O'Connor et al, 1995b

Beyond the Channeled Scabland

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

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

INTRODUCTION

Field trip route

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

Field trip guide organization and units

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

Guide responsibility

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

THE MISSOULA FLOODS

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

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

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

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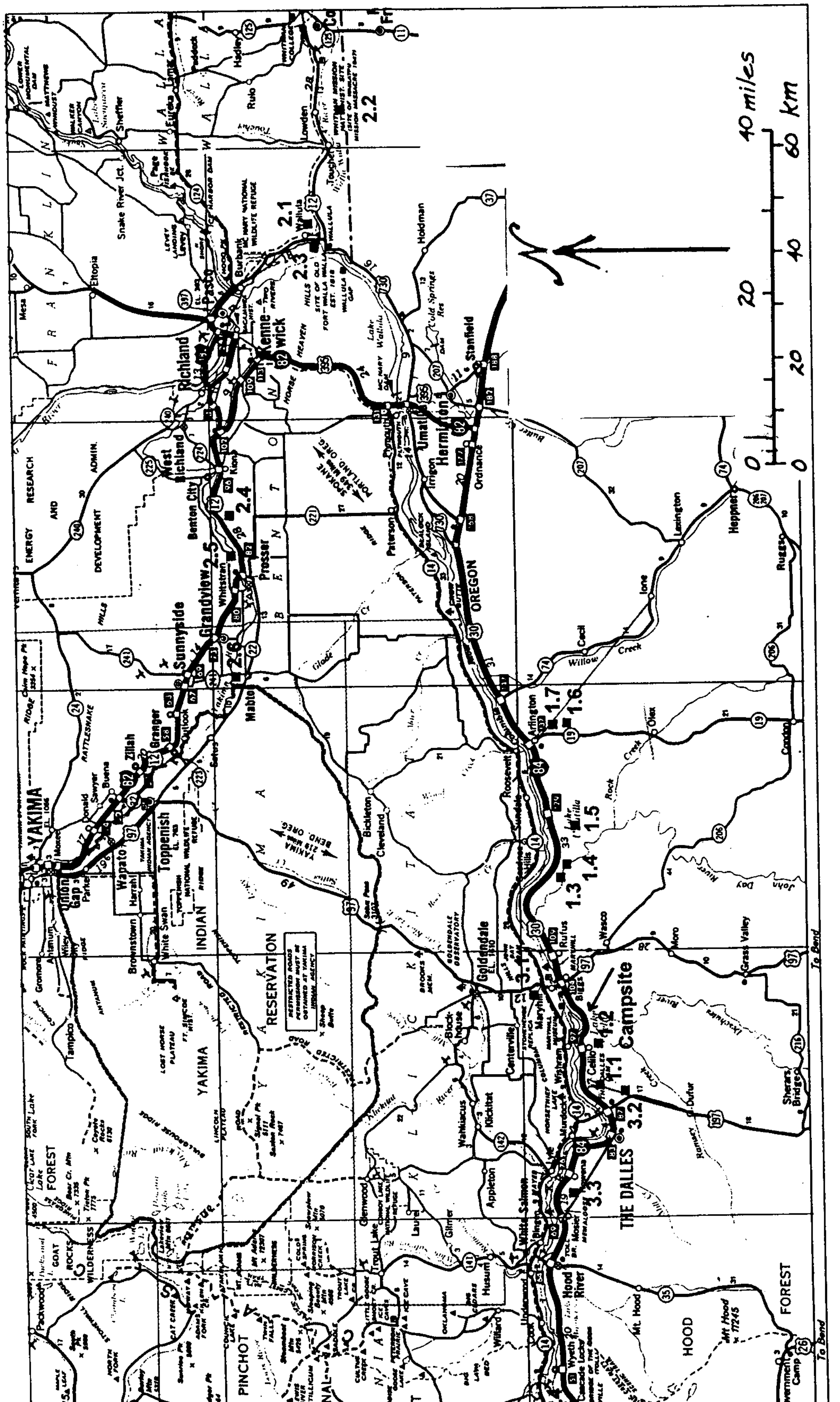

Figure 1. Road map showing approximate locations of field trip stops.

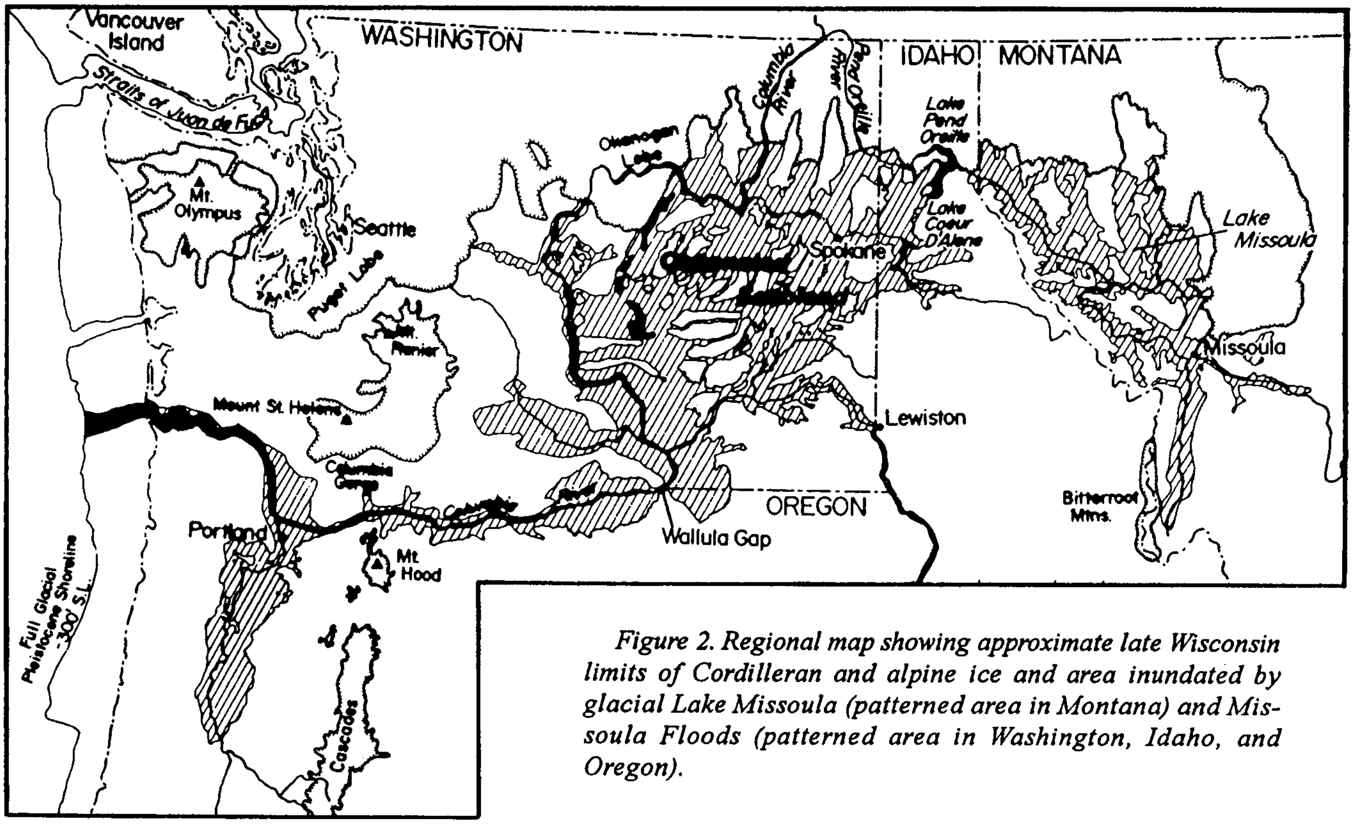

Figure 2. Regional map showing approximate late Wisconsin limits of Cordilleran and alpine ice and area inundated by glacial Lake Missoula (patterned area in Montana) and Missoula Floods (patterned area in Washington, Idaho, and Oregon).

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

BEYOND THE CHANNELED SCABLAND

Early studies of the Columbia River valley

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

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

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

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

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

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

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

Recent work in the Columbia River Gorge

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

Flood hydraulics and hydrology

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

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

Radiocarbon dating and flood chronology in the Columbia River valley

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

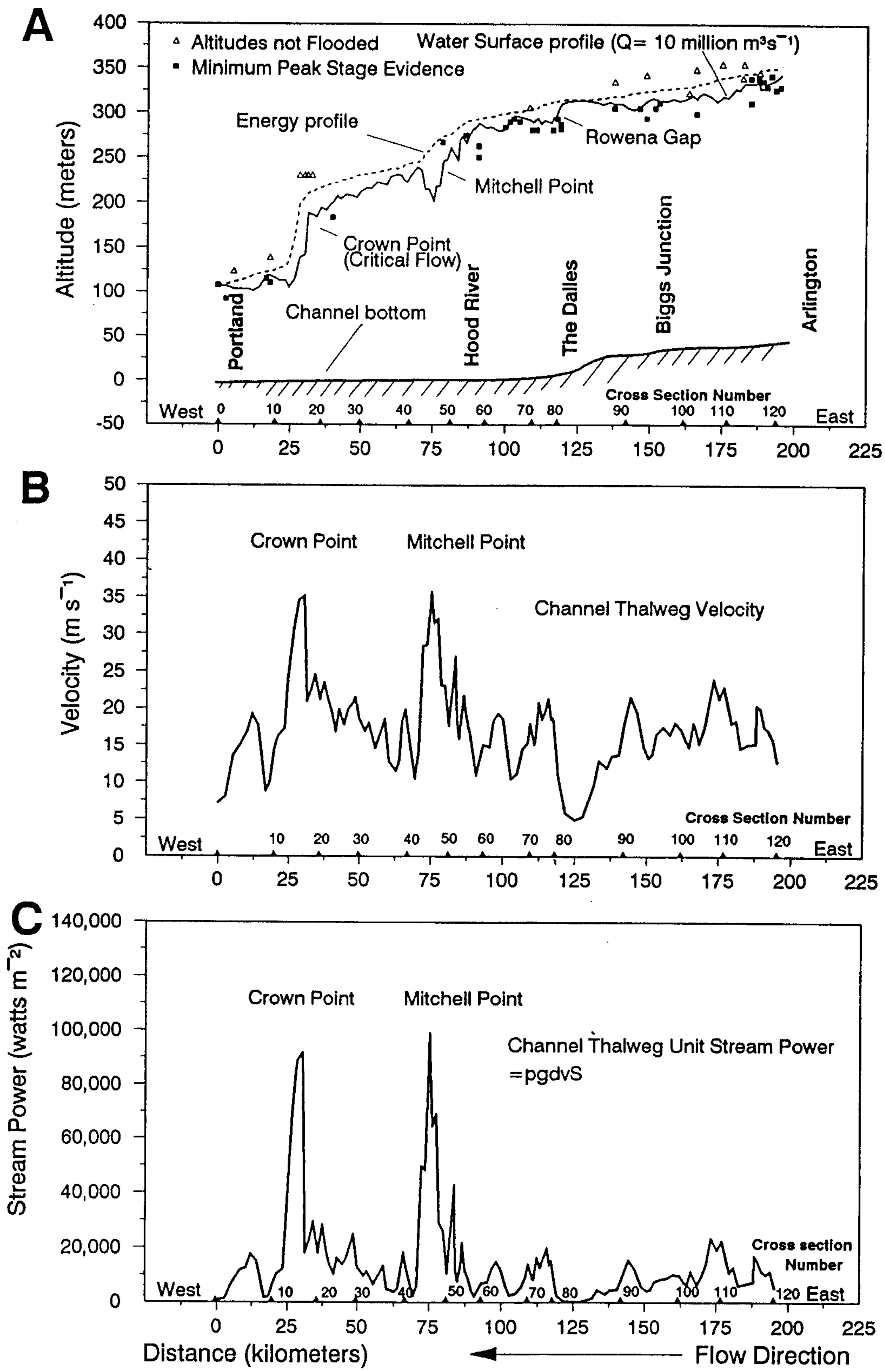

Figure 3. Profiles of calculated hydraulic conditions between Portland and Arlington. All profiles determined on the basis of step-backwater calculations for a 10 million m³/s discharge for 120 cross sections. A: Water-surface and energy-surface profiles (and field evidence of maximum flood stages). B: Channel velocity. C: Unit area stream power.

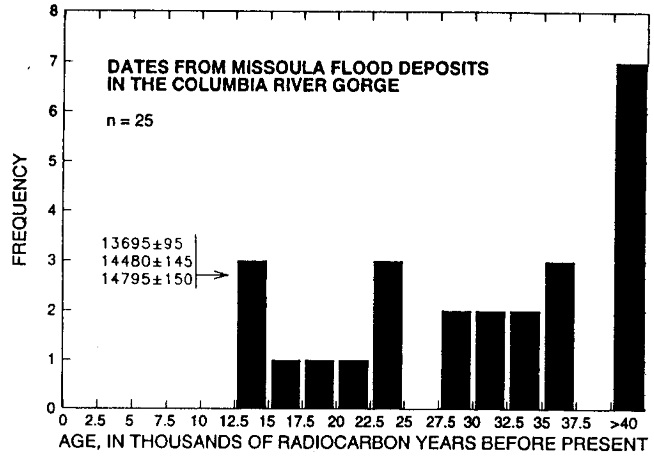

Figure 4. Histogram of radiocarbon ages from samples collected (by Benito and O'Connor) from within or below Missoula flood deposits. All samples were collected between Hood River and Arlington, and most were from high-altitude gravel bars. We emphasize that all of these ages are maximum limiting ages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

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

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

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

THE QUESTION OF REPEATED GIANT LATE-WISCONSIN FLOODS

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

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

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

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

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

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

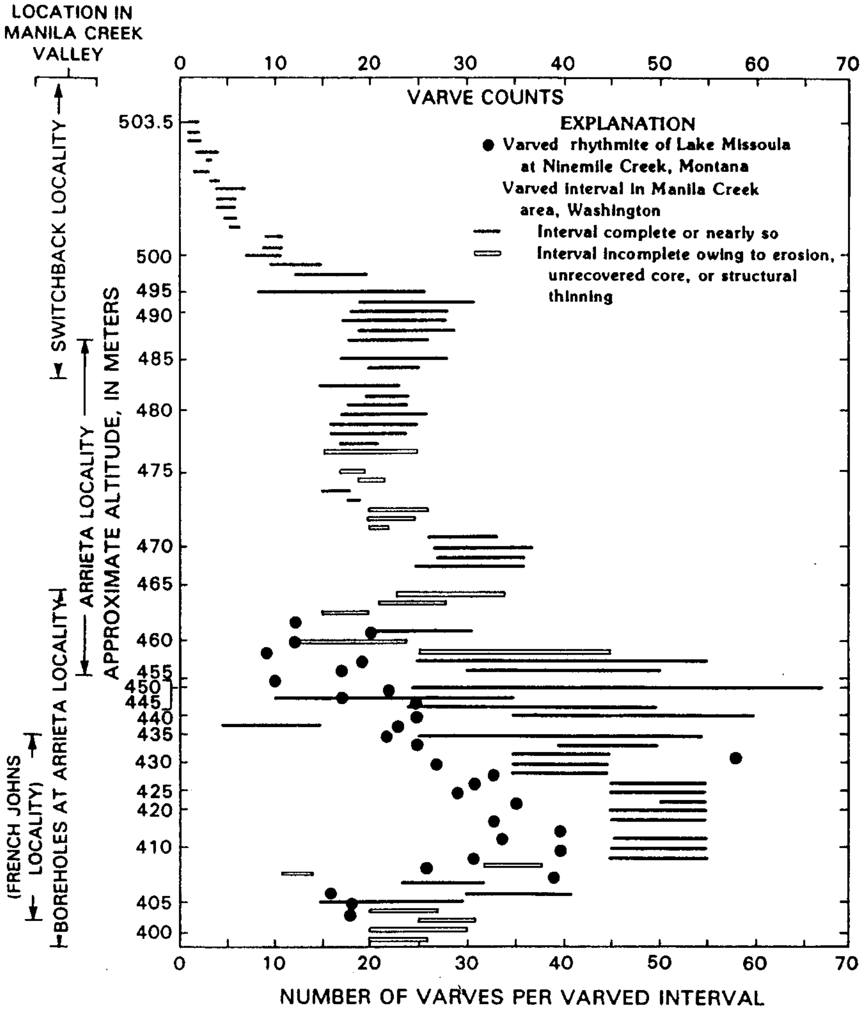

Figure 5. Data on varves (of glacial Lake Columbia) interbedded between 89 beds laid by Missoula floods, at the composite section at Manila Creek, Sanpoil valley, northern Washington (from Atwater, 1986, Figure 17). The bar range of a varve bed reflects the difference between a stingy count (dubious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

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

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

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

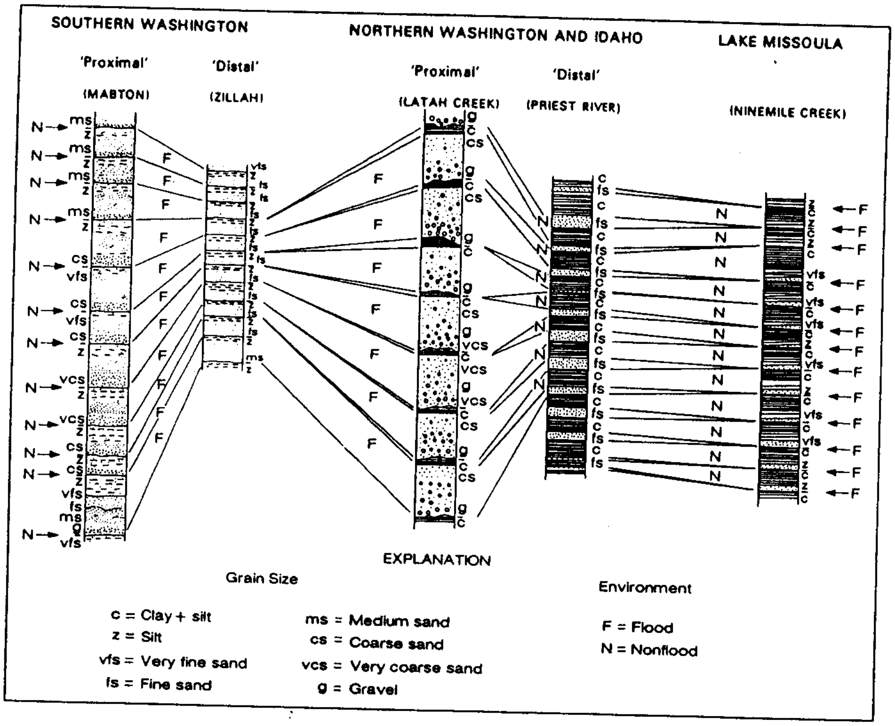

Figure 6. Inferred relations between flood rhythmites in southern Washington, flood rhythmites interbedded with varved glacial-lake deposits in northern Washington and Idaho, and rhythmic and varved glacial Lake Missoula sediments in western Montana. From Waitt (1985b, Figure 17).

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

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

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

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

We regret!

A slight computer "glitch" around the end of 1994 caused us to lose temporarily some of your addresses. We apologize sincerely!

If you missed your January issue of *Oregon Geology*, please let us know. We shall be glad to send you the missing copy.

DOGAMI PUBLICATIONS

Released March 28, 1995:

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

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

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

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

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

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

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