry's personal goals were additional hopes of helping to make a big discovery, finding the elusive nugget "as big as your fist" for the public good, or perhaps just to finding disseminated gold caught in one's cuff during a long trek across the High Desert. Actually, finding low-quality gemstones would do.

These loves meshed well with growing efforts in the Department to attract federal funds to grid sample large areas and to identify anomalies in need of more attention by government or the private sector. For a BLM-funded effort in the early 1980s several agency positions hinged on the success of rigorous field efforts for which we had precious little experience. Jerry was put in charge and succeeded where others might have failed. The pure determination, persistence, faith, and true grit that Jerry brought to the project assured the success of this effort and many other efforts in the years to follow.

The attributes needed for a new program to succeed are not found in text books. One finds them only in rare employees like Jerry Gray.

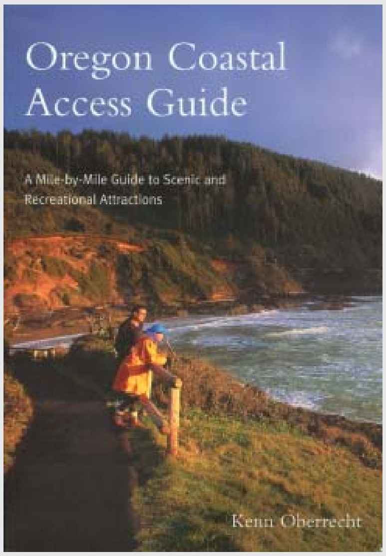
Concurrently, Jerry was aware that institutional knowledge within the agency regarding mineral deposits, mines, and exploration would disappear with the impending retirement of various long-term employees. He adopted agency efforts to systematically computerize all agency records. Included were records published and unpublished, exploratory and production oriented, metallic and nonmetallic throughout the state.

Instead of growing quartz crystals as he had during the Korean War, Jerry grew data bases. He reveled in each new accomplishment. The effort (Mineral Information Layer for Oregon, or MILO) continues today and is among the finest in the nation at the state or federal level.

Also surviving among Agency staff and his other acquaintances are a wealth of memories involving dirt, grime, sweat, tears, progress, love of gems, love of geology, and commitment to perseverance, belief in individual effort, commitment to fair play, and passion for life. He was a real gem, and we are all better for knowing him.

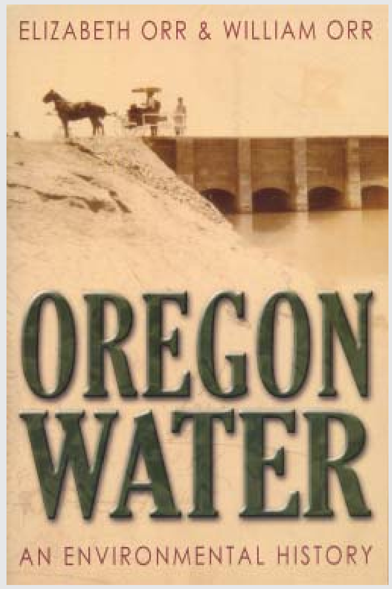
Highlighting Recent Publications

Available from The Nature of the Northwest Information Center



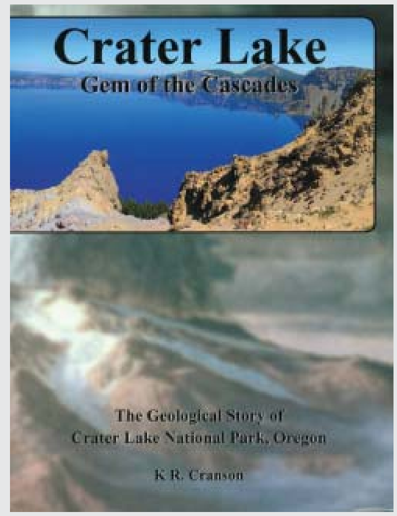
Oregon Coastal Access Guide, A Mile-by-Mile Guide to Scenic and Recreational Attractions, by Kenn Oberrecht. Oregon State University Press, Corvallis, 2005. 342 p., paperback, $19.95.

A complete and illustrated guide to the Oregon coast, this book offers a detailed north-to-south tour of Oregon's nearly four hundred mile-long Pacific edge, with extensive mile-by-mile coverage of scenic U.S. Highway 101. It provides details on and directions to natural areas from estuaries and lakes to dunes and headlands, along with sidebar features on history, marine and coastal wildlife, weather and climate, and cultural attractions.



Oregon Water, An Environmental History, by Elizabeth Orr and William Orr. Portland, Oregon, Inkwater Press, 2005. 279 p., paperback, $24.95.

Can a state that's known for its rain have water resource problems? The authors examine the role of water in navigation and commerce, power generation and agriculture, and discuss sustainability and ecological issues as Oregon's population and water needs increase.



Crater Lake, Gem of the Cascades: The Geological Story of Crater Lake National Park, Oregon, 3rd ed., by K. R. Cranson. Lansing, Michigan, KRC Press, 2005. 168 p., $15.95.

Written in nontechnical language by a former Crater Lake park ranger, this volume describes the volcanism and limnology of this magnificent national park. Many diagrams and photographs, notes on earlier geological research as well as new research since the second edition, and a glossary and annotated reference list make this an accessible introduction to Crater Lake for the layperson.

Nature of the Northwest

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Publication of *Oregon Geology*

Budget cutbacks and changing technology require that we make changes to the magazine. We will now try to publish two issues a year as a journal on our website.

We will also predominantly compile rather than extensively edit the material submitted. Consequently, we are now asking that material be submitted to us in production-ready quality. For details and the new publication schedule, see "Information for Contributors" below.

We believe *Oregon Geology* is an important publication, offering a unique and suitable place to share information about Oregon that is useful for the geoscience community and ultimately for all Oregonians. Please help us by continuing to read the journal *Oregon Geology* and submit articles.

Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers in the geoscience community who are interested in all aspects of the geology of Oregon and its applications. Informative papers and notes, particularly research results, are welcome, as are letters or notes in response to materials published in the journal.

Two copies of the manuscript should be submitted, one paper copy and one digital copy. While the paper copy should document the author's intent as to unified layout and appearance, all digital elements of the manuscript, such as text, figures, and tables should be submitted as separate files. Hard-copy graphics should be camera ready; photographs should be glossies. Figure captions should be placed 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*.) References are limited to those cited. We accept only those articles that have at least one acknowledged outside review. We maintain the authority to request a copy of the reviewer's comments. Pre-submission reviewers should be included in the acknowledgments. In view of increasing restrictions on editing time, adherence to such style will be required more strictly than in the past.

For the foreseeable future *Oregon Geology* will be published twice annually on the Department website http://www.oregongeology.com, a spring issue on or shortly after March 15 and a fall issue on or shortly after October 1. Deadline for submission of scientific or technical articles will be January 31 and August 15, respectively. Such papers will be subjected to outside reviews as the Department will see appropriate.

Conclusions and opinions presented in articles are those of the authors and are not necessarily endorsed by the Oregon Department of Geology and Mineral Industries.

Authors will receive a complimentary CD with a PDF version of the issue containing their contribution.

Manuscripts, letters, notices, and photographs should be sent to Deb Schueller, Editor, *Oregon Geology*, 800 NE Oregon Street #28, Portland, OR 97232-2162, e-mail contact deb.schueller@dogami.state.or.us.

Please send us your photos

Since we have started printing color pictures in *Oregon Geology*, we are finding ourselves woefully short of good color photographs showing geologic motifs in Oregon. That is why we invite your contributions.

Good glossy prints or transparencies will be the best "hard copy," while digital versions are best in TIFF or EPS format.

If you have any photos you would like to share with other readers, please send them to us (Editor, *Oregon Geology*, 800 NE Oregon Street #28, Portland, OR 97232-2162, # 28; e-mail deb.schueller@dogami.state.or.us.) with information for a caption. If they are used, publication and credit to you is all the compensation we can offer. If you wish to have us return your materials, please include a self-addressed envelope.

OREGON GEOLOGY
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Places to see—**Recommended by the Oregon Department of Geology and Mineral Industries:**

Bowman Maar, near Prineville: A maar is a special type of volcanic vent that forms when ascending magma interacts with groundwater or surface water. The result is a low-relief, bowl-shaped crater that is composed of tuff and cinders that are rapidly ejected from the vent and pile up around the rim. The Bowman marr is one of several volcanic vents that erupted basalt lava flows into the Lower Crooked River Basin during the late Miocene and Pliocene. Geologic evidence collected by DOGAMI geologists indicates that these vents and basalt flows interacted with water and were a major control on the geographic distribution of the ancestral Crooked River. The dissected Bowman maar now exposed along Prineville Reservoir is one example of the interaction of rising magma with water.

Access: In Prineville, turn south onto Crooked River Road (also Main Street) and travel 13.2 miles toward Bowman Dam. The overlook is just north of the boat ramp at Prineville Reservoir. There is a pullout at mile 13.7. The road follows the wild and scenic Crooked River, which has cut into a basalt-lined canyon. The canyon walls expose basalt lava flows of the Deschutes Formation (Pliocene and late Miocene) and Prineville basalt (middle Miocene) that were erupted from local vents approximately 16 to 5 million years ago.

(Photo contributed by Jason D. McClaughry)