OREGON GEOLOGY

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DOME BUILDING ON MT. ST. HELENS

ALSO IN THIS ISSUE:

GEOLOGY AND HAZARD RESPONSE PLANS

GLACIAL STRATIGRAPHY AND HISTORY OF THE BLUE RIVER DRAINAGE

CRYSTAL SPRINGS ZONE OF CONTRIBUTION

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OREGON GEOLOGY

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On the Cover

Mount St. Helens new growth, from the north.
USGS Photograph taken on November 29, 2004, by Jim Vallance and Matt Logan.

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FROM THE STATE GEOLOGIST, DR. VICKI S. McCONNELL
Geology and hazard response plans

Although the awakening of Mount St. Helens is not the only geologic activity that has occurred in or near our state in the last year, it certainly created the biggest stir. Why is that? Volcanoes certainly garner a certain amount of curiosity and infamy in general; that attention increases during an eruption. Other events like minor earthquakes or the opening or closing of quarries are not considered front page news.

A more pragmatic reason for the notice associated with Mount St. Helens is the immediate impact of policy decisions made to address the increase in risk—closing of visitor centers and restricting access to areas and roads. If you want the public to notice something, just tell them they can't go there!

The policy decisions made in response to the increased risk of a volcanic eruption from Mount St. Helens were not arbitrary. They resulted from following a decision tree outlined in a coordinated hazard response plan for Mount St. Helens. Response plans for geologic hazards are the logical outcome of a basic part of DOGAMI's mission—to identify and characterize the geology of the state of Oregon.

To me, the development of geologic hazards response plans represents an excellent measure of the success of both our geologic work and our public education programs at DOGAMI. Writing a response plan is done when you have learned of a hazard or threat and you determine there is enough information available to make adequate decisions.

The challenge in preparing any response plan is ensuring that proper organizations are involved in the creation of the plan and that everyone has the necessary information to aid with decision making.

Here in Oregon we have our fair share of geologic hazards to plan for, including our own volcanoes. For example, DOGAMI staff serves as the state geology representative to review and revise the Mount Hood Coordination Plan that is slated to be released early in 2005. If you would like to preview the plan, you may do so from our website, oregongeology.com, and click on the "Earthquakes and other natural hazards" page.

A more challenging volcano response plan involves the threat to the communities and resources in the Central Cascades. From Mount Jefferson to Newberry Volcano there are several volcanoes and volcanic centers, with a wide scale of potentially hazardous types of eruptions and erupted materials. The hazard could impact communities on both sides of the Cascades.

We do much more than volcano response plans. We are assisting coastal communities with their planning for response to tsunami hazards. We research and map the extent of past tsunamis and model where we would expect inundation from a future tsunami. Then we help communities map evacuation routes and develop brochures to explain them to coastal residents and visitors.

Landslides, particularly fast-moving debris flows, are a common winter hazard, and call for a different type of response plan. After several fatalities in 1996-98, a debris flow warning system has been put in place, involving the Oregon Department of Forestry, Oregon Emergency Management, and the National Weather Service. Rainfall is monitored, and when pre-established threshholds are reached, a debris-flow warning may be issued. Part of the response plan includes highway signs notifying travellers entering potentially dangerous areas.

These are only a few of the various types of response plans that DOGAMI has been involved with. Communities, businesses, government agencies, and individuals can all benefit from planning their responses to the many geologic hazards in Oregon.

Our work to expand and refine information about Oregon's geology continues, as does our coordination with other agencies and organizations. Response plans must be updated periodically to reflect current understanding. The more we know about the potential damage from specific geologic hazards, the more we can all use our limited resources more wisely.

MOUNT ST. HELENS UPDATE

BY VICKI S. MCCONNELL

In late September and early October our most active volcano in the Cascade Range gave both geologists and emergency response personnel a real wake up call. Mount St. Helens has entered into a late stage of dome building activity. Although this is a completely normal phase in the life of an active stratovolcano, after several years of negligible activity it seemed quite spectacular.

Beginning on September 22, 2004 seismologists at the US Geologic Survey Cascade Volcano Observatory CVO) noted a marked increase in tiny, shallow earthquakes located under the lava dome. By the next day hundreds of small (less than magnitude 1) earthquakes were occurring and the observatory issued an information statement about it. The earthquakes were so shallow it was not clear if they were actually occurring at the surface and might be associated with Horseshoe glacier that surrounds the dome. By September 26 both the frequency and magnitude of earthquake activity had increased enough that the staff at CVO decided to issue a *Notice of Volcanic Unrest* and the US Forest Service staff closed the flanks of the volcano to hikers and climbers.

The volcano was pressurizing beneath the lava dome in response to fluid migration and there was a good chance a phreatic or phreatomagatic eruption could occur. CVO staff scrambled to emplace additional monitoring instrumentation to capture inflation or deflation, increases in magmatic gases, and increases in the thermal output at the surface. The volcano continued to pressurize as the number of earthquakes increased to 3-4 per minute and as large as M3.3 and uplift of the lava dome was observed. The decision was made to upgrade to alert level 2, a *Volcano Advisory* and scientists forecast a 70% chance of eruption within a month.

At 11:57 am on October 1, 2004 the volcano issued a 24-minute emission of steam and ash from the northern edge of the lava dome near where the inflation was occurring. The system repressurized by late that same day. It was still not clear at that time if the activity was the result of hydrothermal activity interacting with groundwater or if some magma was migrating within the cooling lava vent. Then on Saturday, October 2, the first low-frequency tremor earthquakes were observed and scientists decided magma was indeed migrating. This spurred the decision to upgrade to alert level 3, a *Volcano Alert.* Johnson Ridge Observatory was evacuated. Tremor blasts and observable changes in the crater floor increased over the next several days and on Tuesday, October 5 at 9:00 am, a vigorous steam and ash explosion took place that cleared several small vents. Seismicity dropped off markedly and scientists assumed that the opening of the vents depressurized the system. This allowed magma to be extruded to the surface, to begin a dome-building episode if enough lava were available. The volcano alert was downgraded to alert level 2, a *Volcano Advisory*.

Presently Mount St. Helens continues to extrude lava at the northern edge of the 1980-1986 dome, pushing a spire upwards to over 76 m higher than the dome. This poses some threat of collapse and formation of pyroclastic flows and lahars down drainages. Analysis of bombs collected from the steam and ash emissions indicate the lava is rhyolite. This would be expected if the magma is the cooling product of the 1980-1986 chamber that has been cooling and evolving.

The volcano alert level remains at level 2, *Volcano Advisory;* Johnson Ridge Observatory remains closed, and we watch and wait as the mountain continues to rebuild.

Mount St. Helens crater floor, developing glacier (lower left), dome, and uplift with new growth, as seen from the northeast. Photograph taken on October 21, 2004, by Steve Schilling, USGS.

RESEARCH ARTICLE

Glacial Stratigraphy and History of the Blue River drainage, Lane County, Oregon: A stratigraphic study of glaciolacustrine sediments detailing reverse drainage glacial ice-margin oscillations and subsequent ice-dam failure similar to a small-scale Missoula Flood event.

BY ROBERT A. HOUSTON[1]

Abstract

An alpine glacier originating from the combined western flanks of the North, Middle and South Sister volcanic mounts flowed down the McKenzie River valley and terminated just west of the town of Blue River, Oregon. The glacier advanced into and blocked the Blue River drainage creating a proglacial lake environment, greater than 40,000 years before present. The glacial stratigraphy preserved in the drainage detail two glacial advances and retreats. The complete retreat of the glacier from the Blue River drainage may have occurred as a catastrophic flood event resulting from the glacial ice-dam failure, similar to a small-scale Missoula Flood event. Additionally, organic detritus collected from the glaciolacustrine sediments indicates a wet and cooler climate than the present day interglacial period.

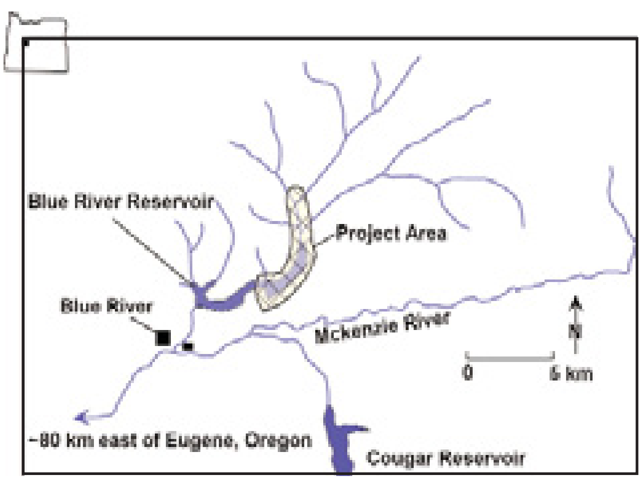

Figure 1. Location map of the Blue River glacial stratigraphy study, approximately 80 km east of Eugene.

[1]Formerly of Northwest Exploration Group, now with the Oregon Department of Geology and Mineral Industries

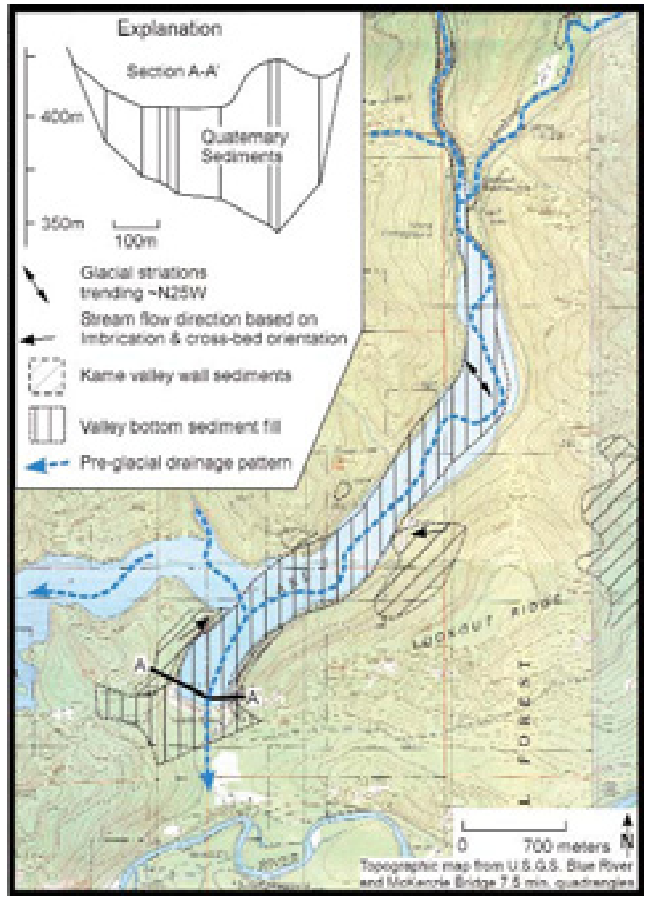

Figure 2. Glacial sediment distribution map showing pre-glacier drainage pattern modified from Swanson and James, 1975.

Introduction

The focus of this paper is to describe the Quaternary stratigraphy and glacial history of the Blue River drainage, Lane County, Oregon (Figure 1). Previous geomorphic and geologic studies in this region included Swanson and James (1975), Walker and Duncan (1989) and Peck and others (1964). Their studies concentrated on the volcanic, glacial, and alluvial histories within the Blue River area. Swanson and James (1975) proposed that the stratigraphy sequence records at least three upstream advances and downstream retreats. However, based on lateral facies changes only two reverse-drainage glacial ice margin advances and retreats are observed in the glaciolacustrine sediments. Additionally, organic detritus collected from the glacial sediments indicates a wet and cool paleo-climatic environment.

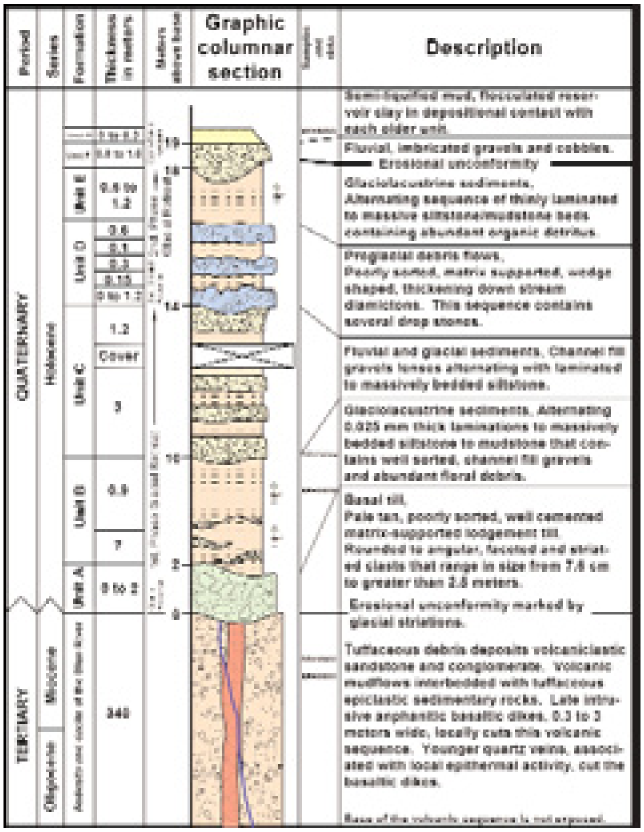

Figure 3. Composite Columnar Section along Blue River drainage, Lane County, Oregon.

Regional Setting

The Western Cascade Range of Oregon is an area of heavily forested, steep, and somewhat unstable terrain (Swanson and James, 1975). The country rock is mainly composed of several thick volcanic sequences that are intruded by small granodiorite and quartz diorite plutonic bodies and smaller basalt dikes.

Based on valley morphology and glacial deposits, the McKenzie River valley was occupied more than 40,000 radiocarbon years ago by an alpine glacier originating from the combined western flanks of the North, Middle, and South Sister volcanic mounts (Swanson and James, 1975). This glacier reached its furthest advance just west of the Town of Blue River. Glacial valley wall deposits mapped by Swanson and James (1975) suggested that the glacier entered the Blue River drainage at two locations (Figure 2). One flow path was through where Saddle Dam is now located and the other through a saddle on Lookout Ridge. Through these locations, the glacier entered and blocked the Blue River drainage and formed a proglacial lake environment. A description and interpretation of these proglacial lake sediments follows.

Stratigraphy

The stratigraphy of the Blue River valley consists of a sequence of glaciolacustrine and fluvial sediments overlying the volcaniclastic deposits (Figure 3).

Volcaniclastic Deposits

The oldest rocks in the study area, evident by lithologic contacts and cross cutting relationships, are andesitic to dacitic mudflow (lahar deposits), massive to bedded fine- to coarse-grained tuffaceous sedimentary rocks, and volcanic conglomerates (Figure 4 & 5). These volcanic units exhibit low-grade metamorphism with primary constituents altered to clay minerals, calcite, zeolite, and secondary silica minerals. Locally, where in contact with larger basaltic dikes, both wallrocks and intrusions are propylitized. This volcanic extrusive unit may equate to the volcanic rocks of the early Western Cascade episode of Priest and others (1983); to the Little Butte Volcanic Series of Peck and others (1964); and equivalent to the volcanic series "Andesite and Dacite of the Blue River," that contains "Tuff of Cougar Reservoir" interbeds, of Priest and others (1988). Sutter, 1978; Fiebelkorn and others, 1983; and Priest and others, 1988 reported that the maximum thickness of this unit is approximately 340 meters and has a K-Ar age of 14.0+0.2 Ma. Within the study area, the basal contact is not exposed.

Intrusive Units

Aphanitic basaltic dikes intrude the older volcaniclastic deposits (Figure 6). These dikes consistently trend NNW-SSE (326 to 330 degrees) and range from 0.3 to greater than 3 meters wide. Vesicles are elongated parallel to the chilled margin. Some vesi-

Figure 4. Matrix supported volcanic mudflow deposit. 15 cm pencil for scale.

Figure 5. Clast-supported volcanic epi-clastic conglomerate in a tuffaceous matrix. The tuffaceous matrix has been weakly chloritized and is cut by veinlets of quartz. The large brownish clast in the center of the picture is 14 cm in diameter.

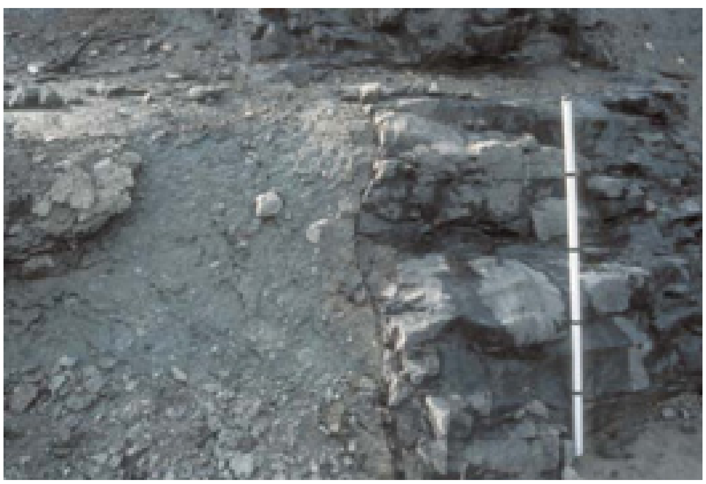

Figure 6. Basaltic dike cutting volcaniclastic mud/debris flow. 1.5 meter staff for scale.

Figure 7. Unit A, poorly sorted, matrix-supported basal till. 1.5 meter staff for scale.

cles are filled with calcite, zeolite, or silica. Priest and others (1988), suggested dike emplacement occurred from 15 to 5 Ma years ago. Both volcaniclastic deposits and dikes are cut by 1 mm to 50 mm wide, barren quartz veins associated with the Blue River District hydrothermal system. The emplacement of the Blue River District granodiorite gave a K-Ar age of 13 Ma years ago (Field, C.W., personal communication, 1998).

Glacial Units

Unit A: Basal Till

Light brown gray (weathered-dry), angular to sub rounded, cobbles to boulders, well-consolidated, matrix supported, unstratified till of Unit A erosional unconformably overlies volcaniclastic deposits. The matrix consists of clay to sand size particles derived by abrasion of the glacier bed and from reworking of pre-existing fine-grained sediments (Figure 7). Clast composition ranges from basaltic to rhyolitic derived from rock exposures in the upper McKenzie River watershed (Figure 8). Large boulders, greater than 2.5 meters in diameter, have faceted and striated surfaces, the result of abrasion (Figure 9).

Unit B: Glaciolacustrine Sediments

A sequence of laminated (parallel to contorted) to massive siltstone and mudstone beds of Unit B conformably overlies Unit A. Additionally, this unit contains minor, well-sorted, channel fill fluvial gravels (Figure 10).

Numerous floral remains were collected from the glaciolacustrine sediments within Unit B. These floral remains include Pine (Pinus) needles (Figure 11), seedpods (Figure 12), plant fragments (possibly moss) (Figure 13), and abundant woody debris (Figure 14). Swanson and James (1975) identified Pacific Yew: Taxus brevifolia; Western Hemlock: Tsuga heterophylla; or Incense Cedar: Librocderus decurrens. The most abundant concentration of floral debris is located in silt/sand ripple troughs. Swanson and James (1975) performed radiocarbon dating methods on wood fragments collected from these glaciolacustrine sediments. These wood fragments gave a radiocarbon age estimate of more than 40,000 years before present (Swanson and James, 1975). A second organic sample collected immediately underlying the glaciofluvial sediments produced an age constraint of greater than 35,500 radiocarbon years before present (Swanson and James, 1975). These floral remains indicate a wetter and cooler climate than that of the present interglaciation period.

Unit C: Fluvial, Open, or Closed System
Conformably overlying and eroding into Unit B, Unit C is an alternating sequence of thinly laminated siltstone/mudstone beds and well-sorted, clast-supported, imbricated fluvial channel fill gravels (Figure 10 & 15). The orientation of imbricated fluvial gravels indicates that the paleo-stream flow direction was down stream, toward the confluence of the Blue River and the McKenzie River valley.

Unit D: Proglacial Debris Flows
Thinly laminated siltstone/mudstone beds alternating with poorly sorted, matrix supported, wedge shaped (thickening down stream toward the ice margin) proglacial debris flows and glaciolacustrine siltstones conformably overlies Unit C (Figures 15). This unit contains glacial drop stones, evident by the soft sediment deformation of the surrounding siltstone/mudstone laminations in contact with cobble to boulder size subangular rocks (Figure 16). The occurrences of glacial drop stones indicate a glacial ice rafting, proximal ice margin environment.

Unit E: Glaciolacustrine Sediments
Laminated to massive alternating siltstone-mudstone sediments of Unit E conformably overlies Unit D. Unit E contains abundant organic detritus.

Fluvial-Reservoir Units

Unit F: Fluvial Open-Drainage
Imbricated fluvial gravels and cobbles deposited on an elevated bench conformably overlies Unit E (Figure 10 and 15). Substantial down cutting of a braided stream environment produced a channelized meandering stream morphology as the stream transitioned from the elevated base line level (high depositional rates of glacial sediments) back to its pre-glacial, bedrock controlled, base level elevation. Reworked fluvial gravels to boulders characterize the active stream channel.

Figure 8. Unit A: Obsidian clast (15 cm pencil for scale), note the internal flow banding.

Figure 9. Faceted and striated boulder, common in the basal till, Unit A and the Saddle Dam area. Elaine and 1.5 meter staff for scale.

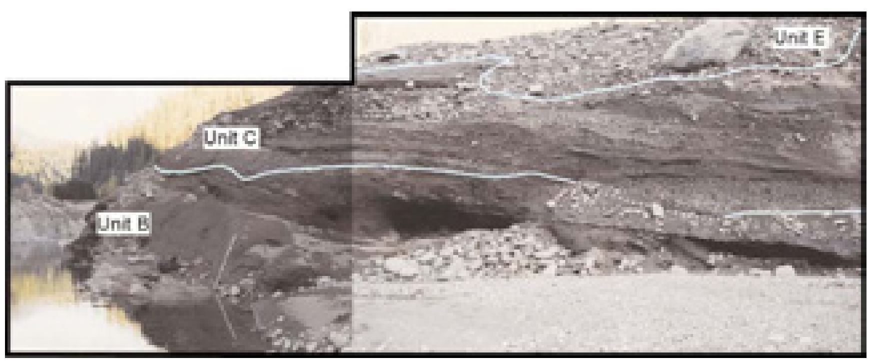

Figure 10. Unit B, glaciolacustrine sediments, thinly laminated to massively bedded siltstone/mudstone alternating sequences. Few channel fill gravels occur in this unit. Unit C, fluvial channel fill gravels are strongly imbricated toward the ice margin, down stream. 1.5 meter staff for scale. Down drainage to the right.

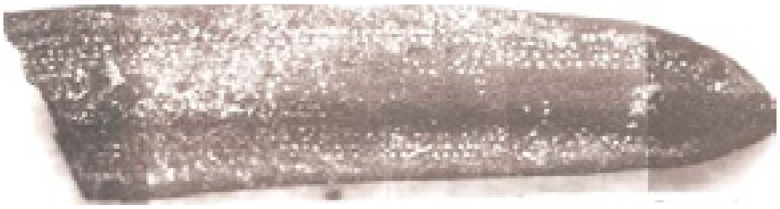

Figure 11. Pine needle (8.5 mm), magnified by 40 times, a wet climate indicator. The white dots are zeolite crystals.

Figure 12. Seedpod (0.89 mm) magnified by 40 times. Two types of seedpods are present in Unit B: one being spherical (shown) and the other is ellipsoidal (not shown).

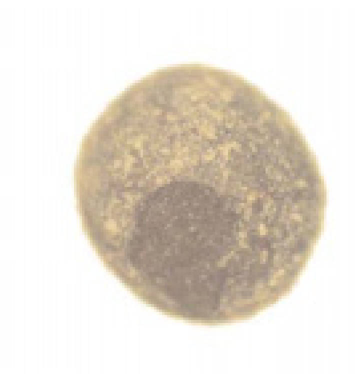

Figure 13. Plant fragment (2.2 mm) magnified by 40 times. Possibly, a fragment of a moss's stem.

Figure 14. Wood fragment (c-axis 5 mm long) magnified by 40 times. The type of wood is presently unknown.

Unit G: Reservoir Clay

Unit F represents a thin (10 to 17 cm) deposit of present day, semi-liquefied, brown (wet) flocculated reservoir clay. This deposit mantels topography and is in contact with all older units in the reservoir ponding area (Figure 17).

Discussion of Glacial History

The distribution of glacial features, glacial deposits, and geomorphic characteristics in upper parts of the Blue River watershed suggests that glaciers of sufficient size did not extend into the map area from typical downstream glacial advances in the Blue River valley (Swanson and James, 1975). Additionally, Swanson and James (1975) proposed weathered till and kame terrace deposits on Lookout Ridge combined with the orientation of glacial striations in the Blue River drainage as evidence that the glacier "spilled into Blue River through a 640-m elevation saddle in Lookout Ridge" from the McKenzie River valley (Figure 2). In addition, based on U.S. Army Corps of Engineers core records from the Saddle dam area, Swanson and James (1975) proposed that the glacier advanced into the drainage through the Saddle Dam area (Figure 2).

The glacier advanced ~1.8 km up (reverse drainage) and blocked (close system) the Blue River drainage forming a proglacial lake environment approximately 40,000 years ago (Swanson and James, 1975). This initial glacial advance into the Blue River drainage striated the volcaniclastic country rock and deposited a basal till of Unit A (Figures 18, 19 & 20).

A thick sequence of glaciolacustrine sediments (Unit B) overlies Unit A. This transition from basal till to glaciolacustrine sediments describes a partial retreat of the glacial ice margin down-drainage (Figure 21).

Fluvial gravels and laminated siltstones (Unit C) overlie the glaciolacustrine sediments of Unit B. Unit C is a fluvial braided stream environment and could represent two different continued glacial retreat scenarios (Figure 22). First scenario: Unit C may represent a fluvial closed-drainage environment, where the glacial ice margin (still blocking the drainage) retreated far enough down drainage to allow the fluvial depositional environment to prograde over the older glaciolacustrine sediments, similar to a coarsening upwards, Gilbert-type regression of a deltaic sequence. Second scenario: Conversely, "complete retreat" of the glacier out of the drainage produced an open-drainage fluvial environment to the McKenzie River valley.

Three distinct wedge-shaped glacial ice margin debris flows containing drop stones (Unit D) overlies the fluvial sediments of Unit C. Unit D represents glacial re-advance (closed-drainage, proximal glacial ice margin) within and blocking the Blue River drainage (Figure 23).

Laminated to massively bedded siltstones containing abundant organic debris (Unit E) overlies Unit D. The glaciolacustrine sediments of Unit E suggest partial retreat of the glacial ice margin (closed-drainage, distal glacial ice margin) (Figure 24). Fluvial gravels and cobbles of Unit F overlie the glaciolacustrine sediments of Unit E and are deposited on an elevated bench. This transition to a fluvial environment indicates a complete retreat of the glacier out of the Blue River drainage (Figure 25). A deposite of glacial sediments filled and blocked the original drainage pattern through the Saddle Dam area (Figure 2). This deposit diverted the river over bedrock at the head of the reservoir near the mouth of Scout Creek (Swanson and James, 1975) (Figure 25).

This open-fluvial system eroded down to bedrock and channelized into the glacial sediments. The complete retreat of the glacier from the Blue River drainage may have occurred as a catastrophic flood event resulting from the glacial ice-dam failure, similar to a small-scale Missoula Flood event. The substantial down-cutting and channelization into the glaciolacustrine sediments may relate to the glacial ice-dam failure and subsequent head-cutting action of the draining proglacial lake. Deposition of volcanic mud and debris flows identified in the deep fluvial gravel deposits around the Eugene area by O'Connor and others, 2001 may correlate to these types of up-drainage ice-dam failure events.

During the 1960s, the US Army Corp of Engineers built the Blue River Reservoir. Flocculated, semi-liquefied, mud of Unit F represents deposition of suspended sediment during quiescent high reservoir levels (spring through fall).

Blue River Glacial Age Correlation Discussion

Swanson and James (1975) reported two radiocarbon age estimates of "more than 40,000 years" and "greater than 35,500" years before present from organic detritus in the glaciolacustrine sediments.

Figure 15. Unit D, Wedge-shaped ice margin debris flows alternating with glaciolacustrine sediments (siltstone/mudstone laminated beds) is overlain by a wedged shaped laminated to massive glaciolacustrine deposit of Unit E. Overlying Unit E are the imbricated gravels of Unit F. Imbrication indicated normal stream drainage toward the McKenzie River. 1.5 meter staff for scale. Down drainage to the right.

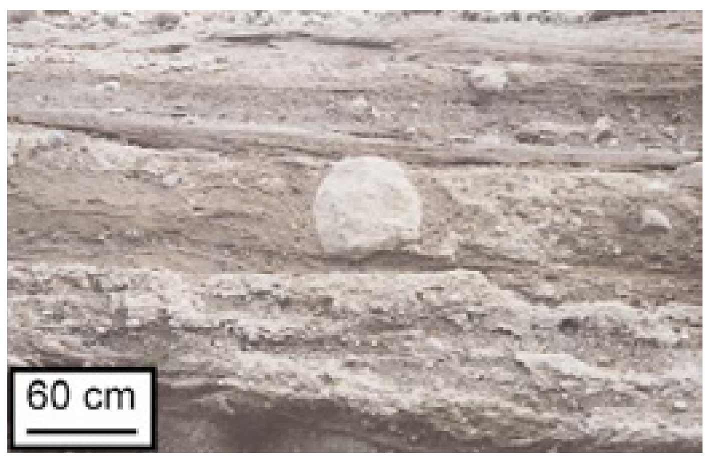

Figure 16. Unit D, A close-up view of two ice margin debris flows that are separated by a thin bed of siltstone. The larger rock in the center of the picture is 60 cm in diameter. On the left-hand side of the rock displays highly contorted siltstone, conversely on the right-hand side of the rock there is a 60 cm thick deposit of ice marginal debris flow. The interpretation is as the ice margin debris flow was emplaced it scoured the depositional surface and incorporated a large amount of silt particles into the flow. The silt particles piled up in front of the boulder as it was being emplaced, in much the same way a bulldozer pushes dirt in front of it. Note the scoured depositional contact located to the lower right of the boulder.

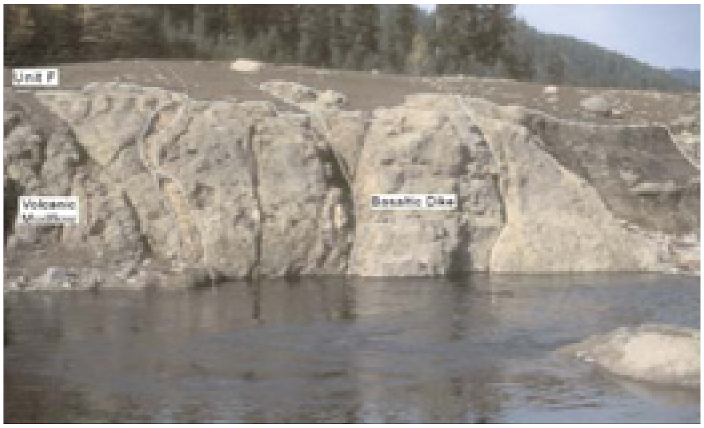

Figure 17. Flocculated reservoir clay deposited spring through fall, prior to annual reservoir drawdown. Unit F is in contact will all older exposures with the reservoir area. Central basaltic dike is 3 meters wide for scale.

Figure 18. Depositional contact of the glacial basal till on striated volcaniclastic mud/debris flow. Rock hammer for scale.

Figure 19. A view looking up drainage, glacial striations carved into a volcanic mud/debris flow. The striations (N25W) are oriented parallel to the long c-axis of the Blue River valley. 15 cm pencil for scale. These striations are located on Figure 20.

Within Oregon, glacial advance in the Blue River drainage may correlate to the Suttle Lake member of the Cabot Creek Formation (till), the Jack Creek Formation (till), and the older Abbott Butte Formation (till). These formations represent glacial advances in the Metolius River area on the eastern flanks of the Cascade Range. The Jack Creek glaciation probably dates from either of the high ice-volume intervals between 80 to 40 ka or 200 and 120 ka (Scott, 1977). These dates are based on the oxygen isotopic record of core V28-238 and the Quaternary glacial record in the Metolius area that seem compatible with current understanding of glacial chronology in the Pacific Northwest.

The Rocky Mountain region identifies a similar high-frequency record of glacier oscillations as observed in the western and eastern Cascades, (Clark and Bartlein, 1995). Obsidian hydration data suggest advances of the Yellowstone ice cap occurred between 70 and 45 ka, followed by a major advance between 40 to 30 ka (Pierce and others, 1976). Additionally, the glacial records at McCall, Idaho suggest glacial advance occurred from 60 to 50 ka and 20 to 14 ka (Colman and Pierce, 1981 and Pierce and Colman, 1986). Glacial advances of the Laurentide Ice sheet, at the Lake Ontario Basin region (Scarborough Formation) occurred from 54 to 40 ka. However, the Cowichan Head Formation (58 to 24 ka 14C) of the Puget lobe/Vancouver Island region may correlate to a glacial retreat.

Additionally, glacial advance into the Blue River drainage may correlate to greater than and including Heinrich Event 4, as identified in the deep-sea sediment core Me69-17.

Additional dating of the glacial advance, using the methods described below in the "Follow-up Research" section, will help constrain the chronology of the glacial ice-margin fluctuations recorded in the Blue River glacial stratigraphy. These correlations will develop a regional model of glacial responses to Heinrich events within the North Atlantic region. Thus, if Heinrich events are proxies for the collapse of the Laurentide ice sheet, then the chronology of glacial advances and retreats will be in response to a global climatic forcing mechanism, the collapse of the Laurentide ice sheet.

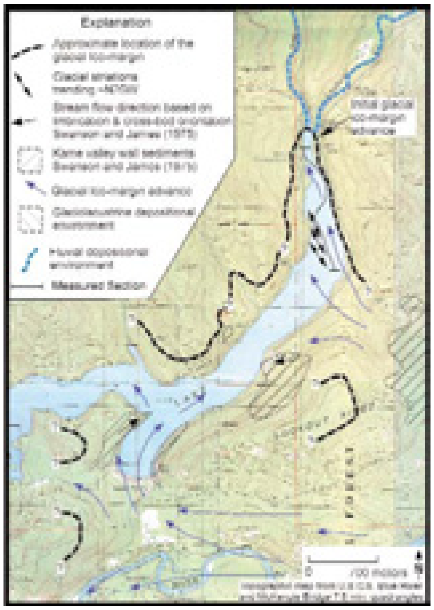

Figure 20. Initial glacial advance into the Blue River drainage and deposition of the basal till: Unit A .

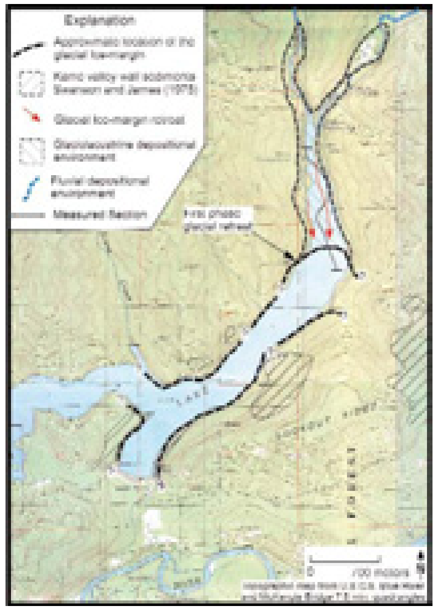

Figure 21. First Phase glacial retreat. Deposition of glaciolacustrine sediments (Unit B) in a closed system.

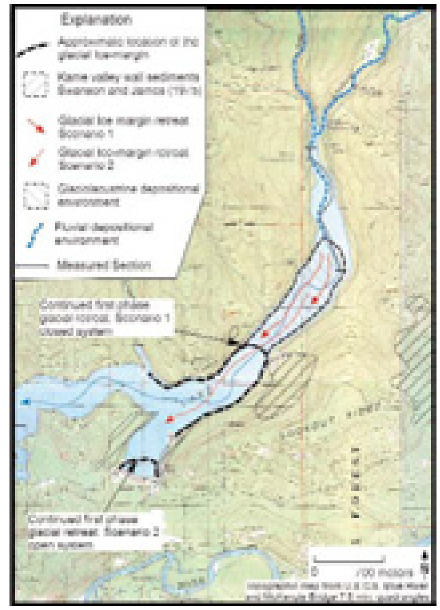

Figure 22. Continued first phase glacial retreat. Deposition of fluvial sediments (Unit C) described by either scenario 1 (fluvial close system) or 2 (fluvial open system).

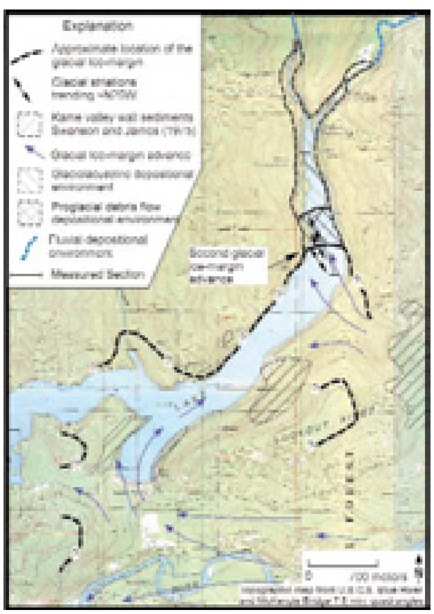

Figure 23. Secondary glacial advance. Deposition of proglacial debris flows of Unit D.

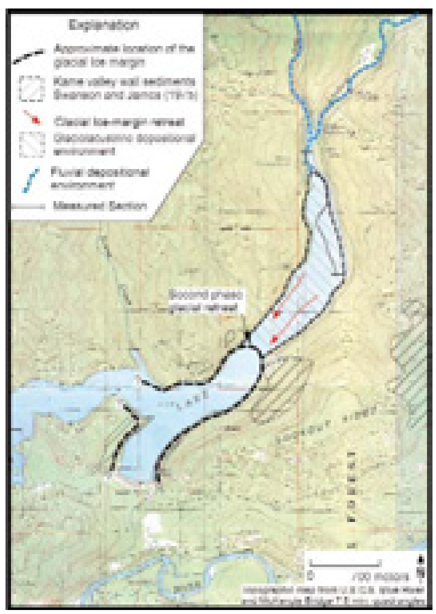

Figure 24. Second phase glacial retreat. Deposition of glaciolacustrine sediments of Unit E.

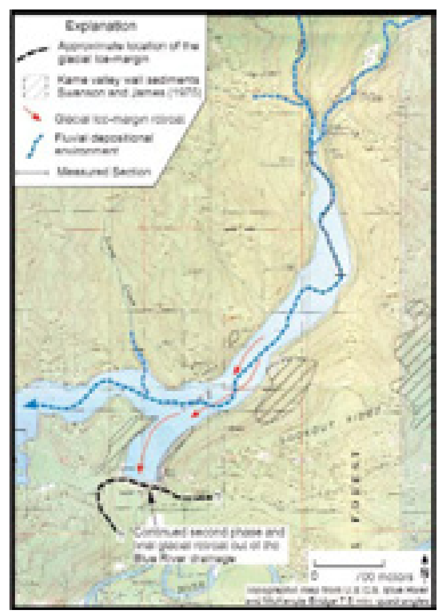

Figure 25. Complete and final (continued second phase) glacial retreat out of the Blue River drainage. Deposition of fluvial sediments of Unit F.

Conclusion

The glacial stratigraphy in the Blue River drainage describes glacier advances greater than 40,000 years ago into the Blue River valley (reverse drainage) through where Saddle Dam is now located and just east of Lookout Ridge. This glacier blocked the Blue River drainage, producing a proglacial lake. Swanson and James (1975) proposed that the glacial stratigraphy records at least three upstream advances and downstream retreats. However, only two facies changes describing glacial advances and retreats were observed in the preserved glacial stratigraphy. The lack of weathered horizons in the glacial stratigraphy indicates a relatively short period for the occurrences of glacial ice-margin oscillations in the Blue River drainage. The maximum glacial advance and deposition of the basal till (Unit A) may have obliterated older deposits of glacial advances and retreats. The final retreat of the glacier returned the Blue River drainage back to an open-fluvial system. This retreat may have occurred as a catastrophic flood event (glacial ice-dam failure), analogous to a small-scale Missoula Flood event.

Follow-up Research

- Additional radiocarbon dating of abundant organic detritus from Unit A and F
- ^{10}Be and ^{26}Al measurement on quartz veins and quartz grains exposed to cosmogenic nuclide bombardment
- ^{3}He measurement on olivine or orthopyroxene grains found in basaltic dikes exposed to cosmogenic nuclide bombardment.
- Thermoluminance dating of abundant quartz grains collected from exposed boulders around the Saddle Dam area.
- Measurement of obsidian hydration rinds present in the basal till could be used to approximate deposition of the basal till in the Blue River drainage.

Acknowledgement

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CRYSTAL SPRINGS

ZONE OF CONTRIBUTION

Crystal Springs Water District
Odell, Oregon

January, 2003

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Feeder Dikes to the Columbia River Flood Basalts: Underpinnings of a Large Igneous Province

HEATHER L. PETCOVIC (PH.D., OREGON STATE UNIVERSITY, 2004), 194 p.

Feeder dikes to the Columbia River Basalt Group (CRBG) large igneous province provide a rare opportunity to examine magma transport through the shallow crust during flood basalt eruptions. Over 70% of the CRBG erupted from the Chief Joseph dike swarm that is exposed across southeastern Washington, eastern Oregon, and western Idaho. The four manuscripts of this dissertation examine physical, thermal, and compositional characteristics of dikes from the southern Chief Joseph swarm.

The majority of CRBG dikes are chilled against their wallrock; however, rare dikes have induced partial melting in their wallrock. Melt zones in tonalite wallrock adjacent to the Maxwell Lake dike are up to 4 m thick and contain up to 47 volume percent quenched silicic melt produced from dehydration-melting reactions involving biotite, hornblende, quartz, orthoclase, and plagioclase. Melt zones record the thermal history of basalt flow and cooling in the Maxwell Lake dike, a feeder to Wapshilla Ridge flows (Grande Ronde Basalt). Results of one- and two-dimensional numerical modeling suggest that basalt flowed in the Maxwell Lake dike for 3-4 years, yielding maximum eruption rates of 3.4-4.6 km 3/day for typical Wapshilla Ridge flows. The Maxwell Lake dike likely represents an upper crustal exposure of a long-lived point source in the CRBG.

Chief Joseph dikes are concentrated into sub-swarms of 7-12 dikes per km 2. Based on transects through four sub-swarms, dikes become more aligned, more frequent, thinner, and more closely spaced from northwest to southeast across the southern Chief Joseph swarm. Fewer than 2% of dikes, and less than 0.5% of cumulative dike length, had caused extensive melting in their wallrock. In the Cornucopia subswarm, numerical modeling of cross-cutting and compound dikes suggests that magmatic activity occurred intermittently over 2-4 years. Compositional data collected from ~250 southern Chief Joseph dikes indicate that most are Grande Ronde Basalt, although isolated Imnaha and Dodge (Eckler Mountain Member, Wanapum Basalt) dikes also occur. Imnaha dikes are compositionally primitive, whereas Grande Ronde and Dodge dikes are more evolved. Subtle compositional differences between sub-swarms of Grande Ronde dikes suggest that each sub-swarm represents a discrete episode of Grande Ronde volcanism.

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