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

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

Cover photo

The quarry at Yaquina Head during mining operations in 1976 (top) and after reclamation in 1994 (bottom) by the U.S. Bureau of Land Management (BLM) as "Quarry Cove," a public tide-pool area. The DOGAMI Mined Land Reclamation program (MLR) honored this effort as outstanding reclamation by a government agency. See report on MLR awards on page 91.

Top picture Oregon Highway Division photo, courtesy MLR. Bottom photo courtesy BLM/Chuck Forinash, Newport, copyright 1995.

Oregon Department of Geology and Mineral Industries and USDA Forest Service receive Hammer Award

The Oregon Department of Geology and Mineral Industries (DOGAMI) and the USDA Forest Service (USFS) together received the Hammer Award, Vice President Al Gore's special recognition to teams that have made significant contributions in support of the National Performance Review principles. The award was presented on May 30 at the Jantzen Beach Red Lion in Portland by Doug Farbrother of the Vice President's National Performance Review Team.

The Hammer Award was given to DOGAMI and the USFS for their partnership in running the Nature of the Northwest Information Center, a one-stop center for information about outdoor recreation and natural resources in the Pacific Northwest. The Center is located on the first floor of the State Office Building at 800 NE Oregon St. in Portland. It carries brochures, publications, and maps from a variety of state, federal, and local governments, as well as commercial publications related to outdoor recreation.

Begun in 1992 by DOGAMI as the Nature of Oregon Information Center, the Center changed its name and scope of operations in the fall of 1994, when the USFS closed its information center in downtown Portland and moved in as a partner with the State of Oregon. Today, the newly expanded Nature of the Northwest Information Center serves several hundred people each day, making it easier for them to get outdoor recreation information.

The principles of the National Performance Review emphasize putting customers first, cutting red tape, empowering employees, and cutting government back to basics. The award is named for the notorious hammer that once cost the government $600. The tangible award consists of a plain hammer placed on black velvet background, decorated with a red-white-and-blue bow, and framed together with a handwritten citation by Vice President Gore that reads "Thanks for building a government that works better and costs less."

According to Don Haines, Nature of the Northwest Information Center manager, "People come to us or call us when they need information about the out-of-doors. In many cases they don't know who runs their favorite recreation site. They don't want to have to go to several different agencies to find out. They just want to get where they want to go. So we help them in our one-stop information center—in the fastest, simplest way possible."

Information about how to contact the Nature of the Northwest Information Center is listed in the box on the left. □

Beyond the Channeled Scabland

A field trip to Missoula flood features in the Columbia, Yakima, and Walla Walla valleys of Washington and Oregon—Part 2: Field trip, Day one

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

A preliminary version of this field trip guide was prepared for the first annual field conference of the Friends of the Pleistocene, Pacific Northwest Cell, May 13–15, 1994. Part 1 of the guide appeared in the May 1995 issue of this magazine. This second part includes the first day of the three-day field trip. Days two and three will be printed in the next issue. —ed.

DAY ONE

Day 1 includes stops at some of the most spectacular Missoula flood features between The Dalles and Arlington. Trip route remains on the Oregon side of the river for the entire day. (Maps: U.S. Geological Survey (USGS) The Dalles 1°×2° sheet; USGS Hood River and Goldendale 1:100,000 sheets)

En route to Stop 1.1

From the Deschutes River Recreation Area, head west to The Dalles and then up the valley of Fifteenmile Creek. The local geology is dominated by the Columbia River Basalt Group, a thick sequence of middle and late Miocene (regionally, 17–6 Ma, locally 17–12 Ma) basalt flows that were issued from vents in northeastern Oregon and adjacent Washington and Idaho. In this region, the Columbia River Basalt Group has been deformed by a series of east-trending folds and high-angle reverse faults and by northwest-trending right-lateral strike-slip faults. Between the Deschutes River and the Hood River, the Columbia River Basalt Group is overlain by the Dalles Formation, a late Miocene (mainly 9–7 Ma) volcaniclastic and alluvial fan shed northeast from the Cascade Range. The Dalles Formation, with its several-meter-thick cover of loess, forms the rolling topography of the uplands, interrupted locally by gullies, landslides, and Missoula flood features.

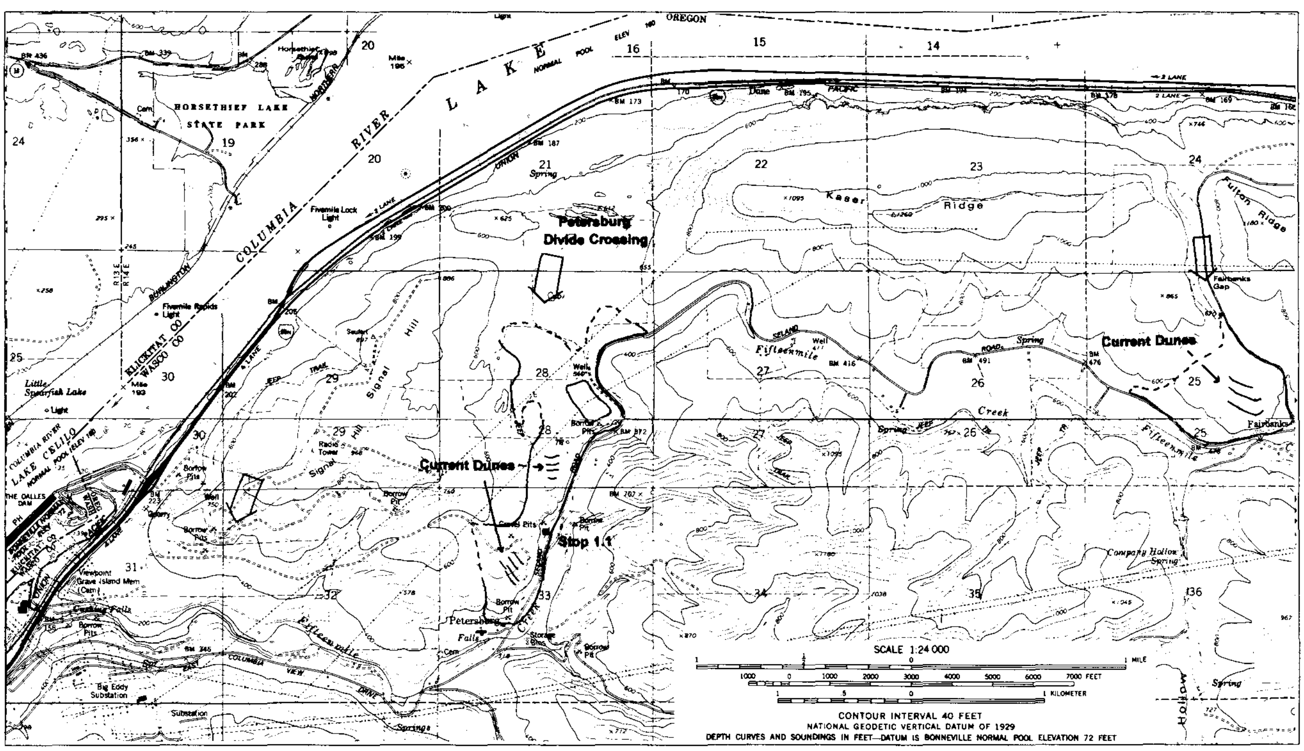


Figure 7. Topographic map of the settings of Petersburg and Fairbanks divide crossings, with approximate extent of the gravel bars that were deposited as flow (arrows) spilled into the valley of Fifteenmile Creek. Topographic base from Stacker Butte and Petersburg USGS 7½′ quadrangles.

Fifteenmile Creek parallels the Columbia River for about 15 km before joining it near The Dalles. Flow from the Missoula floods overtopped the ridge between the Columbia River and Fifteenmile Creek and spilled south into the valley of Fifteenmile Creek at two locations, forming two large "flood deltas" (Figure 7).

Stop 1.1. Petersburg bar

This is a privately owned gravel pit. Please do not enter without permission of the property owner! This large gravel pit exposes deposits from flow(s) spilling south into the valley of Fifteenmile Creek (Figure 7). Boulders, gravel, and sand were deposited in steeply dipping foresets, apparently as this "flood delta" prograded southward. Many of the contacts between thick gravel beds are unconformable, indicating erosion of the underlying unit before subsequent deposition. The topmost gravel bed is distinctly coarser with a more openwork texture. The entire deposit is capped with about 1 m of loess that contains a weakly developed soil typical of late Pleistocene age. The surface of the bar displays two small sets of giant current dunes. Exposures 0.5 km to the northeast at the east edge of the bar also show several units that are finer, thinner, and more gently dipping than the deposits here.

One question here is: Do each or any of these unconformity-bound units represent individual floods? Without definitive evidence of subaerial exposure between units or good chronologic information, it is difficult to answer this with certainty. Yet, based on other exposures of coarse-grained deposits that do have evidence of subaerial exposure (such as loess deposition) between units, we tentatively infer that each of the coarse depositional units here, some capped with fluvially deposited sand, is the result of a separate flood. If true, depending on how one counts, there are 6–10 floods. Hence, perhaps at least that many separate floods overtopped the divide. A similar number of unconformity-bound gravel and sand couplets are exposed in the pit to the northeast.

The present altitude of the divide crossing is about 180 m (600 ft). According to our modeling, a discharge of at least 3 million m^3/s would be required to overtop this divide (Figure 8). So we conclude tentatively that there were at least 6–10 separate floods that had peak discharges greater than 3 million m^3/s.

Radiocarbon dates from this exposure, all from low in the stratigraphic sequence, yield ages between 16,720±210 ^{14}C yr B.P. to >40,000 ^{14}C yr B.P. The youngest date (16,720±210 ^{14}C yr B.P.) came from a plant fragment within an organic-rich silt clast, which yielded a bulk date of 24,200±1,900 ^{14}C yr B.P. Additional bulk analyses from similar clasts of organic-rich silt at this site yielded ages of 23,400±250, 31,870±650, and 45,500±2700 ^{14}C yr B.P. We have also dated a soil clast high in the stratigraphic sequence at the east end of the bar. The stratigraphic relation between the deposits at the east end of the bar and those exposed at the trip stop is uncertain, although the deposits at the east end of the bar may simply be a finer facies.

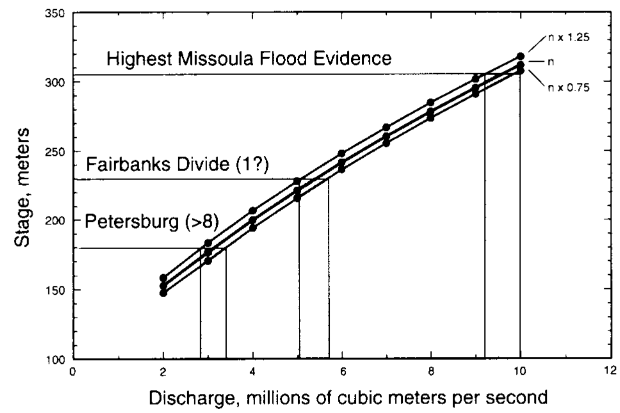


*Figure 8. Stage-rating curves constructed on the basis of step-backwater calculations for the reach near the Fairbanks Gap and Petersburg divide crossings. The sensitivity of the step-backwater calculations to uncertainty in Manning **n** values is shown by the three separate curves, one based on a best guess of roughness, the other two based on adjusting those values by ±25 percent. At sites such as these that are upstream of critical-flow sections, sensitivity to Manning **n** values is usually small. The numbers after the names of the divide crossings are the number of unconformity-bound depositional units exposed in the downstream delta bars.*

A whole-sample analysis of the sample from the east end of the bar yielded an age of 32,920±650 ^{14}C yr B.P.; an analysis of the separated humic acids (NaOH extract) gave an age of 14,480±145 ^{14}C yr B.P., which is probably a close age for the deposit.

En route to Stop 1.2

From Petersburg bar continue east along the valley of Fifteenmile Creek. In valleys to the south, ice-rafted erratics and a thin layer of sandy silt 0–4 m thick were deposited over the loess-covered landscape to an altitude of at least 285 m (940 ft).

About 5 km up Fifteenmile Creek, another large bar was deposited by flow diverging from the valley of the Columbia River across the divide through Fairbanks Gap (Figures 7 and 9). This bar has large crescentic current dunes on its surface, expressed by crenulations in the contour lines. An exposure of the delta front near the intersection with Company Hollow Road reveals coarse gravel deposits that lack the sweeping unconformities and interbedded sand layers of the deposits at Petersburg bar. A possible explanation for the coarseness is that the Fairbanks Gap divide crossing is much narrower than the Petersburg crossing and produced higher flow velocity as water passed through. Possible explanations for the lack of unconformities in the exposed section include that (1) stratigraphic exposure is too shallow; (2) the contacts are just not visible where bouldery units are amalgamated together; and (3) only one flood overtopped the divide here. Two radiocarbon analyses of organic-rich silt clasts gave >40,000 ^{14}C yr B.P. dates. The weak soil, however, indicates that this deposit is of late Wisconsin age.

Turn left on Old Moody Road and climb up the east margin of the bar. The undulating topography on the bar surface (wheat field) is created by giant current dunes. Proceed through Fairbanks Gap, a divide crossing cut through the Dalles Formation down to the contact with the Columbia River Basalt Group. The upper limit of erosion is about at altitude 300 m (1,000 ft). The col of the Fairbanks Gap divide is at altitude 250 m (820 ft), some 70 m higher than the Petersburg divide, requiring a minimum discharge of about 5 million m^3/s for overtopping (Figure 8). Note that the apex of the bar is higher than the divide crossing, which indicates that the flow was tens of meters deep through the divide as the bar was being formed.

Continue about 2 km east, high along the south side of the Columbia River valley, traveling across a small pendant bar. Stop 1.2 is at a promontory above the railroad bridge. Beware of traffic on this narrow gravel road.

Stop 1.2. Celilo Falls overlook

Before closure of The Dalles Dam in 1956, one had a good view of Celilo Falls from here (Figure 10). Altogether the sets of rapids between Celilo Falls and The Dalles were known by the name "The Dalles of the Columbia," the steepest section of the Columbia River, where the water-surface dropped 25 m in the 19 km between the head of Celilo Falls and The Dalles. At low water, Celilo Falls had a sheer drop of about 6 m. The topography of this reach consisted of narrow chutes, several kilometers long and locally less than 50 m wide, separated by large holes. The holes at Big Eddy and at the head of Fivemile Rapids are more than 40 m deep, with bottoms more than 30 m below sea level. At low water, the Columbia River was confined to the chutes and holes, but at high water, the entire basalt-floored valley bottom was inundated. It is not clear to us whether the channel-bottom topography here is largely a relict of the Missoula floods or whether Holocene flows sculpted the present channels as suggested by Bretz (1924). Nevertheless, Bretz (1924) felt that the processes and topography at this site served as a good analogy for Missoula flood features in the Channeled Scabland.

Topography clearly related to the Missoula floods can be seen across the river above the town of Wishram, where Columbia River Basalt Group flows have been stripped of their surficial cover and eroded into a butte-and-basin "scabland" topography. A local set of northwest-aligned joints or minor faults has been preferentially excavated. At higher altitudes, the basalt has been stripped of loess and regolith but not much eroded. Alluvial fans, talus, and landslide debris shed southward off the Columbia Hills anticline were locally trimmed back, which resulted in Holocene entrenchment of many of the small streams draining the valley slopes. Landslides are ubiquitous on both sides of the river and in major tributary valleys throughout this reach of the Columbia. Many of the most visible of these landslides have pristine morphology, which indicates that they probably postdate passage of the flood peak(s). Nevertheless, they were perhaps triggered by the floods because of excavation of supporting sediment and saturation and excess pore pressures caused by a few days of inundation and subsequent dropping of the water level.

On the north side of the river, forming the high part of the ridge to the east, is Haystack Butte (towers on top). This Quaternary volcano erupted basalt that flowed south into the Columbia River valley at about 900 ka (Bela, 1982). The lowest exposure of these flows is along the southeast margin of Miller Island, a mid-channel island south of Haystack Butte. These rocks at Miller Island, less than 60 m above sea level, indicate that (1) regional base level has not changed much during the last million years and thus the Missoula floods caused little or no overall downcutting of the river bed, at least not more than a few tens of meters; and (2) because the basalt of Haystack Butte must have flowed down a continuous slope to its present position, the entire intervening channel north of Miller Island must have been carved in the last half of the Quaternary, probably by erosion during the Missoula floods. If this channel was carved by flood, it is a huge example of a landform that Bretz noted in various parts of the Channeled Scabland and termed "trenched spurs." Trenched spurs are analogous to flood chutes cut across alluvial meander bends but are instead cut through bedrock.

Along this stretch of the Columbia valley, the floods left a wide spectrum of other erosional features, ranging from streamlined hills formed in the surficial loess and sedimentary deposits, to stripped, plucked, and channelized surfaces on the basalt flows. We compare flow velocities from our modeling (Figure 11) to mapped erosional features for a 30-km reach extending upstream from Celilo Falls to the John Day River confluence. Figure 12 shows how these erosional features plot with respect to the flow depth and velocity calculated for the peak stage of the largest flood. Hills composed of loess and semiconsolidated alluvial deposits were streamlined and channelled under flow depths of 0–40 m and velocities less than 5 m/s. In areas of more intense flow, the loess and alluvial deposits were completely removed, exposing surfaces of the Columbia River Basalt Group. Intact but stripped and grooved basalt surfaces correspond to maximum flow depths between 25 and 125 m and flow velocities of 3–9 m/s. Local erosion of these basalt surfaces into a butte-and-basin morphology was probably a result of unsteady and complex flow phenomena such as vertical flow vortices and cavitation that cannot be directly described by the step-backwater results. Nevertheless, average flow conditions at these sites are characterized by depths of 100–270 m and velocities of 6–24 m/s. Hydraulic conditions at sites of inner channel formation were most intense; flow depths exceeded 250 m at maximum discharge and velocities were greater than 13 m/s. Because many of the features may have been the cumulative product of several floods with hydrographs that spanned a large range of dura-

Figure 9. Panorama view generally north of the delta bar (not cultivated, dark) deposited by water spilling out of the

tions and discharges, the depth and velocity fields of specific "facies" of erosional landscapes should not be viewed as definitive. Yet it is apparent from the high spatial correlation between flood features and local flow conditions that there are important thresholds that must be exceeded for certain types of erosional features to be produced. Did all, a few, or perhaps just one flood cause most of the erosion along the flood route? Different parts of the Channeled Scabland would probably give different answers.

En route to Stop 1.3

Continue east on Old Moody Road, passing over high-level and locally high-relief butte-and-basin scabland before descending into the valley of the Deschutes River. A prominent trimline cut into the slopes above indicates that maximum flood stage exceeded altitude 315 m (1,040 ft). At river level, a large pendent bar extends downstream from the southeastern edge of Miller Island.

A large bar lies along the west side of the Deschutes valley, extending upcanyon about 3 km. An Oregon Department of Transportation gravel pit near the top of it previously exposed seven alternating sand and gravel couplets, ranging from 1 m thick near the bottom to less than 30 cm at the top. Each couplet consists of well-sorted micaceous medium sand deposited in north-dipping foresets unconformably overlain by openwork coarse sand and gravel deposited in south-dipping foresets. Most of the sand units are partly to nearly completely truncated by the gravel unit, except for a trace of sand between the gravel units. The upper 0–3 cm of each coarse unit has a silt matrix that indurates the upper few centimeters of each unit. We infer that this silty matrix resulted from loess deposition between separate floods. The distinct change in texture and current direction within the couplets may result from changing eddy circulation patterns as each flood waxed and waned. If each of these seven units were deposited by individual floods, they all achieved discharges of greater than about 2 million m^3/s, based on their altitude relative to our modeling results.

Proceed east along the frontage road to Biggs Junction and enter Interstate 84 eastbound. Continue 19 mi east, passing the John Day Dam and the mouth of the John Day River, exiting at Philippi Canyon (Exit 123).

Ascend Philippi Canyon, where a large eddy bar has been deposited along the eastern valley margin. Near the road junction is the col of a major divide crossing between the Columbia and John Day River valleys (Figure 13). Bretz (1928, p. 686–690) described this region in detail, using it as a cornerstone in building a case for huge flows downs the Columbia.

The following section is on private property. Be sure to obtain permission before entering! (If you wish to bypass the private land, go on to Stop 1.4.)

valley, through Fairbanks Gap, and into the valley of Fifteenmile Creek (foreground). USGS photograph by A.M. Piper.

Turn right (west) at the intersection and follow the private road that flanks the north edge of a channel and cataract complex that has been eroded through the Columbia River Basalt Group and overlying Tertiary gravel. To the west, a large flood entering the John Day valley from the Columbia deposited an immense bar, 150 m (500 ft) high and mantled with rounded boulders 2–3 m in diameter.

Stop 1.3. Columbia River overview

This superb view of the valley of the Columbia River is from 310 m (1,020 ft) above what used to be the normal river level but is now submerged 25 m due to the John Day Dam. Some 15–30 m (50–100 ft) above the maximum flood stage, this site would have been a good if somewhat frightful place to watch the largest Missoula flood(s). In this area, the maximum flood stage can be confidently constrained as being less than 340–350 m (1,120–1,150 ft) by a divide 300 m to the east that was apparently not crossed. However, about 5 km west, laminated sand and silt mantle loess to an elevation of at least 330–340 m (1,080–1,120 ft). Another divide crossing, 2 km west, has a minimum elevation of more than 310 m (1,020 ft), with evidence of erosion as high as 340 m (1,120 ft).

A tremendous current must have developed between the Columbia and John Day River valleys to erode the scabland of this divide. Such a current indicates a substantial difference in the water surface elevations between the flooded Columbia River valley and the backflooded John Day River valley, a rather quick rise in flood stage. The travel distance over which this gradient was developed was only about 30 km. We can speculate about what the rate of rise may have been by assuming that the divide crossing was not eroded significantly below the level of backflooded water in the John Day River valley at the time of the initial crossing, hence putting that water level at about 230 m (750 ft). The water level at initial overtopping of the divide may have been about 300 m (1,000 ft). Assuming that the flood wave moved downstream at the celerity of the flow velocity at peak stage (about 10–15 m/s), it would have taken 50–75 minutes for water levels to translate down the Columbia River valley and back up the valley of the John Day River. Considering the ~70-m elevation difference between the water levels tenuously indicated by the field evidence, this translates into a water level rise of about 1 m/min.

En route to Stop 1.4

Continue westward on the peninsula between the John Day and Columbia Rivers and turn around at the divide crossing at about the 310-m (1,020 ft) elevation. Here, flow overtopped a low point in the ridge between the two rivers,

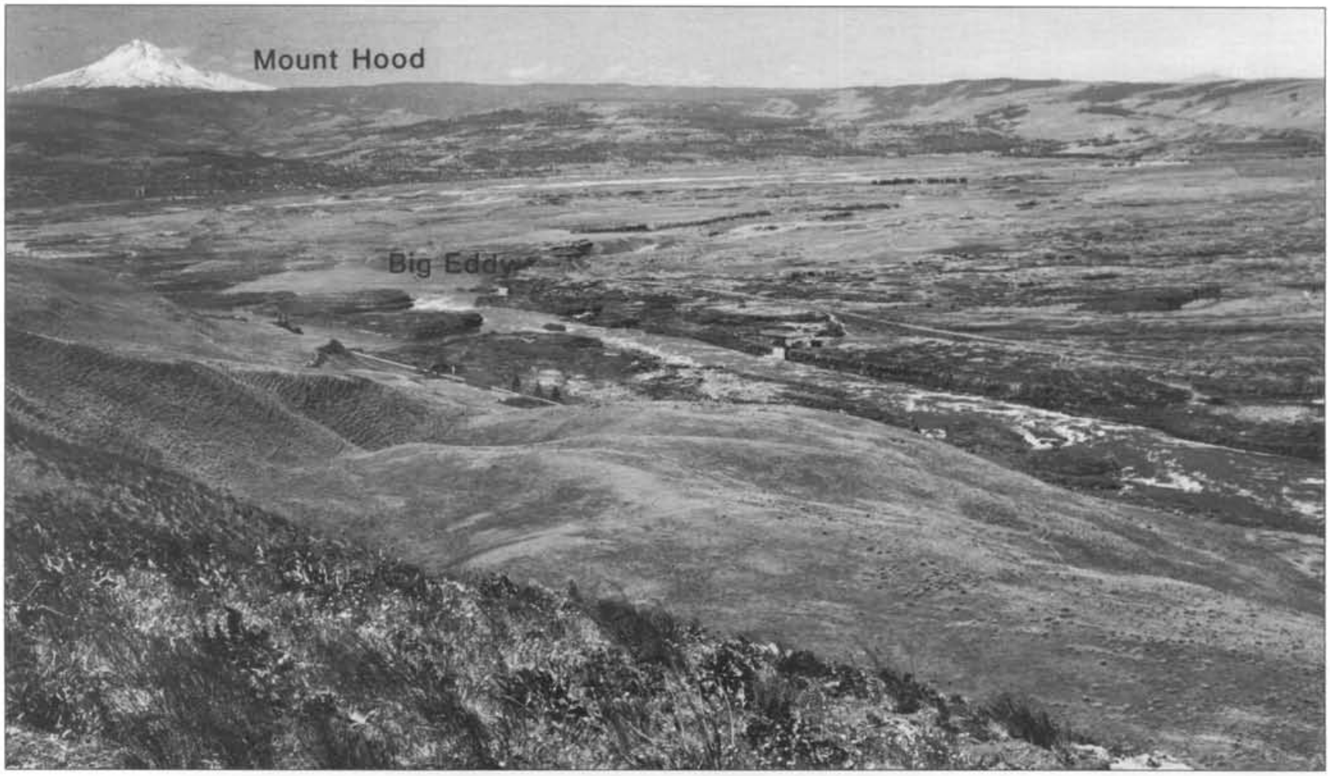
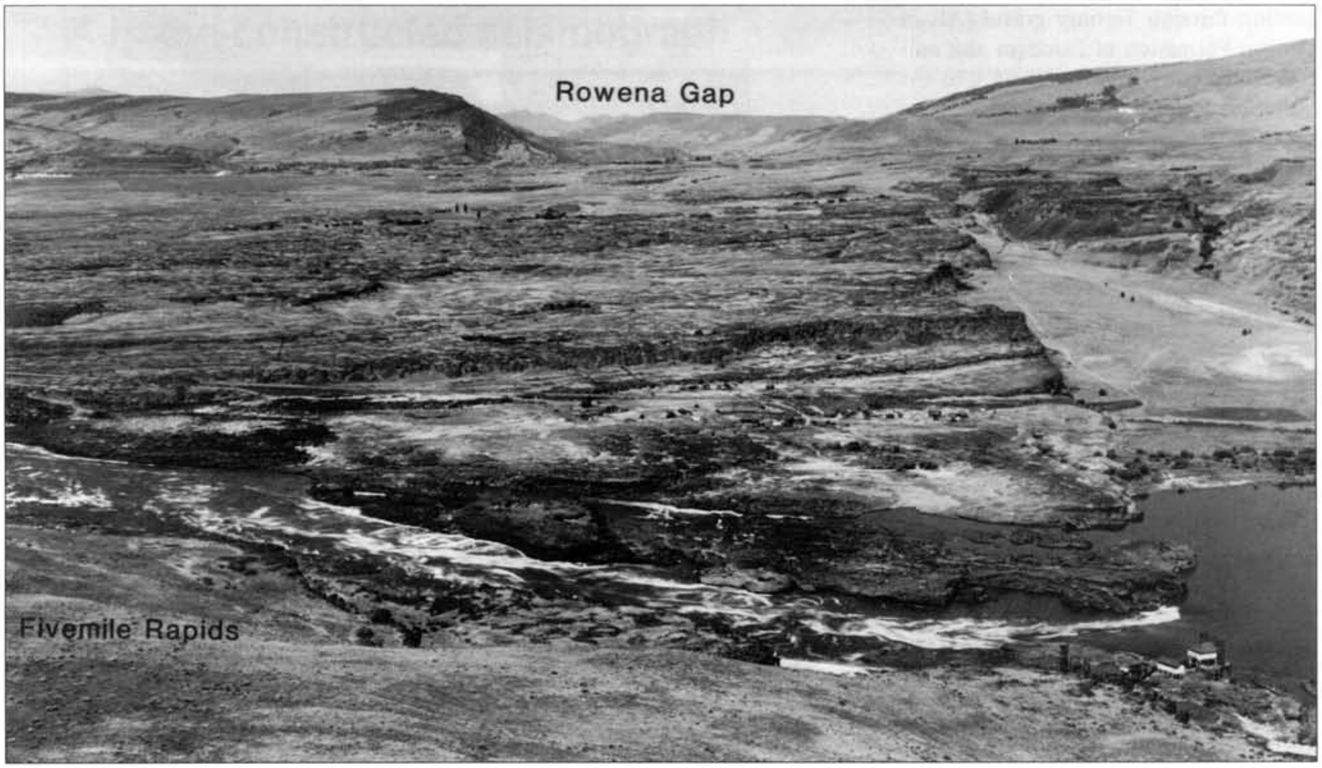
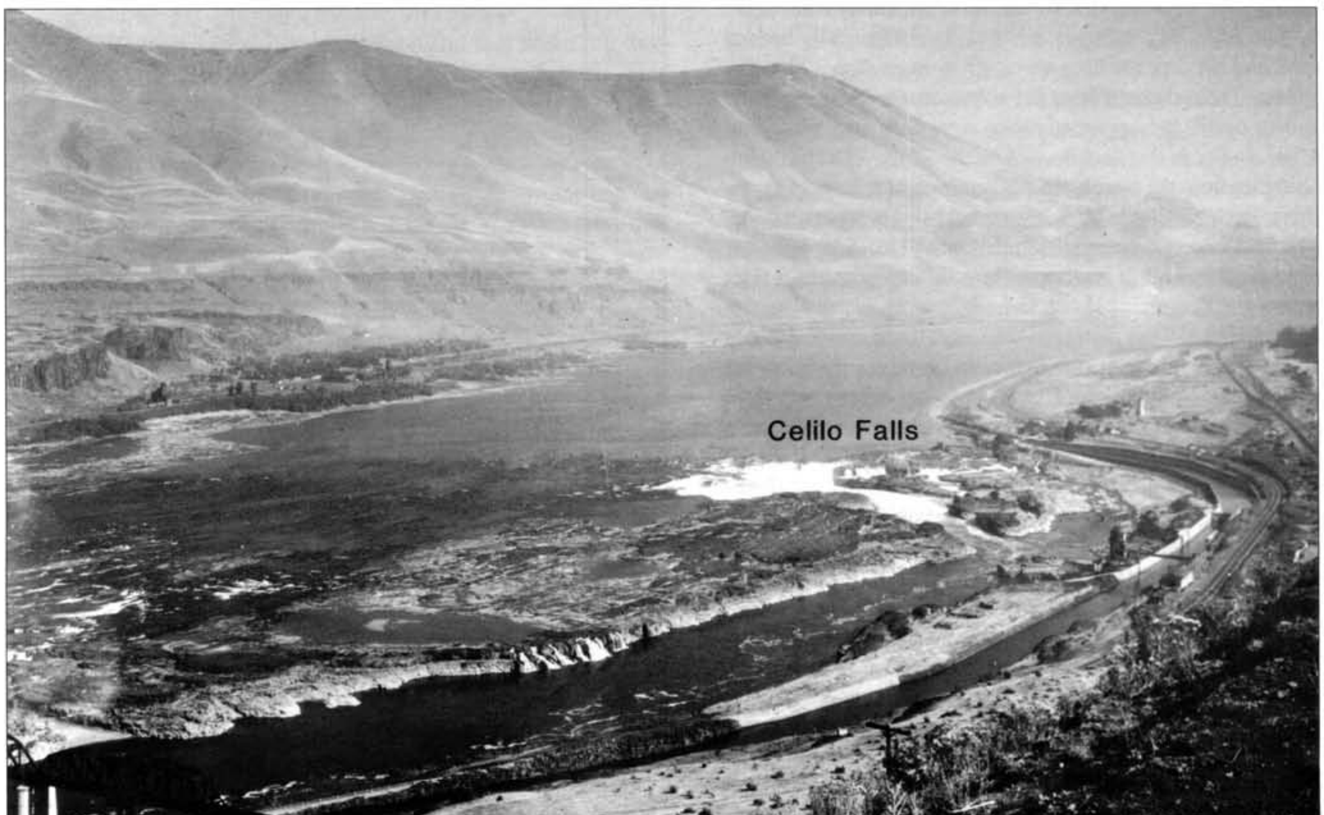


Figure 10. Panoramas of "The Dalles of the Columbia" before inundation by The Dalles Dam. Views are from south valley side and





generally west-southwest in the upper panorama, generally north from near Stop 1.2 in the lower. USGS photos by A.M. Piper.

eroding through Tertiary gravel (Alkali Canyon Formation of Farooqui and others, 1981) but not entrenching into the Columbia River Basalt Group that floors the channel.

Turn around and drive back to Philippi Canyon road. Stop 1.4 is just south of the intersection on that road.

Stop 1.4. Scabland

Take some time to walk around this "amazingly wild scabland" (Bretz, 1928, p. 688). Note the closed rock basins and the basalt protrusions, the steep-sided canyons with floors that slope in various directions. Imagine what the landscape looked like before the floods.

Much of the coarse debris eroded from this scabland was deposited in two large bars whose apices lie just downcurrent from each of the two sets of cataracts formed by water overflowing into the John Day valley (Figure 13). The smaller bar, south of the southeastern flow route, has giant crescentic current structures on its surface. Together, these bars displaced the John Day River southward onto a shelf of basalt that forms the south valley side.

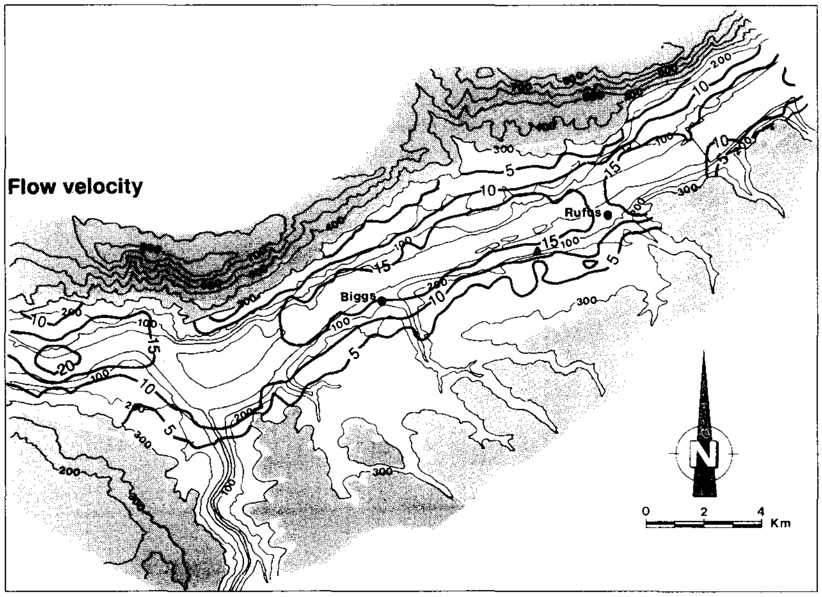


Figure 11. Isovel (equal velocity) map for a 10 million m^3/s discharge near the confluence of the Columbia and Deschutes Rivers. Velocity values are in m/s. Area above flood limits shown by stipple pattern.

The John Day valley is mantled by rhythmically bedded sand and silt deposits from its mouth to more than 30 km upstream. These deposits have not been examined systematically and in detail, but apparently they were deposited by several Missoula floods that backflooded up the valley. At a site 30 km upstream from the mouth, there is a section of at least 14 rhythmites, each rhythmite probably representing a separate flood. The field evidence includes bioturbation and loess deposition at contacts. The eighth rhythmite from the top contains a faint tephra couplet, probably the 13-ka Mount St. Helens "set S." The relation of these rhythmite sequences to the coarse deposits at the divide crossings is not clear, but it seems doubtful that rhythmites along the John Day River valley downstream from the large bars near the point called the "Narrows" could have survived a deluge traveling down the John Day River from the Philippi Canyon divide crossings. We speculate that the rhythmites in the John Day River valley, especially those in the lowest reaches, postdate the flows that formed the scabland and great bars resulting from overflow at Philippi Canyon.

According to our flow-modeling results, flow over the divide at Philippi Canyon requires a minimum of about 5 million m^3/s. In contrast, emplacement of the 14 rhythmites requires minimum discharges of only about 1.5 million m^3/s.

The only chronologic information we have regarding the deposits at the Narrows is a radiocarbon age from a soil clast in a colluvial deposit below a single Missoula-flood deposit north of the large bar. The bulk radiocarbon analysis of the clast yielded a result of 29,845±470 ^{14}C yr B.P. An analysis of the humic acids (NaOH extract) resulted in

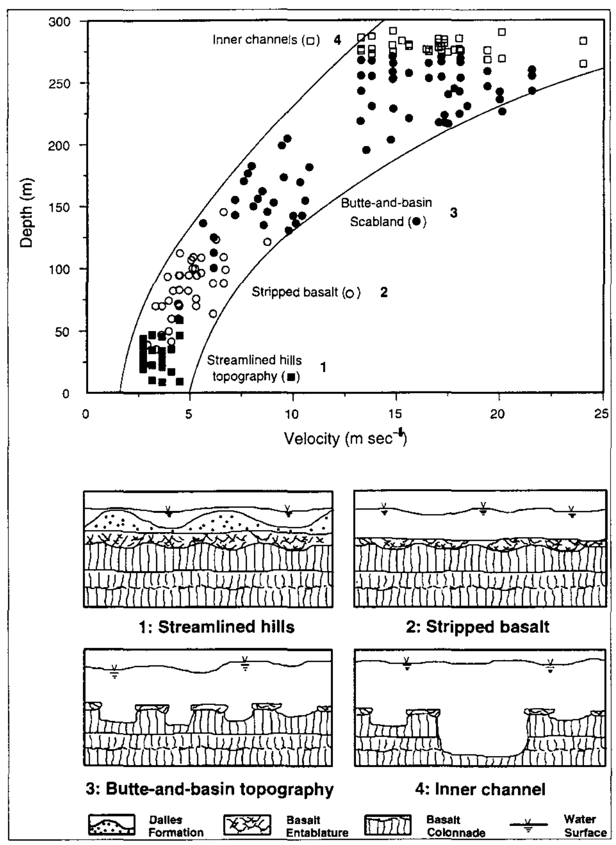


Figure 12. Relation of erosional features in the area of Figure 11 to local flow depths and velocities calculated for a 10 million m^3/s discharge. The various "facies" of erosional features are portrayed in lower part of figure.

19,015±145 ^{14}C yr B.P. In this case, these dates provide a maximum age for the overlying flood deposit and simply confirm that the most recent flow(s) over this divide were during the late Wisconsin.

En route to Stop 1.5

Continue east, traveling up Philippi Canyon. From this point eastward, almost to Wallula Gap, the largest Missoula floods spilled well out of the Columbia River valley, inundating large tracts of upland surfaces. These high surfaces are underlain by basalt gravel and tuffaceous sediment of the late Miocene to early Pliocene Alkali Canyon Formation (Farooqui and others, 1981; Smith and others, 1989), which in turn overlies the Columbia River Basalt Group.

Stop 1.5. Ice-rafted erratics

Near the telephone pole are some ice-rafted erratics. Commonly, accumulations of diverse rocks are found in concentrated zones, locally forming mounds. Many, like these, are on the east sides of ridges that stood up above the maximum flood stage. The erratics here have been cleared from the fields but probably have not been moved far. They are at an elevation of about 325 m (1,060 ft), consistent with the high-water evidence discussed at Stop 1.3 and local divide crossings and trimlines up to an altitude of 335 m (1,100 ft). For the next 80 km upstream, to the downstream end of the constricted reach at Wallula Gap, maximum stage evidence closely hovers about the 1,100-ft contour (335 m), indicating that there was little gradient to the largest flood at peak stage. The flatness of the water-surface profile in this reach fueled Allison's (1933) speculation that physical damming downstream was the cause of the high water levels in the Columbia valley.

En route to Stop 1.6

Continue east to Blalock Canyon road, then southwest to Alkali Canyon and north to Oregon Highway 19. Alkali Canyon was the largest of several overland flow routes from the north that spilled water into the John Day valley. A gravel eddy bar at the junction of Blalock Canyon and Alkali Canyon roads attests to the flow velocity. Westward travelers of the Oregon Trail ascended out of Alkali Canyon via this eddy bar after following the south side of the canyon for several kilometers.

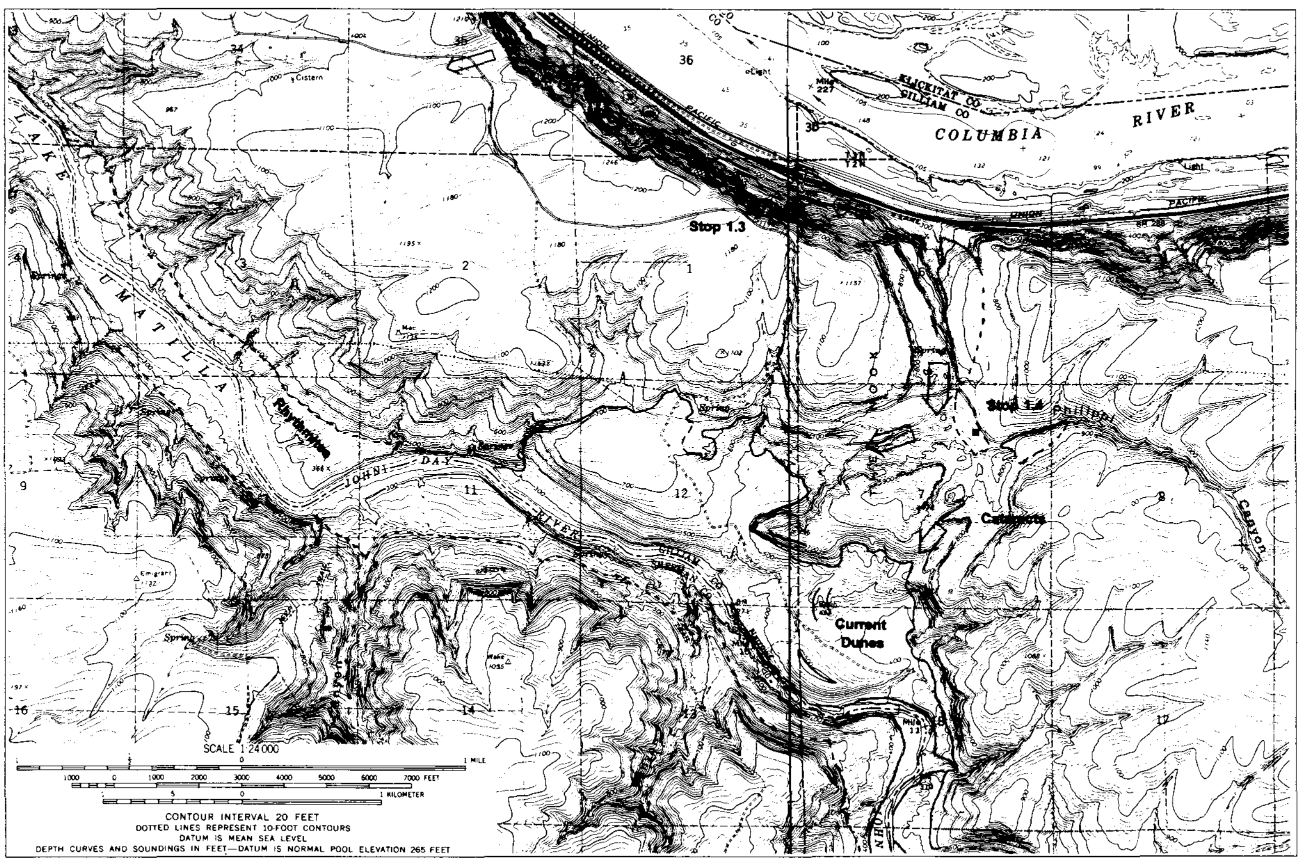


Figure 13. Topographic setting and approximate distribution of Missoula flood deposits in the area of the divide crossing between the Columbia and John Day valleys near the "Narrows." Topographic base from Quinton and Sunrise NW USGS 7½′ quadrangles.

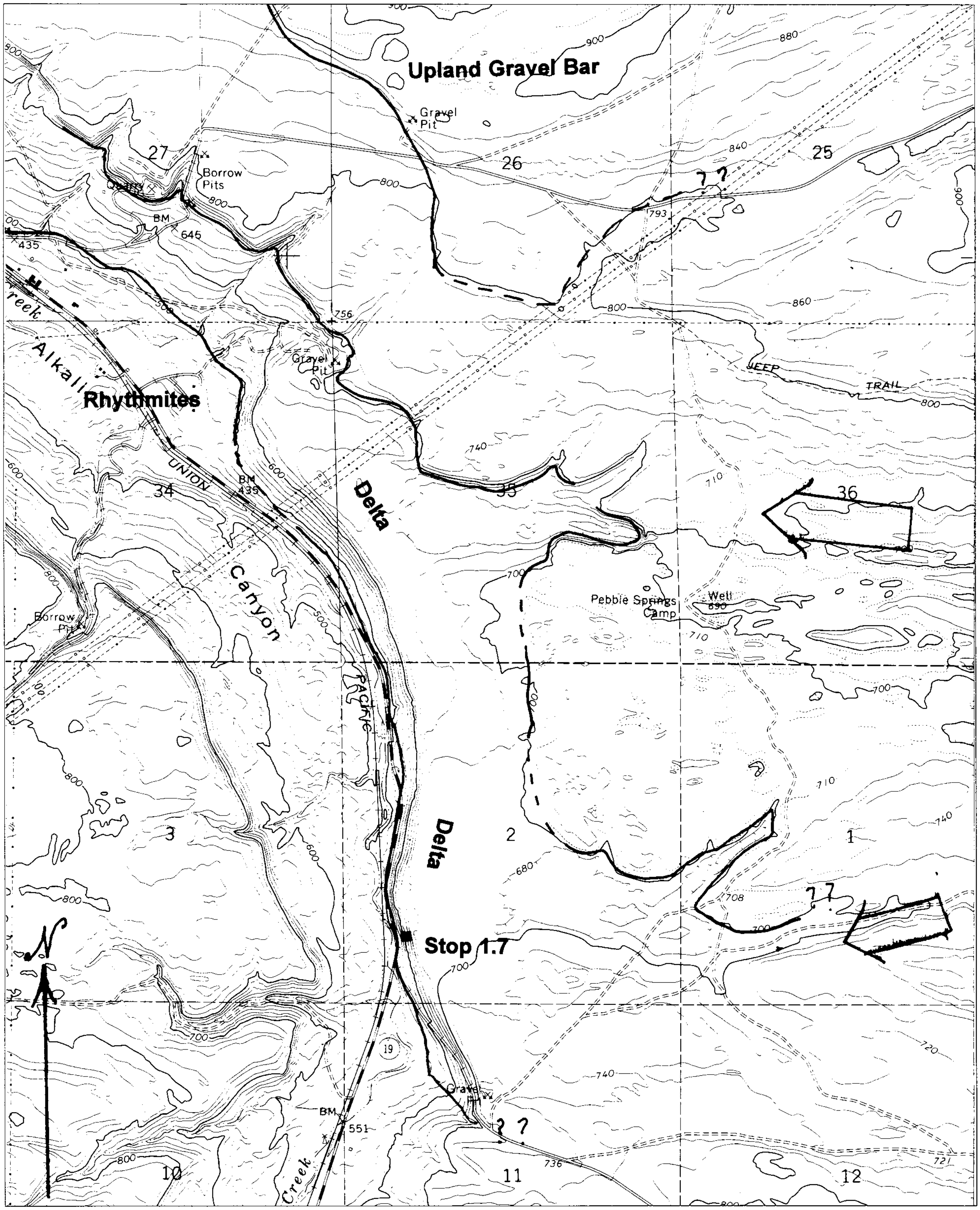


Figure 14. Topographic setting and approximate distribution of Missoula flood deposits southeast of Arlington. The delta bars were mainly deposited by flow spilling into Alkali Canyon from the two upland channels to the east. There was substantial flow over the entire upland surface, however, as evidenced by the large gravel bar deposited on the upland surface that is depicted on the north part of the map. Topographic base from Arlington USGS 7.5′ quadrangle. Land sections (numbered) are 1 mi (1.6 km) across.

Stop 1.6. Arlington rhythmites

This stop is an appetizer for the stops on Day 2. About 15 fining-up sand-to-silt beds are deposited over preexisting landscape. Thin stringers of Mount St. Helens "set S" tephra lie at the top of about the fourth bed from the top. Is it possible that each of these beds was deposited by a separate flood? Day 2 stops will address this question in detail.

En route to Stop 1.7

As you continue north on Highway 19, you gain a view of a large delta that enters and partially fills Alkali Canyon from overland flow routes to the east.

Stop 1.7. Arlington flood delta

The final stop is at an exposure of a large delta complex of bouldery gravel deposited in Alkali Canyon about 4 km southeast of Arlington (Figure 14). Bretz (1925, p. 243–244) described this feature in his first report on Missoula flood features in the lower Columbia River valley. Bretz did not fully understand how high the water had risen here, even in his last report on the lower Columbia valley (1928, p. 681–686). But Allison (1933) did, and the question was one element of the contest between those two.

The entire upland surface south of the Columbia River was in fact submerged by water during the largest Missoula floods, although two channels (Figure 14) identified by Bretz (1925) that eroded through the Alkali Canyon Formation down to the surface of the Columbia River Basalt Group probably conveyed most of the upland flow. The exposure here lies at the south end of a large delta complex that was deposited as flow dropped into Alkali Canyon from those overland channels. The exposed part consists of 30°-W.-dipping foresets of gravel with clasts as large as small boulders. Many of the clasts are well-rounded basalt cobbles, 10–20 cm in diameter; these were probably reworked from the Alkali Canyon Formation. Coarser and angular to subrounded Columbia River Basalt Group clasts, as well as clasts of soil and loess, were clearly transported only short distances. The steep dip of the foresets precludes viewing much of the stratigraphic sequence in this exposure. Nevertheless, there are no sweeping unconformities like those in some other delta deposits, such as at Petersburg. Perhaps the forsets exposed here were deposited by just one flow. Other exposures in this delta complex, however, both near the apex of the northern channel and down near the toe, indicate that perhaps at least two flows were vigorous enough to transport gravel over the 215-m-high upland surfaces to the east.

An exposure 5 km to the southeast, also at an altitude of 215–220 m (710–720 ft), gives more clues to the number and magnitude of floods that inundated this area. A roadcut exposes silt and fine sand deposited in six or seven cycles of fining-up sequences. The cycles themselves thin and fine upwards from 20–30 cm thick near the bottom of the exposure to a few centimeters thick at the top. Three stringers of tephra are also exposed, two near the top of the fifth cycle down, and one at the top of the fourth cycle from the top. Similar in setting and stratigraphy to exposures to be discussed on Day 2, these tephras are probably also Mount St. Helens "set S." If each of these rhythmites was deposited by separate floods, then there were at least seven floods that achieved stages of 215–220 m (710–720 ft), equivalent to a discharge of 3–4 m^3/s, with four of these flows postdating 13 ka. Many of these flows, however, may not have had the strength to transport gravel across the upland surfaces and contribute to formation of the Arlington delta.

En route back to Deschutes State Park

Proceed northwest on Oregon Highway 19 toward Arlington. For the first couple of kilometers, we follow the curved delta front of deposits from the overland channels to the east. The west side of the valley is covered with numerous landslides and is locally mantled with Missoula flood sand and silt. Shortly after leaving the delta front, we pass an exposure of rhythmically bedded sands and silts that compose the flat but gullied surface along part of the valley floor (Figure 14). These deposits, apparently inset against the gravel delta bars, were left by tens of floods that probably postdate the delta bars. Although we have not done a thorough search, we have not found the "set S" tephra, so the floods represented by these deposits may all postdate 13 ka.

Enter Interstate 84 westbound and head back to Biggs Junction. Along the way note the abundant bars deposited on the downstream side of valley protrusions and in tributary mouths. Bretz (1924, 1928) described many of these, noting:

> "In this part of its valley are numerous deeply trenched tributary canyons. . . Dèposits of fresh, dominantly little-worn basalt gravel occur at various altitudes in this canyon portion. If they are remnants left by dissection of a once complete fill, they should be most extensive between the tributary mouths, not in them. If they are original deposits left by a very great flood and individually determined by local conditions, tributary mouths would be logical places for them." (Bretz, 1928, p. 684)

DAY 1 ROAD LOG (mileage is approximate)

Miles

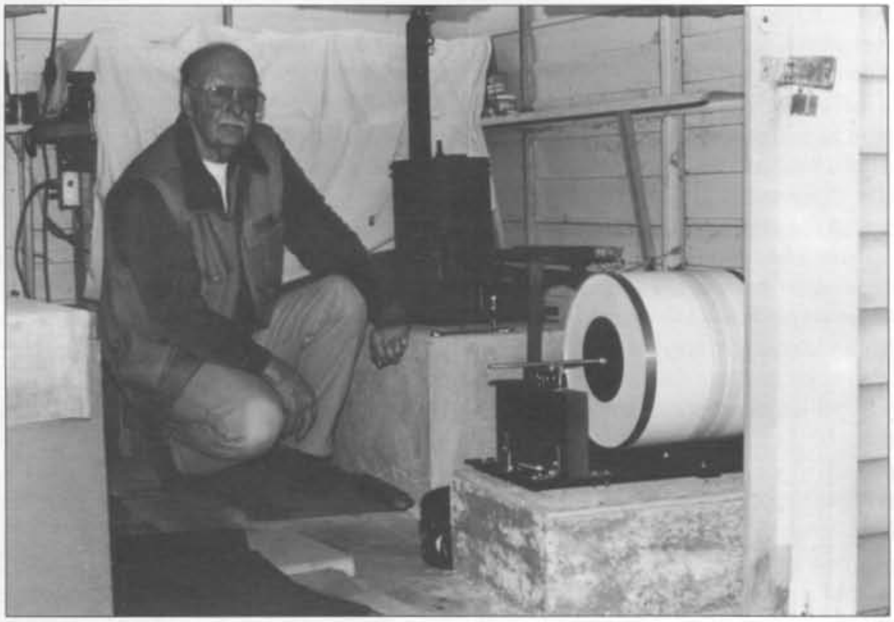
0.0 Deschutes State Park overflow area.
0.2 Turn left (west) onto Oregon Highway 206 (old US 30).
3.4 Turn right (north) and pass under I-84.
3.6 Turn left (west) and enter I-84 westbound.
14.0 Exit I-84 at Exit 87. Turn left (south) onto Oregon 197.
14.3 Stop sign at junction of Oregon 197 and US 30. Turn left, continuing south on Oregon 197.
14.6 Turn sharply left onto Columbia View Drive, proceed up the hill with good views of The Dalles Dam, including fish ladders on the east and west sides of the dams. To the west, on Sevenmile Hill (northwest of The Dalles), a prominent trimline is visible about halfway up the slope.
16.0 Cross under power lines from The Dalles Dam.

16.4 Stop sign. Turn right (east) onto Seland Road.
17.6 Cross bridge over Eightmile Creek. Bear left at yield sign, continuing on Seland Road.
18.1 Cross bridge over Fifteenmile Creek.
18.2 Abandoned gravel pit on left, south margin of Petersburg Delta. Site of Petersburg settlement and school.
18.7 **Stop 1.1**, Petersburg Bar. Pull off and park on gravel parking strip on the right side of the road. When you leave, continue north on Seland Road.
19.9 North margin of Petersburg delta exposed along road. Roadcuts for next few miles are in the Columbia River Basalt Group.
22.8 Roadcuts expose western margin of Fairbanks bar.
23.7 Junction with Company Hollow Road from the south. Large exposure of Fairbanks bar in the gravel pit on the north side of the road.
23.9 Turn left on Old Moody Road (one-lane gravel road).
24.5 View left to surface of Fairbanks bar. Hills and swales on bar surface are giant crescentic current dunes.
24.7 Fairbanks Gap.
25.3 View down to the Columbia River (Lake Celilo), 180 m below.
27.1 **Stop 1.2**, Celilo overlook. Pull off as far as possible on right side of road. Watch for traffic on narrow road. When you leave, continue east on Old Moody Road.
27.8 Traveling across high-altitude basin-and-butte scabland surface.
29.3 Ranch on right.
29.9 Begin descent into Deschutes River valley.
30.5 Oregon Department of Transportation gravel pit.
30.9 Pass under Burlington Northern railroad.
31.2 Heritage Landing (restrooms).
31.4 Stop sign at junction with Oregon 206/US 30. Turn right (east).
31.6 Cross over Deschutes River.
31.8 Turnoff to Deschutes River State Park camping area.
33.2 Junction with Oregon 206. Continue east on US 30.
35.8 Enter Biggs Junction.
36.2 Four-way stop. Turn left onto US 97.
36.3 Turn right and enter I-84 eastbound.
43.9 John Day Dam.
46.1 Cross John Day River.
54.9 Exit I-84 at Philippi Canyon (Exit 123)
55.2 Stop sign. Turn right onto Philippi Canyon Road.
57.0 Top of large eddy bar deposited in east side of Philippi Canyon.
57.1 Pavement ends. Turn right onto Philippi Lane (private road).
57.7 View down into John Day valley and large bar.
57.8 Pass under power lines.
58.9 **Stop 1.3**, Columbia River overview. When you leave, continue west on Philippi Lane.
60.0 Exposure of the Alkali Canyon Formation and old soils in road cut on right.
60.6 Divide crossing (sec. 35, T. 3 N., R. 18 E.)
60.7 Turn around.
64.2 Junction of Philippi Lane with Philippi Canyon Road (signed as Quinton Lane and Heritage Road). Turn right (south).
64.4 **Stop 1.4**, Scabland of the "Narrows" divide crossing. Park on right side of road and hike about 500 m southwest to the knob of basalt with the power line standard for views of the divide crossings between the John Day and Columbia Rivers. When you leave, continue south and then east, following Philippi Canyon Road up Philippi Canyon.
64.4 Small eddy bar.
69.1 **Stop 1.5**, Ice-rafted erratics (next to first utility pole on north side of road). Park on right side of road. When you leave, continue west.
69.3 Junction with Hoag Road. Pavement begins. Proceed straight ahead.
71.1 Turn right (south) onto Blalock Canyon road. (Turn left to rejoin I-84.)
72.6 Pavement changes to gravel.
74.2 Bear left, continuing on Blalock Canyon Road.
75.9 Pass under power lines.
76.5 Exposure of the Alkali Canyon Formation.
76.8 Descent into Alkali Canyon, crest of small eddy bar on left.
77.0 Left at Y, join Alkali Canyon Road eastbound.
79.8 Junction with road to chemical waste dump on left.
80.7 Railroad crossing.
84.2 Junction with Oregon 19. Turn left (north) toward Arlington.
85.4 **Stop 1.6**, rhythmically bedded sand and silt. Park on left side of highway. Watch for traffic. When you leave, continue north on Oregon 19.
86.6 View of delta front from upland channels to the east.
87.5 **Stop 1.7**, delta from upland channels to east. (Just past junction with Eightmile Road.) Park in gravel area on right side of highway. When you leave, continue north on Oregon 19 toward Arlington.
89.3 Exposure of several rhythmites on left (east) side of highway.
90.3 Exposure on right side of road of two gravel units, capped by rhythmites.
91.2 Railroad crossing. Follow signs to I-84 westbound.
91.6 Enter I-84 westbound.
124.5 Exit I-84 at Biggs Junction (exit 104).
124.7 Stop sign. Turn left onto US 97.
124.8 Four-way stop. Turn right onto old US 30.
129.2 Turn left into Deschutes State Park camping area.

End of Day 1.
To be continued in next issue

A home-constructed seismograph

by John L. Rhudy, amateur seismologist, 35752 East Wills Road, Creswell, Oregon 97426



Author John L. Rhudy and his most recent seismograph.

My interest in seismology developed while I was completing my first course in geology in 1947—by correspondence. Among the many fascinating events that I studied was the great Lisbon earthquake of November 19, 1756. Other outstanding seismic events that captivated my imagination were the San Francisco earthquake of 1906 and the great Kanto earthquake in Japan (near Tokyo) of 1923. As I continued to study historical and present-day earthquakes, I began to think what a wonderful experience it would be to build a seismograph. At the time, that was quite an ambitious idea, considering that I had never seen one!

Through the following years my interest was kept alive by going on field trips, taking geology classes, and building my geology library. In 1960, my wife and I purchased a house that had a full daylight basement and was heated by a sawdust furnace. This basement provided a dry environment and uniform temperature for my first attempt at building a seismograph.

Studying schematic drawings in my textbooks on geophysical prospecting and other geology texts that touched on the subject of seismology, I began to understand that most seismographs utilize a pendulum of some type. Some use a horizontal pendulum, others a vertical pendulum, and some a torsion pendulum. From the schematic drawings, it seemed to me that the Bosch-Omori-type mechanical seismograph (German-Japanese design) had the simplest elements to try and reproduce. So I decided to make my instrument as closely as possible after that general design.

The seismograph of the Bosch-Omori type uses a horizontal pendulum weighing 200 lb that is suspended by piano wire from a vertical mast. A pendulum this heavy requires a substantial base, so I started with a ¾-in. steel plate, 12 in. in width and 24 in. in length and equipped with three leveling screws. For a mast, I welded a 24-in. length of 2-in. channel iron to a triangular steel plate that was also provided with leveling screws. The pendulum was a ¾-in. steel bolt, 12 in. in length, with an 8-in.-diameter disc of steel for the center, lead discs slipped along the bolt on each side of the center steel disc, and the assembly suspended with the discs in horizontal position. A 1½-in. length of steel rod with a sharp point on one end was screwed to the steel center disc, with the point of the rod fitting into a small steel cup at the base of the mast. This provided a pivot for the pendulum.

A mechanical seismograph amplifies the ground motion by means of a lever system. We may illustrate this with an ordinary lead pencil. If we place a pivot in the center of the pencil and move one end back and forth around the pivot, it will be observed that both ends of the pencil travel the same distance. On the other hand, if the pivot is located near one end of the pencil, then, when the pencil is maneuvered in the same manner, it will be obvious that the long end travels a much greater distance than the short end. Another way of illustrating this phenomenon is by the "swinging door principle." When the door is opened and closed, the outer edge of the door moves a much greater distance than the edge where the hinge is located.

To my pendulum I fastened a 30-in. length of electrical conduit pipe, the "boom." After reducing the inside diameter of one end of the pipe to the proper size, I inserted a short length of 3⁄16-in. rod and fastened it in place with set screws. To the end of the rod I soldered a ¼-in. ball bearing. The ball bearing was made to fit into a slot on the short end of the arm that was to carry the recording pen, with contact screws on each side of the bearing. I placed a pivoting support for the pen arm within 1 in. of the ball bearing and made the other end of the arm with the pen attached about 8 in. long. For the pivot I used the balance wheel of an ordinary windup clock; and for the recording pen I used a modified hypodermic needle. With a short length of rod pivoted by the pendulum at the base of the mast I had amplified the pendulum motion many times.

Theoretically, when an earthquake occurs, the pendulum, because of its suspension, remains at rest, while the earth and the supporting apparatus move beneath it. However, if the ground motion continues long enough the pendulum will begin to swing. Consequently, a damping device is needed to restore the pendulum to the rest position as soon as the ground motion ceases. For a damper I attached a vane beneath the 30-in. boom. The vane moves in a laterally elongated cup that I filled with ordinary motor oil. I placed the assembly on a 16-in.-high concrete pier.

Now I had a seismo*meter*. The seismometer detects the earthquake, but without a recording component there would be no way of knowing that the earthquake had occurred. I had to have a seismo*graph*.

I fashioned two drums out of ordinary tin cans about 6 in. in diameter and mounted them on shafts of $^3/_{16}$-in. rod with bearings made from .22-caliber shell casings in proper supports. After aligning the drums and spacing them the proper distance apart, I placed a stainless steel table between them. The entire length of the 2-in.-wide paper tape on which I intended to record would be wound around the feeder drum. The end of the tape would be pulled across the table and attached to the drive drum with a small piece of masking tape. The table was designed so that it could be raised and lowered to adjust the pressure of the pen on the tape. To one end of the drive drum shaft I fastened a crank device made from the minute hand of an electric clock. The electric clock would rotate the drive drum as its minute hand came in contact with the crank I had mounted on the drive shaft.

To make my recording tape, I cut some tracing paper into 2-in.-wide strips and glued the ends together, until I had a strip of tape long enough to last twelve hours. As I glued the paper strips together, I marked the hours on the tape at intervals that I had determined experimentally.

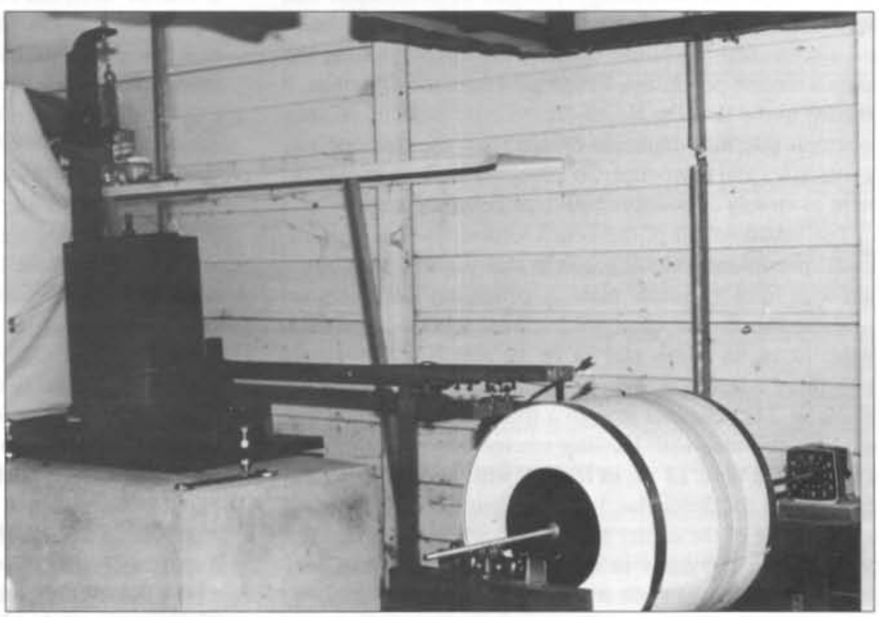
In 1963, my wife and I visited Lassen Park, California, where I was able to view a working seismograph for the first time. Two mechanical seismographs of Bosch-Omori type were operating in the visitor center, monitoring Mount Lassen and recording on smoked paper. No one was allowed in the vault where the instruments were set up, but they could be observed through a window. I was able to see enough to realize that although I was on the right track, important changes would have to be made in my own instrument.

I continued to use the instrument I had built in 1962 until 1967, when we bought property southeast of Creswell, Oregon. During the five-year period while we lived in Eugene, I recorded several earthquakes and was very happy with the results—but the Alaska quake of 1964 was something else! During this earthquake, my pen swung several inches off the recording tape on both sides. I knew then that the only practical way to record was on a rotating drum 10 in. or more in length. Another problem in trying to record on tape was the time element. As the tape built up on the drive drum, its speed increased, making the time inaccurate. The pendulum also was not a good design. It was not like the pendulum on the instruments I had observed at Lassen Park.

My instrument remained stored away for a number of years, while I searched for a suitable place to set it up again. I was looking for bedrock, because I was convinced that it is the ideal foundation for a seismograph. Unfortunately, we live on a glacial deposit. The first 16–18 in. of clayey soil down from the surface is filled with subangular rocks with glacial striae on them. I did not find the solid rock I was looking for.

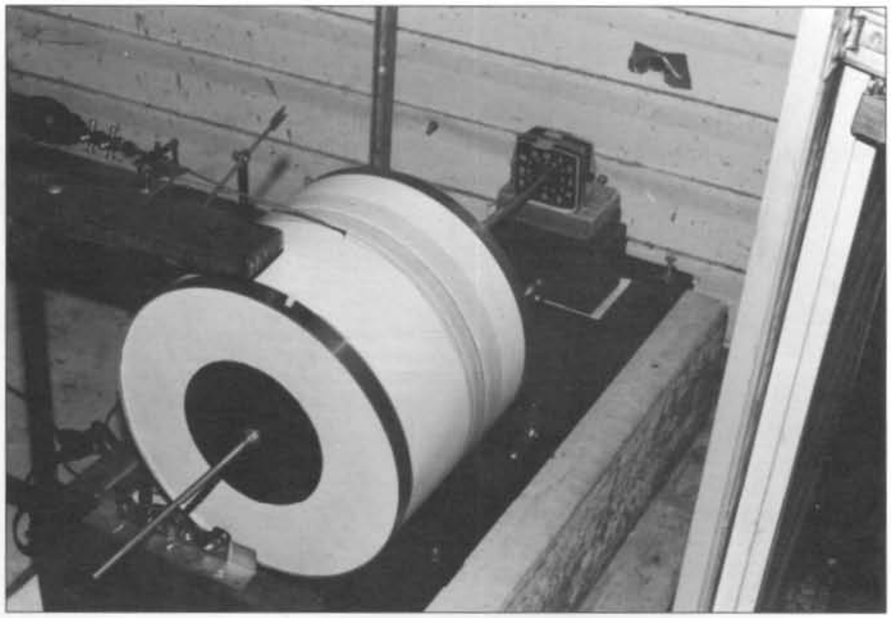
Seven years ago, I decided to remodel my instrument and set it up in the building that houses my water-pressure tank. This building had a concrete floor, which provided a fairly good foundation for my seismograph.

The two instruments I had observed operating at Lassen Park used a cylinder filled with lead discs for a pendulum. I purchased a pipe 12 in. long and 9 in. in diameter from a scrap dealer. To the bottom of the pipe I welded a 9-in. piece of 2-in.-wide flat steel with a ½-in. hole drilled in the center. Another piece of flat steel of the same dimension and with the same hole in the center would be used on top



Complete seismograph assembly.

of the cylinder. A ½-in. machine bolt was inserted in the hole of the bottom steel strap and welded in place. Lead discs were cast with a ½-in. hole in the center and lowered down over the machine bolt to rest on the flat steel strap welded across the bottom of the cylinder. Finally, the steel strap for the top of the cylinder was put in place and tightened down to hold the lead discs firmly in place. When I added the boom and short pivot rod to the cylinder, I had a pendulum like the ones I had observed at Lassen Park. I used the same setup as before to suspend this pendulum.



Closeup of recording section of seismograph.

Next, I turned my attention to the problem of building a recording drum. I did not know how to build a drum, and I was sure the cost of purchasing one would be prohibitive. By this time I was retired. Retirement income does not leave much money to spend on hobbies.

At a local craft store I found two styrofoam discs, 12 in. in diameter and 1 in. thick. They appeared to be perfectly round, but I needed to find the center of the discs. So, with my compass I drew circles on four pieces of poster card (thin cardboard), cut them out, and glued one to each side of the styrofoam discs. I now had the center of the discs. It seemed that a ⁵⁄₁₆-in.-diameter shaft would be about the right size. In a hardware store I found a ⁵⁄₁₆-in. threaded rod, 36 in. long. After drilling a ⁵⁄₁₆-in. hole in each of the discs, I slipped them on the shaft, spacing them the distance that I wanted the length of my drum to be (10 in.), and then secured each disc with a nut and washer on each side. I purchased a piece of sheet aluminum 10 in. wide and 38 in. long. The dealer was kind enough to roll it for me, without charge, to cylinder with a 12-in. diameter. When I slipped the shaft with its styrofoam discs through the cylinder of rolled aluminum and taped the ends of the aluminum tightly together, I had a recording drum.

The next problem that puzzled me for some time was how to rotate the drum? I knew that in order for the clock to turn the drum, the drum would have to be rotated on knife-edge wheels so as to eliminate as much friction as possible. I did not have the faintest idea where one would get knife-edge wheels, except to have a machinist make them; and I was sure the expense of this would be outside a retirement budget.

One day, my wife and I were shopping in a Fred Meyer store, when I noticed some ordinary kitchen can openers on display in the household department. Instantly, I knew I had found my knife-edge wheels! I modified the frames of the four can openers I purchased and moved the wheels to the end of each frame. Then I mounted two of the frames to a piece of 1-in. aluminum angle, so that the wheels were opposed to each other, repeated this procedure on another piece of aluminum angle, and placed the pieces on each side of the frame I had built for the recording drum. The threaded shaft then rested on the knife-edge wheels, and the knife edge of each wheel ran in the threads of the shaft.

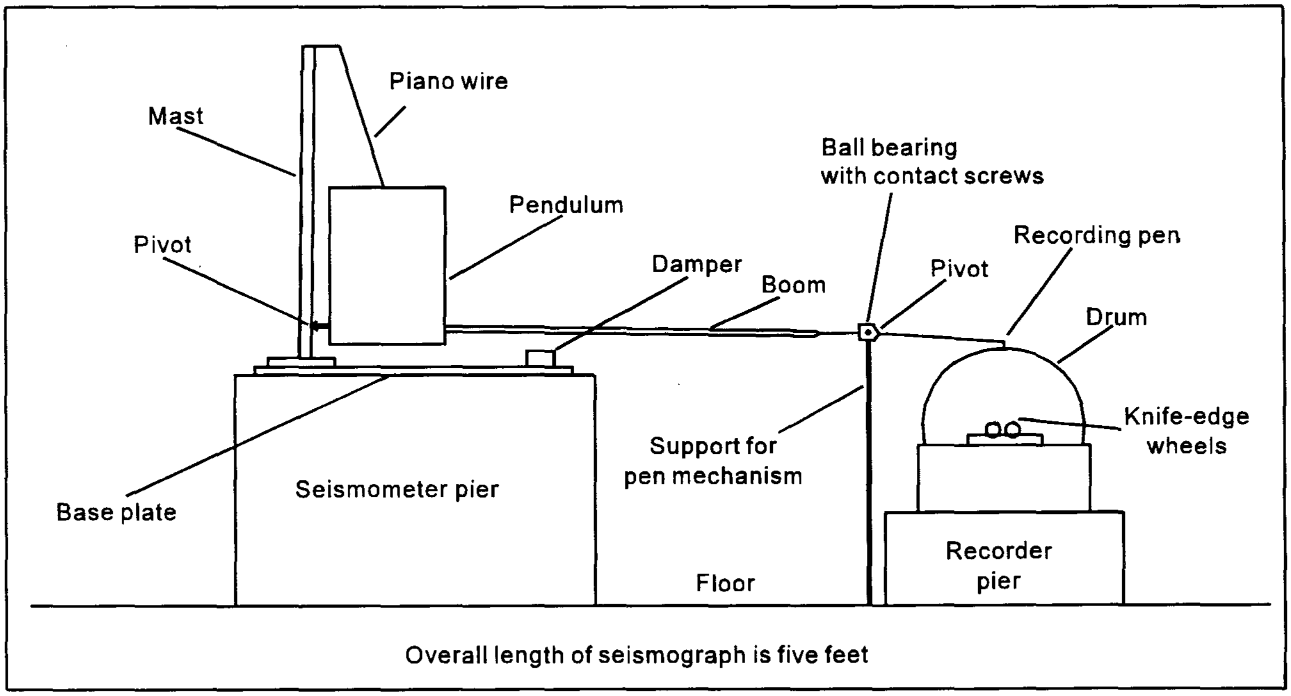
This arrangement not only held friction to a minimum but also provided the necessary "translation" of the drum (movement of the drum along its axis): With each revolution, the drum was moved sideways by the width of the shaft's thread, always providing clear paper for the trace of the recording pen.

A final problem was to connect the drum shaft to the minute hand of the clock. I fashioned a sleeve from a length of aluminum tubing with a slot running almost the entire length of the sleeve and a notch cut in the end of the sleeve to fit on each side of the minute hand of the clock. I inserted a small brass pin in the drum shaft near the end. When I slipped the sleeve onto the shaft, the pin followed the horizontal slot, allowing the drum to move as it was rotated by the clock. All of the recorder parts were mounted on a steel plate with leveling screws, and then the assembly was placed on a concrete pier about 8 in. in height.

I record on roll copy paper, 8½ in. in width. I now use a pen like the ones used on recording barometers. The pen made from the hypodermic needle clogged too easily. I use standard recorder ink, and my instrument operates 24 hours a day, 7 days a week.

Having constructed another drum like the first one, I now have a replacement drum ready when space runs out on the one in operation. I change drums every three days.

I have amplified the pendulum's movements more than



Schematic representation of seismograph built by John Rhudy.

200 times. With such relatively low amplification, my seismograph would be classified as a strong-motion instrument. However, I am pleased with the results. Of the numerous earthquakes my seismograph registered, I want to mention only a few that gave me particular satisfaction:

I recorded the Landers, California, earthquake on June 28, 1992, which had a magnitude of 7.5. This earthquake occurred 800 mi from my location. Several quakes from the Gorda Ridge area off the coast of California were recorded as well. At least two earthquakes were recorded from the Eureka, California, area. I obtained a beautiful record of the earthquake at Scotts Mills, Oregon, on March 25, 1993, with a magnitude of 5.4 to 5.7. I recorded both sister shocks and one strong aftershock of the earthquake at Klamath Falls, Oregon, on September 17, 1993, and another aftershock on December 4, 1993, with a magnitude of 5.2. I was even fortunate enough to watch the instrument in operation while receiving one of the strong sister shocks from the Klamath Falls earthquakes on September 17, 1993.

I have encountered some problems involved with keeping the instrument in continuous operation. Heavy rains will cause the pen to drift, probably due to saturation of the subsoil beneath the seismometer pier. Evidently, this causes the mast to tilt, which results in a slight swing of the pendulum. I believe this problem can be corrected with better drainage. The seismometer is extremely sensitive to the temperature differential between day and night, particularly during the summer months. When these deviations occur, the pendulum must be readjusted. I accomplish this maneuver with one of the leveling screws on the mast base.

I have other hobbies but none quite as satisfying as amateur seismology. □

Museum guide available in new edition

The *Pocket Guide to Oregon Museums* has been published in a new edition accurate as of April 1995. It lists more than 130 museums all over the state. The list is alphabetical by city, and the cities are keyed to a map.

The brochures are available at the Nature of the Northwest Information Center and the DOGAMI field offices.

Amateur paleontologists invited

The Northwest Museum of Natural History Association will be conducting investigations of fossil vertebrate mammal faunas in Baker and Malheur Counties this coming month, August 3–23. The investigations will be led by Dr. David Taylor. People interested in paleontological work are invited to participate. Information about details of the program are available from the Museum office at (503) 725-5900 or Dr. Taylor at (503) 297-7415.

PSU honors geology educator Allen

John Eliot Allen, professor emeritus of geology at Portland State University, received a Presidential Citation from PSU President Judith A. Ramaley at the university's spring commencement. He was honored for his "outstanding service and dedication" to the university.

(Continued on page 94, Allen)

Outstanding reclamation by mine operators recognized

The Mined Land Reclamation (MLR) program of the Oregon Department of Geology and Mineral Industries presented reclamation awards at the annual meeting of the Oregon Concrete and Aggregate Producers Association (OCAPA) on May 20 in Seaside.

By law, most Oregon mines must be reclaimed to a second beneficial use after mining. During mining, they must be operated in such a way that they comply with the requirements of their permits. Each year, the MLR program of the Oregon Department of Geology and Mineral Industries recognizes operators that perform outstanding reclamation, sometimes voluntarily and beyond the requirements of their permits, sometimes through innovative approaches to reclamation.

The awards selection committee consisted of Dorian Kuper, David Newton Associates, Portland; Bill Levens, LTM (Lininger Tru-Mix), Medford; David Haight, Oregon Department of Fish and Wildlife, Central Point; Diane Stone, Linn County Planning Department, Albany; and Cole Gardiner, Oregon Trout, Portland.

Categories of awards and winners are as follows:

Outstanding Operator Award—Ellendale quarries, Valley Concrete and Gravel Company, Inc.: Another owner began mining this site, which consists of two quarries, in 1956. When Valley Concrete assumed ownership of the quarries in 1993, the site was in disarray. The new owners, however, rapidly solved existing problems, such as runoff of waste water into nearby Ellendale Creek and an accumulation of oversize rock produced by poor blasting practices. Valley Concrete quickly broke down the oversize material, reshaped the floor of the upper quarry to improve drainage, redirected storm water so none of it flows into Ellendale Creek, and improved blasting techniques so that neighbors no longer complain of noise or vibration.

Outstanding Reclamation Award—Oil-Dri Production Company: Oil-Dri changed its mining plan approximately three years ago so that mined land is now reclaimed while mining is still occurring elsewhere in the operation. Topsoil and overburden are hauled directly to areas where mining has been completed, which reduces the amount of disturbed soil at the site, increases species diversity by using residual seed already in the soil, and saves money and time otherwise spent in double handling of the material. Oil-Dri has chosen to revegetate the site with a mix of native seeds costing $80/acre, whereas revegetation is normally done with crested wheatgrass seed that costs only $12/acre. The company also changed the original design of a waste-water pond so that it now has islands and an irregular shoreline to attract waterfowl. Finally, Oil-Dri has given the U.S. Bureau of Land Management a $17,500 grant to analyze and salvage nearby archeological sites.

Good Neighbor Award—Farmington quarry of Baker Rock: This hard-rock quarry has been in operation since 1956. When it originally began operating, few houses were nearby, but as the quarry is near Beaverton, residential housing has gradually spread up to the permit boundary. To minimize the effect of mining on their new neighbors, Baker Rock now meets with all people thinking of buying property adjacent to the Farmington quarry, showing them the quarry and explaining the operation. The company also negotiates and pays for a noise and dust easement for new houses in the area. This "good neighbor policy" has minimized fears and concerns of neighbors and has given potential property buyers the information they need to make informed decisions about their home purchases.

Outstanding Reclamation by a Government Agency—Yaquina Head, lower quarry, Salem District of the Bureau of Land Management (BLM): In 1980, BLM was given responsibility of reclaiming two large rock quarries located at the Yaquina Head Outstanding Natural Area located 3 mi north of Newport. The seawall keeping the ocean

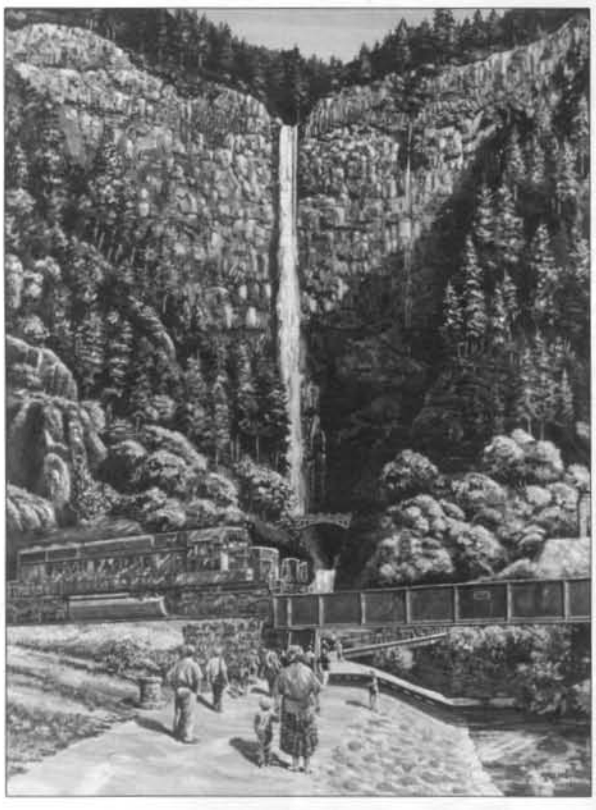
Quarry Cove tide pools, the outstanding reclamation project of the U.S. Bureau of Land Management at Yaquina Head, on opening day, Sept. 23, 1994.

out of the lower quarry was gradually removed, and the abandoned quarry was converted to a rocky intertidal area with tide pools, rock outcrops, and surge channels. A gently sloping pathway now allows visitors, including those with mobility impairments, to pass through the intertidal area. The upper quarry was converted into a parking area. A rich community of organisms characteristic of the Pacific Northwest is rapidly developing in the lower quarry, which saw almost 20,000 visitors by Nov. 1, 1994.

Exploration Award—Jessie Page quarry, MK Gold Company: This site, which is in a relatively remote location 45 mi southwest of Vale and west of the Owyhee Reservoir, has been successfully reclaimed to the pre-exploration topography. Revegetation has been accomplished, and reshaping of the topography has been done in a manner that prevents erosion by rain and snow. Over time, slight differences between the vegetation on the reclaimed roads and surrounding rangeland will disappear. □

Columbia Gorge art to be on display

Mike Kelly, technical illustrator and artist from Portland, will exhibit paintings and drawings of the Columbia Gorge starting August 5 at the Indian Heaven Art Gallery, 280 SW Second Street, Stevenson, Washington. Kelly, who is an avid outdoorsman with a serious interest in geology, focuses on geologic details as he produces his drawings and paintings. His work as technical illustrator with Portland geotechnical firms has provided him with the foundation, interpretive skills, and patience necessary for his brand of representational art.



Multnomah Falls, by Mike Kelly

Kelly's artwork will be on display through September 5. Hours at the Indian Heaven Art Gallery are from 10:30 a.m. to 5:30 p.m., Monday through Saturday, and from noon until 4:00 p.m. on Sunday. The gallery's phone number is (509) 427-7754. □

DOGAMI PUBLICATIONS

Relative earthquake hazards now mapped for Mount Tabor quadrangle

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released *Relative Earthquake Hazard Map of the Mount Tabor Quadrangle, Multnomah County, Oregon, and Clark County, Washington*. This map is now available as DOGAMI map GMS-89 for the price of $10.

The new publication is the first full-color earthquake hazard map of the Portland metropolitan area that combines four maps on one sheet: A large-scale map (1:24,000, map size approximately 16×23 in.) depicts the relative earthquake hazard in a manner that assists nongeologic and nonengineering users in working more effectively toward reducing the risk to life and property through planning policy and mitigation measures. Three smaller maps (1:55,000, map size approximately 7×10 in.) depict the single hazards of ground motion amplification, liquefaction, and slope instability that were combined in developing the larger, composite hazard map. The single-hazard maps assist users in identifying the specific sources of hazards at a given site.

The Mount Tabor quadrangle covers an area bounded, roughly, on the west by 37th Avenue, on the north by Mill Plain Boulevard in Vancouver, Clark County, Washington, on the east by 155th Avenue (SE Fisher Road in Clark County), and on the south by SE Division Street. It is situated adjacent to the eastern edge of the Portland quadrangle, for which similar maps were published earlier: the composite relative hazard map by Metro/DOGAMI and the single-hazard maps by DOGAMI (GMS-79). DOGAMI map GMS-79 also includes a text that explains in technical detail how the various maps were developed.

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

The Diamond Lake fireball of March 28, 1994

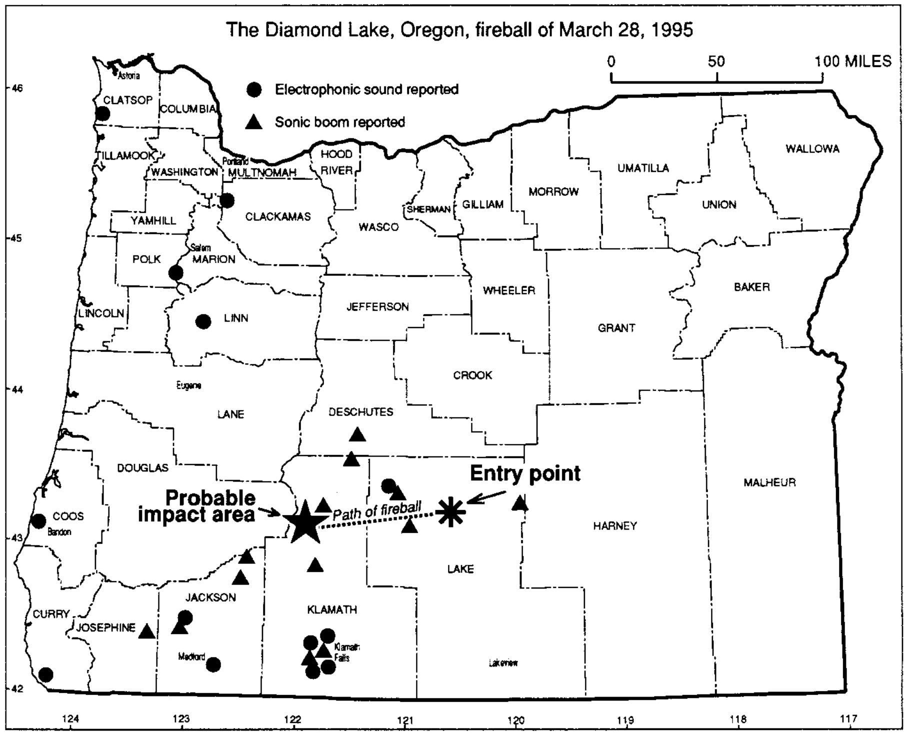
by Richard N. Pugh, Science Department, Cleveland High School, Portland, Oregon 97202

The following report is the result of interviews with more than 150 people who saw, heard, or felt the event.

The fireball occurred at 9:16 p.m. PST, March 28, 1994. It was seen from Goldendale, Washington, lat 45°49'N., long 120°49'W., in the north to Reno, Nevada, lat 39°32'N., long 119°49'W. in the south and from Wagontire, Oregon, lat 43°15'N., long 119°52'W., in the east to Bandon, lat 43°07'N., long 124°24'W., in the west.

The fireball entered the atmosphere just south of Bunchgrass Butte, lat 43°23'N., long 120°34'W., 5 mi east of Christmas Valley, Lake County, Oregon. The end point of the fireball was 5 mi east of the north end of Diamond Lake, near Mount Thielsen, lat 43°09'N., long 122°04'W., in Douglas County, Oregon.

The angle of descent was about 30°, steepening to near-vertical when the fireball extinguished.



Map showing locations of fireball event and reported sounds.

The duration of the fireball was 5–6 seconds. Most people reported a fireball from one to five times the diameter of a full moon. The brightness was reported as brighter than a full moon to too bright to look at, the shape as round to teardrop with a long tail. As the fireball slowed down in the atmosphere, the color changed from blue-white to green to yellow ending with orange and red just before it exploded. The tail was mostly yellow-white. Sparks and flames were seen in the tail, which appeared to be twisted.

The fireball exploded up to three times near the end of its path, producing at least twenty fragments. There were several reports of "black objects" that came out of the last flash. Sonic booms were heard from Arrow Gap (near North Lake School/Silver Lake) and Hole-in-the-Ground in Lake County to Prospect and Union Creek in Jackson County. Some of the booms were so heavy that they shook houses. There were many reports of electrophonic sound (sound heard at the same time the fireball was seen). These sounds were reported as popping, snapping, squealing, swishing, crackling, and whirring sounds. In most cases, the people who heard these sounds were standing near a truck, wire fence, or other metal object. Three people reported the hair on the back of the neck stood up, while one person reported she felt pressure on her body. There was one report of a radar detector in an automobile that was set off by the fireball. There were several reports of birds that stopped singing, coyotes that stopped howling, and dogs and cats running into their houses.

It is interesting to note that sonic booms were heard at a maximum distance of 165 km away, whereas electronic sound was heard as far as 385 km away. This is a very long distance for electrophonic sound to be detected.

Electrophonic sound is produced at high altitude in the turbulence behind the fireball. Very low frequency (VLF) electromagnetic energy excites sounds in nearby objects, producing acoustic waves (Keay, 1980; Keay and Ceplecha, 1994).

It is believed that this fireball produced meteorites in the area northeast of Diamond Lake. The meteorites would be black or brown stony objects, ranging in size from marbles to basketballs and with a thin black fusion coating.

REFERENCES CITED

Keay, C.S., 1980, Anomalous sounds from the entry of meteor fireballs: Science, v. 210 (October 3, 1980), p. 11–15.

Keay, C.S., and Ceplecha, Z., 1994, Rate of observation of electrophonic meteor fireballs: Journal of Geophysical Research, v. 99, no. E6, p. 13163–13165. □

In memoriam: Carol Brookhyser

Carol S. Brookhyser, retired staff member of the Oregon Department of Geology and Mineral Industries (DOGAMI), died June 21 at age 74.

She worked with DOGAMI as an editor and librarian from 1971 through 1976. Her many contributions to the Department's efforts in communicating geology to the citizens of Oregon are still well remembered by those who worked with her. In 1973, she participated in the compilation of DOGAMI Bulletin 78, a major bibliography of the geology and mineral resources of Oregon.

Mrs. Brookhyser was born October 25, 1920, in Timber Lake, South Dakota as Carol Schlonga. She married Robert Brookhyser on June 22, 1947.

Survivors are her son Donald of Las Vegas, her daughter Ann Eichelberg of Portland, her brother Richard Schlonga of Vancouver, Washington, her sister Charlotte Rivell of Ormond Beach, Florida, and five grandchildren.

Donations in her memory may be given to the Habitat for Humanity, Planned Parenthood, or the Resurrection Lutheran Church Memorial Fund. □

NESTA offers tools and opportunities for teachers

The National Earth Science Teachers Association (NESTA) was chartered in April 1982 to promote, extend, and support earth science education and offers membership to anyone interested in earth science education. NESTA is divided into ten regions and elects a Regional Director for each region. For the Pacific Northwest, a new Regional Director will be elected during May 1995. Each state also has a State Contact Person who is responsible for promoting earth science at science teacher meetings and for maintaining contact among the state's NESTA members. Oregon's State Contact Person is Michael Goodrich, who teaches earth sciences at Lake Oswego High School. His address is 42 Churchill Downs, Lake Oswego, OR 97035, phone (503) 635-5123, and internet msgneiss@aol.com.

NESTA conducts a membership meeting as well as a Board of Directors meeting each year at the NSTA national convention. NESTA coordinates Share-a-thons at all NSTA meetings. NESTA members demonstrate of their favorite activities at Share-a-thons. One of the most popular sessions at the conventions, Share-a-thons draw a large number of the convention attendees. A second NESTA session at NSTA meetings is the Rock Swap and Coffee Social Hour. NESTA members and other supporters donate quality rock and mineral specimens which are raffled off during the session. NESTA Rock Swap attendees at the 1995 NSTA Philadelphia meeting took home over 100 specimens along with several boxes of free samples.

NESTA's publication, *The Earth Scientist*, is published four times a year with a special "Summer School Opportunities for Teachers" issue. Each issue of *The Earth Scientist* contains a topical theme along with association news, reviews, and teaching tips. The summer school issue is a compilation of a geoscience department survey reporting summer school opportunities. In addition to journal publications, NESTA markets scripted slide sets that have been developed by NESTA members. The slides sets range in size from 10 to 30 slides and include a number of subjects of interest to the earth science teacher.

NESTA sponsors summer field trips coordinated by NESTA members. Past trips have traveled to the Southwest, Great Lakes, Yellowstone, and the Grand Canyon among other locations. Trip guidebooks, special tours, and college credit are available, and families are encouraged to attend when appropriate. New field trip locations are being sought. For information on how to develop a NESTA field trip, contact NESTA's Executive Advisor (address below). NESTA is currently developing a National Summer Field Conference series that will be inaugurated during the summer of 1996. The summer field conference will encourage family participation in a week-long summer vacation excursion. The conference will include sessions with contributed papers, speakers, field trips, family-oriented activities, and exhibits.

For further information about NESTA contact: Dr. M. Frank Watt Ireton, NESTA Executive Advisor, 2000 Florida Avenue NW, Washington, DC 20009, phone (202)-462-6910 ext. 243, internet fireton@kosmos.agu.org. □

*(**Allen**, continued from page 90)*

Allen began his professional career in 1935 as a park ranger/naturalist at Crater Lake National Park. He was part of the beginnings of the Oregon Department of Geology and Mineral Industries and served on its staff for nearly a decade. He also guided the early steps of the PSU geology department, serving as its head for 18 years. In 1972, the National Association of Geology Teachers honored him for his teaching with the Neil Miner Award.

Since retiring 22 years ago, he has concentrated his writing about geology on the lay reader. He authored or coauthored books about the Columbia Gorge (*The Magnificent Gateway*, 1979; and *Cataclysms on the Columbia*, 1986)* —an area he had studied first for his master's degree in 1932. In the 1980s he wrote more than 200 articles on Northwest geology for *The Oregonian* in a weekly column called "Time Travel." He has authored and contributed to numerous DOGAMI publications and is still an ardent contributor to *Oregon Geology*.

We are glad to see John Eliot Allen honored in this way and congratulate him sincerely.

*Allen, J.E., 1979, The magnificent gateway. A layman's guide to the geology of the Columbia River Gorge: Forest Grove, Oreg., Timber Press, 144 p.

Allen, J.E., Burns, M., and Sargent, S.C., 1986, Cataclysms on the Columbia. A layman's guide to the features produced by the catastrophic Bretz floods in the Pacific Northwest: Portland, Oreg., Timber Press, 211 p. □

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City/State/Zip________________________________

Please charge to Visa__ / Mastercard__, account number: ____________________

Expiration date: ____________________

Cardholder's signature____________________