Geologic Interpretation of Floodplain Deposits of the Southwestern Willamette Valley, T17SR4W
With Some Implications for Restoration Management Practices
Eugene, Oregon

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EXECUTIVE SUMMARY

A three-and-one-half mile, NW-SE transect of soil auger borings was done in West Eugene from Bailey Hill Rd to Oak Knoll across parcels that make up part of the West Eugene Wetlands. The transect ran from hillslope to bottomland across T17SR4W and T18SR4W. Included in the analyses were data from two-ten foot deep trenches that were excavated in earlier investigations. The stratigraphy of nineteen profiles was mapped using soil descriptions, texture and mineralogy. Hillslope and bottomland stratigraphic units were identified in borings as deep as ten feet. Profiles were correlated to each other and three distinguishable bottomland Holocene stratigraphic units were identified (Units I, II and III), including a massive clay, overlying one of four separate substrates (Unit IV) identified in bottomland corings. Surface soil in the hillslope profiles contained the same unique mineralogy present in the upper three units in the bottomland.

A literature search was conducted on the general archaeological, geologic and climatic chronology of the southwestern Willamette Valley. This broad view of the pre-history of the area was included to identify possible major geologic or climatic events that could have been responsible for part of the deposition of sediments in this area. General Land Office survey notes, historic maps and 1930's era aerial photographs were consulted in order to understand landforms, hydrology, and vegetation conditions that observed in the area at the time of Euro-American settlement and to document changes in those patterns in the intervening years.

Rerouting of water during early settlement and subsequent urbanization of Eugene has removed the mechanism of overbank flooding and deposition of Willamette River alluvium from the western side of the valley floor. Amazon Creek, previously a shallow and meandering stream which crossed the wetlands to join the Long Tom River, was excavated to a depth of fifteen feet and the channel course was redirected to flow along the southern foothills. Tributary streams to Amazon Creek were routed into storm sewer drains and pipes that flow directly into Amazon creek. These actions have isolated the Amazon Creek drainage from the land surface across which it once flowed.

Today, the bottomland surface comprising the West Eugene Wetlands, is characterized by periodic ponding following seasonal rains, a result of clay units that swell and create an impermeable surface. During summer, the clay shrinks and cracks. After the initial onset of fall rains, miles of subsurface channels in the grey clay become temporary underground streams until the clay saturates and swells into its wintertime impermeable surface. It appears that there may be several separate hydrologic systems operating throughout the year. A regional water table exists at or below ten-feet in depth and recharges Amazon Creek. It is postulated that the wetland conditions found in West Eugene today did not exist prior to deposition of the clay. The soil layers beneath the massive clay appear to have been formed in a landscape with slightly more relief than the present surface. The more oxygenated red, yellow and orange soil colors indicate that no wetland soils were present during this time.

Textures of the stratigraphic units of the bottomland indicate that there is a loamy surface soil present that is underlain by a thick sequence of clay. A massive grey clay unit overlies an olive brown silty clay unit. Mineralogically and texturally both units appear to be from the same source and possibly are contemporaneous. Below the clay units are weathered Fisher and Spencer Fm. bedrock, fluvially bedded silts, sands, or coarse sand and gravel deposited by Willow Creek or the Willamette River. Frequently a buried paleosol caps the lower sediments and bedrock.

Clay mineralogy in all samples indicates no Missoula Flood silts are present in the area. In all samples there is an absence of mica, K-feldspar, diopsitic pyroxene, and lithic fragments of granitic and metamorphic rocks, precluding it being Missoula Flood Silt.

Radiocarbon dating of the sediment was problematic due to a lack of abundant datable material. However, the sediments appear to be Holocene in age. Soil development was characterized in the bottomland profiles by paleopedological methods and results indicate that the units have had short residence times on the surface of the floodplain before burial. No archaeological sites are found in the study area. Dated sites in the vicinity of West Eugene within the Willamette and the Long Tom River floodplains, appear Holocene in age at depths similar to this study. A grey clay found at a Woodburn archaeological site with identical mineralogy to West Eugene, was dated at 6800 BP, contemporaneous to the Mt. Mazama eruption (7700 years ago).

Located within the study transect is a relict Willamette River channel. The channel is filled with gravels, cobbles and overbank deposits and discernible only by slight changes in elevation and relict channel landforms. This relict channel cuts the massive clay unit indicating that the channel post-dates the deposition of the clay unit.

A unique suite of minerals and lithic fragments was identified in the massive clays of all sample sites in the West Eugene Wetlands (and samples from Irish Bend and Woodburn). The mineral crystals are very euhedral, lack rounding or abrasion, are shiny and easily loosened from their clay matrix. They are free of clay coatings and iron oxide stains. This suggests little fluvial transport was involved in their arrival at the site and that the soils are quite young (immature). The mineral suite is different from local Cascadian andesitic and basaltic andesite volcanism or the rhyolitic volcanism of Fisher Fm. The distinctive minerals are rhyolitic in nature and match Mt. Mazama tephra.

The percentages of characteristic elements that make up the suite of different minerals analyzed are not the same as those produced by typical Cascadian andesitic and basaltic andesite volcanism. Trace element studies demonstrated that the upper clays have a common “signature” which is quite different from the weathered paleosols formed on the underlying bedrock or alluvial units. Characteristic element values for Willow Creek sediments were nearest to those of the upper clay soils but were still generally lower, with the exception of arsenic. The Fisher Fm., which forms the bedrock in the Willow Creek headwaters, appears to be the source area contributing to the high background levels of arsenic in the Willow Creek sediments.

High conductivities were measured in the bottomland clay units. Lower conductivities were measured in the coarser textured substrate units and in all hillslope profiles. Specific anions were identified to attempt to explain the high conductivity values. Chloride and sulphate were always present; however, other dissolved elements present include fluorine, nitrogen compounds, phosphate and bromine. These results are similar to water quality data collected from Crater Lake water.

Quantities of soluble ions in a recently exposed soil in a wetlands soil treatment project were measured. With the removal of sod, established plants and soil organisms no longer can take up nutrients and the elements are readily released into soil and surface waters. After sod removal, nitrate and phosphorous were shown to become available for entry into a waterway.

ACKNOWLEDGEMENTS

Data in this report have been collected through many cooperative efforts beyond that generated by this project. Data include soils work from the BLM (Karin Baitis, unpublished data), and water quality data from The Long Tom River Watershed Council including regional surface water conductivity studies (Michael James, volunteer Water Quality Monitor). Additionally, lab work and interpretation were performed by numerous people. Soil profile conductivity definition was conducted by ion chromotography (Michael James, James Geoenvironmental Services and Professor Paul Engelking, U of O Chemistry Department), C-14 radiometric, tephra and pedological analyses (Beta Analytic in Florida, and Professor Franklin Foit, WSU Geology Department; and Professor Greg Retallack, U of O Geology Department), comparative clay mineralogy (J.R. Glassman, Willamette Geologic Service), soil nutrient analysis (Will Austin, OSU soils lab), and trace element values by neutron activation (Professor Erwin Schutfort, Radiation Center, OSU). We would also like to acknowledge countless others in the community who spent time in discussing and reviewing our data, and in allowing office space for use to store samples and conduct our work: Mike Remboldt, PE, (K & A Engineering), Mark Reed (U of O Geology Department), Paul Wallace (U of O Geology Department), Ewart Baldwin (Emeritus, U of O Geology Department), Herb Huddleston (OSU Soil & Science Department), Clif Fanning (BLM, Soil Scientist), Nate Sheldon (U of O Geology graduate student) and John Donovan (Microprobe Lab, U of O, Department of Geology). This study was funded by the Bureau of Land Management.

CHAPTER 1
INTRODUCTION

There are several motivating forces for carrying out this study. The first one is for the lack of a detailed investigation of the relationship between the hydrogeomorphic conditions found in the West Eugene Wetlands and the geomorphic history of the soil sequence that underlies the area. Structural components of the ecosystem and the surrounding landscape, including plants, soils, hydrology and animals, all interact with a variety of physical, chemical and biological processes. The first step in understanding these processes and how they are interrelated is to understand the geologic and geomorphic history of the southern Willamette Valley. Secondly, as management plans and prescriptions are developed to improve the wetland ecosystem it is important to understand the geochemical makeup, textures and depths of the soil units that underlie the area and their distribution. Thirdly, given that the goal of many supporting partners of the West Eugene Wetlands is to create an environmental educational outreach program, it is important to be able to describe the *geosphere*, the *hydrosphere*, the *biosphere* as well as the pre-colonial anthropological activities that took advantage and helped form the wetland ecosystem. A fourth reason for this inquiry grew out of the results of over three years of water quality data collected by volunteers associated with the Long Tom Watershed Council. Results indicate that Amazon Creek and several of its tributaries possess abnormally high conductivities (3 to 4 times higher) that do not seem to be strictly related to human activities, but rather to natural background levels (Thieman and James, 2001, unpublished data).

To date, collection of data and inventories that have been undertaken at the wetlands have been mostly for biological ends (e.g., Jancaitis, 2001; Gitzendanner, 1998; Hammond et al, 1992;

LCOG, 1997; Pendergrass, et al, 1998; Schultz et al, 1998). Preliminary hydrologic study and modeling was performed at the Willow Creek Natural Area (Shafer,1993; Shafer,1995) and some hydrologic data were collected during fill permit reporting (LCOG, 1988). Soil studies include wetland delineations that cite the 1987 Lane County Soil Survey (Patching, 1987) and use the methodology of the 1987 U.S. Army Corps of Engineers Wetlands Evaluation Techniques. Currently the list of criteria to describe hydric soil characteristics has amplified two-fold because of new methods and field techniques that have been developed over recent years. A new statewide guidebook for Hydrogeomorphic Classification has been developed by the Oregon Division of State Lands (Adamus, 2001).

Confusion over why certain soil types are mapped in this area is another important reason for why it is necessary to carry out a more detailed and soil-genesis oriented study. It is logical that discrepancies exist considering that since the time that the majority of field work was carried out and used in developing the 1987 soils mapping, new geomorphological, geological and hydrological models have been developed and accepted. These models present new hypotheses to evaluate when considering detailed soil mineralogical and chemical analyses of soil profiles observed across wetlands. This study reached greater depths of exploration (7 to 10 ft.) compared to the more typical soil survey studies (1 to 5 ft.), and provides important additional information about origins of soils units not available before.

Congress has appropriated millions of dollars to the Bureau of Land Management (BLM) to acquire wetlands in West Eugene. The BLM owns over 2,200 acres and acquisition of lands continues in an effort to provide protection for the wetlands and adjacent uplands. The wetlands project area encompasses over 8000 acres overall with management shared by the BLM, the City of Eugene, The Nature Conservancy, Army Corps of Engineers, Oregon Youth Conservation Corps and U.S. Fish and Wildlife. A clear understanding of the origin and the developmental history of the wetland soils is a cornerstone for the development of management tools, educational programs for people of all ages, and for the protection of wetlands.

Location

In Figure 1.1 part of the study area is displayed in aerial photography of 1936, showing old soil characteristics through vegetation patterns. The photos indicate that farm machinery was strong enough to handle the clayey soils of this area at this time and also shows the degree to which urbanization had taken place.

Figure 1.1 These 1936 air photos of the west Eugene area show Willow Creek and the historic drainage patterns of Amazon Creek. The darker vegetation pattern evident in the center of the photos is a relict Willamette River channel. Agriculture had altered the landscape and urbanization was well underway with the building of streets and railroads.

A three and one-half mile transect was done extending from Bailey Hill Road on the east side of the lower Willow Creek drainage (The Nature Conservancy's Willow Creek Parcel), northwestward to Oak Hill and then east to Wallace Butte (Figure 1.2), elevation 380 to 450 a.s.l.

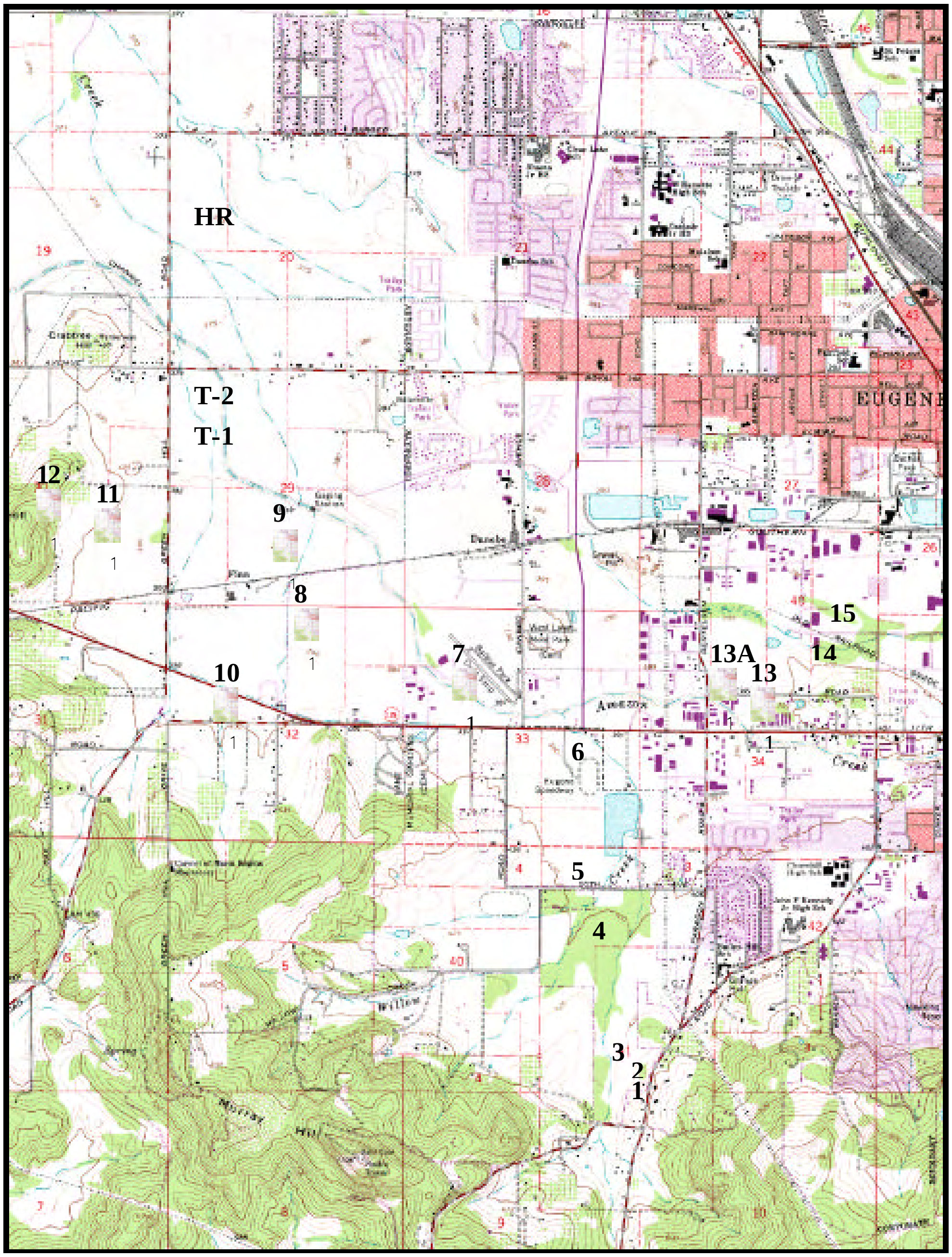


Figure 1.2 Location of soil auger borings on the Eugene West, Oregon, Quadrangle. U.S.G.S., Photorevised 1986.

From Willow Creek, the sample sites are located north and west, between W. 18th Ave. and W. 11th Ave, turning westward near the confluence of the A-Channel and Amazon Creek Channel and ending on the east flank of Oak Knoll west of the Greenhill Humane Society. Another transect eastward, crosses Greenhill Road finishing near 1st Ave. and Wallace Street. The objective was to study soil profiles from the hillslopes of known Fisher and Spencer Fm. bedrock, and soils located on the bottomland wetlands areas of Willow Creek, Amazon Creek, and a discovered relict Willamette River channel and its alluvial terraces.

Numerous deeper borings with reasonably well logged stratigraphic columns were available northeast of the transect. These borings are related to contamination monitoring studies and permit the continuation of this transect for several miles into the heavily urbanized River Road and North Eugene areas. Additionally, several sites in the south hills of Eugene and one site at Irish Bend, north of Harrisburg, were sampled for soil mineralogy to compare to trends found in the project area. Below are seven photos that present a visual perspective of the transect.

Photo1.1 View of sites BLMST – 1, 2 and 3 from Bailey Hill Rd. looking west towards the Willow Creek drainage. These sites are located on Fisher Fm. bedrock.

Photo 1.2 A view to the north from 18th Ave., where the street crosses Willow Creek.

Photo 1.3 View of sites BLMST– 5 and 6, looking northwest from 18th Ave at Willow Creek and confluence of Hynix/Westec subterranean drainage outflow

Photo 1.4 View of site BLMST– 4 looking south from 18th Ave.

Photo 1.5 Looking north from 18th Ave., to sites BLMST– 5, 6, 7 and toward the BLM “RED HOUSE” office on Danebo Road.

Photo 1.6 View to the north from the railroad tracks towards site BLMST– 9.

Photo 1.7 View to the southeast from dike and bike path of the 1135 Project along sample transect. The transect includes auger sites BLMST—1, 2, 3, 4, 5, 6, 7, 8, 9 and 10.

CHAPTER 2
WEST EUGENE GEOLOGIC BACKGROUND

Tertiary and Quaternary Geologic Units Underlying Area

The West Eugene Wetlands occupy the southern end of the elongate Puget-Willamette lowland (P-WL), a forearc basin formed by slow bending down or folding between the uplifting Coast Range and the more stable Cascades. The basin is maintained by compression generated by the slow east-west movement of the remnant of the Farallon Plate beneath the western edge of the North American Continental Plate. This general model is complicated by the fact that this small piece of plate has rotated, been fractured and is being shoved, with an active dorsal (Gorda spreading center) positioned perpendicular to the continent, into the N-S oriented Pacific subduction zone. The structural valley continued to the south perhaps as far as Medford-Ashland at one time.

The valley can be subdivided into more or less northern and southern zones that are characterized by distinctive tectonic activity levels, with the northern area much more active. The division occurs near Salem where a thick remnent of Columbia River Basalts crossed the valley for the most part. The modern alluvial sedimentary record demonstrates the importance of sediment laden tributary rivers flowing into the valley from the Cascadian Province to the east and to a lesser degree from the Coast Range to the west. The headwaters of the Willamette River in Eugene that have influenced the sedimentary history of West Eugene include the McKenzie, Middle and Coast Forks of the Willamette. Amazon Creek, Willow Creek and Dead Cow Creek form in the foothills to the south of Eugene. These are creeks of low relief and their sediment reflects only the Eugene/Fisher Formation, in contrast to the sediment of the Willamette River which is influenced by all of Central Cascadian geologies.

The Tertiary sedimentary rock record in the area documents that the region was first subject to marine deposition in an elongate southward narrowing bay during the Eocene and Oligocene periods (Eugene Formation). Voluminous acid to intermediate pyroclastic eruptions from pre-Cascadian volcanic activity to the South and East of the area (Retallack, unpublished, 2002) gradually filled the shallow sea with epiclastic sediments and pyroclastic flows until it became a transitional and eventually a subaerial environment (Fisher Formation) (Figure 2.1).

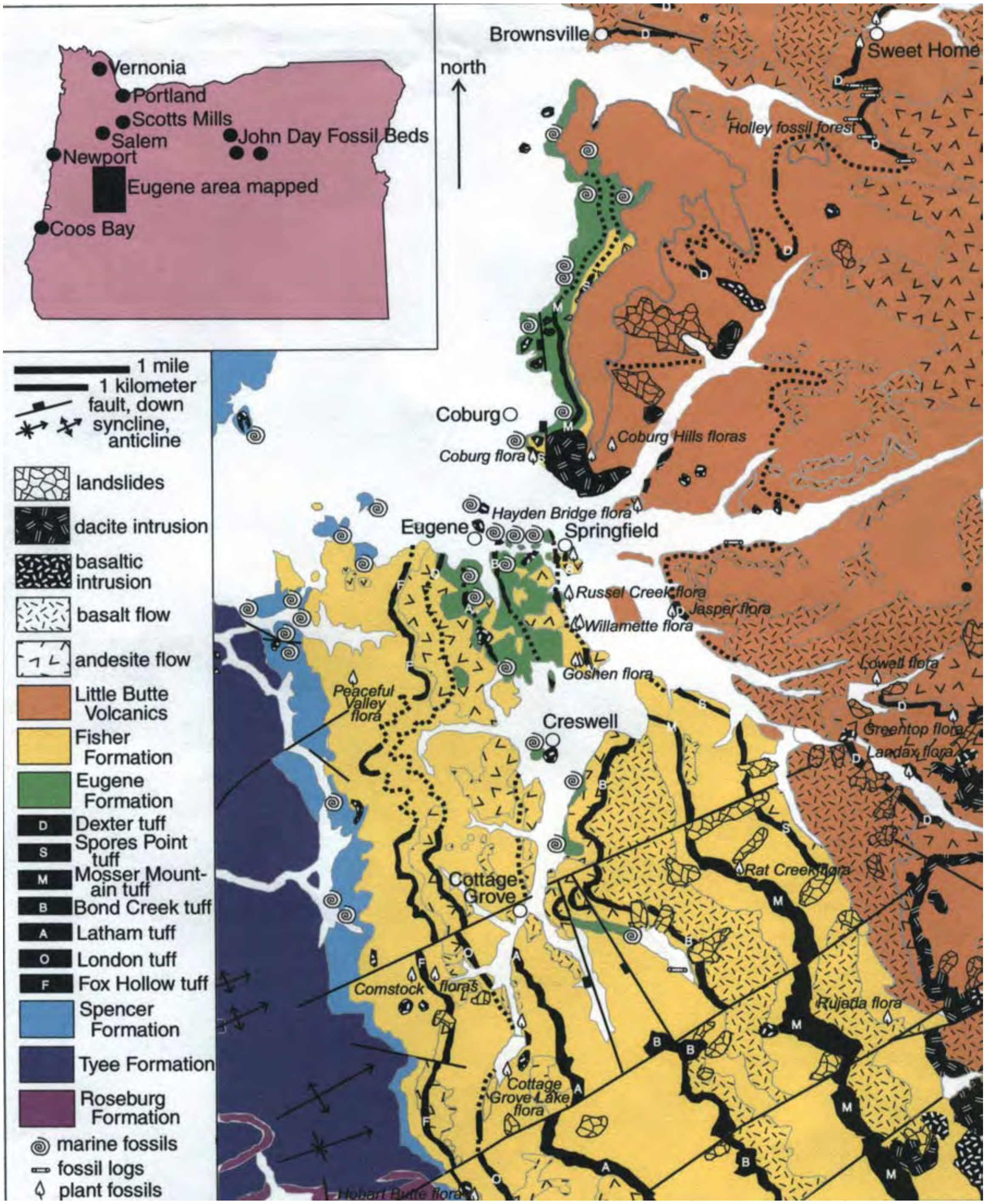
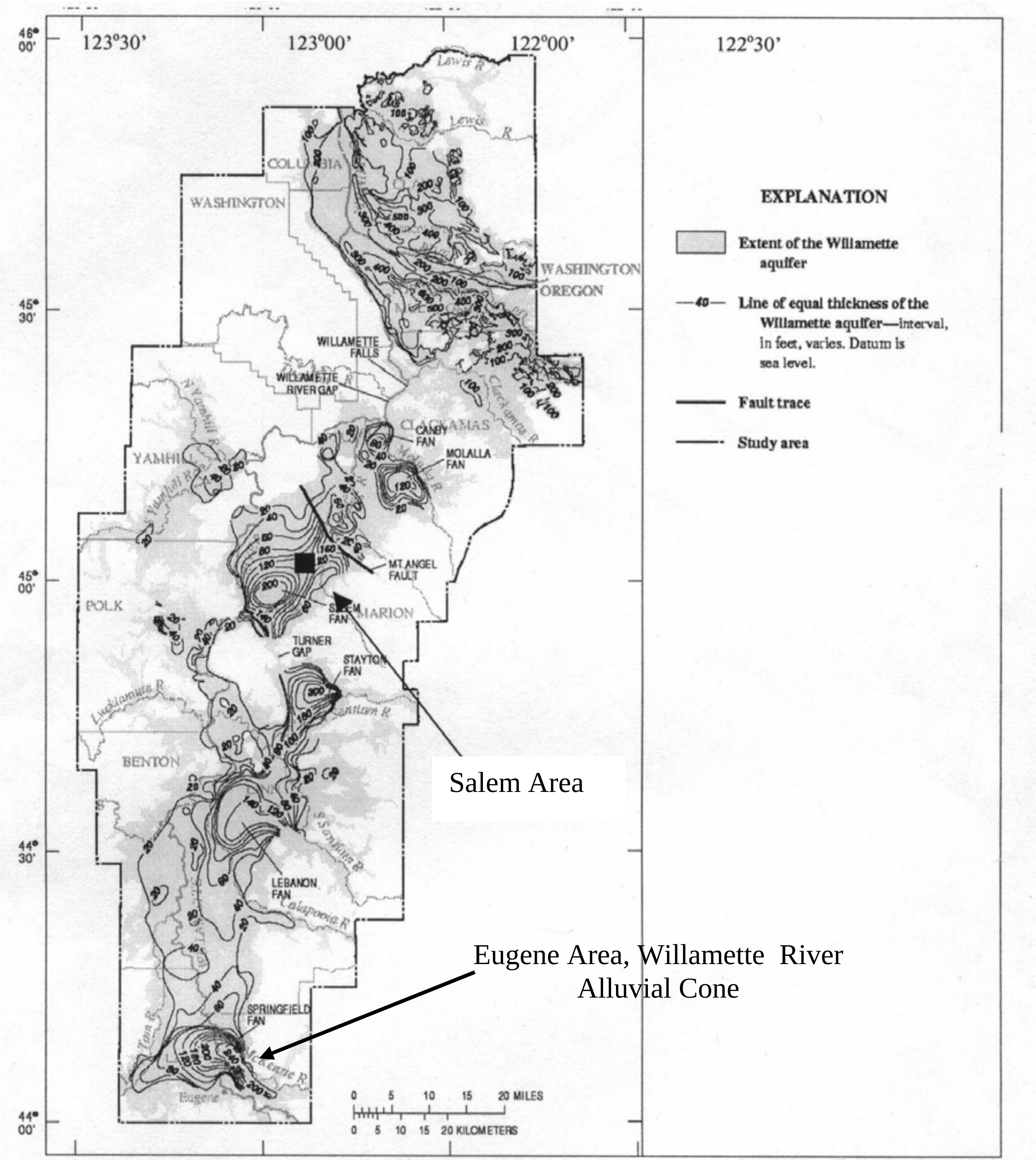


Figure 2.1 Geology of the southern Willamette Valley, Eugene, Oregon. From Retallack, unpublished, 2002.

The Eugene and Fisher formations were deposited over the marine Spencer Formation (late Oligocene) which was derived from erosion of the thick Tyee Formation (early and middle Eocene), the backbone of the Coast Range. The Spencer probably interdigitates with sequences of volcanoclastic units from the early Western Cascades to the east but this contact is covered by the younger volcanoclastic, epiclastic and alluvial sedimentary formations mentioned. The volume of Oligocene volcanic detritus which included welded tuffs, ashflows, lahars, and volcanoclastic sediments is represented in the fossil record by a transition from a marine environment in the Spencer and Eugene Fms. to a terrestrial environment in the Fisher Fm. as the basin filled with sediment and the sea retreated to the North. Leaf impressions and permineralized wood are very common in the Fisher Fm.

During the late Pliocene and early Pleistocene a thick sequence of alluvial and colluvial cones originated from both sides of the valley but with a much higher percentage coming from the Cascade Mountains (Orr and Baldwin, 1992; Gannett and Caldwell, 1998). Terrace deposits exclusively of fluvial origin, consist of slightly inclined silt, sand and gravel beds that are generally sub-parallel to the gradient of the Willamette river while a more chaotic origin including less textural selection of materials with steeper bedding angles, mark those generated in colluvial-alluvial cones that penetrate the valley perpendicularly from major drainages entering either side of the valley. Today these make up the very important Willamette Aquifer. The drainages from the Cascadian tributaries such as the Santiam, McKenzie and Willamette Rivers have generated much thicker and voluminous cones than those from the Coast Range (Gannett and Caldwell, 1998) reaching depths of 300 ft below Eugene, in the region to the east of Albany and below Salem.

As an aside it is important to observe the maps of the Willamette aquifer of Gannett and Caldwell (1998) which show Plio-Pliestocene alluvial cones that formed (Figure 2.2) downstream from the mouths of the larger rivers entering the valley which are great sources for subterranean water in the valley. They demonstrate that the Paleo-Upper Willamette River which included the present Cascadian tributaries (McKenzie, Middle Fork and Coast Fork) plus the S. Santiam River, probably flowed due west directly across the Coast Range through a valley occupied by the present day Long Tom River. It appears that the Willamette River flowed through a narrow valley that begins to the west of Veneta and Noti, possibly connecting with Wildcat Creek before reaching the Siuslaw River. Although this idea is unpublished, Prof. E. Baldwin proposed a similar idea in the 1950's, in which he theorized that Coyote Creek, today a Long Tom River tributary, once flowed through the valley west of Veneta into the Wildcat Creek drainage which eventually reaches the Siuslaw River. According to Gannett and Caldwell much of the West Eugene area is underlain by old Willamette River gravels. Because it is not known how long ago tectonic activity occurred on several E-W to NW trending faults that cross through the hills South of Eugene, or when a rapid uplift of the Coast Range occurred, it is unknown when the Willamette River became blocked in its westward route. The shape and orientation of the Willamette cone are evidence that the Willamette River flowed westward, however no study has yet been undertaken to find evidence of an unequivocal Cascadian sediment in the narrow valley mentioned.



Salem Area

Eugene Area, Willamette River Alluvial Cone

Geologic data modified from Gannett and Caldwell, 1998, USGS Professional Paper 1424-A.

Figure 2.2 Map of Willamette aquifer modified from Gannett and Caldwell, 1998, U.S.G.S. Note that in the Eugene area, the Willamette River's alluvial cone deposits are in a westward direction toward the Coast Range into the valley occupied today by The Long Tom River.

Late Pleistocene and Holocene Willamette Valley Alluvial Sequences

Terminating each glacial epoch and most notably during the latest or Wisconsin Glacial stadia and early interglacial stage, great ice dams formed in the headwater regions of the Columbia River in Idaho and Montana. As the dams ruptured, they generated large floods in the Columbia River basin that swept millions of tons of sediment from the Rocky Mountain and Palouse regions of eastern Washington into the Willamette Valley.

The flood events became known as the Missoula Floods. These short but catastrophic events were due to temporary hydraulic damming on the Columbia River including the passage through the Cascades at The Dalles, Oregon, and a narrows in the Coast Range near Rainier, Oregon (Bretz, 1925). The floods deposited extensive silty layers in the Willamette Valley with occasional large glacial erratics that were rafted by blocks of ice into the area. The erratic rocks are composed of lithologies very foreign to the Willamette Valley (granites, gniesses and types of metasedimentary rocks typical of Northern Idaho and Montana, Allison, 1978).

The last Missoula Floods occurred between 12.7 and 15 thousand years ago. The deposits are known as the Portland Gravels to the north and the Willamette Formation (O'Conner et. al., 2001) in the southern valley which include the Irish Bend and Greenback Members. These deposits form all but the very surface soils of extensive alluvial terraces and are found to about 345 feet above sea level (a.s.l.). The southernmost confirmed exposure in banks of the Willamette River is at about 325 ft .a.s.l. at Harrisburg and McCarty Park, located approximately 20 miles, to the north of the Eugene. The Missoula Flood units thicken towards the north reaching over a hundred feet around Portland, Oregon. If the Missoula Floods reached the 400 foot elevation it would which have brought the waters to Eugene, however, no silts have been identified in the general area.

The termination of the glacial epoch coincided with the melting of alpine glaciers of the Cascades and appears to have coincided with a number of large and abrupt climate oscillations (Benson et al, 1997). The Cascade glaciers were probably melted by the early Holocene, approximately 10 thousand years ago (Clark and Bartlein, 1995). Proxy (fossil pollen) data indicates that early Holocene climate experienced severe summer drought and more frequent fires (Long, et. al., 1998). The warmest period of the Post-glacial era occurs around 6,000 years ago, recorded by world wide evidence of sea-level rising, vegetation zone shifts and changes in atmospheric gases. It was relatively short lived. Around 5.6 thousand years ago the climate began to become cooler and moister again in the Coast Range near Eugene (Worona and Whitlock 1995).

Volcanic activity has been common in the Pacific Northwest during the Holocene. Belnap Crater and Sand Mountain in the McKenzie Pass lava fields were active as recently as 400 years ago. Explosive ash producing eruptions have occurred in the last 150 years at Mt. St. Helens and Mt. Hood (Orr et al, 1992). Many other eruptions have occurred, but the most important and possibly most related to deposits found in the Willamette River drainage is Mt. Mazama which erupted approximately 7,700 years ago. It has generally been accepted that the majority of the ash was deposited to the north and east of the volcano, however pyroclastic flows did flow down the western drainages and it can be assumed that airfall material was washed into the Willamette River basin. As will be discussed in this paper, preliminary results from this study suggest that a substantial amount of airfall material was also deposited in the Willamette Valley.

Surficial deposits adjacent to the Willamette River and in the southwestern Willamette Valley have more recent Willamette River deposits. These are sand and gravel deposits, the result of an anastamosing or braided stream pattern typical of sediment-laden streams that flow out of mountain valleys onto the open valley floor. General Land Office Survey notes indicate that the Willamette River frequently occupied the west Eugene wetland area of the valley floor with overbank flows that inundated the area between 1 and 3 feet deep (GLO, 1853). The U.S. Army Corps of Engineers in 1875, described the Willamette River channel upriver of Corvallis as *"…cut up into so many useless sloughs, and at each liable to undergo very marked and frequent changes…New channels are not infrequently cut out and old ones have been nearly left bare; the latter, after being closed for years are again reopened…The river above Corvallis is very tortuous, at places very narrow, and runs at many localities with great rapidity. Captain Miller, one of the oldest and most experienced pilots in shoal waters of the same nature as the Willamette, has stated that he has never run the same channel for two consecutive years between Harrisburg and Eugene"* (Benner and Sedell, 1997). The instability or 'braidedness" of the river changed markedly with urbanization and with the emplacement of the flood control dams up and down the Willamette Valley between 1949 and 1970.

Additionally, smaller streams have lost connectivity and sinuosity across the southwestern Willamette Valley. Amazon Creek, which flows through the West Eugene area has been channelized for flood control and agricultural needs. Alicia Lyman-Holt, 2002, Draft West Eugene Wetlands Land Use, using air photos to interpret land use change, measured remnant river channels across the West Eugene Wetland area. She concludes that 40.3 km of remnant channels were clearly visible in 1936 air photos and this was reduced to 6.8 km in 1994.

In West Eugene, below an upper more silty and probably alluvial deposit is a layer of a one to two foot thick massive grey clay. It is found covering extensive alluvial terraces of both the Willamette River and tributary streams like Willow Creek. It is a very impermeable layer and underlies the greater part of the prairie wetland Flats that have been preserved in West Eugene. Much discussion has been generated around the origin and distribution of this layer which is one of the primary objectives of this study.

Balster and Parsons (1968), invoked a marine invasion to explain the smectitic nature of the "Malpass Clay" found in the central and northern Willamette Valley that appears to have similar characteristics to the grey clay found in West Eugene. Some researchers have suggested that deposits in West Eugene are possibly contemporaneous with the Willamette Silts (McDowell, oral communication, 2002), others suggest local derivations of deposits from catastrophic erosion of residual soils from the hillslopes around the southern edge of the Willamette valley formed by Spencer, Fisher and Eugene Formations (Retallack, oral communication, 2002), others consider the deposits the distal portions of large soil laden mudflows from the Willamette river drainages and possibly the results of floodwater deposition in low-energy backwater basins formed after large debris jams changed river courses across the valley floor (Glassman, oral communication, 2003). The objective of the present work is to use sedimentological, stratigraphic, mineralogical and some chemical characteristics to determine potential provenance zones for the West Eugene sediments and propose logical mechanisms for the deposition of the units.

CHAPTER 3
RESULTS

During this report, we refer to two landforms: hillslopes and bottomlands. The hillslopes are those areas adjacent and upslope of the Willamette Valley. Because the mechanism of overbank flooding has effectively been eradicated by modern flood control and channelization, it has resulted in the complete abandonment of many parts of the valley floor by the Willamette River and there no longer is a wide broad floodplain. Therefore, the term bottomland is adopted as a surrogate for floodplain.

3.1 MAPPING

3.1.1 Stratigraphy and Soil Investigation

Methodology

Previous to the initiation of this study, in July 2001, two trenches were excavated to a depth of approximately 10 feet in the west Eugene wetlands 1135 Project near Greenhill Rd. by Karin Baitis of the BLM. The variation of these profiles from the published information on Willamette Silts raised questions. This information was compared with the resulting logs of seventeen manually augered borings with a 4” bucket used in this study at the sites located in Figure 1.2. The borings typically reached an impenetrable layer or until a major paleosol and underlying parent material were identified. The deepest exploration was 9.5 feet in BLMST-10 and the shallowest was slightly less than 27 inches in BLMST-14 (the center of an abandoned Willamette R. channel). In the bottomland, the depths typically reached 7-8 feet, while on the hillslope they were 4-6 feet.

Soil descriptions of samples are located in Appendix A, in which the Munsell colors and textural variations are tracked as well as hydromorphic features, presence of charcoal, or lithological features. Notes on differing characteristics aided in understanding provenance and depositional processes. Color photos of each profile are found in Appendix B. Representations of the profiles in juxtaposition are presented in Figure 3.1.1 and a full set of the profiles can be found in Appendix C.

Findings

Using soil descriptions, texture and mineralogy, this study resulted in the identification of hillslope and bottomland stratigraphic units that could be correlated to each other. Four stratigraphic units were identified in the bottomland profiles. Unit I is a greyish brown silt, Unit II is a grey clay, Unit III is an olive brown silty clay, and Unit IV is made up of alluvium, residual soil, or bedrock (Figure 3.1.1). The surface unit of the hillslope profiles was identified as correlating to bottomland Units I, II and III. The hillslopes had a surface unit that buried an old residual soil (paleosol) that appears to be of a similar age to the paleosols found in the bottomland. There are some textural and mineralogic similarities between the hillslope and bottomland sediments and these will be discussed further later in this report.

The Munsell color values in each profile demonstrate how uniform the tones and colors are across the 3.5 mile transect in the first 5 feet of the different bottomland (wetland) profiles (BLMST-4 to BLMST-10, BLMST-15 and BLMST-HR). The color variations follow

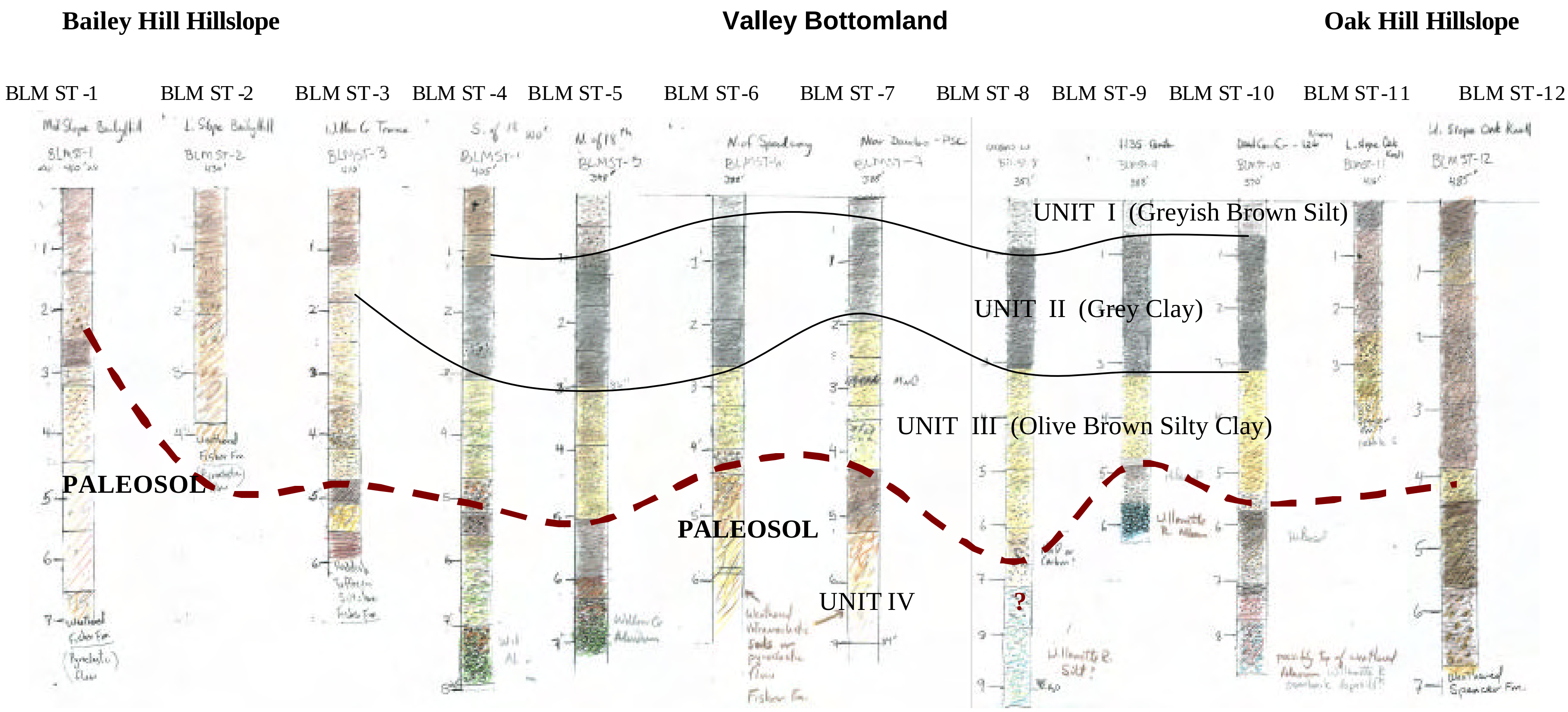


Figure 3.1.1 Stratigraphic columns BLM ST-1 through BLM ST-12. Additional columns from extended sampling conducted further into the valley and into Willamette River sediments can be found in Appendix C. This figure represents a south to northwest transect crossing the west Eugene wetlands. The stratigraphy was chronologically correlated using soil descriptions, texture, and mineralogy. Brown dashed line shows contact between residual soils and air fall deposit.

distinct and uniform textural changes too. Usually there is a greyish brown silt (Unit I) 6 to 11 inches deep overlying a dense grey clay layer (unit II) which appears in each of the bottomland profiles. The Units vary slightly in thickness. An olive brown to yellow clayey silt or fine sand (Unit III) is found at between 30-39 inches. Unit III generally extends to 59-67 inches where both a sharp textural and color change occur. At this contact (UNIT IV) is either a paleosol, an alluvial layer or weathered bedrock. The paleosol color varies between browns (yellow to red). The alluvium is gray or yellow, and sometimes weathered bedrock is present. In the majority of the profiles, the colors demonstrate that a more oxygen-rich environment and probably a more dissected terrain than the present "billiard table" landscape existed. Both Unit II and a flat surface contribute strongly to the wetland conditions that are prevalent in West Eugene.

The lack of fluvial bedding patterns, in terms of textural variation, remains one of the mysteries of Units II and III. Strong fluvial influence would be demonstrated by textural variation in the form of lenses of sandier material, or even gravel. This is rarely evident within these Units. Their thickness on the south to southwestern edge of the McKenzie-Willamette Alluvial Fan would require an extremely large natural event such as a persistant dam and water ponding to settle out so much clay. The damming would have had to be large enough to be the width of the extent of this soil unit, which is several miles. In contrast to the massive, monotonous thickness of UNITs II and III, when the borings passed into alluvial sediments (UNIT IV) of the tributary creeks and the Willamette River, the more typical alluvial textural variation was identified immediately (Appendices B and C).

Also of interest are the lower paleosols within the hillslope profiles. In most of the hillslope profiles a paleosol was found below a reddish brown silty soil. The upper soil was between 35 and 50 inches thick. Equally interesting, as mentioned above, is the fact that many of the paleo or residual soils located in the lower profiles, are redder and clayier, demonstrating greater age (more soil development) than the overlying reddish brown silts. As will be discussed later, mineralogical trends reflect these same color and textural breaks both at the hillslope sites as well as in the bottomland sites.

In terms of soil mapping, the 1987 Lane County Soil Survey divides the study area rather arbitrarily into Dayton and Natroy soils in a line that runs N-S near the BLM ST-8 site. It is evident from the profiles that there is very little change in the profiles as one moves across the bottomland from the east to the west of this site, except for depth of topsoil (Appendix C). It is plausible that a contact between Dayton and Natroy exists, but possibly is located further to the north and west of the study area, where Willamette Silts underlie the bottomlands.

3.1.2 Chronology of Lithologic Units: Radiocarbon Dating and Paleopedology

Methods

Radiocarbon Dating: On July 3, 2001, two 10 foot deep trenches were unearthed at the 1135 site in the West Eugene Wetlands (elevation 380 feet a.s.l.). The trenches were approximately 1000 feet apart and the stratigraphy showed a sequence of distinctly similar lithologic units between the two. The trenches are named T-1 and T-2 and are displayed on the Location Map (Figure 1.2). Samples taken from BLM T-1 #2 (Unit I), T-1 #4 (Unit III) and T-1 #6 (Unit IV) (see Appendix A) were submitted to Beta Analytic, Miami, Florida, for analysis. Applicable calendar calibrations were performed by Beta Analytic. These results are compared with data of two archeological studies of human occupation sites located nearby: the Long Tom River and Flannagan sites.

Paleopedology Analysis: Greg Retallack, University of Oregon Geology Department, aided in keying out the different stratigraphic units. Soil development was characterized using a microscope. All samples from BLM T-1 were used during this characterization, the soil descriptions of T-1 are found in Appendix A.

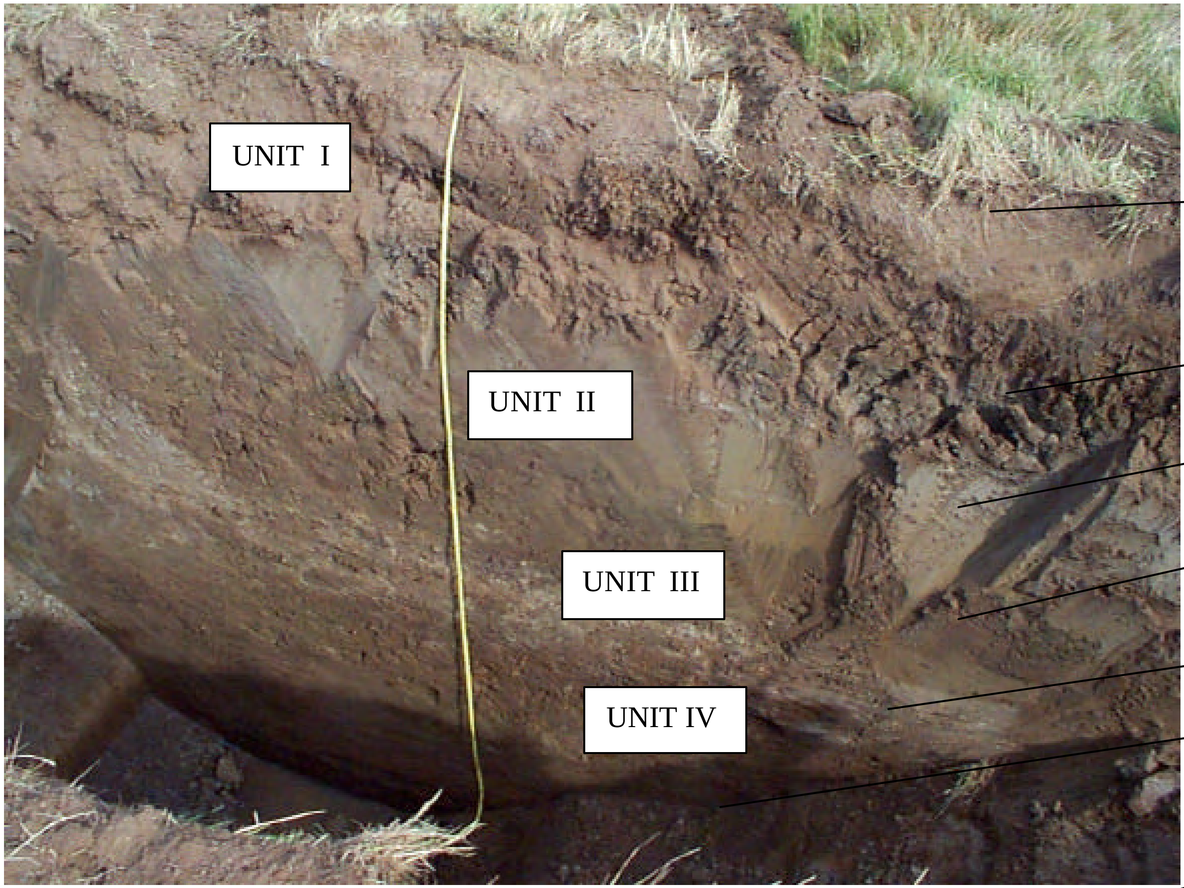
Radiocarbon Dating Findings

The following Table 3.1.1 lists depths of sample, radiocarbon age and material dated from Trench 1 (T-1).

Table 3.1.1 This table represents three samples sent to Beta Analytic for radiometric dating, their depth, UNIT, age, material that was sampled and lab number.

Depth (inches)	**UNIT**	**Age (yr BP)**	**Material**	**Lab #**
15	I	1480 +/- 60	Organic Sediment	Beta-159839
42	III	16000 +/- 50	Organic Sediment	Beta-157842
65	IV	6280 +/- 50	Organic Sediment	Beta-159840

Photo 3.1.1 displays that the radiocarbon dates are chronologically out of sequence. The surface soil 9 (UNIT I), as expected, has a young date of 1480 +/-60 ^{14}C BP, Cal AD 430 to 660 (Cal BP 1520 to 1280), however with depth, the soil results showed a discrepancy between the middle depth (UNIT III) and the lowest depth (UNIT IV): The lower depth resulted in a younger date of 6280 +/- 50 BP, Cal BC 5340 to 5280 (Cal BP 7290 to 7150) and Cal BC 5180 to 5080 (Cal BP 7130 to 7020), vs. the Unit III date of 16000 +/- 50 BP, Cal BC 17560 to 16740 (Cal BP 19510 to 18690). These are bottomland sediments that are in contact with water throughout much of the year from a regional water table and from overland runoff. Inherently there are problems with dating bulk sediments. The chronological incongruity described above, leaves two possibilities: 1) The bulk sediment results may be confused by modern carbon mixed with a lot of old sediment (such as landslide debris that may have contained carbon from very old soils, the mixing of caldera materials during a volcanic eruption, or sources from fossils); 2) There is always the possibility that the younger age of the lowest unit in the soil profile may have resulted from contamination of the circulation of recently infiltrated ground water with a high carbon content at this contact. Unfortunately, the results present a challenge and further investigation of the sediments was necessary to come to any conclusions regarding the age of the floodplain sediments.



Plow Layer 0-10”

Topsoil 10-21”
Organic Sediment 1480 +/-60 BP

Grey Clay 21-42”

Olive/Brown Clay 42-58”
AMS Organic Sediment 16000 +/- 50 BP

Silica-rich Clay 58-106”
AMS Organic Sediment 6280 +/- 50 BP

Alluvium-fluvially bedded silt 106-114”

Sand layers +114”

2nd trench--gravels at base 0-6cm in size
Water table at approximately 10 feet

Photo 3.1 .1 This photo shows the stratigraphy of site T-1. Note that the sediment at deeper depth was younger than the stratigraphic unit above it.

There isn't a large body of existing radiocarbon dating available in the immediate area. According to Tom Connolly, 2002, University of Oregon Department of Anthropology, no occupation sites have been found in our study site area. There are several archeaological and geomorphological investigations in the Veneta area on the floodplain of the Long Tom River (Freidel, 1989), and some other studies related to highway construction and the development of the sewage lagoon. Freidel had a series of C-14 dates from an occupation site, and defined five distinctive textural/mineralogical units in three 10 foot (3.0 m) deep transects. The deepest unit at about 200 cm. below the present surface, has some textural and mineralogical similarity to the grey clay unit found in this study in West Eugene. The unit is described as having: 1) no mica, 2) high clay content, and 3) the presence of charcoal. Friedel describes the unit as covered with several layers of mica bearing silty sand and sandy units clearly derived from the nearby uplands. The age of this unit is around 9400-9600 +/- 180 yr B.P. based on two charcoal and one bulk soil date.

An archeaological site closer to the this study area, is the Flannagan site (Toepel, 1985). It is located about 2 miles north of the BLM ST-Harvest Ridge samples. The site was adjacent to a series of northwest-southeast trending swales and is described as being located on the Winkle geomorphic surface, a surface described by Balster and Parsons (1968) as being abandoned by the Willamette River between 5250 and 3300 years ago. The Flannagan study notes that the occupation site was located only slightly higher in elevation than the Ingram surface, which was the current flood plain of the Willamette River in 1853. 1853 Land Survey notes indicate that the area was "inundated from 1 to 3 feet deep by the Willamette River at high water" and that "flood water sometimes passes through the above noted swales from the Willamette to the Long Tom rivers."

The Flannagan soil sequence is characterized by three distinct stratigraphic units, two of which had anthropogenic materials (fragments of oxidized soils) or crude tools and some dateable materials. Textural analyses of the sequence were taken in 10 cm increments. The surface 50 cm is a silty sandy clay and below they are classified as sandy silty clays. All have greater than 30 % clay and average clay content ranges between 40 and 50%. The upper stratum is a dark clay loam and in the first 12" cultural materials are scarce but from 12-18" flecks of bisque are common. The middle layer of the cultural deposit is a gray clay loam. This stratum is flecked with bisque. Below the cultural layer lies Stratum 3, also a grey clay loam. It is distinquished from the above layer by its greater compactness, slightly lighter color and by an absence of occupation materials. The C-14 dates associated with these materials can be grouped into each stratum (Table 3.1.2).

Table 3.1.2 The deepest depth at 120 cm (47 inches) has a C-14 date of approximately 5750 BP. This indicates that accretion of the floodplain occurred in this area during the last 6000 years.

Stratum	Depth (cm)	Years B.P.	Sample #
Upper stratum	30	1800 +/- 110+	GaK-8362
Upper stratum	50	1760 +/- 100+	GaK-8363
Middle stratum	60	3230 +/- 150+	GaK-8368
Middle Stratum	60	3300 +/- 220+	GaK-8369
Middle Stratum	120	5750 +/- 200+	GaK-9220

Pleistocene megafauna remains were discovered at an archaeological site in Woodburn at Mill Creek. The remains were found immediately above Willamette Silts (Missoula Flood deposits) and were dated to be approximately 12,000 years of age. Above these bogs and woodland sediments, a massive clay with no remains was found (Stenger, 2003). On June, 27, 2003, a sample of the grey clay was collected to be used in a comparison with this study. The clay unit was dated at 6,850 BP. Texturally, the unit was very similar to the grey clay found in West Eugene, although finer. The unit also contained the identical unique mineralogical suite that will be discussed in the following chapters.

Paleopedology Findings

The weathering of sediments and soil development may be used as a surrogate for dating the age of floodplain sediments (Figure 3. 1.2). By identifying the Soil Order through diagnostic features we can ascertain how long it may have taken for the soil to develop. In floodplain soils that are periodically buried, soil development ceases upon time of burial.

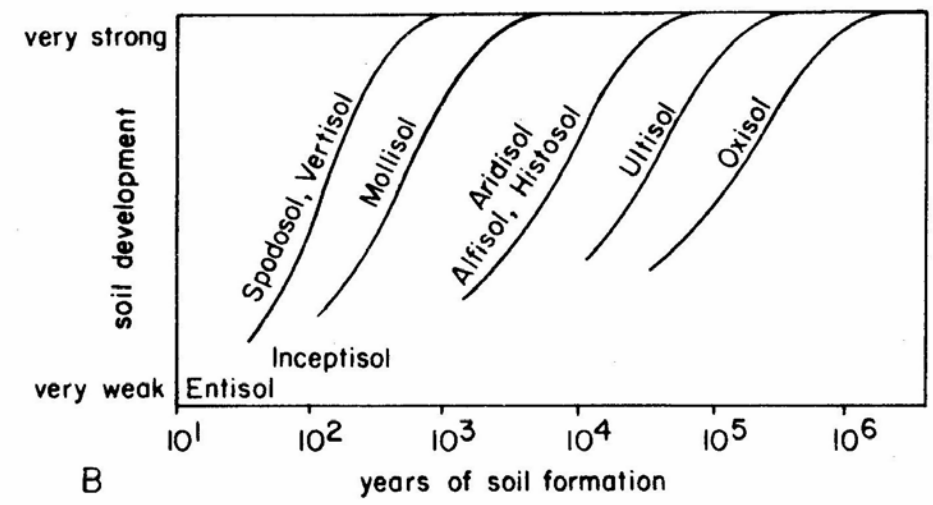


Figure 3.1.2 Soil Orders may be characterized using developmental features. This can give an indication of how long it may have taken for that soil to develop. From Retallack, 1990.

Through careful examination under a microscope, the amount of weathering of the following samples was documented and in some cases, classified as a particular Soil Order.

Surface Silt Loam BLM T-1 #1 and 2 (UNIT I)
Bulk soil 1480 +/- 60 BP

The surface unit is an alluvial deposit located within the floodplain. The soil is vegetated with grass and has been plowed. The soil is currently mapped as a Dayton soil, a Fine, montmorillonitic, mesic Typic Albaqualf. However, visual observation indicates that this is a Mollisol. A Mollic epipedon contains 1 percent or more organic matter in mixture of the upper 7 inches. The color values are darker than 5.5 dry and 3.5 moist and chroma less than 3.5 moist. Structure is not massive and hard. The epipedon is not naturally dry in all parts more than 9 months/year.

Grey Clay BLM T-1 and T-2 #3 (UNIT II)

The grey clay unit appears to have unweathered volcanic lithic fragments floating in a clay matrix. It is very massive. There are no clay skins, no cutans, no peds, no root channels and no bedding. Slickenslides are evident from the high shrink/swell capacity of the clay. There appears to be no soil development.

Silty clay BLM T-1 #4 (UNIT III)
Bulk soil 16000 +/- 50 BP
This sample may have soil structure. The top 6 to 10 inches have stringers of manganese that have the appearance of fine root channels. Generally, it takes decades to centuries to have manganese precipitate out. Weathering characteristics make this a very youthful soil, it appears to be an Entisol (Aquent) that may have had approximately 500 years of development. The soil lacks any developed horizons. There are some volcanic clasts present, but are poorly sorted. The radiocarbon date appears to be out-of-line with the weathering profile.

Silica rich clay BLM T-1 # 5, 6, 7 (UNIT III)
Bulk soil 6280 +/- 50 BP
This unit has lithic fragments present, and those that are present, are well sorted. There are beds of white ashy tuff. Quartz that is present is double terminated, bipyramidal. There are potentially two local outcrops of this type of tuff within the Eugene Formation. The Bond Creek Tuff is found along the Willamette River on the east bank across from the EWEB plant. The Fox Hollow Tuff contact lies from South Eugene to Spencer Grange to Bailey Hill Road and west of Wallace Butte. This unit appears to be an Inceptisol (Ochrept). Inceptisols are immature soils having weak expression of the soil profile and retain close resemblance to the parent material. Frequently there is a high abundance of volcanic ash. The suborder Ochrept is a wetness criteria with Ochrepts having ochric (light-colored surface) epipedons. The soil horizons are weakly expressed and lack significant accumulation of clay in the B horizon. The soil development is a cambic Bw, with no gleying. The cambic horizon is altered but does not have dark color, organic-matter content and structure. However, much manganese is present that is 5-10 mm in diameter. Manganese development of this nature would take 4000-5000 years.

Silt Bed BLM T-1 #8 (UNIT IV)
Fluvially lain silts and sand containing minor amounts of quartz. These are thin sequences of cross-bedded sediments. The silt appears to have many iron bearing minerals (40%) that are somewhat weathered.

Sand and Gravel BLM T-1 #9 (UNIT IV)
Volcanic fragments include quartz and iron minerals. There isn't much of a clay matrix, there are no clast supported grains. Some of the grains are angular suggesting that they were not transported very far. Gravels are well-rounded. The regional water table appears at the top of this unit.

3.1.3 Summary

Using existing data in a comparison to correlate stratigraphic units between the Long Tom River, the BLM T-1 and the Flannagan sites was not possible. There are similarities between the high clay contents and depths of some of the clay units. The radiocarbon dates obtained show approximate similarities in depths, however, no clear conclusion can be drawn that they support each other mutually. It is evident that aggradation of the floodplains occurred during the past 10,000 years. Soil development within the stratigraphic units indicates short residence times on the surface of the floodplain, before burial. Given the length of time that soil takes to develop, assuming that no erosional events occurred, the pedological results indicate again, that the sediments are Holocene in age.

3.2 CHARACTERIZATION OF SEDIMENTS

3.2.1 Textural and Sedimentological Analysis

Methods

Textures of the sample soils were studied using a one sieve analysis method that served to give a general idea of textural variation. It also permitted recovery of coarse and fine separates for mineral microscopic identification, to make thin sections for petrographic analyses, and to employ different classes of chemical analysis methods described later in this Chapter.

About 200 gm of oven dried sample was taken proportionally from the total amount for any given interval and washed through a 50 mesh sieve (openings of 0.297 mm), retaining grains larger than a medium sized sand (USCS). The material that passes through the sieve is placed into a concave steel mixing bowl and allowed to settle 5-10 seconds before being slowly poured off. Fine sand and coarse to medium silt are retained in the bowl with minor amounts of fine silt and clay. This procedure was carried out in the same manner for all the soils. The results are presented in Appendix D (Columns 3, 4 and 5).

Findings

Bottomland Profiles

Sedimentary characteristics were observed initially as the samples were taken out of the auger bucket. Changes from a clay or clayey silt texture to sand or gravelly textures were evident. In typical alluvial sequences such changes are frequent, reflecting the dynamics of rivers and creeks on a relatively flat surface in a pre-colonial setting. Under the microscope, grain roundness was also used as an indicator of fluvial transport. The grains of the loose sand unit in BLMST-15 that underlie upper units are clearly more rounded than those of Willow Creek (BLMST- 4-8 and 4-12) reflecting the greater transport distance and smoothing force of much larger volumes of water and sediment involved in their arrival to this point.

The textural data from the majority of bottomland profiles show that the upper 3 units; grey silt, dark grey clay and olive brown clayey silt (Units I, II and III) have roughly similar ratios of medium coarse sand : fine sand : silt and clay. Their combined thickness averages between 55-65 inches. Below Unit III there is not any particular consistency in texture. Unit IV varies from alluvial material to weathered sedimentary or pyroclastic Fisher Fm. bedrock.

The range of values for coarser than medium sand are between 1-6% in stratigraphic Units II and III. In general, we found that coarser contents (sand sized) were slightly greater in Unit I with Fe_2O_3 cemented aggregates making up the major part. Sand-sized contents were lower in Unit II and III and higher again towards the lower contact of Unit III, where there were more grains of lithic fragments, usually yellowish and white which give this zone a “salt and pepper” appearance, implying normal grading. An important finding is that the largest grains were rarely greater than 3-8 mm within most of the study area, except where the augering met the relict Willamette River channel and gravels and cobbles became evident.

The range of values for fine sand and coarse silt in Units II and III varies from 18 to 60% and follows the same tendencies as the coarse sand fraction, in general increasing with depth. It tends to be higher in Unit III than in the grey clay Unit II.

The contact with underlying materials in Unit IV, in the lowlands profiles, is usually marked by a sharp increase in coarse sand and gravel content as the boring enters either alluvial or weathered bedrock substrates. These textural values contrast with the overlying units. The textural values of Units II and III are not typical of water lain or mudflow processes, but rather they are closer to that of tephra or airfall ash deposits (Fisher and Schmincke, 1984), that is, they are normally graded (coarser below, fining upward). Unit I appears to be a fluvially reworked unit in which fines (fine silt and clay) have been washed out leaving only coarser material. The only lower strata in Unit IV that represent textural values similar to the overlying Unit are BLMST 4-10 (67-77"), BLMST 5-9 (61-75") and BLMST 8-10 (87-95") which are clay lenses 10-15 inches thick interspersed between coarser units. This would be expected in a fluvial facies, more typical of a meandering stream or river. Concurrent with the textural change between Units III and IV, is a change in color to brighter reds and orange tones, indicating there was more oxygen present in the soil profile and that little or no wetland existed during Unit IV time.

Hillslope Profiles

The colors of the surface soils on the hillslopes are markedly different from the lowland soils and the textural data show different patterns. In Appendix D profiles BLMST-1,-2,-3 and 11 indicate that the coarse sand value increases from 7.2% – 64.4% with clay values dropping in response. The fine sand values are higher than in the bottomland profiles and exhibit minor increases with depth. A considerable amount of the increase of coarser material consists of iron oxide concretions made up of silt and finer sized particles cemented by Fe_2O_3 and MnO into aggregates.

Paleosols are present beneath the surface soils of all hillslope borings. A paleosol formed in residual soil below the surface sediments on Fisher Fm. in the BLMST-1, -2, -3 and BLMST-13A. Another paleosol formed on a residual soil at BLMST-11 and -12, these two borings are assumed to be over Spencer Fm. sediments (Retallack, pers. com., 2003). These latter profiles show a sharp increase in coarser textured grains with a high degree of roundness (pebbles) with depth. These grains appear as clasts in a conglomeritic sandstone found at the base. The lithologies of these grains are more typical of Klamath Province lithologies than the Cascadian region.

3.3 MINERALOGY

3.3.1. Soil

Methods

The mineral separates produced by the study of soil textures served as the basis for a microscopic analysis of each profile. During an initial mineralogical review an equal amount of time (10-15 minutes) was spent studying each sample. This qualitatively determined the importance of each type of mineral, noting characteristics such as roundness, secondary coatings, presence of charcoal and manganese oxides or any other notable feature. A binocular microscope with 30x magnification was used to review the > 50 mesh and < 50 mesh fractions of 147 samples. The results are presented in Appendix D (Columns 6-28).

Secondarily, eighteen thin sections were made of coarser than 50 mesh soil minerals from samples in three profiles which were selected to represent a hillslope site BLMST-1 (Fisher Fm.), and two bottomland sites BLMST-9 (silty substrate) and BLMST-HR (gravelly substrate of Willamette River alluvium).

Findings

Microscopic Analysis

One of the principal findings of this study is that there is unique suite of minerals and lithic fragments associated with Units I, II and III that are always present in the bottomland and hillslope profiles and are characterized by similar textural classes (Photos 3.3.1, 3.3.2, 3.3.3, 3.3.4, 3.3.5 and 3.3.6 photographed at the University of Oregon, Geology Department). These minerals are very distinctive from both, the mineral suites originated by weathering and erosion of the south hills (Fisher and Spencer Fm.) and the Cascades.

A distinctive suite of eight minerals and various types of lithic fragments form a diagnostic tracking tool for the stratigraphic units. The minerals include: 1) well formed tabular crystals of clear plagioclase (andesine-oligoclase), 2) euhedral, quite magnetic, light green orthopyroxene (hyperstene) with opaque inclusions of ilmenite and magnetite, 3) coarse grained dark brown to black hornblende, 4) coarse grained quartz sometimes completely or partially bipyramidal, oftentimes fractured, 5) euhedral spinel, 6) flat hexagonal ilmenite, sometimes formed around a nucleus of dark green glass, 7) chromite and 8) zircon. Lithic fragments include white, grey or brown aluminosilicate with tiny metallic inclusions, fine grained granordioritic or rhyodicitic rock, iron-oxides, and white to brown scoricious material with abundant vesicles.

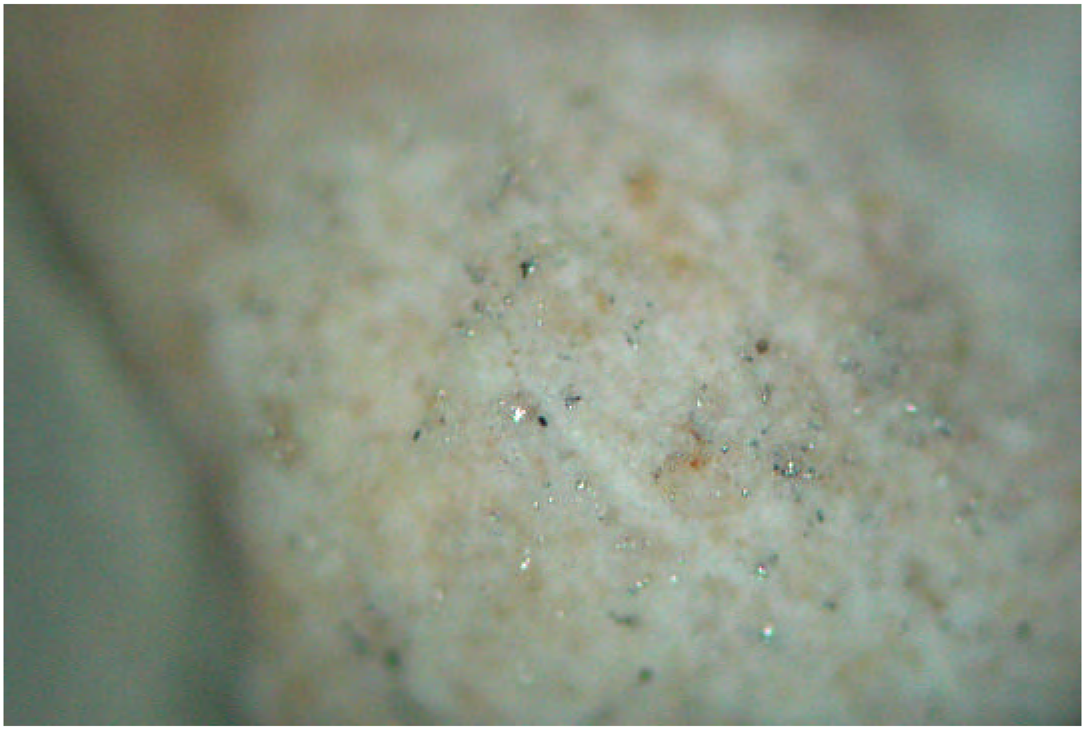


Photo 3.3.1 White lithic fragments with metallic flakes with no volcanic attributes.

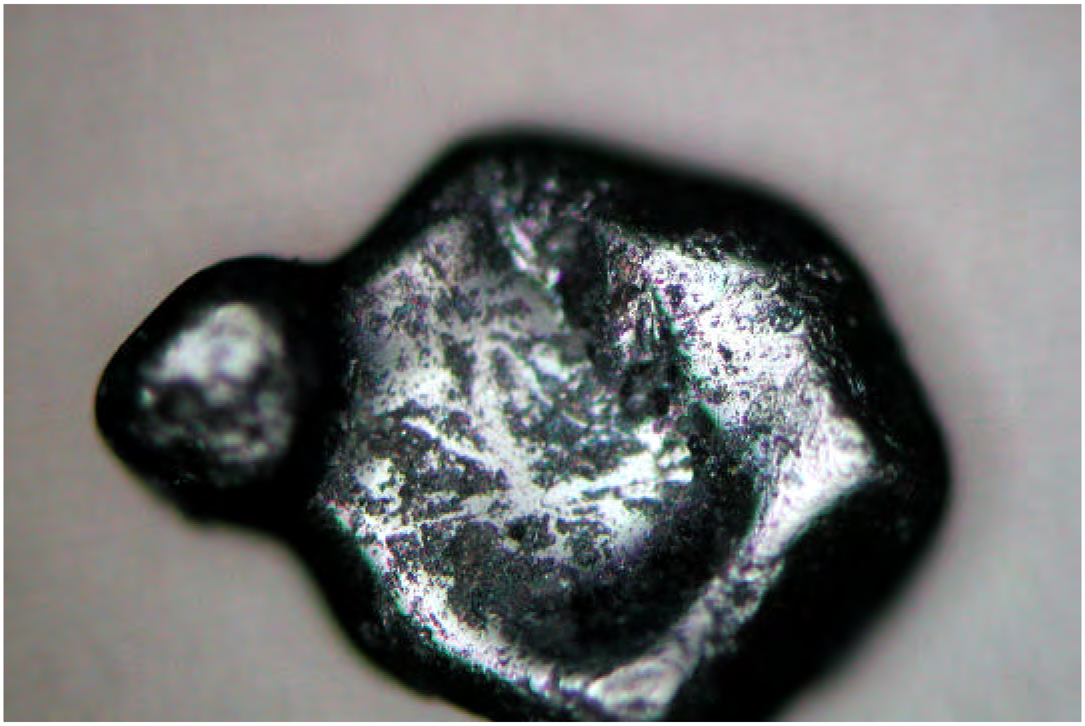


Photo 3.3.2 Ilmenite, titanium iron oxide grains with slightly high magnesium content.

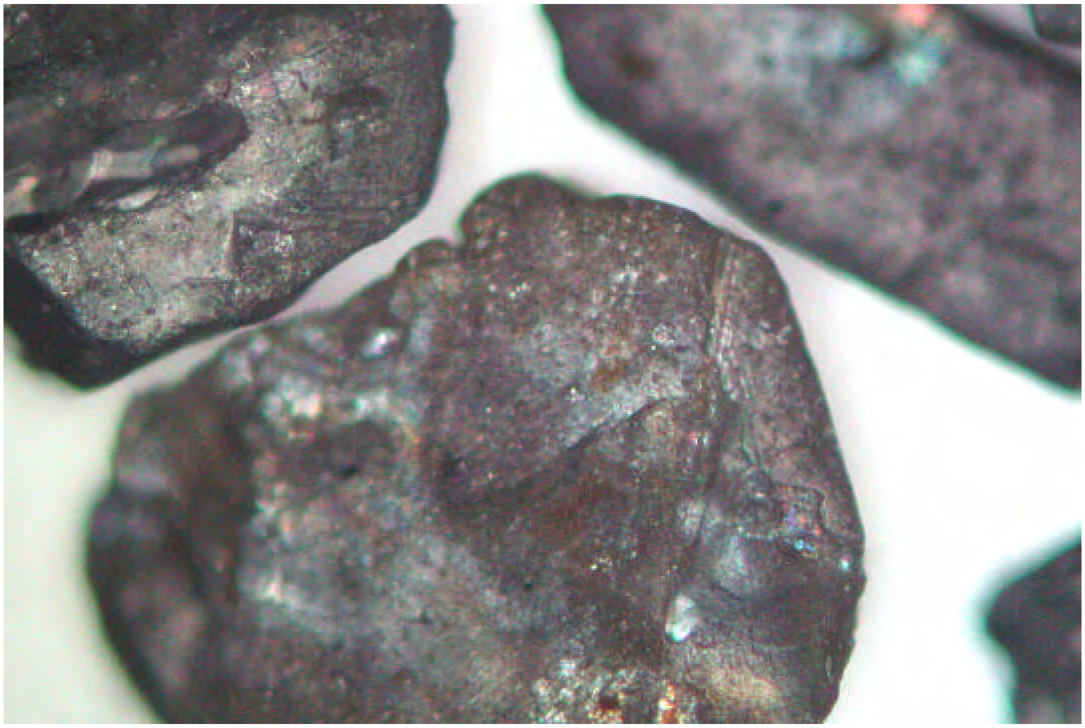


Photo 3.3.3 Plagioclase. Tabular, quite euhedral.

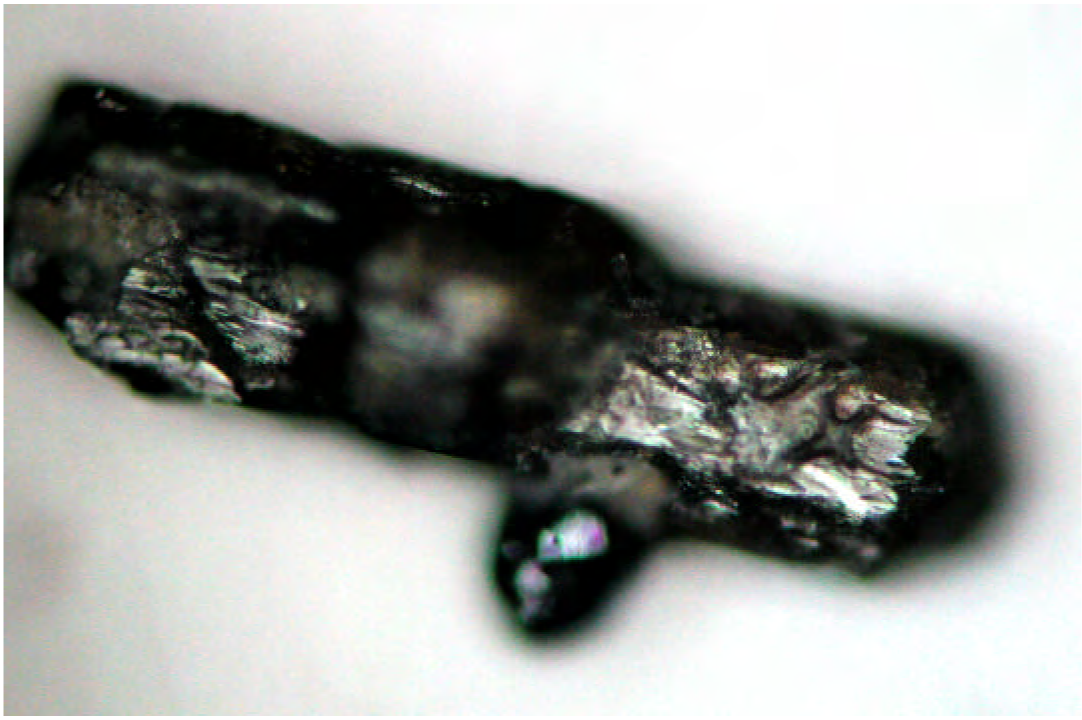


Photo 3.3.4 Orthopyroxene (hyperstene) with ilmenite and magnetite Inclusions, always magnetic. Its euhedral crystal form and twinned appendages argue against fluvial transport

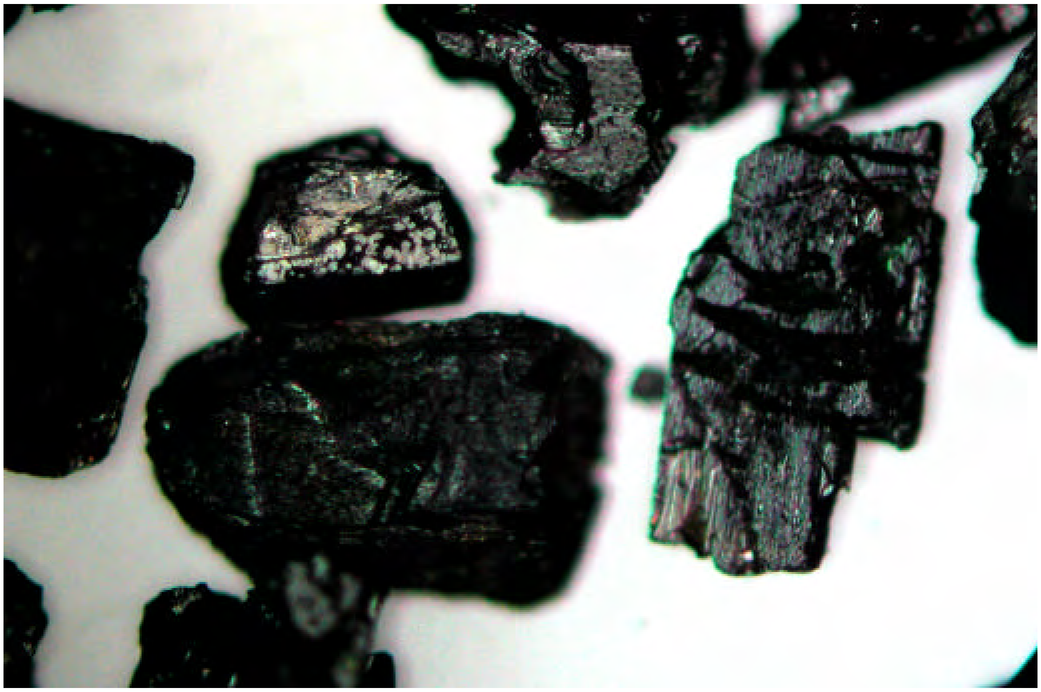


Photo 3.3.5 Large broken hornblende crystals demonstrate twining and well formed crystal faces.

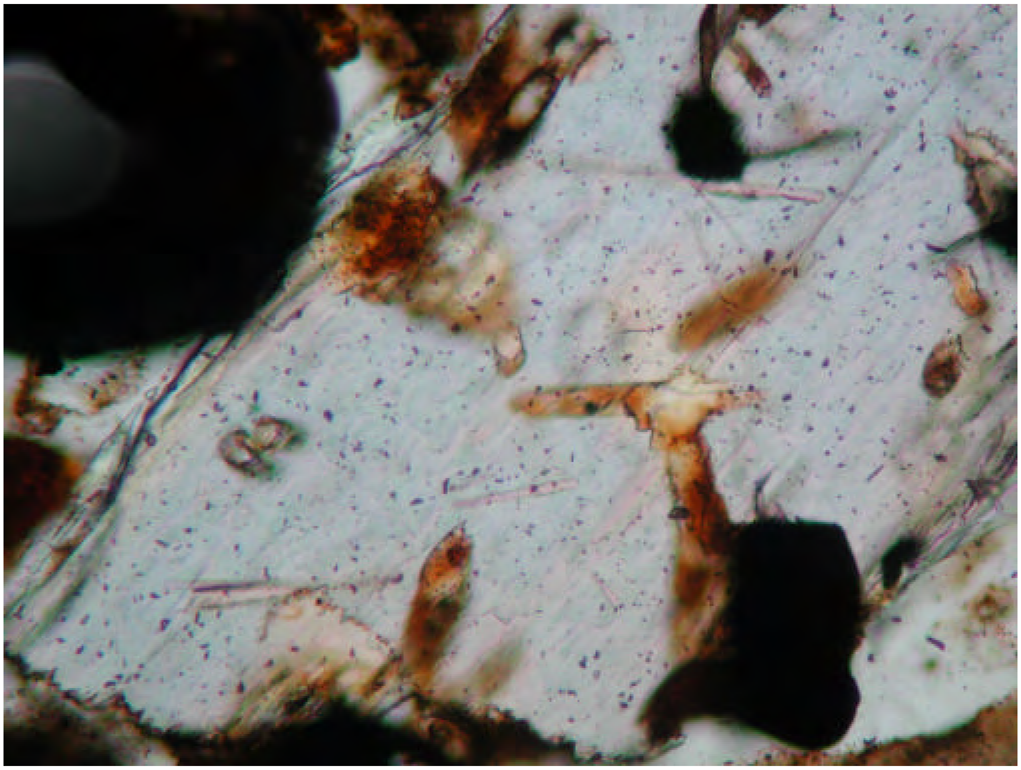


Photo 3.3.6 Thin section view of orthopyroxene (hypersthene) showing inclusions of ilmenite or magnetite (black) and light colored blade-like apatite (phosphate bearing mineral) crystrals.

The most distinctive and probably diagnostic mineral of the group is the light colored orthopyroxene (hyperstene) with inclusions (Photo 3.3.6), followed by the large hornblende crystals (Photo 3.3.5). Also very important are the white and grey lithic fragments with tiny metallic inclusions and sometimes very scoriacious which are present throughout the bottomland Units I, II and III (Figure 3.1.1). Many of these fragments are glass and occasionally a small pumice grain is found. The indicator orthopyroxene is found most commonly in Units I and II. Occasionally small fragments of this mineral are found in Unit III, but the white and grey lithic fragments increase in percentage with depth along with the spinel and the flat hexagonal ilmenite and magnetite grains toward the base of Unit III. The lower 6-15" of Unit III is oftentimes quite spotted with white, yellow, orange and brown colored coarser grains.

These minerals are very euhedral, lack much rounding, are shiny, are usually easily loosened from their clayey matrix and are free of clay coatings and iron oxide stains. These indicators suggest that they were formed in liquid or gaseous environment and that little fluvial transport was involved in their arrival to these sites.

Very surprisingly, the same indictor minerals are present in the upper units of the hillslope (Appendix D). To investigate the possible extent of this mineralogic assembledge, two additional profiles were examined: one in the south hills about a mile to the east (Buck Street) of the study site, and the other at the Irish Bend site (Malpass Clay), 24 miles to the north of Eugene. The same minerals were present in the surface soils (0-40" and 0-24" respectively) at these two sites. Additionally, a grey clay sample from Woodburn, 75 miles north of Eugene, was collected. Again, minerals were identical to the clays (Units II and III) of the West Eugene area.

The implication of the relatively original euhedral form of the minerals is that they have not weathered from local bedrock. They are not present in lower stratigraphic units, but they are present across hillslopes and bottomlands, and over a wide geographic area. This correlates with the idea of airfall deposition and clearly something other than fluvial deposition. Volcanic eruptions have occurred recently in the Cascades and airfall deposits are known to have reached the Willamette Valley (O'Connor, 2001). Pumice, scoriacious lithic fragments and glass found in Units II and III supports that the deposit is the result of volcanic eruption. The study site samples are different from most local Cascadian andesitic, basaltic andesite sources being of a more acid composition. Given the young age of the West Eugene deposits, the contemporaneous age of the Woodburn site (6800 BP) to the Mt. Mazama eruption, this study concludes that there is immense similarity to the petrology and chemistry of the extensive Mt. Mazama pumice deposits.

The mineralogy of these profiles was also compared with the coarse mineralogy of the Missoula flood deposits (Irish Bend 10-12' deep) and the paleosol below (Diamond Hill Member). As can be seen in Appendix D there is very little common ground between Missoula Flood mineralogy and that of the indicator mineral group. The Missoula Flood deposits are dominated by quartz, plagioclase, orthoclase, muscovite, biotite, amphibole and metamorphic and intrusive rock lithic fragments, reflecting the region of origin and the scablands of Eastern Washington which were scoured by the catastrophic flows. This mineral suite is not found in this report's study area, demonstrating that the Missoula Floods deposits are not found in the West Eugene, confirming findings of numerous studies that measurable deposits of Irish Bend Member aren't found above 325-350' a.s.l. (the West Eugene study area elevation is 380-450' a.s.l.). There is an absence of heavy minerals in the fine sand fraction of the Missoula Flood sediments. This contrasts strongly with the abundant black sands (ilmenite, spinel and magnetite) found in Units I, II and III of the West Eugene profiles.

Below the bottomland Units I, II and III, and the surface hillslope unit, mineralogic changes always occur. They vary in different profiles according to the geologic substrates they encounter. These range from alluvium to residual soils found on bedrock. There is a marked increase in the plagioclase/quartz ratio, and volcanic lithic fragments compared to the grey, white and brown lithic fragments common in upper units (Appendix D). In alluvial units, more non-magnetic and darker green pyroxene appears and hornblende disappears. In the weathered soils, there is an increase in clay skins and clay aggregates, as well as iron oxides. The plagioclase is present as fragments, quite corroded, and very small crystals.

Thin Section Analysis

The semi-rigorous study of eighteen thin sections confirmed the binocular microscopic observations and revealed several other details about the mineral suites. To date not all the minerals observed in the thin sections have been identified. By associating detailed chemical data with the mineral species it was possible to identify particular species of some of the minerals.

In all the bottomland profiles, sharp differences are observed in thin sections between the mineralogy of the bottomland Units I, II and III and the underlying Unit IV (Appendix D). Units I, II and III contain lower temperature range forming minerals such as the coarse grained hornblende, the light green orthopyroxene (hyperstene) with ilmenite and apatite inclusions and the sometimes magnetic, white, gray and brown lithic fragments. As a typical example, in profiles BLMST-9 and BLMST-HR (Appendices B and C), the mineralogy changes from the consistent eight indicator minerals in the upper 30-36", and an increase in lithic fragments and Fe and Mn oxides with the continuation of spinel and ilmenite through Unit III (to approximately 60") passing through to Unit IV where variable mineralogical suites occur according to which substrate is encountered. Only ilmenite and some fine magnetite continue with plagioclase and some quartz into Unit IV which is a residual soil formed on fine-grained alluvium of the Willamette River.

In other areas in Unit IV, thick clay skins coat highly weathered plagioclase and other glassy grains of pyroclastic flow or epiclastic sedimentary parent material appear where Fisher Fm. is encountered (BLMST 6, 7 and 13A) and more Cascadian alluvial sediments in the other cases of Willamette River alluvium (BLMST 8, 15, T-1 and T-2) or petrified wood and volcanic lithic fragments with some quartz and plagioclase enriched sediments in the case of Willow, Dead Cow or Amazon Creek sediments (BLMST 4 and 5). These latter sites characterize the suite of minerals expected from the erosion of the South Eugene Hills.

Under mineral microscopy, the same mineral suite can be found in the thin section analyses in the surface layers (35-45" deep) of the hillslope sites. For example, at BLMST-1, a similar change in characteristic minerals occurs between the surface and subsurface residual soil formed on Fisher Fm. The surface (0-39") contains the same minerals as the bottomland, and again, moving downward in the profile, the variety and size of the minerals decreases dramatically. Clay minerals and iron oxides (limonite and geothite) dominate the residual soil in the profile with few recognizable nucleuses of plagioclase and opaque ilmenite or magnetite grains. This same relationship is found at the Oak Hill and Wallace Butte hillslope sites (BLM ST 1, 2, 3, 11, 12, and 13).

Generally, soils weather from the surface downward, unless they are buried by alluvium or colluvium. This begs the question, how larger, less weathered and clay-free minerals could exist above a more weathered residual soil on these low slopes without some upslope transport process. In the upper 40" of the hillslopes, there is an increase in the variety of minerals that are low temperature forming (more typical of non-volcanic environments) crystals such as the coarse grained hornblende, ilmenite and apatite inclusions. These minerals are not a product of weathering from volcanic rocks (higher temperature) found in the epiclastic Fisher Fm (Appendix C). Even invoking mass movements from upslope couldn't bring these minerals in, because no low temperature (non-volcanic) source exists above them. No such source is evident at either the Bailey Hill or Oak Knoll sites where this relationship is found. The primary existence of the surface soil minerals identified in this study, does not appear to originate from sporatic slope instability processes from upslope.

The conclusion is that the upper unit was deposited as airfall material from Mt. Mazama. The mineralogical consistency of the three upper units of hillslope and bottomland profiles in West Eugene argues strongly for an airfall deposition event of great proportions. It has generally been observed that the recent volcanic eruptions in the Cascades (Mt. St. Helens, Mt Jefferson, Newberry Crater or Mt Mazama) have not had their thick ash plumes blown into this area. O'Connor, et.al. (2001) and Shipley and Sarna-Wojicicki (1983) summarizes the ash fall events, and the few thin traces of deposits that were encountered in recent Willamette River alluvial sediments near Coburg, suggesting that there was minimal impact on this region. Our data suggest otherwise.

3.2.2 Tephra Analysis

Methods

Tephra Analysis was performed on the white lithic fragments from Units III and IV. December 14, 2001, Tephra Analysis was done by Nick Foit, Director, Electron Microbeam and X-ray Analysis Labs, Dept of Geology, Washington State University, Pullman, Washington. Samples were analyzed by Microprobe Thin Section.

Two samples mailed, BLMT-1 #6 (Unit IV) contained fine ashy material from "salt and pepper" unit approximately 62 inches down the profile. BLMT-1 #4 (Unit III) contained small fragments of pumice-lapilli looking fragments selected from between 42 and 58". The samples were prepped twice and no known tephra was found. Neither samples contained any glass. Both samples were fine-grained sediments consisting of quartz and aluminosilicates. Some carbonate was found in sample #6 as it fizzed slightly in acid.

Findings

Macroscopically, the samples look like tephra but under a petrographic scope it does not resemble glass—everything is birefringent (i.e., crystalline). There are tiny (few microns) rounded material (clay masses?). He concluded that the glass was completely weathered away (devitrified) and could not be analyzed. With more detailed observations from this study, pumice and glass has been identified in the samples and future study needs to focus on chemical composition.

3.3.3 Clay XRD

J.R. Glasmann, Willamette Geologic Service, Philomath, Oregon, graciously performed X-ray Diffraction analysis (XRD) on a series of our samples, ad honorem, and much of the discussion presented on the significance of the results are taken from his interpretations that are found in their original form in Appendix E.

Methods From D'Amore, et al, 2000

A variety of sub-samples were taken from the samples collected along the wetlands transect (BLMST 4, Trenches 1 and 2 and BLMST HR). These clays were compared to sample data collected previously by Reed Glasmann including Willamette Silts (Irish Bend and Greenback Members) and several older soils and paleosols developed on the Willamette Valley floor and residual soils of the Coast Range foothills. Clays were dispersed by mixing 2 to 5 g of moist soil with 200 mL of distilled water and 5 mL of 0.5% (w/v) Na-hexametaphosphate in 250-mL polyethylene bottles and placing the mixture in an ultrasonic bath for 10 minutes. Following the ultrasonic treatment, the suspension was stirred with a milkshake blender for 1 minute. After stirring, the suspension was allowed to settle for 15 minutes and the suspended fraction (<15-µm) was decanted into another set of 250-mL centrifuge bottles. The clay fraction (<2 µm) was separated by centrifugation and was concentrated by flocculating with a few drops of 0.5 M $MgCl_2$. This separation process was repeated 3-4 times until near quantitative separation of the various size fractions occurred. The clay concentrate was saturated with Mg by washing three times with 0.5 *M* $MgCl_2$ followed by three rinses with distilled water. Oriented slides of the <15-µm silts and Mg-saturated clays were prepared for X-ray powder diffraction analysis (XRD) by a paste method (Thiessen and Harward, 1962). The remaining clay was then K-saturated with 1 *M* KCl using a similar procedure and oriented slides were prepared for XRD. The slides were treated according to the method outlined by Glasmann and Simonson (1985), excluding the glycerol solvation and high temperature treatments. Slides were analyzed using a computer-automated Phillips XRG 3100 (Phillips, Eindhoven, the Netherlands) equipped with compensating slits and a focusing monochromator. Copper k radiation was used (40KV, 35 mA) and slides were step scanned from 2 to 40° 2-theta, using a step size of 0.04^{o} 2-theta and a count time of 2 s. Semiquantitative interpretation of the clay mineralogy of each sample was facilitated by comparison of sample XRD spectra to computer-generated clay mixtures calculated using NEWMOD (R.C. Reynolds, Jr., 1985, Hanover, NH).

Findings

Pre-Missoula Flood Paleosols and Missoula Flood Deposits

Buried paleosols are common beneath Missoula flood deposits in the Willamette Valley and exhibit a distinctive clay mineral assemblage that generally consists of highly disordered kaolinite, hydroxy- interlayered smectite/vermiculite (chloritic intergrade), quartz, and iron oxides (Figure 3.3.1). Where such paleosols are covered by Missoula Flood deposits, the mineralogical character of the soil frequently displays a sharp change that is associated with similar changes in other soil properties (color, texture, structure, etc). The pedon represented in Figure 3.3.1 below the Willamette silts, illustrates such a sharp mineralogical boundary, with olive brown, strongly micaceous, chloritic, and feldspathic Missoula Flood silts overlying reddish-brown non-micaceous, quartzose, kaolinitic paleosol clays associated with weathered Spencer sediments. Missoula Flood deposits have not experienced the prolonged weathering of older paleosols and contain considerable mica and feldspar (both K-feldspar and plagioclase), as well as minor amounts of other easily weatherable minerals (augite, hornblende, biotite). These are the mineralogical fingerprints one might expect to see in the southwestern Willamette Valley wetland soils, if Missoula Flood deposits were present (See Appendix C for coarse mineral comparisons which bear out these observations very well).

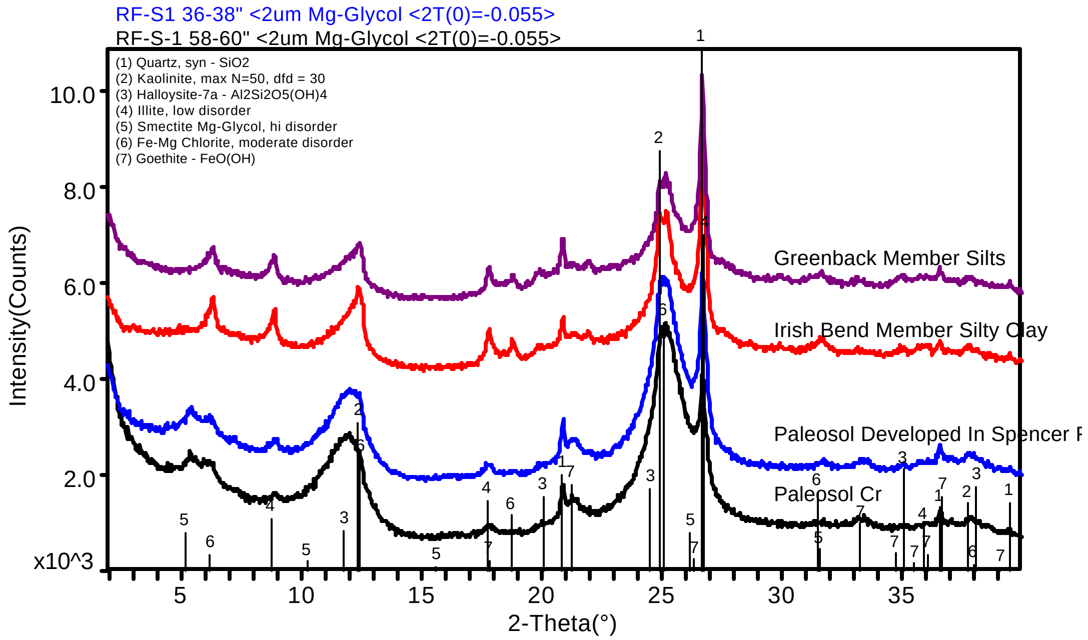


Figure 3.3.1. Above are XRD examples of the clay mineralogy of a soil with known Willamette Silts (Missoula Flood silts) that lap onto old weathered material from the Spencer Formation and two samples from a paleosol that underlies the Missoula Flood, Irish Bend Member.

If the West Eugene wetland soils were derived from erosion of older weathered deposits from surrounding foothill environments, one might expect to see sediments enriched in quartz (a residual mineral), disordered kaolinite/halloysite, and chloritic intergrade, although stream incision could also mix these minerals with less weathered material (expandable clays,mica,feldspar).

Although relatively thick Missoula Flood deposits are common in the northern and mid-Willamette Valley, the silts thin against the valley margins and are frequently absent at elevations above 300-ft. The commonly reported 400-ft upper limit of Missoula deposits in the valley generally coincides with the upper limit of mapped glacial erratics believed associated with a single flood event; however, pedogenically significant thicknesses of identifiable lacustrine silt are uncommon above 350-ft in the southern Willamette Valley.

Cascadian Sediments

Stratified, poorly consolidated, cross-bedded, very fine-grained silty sands were encountered at depth in bottomland trench T-1 #8 (Unit IV). The clay mineral assemblage of this stream-deposited sand is smectite dominated (Figure 3.3.2) and correlates well with the coarse mineral identification. The <15-µm fraction of this stratified sand contains major amounts of calcic plagioclase derived from erosion of Western Cascade andesitic/basaltic volcanic rocks (Figure 3.3.2). Quartz occurs in very minor amounts, reflecting the general absence of quartz in volcanic rocks of basic to intermediate composition. The smectite-plagioclase rich composition clearly identifies this silty sand as a Cascadian deposit. If the sediment were derived from erosion of exposed Coast Range sedimentary formations or Missoula Flood deposits the silt fraction should contain larger amounts of quartz and mica, along with minor amounts of K-feldspar. Similarly, if these sediments were exposed to significant post-depositional weathering, one would expect to see destruction of easily weathered phases such as calcic plagioclase and enrichment of the residual sediment in quartz and clays. The relatively unweathered nature of this sample, as indicated by the low amount of quartz relative to feldspar, suggests that the sand is probably a Late Pleistocene or Holocene deposit.

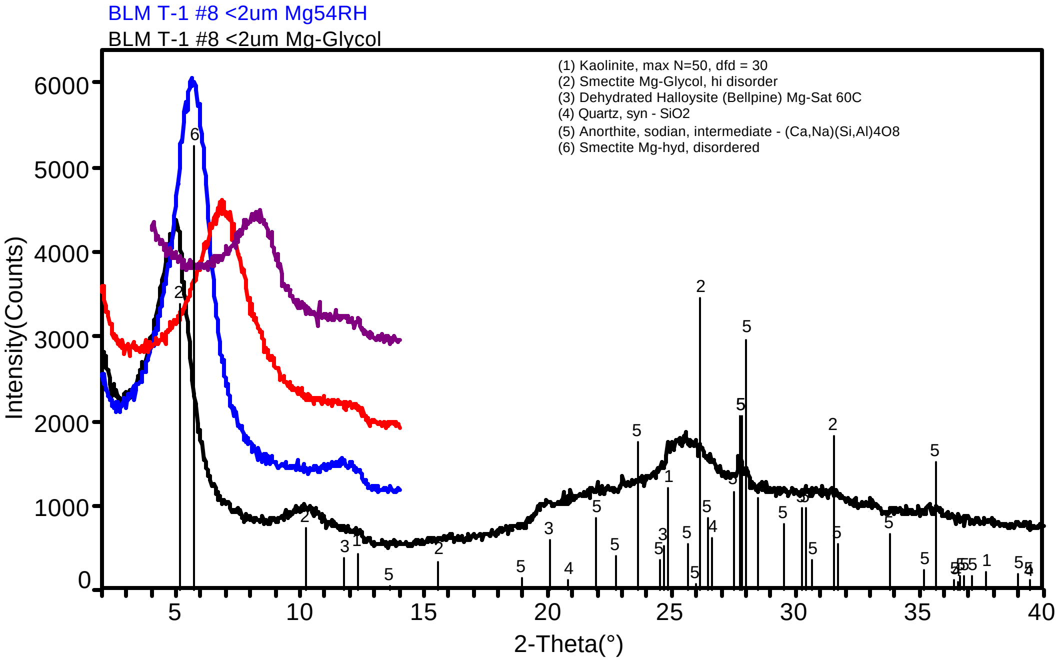


Figure 3.3.2. This XRD pattern represents the clay component of a cross-bedded silty very fine grained sand unit from Trench 1 (#8, 106-114 inches). The smectite-dominated clay mineral assemblage of this sample is very similar to that observed in modern McKenzie River sediments.

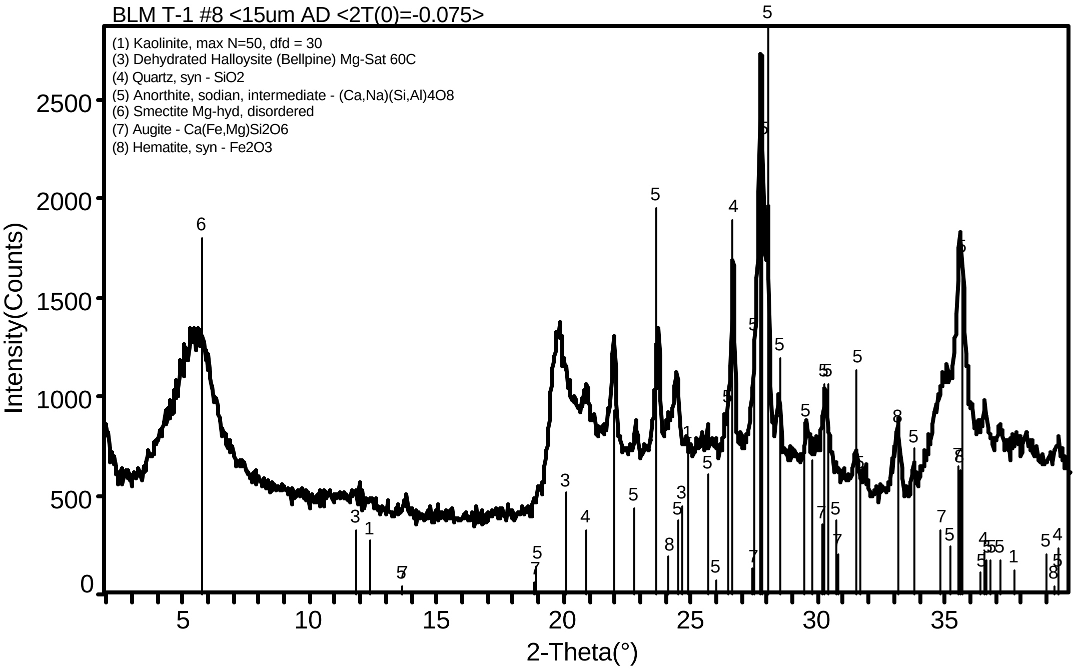


Figure 3.3.3. This pattern represents the silt component of a cross-bedded silty very fine grained sand unit from Trench 1 (#8, 106-114 inches). Note the absence of mica and the relatively low intensity of the quartz component. Quartz is generally absent in basaltic/andesitic rocks of the Cascades, but can be concentrated in deeply weathered deposits due to destruction of feldspar. The very low quartz/plagioclase intensity ratio of this sample indicates that it is relatively unweathered.

Sample T-2 #2 (Figure 3.3.4), described as grey clay (Unit II, here it is at 20-55 inches), is characterized by the presence of smectite (both high and low charge, looks like there may be vermiculite by the sharp character of the K-saturated peak at 1.0 nm), halloysite, and a well-ordered kaolinite component. The sharp nature of the kaolinite component possibly represents a distinct provenance resulting from erosion of hydrothermally altered volcanics somewhere upstream because this mineral does not form pedogenically. The silt fraction contains a moderate component of Ca-plagioclase, indicating that weathering at this location is not all that severe. If the clays formed by intense weathering one would not expect to find any fine-grained feldspar left in the rock. The absence of detrital mica precludes a significant sediment component from the Spencer Formation or Missoula Flood deposits. If the mica had been removed by intense weathering, one would expect the plagioclase to have been removed from the clay fraction. This is not the case, so the absence of mica must reflect depositional origin – i.e., there wasn't any mica in the material eroded and transported to the site of deposition.

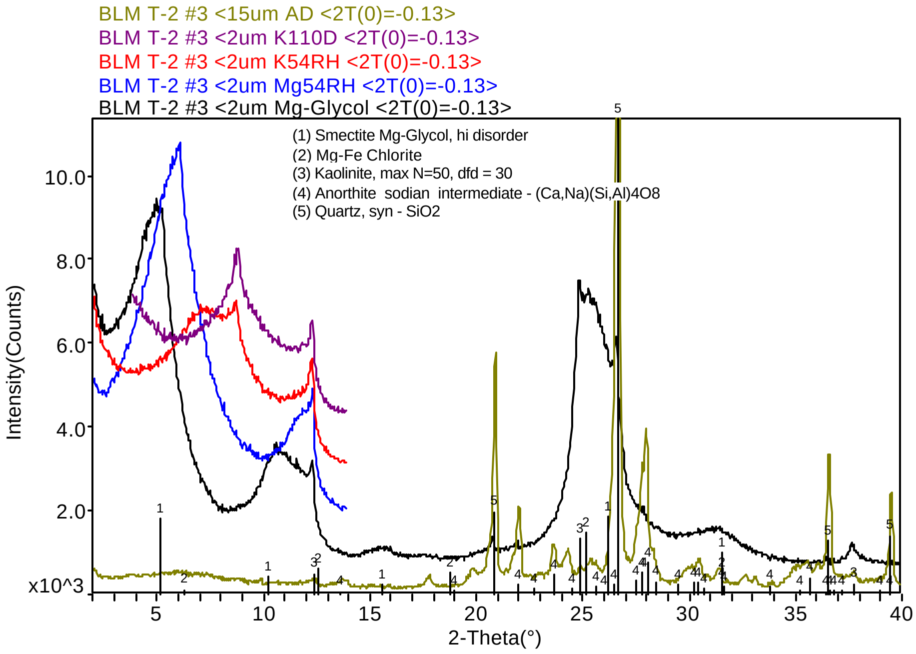


Figure 3.3.4 XRD patterns representing the silt and clay fractions of the Grey Clay Unit II in Trench 2 (20-55 inches). This sample is enriched in well-ordered kaolinite and vermiculite relative to Trench 1 # 8 clays and the silt fraction is similarly enriched in plagioclase. The presence of a minor zeolite component (small peak @ 10 degrees 2-Theta) suggests Cascadian influence. The complete absence of mica and K-feldspar excludes Missoula Flood sediments.

XRD Observations of other samples

T-1#2 The modern A horizon of wetland soil (Unit I) at Trench 1 consists of a mixture of smectite and halloysite, with a very quartz-rich silt fraction. The surficial clays contain a component of well-ordered kaolinite. It is doubtful that this better ordered kaolinite phase developed from pedogenic weathering, since the trend of weathering is to produce messy, poorly ordered phases such as halloysite.

BLM 4 #9 This is a sample of weathered alluvium of the Willow Creek drainage, bottomlands Unit IV. The silt fraction of this sample is greatly enriched in quartz. Deeply weathered soils developed on the andesitic/dacitic tuffs of the Western Cascades have fine-grained quartz as a result of concentration during weathering, however the source of these materials are clearly the south hills formed in Fisher Fm. There is a presence of the well-ordered kaolinite component suggesting derivation from some sort of mineralized zone (possible ore-bearing). This kind of sharp peak character is found in geologic (hydrothermal) clays, not pedogenic, certainly not typical of the Willamette Valley pedogenic clays.

T-1#4 This is a sample of bottomlands Unit III. The clay mineral assemblage is highly smectitic and halloysitic, with the weak collapse of a component of the expandable clay with K-saturation. This suggests that the smectite consists of a mixture of high charge (i.e., vermiculitic) and lower charge (montmorillonitic) clays. These clays have not been affected by precipitation of AL/Fe interlayer material. Such precipitation alteration is common in older soils with a long history of repeated wetting and drying (such as seen in the first XRD pattern from the old geomorphic surface). The absence of hydroxyl interlayer material suggests a couple of possibilities: the soils are always wet, therefore not impacted by Al/Fe hydroxide precipitation; the soils are not very old and haven't had the time for hydroxide precipitation to do much; or a combination of these 2 possibilities. The clay fraction doesn't contain much feldspar, and the quartz/feldspar intensity ratio of the silt fraction is much greater than that of the underlying Cascadian sand, suggesting more pronounced weathering; however, the level of pedogenic development is inconsistent with large-scale in situ alteration of feldspar.

3.3.4 Summary

The XRD clay mineralogy study results indicate that there is no Missoula Flood signature in the West Eugene stratigraphy. The clays contain varying amounts of smectite and in some cases highly ordered kaolinite, typical of Cascadian origin. The absence of detrital mica and feldspar (both K-feldspar and plagioclase), as well as minor amounts of other easily weatherable minerals (augite, hornblende, biotite), also excludes it being a component of the Spencer Formation or Missoula Flood deposits.

The sediments in the bottomland appear to have had little soil development. The quartz/feldspar intensity ratio of the silt fraction of Units I, II and III are greater than that of the underlying units. Because the low level of pedogenic development is inconsistent with large-scale in situ alteration of feldspar, the weathering wouldn't have taken place here. The sediments would have originated from upstream deeply weathered or hydrothermally altered areas. The absence of strongly developed soil structure or clay skin development, indicate a short duration of pedogenic modification.

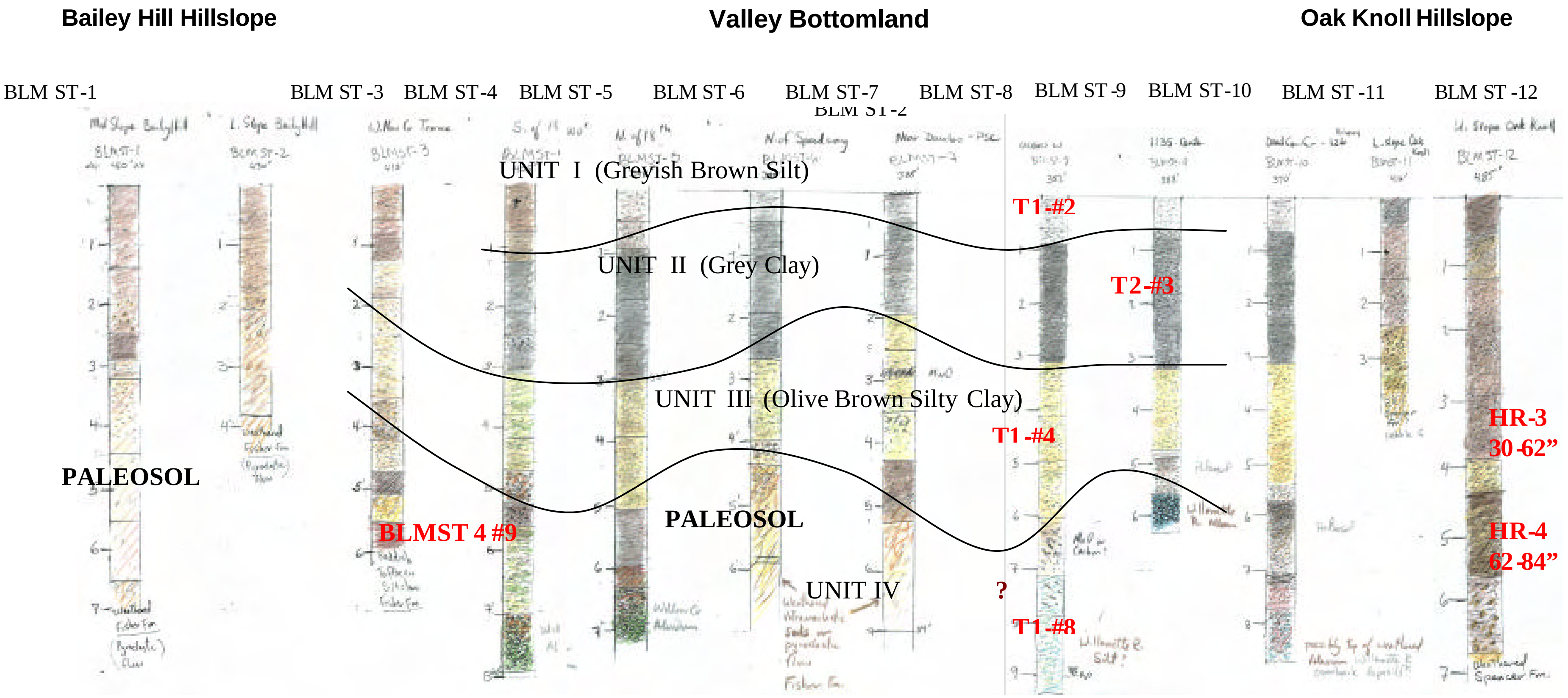


Figure 3.3.5 Locations of XRD samples along the study transect are marked in red. Trench 1 (T-1) and HR are placed in close proximity to their location on the bottomland. No stratigraphic column was drawn for either T-1 or HR, however they correlate stratigraphically as shown.

3.4 MINERAL CHEMISTRY

Selected mineral samples were studied with the microprobe in the Department of Geological Science at the University of Oregon, under the direction of John Donovan. Trace elements were studied at the Radiation Center, Oregon State University, by Neutron Activation with the guidance and direct support of Erwin Schutfort.

3.4.1 Microprobe and Neutron Activation

Methods

Microprobe

Major element chemical compositions of the five indicator minerals, plagioclase and lithic fragments were obtained through microprobe analyses of hand picked mineral concentrates from the soil boring samples. Grain mounts were prepared in the University of Oregon thin section lab by Lori Suskin with multiple grains of each mineral. 757 analyses were run on 48 different mineral or lithic fragment grains. These values were helpful in determining specific mineral species in several cases, supporting findings from the thin section analyses.

Electron Probe Microanalysis (EPMA) is an elemental analysis technique which uses a focused beam of high energy electrons (5 - 30 KeV) to non-destructively ionize a solid specimen surface for inducing emission of characteristic x-rays (0.1 - 15 KeV). Quantitative matrix (inter-element) correction procedures (Phi-Rho-Z) based on first principle physical models provide great flexibility and accuracy in analyzing unknown samples of arbitrary composition. Spatial distribution of elemental constituents can be visualized quantitatively by digital composition maps and displayed in gray scale or false color.

At the University of Oregon the Electron Microanalytical Facility is a Cameca SX-50 (1988) automated electron microprobe with 4 wavelength spectrometers, using analytical conditions of 15 keV, 20 nA. Standards are generally pure metals, oxides and some silicates and glasses (polished to 0.05 um colloidial silica and carbon coated with 20 nm of Spec-Pure graphite). A sampling of the results is presented in Table 3.4.1.

Neutron Activation

Thanks to the special collaboration of Erwin Schutfort, director of the Radiation Center at OSU, trace elements were analyzed in whole soil samples of Unit II at six sites, and from four profiles, one located over Fisher Fm. (BLMST-1), one located over Willow Cr. alluvium (BLMST-6) and the other two over Willamette River alluvium (BLMST-8, BLMST-15). At BLMST-6 #2, three samples were studied including the whole soil, and the fine sand and coarse sand fractions. Approximately 100 grams of sample was pulverized and digested for this analysis. The procedure then involves radiating the sample in the experimental nuclear reactor. The count of the different elements is based on the decrease in the isotope quantities of the different trace elements over a specific time period.

The results for each trace element were compared between each sample, giving special attention to the soil profiles where the bottomland upper three units can be compared to the paleosol or deeper layers of underlying Unit IV which might show considerable differences. As an additional way to view these results they were normalized to the basic C-1 chondrite values (Appendix F) which are considered to be representative of the earliest, most primitive, pre-solar system, magmatic values. This technique is used to compare different rock types and evaluate the degree of differentiation that an igneous rock has experienced.

3.4.2 Major Elements

Microprobe Findings

Representative microprobe results are summarized, by mineral or lithic fragment class, in Table 3.4.1. The high level of consistency of results on different runs of the same mineral type from different profiles, suggests that there is considerable uniformity of composition in the mineralogy of Units I, II and III. The minerals studied were taken from different profiles across the 3.5 mi transect and their origin should be considered to be from the same event or source area. For such a thick sequence (50-60”) with a probable airfall depositional mechanism, it is quite remarkable that the major element chemical values are so stable. The trace element values show certain consistency, but somewhat more variability. The results of the four profiles (BLMST-1, Fisher Fm. near Bailey Hill Road; BLMST-4, Willow Creek alluvium; and BLMST-8 and -15, Willamette River alluviaum) located over three different substrates, clearly demonstrate certain elemental tendencies as the profile passes into Unit IV, in each case. Chemical values and tendencies of each of the indicator minerals will be presented, followed by a discussion comparing the minerals found in Units I, II and III, with those of Cascadian volcanic rocks or events in the area to observe similarities and differences.

Pyroxene

The light green mineral is a low-Ca orthopyroxene (Table 3.4.1) with intergrowths of ilmenite and magnetite (Photo 3.4 and 3.6). It has the composition of an orthopyroxene (hyperstene) but it is an unusual mineral in that the FeO content (19.7 oxide %) is very nearly the same as the MgO (22.9%). This would push it towards being a protoenstatite and it is an indicator of lower temperature formation (Deere, Howie and Zussman, 1966). The crystal form is generally barrel shaped with flat shiny but corroded faces and in a few cases with a nice conical cap. The large ilmenite or Fe-oxide mineral inclusions oftentimes are protruding from the surface as rounded domes. Many examples of twinned crystals were observed.

It is important to note that in the bottomland grey clay (Unit II, common) and olive brown clayey silt (Unit III, rarely), this is the only pyroxene (hyperstene) found, which contrasts with the clearly alluvial material below, especially Willamette R. alluvium (Unit IV), where darker green diopsitic and other lighter green pyroxene crystals are found together frequently. No specimens in Unit IV have inclusions, nor are they magnetic, nor do they show signs of abrasion and fractures.

TABLE 3.4.1 Chemical Composition/Major Elements of Minerals (Oxide Wt. Percent).

Mineral	SiO2	Al2O3	FeO	TiO	CaO	K2O	Na2O	MgO	Cl	F	P2O5	Cr2O3	Ni	SO3	Total
Lt.gr. Pyrox. 1	52.385	.651	19.897	.215	1.185	.011	.024	23.115	.009	.024	.017	.009	.018		97.411
Lt.gr. Pyrox. 2	52.535	.389	20.289	.135	1.078	.015	.027	22.444	.021	.027	.018	.007	.023		97.026
Oxide incl. Pyx	.070	1.084	74.454	8.616	.000	.000	.004	1.361	.008	.030	.028	.019	.038		91.100
Hornblende 1	42.745	10.045	11.225	2.862	11.257	.378	2.279	14.798	.048	.217	.098	.025	.034		94.607
Hornblende 2	41.809	9.760	12.808	3.251	10.837	.265	2.510	13.530	.040	.146	.032	.006	.016		95.115
Plagioclase 1	58.881	25.202	.330	.032	7.449	.290	7.472	.015	.009	.036		.005	.052	.013	96.632
Plagioclase 2	59.132	24.389	.287	.057	6.728	.270	7.519	.025	.010	.145		.005	.020	.021	98.858
K-spar in Plag.	67.100	18.209	.011	.037	.123	9.030	.105	.000	.024	.181		.018	.013	.004	93.931
Plagioclase 3	58.562	24.270	.338	.018	6.655	.317	7.364	.020	.014	.087		.017	.014	.014	97.689
Ilmenite 1	.001	.145	46.600	48.436	.010	.000	.000	2.017	.009	.025	.002	.025	.023		97.297
Ilmenite 2	.003	.475	48.972	42.476	.013	.001	.005	4.367	.007	.035	.003	.024	.012		96.395
Chromite	.011	22.562	31.539	1.058	.002	.003	.002	10.366	.011	.000	.022	34.225	.179		100.063
Magnetite	.004	1.489	79.189	9.647	.004	.000	.010	.344	.009	.002	.019	.021	.023		90.878
White Lithic 1	78.509	5.181	1.085	1.735	.790	.169	2.147	.065	.018	.210	.000	.000	.017		89.949
White Lithic 1	59.823	4.097	.221	.321	.499	.129	.575	.126	.044	.294	.021	.007	.009		67.133
Wht. Lith. incl.	16.344	8.613	57.427	.283	.382	.062	.035	.472	.039	.194	.580	.050	.026		84.549
Oxd w/ glas cor	.046	.143	48.417	45.923	.031	.010	.010	2.146	.000	.000		.000	.061	.000	96.776
glass core	33.241	15.104	33.213	1.471	.667	.445	.219	.573	.067	.826		.098	.025	.069	86.020
Weath Lith frag 1	93.733	1.336	1.589	.553	.139	.100	.393	.052	.064	.295	.000	.000	.074		98.339
Weath Lith frag 2	90.114	1.256	1.549	3.343	.308	.140	.114	.066	.015	.224	.117	.005	.037		97.343
“ Fe rich zone 2	34.234	12.298	35.453	2.938	.673	.092	.108	.593	.024	.081	.460	.010	.000		86.962
Weath Lith frag 3	76.546	10.615	2.027	.721	1.793	2.027	3.677	.004	.000	.094	.501	.000	.071		96.709
“ F rich spot 3	40.897	11.391	1.488	.244	1.527	.372	5.327	.217	.082	1.378	.000	.000	.013		62.956

This pyroxene (hyperstene) is found intergrown with numerous and large specimens of other minerals (ilmenite and magnetite). No grains of this type were observed in the Cascadian or Fisher Fm. derived sediments (Unit IV) found below the grey clay/olive brown silty clay sequence (Units II and III). This demonstrates on some level how unique this class of mineral is in the Cascadian region. In the mineral distribution table (Appendix D) it is apparent that this mineral is present in the greyish brown silt (Unit I) and the grey clay (Unit II). In Unit III only occasional tiny broken fragments were found. The hyperstene is always very well represented in Unit I, confirming that this might be an alluvial layer that may contain these minerals and sediments as a result of reworking of Unit II after deposition.

There are two non-mineralogical aspects of the mineral that shed light on the provenance and mechanism of transport of these mineral assemblage-bearing units. The fact that several examples of the delicate twinned crystals were observed exclusively in Units I and II would seem to preclude transport by a mudflow or a hyperconcentrated flow of the Willamette or McKenzie Rivers. Perhaps these crystals might have withstood erosion and transport from the local south hills area. However, considering that these pyroxenes were only found in the surface soil of the hillslopes, no pyroxenes were found either in the residual soil or decomposed bedrock of the south hills and those present in Willow Creek alluvium are not of this type or form. Typically only very fine grained weathered plagioclase and ilmenite were detected in the soils as small corroded irregular crystals.

In terms of paragensis or the conditions and magmatic environment necessary for the formation of an orthopyroxene with about equal parts Fe and Mg, 20% vs. 22.5%, with very low Ca values (1.1%), would entail a moderately high temperature (900-1200 degree C) and high pressure (10 K Bars) and a magma composition poor in calcium but relatively basic, similar to the conditions required to generate synthetic orthopyroxenes. However, there is another problem, according to experimental studies, the only way to form strongly magnetic orthopyroxene is to expose them to very cold temperatures on the order of <4 K (Shenoy et.al., 1969, Pasternak, et al, 1992; Eeckout, et al, 2001). At these temperatures magnetic ordering begins to occur as electron spins are modified slightly and Fe+2 atoms are oriented in such a way that they create a magnetic field. In their formational environment they must be in contact with other magnetic minerals such as magnetite, spinels and ilmenite because these are attracted to the opx structure and incorporated as the mineral continues to grow. According to Charles Bacon, U.S.G.S., naturally formed magnetic orthopyroxene was found in the Mt. Mazama eruption and the whole assemblage of plag, opx, hornblende, magnetite and ilmenite were happy together at 880C, 1-2 kb pressure.

The fact that these crystals are so euhedral suggests strongly that transport to the site is via airfall as in the case of a volcanic eruption. The thicknesses of Units II and III sum to 4-5 feet of fine textured material which also supports an airfall depositional mechanism given that very little stratigraphic bedding features or textural changes are observed throughout the sequence. These lines of evidence are supported by the presence of the mineral suite that contains magnetic orthopyroxene, both at the hill slope and bottomland sites, pointing again to an airfall deposit. There may have been some sheetwash erosion of this deposit from the local hillslopes down to the bottomland.

Amphibole

The second most common and unique mineral found was a larger sized amphibole which according to its chemical signature is possibly a basaltic hornblende (Deere, Howie and Zussman, 1966), although the Fe content is quite low (12% vs. 17%), the Al content a little high (10% vs. 7.5%) and the Ti slightly high (3.2% vs. 2.1%) compared to the examples cited. Its notable in Table 3.4.1 that the chemical values are very consistent considering the different analyses are of grains collected in different profiles across the study transect. The amphibole grains are larger than the pyroxene, are very shiny and usually have one side or edge with an original crystal face. The grains are not magnetic and striations are common on the original crystal faces (Photo 3.5). Conical terminations are rare, though they were found on a few smaller crystals.

Again although hornblende or other dark amphibole grains were occasionally found in the clearly alluvial sediments (Unit IV), rarely were they as large and well preserved as these grains are in Units I, II and III. Those in Unit IV always showed strong signs of abrasion and fluvial transport. The distribution of hornblende in the 3 upper soil units is similar to that of pyroxene although it is found slightly more frequently in both Units I and III.

Hornblendes are particularly characteristic minerals of intermediate plutonic rocks but also occur as products of primary crystallization in ultrabasic and basic rocks, as well as rocks of acid and alkali composition (Deere, Howie and Zussman, 1966). They tend to form at lower temperatures than pyroxenes. The minerals studied have a ratio of $Mg:Fe^{+2}$ of about 1:1 which is an indicator that they probably formed in a quartz diorite or other intermediate rock of the calc-alkaline series. A basaltic hornblende might be associated with more basic rocks such as an andesite. The hornblende in many igneous magmas forms after the pyroxenes and in fact oftentimes forms rims around pyroxene crystals. No such examples were found in the samples studied. The primary pyroxene mineral described above is a low calcium type and the hornblende has up to 11% calcium.

Plagioclase

The most common mineral found in the suite is plagioclase in the form of variable sized euhedral, sometimes internally fractured, translucent and white crystals (Photo 3.3). In thin section they show signs of twinning and in some cases intergrowths of potassium feldspar (anti-perthite). The composition of several grains obtained north of the transect give uniform values in the oligoclase-andesine range (An_{30}) with relatively equal Ca:Na values (6.7%:7.5%). The abundance, larger size and well formed crystals of Units I, II and III in the bottomlands, compared to the abundant plagioclase of the weathered Fisher and Spencer Fms. correlates with similar situations in the hillside profiles.

Because plagioclase is a mineral sensitive to weathering processes, it is significant that it is such an important mineral throughout the bottomland Units I, II and III. Part of the reason for the classification of one soil unit as an Entisol (Retallack, this paper) is the presence, size and the form of this plagioclase. Unit I contained less plagioclase than Unit II and III probably as a result of weathering losses.

The zoned euhedral crystals are an indication that they formed floating freely in a liquid. In Unit III, as the percentage of lithic fragments increases, diluting the content of plagioclase and quartz, the intensity and number of fractured crystals increases. The ratio of plagioclase to quartz increases notably in most cases when the borings enter the clearly alluvial sediments of Unit IV in a response to the drop in content of quartz grains. The typical Cascadian sediment is predominantly plagioclase rich reflecting the basic to intermediate volcanism of the Cascade Range.

Ilmenite, Magnetite, Chromite and Zircon

The shiny black hexagonal mineral that sometimes has an angular hole or glass-filled core and at other times contains a slight depression as seen in the Photo 3.2. is a slightly magnesium enriched ilmenite. In Table 3.4.1 two representative analyses of different grains demonstrate that Ti or Fe dominance varies from grain to grain.

In general ilmenite is resistant to weathering and is found throughout the upper 3 Unit stratigraphic sequence across the bottomland and the surface soil of the hillslopes. It is somewhat diluted in the bottomlands Unit III, as the lithic fragments increase. In hydro-gravity concentrations using a gold pan, it is evident that the black, heavy mineral component of the fine sand fraction is at least twice as high in all three of the upper units (I, II and III) as it is in the lower alluvial or weathered residual soils formed on either Fisher or Spencer Fms. (Unit IV). This is significant information for finding the source of this material because such differences indicate a more Fe-rich magma than that responsible for Fisher Fm. Ilmenite makes up an important part of that component, with magnetite, titaniferous magnetite, chromite and zircon (Table 3.4.1).

The last three minerals are very interesting and confuse the discussion of origin even more given their varied, typical formational environments (Table 3.4.1). The magnetite has 9.5% Ti and is an indictor of a very high temperature formation (1524-1594°C). The crystal forms observed are oftentimes euhedral. The Fe enriched chromite variety is usually associated with layered ultramafic intrusive rocks, with olivine rich inclusions in basalts or associated with meteorites (Deere, Howie and Zussman, 1966). Finally zircon, of which there are both small and large grains, including one found in a thin section, is a common accessory mineral of igneous rocks. It is found in plutonic rocks and especially those relatively rich in sodium (Na). What is unusual is that the other minerals studied here tend to be somewhat deficient in Na. In general the shiny, sometimes well-formed crystal habit of all of these fine, heavy minerals is an indicator of airfall or volcanic delivery to the site.

It is interesting to note, that the analysis of a glass core in an ilmenite grain gave a result of a very unusual basic Fe silicate material. It had a low total (86%) that may have been due to an uneven polished surface but the fact that similar compositions were found in a few different internal zones of various lithic fragments, seemingly indicates that these values (33.241% Si, 15.094% Al_20_3, 33.213% Fe0, 1.471% Ti0) point towards a possible primordial or initial magma composition, rather than a very felsic, explosive volcanic rock.

White, Grey and Brown Weathered Lithic Fragments

Randomly distributed white, yellow and orange lithics distinguish all 3 upper units of the bottomland and are especially evident in the lower 8-10 inches of Unit III. A detailed analysis by Dr. Foit at WSU indicate that they consist of quartz and aluminosilicates. Observations in thin section, in this study, indicate that they are scioricious and crystalline. The idea that they are eroded products of extremely altered rocks from hydrothermal deposits is a possibility. If these are airfall deposits this would preclude their erosion of one of the mineralized deposits upstream in the Coast Fork of the Willamette River such as Bohemia or Hobart Butte.

In Photo 3.3.1, it is evident that the white fragments sometimes have tiny metallic minerals distributed in an amorphous or swirling fine grained texture. Oftentimes the lithics are lightly to strongly magnetic. The analyses selected for Table 3.4.1 are representative of the range of variation that is seen as the probe steps across the surface in 50 micron increments. The largest variations occur in SiO_2 content, followed by Al, Fe, Na and Ca oxides. The totals oftentimes do not sum to 100%, which either implies the presence of an uneven polished surface or the presence of unmeasured elements for which standards were not included in the run. Again these materials, which are always associated with the upper three bottomland units (Units I, II and III), appear to be pumitic airfall.

Comparison of Eugene Soils Mineral Chemistry to Cascadian and Other Sites

A literature search with the goal of comparing the chemical composition of the coarse minerals found in this study with samples from Crater Lake--Mt. Mazama (Druitt and Bacon, 1989) , Mt. Jefferson (O'Conner et. al., 2001), Central Oregon maars--Fort Rock, Big Hole Butte and Moffitt Butte (Bergenham, 1997), Columbia River Basalt (Draper, 1991), mantle inclusions from Hawaii (Hauth, 1991) and even analyses of Lunar soils and microbreccia (Bunch et. al., 1970, Roedder and Weiblen, 1973), was carried out. The three Oregon sites are considered to be a relatively representative sample of the minerals formed in Central Oregon Cascadian volcanism and hence a reasonable sample of Willamette River sediment mineral chemistry for this preliminary evaluation. The differences and similarities will be discussed in the order of glass, plagioclase, orthopyroxene and hornblende.

Glass

Cascadian volcanic glass chemical values have very rhyolitic tendencies reflecting how the silica-rich fluids and gasses migrated towards the upper part of the magma chamber before the eruption occurred at andesitic volcanos like Mt. Jefferson and Mt. Mazama. O'Connor et. al. (2001) summarizes volcanic glass compositions from several eruptions that left residues in the Willamette Valley and that are correlative with tephra layers in the western U.S. The most relevant analyses are from the Mazama eruption 6730+/-40 BP: because it is the closest to the West Eugene site, which are 73.48% SiO_2, 0.37% TiO_2, 14.45% Al_2O_3, 2.1 FeO,1.5% CaO, 4.8% Na_2O and 2.81% K_2O . These results are very similar to results of analyses of volcanic eruptions in Trego Hot Springs, Summer Lake, Tulelake, and Mt. Jefferson. Even the values from a mantle inclusion in Hawaiian basalts, which would be expected to be more basic are not too different. The glasses from 3 Central Oregon maars are somewhat more basic, (an approximate average value) 49%o SiO_2, 1.9% TiO_2, 15% Al_2O_3, 12% FeO,1.5%, 6% MgO, 9% CaO, 3.5% Na_2O and 0.6% K_2O, and yet they are still a long way from the most basic values found in this study. The Eugene soil glass values based on only three results are: 33.2% SiO_2, 1.5% TiO_2, 15% Al_2O_3, 33.2% FeO,1.5%, 0.5% MgO, 0.67% CaO, 0.2% Na_2O and 0.5% K_2O.

Its important to mention that the glass that was found in this study, was found only as inclusions, as a nucleus of ilmenite crystals and in two places within a white lithic fragment. The high Fe and very low Si values are the most different while Ti, Mg and Al values were similar to the other glasses in this comparison.

Plagioclase

The zoned plagioclase minerals studied in these soils also showed variations of three elements compared to the typical Cascadian values. Its important to qualify our statement in the sense that our information sources over represent the values of the youngest High Cascade rocks as the "Cascadian type" even though the Coast Fork of the Willamette River drains a large area of the Western Cascades and the Fisher Fm. which one would expect vary somewhat from these elemental value parameters.

Results of analyses of plagioclases from Mt. Mazama, Central Oregon maars, and the Columbia River Basalts, representing volcanic activity spread over 16 my in the region, fit into the following ranges, demonstrating how stable the mineral generating processes have been at this continental border/subduction zone interface: 50-54% SiO_2, 29-31 Al_2O_3, 0.6-0.8% FeO, 11.5-14.5% CaO, 3.3-4.9% Na_2O and 0.8-0.12% K_2O. These values refer to plagioclase with a general compositional range of An^{44-69} with the majority in the An^{50-56} which contrast significantly with all 20+ analyses of plagioclase made in this study which detect an Andesine-Oligoclase type (An^{30-33}). The values for plagioclase in this study are 58% SiO_2, 25-27% Al_2O_3, 0.34% FeO, 6.5-7.5% CaO, 7.4% Na_2O and 0.17% K_2O. This type of plagioclase is usually associated more with intermediate intrusive rocks like granodiorite rather than explosive volcanics. The most striking differences are the higher SiO2 content and balanced values of Ca and Na around 7%

Orthopyroxene and Hornblende

The values obtained for these two minerals are very similar to those of Mt. Mazama. The only unusual aspect is that both these minerals are found together in the airfall deposit. Part of the reason for their rare ocurrence in an explosive eruption is that they indicate different temperatures of formation. However, Charles Bacon, U.S.G.S., suggests that the individual mineral temperature formation phases are not that important and that the whole assemblage is happy together at 880 C, 1-2 kb pressure. Of interest is that hornblende, which is one of the better represented minerals in the suite found in this study, has 11-12% CaO, while the OPX has less than 2% CaO and the difference between the more typical Cascadian plagioclases and the andesine-oligoclase of these soils is 7-10% less CaO. Could a late-stage mineral have calcium available when the earlier forming minerals apparently were Ca-deficient? As mentioned before this group of minerals is unusual and requires more study to understand how they could have all formed or where they were erupted from.

3.4.3 Trace Elements

Neutron Activation Findings

Trace element distributions were studied by the Neutron Activation method (INNA) in four of the stratigraphic profiles. A sample was taken from each Unit: II, III and IV. BLMST-1 is a hillslope site over weathered Fisher Fm. volcanoclastic sediments, BLMST-4 is located over Willow Creek alluvium (provenant exclusively from the South Hills of Eugene), BLMST-8 is situated over a silty Willamette River deposit and BLMST-15 is located over a sandy deposit of the same river. Results are found in Table 3.4.2.

The objectives of the trace element analysis of the different stratigraphic units are to compare the similarity of the "elemental signature" of the two upper Units which are quite similar, with that of the underlying local rocks and the Cascadian sediments of the Willamette river, BLMST-8 and 15. The degree of weathering, loss to soil water or sequestration by clays, oxides or organic material of the individual trace elements can also be determined qualitatively observing the changes in elemental totals between layers and between the different fractions of BLMST 6-2.

In Table 3.4.3 there is strong evidence of the similarity between Units II and III which contrasts starkly with the variation between either of them and Unit IV. The substrate units are presented separately in the table. The values in this study for basic to intermediate (BLMST- 8 and 15) and more rhyolitic (BLMST-1 and 4) volcanic rocks follow trends. Our data demonstrates how trace elements are excellent markers of parent material and that the close similarities between the values in Units II and III are strong arguments to a common source of origin. This supports mineralogical and textural data cited previously in this report.

TABLE 3.4.2 Trace Elements

Soil Profile Trace Elements																				
	Hillslope Profile			**Bottomland Profiles**													**West. Cascade Volcanics**		**Columbia R. Basalts**	**Meteorite**
Sample #	BLM 1-3	BLM 1-5	BLM 1-7	BLM 4-3	BLM 4-5	BLM 4-10	BLM 8-3	BLM 8-6	BLM 8-9	BLM 15-2	BLM 15-3	BLM 15-6	BLM 7-2	BLM 6-2	BLM 6-2 >50M	BLM 6-2 <50M	SRM1633A	SRM278	CRB-1	ALLENDE
FeO (%)	7.20	6.64	7.91	6.72	7.01	7.26	6.42	6.45	7.34	6.48	7.30	6.93	5.95	6.65	7.54	4.31	12.07	1.91	11.84	31.17
Na2O (%)	0.82	0.75	0.151	1.06	1.27	1.17	0.850	0.88	0.61	1.724	2.319	3.12	1.257	0.846	3.92	1.55	0.250	4.800	3.29	0.520
K2O (%)	1.3	1.4	0.5	1.1	0.7	1.1	0.6	1.6		0.63	0.9	1.9	1.0	0.5	2	1.4	2.40	3.7	2.6	0.20
Sc (ppm)	16.53	15.53	23.98	18.75	19.35	19.58	17.37	15.52	21.97	21.58	22.42	19.84	16.45	18.39	4.00	10.60	40.12	5.32	31.89	12.80
Cr (ppm)	68.6	60.0	11.3	103.4	78.4	106.6	154.5	187.1	111.1	89.0	89.1	85.5	104.1	117.9	58.6	130.4	194.8	8.1	11.4	3681.0
Co (ppm)	18.24	20.81	26.70	14.45	12.02	16.6	8.49	20.92	26.83	17.5	20.9	21.00	50.6	10.51	23.8	8.8	42.8	3.01	34.7	636
Ni (ppm)	22	23	31	28	31	31	34	52	59	24	67	43	22	33	14	0	147	20	31	13995
Zn (ppm)	80	80	120	62	69	66	57	55	68	70	79	89	55	57	22	31	221	51	131	111
As (ppm)	34	31	17.1	30.0	29	45	8.3	10.2	5.8	8.6	9.5	8.8	21.3	18.9	105	19.6	144.9	3.8	1.3	1.6
Sb (ppm)	0 91	0.39	0.43	0.16	0.35	0.53	0.57	0.53	0.53	0.87	0.75	0.62	0.37	0.26	0.77	0.48	2.48	2.03	0.16	0.46
Rb (ppm)	28	30	16	22	23	22	20	18	8	17	18	22	29	16	8	18	128	128	47	26
Cs (ppm)	1.42	1.34	1.06	1.42	1.59	1.00	2.31	1.19	0.67	1.66	2.04	1.71	2.06	1.75	0.60	0.93	9.97	5.13	0.95	0.00
Sr (ppm)	109	110	65	106	166	122	115	158	182	307	435	472	170	77	285		854	43	292	922
Ba (ppm)	289	322	203	283	319	302	178	570	349	354	441	458	316	177	196	270	1251	1042	713	200
La (ppm)	26.2	25.6	42.7	18.5	17.9	19.9	25.3	29.5	51.2	19.1	17.2	16.9	29.1	22.3	9.7	11.2	82.1	28.9	25.1	0.9
Ce (ppm)	45.6	45.0	63.2	36.6	35.8	38.1	44.6	50.7	117.1	39.5	36.3	33.9	63.2	47.7	20.9	23.7	166.8	63.8	49.4	8.5
Nd (ppm)	25.5	22.3	32.1	19.8	20.5	22.4	23.9	28.6	52.3	23.7	21.8	18.8	31.3	24.9	10.4	8.4	78.4	27.4	25.6	6.9
Sm (ppm)	5.54	5.15	5.89	4.74	4.21	5.38	5.07	7.45	10.75	5.07	4.69	4.40	7.18	5.42	2.07	2.27	16.96	5.31	6.34	0.38
Eu (ppm)	1.28	1.18	1.57	1.41	1.32	1.61	1.37	2.23	2.95	1.76	1.50	1.42	2.20	1.54	1.93	0.82	3.62	0.85	1.87	0.12
Tb (ppm)	1 02	0.93	0.92	0.82	0.63	1.02	0.73	1.38	1.02	0.91	0.87	0.76	1.08	0.79	0.34	0.33	0.00	1.14	0.00	0.17
Yb (ppm)	4.0	3.7	2.2	2.7	2.4	3.8	2.5	4.5	2.8	2.8	2.6	2.5	3.5	2.8	1.4	2.0	7.7	3.7	3.1	0.6
Lu (ppm)	0.61	0.58	0.32	0.41	0.37	0.61	0.38	0.73	0.38	0.43	0.42	0.37	0.55	0.43	0.22	0.35	1.18	0.68	0.52	0.09
Zr (ppm)	372	322	213	223	205	239	296	470	212	140	180	131	295	302	84	460	257	283	187	244
Hf (ppm)	12.22	11.64	6.06	6.88	6.25	7.93	9.94	13.60	5.34	4.75	4.24	4.12	8.36	8.83	2.53	15.20	7.44	8.74	4.94	0.31
Ta (ppm)	1.63	1.53	0.94	1.05	0.94	1.22	1.07	1.18	0.63	0.60	0.54	0.51	1.09	1.25	0.32	1.22	1.83	1.31	0.75	0.34
Th (ppm)	5.32	5.03	2.60	3.95	3.90	3.56	5.94	4.36	3.07	3.25	2.87	2.73	4.71	4.54	2.05	2.93	24.82	12.50	5.72	0.46
U (ppm)	1.5	1.7	0.4	1.6	1.0	1.8	2.1	1.0	0.5	0.6	0.7	0.6	1.3	1.3	0.7	0.9	9.8	4.9	1.7	
Au (ppb)	8	6	5	6	7	7	4	7	8	2	4	5	3	5	3	3	8	7	9	101
Ir (ppb)																				810.00

TABLE 3.4.3 Summary of Averages and Comparison of Trace Elements

SUMMARY OF AVERAGES & COMPARISON OF TRACE ELEMENTS - WEST EUGENE WETLANDS

	Bottomland			Hillslope			Trace Elements																										
	FeO	Na_2O	K_2O	FeO	Na_2O	K_2O	Zr	Hf	Zr/Hf	Ba	Sr	mBa/mSr	As	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	Th	U	Ta	Cr	Ni	Co	Zn	Sb	Cs	Rb	Sr	Rb/Sr
	%	%	%	%	%	%	ppm	ppm		ppm	ppm		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
Soil Units/Rock type (# sam)																																	
BLM Unit II *	6.28	1.22	0.82	7.2	0.82	1.3	271	8.49	31.9	266	147	2.84	20.2	23.4	46.2	24.9	5.5	1.59	0.89	3.05	0.46	4.62	1.4	1.12	106	27	20	63.5	0.52	1.77	22	147	0.146
BLM Unit III **	7.01	1.74	0.95	6.64	0.75	1.4	294	8.93	32.9	413	217	3.09	19.9	22.6	42	23.3	5.38	1.56	0.95	3.3	0.53	4.04	1.1	1.02	104	43	18.66	70.8	0.51	1.54	22.3	217	0.1
BLM Unit IV **	6.94	2.12	1.83	7.91	0.15	0.5	199	5.7	34.9	328	210	2.45	19.8	32.7	63.1	31.4	6.61	1.89	0.93	2.83	0.42	2.99	0.83	0.83	78.6	41	22.8	85.8	0.52	1.11	17	210	0.079
BLM - 6-2 w/ clay	6.65	0.85	0.5				302	8.83	34.2	177	77	3.6	18.9	22.3	47.7	24.9	5.42	1.54	0.79	2.8	0.43	4.54	1.3	1.25	118	33	10.5	57	0.26	1.75	16	77	0.203
BLM - 6-2 <50 mesh seive	7.54	3.92	2				460	15.2	30.3	270			19.6	11.2	23.7	8.4	2.27	0.82	0.33	2	0.35	2.93	0.9	1.22	130	0	8.8	31	0.48	0.93	18		
BLM - 6-2 >50 mesh seive	4.31	1.55	1.4				84	2.53	33.2	196	285	1.1	**105**	9.7	20.9	10.4	2.02	1.93	0.34	1.4	0.22	2.05	0.7	0.32	58.6	14	23.5	22	0.77	0.6	8	285	0.027
Weath. Fisher Fm (1)	7.91	0.15	0.5				213	6.1	34.9	203	65	4.91	17.1	42.7	63.2	32.1	5.89	1.57	0.92	2.2	0.32	2.6	0.4	0.94	11.3	31	26.7	120	0.43	1.06	16	65	0.24
Willow Cr. Alluvium (1)	7.26	1.17	1.1				239	7.93	30.1	302	122	3.89	**45**	19.9	38.1	22.4	5.38	1.61	1.02	3.8	0.61	3.56	1.8	1.22	107	31	16.6	66	0.53	1	22	122	0.176
Willamette R. sand (1)	6.93	3.12	1.9				131	4.12	31.8	458	472	1.52	8.8	16.9	33.9	18.8	4.4	1.42	0.76	2.5	0.37	2.73	0.6	0.51	85.5	43	21	89	0.62	1.71	22	472	0.047
Willamette R. silt (1)	7.34	0.61					212	5.34	39.7	349	182	3.01	5.8	51.4	117	52.3	10.75	2.95	1.02	2.8	0.38	3.07	0.5	0.63	111	59	26.8	68	0.53	0.67	8	182	0.043
Willamette R. mean	7.14	1.85					171	4.73	36.2	404	327	2.28	7.5	34.1	75.5	35.6	7.58	2.19	0.89	2.7	0.38	2.9	0.55	0.57	98.3	51	23.9	78.5	0.58	1.19	15	327	0.046
Values from Literature																																	
40 North American Shales														32	73	33	5.7	1.24	1.04	3.1	0.48												
Trace Elements in Amazon Cr (U.S.G.S., 1993)																																	
bottom seds >63 microns													120												118	69	83	160	0.9				
<63 microns													90												213	74	77	535	1.3				
NAWQAS* Nat'l Average, 781 sites																																	
Streambed seds (U.S.G.S., 1991)										490	140		6.9	40	73	34		2		2					65	28	16	120	0.9				
Low potential for toxicity TEC**													9.8									12	3.9		43.4	23		121					
High potential for toxicity PET													33												111	49		459					

* average of 5 samples in bottomland, 1 sample on hillslope, 6 samples in elements

** average of 3 samples in bottomland, 1 on hillslope, 4 samples in elements

The differences between stratigraphic Units II and III, and Willamette River silts and sands (representing the general Cascadian source area), needs to be explained. There are also significant differences between Units II and III and the weathered Fisher Fm. soil and the Willow Creek alluvium. A relationship seems to exist between the clay Units II and III and more felsic or silica rich magma, rather than deposition from the possible erosion of the South Hills lithologies that include primarily Fisher Fm. sediments.

The weathering susceptibilities of certain trace elements can be appreciated by comparing values of unit II and III, but a basic assumption is made that they were almost completely identical and that Unit II has been exposed to weathering agents much more that Unit III. To check these observations, the values of a fractionated sample were evaluated. Total sample BLMST 6-2 (clay fraction 78.5%) values compared to the values of the medium to coarse sand (2.7%) and that of the medium to fine sand (18.8%), will indicate sequestration if the clay fraction values are larger than both the other components. If the opposite is true then the element is being flushed out of the system. There is a high correlation between the two methods, as to which elements are more mobile or more weatherable.

These two analyses indicate the following elements are being sequestered as they are liberated from the mineral structure they occupy or that they cannot be extracted very easily: Th, U, Ta, La, Ce, Nd, Sm, Tb, Yb, Lu, Cs, and Rb. Those that are migrating away from their soil minerals and not being retained well are Zr, Hf, Ba, Sr, As, Ni, Co, Zn and Sb (Table 3.4.3). Some of these are taken up by plants or organic material complexes but the majority enter the ground water system. The most reknown and probably most dangerous element present at high levels is As which is quite high in the coarse sand fraction of BLMST 6-2 and is present in the coarse alluvium of Willow Cr. The other elements found in this study are Co, Ni and Zn. In addition to these toxic elements the U.S.G.S. (Rinella, 1993) found high levels of Ag, Cu, Pb, Cd, Hg, Mn and Ti in excess of the breakpoint values established for the Willamette River Basin, in the Amazon Creek sediments. It appears that several elements are available to ground water.

In comparing soil trace element values with those of various worldwide data bases and the values for the same elements in the sediment of the Amazon Creek as presented by the U.S.G.S. (1993) it seems that while the majority of the elements looked at in this study are “normal” the following ones are above safe limits or pushing the upper limits of the established parameters for aquatic organisms: As, Cr, Ni, Zr and Hf. Considering the other metals that resulted with high values in the U.S.G.S. study, it is probable that Cu, Pb, Hg, and Cd are present in soils in higher than normal values.

3.4.4 Summary

Microprobe analyses of twelve mineral specimens collected from Units I, II and III in several soil profiles along the transect both on hillslope and bottomland sites reveal very uniform major element compositions. The composition of the assemblage is somewhat unique in that it includes a range of high temperature minerals such as chromite, zircon, magnetite and othopyroxene on the one hand and lower temperature minerals such as plagioclase (oligoclase-andesine), quartz (some bipyramidal), hornblende and K-feldspar on the other. They all have euhedral or nearly euhedral crystal form, shiny surfaces, and are oxide free. In thin section, it was evident that the pyroxenes and hornblende minerals are not altered but plagioclase is zoned and has undulatory extinction. These physical characteristics support an air fall depositional mechanism as if from a volcanic eruption. In contradiction to a volcanic eruption hypothesis, is the lack of glass shards, ash or pumice in the 5-6' thick deposit of Units II and III or the upper 3' to 4' of soil found on the hillslopes.

In terms of trace elements, incongruities are revealed in spite of very good quality data for the sixteen soil samples analyzed. The heavy and light rare earth element tendencies are not clearly representative of either the more basic volcanic activity of the Central Cascades in the area of the Willamette River Watershed or the more intermediate to rhyolitic volcanism characterized by the Fisher and Eugene Formations that make up the majority of the Coast Fork of the Willamette River to the south of Eugene. The trace elements do demonstrate that Unit II and Unit III appear to be of common origin in comparison to the four different substrates of Unit IV. The elemental distribution of the Willamette River sands and silts (BLMST–15 and 8) follow world wide tendencies of andesitic and basaltic andesite rocks while weathered Fisher Fm. and Willow Creek alluvium (BLMST-1 and 4) are clearly more rhyolitic.

These elements also define the weathering history of these soils and sustain the paleopedological evaluation in the sense that some removal of labile ions and retention of Th, Fe, Zr and Ha has occurred between Unit II and Unit III, but much less than in the weathered hillslope Fisher Fm. The incongruity remains as to how a relatively young soil unit can be so clay rich. It doesn't appear that it formed in place, yet it doesn't have trace element signatures of either possible upstream source areas.

3.5 SURFACE AND SOIL WATER CONDUCTIVITY

Surface water conductivity anomalies in Amazon Creek were discovered during the Water Quality Monitoring Program of the Long Tom Watershed Council thanks to the data set of monthly readings at seventeen sites throughout the Long Tom R. Watershed from 1999-2002. Because conductivity readings were anonymously high in the Amazon Creek drainage, interest developed in extending the data collection above the influence of the urban area into headwater tributaries. The study was also extended to regional rivers (Marcola, McKenzie and Willamette) and streams to the south (Creswell and Cottage Grove) so that a lithological unit comparison could be made. Another impetus to delve into this aspect of water quality had to do with the very high values of trace element and organic compounds in the Amazon Creek sediments and water, results of earlier studies carried out by the USGS (Rinella, 1993). The question of how high in the watershed do these values persist was an important geological research question, as well as, of course, why? Thanks to the assistance, ad honorem, of Dr. Paul Engelking of the Chemistry Department at the University of Oregon it was possible to determine the quantities of part of the elements responsible for the conductivity and indirectly from extrapolations, have an idea of the quantities of organic or other elements that were not specifically analyzed for, without knowing specifically which they are.

3.5.1 General Experiment Design

Methods

Conductivity and temperature was measured and recorded with a hand held conductivity meter (glass/platinum cell conductivity meter) at multiple sites around Eugene. This included Amazon Creek and its tributaries, various ponds and impoundments in the West Eugene area, the Willamette, McKenzie, and Mohawk Rivers, and several streams to the south in the Creswell and Cottage Grove areas. Readings were taken during different seasons to observe changes related to temperature and biological activity cycles, over the span of 1.5 years (5/01-12/02).

Professor Paul Engelking, University of Oregon, Chemistry Department, aided this study on a voluntary basis using Ion Chromatography, a newer technology that permits the detection of very low quantities of ions in water without having to do repeated concentrations. Within the "Green Chemistry" curriculum at the University of Oregon, chemistry students were involved in sampling many of the same sites where the Long Tom Watershed Council conductivity readings had been taken, to assure quality control of data collection. Analyses were run with the "anion column" which detects the quantities of ions floating freely in stream water including F, Cl, NO2, Br, NO3, P2O5, and SO4 (fluoride, chloride, nitrite, bromide, nitrate, phosphate and sulphate).

In an attempt to evaluate the contribution of soil water to stream conductivity, a series of experiments were run in which 1 part soil from each sample was placed in 5 parts distilled water (initial conductivity of 2.7-3.6µS/cm^2) and allowed to equilibrate over 10-15 days. Readings were made in the same manner as were the stream samples. All samples from profiles BLMst-1 through BLMst-6 were then analyzed by Dr. Paul Engelking with the Ion Chromatograph to observe and determine the dissolved components that were contributing to the final conductivity results. The results of this study are in Appendices D and G.

Ion Chromotography Methods

Inorganic fluoride, chloride, nitrite, bromide, nitrate, phosphate and sulphate anions in water and soil samples were measured with ion chromatography. Total ion conductivity was also measured. Combining the two types of measurements gave information on the presence and amount of carbonate, bicarbonate, and organic anions, not otherwise accessible to measurement with either alone.

In ion chromatography, anions are deposited at one end of a porous column containing a finely divided, alumina support, coated with a proprietary ion-exchange resin. A flow of a liquid elutant carries the ions through the column. Different ions pass through the column at different rates, depending upon each ions affinity for the mobile, liquid phase versus its affinity for the stationary phase. The ions analyzed--fluoride, chloride, nitrite, bromide, nitrate, orthophosphate, and sulphate are removed from the column by chemical flux of an elutant, in that order, and are detected by conductivity. Ions are identified by arrival times, and quantified by the amount of conductivity, calibrated by use of known reference standards.

In conductivity measurements, aqueous samples are placed in a glass or plastic container, and the resistance between two electrodes is measured. Since pure water has a conductance of approximately 0.055 microsiemens/cm, most of the conductivity seen in water is due to the presence of ions.

Soil samples were extracted with water, simulating exposure to freshwater in the environment. The amount of anions washed out of samples by using water in the laboratory is expected to be representative of the amount of anions washed out of samples exposed in the field. Furthermore, use of water extraction allows measurement of anions such as chloride and sulphate, and measurement the total ionic conductivity, which would not be available if concentrated salt or buffer solutions were used for anion extraction.

This extraction methodology differs from that of standard agricultural analysis for total nitrate and total soluble phosphate using concentrated salt solutions (e.g. 2.0 molar potassium chloride in water) to enhance the extraction of these ions from soil samples. The use of salt solutions is motivated by the desire to determine all of the nitrate or phosphate that could be released from a soil sample, regardless of whether these anions readily dissolve in just water, or are tightly chemi- or ydrop-sorbed within the soil. Assuming both the readily mobile and the more tightly bound, but replaceable, anions would be available to the root system of a growing plant, the standard agricultural soil testing protocols flood the soil sample with replacement anions, such as chloride, attempting to mobilize these more tightly bound anions along with the more mobile anions, to determine the "total available" nitrate or phosphate. Chemi- or ydrop-sorbed anions that would only be displaced in concentrated salt solutions are not readily released into just water. Extraction by salt solution attempts to address a different question, such as, what are the amounts of anions that are mobilized in a sample by exposure to active, organic compound secreting roots? The methodology used here is thought to be more suitable to address issues involving the most readily soluble forms of the anions, such as transport, mobility, wash-out, and run-off.

Equipment

Conductivity was measured with either a glass/platinum cell conductivity meter, or a plastic cup, hand held conductivity/temperature/pH tester (Cambridge Scientific Industries, Cat. No. 301353). Conductivity was measured within a degree or two of 21 C, and has been reported as the raw number at the measured temperature (and was not corrected to 25 C equivalent conductivity).

Anions were analyzed with a Metrohm model 761 ion chromatography instrument using a Metrosep A SUPP 5 column, 4mm dia. By 100 mm length. The mobile phase was a 3.2 mM sodium carbonate/1.0 mM Sodium bicarbonate eluent mixture, operating at 0.7 ml/min and at 6 megapascal typical back pressure. Samples were loaded from a Metrohm 766 autosampler, and 20 microliter injections were used to place material on the column.

Procedure

Stream or surface water samples were collected in Nalgene bottles. It was found that neither variations in the time passed before processing or temperature changes seemed to affect the conductivity readings in a significant way.

Soil samples were mixed with de-ionized water (approximately 2 microsiemen/cm conductivity) in 1:5 ratio (100 gram soil/500 gram water) in covered plastic containers having approximately 100 cm^2 surface area in contact with air. Samples were left to equilibrate for several days, while measuring conductivity. When the conductivity changes were less than approximately 10% of the reading value, approximately 100 ml of the supernate was decanted to a polyethylene bottle. These water extracts of the soil samples were then treated as water samples for subsequent analysis steps.

Water samples were measured for conductivity and analyzed by ion chromatography. Each sample was first filtered with a 0.22 micron, 25 mm dia. Syringe driven filter unit, using a 10 ml plastic syringe. Initially, pharmaceutical grade Millex-GV Durapore PVDF ydrophilic filters were used. It was determined that these filters could contribute as much as 0.3 ppm fluoride contamination to samples, if the filters were not washed first. All work reported here was with samples filtered with 0.2 micron 25 mm dia. Millex-LG PTFE hydrophyllic filters (Millipore). Although these filters showed very little contamination when tested with blank solutions, our prior experience with other filters prompted us to first wash each with 18 Mohm distilled water before use.

About 4 ml of filtered aqueous sample was loaded into a polyethylene sample tube, and placed on the autosampler, and subsequently analyzed with the ion chromatograph. Calibration runs consisted of dilutions of a 100 ppm standard solution (Metrohm) of fluoride, chloride, nitrite, bromide, nitrate, phosphate, and sulphate ions (mass per mass units). The total ion mass is reported (e.g., nitrate is ppm nitrate, NO_3 , and not as ppm nitrogen).

The chromatograms, integrated by software, were carefully reviewed, and hand integrated as deemed necessary to set endpoints, and to exclude interferences (Figure 3.5.1). In many chromatograms, the bromide peak overlapped the "system peak," and the value was often omitted from the report. Additionally, the chromatograms showed the presence of peaks corresponding to other ions, especially in the samples from soils where considerable organic material was present. Near fluoride, acetate and simple aliphatic acids elute, while at later times, near bromide, aromatic acids elute, and finally, polyphenolic humic acids elute near phosphate and sulphate. Occasionally, extra peaks appeared in all three regions, but more frequently, an extra peak, believed to be acetate, appeared near fluoride.

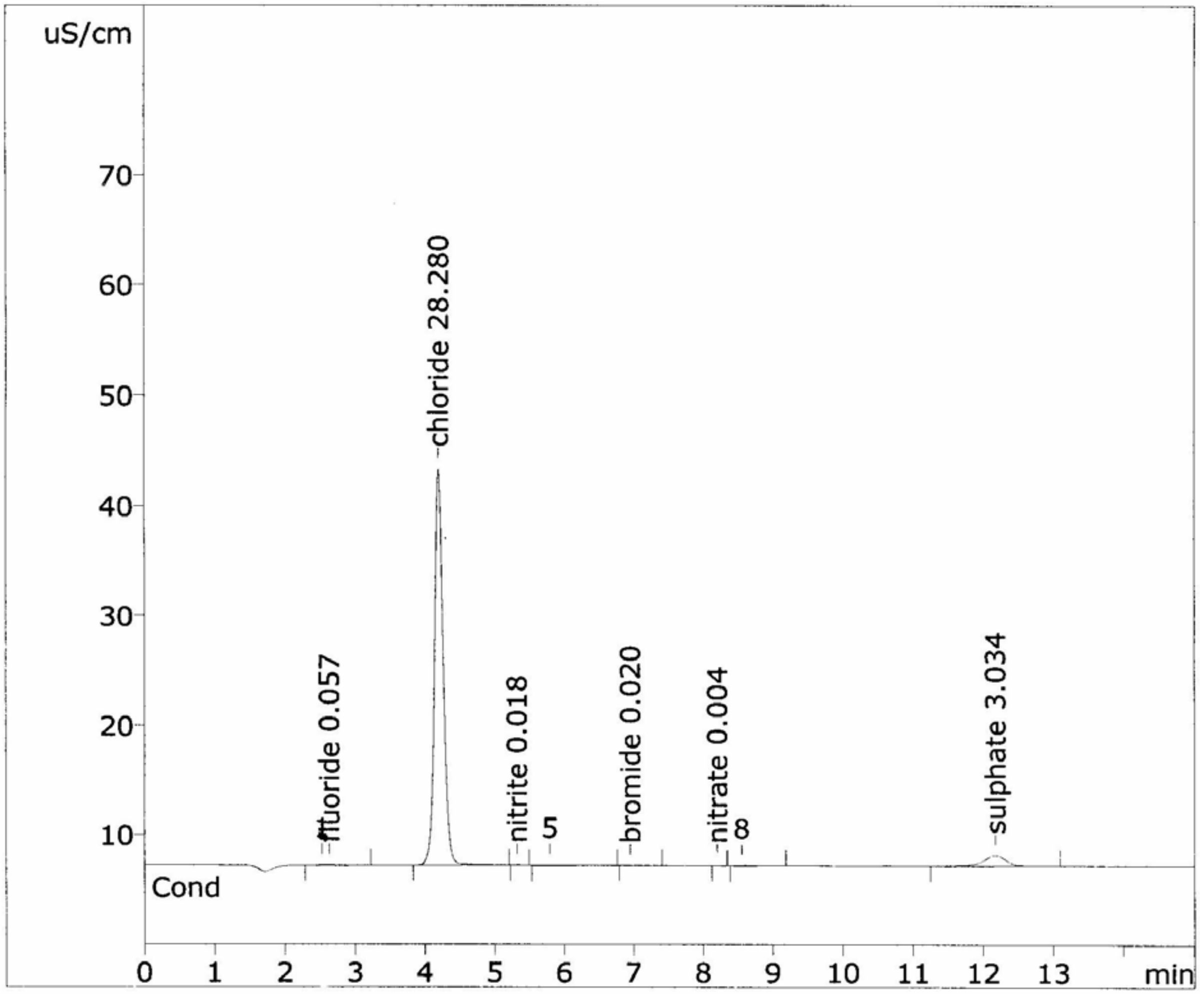


FIGURE 3.5.1 Example of ion chromatograph read out.

The repeatability of the chromatograms appeared to be high, often to three places for a stable peak, chloride. The instrumental accuracy was approximately given by +/- 5% of the reading, in conjunction with a threshold error of approximately 0.02 ppm (one standard deviation). Small differences could often be discerned even below this. Errors caused by handling or extraction of samples were considered likely to be greater than instrument errors.

How to Read Ion Chomatographic Data

The ion chromatography data could be combined to give a total charge normality in each analyzed solution due to all the measured anions. This could be compared to the total ionic conductivity. This would identify the presence of ions that were not found by ion chromatography. The most convenient method for this comparison was to divide the total conductivity by the total charge normality found. This resulted in a “specific ionic conductivity.” Since most ions, both positive and negative, have specific conductivities around 75, a sample would contain at least the corresponding positive or negative counter ions, which would predict a total specific conductivity of about 150, if all of the anions in the sample were those accounted fore by chromatography. (Higher specific conductivities occur only for ions hydroxide (150) and hydrogen (330), but these would not contribute significantly if the samples are within pH 5-9.) Thus, if the calculated specific ion conductivity is, say, 300 or above, this indicates a significant presence of additional conducting anions, in addition to those inorganic anions already identified and measured by chromatography. The likely ions present are threefold:

1. Carbonate ions, which would not be detected by the ion chromatograph, since it uses a carbonate/bicarbonate buffer. If present in large quantities, they can manifest themselves by a distortion of the “system peak” near bromide..
2. Bicarbonate ions, for the same reasons.
3. Anions of organic acids. These can give slight peaks in the chromatograms if present in quantity. Since most organic acids are weak, and the chromatograph first converts anions into acids for detection, it is relatively insensitive to weak acids. However, short aliphatic acids such as acetate show up at short times, aromatic acids, at mid times, and polyphenols at long times. All of these have types of peaks been seen in some chomatograms.

The very high specific conductivity numbers seen with the samples from mostly undisturbed, heavily vegetated sites are mostly likely the result of organic substances that would be expected to be present there. For example, in an experiment carried out during this study where runoff from a recently soil stripped field is compared to the runoff from an area that hadn’t been touched for over 40 years, and others with varying levels of agricultural use or that had been stripped previously. Upon stripping, not only do inorganic ions such as nitrate increase dramatically, but most likely, the organic ions decrease, as shown by the decrease in specific ion conductivity numbers. This would have the effect of decreasing the organic material available to obligatory heterotrophs that may be present in the soil.

The presence of living organisms was suspected in aqueous samples extracted from soil from some of the sites. This was inferred from the consumption of nitrate and to lesser degree, phosphate, in sample tubes over two days. Although a 0.2 micron filter would be capable of filtering out large bacteria, smaller bacteria such as the cyanobacteria microcystis, might pass through. These would have limited opportunity for nitrate consumption in the whole soil samples, or even in the extracts, kept in the dark, but may initiate autotrophic activity in an aerobic, illuminated environment, such as in a sample tube in the autosampler carrousel. Microscopic examination of the liquid after several days did show small, round bacteria, consistent with, say, the genus microcystis.

3.5.2 Amazon Creek and Area Stream Conductivities

Findings

Sixty one sites were sampled in the Long Tom Watershed and Eugene area. Data indicate that the highest conductivity values are found in the Amazon, Coyote, Spencer and Camas Swale Creek watersheds. These sites are located in what has traditionally been mapped as Natroy Soils. The bedrock lithologies that underly most of this area are Fisher and Eugene Fm. in hilly areas and in the bottomland sites South Hills stream alluvium (Willow Cr.) and Willamette River alluvium. Additionally, one sample of Crater Lake water was analyzed. The result was consistent with U.S.G.S. long term water quality data which showed high conductivity readings in Sufate, Chloride and Nitrite plus nitrate.

Conductivity values drop with greater flow rates, and increase to maximums late in the summer as the source of flow comes principally from groundwater seeps. Conductivity values for Amazon Creek are consistently higher than those of the Long Tom River (Long Tom Watershed Council Monitoring Data, Internal Report) over a 3 year period, sampled at sites only a few miles apart near Junction City (Table 3.5.1 reports a few results of the Internal Report, in progress).

Outside the general area of the high conductivity streams, which radiates around Spencer Butte, conductivity values are relatively constant and lower. Many of the low conductivity bearing streams and rivers sampled flow over Fisher and Eugene Fms. (as do the majority of the high value streams), the High and Western Cascade volcanic lithologic formations (McKenzie, Mohawk, and Middle Fork Willamette River) and the eastern foothills of the Coast Range to the west (Long Tom River, Wolf Creek).

Cascadian streams display the lowest conductivities (50-65 $\mu S/cm^2$) which suggest the typical mineral suites and rock types that are in contact with runoff and soil water in this region are not easily dissolved or they are diluted. The high gradient of these streams also insures a low residence time or contact with the rocks because of higher stream velocities. Lower conductivity readings were also found in streams flowing over weathered Fisher and Eugene Fms to the south, east and west of Cottage Grove, generally giving readings of 70-85$\mu S/cm^2$. These slightly higher values than the Cascadian streams, reflect more deeply weathered pyroclastic or epiclastic rocks in a warmer climatic zone, and a lower relief which means slower, lower gradient streams. Lower gradient streams permit longer residence time in contact with soluable elements. A 10-15$\mu S/cm^2$ difference seems quite logical as a comparison between these two geologic and stream gradient regimes.

To explain the much larger differences in conductivities of the Amazon, Coyote, Spencer and Camas Swale Creeks is certainly more difficult. One possible explanation is the presence of mineralized springs that might exist along little known fault traces in the Eugene South Hills. Ian Madin of DOGAMI (pers. communication, May 2003) suggests that there are probably several E-W or SW-NE structures in this area related to the “uplift” of the south hills. Never the less, the high conductivity values aren’t what one would expect as the result of multiple “point

TABLE 3.5.1 Long Tom Watershed Council Monitoring Data**.**

CONDUCTIVITY READINGS OF AMAZON CREEK AND VARIOUS HEADWATER STREAMS

Site	Stream Sample Site	Conductivity	Temperature	Date
LONG TOM R.				
LONG TOM RIVER	Long Tom R. at W11th embayment F.R.Res	96.1	26.5	7/23/2001
LONG TOM RIVER	Above Fern Ridge Res.	105.6	16.5	9/6/2001
LONG TOM RIVER	Long Tom R. at Hwy. 36 below Fern Ridge Reservoir	113.8	4.2	12/12/2000
LONG TOM RIVER	Long Tom R. at Hwy. 36 below Fern Ridge Reservoir	83.3	5.6	1/9/2001
LONG TOM RIVER	Long Tom R. at Hwy. 36 below Fern Ridge Reservoir	100.8	4.8	2/13/2001
LONG TOM RIVER	Long Tom R. at Hwy. 36 below Fern Ridge Reservoir	93.8	9.8	3/13/2001
LONG TOM RIVER	Long Tom R. at Hwy. 36 below Fern Ridge Reservoir	93.8	11.1	4/10/2001
LONG TOM RIVER	Long Tom R. at Hwy. 36 below Fern Ridge Reservoir	101.3	15.5	5/8/2001
LONG TOM RIVER	Long Tom R. at Hwy. 36 below Fern Ridge Reservoir	98.2	16.4	6/12/2001
LONG TOM RIVER	Long Tom R. at Hwy. 36 below Fern Ridge Reservoir	101.3	21.8	7/10/2001
LONG TOM RIVER	Long Tom R. at Hwy. 36 below Fern Ridge Reservoir	98.2	22.4	8/7/2001
AMAZON CREEK				
AMAZON CREEK	Amazon Cr. + Highpass Rd	233.5	3.65	12/12/2000
AMAZON CREEK	Amazon Cr. + Highpass Rd	230.2	5.7	1/9/2001
AMAZON CREEK	Amazon Cr. + Highpass Rd	206.3	5.1	2/13/2001
AMAZON CREEK	Amazon Cr. + Highpass Rd	223	11.1	3/13/2001
AMAZON CREEK	Amazon Cr. + Highpass Rd	198.6	12.1	4/10/2001
AMAZON CREEK	Amazon Cr. + Highpass Rd	237.3	17.2	5/8/2001
AMAZON CREEK	Amazon Cr. + Highpass Rd	248.5	17.2	6/12/2001
AMAZON CREEK	Amazon Cr. + Highpass Rd	265.9	22.8	7/10/2001
AMAZON CREEK	Amazon Cr. + Highpass Rd	255.9	22.6	8/7/2001
AMAZON CREEK	Amazon Cr. + Highpass Rd	260.1	16.6	9/10/2001
TRIBUTARY STREAMS				
WILLOW CR.	Willow Cr. At Gimple Hill Rd.	242.1	16.7	6/22/2001
WILLOW CR	Willow Cr. At W. 11th - Below HYNIX	**438**	20.1	7/31/2001
CHAMBERS ST. CR.	Outflow to N. behind Albertsons W tube	249.1	15.6	6/31/2001
COLLEGE HILL CR.	Confluence from West at 27th St.	260.3	15.9	6/8/2001
EMERALD ST. CR.	Confluence trib from East at 27th St.	**650**	20.6	6/8/2001
CITY VIEW CR.	Tributary from S. below City View St	387.9	19.5	8/28/2001
STOREY BLV. CR.	Creek from south side Madison + 29th	230.1	15.4	9/10/2001
CREST DR. CR.	Morse Ranch Cr. 30th and Lincoln	169.5	17.1	9/10/2001
S. SIDE P.OFFICE CR.	Trib. At 35th and Olive (P. Office Cr.)	273.4	13.6	6/6/2001
TUGMAN CREEK	Tugman Creek in Park	387.8	14.1	6/2/2001
BRAEBURN CR.	Braeburn Cr. Upstrm. From 2nd crossing near cem.	335	15.1	6/6/2001
BRAEBURN CR.	Braeburn. Cr. W. Fork above development, 250' above prev. site	120.8	12.9	6/6/2001
AMAZON CR. HEADWATERS	Amazon Cr. Above Martin St. (51st.) E. Fork	175	12.3	6/2/2001
AMAZON CR. HEADWATERS	Amazon Cr. Above Martin St. W. Fork	267.7	12.4	6/6/2001
AMAZON CR. HEADWATERS	Amazon Cr W. Fork upstream-from. Hollow Res	240.1	13.3	6/6/2001
AMAZON CR. HEADWATERS	Most Easterly Fork of Amazon from Dillard Rd.	261.1	15.4	9/10/2001
AMAZON CR. HEADWATERS	Amazon Cr, E Fork at FootBridge Ridgeline trail	201.1	12.6	6/6/2001
AMAZON CR. HEADWATERS	Amazon Cr. Above Martin St. W. Fork	267.7	12.4	6/6/2001
NEARBY W.S. STREAMS				
COYOTE CR.	Coyote Cr. At Petzold Rd, near Crow Rd	247.3	20.9	7/23/2001
COYOTE CR.	Coyote Creek embayment of Fern Ridge. Res.	344.6	25.8	7/23/2001
COYOTE CR.	Doane Creek from S , near Doane Rd, above Dam (Puddles)	**11,070**	17.9	7/23/2001
SPENCER CREEK	Spencer Cr. And Crow Rd. (2 days after rain)	283.4	17	6/28/2001
OTHER AREA RIVERS				
WOLF CREEK	Wolf Cr., 5 mi W of Crow Rd. (2 days after rain)	42.9	13.6	6/28/2001
WILLAMETTE R.	Willamette R. + Beltline	69.9	18.8	8/28/2001
MOHAWK R.	Front Old Mohawk Market	64.2	19.6	9/3/2001
MCKENZIE R.	McKenzie R. + Mohawk R.	52.8	14.9	9/3//2001
CRESWELL				
CAMAS SWALE CR.	E. Fork of same Cr. - W. Creswell	140	20.8	8/28/2001
CAMAS SWALE CR.	W. Fork Camas Swale Cr. + Sher Khan Rd.	264.1	17.6	8/28/2001
CAMAS SWALE CR.	Downstream Camas Swale Cr. + Hwy. 99 N- Upstr. Short Mt.Ldfill	**538**	19.2	8/28/2001

Sources." One point source was discovered in Doane Cr. located to the east of Crow. At sites 41 and 42 where extremely high values were detected and the source seems to be a spring that was known to have attracted many animals during the colonial period and many hunters as well (comment of neighbor, and a member of the Volunteer Rural Fire Brigade, 2002), but it didn't change the conductivity of Spencer Creek to which it flowed.. One would expect to see more hot spots of this type if the mineral spring source theory was the primary cause of the in stream conductivity values.

3.5.3 Soil Water Conductivity

Findings

The soil water conductivity study reveals that very high values develop over a few days time in many bottomland profiles and Unit III appears to be especially susceptible to generate solutes that cause high conductivity readings. The data is presented in Appendix D (column 1). In general conductivity readings decreased with depth below the contact between Unit III and Unit IV. The case of profile BLMST-15 is particularly illustrative of how conductivity measurements drop dramatically as parent material changes. In this profile the boring passes from olive brown clay silt (Unit III) to loose, recent sand of the Willamette River (Unit IV) in which leached solutes from the upper layers probably couldn't be retained. The drop from 346µS/cm^2 in Sample BLMST-15#3 (32-52") to 21.2 and 28µS/cm^2 in the lower samples BLMST-15 #6 and BLMST-15 #7 (64-75" and 75-78" depths respectively) supports the concept that typical Willamette River sediments ("Cascadian") produce low value conductivities in comparison to the minerals that make up Units II and Units III. The regional river conductivity data reflects this also (Appendix G). In profiles that penetrate residual soils of Fisher Fm. (BLMst-6 and 7) or fine textured alluvial layers of Willow Cr. alluvium (BLMst-4 and 5) or Willamette River alluvium (BLMst-8, 9 and 10) such a sharp decline is not observed, although typically a slow dropoff is detectable. This is most likely due to adsorbtion of solutes leached out of the overlying Unit III soil by the clay fraction of these particularly fine textured Unit IV soils.

3.5.4 Ion Chromatography of Soil Profiles—Paul Engelking

Findings

When soil water chemistry was scrutinized by the ion chromatograph to understand the cause of the high conductivity values the following results were obtained. An example of a readout from the chromatograph is presented in Figure 3.5.1 which demonstrates that F, Cl, NO_2, Br, NO_3, and SO_4 plus two unknown substances (#5 and #8) make up part of the ionic content of these soil waters. In Appendix G the results of different ion chromatograph analyses are presented demonstrating in general, the consistency of the elements that generate the conductivity observed. They include samples of moderate to highly conductive Amazon Cr. water from headwaters streams, the mainstem passing through the urban area, soil water from both hillslope and bottomland profiles, BLM trenches T-1 and T-2, rainwater, and runoff from a recently fertilized grass seed field near Junction City.

It is evident from this data that chloride and sulphate are usually always the two principal anions that are present when a highly conductive sample is analyzed. The other elements that appear with these principal components include F, Br, NO_2, NO_3 and P_2O_5 . Due to the fact that we did not have access to a “cation column” for the instrument, in this preliminary study, Dr. Engelking followed his methodology that assumes that one cation is present for each anion detected and the molar conductivity is indicative of other, including organic molecules that might be present. The measurement of these molecules or elements requires other analytical methods. These results are presented in Appendix G, column L. A number close to 150 indicates that almost all the conductivity has been explained by the anions detected and their cation partners. The larger the number is, the greater presence of undetected ions in solution. As can be observed, sometimes values as high as 2,918 appear (greyish nodules in Braeburn Cr. which we know contains abundant Ca CO_3 , because they effervesce in acid).

3.5.5 Summary

There are several important results of this study. 1) High conductivity can be associated with particular stratigraphic units across the 3.5 mile transect and the high conductivity generating units are always found in bottomland profiles (even though parent materials are the same for hillslope profiles). 2) These soils generate a large quantity of ions in a very short time as rain water comes in contact with them. The dissolved products are what contribute chlorine, fluorine, nitrogen compounds and sulphates to the aquatic system via soil water migration to the deeply excavated channel of the Amazon Cr. and to the biosphere through plant uptake. 3) As the INNA analysis of trace elements demonstrated, many trace elements also enter the biosphere and aquatic system. Such unconventional trace elements and soluable compounds detected in both soil water and stream water probably are part of what the USGS measured in 1991 (Rinella, 1993) that led the Amazon Creek to be placed so high on the list of contaminated streams in Oregon. Further studies are necessary and a separate report will be prepared on this subject (Engelking and James, in prep.).

3.6 RESTORATION TREATMENT SOIL CONDUCTIVITY ANALYSES

Based on the high mobility of solutes discovered in these soils it was decided to carry out an experiment to determine if this methodology (conductivity with ion chromatography) is adequate to measure nutrient release after soil disturbance. The fact that sod removal was used as a treatment to remove rye grass and its seed base in the West Eugene Wetlands project area, and then seeded to promote growth of native species, allowed for a sampling program on an area with similar soils where runoff could be collected from an ash grove approximately 50 years of age (S-0), a mowed field that has been hayed for several years (S-1), a site where soil was stripped during the summer 2002 (S-2), a site where sod was removed in 1998 (S-3) and a site that was stripped in 2000 and then restripped in 2002 (S-4). The results would also give an idea of how much nutrient release occurs into the aquatic system as a result of the use of this restoration method.

3.6.1 Conductivity and Ion Chromatography

Methods

Surface water samples were collected in Nalgene bottles, simultaneously with a 4” deep soil sample. Soil samples were collected on multiple days after differing climate events which included ample precipitation, within the West Eugene Wetlands off of Greenhill Road (Figure 3.6.1). The soils were placed in a volume of distilled water about 5 times their volume. The conductivity was recorded for a 10 day period. The values stabilized at 8-10 days before anion analysis of both soil slurry and runoff water samples was performed by Paul Engelking, Department of Chemistry, University of Oregon. Methods using the Ion Chromatograph are found in Chapter 3.5 and results are found in Appendix H.

Findings

Ion Chromatography measures the immediate availability of an element in the environment. The elements detected during the experiment were fluoride, chloride, nitrite, bromide, nitrate, phosphate and sulphate. The Environmental Protection Agency has standards for human health in drinking water for nitrate (1 ppm), and no standards for sulphate or fluoride. However, “advisories” exist when exceedence levels reach 200 ppm for chloride and sulphates. Fluoride has a standard for fish health in the Columbia River of 0.3 ppm for soft water (generally during winter flow).

Results of soil conductivity are displayed in Figure 3.6.2. Nitrate levels increased in the soil samples with sod removal. The S-0 and S-1 samples have low levels of nitrate (0.04 and 0.09 ppm respectively). The S-2 site reached 1.75 ppm, exceeding standards for water quality if mobilized in runoff. This site was the most recently stripped of all the sample sites, and as predicted, with organic removal, there is a flush of nitrate available because nitrogen is no longer sequestered by plants. Wetlands generally are considered to be an excellent system for microbial processes allowing denitrification to occur and preventing the leaching of mobile nitrates into surface water. With the removal of sod, there is the probability that not only surface erosion occurs, but nitrates which are very mobile, will leach into ditches and waterways.

Figure 3.6.1 This figure represents each of the sample sites: S-0 through S-4. S-0 is located in an ash grove approximately 50 years of age. S-1 is a mowed field that has been hayed for several years. S-2 is a site soil stripped during the summer 2002. S-3 had sod removed in 1998 and S-4 was stripped in 2000 and restripped in 2002.

Of interest also are the levels of chloride and sulphate. Due to stratification of elements, in an undisturbed soil, salt pumping action brings chloride to the surface while sulfates move down in a profile. The results simply show that the sites where the sod has been removed have had the chloride removed along with the topsoil and brought the sulphate to the surface. Again, there are no human health standards set for sulphate, however, it is mobile and may leach into the waterways.

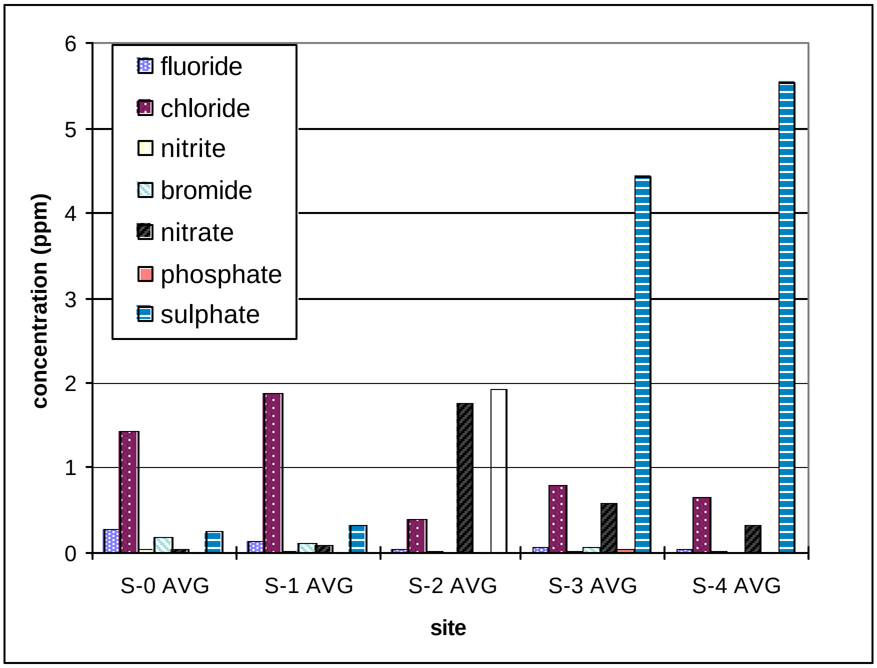


Figure 3.6.2 Anions found in soils in ppm for five different treatment sites. These anions are very mobile and could potentially leach into runoff.

Another way to look at the same sample dataset is the relative concentration between the least disturbed site (S-0) to disturbed sites (Figure 3.6.3). The most recently stripped site (S-2) shows a spike in the nitrate concentration of 45 times over the S-0 site. Sulphate and phosphorous also spike in the three sites where soil has been removed (S-2, S-3 and S-4). The S-3 site had a significant reading of 0.05 ppm of Phosphorous. Phosphorous is coupled to sulphate and calcium, and is tied up with their presence. With the removal of calcium and sulphate, phosphorous is released and can again become mobile and enter surface waters.

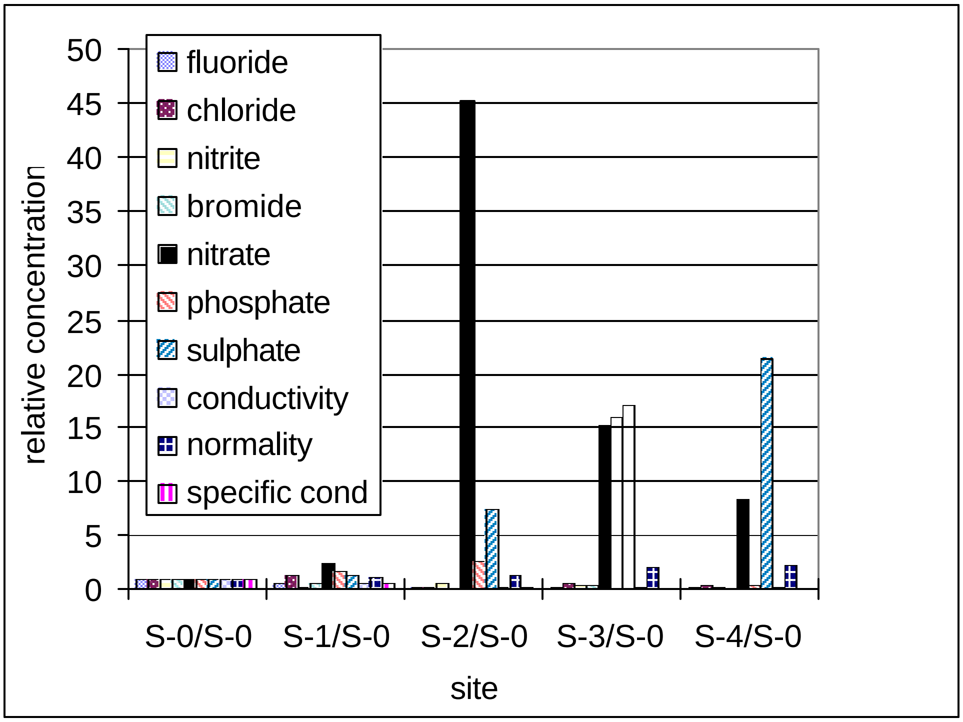


Figure 3.6.3 Relative concentrations of anions between the S-0 site and all other sites. Nitrates phosphate and sulphate appear in much larger amounts after soil stripping.

3.6.2 Nutrient Tests

Nutrient samples were taken from surface of the Greenhill sites mentioned in Figure 3.6.1 and also samples descending downward in the profile from Trench 1 were submitted to the Central Analytical Laboratory, OSU, Department of Crop and Soil Science. Will Austin, Laboratory Director, aided in interpreting the results.

Table 3.6.1 Nutrient samples that were analyzed included six surface samples and six samples taken in descending order at Trench 1 to a depth of approximately 9 feet.

Sample	pH	P ppm Bray	K ppm	CA meq/100g	Mg meq/100g	Na meq/100g	NO_3-N ppm	%OM LOI	CEC meq/100g	Cond ms/cm
S-0	5.5	4	95	6.6	2.5	0.15	1	9.52	-	-
S-1	5.6	4	82	14.7	5.8	0.21	3.2	7.37	-	-
S-2	6.5	3	26	5.6	1.7	0.10	0.7	3.13	-	-
S-3	5.6	4	36	3.9	1.1	0.09	0.6	3.80	-	-
S-4	5.4	6	24	3.1	0.8	0.09	0.8	3.16	-	-
T1-1A	4.7	7	35	3.9	1.0	0.13	23.0	5.08	12.4	0.6
T1-2A	5.7	3	47	9.8	3.9	0.23	3.7	4.44	18.2	0.2
T1-3A	4.9	4	35	4.1	1.0	0.13	0.3	4.60	26.0	1.1
T1-4A	5.3	4	-	-	-	-	-	3.65	21.2	1.8
T1-5A	6.0	5	-	-	-	-	-	7.60	45.3	2.9
T1-8A	6.9	5	-	-	-	-	-	3.97	32.0	4.0
T1-9A	6.8	4	-	-	-	-	-	3.14	22.3	5.4

The following qualifications are based on the opinion of Will Austin, OSU Soils Lab, who compares the results with other western Oregon and Willamette Valley soils. Agronomically, these soils are strongly acid and the agricultural recommendation is to change pH and amend with P and K.

pH measurements show soil is somewhat acid. pH gets more neutral going down in the profile, which is a typical trend.

P values are very low agronomically (20 is a typical low measurement). Phosphorous is critical for plant cell development. If a site is wet and in pasture for a long time, plants and water can mine Phosporous out.

K Values are very low agronomically, typical is 150 ppm.

Ca Calcium values shouldn't be lower than 5.

Mg Values are in the medium to high range.

Na Values are not too critical, values are rather low.

NO_3-N Value of T1-1A is good, all others are low. Nitrate is very mobile and shouldn't be in the clay.

%OM Values are okay. Organic carbon should be at 2.5-3% (take factor of 0.7 to convert from %OM). However, the %OM LOI process volitalizes lots of things and if there are elements such as sulphates present, the number can be skewed higher than the real OM content.

CEC CEC increases with high OM and with 2:1 clays. Low pH can change CEC, OM can cause an increase in CEC. Humus has values of 100-200 meq/100g. Montmorrillonitic clays have high CEC potential.

3.6.3 Summary

This experiment used conductivity/ion chromatograph analysis as a way to measure the quantities of the most soluble ions in a recently exposed soil or body of water fairly rapidly. With a change of vegetation when established plants, soils and organisms are removed, nutrients stored in root systems and around root hairs are suddenly released as the uptake systems are halted. Before pioneer species get established, elements are released into the soil and become soluble in rainwater. Nutrient tests on NO_3-N are very vigorous and can liberate nitrate that is otherwise somewhat locked up (although theoretically available to plant roots).

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

A three-and-one-half mile long transect of soil auger borings was done across public lands, from hillslopes through bottomlands, within a part of the West Eugene Wetlands (WEW). Included in the analysis were data from two-ten foot deep trenches that were excavated in earlier investigations, soil samples collected from 25 and 75 miles north of Eugene in the Willamette Valley, and water samples collected from rivers and streams surrounding the Eugene area. Stratigraphy was mapped using soil and sediment descriptions, mineralogy, and major and trace elements. Soil and water chemistries were measured for anions.

Hillslope stratigraphic units were composed of a silty soil overlying a residual soil (paleosol). Hillslope units correlated to bottomland units through mineral analysis and thickness. Four stratigraphic units were identified and correlated across the bottomland. The following is the bottomland sequence:

> Unit I is an alluvially deposited grey to brown silt-loam layer, 6-15” thick. It appears to be an layer that includes reworked sediments of Unit II. The shrink-swell characteristic of the grey clay unit located beneath (Unit II) causes Unit I to be churned up and down through large cracks that develop and dissipate during the annual cycles of wetting and drying. Additionally, sheetwash and overland flow contribute to the reworking through erosion.
>
> Unit II is a massive, dark grey to grey clay (65-80% clay content) that includes fine sand grains. This Unit is 22-28” thick. The clay is composed principally of smectite and some well-ordered kaolinite. Unit II exhibits intense shrinking during dry summer conditions and swelling during the wet season. With swelling, the high water-holding capacity creates an impermeable surface that creates overland flow across the surface of the bottomland during intense or long duration rains.
>
> Unit III is an olive brown clay silt to fine sand, that is 32-38” thick. Coarse fragment content increases towards the base (normally graded). Few signs of shrink swell exist in this Unit.
>
> Unit IV is the underlying residual soil, formed on different substrates. Unit IV is either a paleosol, formed on weathered tan to yellowish Fisher Fm. tuff or volcanic sediments, alluvium from Willow and Amazon Creeks that consists of coarse sand and gravel (South Hills provenance), or Willamette River alluvium composed of loose sand or slightly clay silt (Cascadian origin). Weathered bedrock is composed of the Fisher Fm.

Soil characteristics of the bottomland paleosols in Unit IV, include coarser particle sizes than overlying Units II and III, and brighter red and yellow soil colors. This suggests that the soils were better drained before the arrival of Units II and III. The deposition of Units II and III appears to have occurred close in time, creating a very flat topography, and an impervious surface. Units II and III were either deposited as clays or were chemically weathered to form clay in situ. The fine particle sizes along with few fluvial bedding structures found, leaves some mystery as to a depositional mechanism of Units II and III. The sediments are young, Holocene in age, and consist of a volume of immense proportions across the width of the bottomland.

Stratigraphy at archaeological sites in the vicinity of the study area could not be correlated to the stratigraphic units identified, however, radiocarbon dates at nearby occupation sites suggest that the upper ten feet of sediments along the Willamette Valley floor in West Eugene are Holocene in age. Age of the West Eugene bottomland sediments in this study was determined by three radiocarbon dates, a preliminary paleopedological evaluation, trace element trends, etched condition of numerous mineral grains and the XRD interpretation of the clay mineral and fine silt fractions. A Holocene age for Units I, II and III was determined. Unit I was dated at one site to be 1480 +/- 60 BP. Units II and III share some common minerals and lithic fragments and the clays show no signs of in situ development. A bulk soil radiocarbon date of 16,000 +/- 50 BP for Unit III doesn't correlate well with the lack of weathering in this stratigraphic unit. More credibility is given to the age of a lower unit sample with a date of 6,280 +/- 50 BP.

XRD analysis of clay minerals confirms that no Missoula Flood Silts exist in the West Eugene bottomland. There is an absence of distinctive Missoula flood mineralogy (muscovite, biotite, K-feldspar and lithic fragments of metamorphic and igneous intrusive rocks). The clay mineralogy of the stratigraphic units found in this study includes smectites and well-ordered kaolinites, both found in the Cascades, however, the quantity of kaolinite presents a dilemma because the possible hydrothermal source areas (i.e., Bohemia, Hobart Butte) are too small to have generated so much material.

A distinctive suite of eight minerals and various types of lithic fragments form a diagnostic tracking tool for the stratigraphic units. The suite correlates to Mt. Mazama minerals. The minerals include: 1) well formed tabular crystals of clear plagioclase (andesine-oligoclase), 2) euhedral, quite magnetic, light green orthopyroxene (hyperstene) with opaque inclusions of ilmenite and magnetite, 3) coarse grained dark brown to black hornblende, 4) coarse grained quartz, sometimes completely or partially bipyramidal, 5) euhedral spinel, 6) flat hexagonal ilmenite, sometimes formed around a nucleus of dark green glass, 7) chromite and 8) zircon. Some scoriacious aluminum silicate lithic fragments are also present in white, grey or brown colors. Occasionally they include metallic minerals.

The coarse mineral fraction (> 50 mesh, 0.226 mm) was investigated by binocular microscope (30X), in thinsection and by a microprobe chemical analysis (including Cl, F, Cr, P and Ni). Results indicate that the plagioclase is andesine-oligoclase (An_{40}), different from the more calcic Cascadian type (An_{50-65}). The large hornblende and magnetic hyperstene crystals have similar chemical values to Cascadian examples. When compared to Mt. Mazama examples, the Fe in hornblende is lower, Al and Ti are slightly higher. This isn't a common mineral found in andesitic terranes and rarely in such large crystals. The hornblende and the magnetic hyperstene crystals, generally have a very euhedral side or sides suggesting formation in a liquid or gaseous environment where they could grow free of interference before their expulsion in a large explosive eruption. The presence of a variety of fine textured, oftentimes euhedral accessory minerals representative of variable temperature conditions and magma chemical compositions including ilmenite, magnetite, chromite and zircon, do not aid significantly in understanding the initial magma composition or its differentiation process.

The origin of the minerals appears to be Mt. Mazama. The presence of this suite of minerals is limited to the upper 40" of the hillslope (none are found in the parent material below) and in Units I, II and III of the bottomland (not found in Unit IV). The low degree of abrasion and high degree of crystal complexity observed microscopically (twinned pyroxenes, double pointed quartz crystals, well formed plagioclase crystals, etc.) and the general lack of fluvial bedding features in the 4-5' thick bottomland deposit, suggests an airfall transport mechanism.

Two grey clays from the Willamette Valley floor were sampled outside this study area. A grey clay unit was identified at a Woodburn, Oregon, fossil site (75 mi. N of Eugene) bearing the similar and unique mineral suite found in this study. The Woodburn fossil site grey clay, has a radiocarbon date of 6800 BP +/- 50, and is located stratigraphically above Missoula Flood deposits. Additionally, a sample of grey clay was collected at Harrisburg, Oregon, (25 mi. N of Eugene) also bearing the similar and unique mineral suite found in this study. This sample was found overlying the Irish Bend member of the Willamette Silts. The presence of the unique mineral suite at all three sites suggests that the three locations with this grey clay unit are related.

Trace element studies of whole soil samples of four soil auger profiles, and one texturally fractionated sample, provided more information about how different these units are in comparison to the surrounding watershed or regional lithologies. The distribution of trace elements demonstrates that there is greater similarity between Units II and III than between these units and Unit IV. Trace element values of Willamette River alluvium were consistent with those reported for andesitic or basaltic andesite terranes around the world. Trace elements of the Willow Creek alluvium and weathered Fisher Fm. bedrock represented more felsic volcanism well, but Units II and III were dissimilar to both. The fact that there are so few differences between the trace element levels in Units II and III supports the idea that Units II and III were laid down from the same source.

The highest arsenic (As) value is found in the coarse textured fraction of a bottomland grey clay sample (Unit II, 105 ppm), yet the whole soil sample has approximately 20 ppm. This may suggest that as arsenic weathers out of the lithic fragments, it is freed into soil water and moves out of the soil profile. High values for arsenic (As) in Willow Cr. alluvium also supports the idea that the Fisher Fm has a relatively high arsenic (As) background level. Unit II has lower amounts of barium (Ba), strontium (Sr), and nickel (Ni) in comparison to Unit III, supporting the concept that leaching of more labile elements occurs. Besides arsenic (As), high values were found for thorium (Th), zirconium (Zr), hafnium (Ha), chromium (Cr), and fluorine (F) during the analyses of the soils.

Regional surface water conductivities have been noted as being anonomously high in the Eugene area. Conductivities were run on all soil samples and it was found in this study that the bottomland soils generated very high conductivities, especially Unit III (400-650 µs/cm). As a comparison, conductivity values in Unit IV, coarse-textured samples, had much lower values than stated above, while Unit IV, fine-textured samples, maintained these values or showed a slight decrease. These results show that slightly high levels of toxic metals may be products of natural soil leaching. It appears that leached elements are retained temporarily by clays and gels, and that a flux of higher conductivity occurs downward in the stratigraphic profiles towards the regional water table. Fluctuations of the regional water table may cause "salt-wicking" towards the surface to build up these values, however, the existing hydrologic system has not been adequately studied, and this theory is only postulated. From this study, it is shown that the sediment profiles found along the study transect tend to form soil/water high conductivities with the exception of those that appear to have better drainage (hillslope profiles) and coarser substrates (BLM T-2 and BLMST-HR).

The combination of conductivity and ion chromatography analyses determined the anions present in stream and soil water high conductivity readings. Chloride (Cl) and sulphate (SO_4) were the most prevalent anions in samples with very high conductivity readings (193 and 42 ppm, respectively). Floride (F), nitrite (NO_2), bromide (Br), nitrate (NO_3), and phosphate (PO_4) were also detected. Available testing did not include ions, metals or organic compounds, and measurements indicated a presence of some unknown elements. High conductivities were traced into the Amazon Creek headwater streams around Eugene and in most cases the values were higher than regional background levels. Nitrogen molecules were detected in a few cases. Consistent with the microprobe analyses of the lithic fragments and certain minerals where low totals were encountered, these analyses demonstrate that other compounds or molecules active in the system were not detected by microprobe analysis. In preliminary analyses with Crater Lake there are similarly higher values for these elements, supporting again a genetic relationship between Mt. Mazama and West Eugene.

Sod removal has been employed to remove commercial grasses along with their seed base as part of restoration treatment in the West Eugene Wetlands. Ion chromatography of surface soils and runoff water was carried out where soil scraping had been applied over a year ago and compared to a site that had lain dormant for over fifty years. Nutrient release of nitrate (NO_3) and phosphorous PO_4) was detected on the sites most recently devegetated of surface soils. Sulphate (SO_4), fluoride (F), chloride (Cl) and bromide (Br) were also detected. Until plants or organisms establish themselves on the bare soil that is left at the surface, these nutrients are available to be flushed out of the soil system into surface water ditches that drain into Amazon Creek.

As a result of this study, questions arose about the origin of a unique suite of minerals found in the massive grey clay that was identified as stratigraphic Units II and III, as well as in the upper surface soils of the surrounding hillslopes. Limited radiocarbon dating indicates that during the Holocene, a large depositional event occurred that blanketed the Willamette River floodplain and the surrounding hills. It appears to have been an airfall deposit which, for the reasons stated above, was generated by an eruptive phase of Mt. Mazama seven thousand seven hundred years ago.

4.2 Recommendations

This study has shown that the chemical and physical characteristics of this wetland are not fully understood. For project planning, it is important that soil and water interactions are recognized. For example, the shallow and variable depth of the topsoil across the bottomland wetland, is a major contributor to the length of time saturated soil conditions are maintained and are most likely linked to the establishment, maintenance and type of wet prairie vegetation found at that site. Knowing the physical limitations of the soil profile and mapping areas where hydric soils have been drained, recontoured or removed, may aid in identifying sites where the successful reestablishment of hydrophytes could readily occur.

The hydrologic relationship to the chemistry and soils found in the area, needs to be explored further. In West Eugene, the hydrology has been dramatically altered. The precise description of hydrologic characteristics requires: 1) detailed knowledge and mapping of annual and long-term duration and timing of surface inundation, and 2) understanding interactions between surface water phenomena and groundwater. It is not clear what connectivity the regional water table or the Willamette aquifer, lying at approximately ten to twelve feet below the soil surface, has with the surface hydrology.

The soil/water chemistry in West Eugene is still not clearly understood. Amazon Creek has been noted to be one of the most contaminated creeks in the State of Oregon. This study identified several naturally occurring elements that point to possibilities that some of the contamination may be from natural soil minerals and lithic fragments that make up these distinctive fine textured soils. It is not known to what extent the soil/water chemistry plays a role with water quality or what the relationship is between soil chemistry and hydrologic regimes occurring locally. If summertime evaporative processes result in salts wicking to the surface of the grey clay unit, overland flows may carry mobile elements into the drainageways during the first rains.

This study has identified minerals in some of the depositional stratigraphic units that are very unusual in the local context. This stratigraphic study coupled with pedogenic development has determined that the age of this unit correlates to the timing of the Mt. Mazama eruptions. Further studies of the complex mineralogy and glass will help understand the chemical characteristics of the massive grey clay found in the Willamette Valley bottomland and how it is associated with surface water chemistry.

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APPENDIX A

SOIL DESCRIPTIONS

Appendix A
Soil Descriptions

BLMST-1	BLMST-2	BLMST-3	BLMST-4	BLMST-5
W. of Baily Hill Rd upslope	**W. of Baily Hill Rd midslope**	**W. of Baily Hill Rd lower slope**	**Willow Cr. S. of 18th St.**	**Willow Cr. N. of 18th St.**
ST-1-1 0-6.5” 7.5YR4/3 Brn, slty. snd., gran. aggre 2mm, roots, loose dry **ST-1-2** 6.5-17” 7.5YR4/4 Brn. Slty snd, massive, wht crse snd, weak, dry **ST-1-3** 17- 30.5” 7.5YR4/4 Brn. Slty to fn snd, 0.5 mm Fe2O3 conc. + wht gry,grn,frags, Blocky struc. 25 –30.5” color chg 5/4 lrger frags 2-3 cm. **ST-1-4** 30.5- 35” 7.5YR4/6 Strn Brn. Wk blky struc, pos. buried A Horizon **ST-1-5** 35-39” 10YR5/4 – 5/6 Yel brn, slty snd, w/ crs yel. wht. Frags 3 x 3 cm. Pos buried b horiz. **ST-1-6** 39-53” 2.5Y6/6 – 7/6 Olv yel to yel., cly slt, no grav, weathered . Fisher Fm.?, pyrocl. Yel, wht, orng. Frags, mottles, plast. Sltly moist. **ST-1-7** 53-67” 2.5Y 7/6 Yellow clay silt w/ sand, variegated yel./orng/wht/brn lines,w/ grayish and whitish angular masses, original texture of ignembrite, Fisher Fm. *weathered Fisher Fm.*	**ST-2-1** 0-7” 10YR4/4 Drk yel Brn, hard, cl silty peds, cubic to polyhed. abun roots **ST-2-2** 7-11.5” 10YR 4/4 Drk yel .brn., hard, cl. silt, gran. to incip blky, dry, roots **ST-2-3** 11.5-21” 10YR3/6 Drk Yel Brn, firm silt to silty snd. w/ yellow, orange and black spots, weaker **ST-2-4** 21-25 “ 7.5Y4/4 Brn, silty sand w/ fragments of yellowish brn ashy material **ST-2-5** 25-36” 10yr 6/8 Brnish yellow to yellow, weathered pyroclastic material (?) *weathered Fisher Fm.*	**ST-3-1** 0-7” 7.5YR 3/2 Drk brn, hard clayey aggregates, roots **ST-3-2** 7-21” 10YR 4/3 Brn to drk brn., slty cl, firm but softer, aggregates, dry, firm, more plastic, slkensdes, shiny **ST-3-3** 21-30” 10YR 4/4 Drk yel brn, slty sand, w/ orng, yel., wht and blk grains **ST-3-4** 30-43” 10YR 6/8 Yellowish brn. coarse sand w/ silt, pyroclastic frags.? **ST-3-5** 43-51” 7.5 YR 4/4 Reddish brn, weathered gravel in sandy matrix. **ST-3-6** 51-56” 10YR 6/8, yellowish brn, silty sand, pyroclastic flow?, soft, damp **ST-3-7** 56-61” 10 YR 2/1 or 2/2, black, paleosol w/ struct. prismatic at base (1” thick) **ST-3-8** 61-67” 10YR 5/4, clayey silt, very plastic, mottles, yellow spots on pinkish gray backgrnd. **ST-3-9** 67-72” 7.5YR 7/1 Lt pinkish gray siltstone, hard, fractured *weathered epiclastic siltstone, Fisher*	**ST-4-1** 0-9” 2.5Y 4/3 or4/4 Olv. Brn, silty, granular, dry, abun. roots, bulbs **ST-4-2** 9-15” 2.5Y 3/3 Drk olive brn, clayey silt, somewhat plastic abun. roots with camus bulbs **ST-4-3** 15-26” 2.5Y 4/2 to 3/2 Drk grayish brn. w/ white, orange and black stops, no clay skins but is more clayey **ST-4-4** 26-37” 2.5Y 4/2 to 5/3, Drk grayish brn., vry plastic, abundant sand size grains white orange. desication cracks **ST-4-5** 37-46” 2.5Y 5/3 Lt. olive brn, clayey silt, no desication cracks **ST-4-6** 46-50” 2.5Y 5/4 Lt. brn.. clayey, sandy silt w/ MnO posibly after charcoal or its charcoal **ST-4-7** 50-56” 2.5Y 4/5 Lt. olive brn, silty clay, mottled w/ orange masses of Fe2O3. possible paleosol on alluvium **ST-4-8** 56-63.5 2.5Y 5/4-5/6 tan weathered sandy gravel w/clay, mottled w/ abund. lt orang. Fe2O3 masses and large crusts of MnO (1.5-2.0 cm)	**ST-5-1** 0-6” 10YR 5/3 Brn silt, w/orange Fe2O3 nodules – hummock **ST-5-2** 6-11” 2.5 YR 5/3 brn silt w/ more clay w orange spots Fe2O3 and black concre. MnO **ST-5-3** 11-14” 10YR 3/3 Drk brn or very drk brn., aggr. peds, large MnO concr. to 4 mm, white grains 1-2mm. Possible paleosol **ST-5-4** 14-20” 2.5Y 3/2 Vry drk gray, clayey silt, w/ masses MnO and orang spots Fe2O3, very plastic **ST-5-5** 20-29” 2.5Y 3/1 Vry drk gray, silty clay w/ white and red spots 1 mm, very plastic **ST-5-6** 29-36” 2.5Y 4/2 Drk grayish brn, clay w/ silt and cream to white spots, afew orange, red and black spots very plastic **ST-5-7** 36-47” 2.5Y 4/4 Olive brn, clayey fine sand, white rnded grns, massive black MnO, reddish Fe2O3 spots. non-alluvial look **ST-5-8** 47-61” 10YR 3/4 Drk yel. brn. silty sand, soft, rounded grains, yellow and blk spots, angular tan gravels.

		Fm.	**ST-4-9** 63.5-67” 10YR 4/3 Brown, coarse sand and gravel **ST-4-10** 67- 77” 10YR 5/3 to 5/4 Yel. brn clay, very plastic, no sand, thick Fe2O3 fracture coatings **ST-4-11** 77-85” Cont. of clay unit **ST-4-12** 85-95” 7.5YR 4/6 str. brn clayey coarse sndy gravel. *weathered Willow Cr. alluvium*	**ST-5-9** 61-75” 2.5Y 5/2 Gray brn, clay, becoming mor yel. w/ depth 4/3. there is a sandy lense, alluvial, transition to gravel **ST-5-10** 75-82” 10YR Orangish brn sandy gravel. Willow Cr. composition (petrified wood, plagioclase rich, volcanic lithics) *weathered Willow Cr. alluvium*

Appendix A
Soil Descriptions

BLMST-6	BLMST-7	BLMST-8	BLMST-9	BLMST-10
S. of W. 11th Ave. Speedway	**N. of AmazonCr E of PSC**	**S. of Amazon Cr. W. of Terry St. Oxbow W.**	**S. of Amazon Cr. W. of Oxbow W and E. of Grnhill**	**N. W. 11th Ave. Dead Cow Cr. E. Greenhill Rd.**
ST-6-1 0-5” 2.5 Y 6/2 Lt brnish gray on surf. and 2.5Y 3/2 Vry. Drk. Grayish brn at 5” silt to clayey silt	**ST-7-1** 0-6.5” 2.5Y 5/2 Grayish brn, clayey silt, abun. Fe2O3 and MnO concre, 5-6 mm mottled orang-black.	**ST-8-1** 0-7.5” 2.5Y 6/2 Lt. brn gray,silt, aggreg.	**ST-9-1A** 0-4.5” 2.5Y 5/3 Lt. olv. brn silt, granular struct.	**ST-10-1** 0-7” 2.5Y 5/2 grayish brn w/ reddish spots of Fe2O3, silt or fine snd.
ST-6-2 5-23” 2.5 Y 3/2 V. drk gr. brn, clayey silt, w/ few lt. colored orng spots (0.5 cm)	**ST-7-2** 6.5-23” 10YR 4/2 Drk gry brn, dense clayey silt, abundant OM coatings, subdued orange spots. Darker w/ depth	**ST-8-2** 7.5-11” 2.5Y 5/2 brn gray silt w/ clay.	**ST-9-2** 4.5-9.5” 2.5Y 6/3 to 4/2 Lt. yel. brn chng. to drk gray brn. silt to clayey silt. aggr. OM coatings on cracks	**ST-10-2** 7-13” 2.5Y 2/2 Vry Drk gray brn w/ red (Fe2O3) and black (MnO) spots.
ST-6-3 23-32” 2.5Y 3/2 Vry. drk gry brn, clay w/ silt and few small grav grns.	**ST-7-3** 23-30” 2.5Y 5/2 Gryish brn, clayey silt w/ fine snd, vry plas.	**ST-8-3** 11-25.5” 2.5Y 4/1 Drk. gray silty clay, plastic, cracks, white snd grns	**ST-9-3** 9.5-22” 2.5Y 3/1 to 4/1 Drk. gray silty clay, vry plastic w/ lt orange spots w/ depth	**ST-10-3** 13-20” 2.5 Y 4/2 Drk gray brn silty clay, stiff, plastic
ST-6-4 32-40” 2.5Y 4/4 Olv. brn, clayey silt. 34-39” unusual zone of MnO lathes or roots transformed to MnO	**ST-7-4** 30-39.5” 2.5Y 5/4 Lt. olv. brn., clayey fine sand, somewhat plastic, mottled w/Fe2O3 orange masses. 34-36” rich in MnO or charcoal.	**ST-8-4** 25.5-32” 5Y 4/2 Olv gry, silty clay, striated fractures	**ST-9-4** 22-39” 2.5Y 4/2 Drk gray clay, @23” abun. MnO or charcoal, @ 30” some hard white grns and one 1 cm gravel of S. S.	**ST-10-4** 20-37” 2.5Y 4/2 Drk gray brn, silty clay w/sand, very plastic, slickensides.
ST-6-5 40-48” 2.5Y 4/4 Olv. brn sandy silt w/clay	**ST-7-5** 39.5-42” 2.5Y 5/4 Lt. olv brn, clayey silty fn snd, plastic	**ST-8-5** 32-38” 10YR 4/2 Drk. gryish brn, silty clay, a few light orange mottles	**ST-9-5** 39-59” 2.5Y 5/3 to 4/3 Lt. olv. brn to olv. brn clayey silt that turns more sandy w/ depth and becomes more OM rich at 58”	**ST-10-5** 37-64” 2.5Y 4/4 to 5/4 Olv. brn. to lt. olv brn. clayey silt, no slickensides,
ST-6-6 48-53” 2.5Y 5/3 Lt olv. brn clayey C. sand w/ angl and rnded gravel also Fe2O3 and white grains.	**ST-7-6** 42-52” 2.5Y 6/3 to 7/3 Yel. brn to pale yel. sandy clay cris-crossed w/ black blades MnO or charcoal.	**ST-8-6** 38-51” 2.5Y 5/3 Lt. olv. brn., clayey silt, plastic, weaker	**ST-9-6** 59-67” 2.5Y 5/2 Grayish brn, clay w/ sand, very plastic	**ST-10-6** 64-68” 2.5Y 4/3 Olv. brn. w/ horiz. red brn lines, clayey silt w/ tiny white spots.
ST-6-7 53-71” 2.5Y 6/4 Lt. yel. brn. silty clay, mottled w/ brt. orange masses Fe2O3 to 5 mm. and gray wht. subhoriz. grayish veins. @ 64 “ Weathered Fisher Fm. pyrocl. flow no mica, plag. vry abundant	**ST-7-7** 52-63” 2.5Y 4/4 to 5/4 Olv. brn, cly silty sand. a nice paleosol.	**ST-8-7** 51-60” 2.5 Y 5/3 Lt olv. brn. silty clay, changing to clayey silt and hue 4/3 at 57” w/ white sand grains.	**ST-9-7** 67-87” Yel. gray sandy clat w/ gravel and masses of MnO. Gravels are weathered w/ some fresh volcanics seems Cascadian	**ST-10-7** 68-76” 10YR 4/6 Drk Yel. brn, clayey fine sand, contains mica
	ST-7-8 63-84” 2.5Y 5/4 Reddish ol brn, clayey silt grayish masses in lt yel. to gryish fine text. pyroclastic flow	**ST-8-8** 60-73” 2.5Y 4/3 Olv. brn-clayey silt w/ more coarse white snd grains dispersed randomly in soil		**ST-10-8** 76-86” 10YR 4/6 Drk yel brn, silty clay snd, gray zones w/ black spots. Charcoal?
		ST-8-9 73-87” 2.5Y 6/3 Lt. yel brn, silt w/ some clay, course sand grns and MnO concr. (81-84”)		**ST-10-9** 86-95” 10YR 4/3 Brn dense clay, finely bedded.
		ST-8-10 87-95” 2.5Y 7/3 Pale yel. clayey silt, w/ Mno concr.		
		ST-8-11 95-114" 2.5Y Lt yel.brn silt w/ clay some nodules, below water table (Fall) 9/18/02 – 98”		**ST-10-11** 95-105” Drk reddish brn. silty clay snd.,rich in buried roots.
weathered Fisher Fm., pyroclastic fl.	*weathered Fisher Fm. pyroclastic fl.*	*weathered alluvium*	*weathered alluvium Willamette R. or Amazon Cr.*	*Weathered alluvium*

Appendix A
Soil Descriptions

BLMST-11	BLMST-12	BLMST-13	BLMST-13A	BLMST-14
Oak Knoll midslope	**Oak Knoll near summit**	**Lower N. Slope Wallace Butte**	**100’ WSW of ST-13 on flat surface**	**Axis old Will. River channel 500’ E of ST-13**
ST-11-1 0-6” 10YR 4/2 Drk gray brn, slty loam, granular, roots. **ST-11-2** 6.0-13” 10YR 4/3 Brn. Slty loam, w/ yel. snd and occas. small gravels **ST-11-3** 13-18” 10.YR 3/4 Drk yel. brn. silt w/ sand. **ST-11-4** 18-29” 10YR 4/3 Brn., sandy silt w/wht, yel, pink and black grains. **ST-11-5** 29-40” 2.5 5/4 Lt. olv. brn, slty C. snd, w/ rnded grns to 2-3mm. **ST-11-6** 40-44” 2.5Y Olv brn, clayey sand w/ silt, coarse rnded grains *Spencer Weathered Fm.?*	**ST-12-1** 0-6” 10YR 5/4 Yel. brn w/ gray overtone, silty fine sand, abun. roots **ST-12-2** 6-14” 10YR 5/4 Yel. brn. silty fine sand, w/ a few gravel sized frags. weath. sstone. **ST-12-3** 14-35” 7.5YR 4/4 Brn. fine sand w/ silt and tiny wht spots, gets redder w/ depth **ST-12-4** 35-46” 7.5YR 4/4 to 3/4 Brn. fine sand to silt, similar to unit above. **ST-12-5** 46-52” 10YR3/6 to 4/6 Brn to strg. brn, silty clay, w/ ang. frags of lt yel. ss to 3 cm. Paleosol. **ST-12-6** 52-67” 7.5 YR 4/6 Strg. brn. clayey silt, w/ more and lrger wht, red, blk and yel. spots in stiff clay **ST-12-7** 67-84” 7.5YR 4/3, clayey silt to silt, w/ frags of weath, sandstone. Hard to auger. *Weathered Spencer Fm.?*	**ST-13-1** 0-13” Drk yel.brn 10YR 3/6, silt, aggregate structure, mod. weak, abundan. roots **ST-13-2** 13-29” Drk yel.brn 10YR 4/6, silt, redder, weak aggregated, near 28” sandier – wht/yel. grains **ST-13-3** 29-43” Strn Brn 7.5YR 4/6 clayey silt for fine sand, w/ bright red Fe2O3 spots (3-5 m)and black MnO spots(1 mm) and yellow coarse sand grains. **ST-13-4** 43-56” Drk brn. 7.5YR, slightly coarser material, aggreg. structure , larger charcoal, (pos. dates) Paleosol above gravels (50-56”). **ST-13-5** 56-63” Dark brn. 7.5YR ¾, abundant MnO after charcoal?, yellow frags, clayier, large gravel at base **ST-13-6** 63-78” Yel. red 5YR 4/6 very clayey and plastic, abun. Fe2O3 and MnO and rock frags. **ST-13-6** 63-78” Drk gray 2.5Y 4/1 mottled w/ red. brn masses. weathrd. Fisher Fm. pyroclast. fl. wht crystals and pumice frags. *Weathered Fisher Fm.*	**ST-13A-1** 0-10” Drk. grayish brn 10YR 3/2, silty, aggregates, loose damp, weak **ST-13A-2** 10-22” Lt. olive brn 2.5Y 5/4 or lt. yellow brn 6/4 silty clay, blocky struc. to mass. mottled lt. orng. around black MnO spots **ST-13A-3** 22-28” grayish brn 10YR 5/2 or brn. 5/3 clayey silt, very plastic, mottled, blocky to mass. struc., w wht spots **ST-13A-4** 28-35” Brn. 7.5YR 4/3, gray clay- mottled w/ large Fe2O3 masses, wht. grains **ST-13A-5** 35-47” Brn. 7.5YR 4/4 Very mottled w/ large Fe2O3, limonitic masses diff. to drill **ST-13A-6** 47-58” Brn. 7.5YR coarse Fe2O3 and MnO, limonite grains, hard to drill **ST-13A-6** 58-69” 5/6 Yel. brn. Weathered Fisher Fm., pyroclastic fl., large squar. crystals similar to BLMST-13 *Weathered Fisher Fm.*	**ST-14-1** 0-21” Drk grayish brn. 10YR 3/2, silty clay, duff layer ½” (sticks leaves and grass), very plastic, hard to mod hard, granular to slightly blocky, abun. roots., some charcoal, mottled from 2” blow surface, w dark red brn masses of Fe2O3. **ST-14-1** 21-27” Drk grayish brn. 10YR 3/2, silty clay mottled w/ subdued orange Fe2O3and black MnO masses more larger pebbles, red,white, yellow. *coarse gravel Willamette R. channel alluvium*

Appendix A
Soil Descriptions

BLMST-15	**BLMST-HR**	**BLMST-T-1**	**BLMST-T-2**
N. of old Will. R. channel 300’	**N of old Amazon channel – near Greenhill Rd**	**Trench 1 ‘ NNW of BLMST-9**	**Trench 2 ‘ N of Trench 1**
T-15-1 0-12” 2.5Y 3/1 Vry dark gray, clayey silt, w/ lt. orng masses to surface. **ST-15-2** 12-32” 2.5Y 2.5-3/1 Blk to vry dark gray, clay, w/ 1 gravel frag. 1.5 cm and wht to gray spots 1-2 mm. **ST-15-3** 32-52” 2.5 Y 4/3 Olv brn. sandy silt w/clay, cont. some gravels and wht weather sand grains **ST-15-4** 52-64” 10YR 4/4 Drk. yel brn, silty fine sand, uniform, no structure 59-64” **ST-15-5** 64-75” 2.5Y 3/3 Drk olv brn, fine to med. snd w/ some clay and rich in OM. Very loose, clean sand after 72” (alluvial) **ST-15-6** 75-83” 7.5YR 3/3 Drk. brn, med. sand w/ OM, loose. Paleosol to contact w/ coarse Will. R. gravel *semi-weathered Willamette R. alluvium*	**ST-HR-1** 0-30” 2.5 Y 4/2 Drk gray clay, massive w lt orng mottles. **ST-HR-2** 30-62” 2.5 4/5 Oliv. brn. clayey silt w/ sand grains, massive, near base larger grains color yel., black, white. **ST-HR-3** 62-84**”** 10 YR 3/4, drk brn sandy silt w/ gravels, “salt and pepper” look with many red, orange, black colors – Paleosol. **ST-HR-4** 84-105**”** 2.5 Y 4/5 Grayish brn. sandy gravel becoming cobbly gravel, water table @ 91” *reasonably fresh Willamette R. alluvium*	**T-I-1** 0-10” Ap 10 YR 3/1 Drk gray, silt loam, slightly plastic and sticky, wet, abundant roots and smooth plow layer boundary **T-1-2** 10-21” A 10YR 4/2 Drk brn, clay loam vry fine granular, plastic , common med. sized MnO concretions, few roots wavy boundary **T-1-3** 21-42” IIC (?) 2.5Y 5/2 Med. gray, wet, to 2.5Y 6/3 Lt. gray, dry, coarse prismatic, very hard, massive when wet, plastic, sticky, few fine roots, wavy boundary **T-1-4** 42-58” IIIAb 10YR 4/4 Medium brn., wet, clay 10YR 5/3 lt. brn, dry, coarse prismatic dry, very hard, strongly cemented, nearly massive when wet, sticky, very plastic common fine mottling along roots, common MnO root channels. **T-1-5** 58-72” IVAb 10YR 4/3 wet , Gray loam medium granular dry, slightly hard, friable, sli. plastic, vry slightly efferves. few MnO in root channels. **T-1-6** 72-94” IVBc 10YR 3/3 wet, Brn, silt loam, hard med. granular, loose, sticky, coarse MnO concr. slightly efferves. diff. boundry **T-1-7** 94-106” IVC 2.5Y 4/3 Brn., loamy sand, hrd med granular, loose, wvy bound. **T-1-8** 106-114” VC 10YR 3/3 Med. brn., wet, silt, very fine crumb, friable, slightly stcky, wavy boundry **T-1-9** 114 + ” VIC 10YR 3/2 Gray, wet, fine sand, loose structureless, below water table *reasonably fresh Willamette R. alluvium*	**T-2-1** 0-12” Ap Similar to T-1-1 **T-2-2** 12-20” A Similar to T-1-2 but a little grayer **T-2-3** 20-55” IIC (?) Similar to T-1-3 and T-1-4 together above the “salt and pepper” unit. Gray massive clay over olive brown clayey silt. **T-2-4** 55-69” Similar to lower part of T-1-5 (?), “Salt and Pepper” unit. **T-2-5** 69-101” Similar to T-1-6 and T-1-7, but thicker, crossbedded silts and fine sands. **T-2-6** 101+ Similar to T-1-8 and T-1-9, Sandy gravel *reasonably fresh Willamette R. alluvium*

APPENDIX B

PROFILE PHOTOGRAPHS WITH DESCRIPTIONS

Appendix B Profile Photographs with Descriptions

BLM ST-1

ST-1-1 0-6.5”
7.5YR4/3 Brn, slty. snd., gran. aggre 2mm, roots, loose dry

ST-1-2 6.5-17”
7.5YR4/4 Brn. Slty snd, massive, wht crse snd, weak, dry

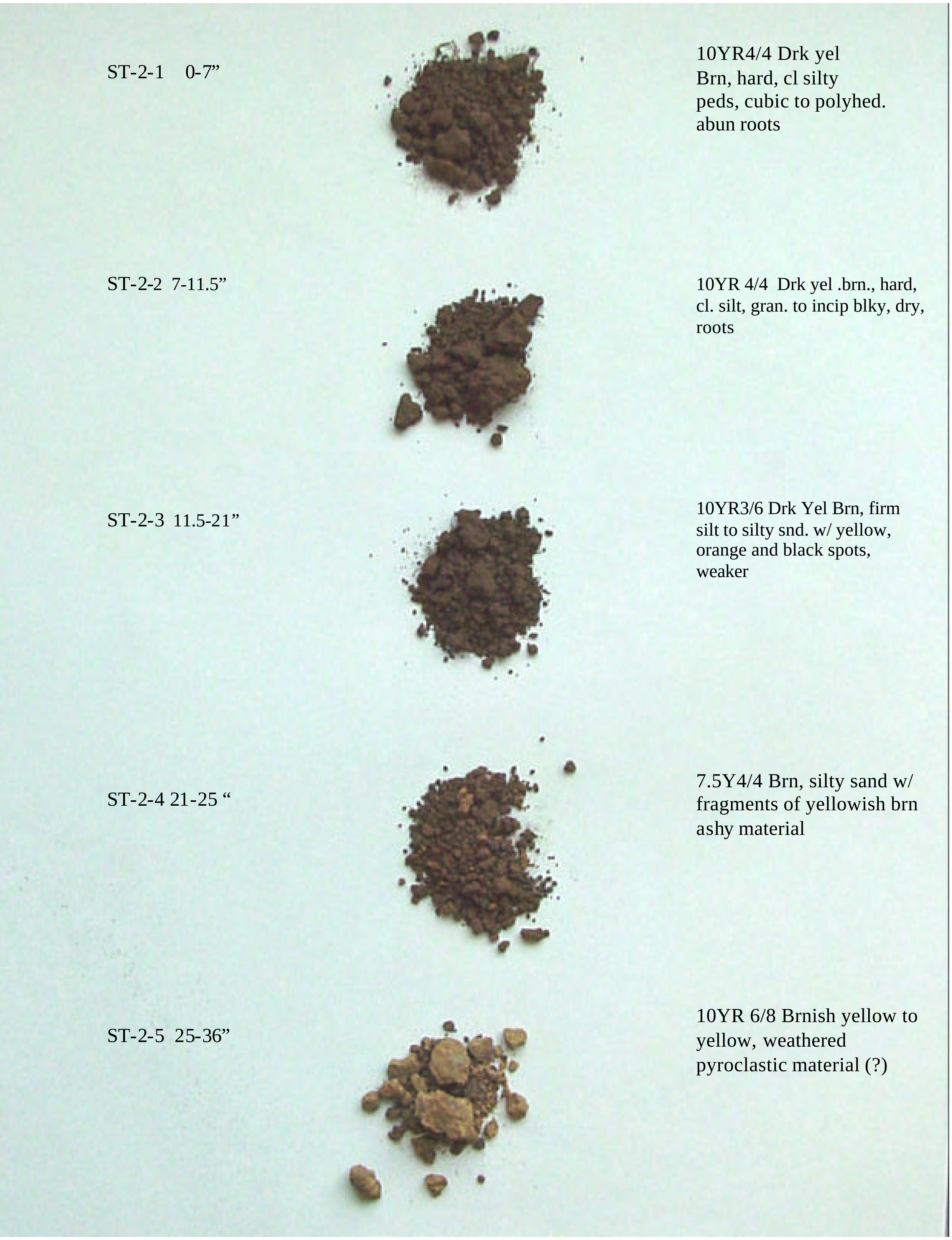
ST-1-3 17- 30.5”
7.5YR4/4 Brn. Slty to fn snd, 0.5 mm Fe2O3 conc. + wht, gry,and,grn,frags, Blocky struc. 25 –30.5” color chg 5/4 lrger frags 2-3 cm.

ST-1-4 30.5- 35”
7.5YR4/6 Strn Brn. Wk blky struc, pos. buried A Horizon

ST-1-5 35-39”
10YR5/4 – 5/6 Yel brn, slty snd, w/ crs yel. wht. Frags 3 x 3 cm. Pos buried b horiz.

ST-1-6 35-39”
2.5Y6/6 – 7/6 Olv yel to yel., cly slt, no grav, weathered . Fisher Fm.?, pyrocl.
Yel, wht, orng. Frags, mottles, plast. Sltly moist

BLM ST 2



ST-2-1 0-7”

10YR4/4 Drk yel Brn, hard, cl silty peds, cubic to polyhed. abun roots

ST-2-2 7-11.5”

10YR 4/4 Drk yel .brn., hard, cl. silt, gran. to incip blky, dry, roots

ST-2-3 11.5-21”

10YR3/6 Drk Yel Brn, firm silt to silty snd. w/ yellow, orange and black spots, weaker

ST-2-4 21-25 “

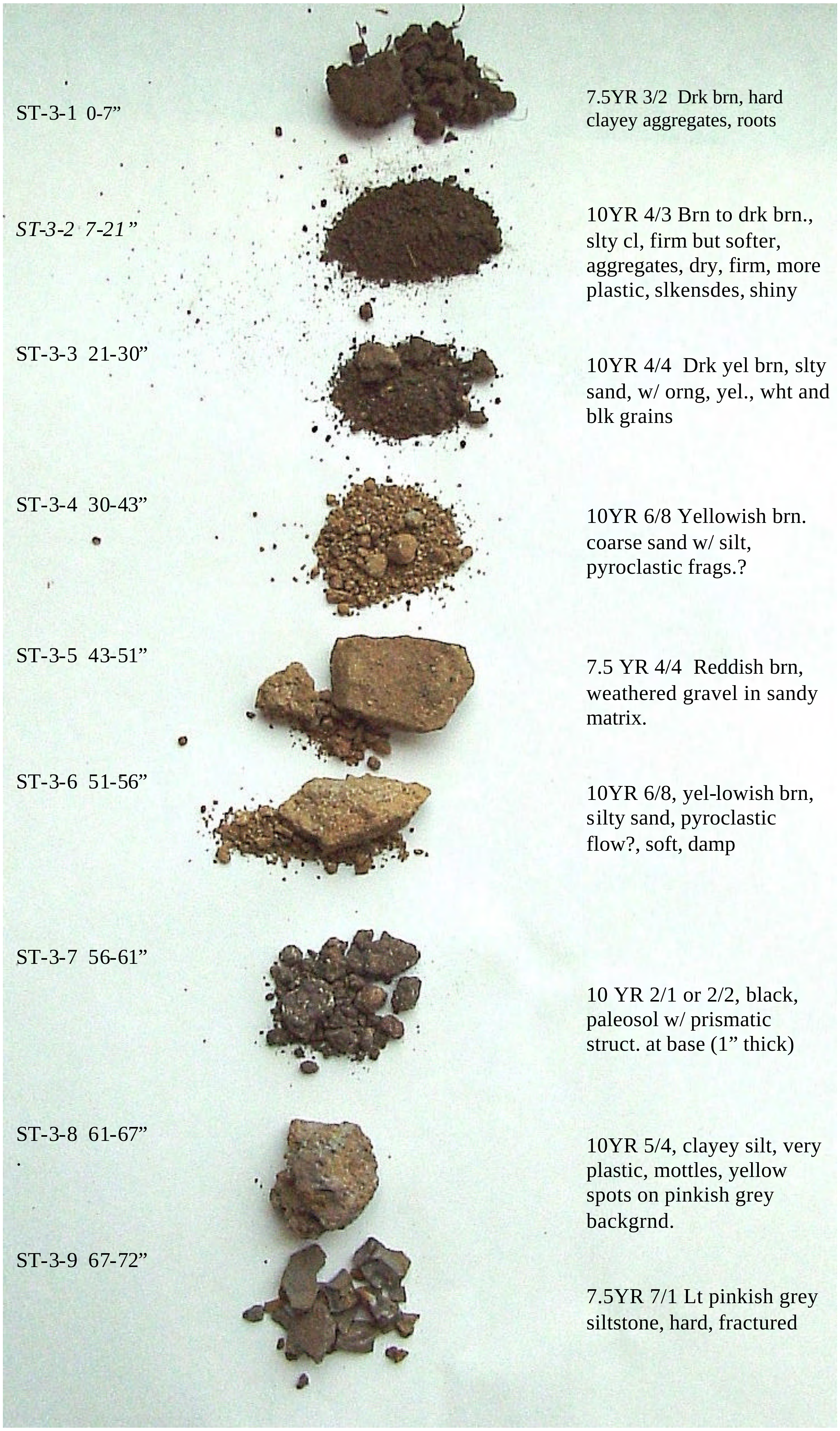
7.5Y4/4 Brn, silty sand w/ fragments of yellowish brn ashy material

ST-2-5 25-36”

10YR 6/8 Brnish yellow to yellow, weathered pyroclastic material (?)

Appendix B Profile Photographs with Descriptions

BLM ST-3



ST-3-1 0-7”	7.5YR 3/2 Drk brn, hard clayey aggregates, roots
ST-3-2 7-21”	10YR 4/3 Brn to drk brn., slty cl, firm but softer, aggregates, dry, firm, more plastic, slkensdes, shiny
ST-3-3 21-30”	10YR 4/4 Drk yel brn, slty sand, w/ orng, yel., wht and blk grains
ST-3-4 30-43”	10YR 6/8 Yellowish brn. coarse sand w/ silt, pyroclastic frags.?
ST-3-5 43-51”	7.5 YR 4/4 Reddish brn, weathered gravel in sandy matrix.
ST-3-6 51-56”	10YR 6/8, yel-lowish brn, silty sand, pyroclastic flow?, soft, damp
ST-3-7 56-61”	10 YR 2/1 or 2/2, black, paleosol w/ prismatic struct. at base (1” thick)
ST-3-8 61-67”	10YR 5/4, clayey silt, very plastic, mottles, yellow spots on pinkish grey backgrnd.
ST-3-9 67-72”	7.5YR 7/1 Lt pinkish grey siltstone, hard, fractured

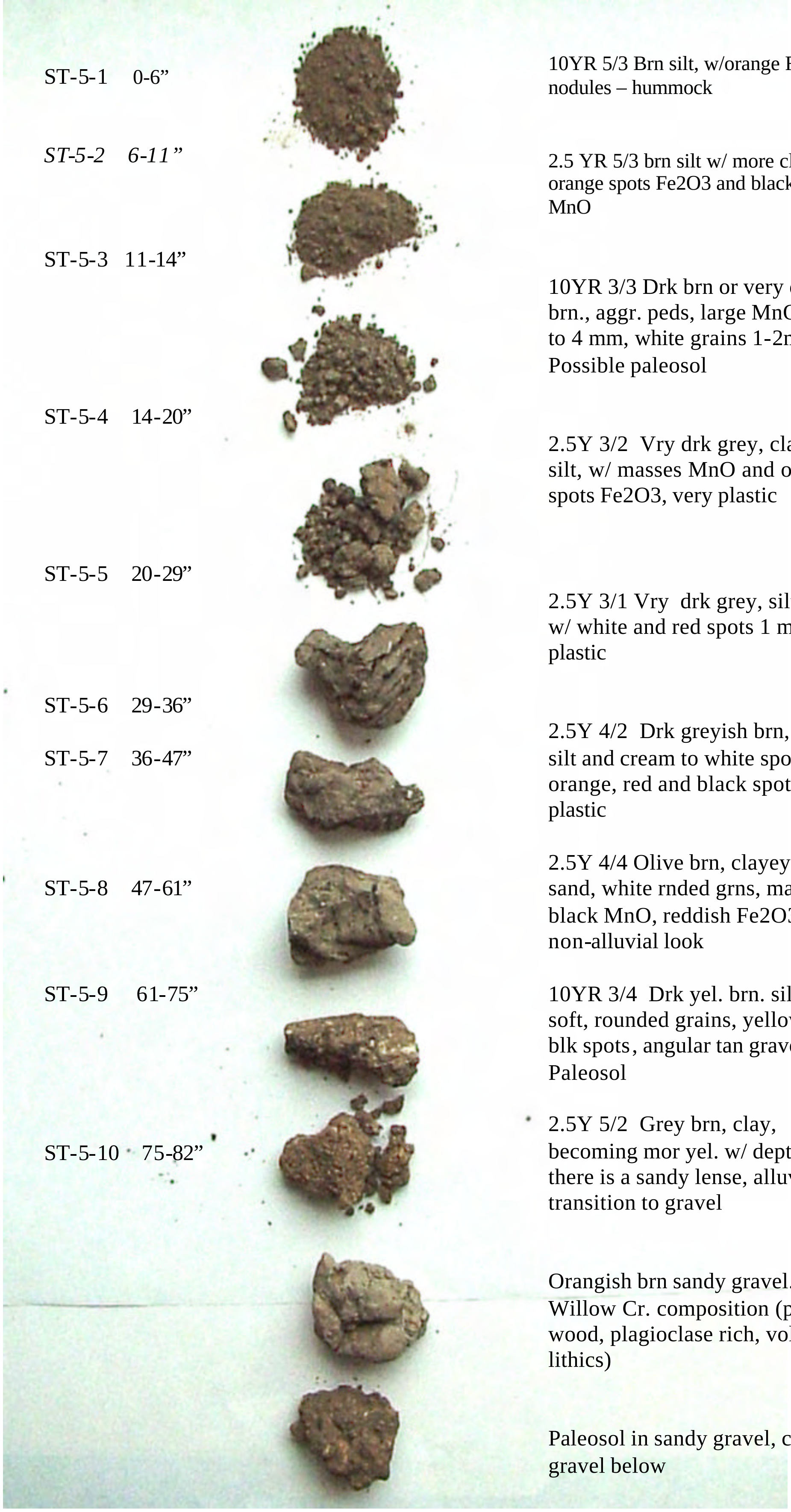
Appendix B Profile Photographs with Descriptions

BLM ST-4

ST-4-1	0-9”	2.5Y 4/3 or4/4 Olv. Brn, silty, granular, dry, abun. roots, bulbs
ST-4-2	9-15”	2.5Y 3/3 Drk olive brn, clayey silt, somewhat plastic abun. roots with camus bulbs
ST-4-3	15-26”	2.5Y 4/2 to 3/2 Drk greyish brn. w/ white, orange and black stops, no clay skins but is more clayey
ST-4-4	26-37”	2.5Y 4/2 to 5/3, Drk greyish brn., vry plastic, abundant sand size grains white orange. desication cracks
ST-4-5	37-46”	2.5Y 5/3 Lt. olive brn, clayey silt, no desication cracks
ST-4-6	46-50”	2.5Y 5/4 Lt. brn.. clayey, sandy silt w/ MnO posibly after charcoal or its charcoal
ST-4-7	50-56”	2.5Y 4/5 Lt. olive brn, silty clay, mottled w/ orange masses of Fe_2O_3.
ST-4-8	56-63.5	2.5Y 5/4-5/6 tan weathered sandy gravel w/clay, mottled w/ abund. lt orang. Fe_2O_3 masses and large crusts of MnO (1.5-2.0 cm) Paleosol on alluvium
ST-4-9	63.5-67”	10YR 4/3 Brown, coarse sand and gravel
ST-4-10	67- 77”	10YR 5/3 to 5/4 Yel. brn clay, very plastic, no sand, thick Fe_2O_3 fracture coatings
ST-4-11	77-85”	Cont. of clay unit
ST-4-12	85-95”	7.5YR 4/6 str. brn clayey co. sndy gravel.

Appendix B Profile Photographs with Descriptions

BLM ST-5



10YR 5/3 Brn silt, w/orange Fe2O3 nodules – hummock

ST-5-1 0-6”

ST-5-2 6-11”

2.5 YR 5/3 brn silt w/ more clay w orange spots Fe2O3 and black concre. MnO

ST-5-3 11-14”

10YR 3/3 Drk brn or very drk brn., aggr. peds, large MnO concr. to 4 mm, white grains 1-2mm. Possible paleosol

ST-5-4 14-20”

2.5Y 3/2 Vry drk grey, clayey silt, w/ masses MnO and orang spots Fe2O3, very plastic

ST-5-5 20-29”

2.5Y 3/1 Vry drk grey, silty clay w/ white and red spots 1 mm, very plastic

ST-5-6 29-36”

2.5Y 4/2 Drk greyish brn, clay w/ silt and cream to white spots, afew orange, red and black spots very plastic

ST-5-7 36-47”

2.5Y 4/4 Olive brn, clayey fine sand, white rnded grns, massive black MnO, reddish Fe2O3 spots. non-alluvial look

ST-5-8 47-61”

ST-5-9 61-75”

10YR 3/4 Drk yel. brn. silty sand, soft, rounded grains, yellow and blk spots, angular tan gravels. Paleosol

2.5Y 5/2 Grey brn, clay, becoming mor yel. w/ depth 4/3. there is a sandy lense, alluvial, transition to gravel

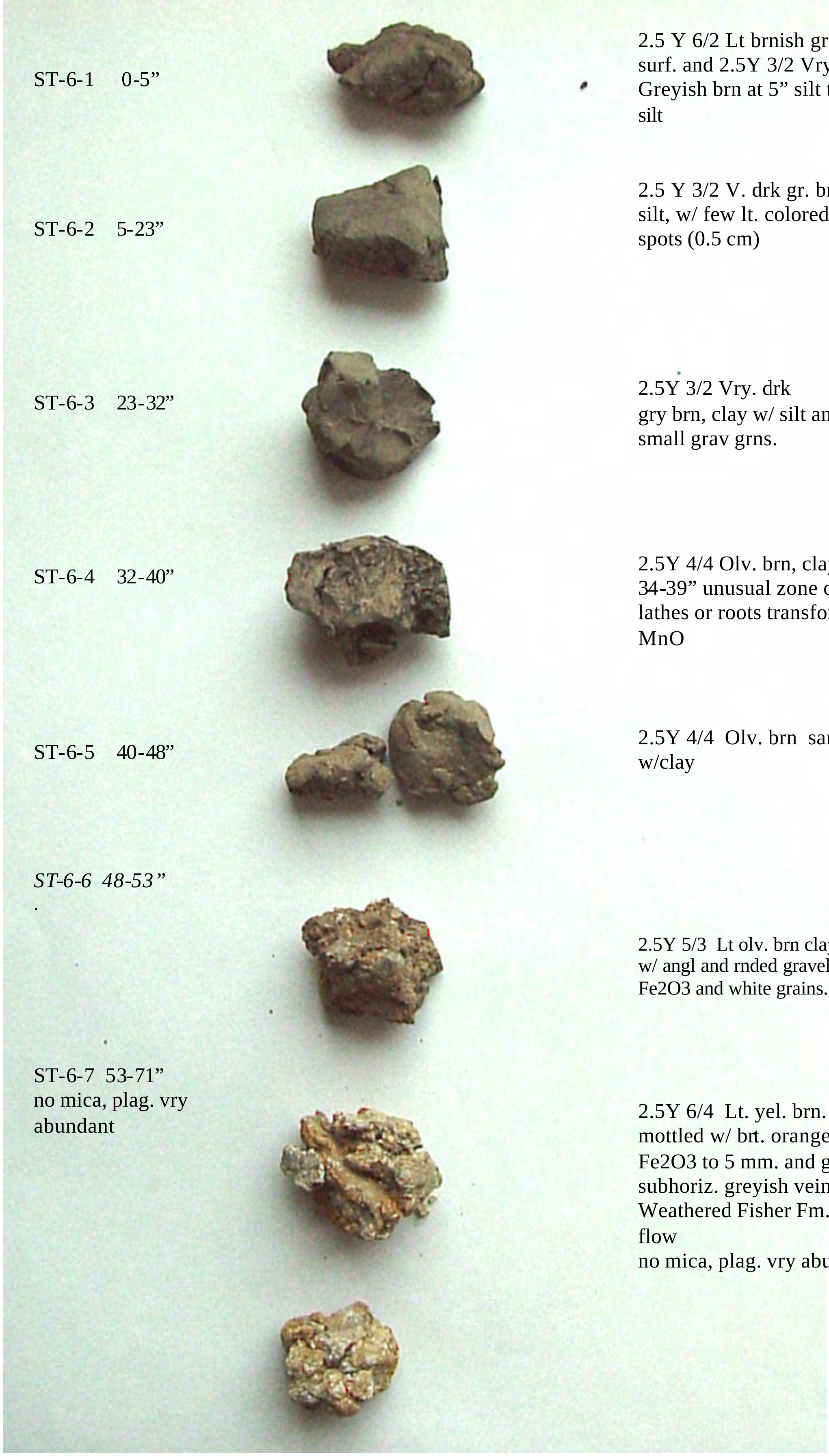
ST-5-10 75-82”

Orangish brn sandy gravel. Willow Cr. composition (petrified wood, plagioclase rich, volcanic lithics)

Paleosol in sandy gravel, coarse gravel below

Appendix B Profile Photographs with Descriptions

BLM ST-6



ST-6-1 0-5”

2.5 Y 6/2 Lt brnish grey on surf. and 2.5Y 3/2 Vry. Drk. Greyish brn at 5” silt to clayey silt

ST-6-2 5-23”

2.5 Y 3/2 V. drk gr. brn, clayey silt, w/ few lt. colored orng spots (0.5 cm)

ST-6-3 23-32”

2.5Y 3/2 Vry. drk
gry brn, clay w/ silt and few small grav grns.

ST-6-4 32-40”

2.5Y 4/4 Olv. brn, clayey silt. 34-39” unusual zone of MnO lathes or roots transformed to MnO

ST-6-5 40-48”

2.5Y 4/4 Olv. brn sandy silt w/clay

ST-6-6 48-53”
.

2.5Y 5/3 Lt olv. brn clayey C. sand w/ angl and rnded gravel also Fe2O3 and white grains.

ST-6-7 53-71”
no mica, plag. vry abundant

2.5Y 6/4 Lt. yel. brn. silty clay, mottled w/ brt. orange masses Fe2O3 to 5 mm. and grey wht. subhoriz. greyish veins. @ 64 “ Weathered Fisher Fm. pyrocl. flow
no mica, plag. vry abundant

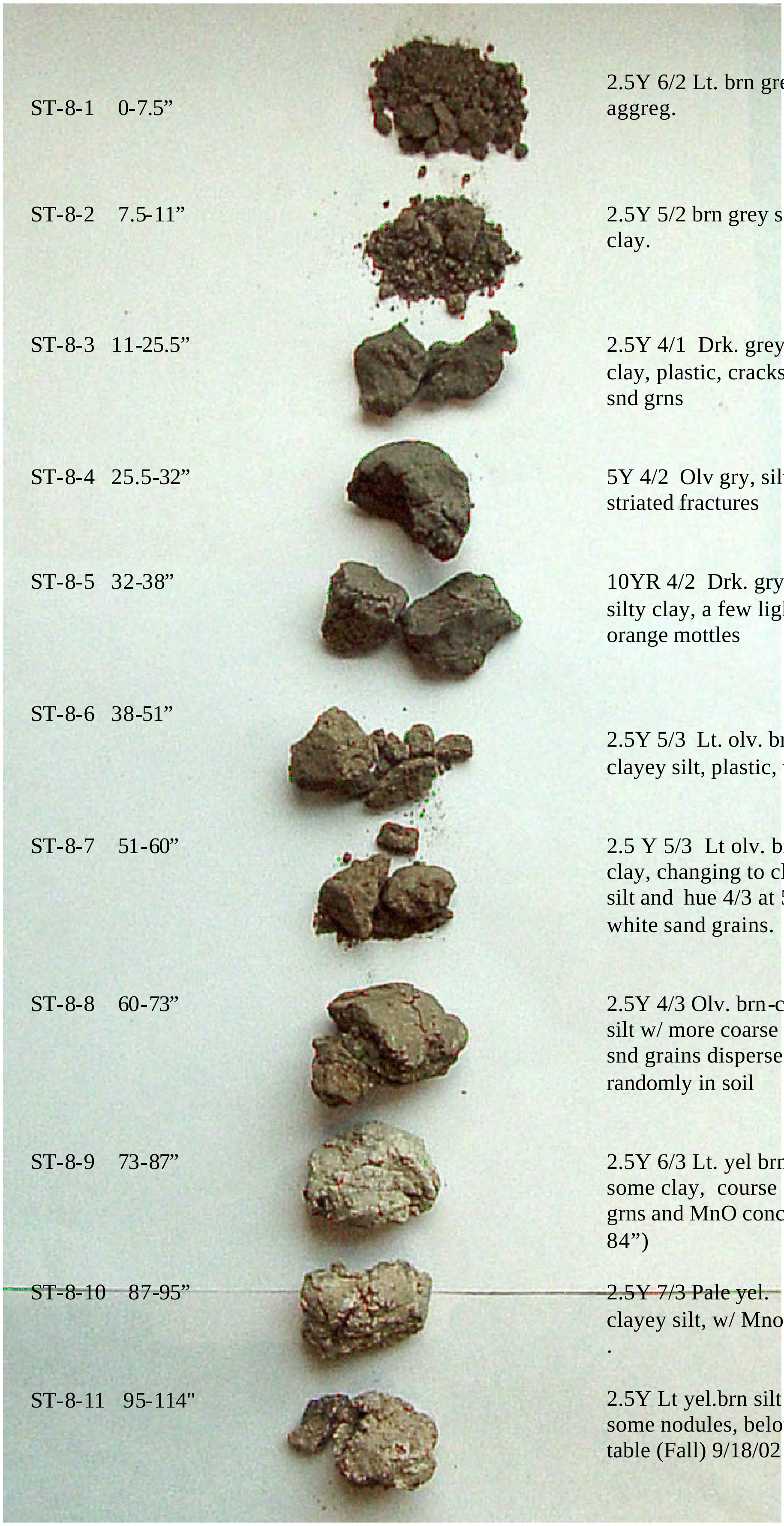
Appendix B Profile Photographs with Descriptions

BLM ST-7

ST-7-1	0-6.5”	2.5Y 5/2 Greyish brn, clayey silt, abun. Fe2O3 and MnO concre, 5-6 mm mottled orang-black.
ST-7-2	6.5-23”	10YR 4/2 Drk gry brn, dense clayey silt, abundant OM coatings, subdued orange spots. Darker w/ depth
ST-7-3	23-30”	2.5Y 5/2 Gryish brn, clayey silt w/ fine snd, vry plas.
ST-7-4	30-39.5”	2.5Y 5/4 Lt. olv. brn., clayey fine sand, somewhat plastic, mottled w/Fe2O3 orange masses. 34-36” rich in MnO or charcoal.
ST-7-5	39.5-42”	2.5Y 5/4 Lt. olv brn, clayey silty fn snd, plastic
ST-7-6	42-52”	2.5Y 6/3 to 7/3 Yel. brn to pale yel. sandy clay cris-crossed w/ black blades MnO or charcoal.
ST-7-7	52-63”	2.5Y 4/4 to 5/4 Olv. brn, cly silty sand. a nice paleosol.
ST-7-8	63-71”	2.5Y 5/4 Reddish ol brn, clayey silt greyish masses in lt yel. to gryish fine text. pyroclastic flow
ST-7-9	75-79”	5Y 7/3 Pale yel. Clayey sand, glassy and plag. Rich pyroclastic flow
		5Y 8/2 Pale yel. Sand w/ clay vertical banding to 10YR

Appendix B Profile Photographs with Descriptions

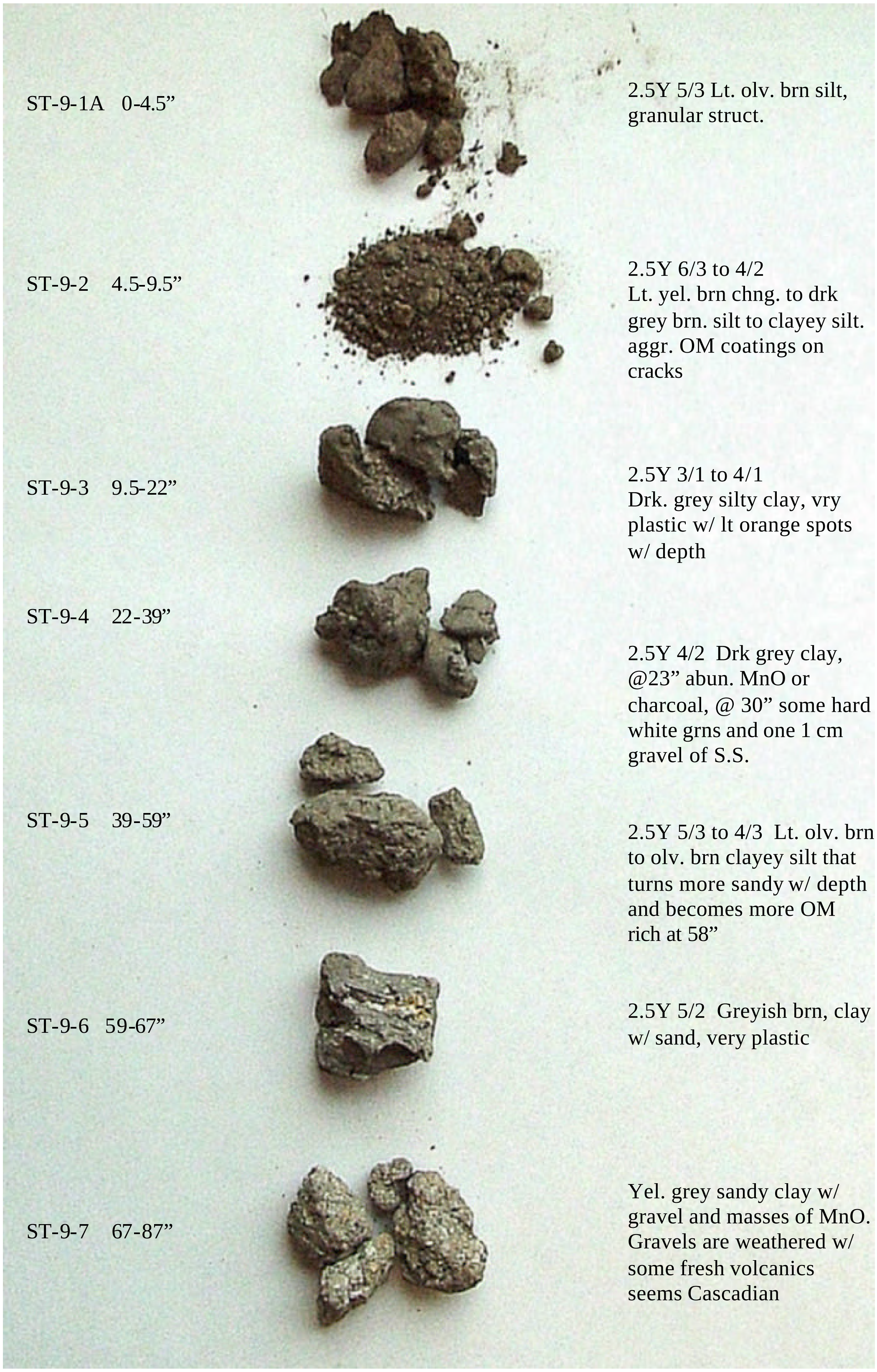
BLM ST-8



ST-8-1	0-7.5”	2.5Y 6/2 Lt. brn grey,silt, aggreg.
ST-8-2	7.5-11”	2.5Y 5/2 brn grey silt w/ clay.
ST-8-3	11-25.5”	2.5Y 4/1 Drk. grey silty clay, plastic, cracks, white snd grns
ST-8-4	25.5-32”	5Y 4/2 Olv gry, silty clay, striated fractures
ST-8-5	32-38”	10YR 4/2 Drk. gryish brn, silty clay, a few light orange mottles
ST-8-6	38-51”	2.5Y 5/3 Lt. olv. brn., clayey silt, plastic, weaker
ST-8-7	51-60”	2.5 Y 5/3 Lt olv. brn. silty clay, changing to clayey silt and hue 4/3 at 57” w/ white sand grains.
ST-8-8	60-73”	2.5Y 4/3 Olv. brn-clayey silt w/ more coarse white snd grains dispersed randomly in soil
ST-8-9	73-87”	2.5Y 6/3 Lt. yel brn, silt w/ some clay, course sand grns and MnO concr. (81-84”)
ST-8-10	87-95”	2.5Y 7/3 Pale yel. clayey silt, w/ Mno concr .
ST-8-11	95-114"	2.5Y Lt yel.brn silt w/ clay some nodules, below water table (Fall) 9/18/02 – 98”

Appendix B Profile Photographs with Descriptions

BLM ST-9



ST-9-1A	0-4.5”	2.5Y 5/3 Lt. olv. brn silt, granular struct.
ST-9-2	4.5-9.5”	2.5Y 6/3 to 4/2 Lt. yel. brn chng. to drk grey brn. silt to clayey silt. aggr. OM coatings on cracks
ST-9-3	9.5-22”	2.5Y 3/1 to 4/1 Drk. grey silty clay, vry plastic w/ lt orange spots w/ depth
ST-9-4	22-39”	2.5Y 4/2 Drk grey clay, @23” abun. MnO or charcoal, @ 30” some hard white grns and one 1 cm gravel of S.S.
ST-9-5	39-59”	2.5Y 5/3 to 4/3 Lt. olv. brn to olv. brn clayey silt that turns more sandy w/ depth and becomes more OM rich at 58”
ST-9-6	59-67”	2.5Y 5/2 Greyish brn, clay w/ sand, very plastic
ST-9-7	67-87”	Yel. grey sandy clay w/ gravel and masses of MnO. Gravels are weathered w/ some fresh volcanics seems Cascadian

Appendix B Profile Photographs with Descriptions

BLM ST-10 N of W 11th 45’ and 400’ to E of Greenhill Road near Dead Cow Creek.

ST-10-1 0 – 7”		2.5Y5/2 Greyish brown, mottled with reddish spots of Fe_20_3 (3-5mm) silt.
ST-10-2 7 - 13”		10YR4/2 or 2.5Y2/2 Very dark Greyish brown, mottled w/red Fe_20_3 spots and black MnO spots, silt with clay.
ST-10-3 13 - 20”		2.5Y4/2 Dark greyish brown, mottled with orange and black spots, clay.
ST-10-4 20 - 37”		2.5Y4/2 Dark greyish brown, silty clay with sand grains, massive shiny striated crack from shrink swell.
ST-10-5 37 - 64”		2.5Y4/4 Light olive brown, clay, no slickenslides.
ST-10-6 64 - 68”		2.5Y4/3 Olive brown, clayey silt containing tiny white spots, horizontal lines formed by grey and reddish brown materials (weathered alluvium?)
ST-10-7 68 - 76”		10YR4/6 Dark yellowish brown, clayey fine sand.
ST-10-8 76 - 86”		10YR4/6 Dark yellow brown, with grey zones and black MnO spots (charcoal sometimes) clayey sand.
ST-10-9 86 - 95”		10YR4/3 Brown with banded Fe_20_3, very dense clay.
ST-10-10 95 - 105”		10YR4/3

Appendix B Profile Photographs with Descriptions

BLM ST-11

ST-11-1 0-6”	10YR 4/2 Drk grey brn, slty loam, granular, roots.
ST-11-2 6.0-13”	10YR 4/3 Brn. Slty loam, w/ yel. snd and occas. small gravels
ST-11-3 13-18”	10.YR 3/4 Drk yel. brn. silt w/ sand.
ST-11-4 18-29”	10YR 4/3 Brn., sandy silt w/wht, yel, pink and black grains.
ST-11-5 29-40”	2.5 5/4 Lt. olv. brn, slty C. snd, w/ rnded grns to 2-3mm.
ST-11-6 40-44”	2.5Y Olv brn, clayey sand w/ silt

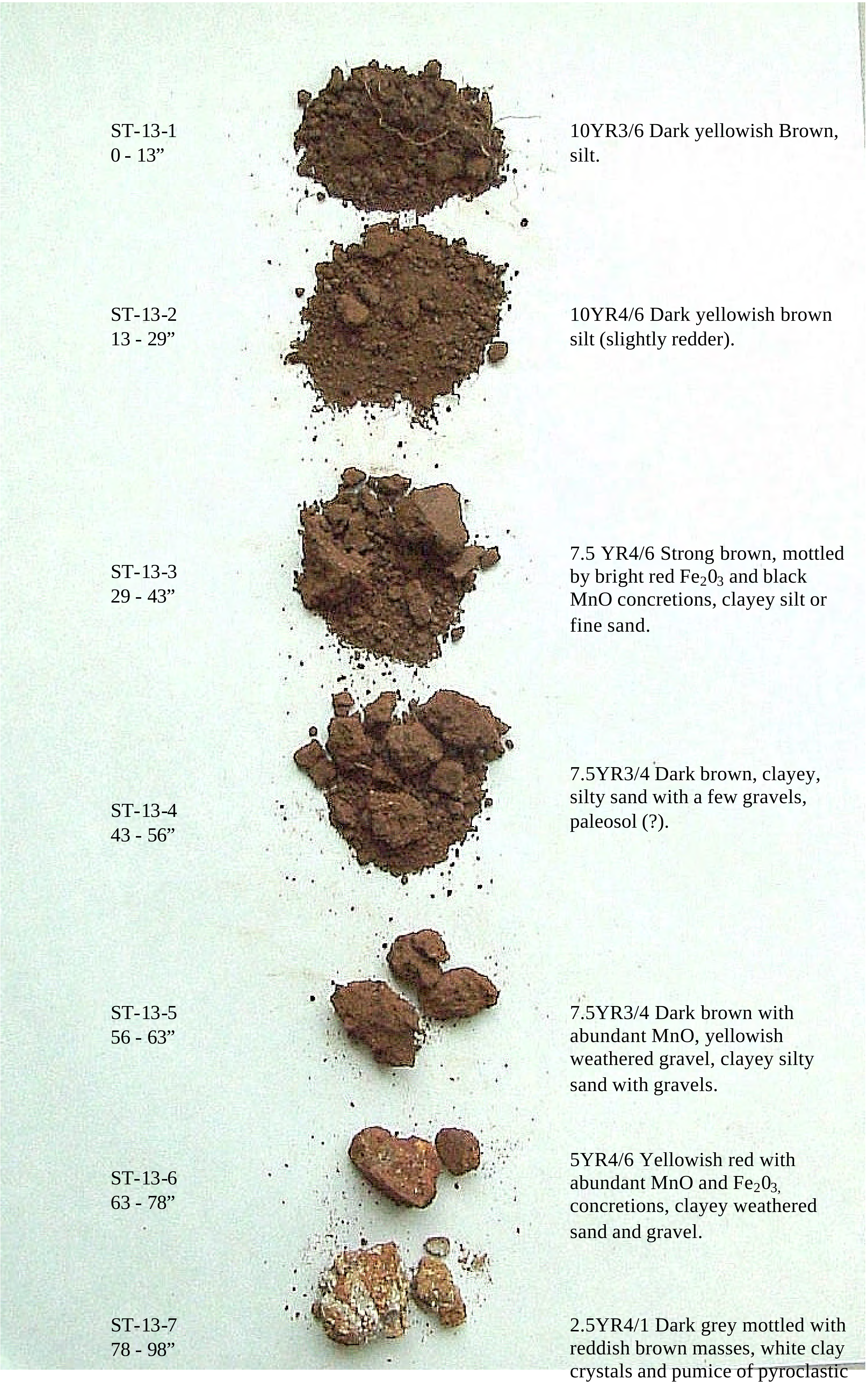
Appendix B Profile Photographs with Descriptions

BLM ST-12

ST-12-1	0-6”	10YR 5/4 Yel. brn w/ grey overtone, silty fine sand, abun. roots
ST-12-2	6-14”	10YR 5/4 Yel. brn. silty fine sand, w/ a few gravel sized frags. weath. sstone.
ST-12-3	14-35”	7.5YR 4/4 Brn. fine sand w/ silt and tiny wht spots, gets redder w/ depth
ST-12-4	35-46”	7.5YR 4/4 to 3/4 Brn. fine sand to silt, similar to unit above.
ST-12-5	46-52”	10YR3/6 to 4/6 Brn to strg. brn, silty clay, w/ ang. frags of lt yel. ss to 3 cm. Paleosol.
ST-12-6	52-67”	7.5 YR 4/6 Strg. brn. clayey silt, w/ more and lrger wht, red, blk and yel. spots in stiff clay
ST-12-7	67-84”	7.5YR 4/3, clayey silt to silt, w/ frags of weath, sandstone. Hard to auger.

Appendix B Profile Photographs with Descriptions

BLM ST-13 200’ south of Abandoned Willamette River Channel. On toe slope of Wallace butte.



ST-13-1
0 - 13”
10YR3/6 Dark yellowish Brown, silt.

ST-13-2
13 - 29”
10YR4/6 Dark yellowish brown silt (slightly redder).

ST-13-3
29 - 43”
7.5 YR4/6 Strong brown, mottled by bright red Fe_20_3 and black MnO concretions, clayey silt or fine sand.

ST-13-4
43 - 56”
7.5YR3/4 Dark brown, clayey, silty sand with a few gravels, paleosol (?).

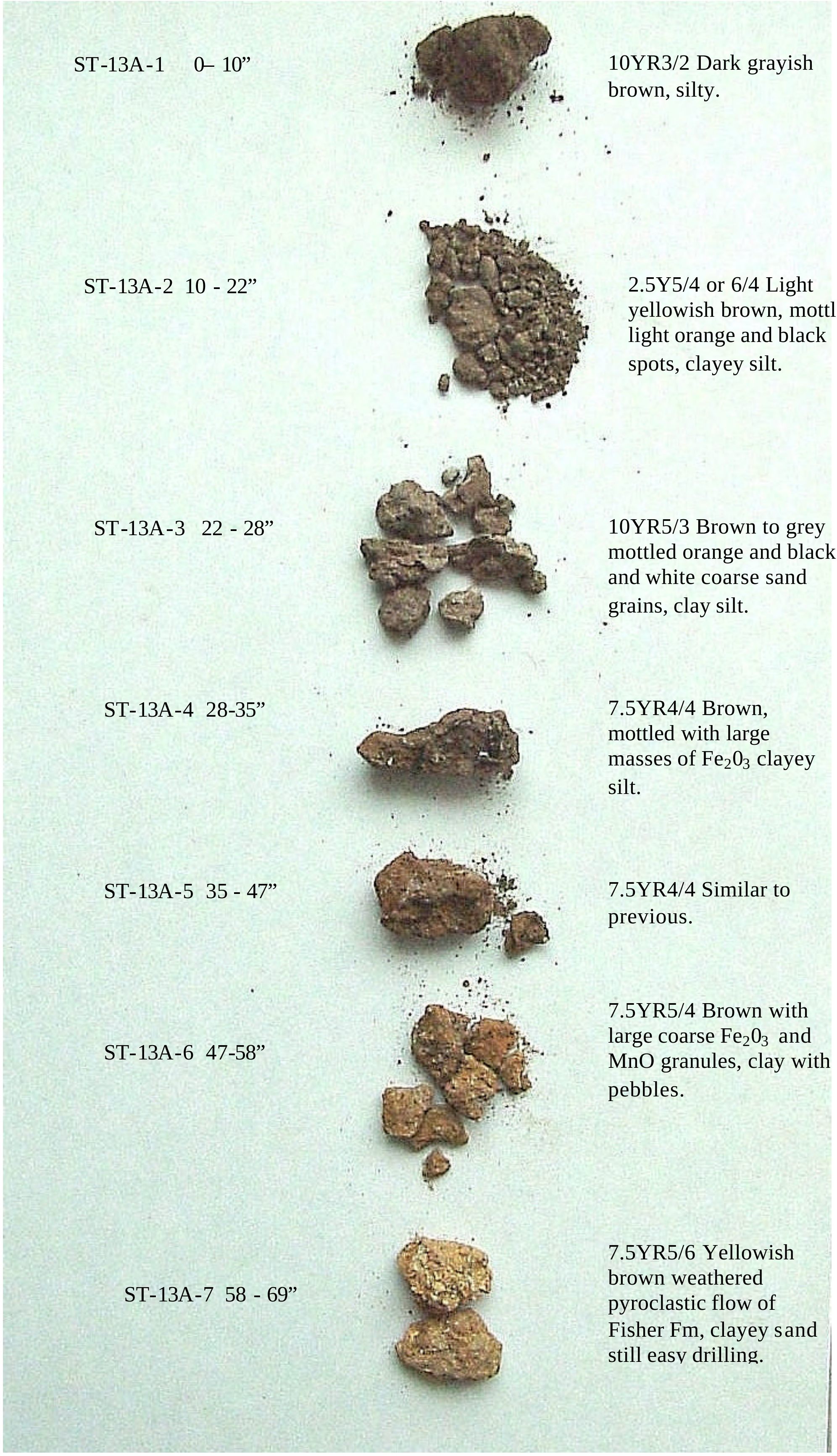
ST-13-5
56 - 63”
7.5YR3/4 Dark brown with abundant MnO, yellowish weathered gravel, clayey silty sand with gravels.

ST-13-6
63 - 78”
5YR4/6 Yellowish red with abundant MnO and $Fe_20_{3,}$ concretions, clayey weathered sand and gravel.

ST-13-7
78 - 98”
2.5YR4/1 Dark grey mottled with reddish brown masses, white clay crystals and pumice of pyroclastic flow (Fisher Fm).

Appendix B Profile Photographs with Descriptions

BLM ST-13A Located 100’ approximate to WSW of 13 on lower flat surface at base of Wallace Butte.



ST-13A-1	0– 10”	10YR3/2 Dark grayish brown, silty.
ST-13A-2	10 - 22”	2.5Y5/4 or 6/4 Light yellowish brown, mottled light orange and black spots, clayey silt.
ST-13A-3	22 - 28”	10YR5/3 Brown to grey mottled orange and black and white coarse sand grains, clay silt.
ST-13A-4	28-35”	7.5YR4/4 Brown, mottled with large masses of Fe_20_3 clayey silt.
ST-13A-5	35 - 47”	7.5YR4/4 Similar to previous.
ST-13A-6	47-58”	7.5YR5/4 Brown with large coarse Fe_20_3 and MnO granules, clay with pebbles.
ST-13A-7	58 - 69”	7.5YR5/6 Yellowish brown weathered pyroclastic flow of Fisher Fm, clayey sand still easy drilling.

Appendix B Profile Photographs with Descriptions

BLM ST-14 Located in center of abandoned Willamette River Channel N of Wallace Butte in E Gateway Section.

ST-14-1
0 – 21”

10YR3/2 Dark greyish brown, mottled dark reddish brown, masses Fe$_2$0$_3$, silty clay.

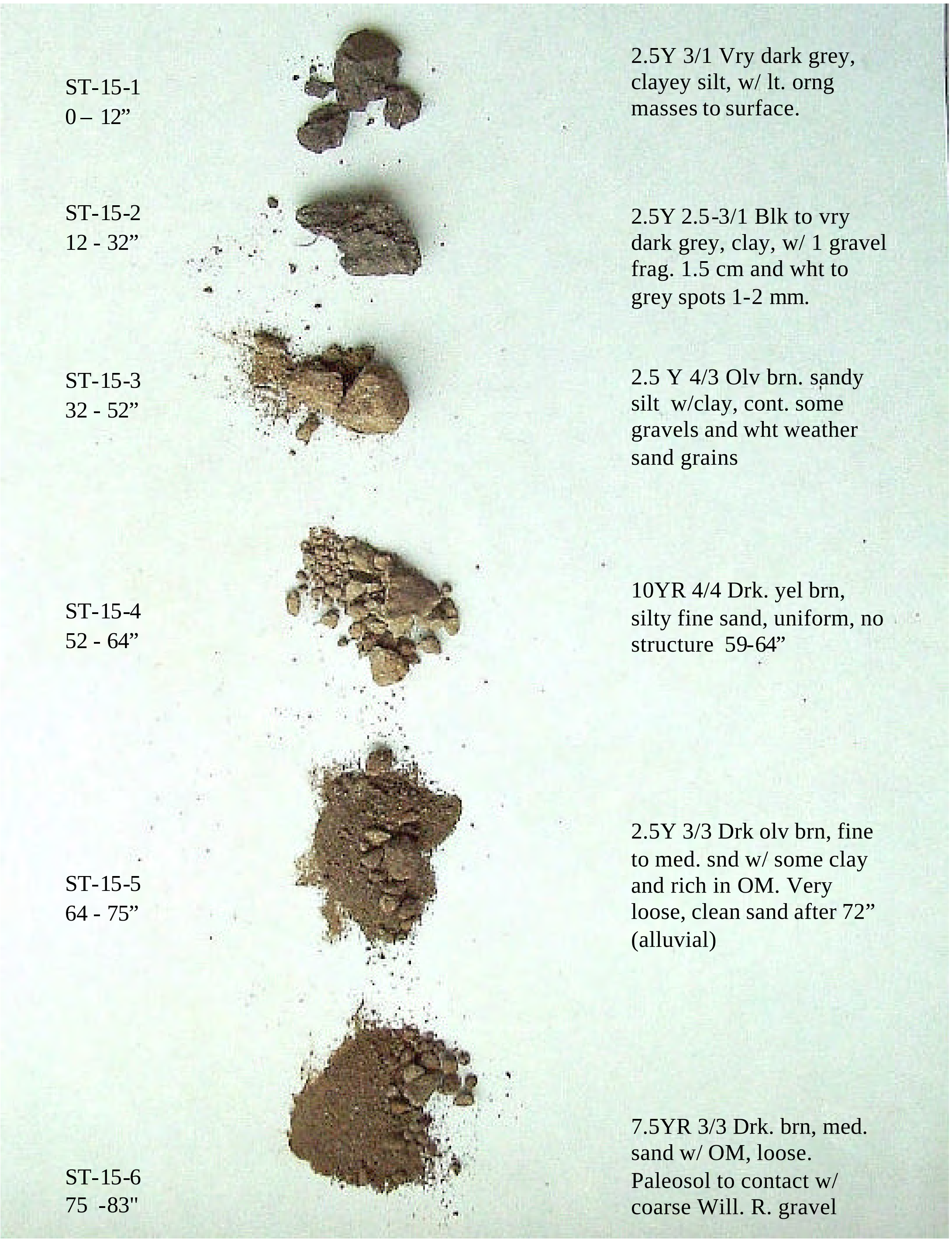
ST-14-2
21 – 27.5”

10YR3/2 Dark greyish brown, mottled with subdued orange and black Fe$_2$0 and MnO concretions, silty clay. Frequent charcoal.

Substrate coarse river gravel and cobbles.

Appendix B Profile Photographs with Descriptions

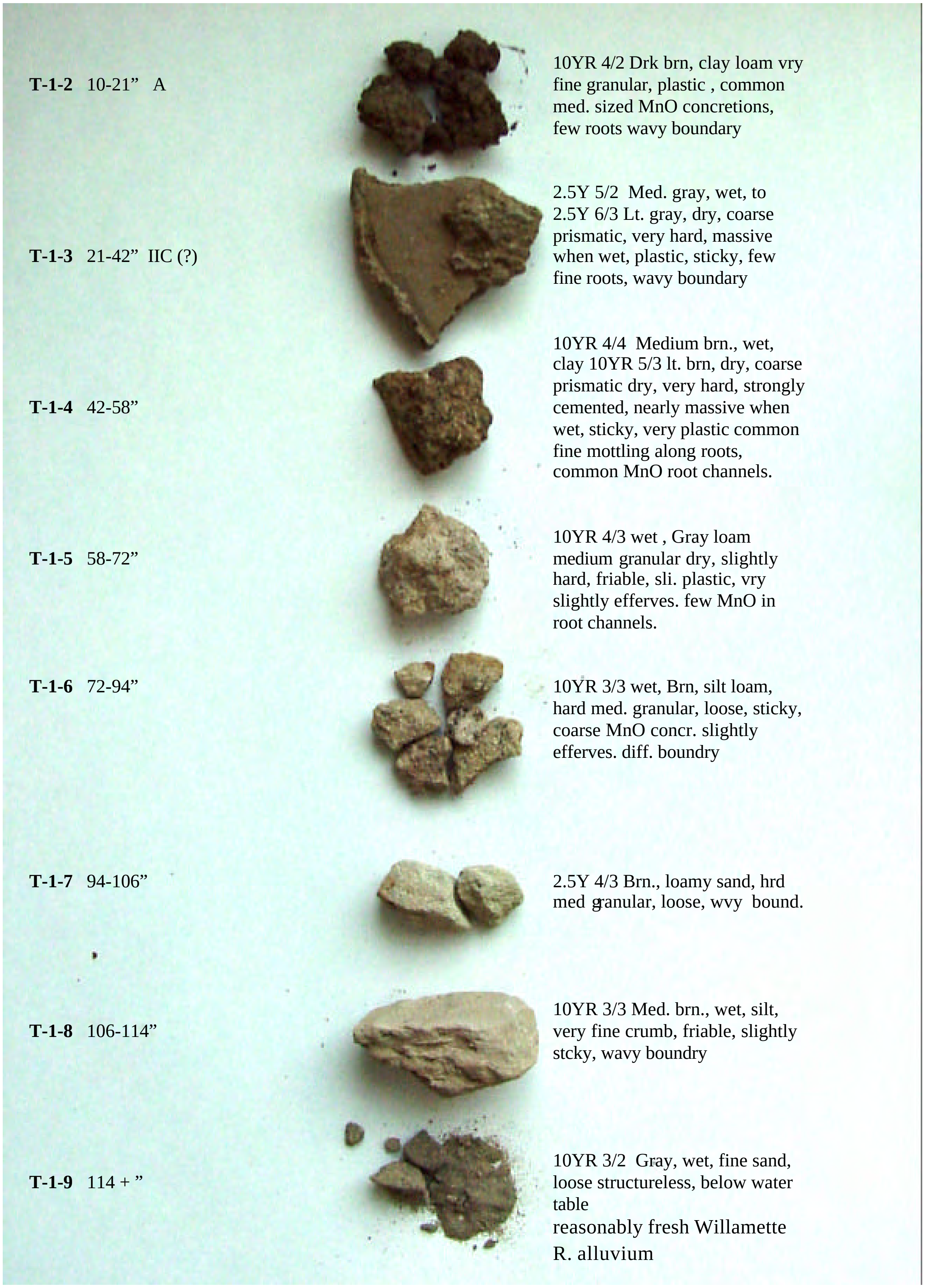
BLM ST-15



ST-15-1 0 – 12"	2.5Y 3/1 Vry dark grey, clayey silt, w/ lt. orng masses to surface.
ST-15-2 12 - 32"	2.5Y 2.5-3/1 Blk to vry dark grey, clay, w/ 1 gravel frag. 1.5 cm and wht to grey spots 1-2 mm.
ST-15-3 32 - 52"	2.5 Y 4/3 Olv brn. sandy silt w/clay, cont. some gravels and wht weather sand grains
ST-15-4 52 - 64"	10YR 4/4 Drk. yel brn, silty fine sand, uniform, no structure 59-64"
ST-15-5 64 - 75"	2.5Y 3/3 Drk olv brn, fine to med. snd w/ some clay and rich in OM. Very loose, clean sand after 72" (alluvial)
ST-15-6 75 -83"	7.5YR 3/3 Drk. brn, med. sand w/ OM, loose. Paleosol to contact w/ coarse Will. R. gravel

Appendix B Profile Photographs with Descriptions

Trench 1 BLM T-1

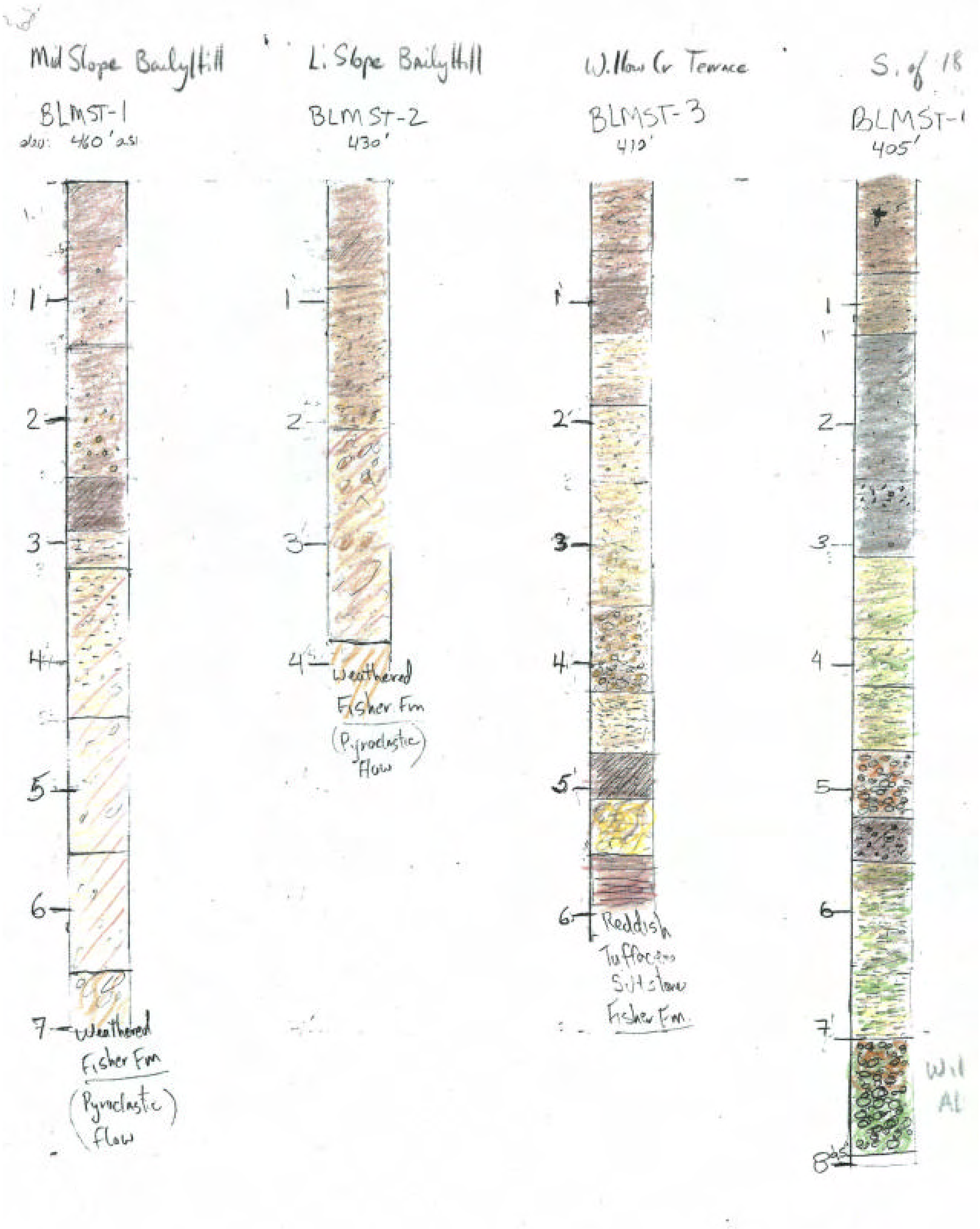


T-1-2	10-21” A	10YR 4/2 Drk brn, clay loam vry fine granular, plastic , common med. sized MnO concretions, few roots wavy boundary
T-1-3	21-42” IIC (?)	2.5Y 5/2 Med. gray, wet, to 2.5Y 6/3 Lt. gray, dry, coarse prismatic, very hard, massive when wet, plastic, sticky, few fine roots, wavy boundary
T-1-4	42-58”	10YR 4/4 Medium brn., wet, clay 10YR 5/3 lt. brn, dry, coarse prismatic dry, very hard, strongly cemented, nearly massive when wet, sticky, very plastic common fine mottling along roots, common MnO root channels.
T-1-5	58-72”	10YR 4/3 wet , Gray loam medium granular dry, slightly hard, friable, sli. plastic, vry slightly efferves. few MnO in root channels.
T-1-6	72-94”	10YR 3/3 wet, Brn, silt loam, hard med. granular, loose, sticky, coarse MnO concr. slightly efferves. diff. boundry
T-1-7	94-106”	2.5Y 4/3 Brn., loamy sand, hrd med granular, loose, wvy bound.
T-1-8	106-114”	10YR 3/3 Med. brn., wet, silt, very fine crumb, friable, slightly stcky, wavy boundry
T-1-9	114 + ”	10YR 3/2 Gray, wet, fine sand, loose structureless, below water table reasonably fresh Willamette R. alluvium

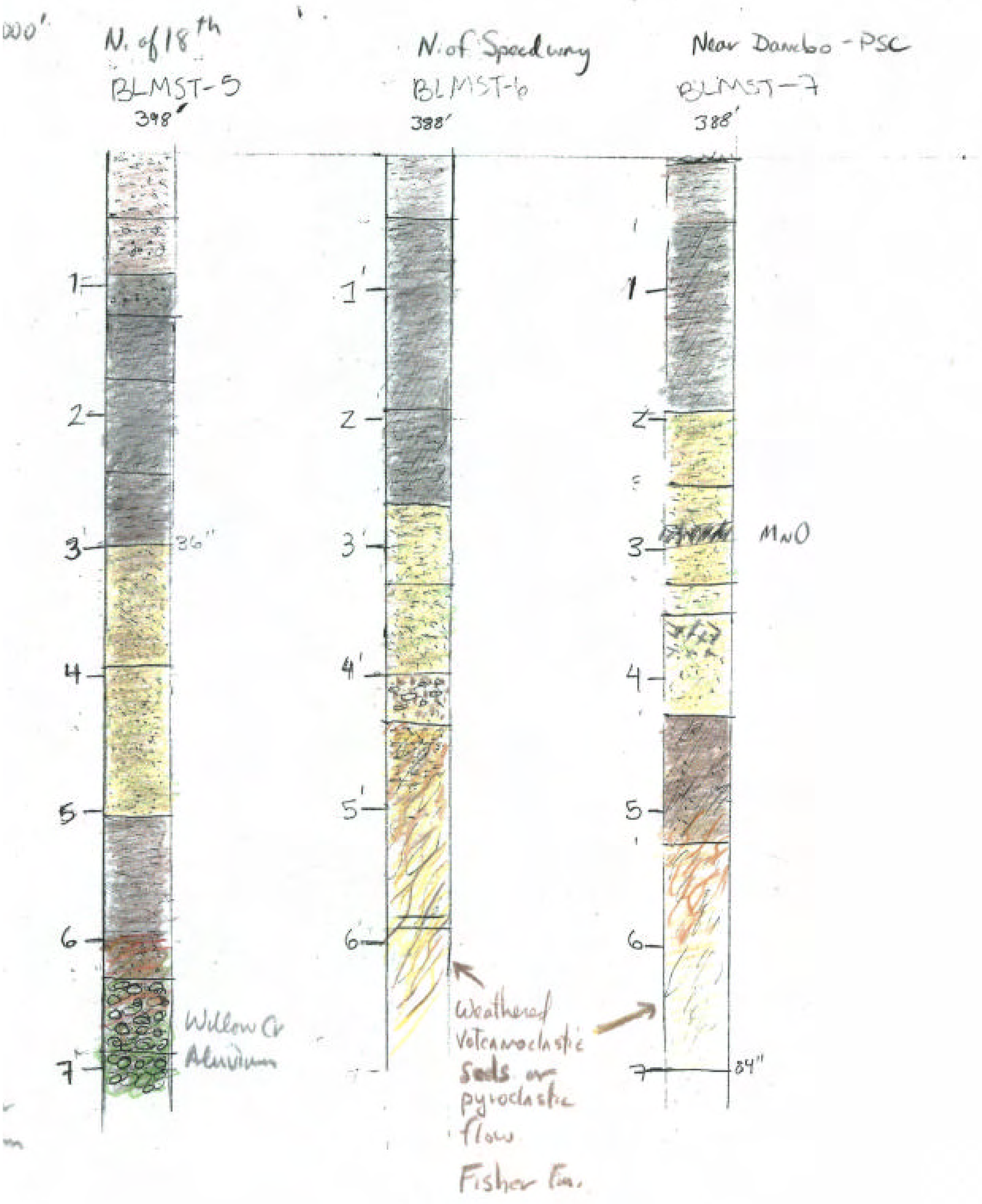
APPENDIX C

STRATIGRAPHIC COLUMNS

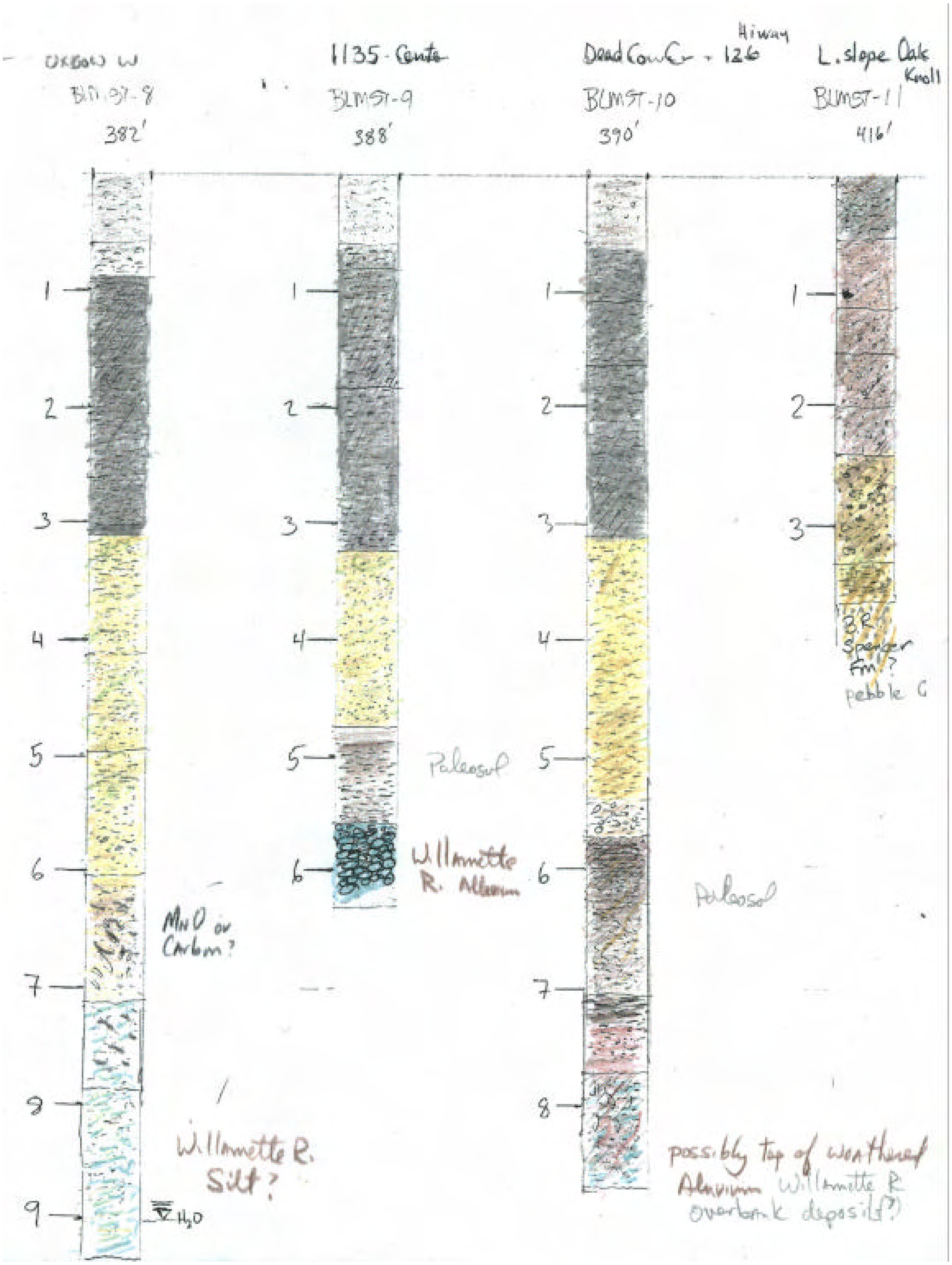
Appendix C
Stratigraphic Columns



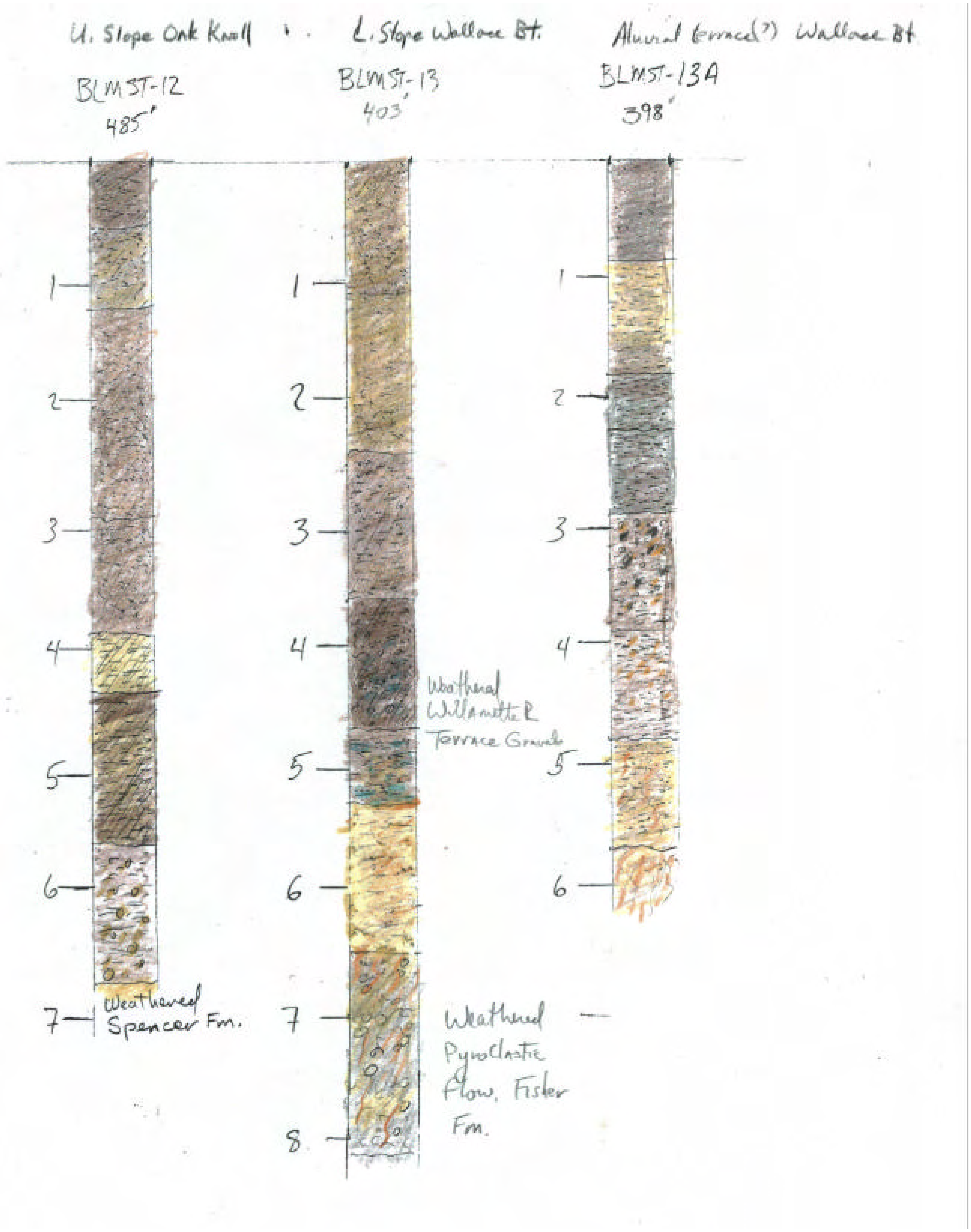
Appendix C
Stratigraphic Columns



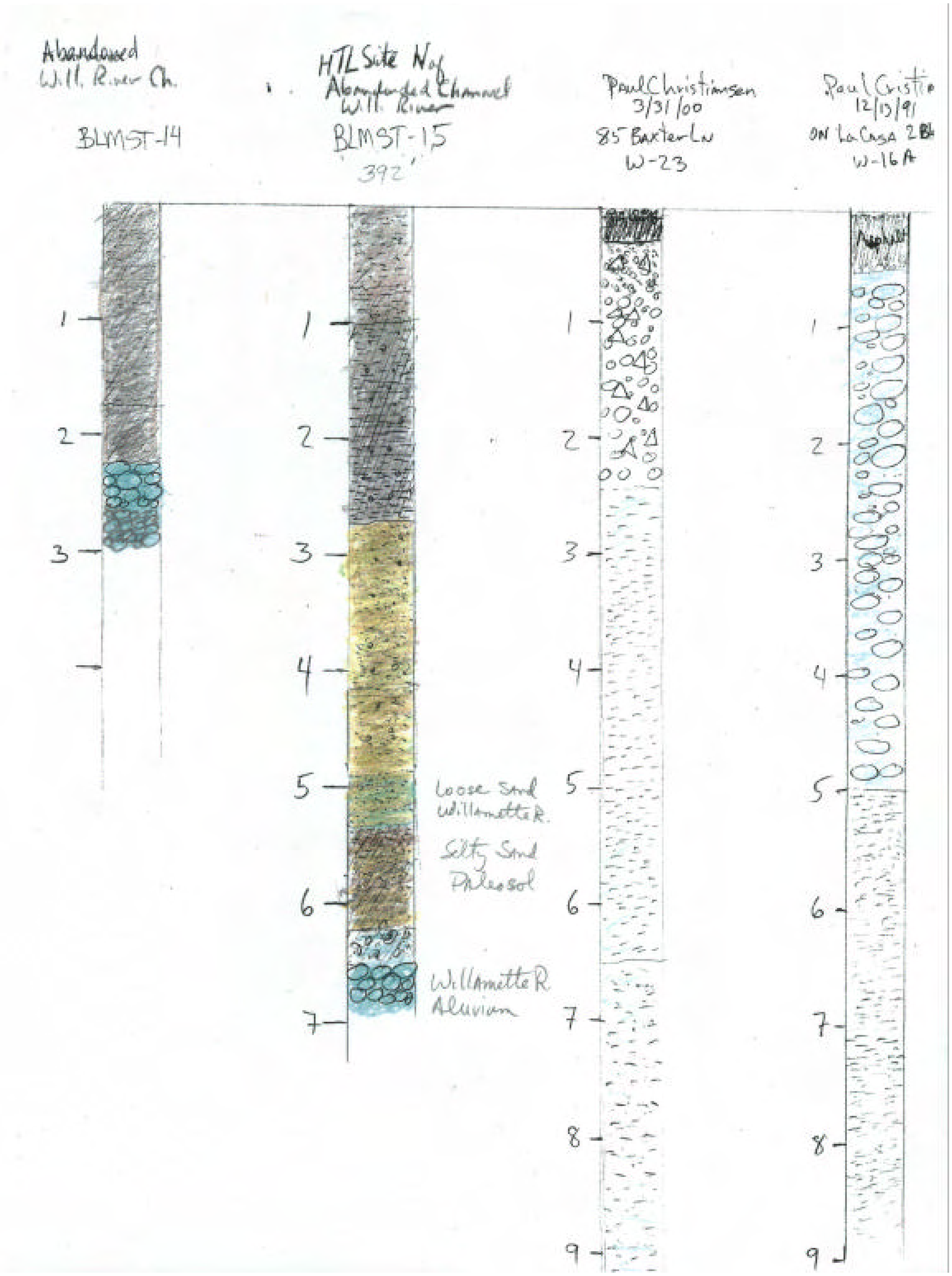
Appendix C
Stratigraphic Columns



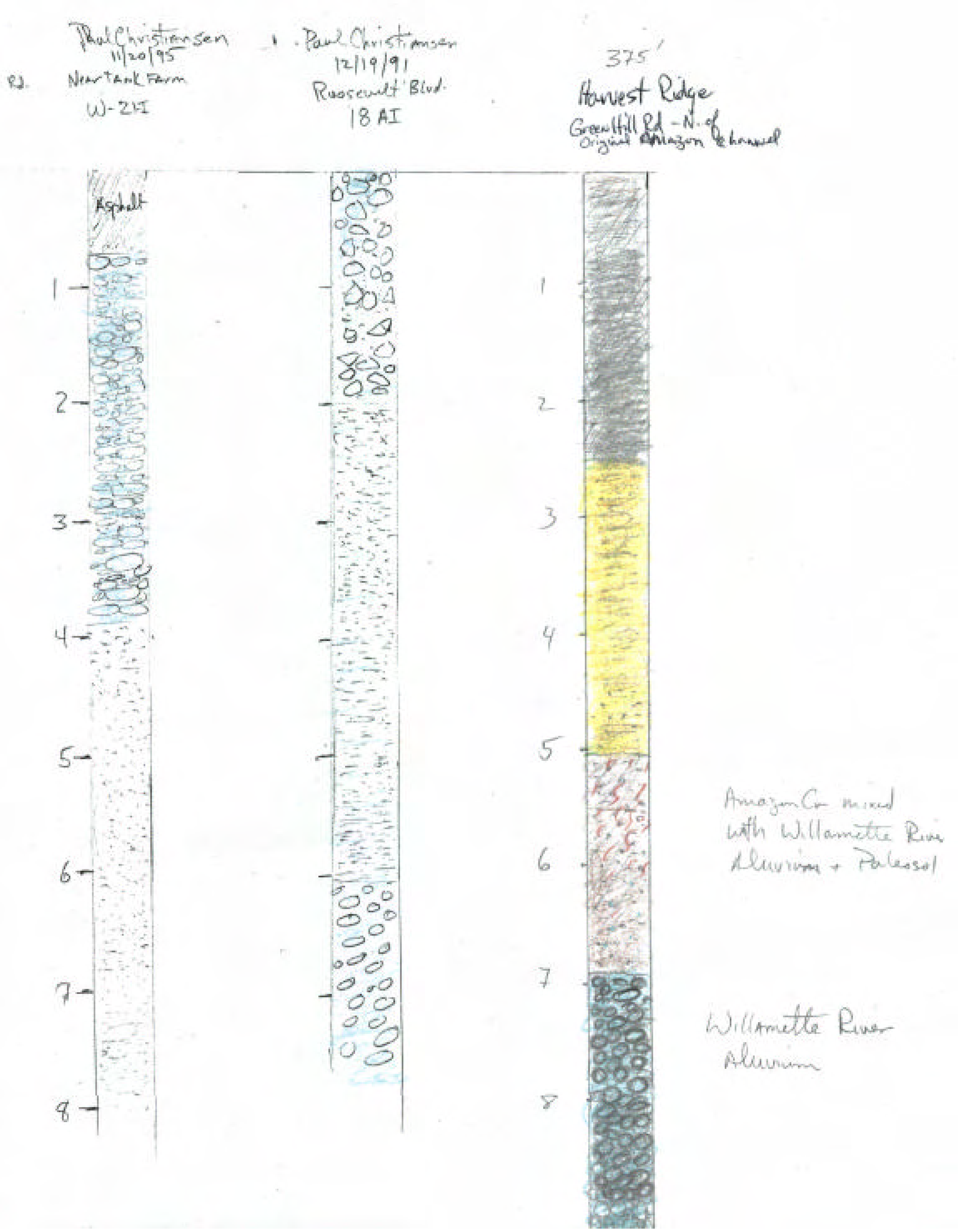
Appendix C
Stratigraphic Columns



Appendix C
Stratigraphic Columns



Appendix C
Stratigraphic Columns



APPENDIX D

TEXTURAL MINERALOGY

CONDUCTIVITY, TEXTURE AND MINERALOGICAL CHARACTERISTICS OF WEST EUGENE SOILS

Conductivity Slurry 5:1(water to soil) Micro seimens/cm 10 days	SAMPLE	TEXTURE			MINERALS											LITHIC FRAGMENTS								OXIDES		COMMENTS	
	sample name and depth	% Medium and Coarse Sand > 50 mesh	% Fine sand & silt < 50 mesh	% Clay & fine silts	Qz	BP Qx	Plag.	t gr.Pyx	Amph.	Spinel Mag.?	Hex. Black flat	Imen.	Biotite	Muscov.	Gr. Pyx	White	Gray	Brown	Volcanic	Schist	Intrusive	Silsd	Qzite	FE	MN		
21.5	BLMst 1-1 0-6.5"	17.8	43.2	39.1	2	0	1	1	--	2	2	0	0	0	0	2	0	1	0	0	0	0	0	3	1	0	0
11.2	BLMst 1-2 6.5-17"	12.1	43.3	44.6	1	0	3	2	1	2	2	1	0	0	0	2	1	1	0	0	0	0	0	2	1	Fulgarite?	0
9.5	BLMst 1-3 17-30,5"	19.5	47.4	33.1	0	0	0	0	0	0	0	1	0	0	0	3	2	0	1	0	0	0	0	2	0	0	0
12.6	BLMst 1-4 30,5-35"	20.2	20.2	59.6	0	0	0	0	0	0	0	1	0	0	0	2	0	2	0	0	0	0	0	2	0	0	0
10.9	BLMst 1-5 35-39"	41.7	35.0	23.3	0	0	0	0	0	0	0	1	0	0	0	2	0	1	1	0	0	0	0	2	0	Weathrd	hbld
11.9	BLMst 1-6 39-53"	35.7	29.9	34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
10.3	BLMst 1-7 53-67"	39.7	18.1	42.2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0	0
18.4	BLMst 2-1 0-7"	8.8	46.9	44.3	2	0	3	1	1	2	0	0	0	0	0	2	1	2	0	0	0	0	0	0	0	0	0
8.9	BLMst 2-2 7-11,5"	9.3	43.9	46.8	2	1	2	1	1	2	2	1	0	0	0	1	0	3	0	0	0	0	0	2	0	0	0
10.1	BLMst 2-3 11,5-21"	8.4	51.4	40.3	--	0	2	2	1	0	0	1	0	0	0	1	1	2	0	0	0	0	0	1	0	0	0
7.0	BLMst 2-4 21-25"	16.1	50.7	33.1	1	0	1	0	1	1	1	0	0	0	0	3	1	1	2	0	0	0	0	2	0	0	0
7.4	BLMst 2-5 25-36"	67.1	23.1	9.8	1	1	2	0	1	0	0	0	0	0	0	1	1	1	3	0	0	0	0	0	0	0	0
31.9	BLMst 3-1 0-7"	7.2	38.3	54.5	1	1	2	1	2	0	1	1	0	0	0	1	1	3	0	0	0	0	0	3	2	0	0
15.9	BLMst 3-2 7-21"	7.6	48.9	43.5	1	0	2	1	1	1	1	1	0	0	0	2	1	3	0	0	0	0	0	3	3	0	0
14.4	BLMst 3-3 21-30"	31.9	25.5	42.6	1	0	2	1	1	1	0	0	0	0	0	2	0	4	0	0	0	0	0	3	2	0	0
19.2	BLMst 3-3 30-43"	53.7	22.3	24.1	1	0	2	1	0	1	0	0	0	0	0	5	1	3	3	0	0	0	0	0	0	0	0
15.1	BLMst 3-5 43-51"	64.4	13.9	21.8	0	0	1	0	0	1	0	0	0	0	0	3	1	3	3	0	0	0	0	4	4	0	0
11.6	BLMst 3-6 51-56"	57.2	14.5	28.3	0	0	2	0	0	0	0	0	0	0	0	2	1	1	4	0	0	0	0	0	0	0	0
8.2	BLMst 3-7 56-61"	62.1	11.1	26.8	1	1	2	0	0	0	0	0	0	0	0	3	1	2	0	0	0	0	0	1	0	Paleosol	0
13.4	BLMst 3-8 61-67"	23.1	35.0	41.9	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	1	0	weatherd	siltstone
23.8	BLMst 3-9 67-72,5"	86.0	8.2	5.8	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	1	0	tuffaceous	siltstone BR
86.3	BLMst 3-9 67-72.5"	86.0	8.2	5.8	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	vugs, weatherd	claystone, fossil?
104.3	BLMst 4-1 0-9,5"	10.5	35.3	54.2	1	0	2	1	1	1	0	0	0	0	0	1	3	2	0	0	0	0	0	2	2	charcoal	
11	BLMst 4-2 9,5-15"	7.7	49.6	42.7	2	0	3	1	0	1	1	0	0	0	1	2	0	2	0	0	0	0	0	2	2	0	0
12.4	BLMst 4-3 15-26"	3.4	23.9	72.7	2	0	2	1	0	1	0	1	0	0	0	1	1	2	0	0	0	0	0	3	2	0	0

Appendix D Conductivity, Texture, Mineralogy

Conductivity Slurry 5:1(water to s Micro seimens/cm 10 days	sample name and depth	% Medium and Coarse Sand > 50 mesh	% Fine sand & silt < 50 mesh	% Clay & fine silts	Qz	BP Qx	Plag.	t gr.Pyx	Amph.	Spinel Mag.?	Hex. Black flat	Imen.	Biotite	Muscov.	Gr. Pyx	White	Gray	Brown	Volcanic	Schist	Intrusive	Silsd	Qzite	FE	MN	COMMENTS	
91.6	BLMst 4-4 26-37"	3.0	18.8	78.1	2	0	3	1	1	0	0	0	0	0	0	1	2	2	2	0	0	0	0	2	2	fine charcoal	0
471	BLMst 4-5 37-46"	2.1	27.3	70.7	2	0	3	1	1	1	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	fine charcoal	0
430	BLMst 4-6 46-50"	3.2	31.0	65.8	1	0	3	0	0	2	0	0	0	0	0	3	1	1	0	0	0	0	0	2	1	abun. Charcoal	0
426	BLMst 4-7 50-56"	6.5	37.0	56.5	1	0	3	0	0	2	0	0	0	0	0	2	1	1	0	0	0	0	0	1	1	charcoal	0
410	BLMst 4-8 56-63,5"	42.6	34.9	22.5	1	1	2	0	1	1	0	0	0	1	0	2	2	1	1	0	0	0	0	1	2	0	0
525	BLMst 4-9 63,5-67"	20.8	26.4	52.8	0	0	0	0	2	2	1	1	0	1	0	2	2	2	2	0	0	0	0	1	1	0	0
491	BLMst 4-10 67-77"	3.9	28.9	67.2	1	0	3	0	1	2	1	0	0	0	0	2	2	1	2	0	0	0	0	1	0	grns ar abraded	0
467	BLMst 4-11 77-85"	5.6	33.9	60.6	1	1	3	0	1	1	1	0	0	0	0	1	1	2	2	0	0	0	0	1	0	grns ar abraded	0
466	BLMst 4-12 85-95"	52.6	24.2	23.2	1	1	3	0	1	1	0	0	0	0	0	2	1	2	2	0	0	0	0	1	1	0	0
22.5	BLMst 5-1A 0-6"	7.1	41.3	51.6	1	1	3	1	2	1	1	0	0	0	0	1	1	2	2	0	0	0	0	1	1	0	0
28.4	BLMst 5-1B 0-6"	10.2	34.5	55.3																							
11.5	BLMst 5-2 6-11"	9.3	45.8	44.9	2	1	3	1	1	1	1	0	0	0	0	1	1	3	1	0	0	0	0	2	1	0	0
10.9	BLMst 5-3 11-14"	11.3	33.9	54.9	1	1	3	1	1	2	0	1	0	0	0	1	1	3	1	0	0	0	0	2	2	0	0
25.9	BLMst 5-4 14-20"	11.5	27.2	61.3	2	1	2	0	1	2	1	1	0	0	0	2	1	3	1	0	0	0	0	2	2	> charcoal	0
124.7	BLMst 5-5 20-29"	5.3	29.4	65.3	3	1	1	0	2	2	1	0	0	0	0	2	2	2	1	0	0	0	0	2	2	vry fn charcoal	0
413	BLMst 5-6 29-36"	11.8	31.5	56.7	2	1	2	0	2	2	1	0	0	0	0	2	2	1	1	0	0	0	0	2	0	"	very fractured
214	BLMst 5-7 36-47"	52.8	41.0	6.2	2	0	2	0	1	12	0	0	0	0	1	2	2	2	1	0	0	0	0	2	0	> variety lithol	0
406	BLMst 5-8 47-61"	57.4	18.0	24.6	2	0	2	0	1	3	0	0	0	0	1	2	3	3	3	0	0	0	0	2	0	lithic>90%	0
259	BLMst 5-9 61-75"	5.6	40.8	53.6	0	0	2	0	2	1	1	0	0	0	1	2	2	3	3	0	0	0	0	2	0	0	0
179	BLMst 5-10 75-82"	27.9	21.8	50.3	2	0	2	0	1	3	2	0	0	0	1	3	3	3	3	0	0	0	0	2	0	cors magnetite	abraded
15.8	BLMst 6-1 0-5"	3.8	32.7	63.4	2	1	3	1	1	1	1	0	0	0	0	2	1	3	1	0	0	0	0	3	1	0	0
22.8	BLMst 6-2 5-23"	2.7	18.8	78.5	2	0	3	1	1	1	1	0	0	0	1	2	1	3	1	0	0	0	0	3	0	0	0
209	BLMst 6-3 23-30"	2.3	26.1	71.5	2	1	2	1	2	1	1	0	0	0	1	3	1	2	1	0	0	0	0	2	0	0	0
340	BLMst 6-4 32-40"	2.0	39.4	58.6	2	1	3	1	1	2	1	0	0	0	0	3	1	2	1	0	0	0	0	2	0	> charcoal	Fe stned f.f.
551	BLMst 6-5 40-48"	6.2	35.8	58.0	2	1	3	0	1	3	1	0	0	0	0	2	1	3	1	0	0	0	0	4	0	vry frac. Plag/qtz	Fe stned f.f.
672	BLMst 6-6 48-53"	26.4	30.3	43.3	2	1	2	0	1	3	1	0	0	0	0	2	1	4	1	0	0	0	0	3	0	grt var. lith fra	ang, no charcoal
618	BLMst 6-7 53-64"	3.0	27.9	69.1	2	0	2	0	0	0	0	0	0	0	0	1	1	4	1	0	0	0	0	5	1	blugrn minrl cu?	amorf tan clay
0	BLMst 6-8 64-71"	4.8	40.2	55.0	2	0	1	0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0	5	2	zeolites?	0
51.1	BLMst 7-1 0-6,5"	2.5	47.4	50.2	2	1	3	1	1	1	1	0	0	0	0	2	1	2	0	0	0	0	0	3	1	blugrn snd	charcoal

Appendix D Conductivity, Texture, Mineralogy

Conductivity Slurry 5:1(water to s Micro seimens/cm 10 days	sample name and depth	% Medium and Coarse Sand > 50 mesh	% Fine sand & silt < 50 mesh	% Clay & fine silts	Qz	BP Qx	Plag.	t gr.Pyx	Amph.	Spinel Mag.?	Hex. Black flat	Imen.	Biotite	Muscov.	Gr. Pyx	White	Gray	Brown	Volcanic	Schist	Intrusive	Silsd	Qzite	FE	MN	COMMENTS	
17	BLMst 7-2 6,5-23"	2.3	29.7	68.0	2	1	3	1	1	1	1	0	0	0	0	2	1	3	0	0	0	0	0	3	2	blugrn snd	charcoal
51.1	BLMst 7-3 23-30"	3.6	36.1	60.2	2	0	2	1	1	1	1	0	0	0	0	3	2	4	0	0	0	0	0	3	2	mor lithics	0
186.2	BLMst 7-4 30-39,5"	4.8	52.3	42.9	2	0	3	1	1	1	1	0	0	0	0	2	2	3	0	0	0	0	0	2	2	petr. wood	charcoal
180.8	BLMst 7-5 39,5-42"	5.5	47.9	46.6	1	1	3	0	0	1	1	0	0	0	0	3	3	2	1	0	0	0	0	2	3	> MnO around rts	0
149.2	BLMst 7-6 42-52"	5.7	48.9	45.4	1	0	2	0	0	1	0	0	0	1	0	1	1	4	0	0	0	0	0	4	3	grnsh wht frag	co2 aggrgts
254	BLMst 7-7 52-63"	16.2	39.3	44.5	2	1	3	0	0	0	1	0	0	0	0	2	1	4	1	0	0	0	0	4	3	vry frac. Plag/qtz	0
302	BLMst 7-8 63-71"	23.5	32.6	43.9	1	1	2	0	1	1	1	0	0	0	0	3	2	4	0	0	0	0	0	3	2	mor grnish clasts	thick clyskns
332	BLMst 7-9 71-75"	36.3	26.2	37.5	0	0	1	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	4	0	diff wht lithic	pumice like
374	BLMst 7-10 75-79"	33.0	24.2	42.8	0	0		0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	2	0	grnish wht grns	0
18.7	BLMst 8-1 0-7,5"	3.2	48.7	48.1	2	1	1	1	2	1	1	1	0	0	0	1	2	3	0	0	0	0	0	2	0	0	0
12.23	BLMst 8-2 7,5-11,5"	6.2	1.9	92.0	3	1	1	1	2	1	1	1	0	0	0	2	1	3	0	0	0	0	0	3	0	0	0
50.9	BLMst 8-3 11,5-25,5"	1.1	27.3	71.7	3	1	1	2	1	1	1	1	0	0	0	1	1	4	0	0	0	0	0	3	0	0	0
206	BLMst 8-4 25,5-32"	1.4	30.8	67.8	2	1	1	1	1	1	1	0	0	0	0	1	1	2	0	0	0	0	0	2	0	0	0
564	BLMst 8-5 32-38 "	1.3	34.8	63.9	3	2	1	0	0	0	2	0	0	0	0	1	1	3	0	0	0	0	0	3	2	>> charcaol	0
668	BLMst 8-6 38-51"	1.9	49.5	48.6	3	1	1	0	0	1	1	0	0	0	0	1	2	4	0	0	0	0	0	4	2	charcoal	0
306	BLMst 8-7 51-60"	5.1	56.6	38.3	4	3	1	0	0	0	1	1	0	0	0	1	2	4	0	0	0	0	0	3	1	Fe stns grns	petrif wood
163	BLMst 8-8 60-73"	9.7	49.9	40.4	3	2	2	0	0	1	1	0	0	0	0	3	2	4	0	0	0	0	0	4	2	> lithic frags	largersizes
218	BLMst 8-9 73-87"	18.9	55.6	25.5	1	0	1	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	1	1	vry weth paleosl	over Fisher Fm.
106.2	BLMst 8-10 87-95"	6.2	56.4	37.4	1	0	1	0	0	0	0	0	0	0	0	2	0	3	0	0	0	0	0	4	2	Charcoal	little mag.or Spin.
118.8	BLMst 8-11 95-114"	11.6	63.2	25.3	1	0	1	0	0	0	0	1	0	0	0	3	0	3	0	0	0	0	0	0	0	lmn dif. > upper	0
61.8	BLMst 9-1A 0-4,5"	1.4	51.2	47.4	1	0	3	1	1	1	1	0	0	0	0	2	1	5	0	0	0	0	0	3	0		0
80.6	BLMst 9-2 4,5-9,5"	2.9	42.0	55.1	2	0	2	1	1	1	1	0	0	0	0	2	2	3	0	0	0	0	0	3	2	charcoal	0
80.6	BLMst 9-3 9,5-22"	1.5	22.6	75.9	2	1	2	1	0	1	1	0	0	0	0	2	2	4	0	0	0	0	0	4	3	charcoal	0
275	BLMst 9-4 22-39"	3.3	39.6	57.2	2	1	2	1	0	1	1	0	0	0	0	1	2	3	0	0	0	0	0	3	3	charcoal?	0
225	BLMst 9-5 39-59"	3.2	46.7	50.2	2	1	2	0	1	1	1	0	0	0	0	3	2	3	0	0	0	0	0	3	2	charc. Or MnO?	0
283	BLMst 9-6 59-67"	6.8	25.9	67.3	2	2	2	0	1	1	1	0	0	0	0	3	4	1	2	0	0	0	0	0	3	CaCO2 agreg.	caliche frm Wis glac.
340	BLMst 9-7 67-87"	52.1	23.9	24.0	1	1	2	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	0	3	grnish and pnk snd	Will. R. source
68.3	BLMst 10-1 0-7"	4.4	60.7	34.9	3	1	2	1	2	1	1	0	0	0	0	1	1	4	0	0	0	0	0	5	2	0	0
16.7	BLMst 10-2 7-13"	4.6	50.7	44.7	3	1	1	1	1	2	1	0	0	0	0	1	1	4	0	0	0	0	0	4	2	0	0

Appendix D Conductivity, Texture, Mineralogy

Conductivity Slurry 5:1(water to s Micro seimens/cm 10 days	sample name and depth	% Medium and Coarse Sand > 50 mesh	% Fine sand & silt < 50 mesh	% Clay & fine silts	Qz	BP Qx	Plag.	t gr.Pyx	Amph.	Spinel Mag.?	Hex. Black flat	Imen.	Biotite	Muscov.	Gr. Pyx	White	Gray	Brown	Volcanic	Schist	Intrusive	Silsd	Qzite	FE	MN	COMMENTS	
22.9	BLMst 10-3 13-20"	2.4	35.7	62.0	2	1	2	1	1	1	1	0	0	0	0	1	1	5	1	0	0	0	0	5	3	0	0
56.4	BLMst 10-4 20-37"	1.7	36.1	62.2	2	1	2	1	1	1	2	0	0	0	1	1	1	5	0	0	0	0	0	5	4	lithics > larg. SS frg	
694	BLMst 10-5 37-64"	2.0	28.4	69.6	2	0	2	0	0	1	2	0	0	1	0	2	2	4	0	0	0	0	0	5	0	weathered mica	0
627	BLMst 10-6 64-68"	2.1	38.1	59.8	0	0	0	0	0	1	0	0	0	2	0	2	2	4	1	0	0	0	0	0	0	mica=Spenc. Fm.	0
534	BLMst 10-7 68-76"	2.8	36.0	61.1																							
389	BLMst 10-8 76-86"	1.4	44.9	53.7																							
335	BLMst 10-9 86-95"	2.8	31.0	66.2	1	0	3	0	0	1	1	0	0	1	0	2	1	4	0	0	0	0	0	4	5	abun. MnO after r	roots, elong. Masses
276	BLMst 10-10 95-105"	2.5	24.4	73.1	1	0	2	0	0	0	0	0	0	1	0	2	1	4	0	0	0	0	0	4	4		
79	BLMst 11-1 0-6"	11.2	47.2	41.6	2	1	1	1	1	1	0	0	0	0	0	3	4	5	2	0	0	0	0	5	4	many rnded grains	0
45.2	BLMst 11-2 6-13"	18.7	66.1	15.2	2	1	2	1	1	1	0	0	0	0	0	3	4	6	2	0	0	0	0	4	0	many rnded grains	0
31.9	BLMst 11-3 13-18"	12.2	52.8	35.0	2	1	2	1	1	1	0	0	0	0	1	3	4	6	2	0	0	0	0	5	0	many rnded grains	0
30.7	BLMst 11-4 18-24"	32.4	26.8	40.8	1	1	1	1	1	1	1	0	0	0	2	4	4	2	2	0	0	0	0	2	0	many rnded grains	0
38	BLMst 11-5 24-29"	37.7	25.9	36.5	1	1	1	1	1	1	1	0	0	0	2	4	4	2	2	0	0	0	0	2	2	many rnded grains	0
28.6	BLMst 11-6 29-44"	51.3	24.1	24.5	1	1	1	0	1	0	0	0	0	0	1	1	1	0	2	0	0	0	0	3	3	many rnded grains	0
42.4	BLMst 12-1 0-6"	9.3	99.0	-8.3	2	1	1	1	1	1	1	0	0	0	1	3	2	2	1	0	0	0	0	4	2	many rnded grains	0
18.56	BLMst 12-2 6-14"	3.3	38.2	58.5	2	1	2	1	1	1	0	0	0	0	1	2	2	3	1	0	0	0	0	4	0	many rnded grains	0
13.6	BLMst 12-3 14-35"	4.3	50.7	45.0	2	1	3	1	1	1	1	0	0	1	1	2	3	2	2	0	0	0	0	4	0	many rnded grains	0
15.1	BLMst 12-4 35-46"	2.6	37.7	59.7	2	1	2	1	1	1	1	0	0	0	1	3	2	3	1	0	0	0	0	4	0	many rnded grains	0
22.5	BLMst 12-5 46-52"	6.8	63.5	29.6	2	2	2	1	1	1	1	0	0	0	1	2	2	3	2	0	0	0	0	4	0	Large frag. Fisher	
43.7	BLMst 12-6 52-67"	4.1	33.7	62.2	2	1	2	0	1	1	1	0	0	0	0	2	2	4	0	0	0	0	0	5	2	Fm., orthoclase grn	charcoal
97.6	BLMst 12-7 67-81"	6.8	45.3	47.9	1	1	2	0	0	1	0	0	0	0	0	2	1	3	0	0	0	0	0	2	2	pyroclas. & volc.	common gray
26.5	BLMst 13-1 0-13 "	6.3	61.6	32.1	3	1	2	1	1	1	1	0	0	0	0	1	0	3	0	0	0	0	0	4	2	0	0
16.93	BLMst 13-2 13-29 "	7.4	63.4	29.2	2	1	2	1	1	1	1	0	0	0	0	1	0	3	0	0	0	0	0	4	0	charcoal	0
33.6	BLMst 13-3 29-43"	6.2	64.8	29.0	2	1	2	1	1	1	1	0	0	0	0	2	1	3	0	0	0	0	0	4	0	0	0
42.3	BLMst 13-4 43-56"	8.4	53.9	37.7	2	1	2	1	1	1	1	0	0	0	0	2	1	3	0	0	0	0	0	3	0	0	0
50.1	BLMst 13-5 56-63"	19.7	51.3	29.0	2	1	2	0	0	1	1	0	0	0	0	1	0	3	2	0	0	0	0	3	1	grav. w/volcan.	and grn. mineral
46.9	BLMst 13-6 63-78"	10.7	50.8	38.5	2	1	2	0	0	1	1	0	0	0	0	2	1	3	3	0	0	0	0	3	1	1 petrified wood	mineralized grains
46.8	BLMst 13-7 78-98"	47.8	85.9	-33.6	1	1	3	0	0	0	0	0	0	0	0	3	2	2	3	0	0	0	0	2	0	basaltic gravels,grn	mineral,few mafics

Appendix D Conductivity, Texture, Mineralogy

Conductivity Slurry 5:1(water to s Micro seimens/cm 10 days	sample name and depth	% Medium and Coarse Sand > 50 mesh	% Fine sand & silt < 50 mesh	% Clay & fine silts	Qz	BP Qx	Plag.	t gr.Pyx	Amph.	Spinel Mag.?	Hex. Black flat	Imen.	Biotite	Muscov.	Gr. Pyx	White	Gray	Brown	Volcanic	Schist	Intrusive	Silsd	Qzite	FE	MN	COMMENTS	
33.6	BLMst 13A-1 0-10"	12.2	47.9	39.9	2	1	3	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	> FeO aggregates	like burned
34.2	BLMst 13A-2 10-22"	9.4	41.2	49.4	3	1	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	4	2	drk. gray trans glass	0
38.7	BLMst 13A-3 22-28"	5.5	42.1	52.4	2	1	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	4	2	drk. gray trans glass	0
17.9	BLMst 13A-4 28-35"	4.8	41.2	54.0	2	1	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	vry. fract. grains	0
25.3	BLMst 13A-5 35-47"	14.2	34.8	51.0	2	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	vry. fract. grains	0
17.8	BLMst 13A-6 47-58"	20.4	38.4	41.2	2	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
16.1	BLMst 13A-7 58-69"	19.3	32.8	47.9	2	1	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	interstitial qtz.	0
35.4	BLMst 14-1 0-21"	4.7	26.7	68.6	2	1	2	1	1	0	0	0	0	0	1	2	1	2	0	0	0	0	0	3	1	abun. Charcoal	0
205	BLMst 14-2 21-27"	7.3	34.9	57.8	2	1	2	1	1	0	0	0	0	0	1	1	1	2	0	0	0	0	0	4	5	lrg. basalt gravel	0
42.8	BLMst 15-1 0-12"	18.5	2.3	79.2	1	0	3	1	0	0	0	0	0	0	1	2	1	2	0	0	0	0	0	4	5	specked glass	0
116.5	BLMst 15-2 12-32"	23.6	5.5	70.9	2	1	1	1	1	1	0	0	0	0	1	1	2	1	0	0	0	0	0	1	3	> lithic frags.	0
346	BLMst 15-3 32-52"	2.5	55.4	42.1	2	0	2	1	0	0	0	0	0	0	0	2	2	3	0	0	0	0	0	3	4	abun. wht & gry frags	0
121	BLMst 15-4 52-64"	1.4	50.7	47.9	1	0	1	1	0	0	0	0	0	0	0	1	1	3	0	0	0	0	0	4	3	yel. aggreg.	0
21.2	BLMst 15-5 64-75"	18.0	67.2	14.8	1	0	0	0	0	0	0	0	0	1	3	3	1	0	3	0	0	0	0	0	0	CO2 aggregats	0
28	BLMst 15-6 75-78"	4.6	67.9	27.5	1	0	3	1	1	1	0	0	0	1	3	3	1	0	2	0	0	0	0	0	0	clear obsidian	0
40.5	BLM Har. Ridge 1 0-15"	3.2	29.2	67.6	2	1	2	1	1	1	1	0	0	2	1	3	0	0	0	0	0	0	0	6	1	0	0
48.5	BLM Har. Ridge 2 15-30"	3.8	41.8	54.4	2	1	2	1	1	1	1	0	0	2	1	3	0	0	0	0	0	0	0	6	2	0	0
53.1	BLM Har. Ridge 3 30-62"	4.7	38.7	56.6	4	2	2	0	1	0	0	0	0	2	1	3	0	0	0	0	0	0	0	0	0	0	0
47.2	BLM Har. Ridge 4 62-84"	32.2	27.6	40.2	1	1	1	0	0	0	0	0	0	1	0	4	8	0	0	0	0	0	0	8	0	grn oxides, petrified wood	0
26.6	BLM Har. Ridge 5 84-97"	5.5	24.3	70.1	0	0	4	0	0	0	0	0	0	1	3	1	6	0	0	0	0	0	0	0	0	0	0
0	BLM Har. Ridge 6 110-130"	2.9	22.0	75.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	Irish Bend 10-15"	4.5	28.6	66.8	1	0	2	2	1	1	0	0	0	1	0	6	0	0	0	0	0	0	0	0	0	0	0
0	Irish Bend 15-20"	6.0	8.2	85.8	2	0	2	2	1	0	0	0	0	1	0	6	0	0	0	0	0	0	0	0	0	0	0
28.3	Irish Bend IIB2 28-32"	0.1	43.7	56.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42.6	Irish Bend flood seds 10-12'	0.0	0.0	0.0	2	0	3	0	0	0	0	1	2	2	1	0	0	0	4	2	2	1	2	1	4	K-feldspar, other metam.	lithic fragments
46.9	Irish Bend Paleosol 12-14'	0.0	0.0	0.0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	pure Fe2O3 aggregates	0
167	19th and Buck St. 0-4"	0	0	0	2	0	2	0	1	1	1	0	0	3	1	4	0	0	0	0	0	0	0	5	0	charcoal	

Appendix D Conductivity, Texture, Mineralogy

Conductivity Slurry 5:1(water to s Micro seimens/cm 10 days	sample name and depth	% Medium and Coarse Sand > 50 mesh	% Fine sand & silt < 50 mesh	% Clay & fine silts	Qz	BP Qx	Plag.	t gr.Pyx	Amph.	Spinel Mag.?	Hex. Black flat	Imen.	Biotite	Muscov.	Gr. Pyx	White	Gray	Brown	Volcanic	Schist	Intrusive	Silsd	Qzite	FE	MN	COMMENTS	
29.2	19th and Buck St. 9-10"	0	0	0	2	1	2	1	2	1	1	0	0	2	1	4	0	0	0	0	0	0	0	5	0	Sanidine?	
17.1	19th and Buck St. 15-16"	0	0	0	2	1	2	1	1	1	1	0	0	2	1	4	0	0	0	0	0	0	0	4	1		
21.4	19th and Buck St. 31-32"	0	0	0	2	0	1	1	1	1	0	0	0	2	1	3	0	0	0	0	0	0	0	5	2		
18.8	19th and Buck St. 44-45"	0	0	0	2	0	3	1	0	1	0	0	0	3	1	4	0	0	0	0	0	0	0	4	0		
16.5	19th and Buck St. 50-51"	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0		

APPENDIX E

CLAY MINERALOGY

Clay XRD

by J.R. Glasmann, Willamette Geologic Service

Results and Discussion

Pre-Missoula Flood Paleosols and Missoula Flood Deposits

Buried paleosols are common beneath Missoula flood deposits in the Willamette Valley and exhibit a distinctive clay mineral assemblage that generally consists of highly disordered kaolinite, hydroxy-interlayered smectite/vermiculite (chloritic intergrade), quartz, and iron oxides (Figure 1). Though some of the paleosols have developed in micaceous, feldspathic sedimentary formations (e.g., Spencer Fm), prolonged weathering has destroyed the mica and feldspar (Figure 1A), transforming these minerals into more pedogenically-stable, quartz-rich, kaolinite and chloritic intergrade clay. Where such paleosols are covered by Missoula Flood deposits, the mineralogical character of the soil frequently displays a sharp change that is associated with similar changes in other soil properties (color, texture, structure, etc). The pedon represented by Figures 1 and 1A illustrates such a sharp mineralogical boundary, with olive brown, strongly micaceous, chloritic, and feldspathic Missoula Flood silts overlying reddish-brown non-micaceous, quartzose, kaolinitic paleosol clays associated with weathered Spencer sediments. Missoula Flood deposits have not experienced the prolonged weathering of older paleosols and contain considerable mica and feldspar (both K-feldspar and plagioclase), as well as minor amounts of other easily weatherable minerals (augite, hornblende, biotite). These are the mineralogical fingerprints one might expect to see in the southwestern Willamette Valley wetland soils, if Missoula Flood deposits were present.

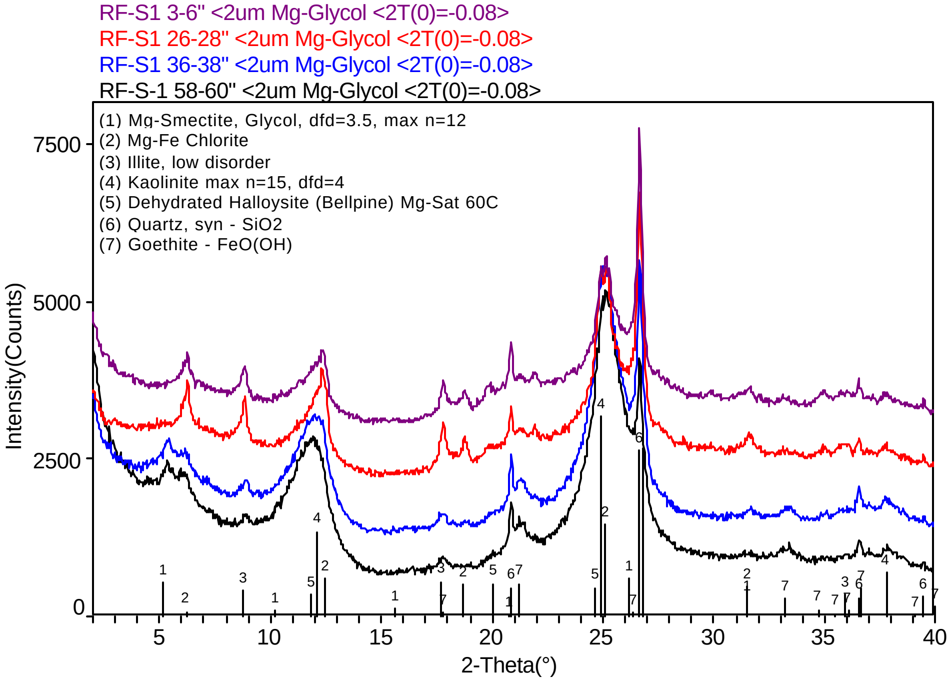


Figure 1. Above are XRD examples of the clay mineralogy of a soil with known Willamette Silts (Missoula Flood silts) that lap onto old weathered material from the Spencer Formation and two samples from a paleosol that underlies the Missoula Flood, Irish Bend Member.

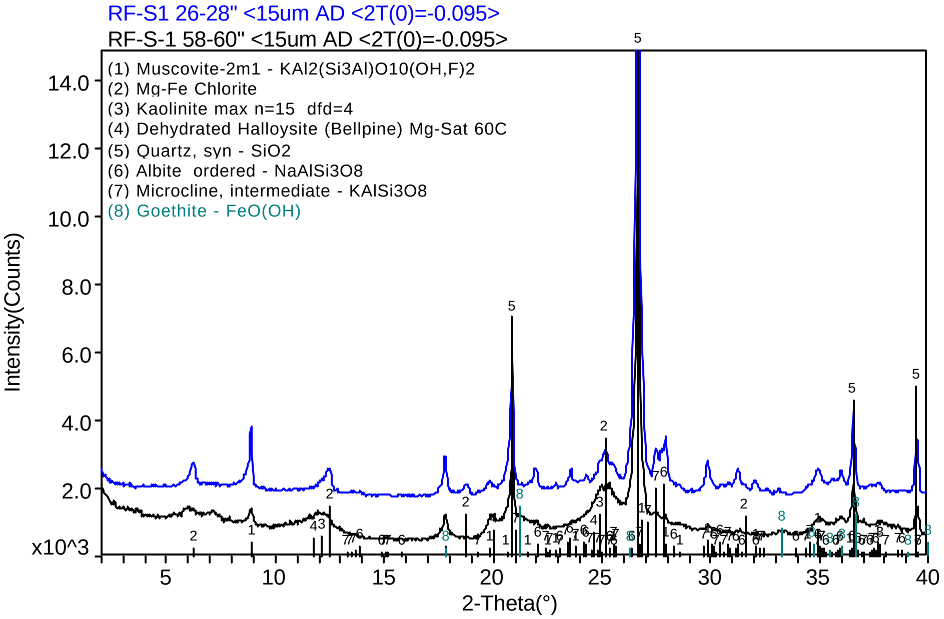


Figure 1A. Comparison of XRD patterns representing the <15-?m fraction of Missoula Flood silts (26-28" depth) and underlying paleosol developed in Spencer Formation. Missoula Flood silts are strongly enriched in mica and feldspar relative to the paleosol.

Relict soils on geomorphically stable surfaces that lie well above known Missoula Flood deposits frequently exhibit the highly weathered character observed in buried paleosols that underlie Missoula Flood silts (Figure 2). This XRD pattern represents the clay fraction of soils developed in the Spencer Formation. There is little variation in clay mineralogy with depth due to prolonged weathering. Most of the weatherable minerals have been destroyed – there is no feldspar and only a trace of mica persists in the deeper soil sample. The clay assemblage consists primarily of highly disordered kaolinite or a mix of kaolinite and dehydrated halloysite, plus well-developed chloritic intergrade. Other minerals indicative of prolonged weathering are gibbsite, quartz, and hematite. Expandable clays (smectite, vermiculite) have been destroyed through precipitation of interlayer Al/Fe hydroxides to form the chloritic intergrade phase. This type of clay mineral assemblage occurs over broad areas in the lower foothills of the Willamette Valley. If the West Eugene wetland soils were derived from erosion of older weathered deposits from surrounding foothill environments, one might expect to see sediments enriched in quartz (a residual mineral), disordered kaolinite/halloysite, and chloritic intergrade, although stream incision could also mix these minerals with less weathered material (expandable clays,mica,feldspar).

Although relatively thick Missoula Flood deposits are common in the northern and mid-Willamette Valley, the silts thin against the valley margins and are frequently absent at elevations above 300-ft. The commonly reported 400-ft upper limit of Missoula deposits in the valley generally coincides with the upper limit of mapped glacial erratics believed associated with a single flood event; however, pedogenically significant thicknesses of identifiable lacustrine silt are uncommon above 350-ft in the southern Willamette Valley.

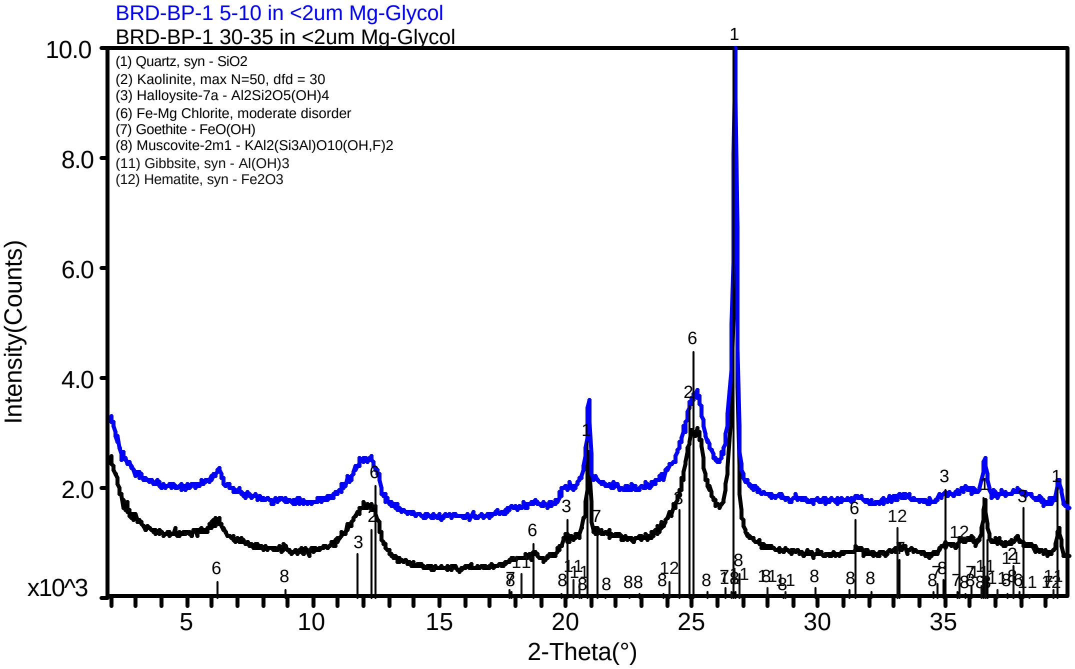


Figure 2. XRD of soils that developed in the Spencer Formation on a stable rolling upland geomorphic surface (Dolph/Eola) at an elevation of about 500 ft on the west side of the Willamette Valley about 5 miles south of Philomath, Oregon.

Results and Discussion

Southwestern Willamette Valley: Modern Cascadian Fluvial Sediments

Modern sediments delivered by Cascadian river systems are typically smectite- and plagioclase-rich, with only minor to trace amounts of quartz and mica, and no K-feldspar (Figure 3). Local variations in suspended and bed load sediment character reflect contrasting geologic history on the watershed level. Thus, the presence of well ordered kaolinite in the Coast Fork of the Willamette probably reflects erosion of hydrothermally altered volcanics associated with mineralized areas south of Mt. Pigsah. In contrast, the presence of zeolite and the strongly smectitic character of lower McKenzie River sediments is characteristic of many Western Cascade streams that are incised into weathered pyroclastic deposits. The Willamette River at Eugene has a sediment composition that reflects mixing of highly smectitic Western Cascade clays with the more kaolin-rich sediments from the Coast Fork (Figure 3). Since the junction of the McKenzie with the Willamette River has migrated northward during post-Missoula time, the impact of McKenzie sediment on the mineralogical character of flood plain deposits in the vicinity of Eugene may have been much greater in the past.

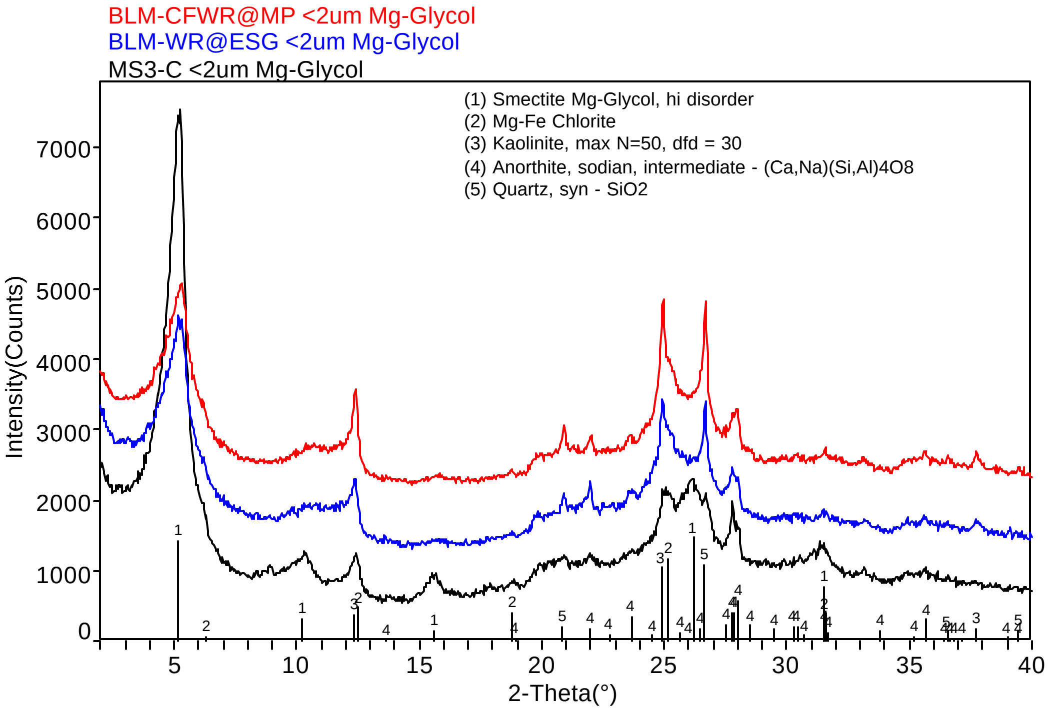


Figure 3. The clay mineral assemblage of modern gravel bars from 3 Cascadian rivers: McKenzie River (bottom pattern), Willamette River at Eugene (middle pattern), and Coast Fork of the Willamette at Mt. Pigsah (top pattern). Note the absence of mica in all 3 patterns. The McKenzie sample contains a minor amount of zeolite (heulandite). Kaolinite is most abundant in the Coast Fork sample and exhibits sharp peak character associated with well ordered hydrothermal kaolin. Contrast this peak shape with that of disordered kaolinite common in paleosol deposits (Figures 1 & 2).

Ancient Cascadian Sediments Underlying Wetlands

Stratified, poorly consolidated, cross-bedded, very fine-grained silty sandstone was encountered at depth in several trenches excavated in the West Eugene Wetlands. The clay mineral assemblage of this stream-deposited sand is smectite dominated (Figure 4A). The absence of kaolinite suggests that the river system that left this channel deposit was not significantly influenced by Coast Fork kaolinitic sediment. The <15-µm fraction of this stratified sand contains major amounts of calcic plagioclase derived from erosion of Western Cascade andesitic/basaltic volcanic rocks (Figure 4B). Quartz occurs in very minor amounts, reflecting the general absence of quartz in volcanic rocks of basic to intermediate composition. The smectite-plagioclase rich composition clearly identifies this silty sand as a Cascadian deposit. If the sediment were derived from erosion of exposed Coast Range sedimentary formations or Missoula Flood deposits, the silt fraction should contain larger amounts of quartz and mica, along with minor amounts of K-feldspar. Similarly, if these sediments were exposed to significant post-depositional weathering, one would expect to see destruction of easily weathered phases such as calcic plagioclase and enrichment of the residual sediment in quartz and clays. Thus, the mineralogical character of the stratified sands clearly identifies them as Cascadian stream deposits with strong similarity to modern McKenzie River sediments. The relatively unweathered nature of this sample, as indicated by the low amount of quartz relative to feldspar (Figure 4B), suggests that the sand is probably a Late Pleistocene or Holocene deposit.

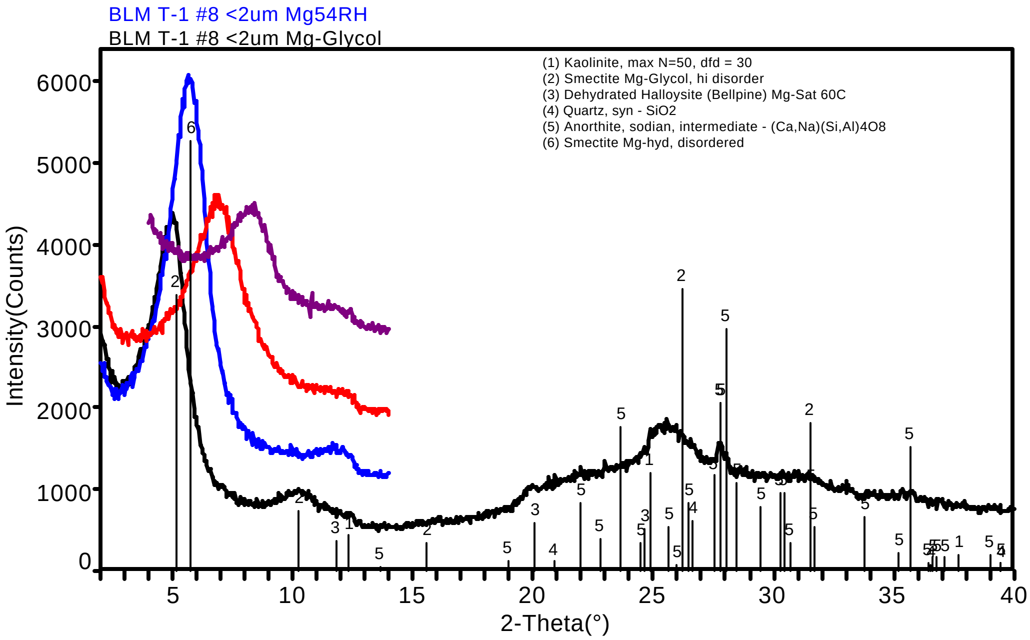


Figure 4A. This XRD pattern represents the clay component of a cross-bedded silty very fine grained sand unit from Trench 1 (#8, 106-114 inches). The smectite-dominated clay mineral assemblage of this sample is very similar to that observed in modern McKenzie River sediments (see Figure 3).

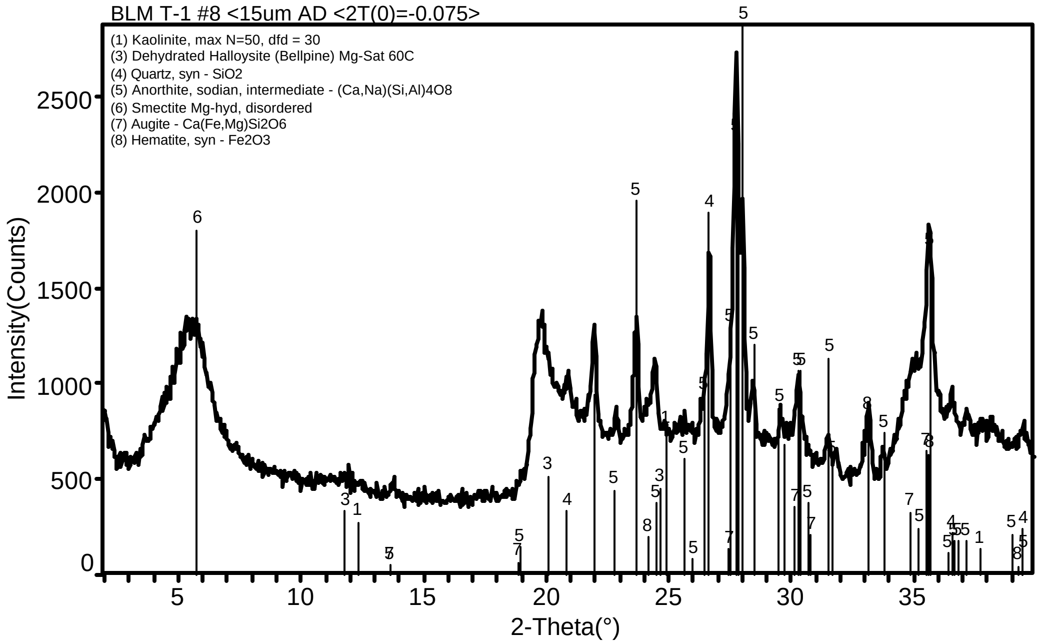


Figure 4B. This pattern represents the silt component of a cross-bedded silty very fine grained sand unit from Trench 1 (#8, 106-114 inches). Note the absence of mica and the relatively low intensity of the quartz component. Quartz is generally absent in basaltic/andesitic rocks of the Cascades, but can be concentrated in deeply weathered deposits due to destruction of feldspar. The very low quartz/plagioclase intensity ratio of this sample indicates that it is relatively unweathered.

In most cases, the stratified sands are overlain by a pebbly sandy-clay paleosol that occasionally exhibits crude stratification. The absence of strong soil structure and weak remnants of geologic stratification indicate a short duration of pedogenic modification.

Pebble composition clearly indicates Cascadian origin, consisting of hard clasts of andesite and basalt without significant weathering rinds. The clay mineral assemblage is highly smectitic and halloysitic, but the weak collapse of a component of the expandable clay with K-saturation suggests that the smectite consists of a mixture of high charge (i.e., vermiculitic) and lower charge (montmorillonitic) clays (Figure 5). These clays have not been affected by precipitation of AL/Fe interlayer material. Such precipitation alteration is common in older soils with a long history of repeated wetting and drying (such as seen in the first XRD pattern from the old geomorphic surface – Figure 2). The absence of hydroxyl interlayer material suggests a couple of possibilities: the soils are always wet, therefore not impacted by Al/Fe hydroxide precipitation; the soils are not very old and haven't had the time for hydroxide precipitation to do much; a combination of these 2 possibilities. The clay fraction doesn't contain much feldspar, and the quartz/feldspar intensity ratio of the silt fraction is much greater than that of the underlying Cascadian sand, suggesting more pronounced weathering; however, the level of pedogenic development is inconsistent with large-scale in situ alteration of feldspar. The absence of a sharp kaolinite component precludes sediment contributions from the Coast Fork of the Willamette. The thick nature of this deposit (3.5 ft), combined with its extremely poor sorting, evidence of crude stratification, mixture of fresh and weathered gravels, and the observed quartz and halloysite enrichment relative to "fresh" Cascadian stream deposits indicates that this unit was probably deposited as a super-concentrated mud flow in a former Cascade river stream channel. The mudflow deposit evidently resulted in the cessation of active channel deposition in the area, as overlying deposits are dominated by very fine-grained overbank deposits with very low sand content.

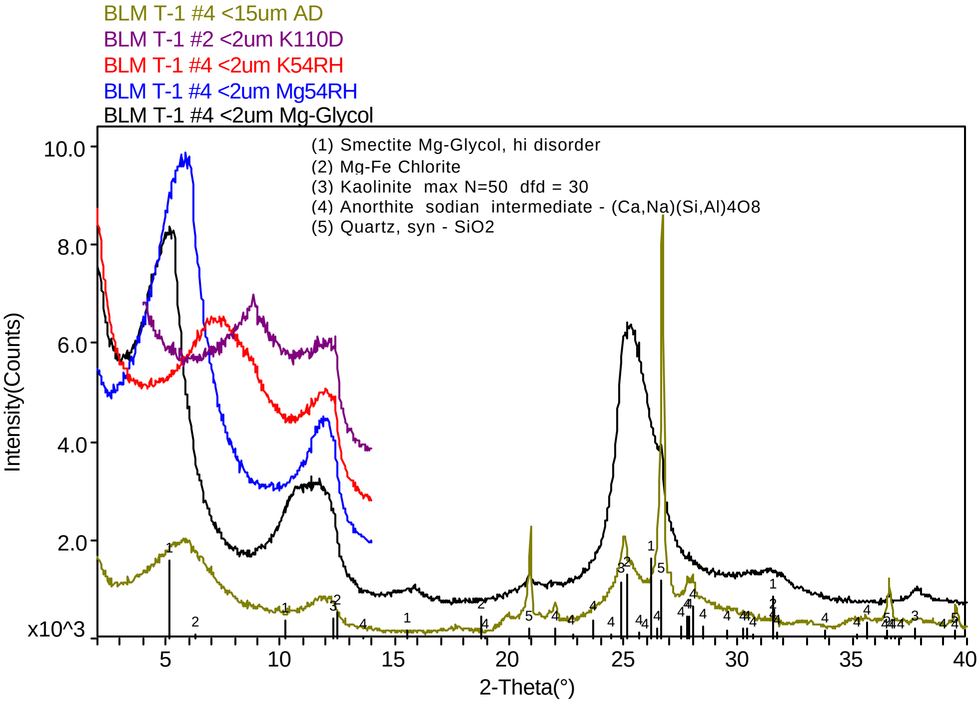


Figure 5. This XRD pattern represents the silt and clay fraction of soil material from Trench 1 #4 (olive brown paleosol, 42-58 inches). Relative to the underlying Cascadian sand, the silt fraction has a much larger quartz/plagioclase intensity ratio. This indicates that the poorly sorted gravelly clay is more highly weathered than the underlying stream sand, although the absence of weathering rinds on gravel within the deposit suggests that the clays may represent material weathered off site and transported along with unweathered gravel. The mixing of materials suggestive of different weathering histories and the extremely poorly sorted nature of this deposit indicates deposition by super-concentrated mudflows.

In comparison to the mineralogy of the channel-plugging, gravelly-clay mudflow deposit that overlies stratified Cascadian sands, the modern A horizon of wetland soil at Trench 1 also consists of a mixture of smectite and halloysite, with a very quartz-rich silt fraction (Figure 6). In contrast to the gravelly clay, the surficial clays contain a component of well-ordered kaolinite. This kaolinite component is increasingly apparent in wetland soils to the southeast (Willow Creek area, Figure 7) and within the Amazon Creek floodplain (Figure 8) that may have be influenced by former Willamette River overbank sedimentation. It is doubtful that this better ordered kaolinite phase developed from pedogenic weathering, since the trend of weathering is to produce messy, poorly ordered phases such as halloysite (see again the first XRD pattern of the relict soils of Figure 2).

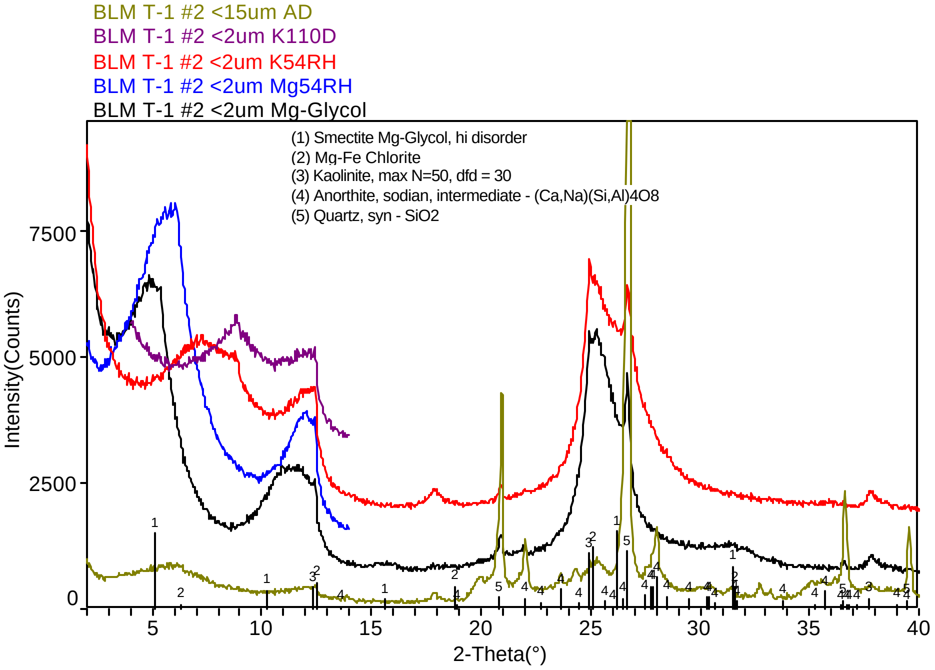


Figure 6. This XRD pattern represents the clay component of the soil material from Trench 1 #2 (A horizon, 10-21 inches). The silt fraction is slightly more feldspathic than corresponding silts from the underlying gravelly mud (Figure 5). The clay fraction also contains a minor component of well-ordered kaolinite that was not found in the underlying sediments.

In contrast to the underlying Cascadian sand in Trench 1, the silt fraction of this sample is greatly enriched in quartz (component 5). This enrichment is probably related to weathering of plagioclase associated with clay formation in the soil. As feldspar is turned into clay, the relative abundance of residual quartz in the soil increases. It would be very unusual to have a fresh Cascadian sediment with such a high quartz content, but deeply weathered soils developed on the andesitic/dacitic tuffs of the Western Cascades have considerable fine-grained quartz as a result of concentration during weathering. If the material weathered in place from originally more volcanic-rich sediments, one could get this kind of quartz enrichment, but it would take a long time. If this material is young, then it follows that the clayey sediments were derived from previously weathered deposits – local soils or older Cascade sediments. To get this kind of sediment from the Cascades, you'd need to erode a large mud slide or debris flow that homogenized older soil materials. Deep erosion into zeolitically altered tuffs wouldn't result in extensive quartz enrichment. The presence of the well-ordered kaolinite component suggests derivation from some sort of mineralized zone (possible ore-bearing). This kind of sharp peak character is usually found in geologic (hydrothermal) clays, not pedogenic, certainly not typical of the Willamette Valley pedogenic clays as shown by Figure 2.

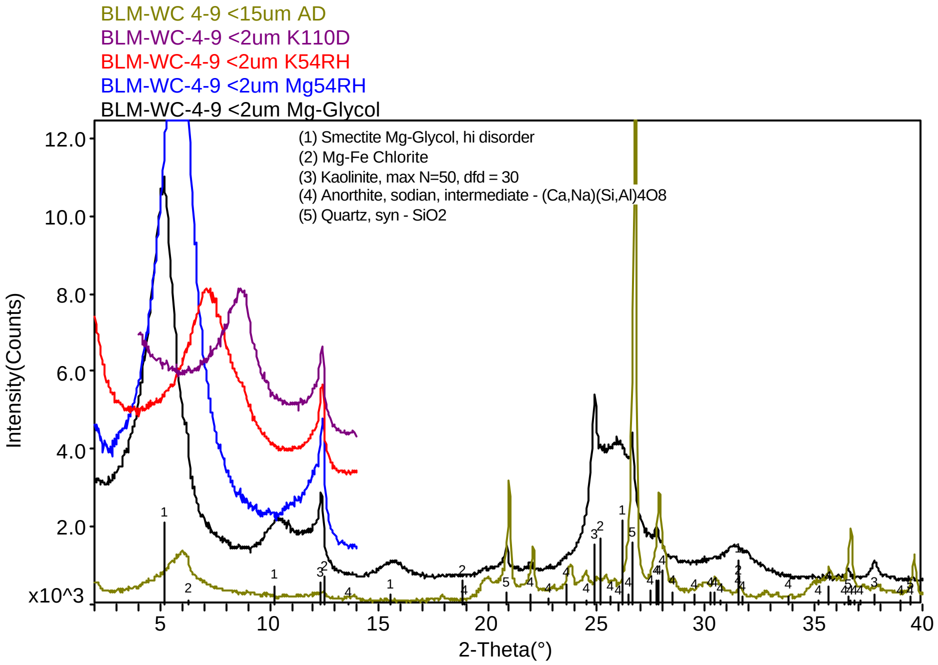


Figure 7. This XRD pattern represents the silt and clay components of soil material from the Willow Creek site (63.5-67" depth). Note the presence of well-ordered kaolinite and absence of halloysite, as well as the fairly plagioclase-rich nature of the silt fraction.

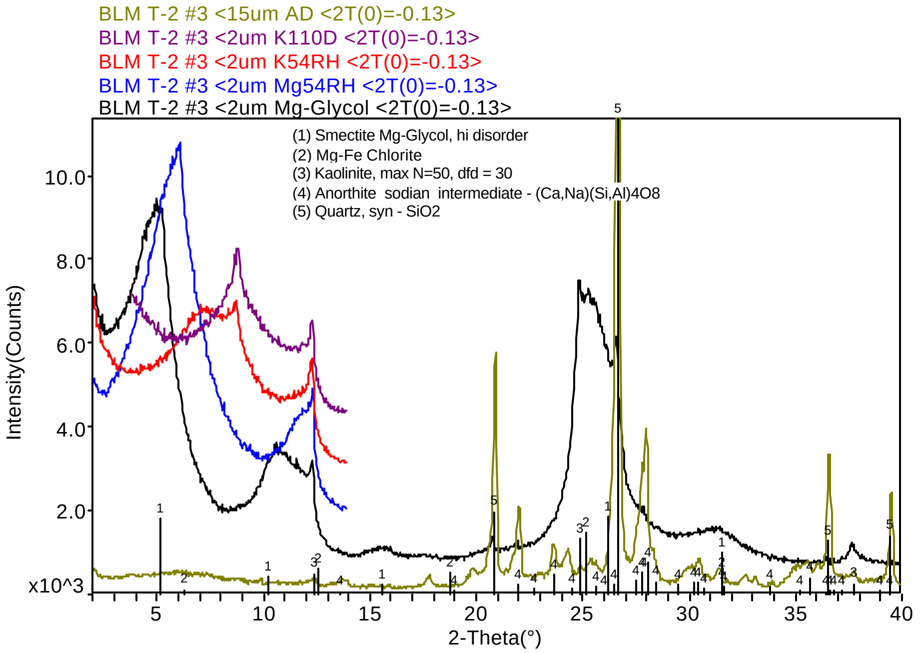


Figure 8. XRD patterns representing the silt and clay fractions of the Grey Clay unit in Trench 2 (20-55 inches). The clay mineral assemblage of this deposit is very similar to that observed in the surficial clays at Trench 1; however, this sample is enriched in well-ordered kaolinite and vermiculite relative to Trench 1 clays and the silt fraction is similarly enriched in plagioclase. The presence of a minor zeolite component (small peak @ 10 degrees 2-Theta) suggests Cascadian influence. The complete absence of mica and K-feldspar excludes Missoula Flood sediments.

The sample described as “grey clay” from Trench 2 (20-55 inches) is characterized by the presence of smectite (both high and low charge, looks like there may be vermiculite by the sharp character of the K-saturated peak at 1.0 nm), halloysite, and a well-ordered kaolinite component. The sharp nature of the kaolinite component is similar to that in Figure 7 and possibly represents a distinct provenance resulting from erosion of hydrothermally altered volcanics somewhere upstream. The silt fraction contains a moderate component of Ca-plagioclase, indicating that weathering at this location is not all that severe. If the clays formed by intense weathering, one would not expect to find any fine-grained feldspar left in the rock. The sand component of this clayey deposit was dominantly fine- to medium-grained, without the volcanic lithic component observed at Trench 1. This deposit has a mixed origin, reflecting fluvial deposition of Cascadian material. The absence of detrital mica probably precludes a significant sediment component from the Spencer Formation or Missoula Flood deposits. If the mica had been removed by intense weathering, one would expect the plagioclase to have been removed from the clay fraction. This is not the case, so the absence of mica must reflect depositional origin – i.e., there wasn’t any mica in the material eroded and transported to the site of deposition.

Soil material from the Harvest Ridge site is enriched in disordered kaolinite and chloritic intergrade relative to clayey deposits at Trench 1 and Trench 2 (Figures 9 & 10). The well ordered kaolinite component that was associated with surficial clays in the trench exposures is generally absent in the clay fraction at Harvest Ridge. The quartz/plagioclase ratio of the silt fraction is generally lower at Harvest Ridge compared to the trench sites. This could result from depositional exclusion of feldspar related to sediment sorting, or reflect more intense weathering. Overbank clays commonly exhibit decreasing silt content away from the channel due to decreasing energy of flow. Distal floodplain deposits are most clay rich and may contain decreased amounts of feldspar simply as a result of depositional sorting. While this argument is conceptually possible, the sediment obtained from the 30-62 inch depth at Harvest Ridge is a sandy clay – hardly a distal floodplain deposit! The sand fraction includes quartz, feldspar, and volcanic lithic fragments. It is difficult to imagine any mechanism that would allow for significant differences in weathering intensity between Trench 2 and Harvest Ridge, since both sites lie with the fairly road floodplain of Amazon Creek and presumably represent deposits of similar age. Deeper strata at Harvest Ridge include gravelly clays similar to those observed in Trench 1. Thus the mineralogical differences between these various locations must reflect differences in primary depositional character. The strongly halloysitic/disordered kaolinite and chloritic intergrade character of the Harvest Ridge clays could reflect an influence of eroded paleosols common to the Coast Range and may indicate mixing of sediments from the Long Tom drainage with Cascadian sediments. Such a scenario is supported by traces of mica in the Harvest Ridge clay assemblage (primarily in the silt fraction of the 30-62 inch specimen) that could be derived from eroded Spencer or Tyee sediments within the Long Tom drainage.

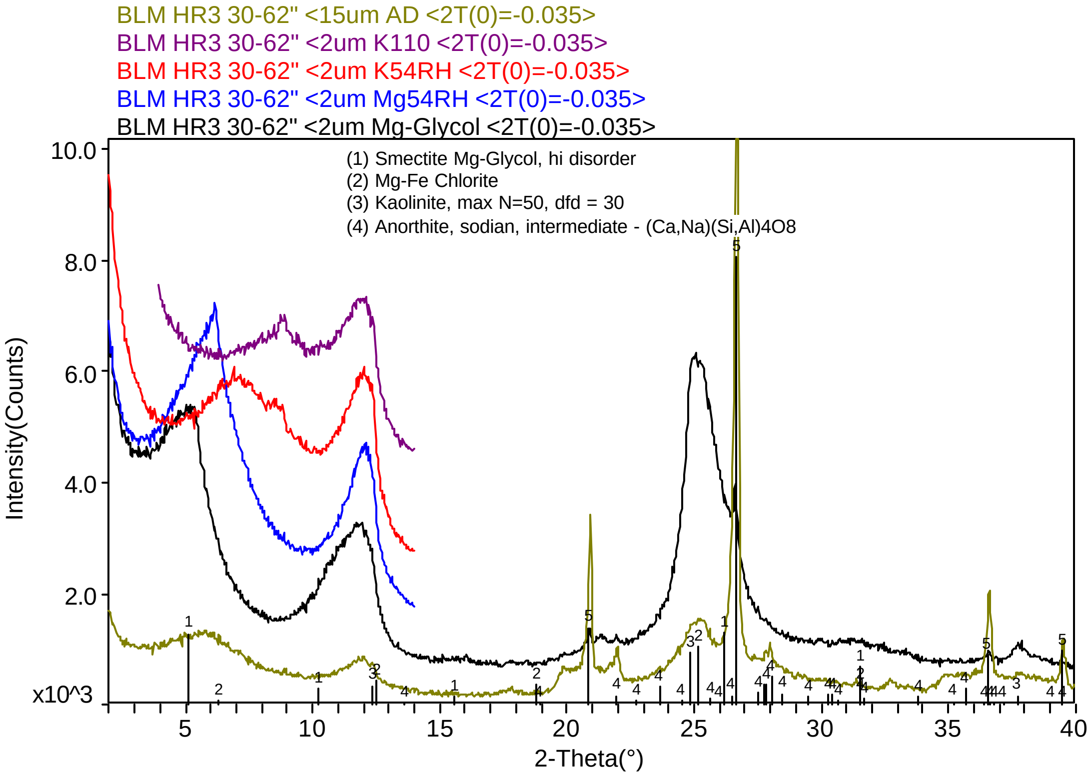


Figure 9. This pattern represents the clay fraction of the Harvest Ridge “outcrop” at 30-62 inches. Note the very low intensity of the plagioclase component in the silt fraction and near absence of plagioclase in the <2-µm clays. The clay fraction is enriched in disordered kaolinite relative to clays from Trench 1 and 2, suggesting either more pronounced weathering or a difference in sediment source area.

Figure 10 represents XRD patterns of the “salt/pepper” clayey sand at the Harvest Ridge site. This deposit consists of clayey gravelly sand, with pebble-sized fragments of altered volcanic material (white, punky gravel that resisted ultrasonic disaggregation). The deposit is clearly of fluvial origin and represents weathered gravelly alluvium derived from the Cascades. The clay fraction is very similar to that observed in the overlying sandy clay. Both the clay and silt fractions are slightly enriched in plagioclase relative to the overlying soil (compare Figure 9 and 10), an indication that the gravelly sediments are not extensively weathered. Ca-plagioclase is easily altered to clay and should not persist in the clay fraction of soils with intense weathering history. This suggests that the deposit is not deeply weathered, but consists of a mixture of alluvial and pedogenic clays developed in place. The stronger component of halloysite in the soils at Harvest Ridge could reflect in situ alteration of somewhat more gravelly sediments or mixing with eroded paleosol components derived from the Coast Range or Cascades. If these sediments were primarily derived from the Cascades, the strong halloysitic component would imply shallow-seated mass failure erosion sources, as deep-seated soil erosion produces a smectite/zeolite/plagioclase dominated sediment, not the smectite/halloysite/quartz clays we see here. Again, the mutual occurrence of fresh and weathered volcanic gravel, the occurrence of easily weatherable minerals in the fine soil, the extremely poor sorting, and the enrichment in quartz relative to modern Cascade gravels points to deposition via superconcentrated sediment flows that may have blocked a paleo Willamette River stream channel, forcing the river system eastward to its present location.

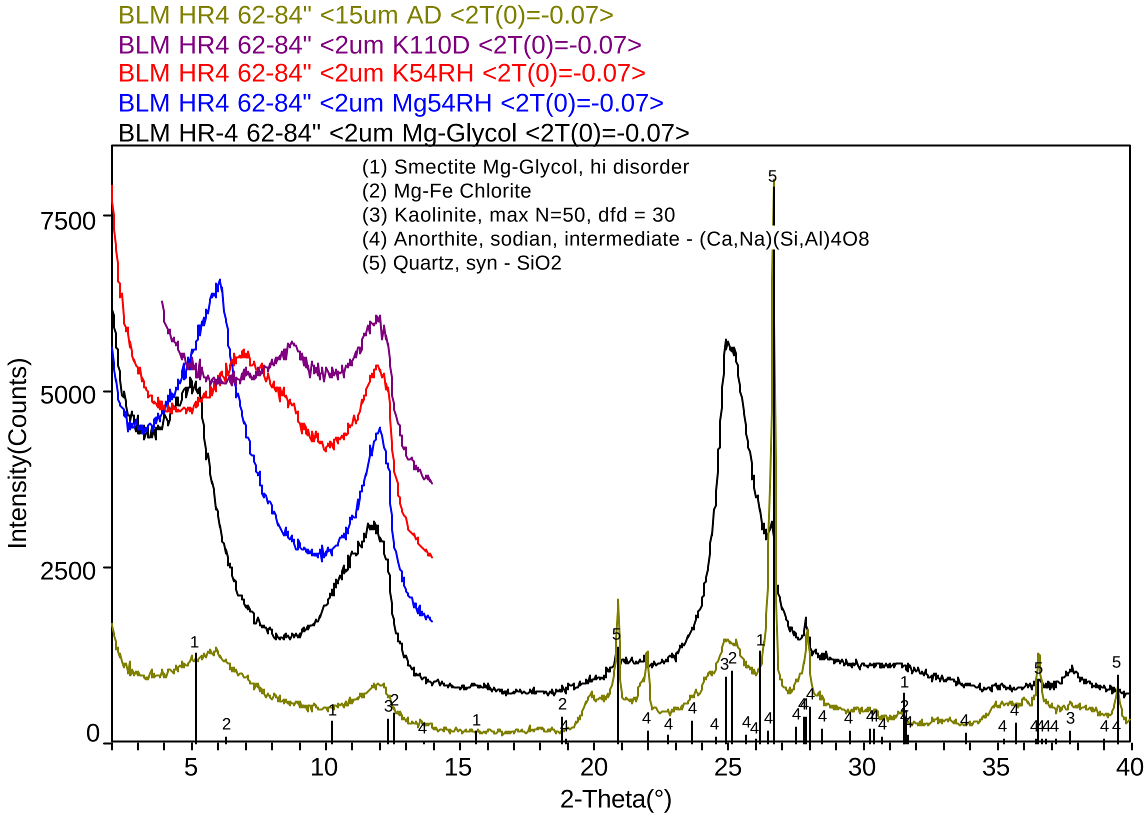


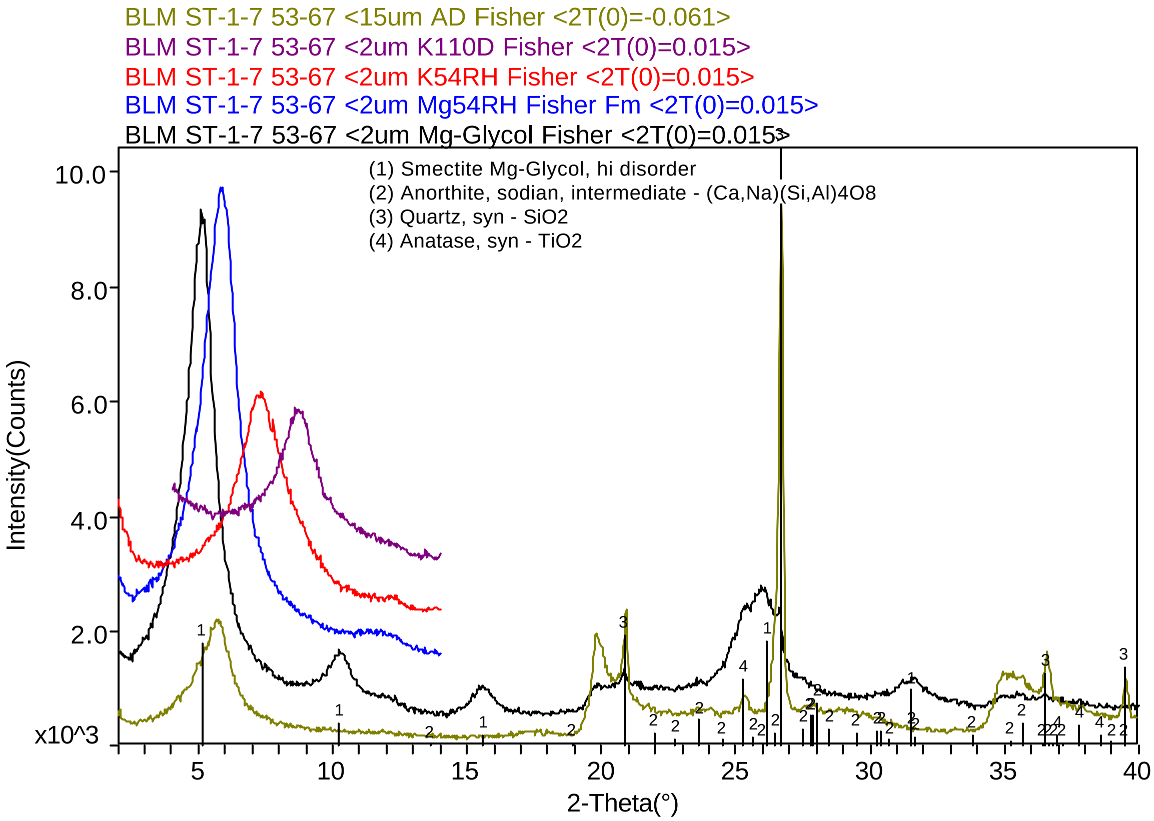
Figure 10. XRD patterns for the silt and clay fractions of soil from the “salt and pepper” zone of gravelly, sandy clay at the Harvest Ridge location (62-84 inches deep). The silt fraction is somewhat enriched in feldspar relative to the overlying sandy clay unit, but otherwise the strata appear genetically related, exhibiting strongly similar clay assemblages. The poorly sorted gravelly clay of this unit may be similar in origin to the channel-filling mudflow deposit observed in Trench 1. The gravelly clay is underlain by relatively unweathered sands and gravels of Cascade provenance.

Conclusions

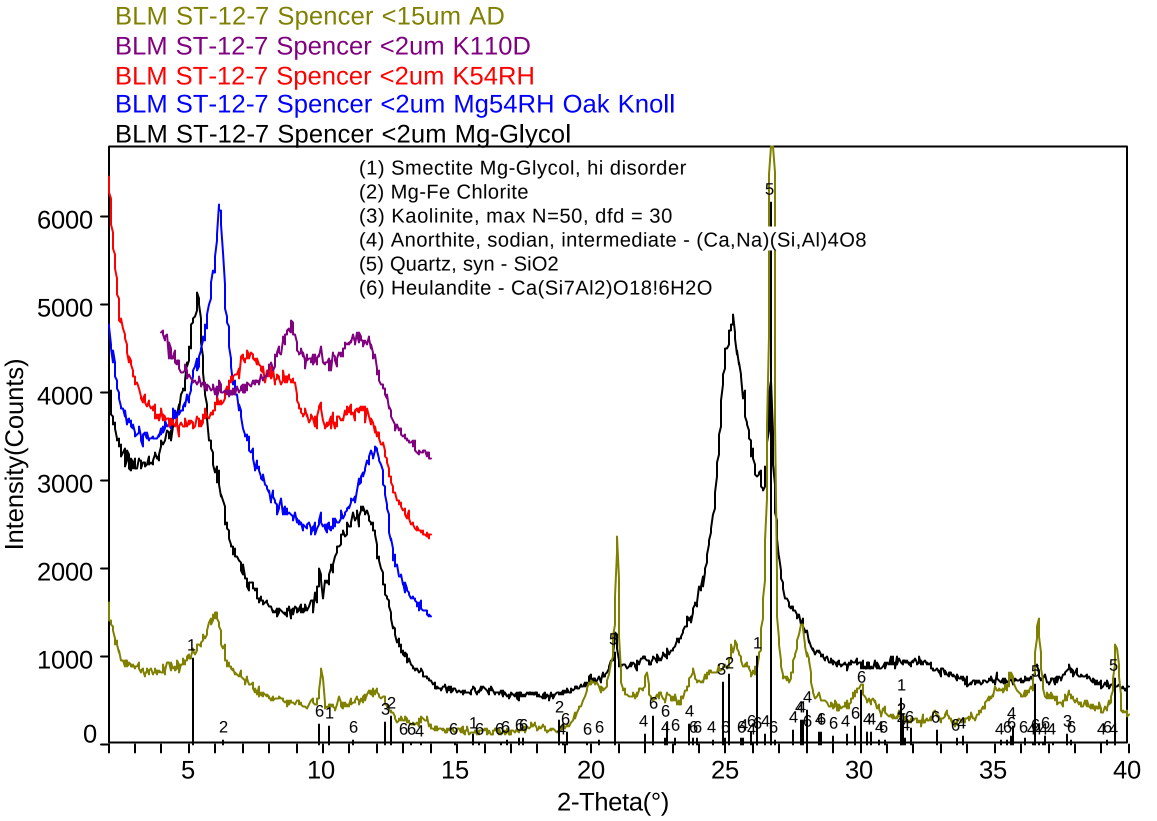
The soil samples taken from the southwestern Willamette Valley have more typical Cascadian clay mineralogy in the lower units (T-1 #8, HR 62-84") and atypical mineralogies in the yellowish sandy clay and the more surficial grey clay. One explanation would be that some of the samples have been subjected to moderate weathering that has caused a major quartz enrichment of the fine soil. However, the pattern of quartz enrichment is unlike that observed in relict and buried paleosols exposed on the margins of the southern Willamette Valley. In these soils, feldspar is typically absent and the quartz occurs in association with large amounts of disordered kaolin and chloritic intergrade. In the wetland soils, plagioclase feldspar is typically present in moderate amounts in the silt fraction and the intermediate calcic composition indicates derivation from andesitic or basaltic volcanic rocks. An halloysitic component is common in most wetland soils and probably indicates pedogenic clay formation; however, clay genesis may not have occurred in situ, but the halloysite could have been transported as a component of Cascadian mudflow deposits. If these sediments were primarily derived from the Cascades, the strong halloysitic component would imply shallow-seated mass failure erosion sources, as deep-seated soil erosion produces a smectite/zeolite/plagioclase dominated sediment (not the smectite/halloysite/quartz clays we see here). This anomaly is worth noting since zeolite is generally absent (excluding Trench 2 grey clays). The general absence of mica and K-feldspar precludes contributions from Missoula Flood silts in this area. Most of the wetland soils in this part of the southwestern Willamette Valley lie elevationally well above the pinchout of Missoula Flood deposits observed along the margins of the valley to the north of the study area. The occurrence of a minor component of well-ordered kaolinite in some of the surficial clays seems to suggest a Willamette River source, possibly reflecting erosion of hydrothermally altered rocks found in the Coast Fork drainage. The initial quartz-poor, non-kaolinitic, smectite-rich mineralogy of the fluvial sediments at the base of the wetland stratigraphic succession suggests a strong influence of the McKenzie River, as modern Willamette River gravels near Eugene contain a component of well-ordered kaolinite.

The stratigraphic succession from cross-stratified stream sands and gravels of Cascadian origin to extremely poorly sorted gravelly clay is indicative of channel plugging by superconcentrated mud flows that ultimately caused channel avulsion, changing the Amazon channel complex from an area of active Cascade fluvial channel deposition to one of distal floodplain clay deposition. Though this study is of a reconnaissance nature and evaluated widely scattered stratigraphic units, critical evidence supports the Cascadian stream-dominated nature of the wetland, with subsequent modification by accumulation of overbank clays from a variety of sources. More detailed study of vertical soil profiles taken along cross-channel and channel parallel transects would better reveal mineralogical trends in the wetland and assist in identifying local sediment sources.

None of the sediments indicate Missoula Flood origin, as the Missoula deposits are enriched in mica, chlorite, and K-feldspar – phases that are not present in any of the West Eugene wetland samples discussed thus far. There is also nothing "Dayton" about these wetland soils, (Dayton soils are mapped in the sample area) they don't have the look of the deeply weathered deposits of low-elevation foothills soils which have a very long history of weathering.



This pattern represents a paleosol developed in the Fisher Formation. The clay assemblage is dominated by smectite. The silt fraction contains moderate amounts of quartz and almost no plagioclase, indicating prolonged weathering and destruction of feldspar in the paleosols just upslope from the wetlands. The presence of anatase is also indicative of severe weathering – it is a residual mineral that is concentrated by intense weathering. The highly smectitic clay assemblage results from weathering of tuffaceous sediments. Erosion of such Fisher-sourced clays could be a means of adding smectite and quartz, while keeping a much lower plagioclase/quartz ratio than common in Cascade streams.



This pattern represents the Spencer Formation in a paleosol adjacent to the wetland. Note that the Spencer is not micaceous and contains a moderate zeolite component (heulandite). The Spencer formation is a complex unit that includes sand, silt, clay, and tuffaceous interbeds. This deposit must have some tuffaceous influence. The halloysitic/smectitic nature of the clay assemblage is typical of many valley margin paleosol deposits, however, the moderate abundance of plagioclase feldspar in the silt fraction, as well as the occurrence of zeolite, suggests that this material is not as highly weathered as the paleosol materials illustrated in Figures 1 and 2.

APPENDIX F

NEUTRON ACTIVATION ANALYSIS

	1u66201b.ufo			1u66202a.ufo			1u66203a.ufo			1u66204a.ufo			1u66205a.ufo			1u66206a.ufo			1u66207a.ufo			1u66208a.ufo		
	BLM 15-2			**BLM 15-3**			**BLM 15-6**			**BLM 4-3**			**BLM 4-5**			**BLM 4-10**			**BLM 1-5**			**BLM 1-3**		
Na2O (%)	1.724	±	0.003	2.319	±	0.009	3.12	±	0.05	1.06	±	0.03	1.27	±	0.04	1.17	±	0.06	0.75	±	0.06	0.82	±	0.07
K2O (%)	0.63	±	0.06	0.9	±	0.2	1.9	±	0.5	1.1	±	0.3	0.7	±	0.3	1.1	±	0.4	1.4	±	0.4	1.3	±	0.3
As (ppm)	8.6	±	0.2	9.5	±	0.4	9	±	2	30	±	2	29	±	2	45	±	3	31	±	2	34	±	3
Br (ppm)	3.2	±	0.6	6	±	1	3	±	1	1.7	±	0.8	1.2	±	0.7	2	±	1	5	±	1	6	±	1
Ba (ppm)	354	±	59	441	±	54	458	±	39	283	±	37	319	±	38	302	±	42	322	±	35	289	±	45
La (ppm)	19.1	±	0.1	17.2	±	0.2	16.9	±	0.2	18.5	±	0.3	17.9	±	0.2	19.9	±	0.3	25.6	±	0.3	26.2	±	0.4
Sm (ppm)	5.07	±	0.02	4.69	±	0.03	4.40	±	0.04	4.74	±	0.04	4.21	±	0.04	5.38	±	0.05	5.15	±	0.05	5.54	±	0.05
Yb (ppm)	2.4	±	0.1	2.3	±	0.1	2.0	±	0.1	2.6	±	0.1	2.4	±	0.1	3.7	±	0.1	3.6	±	0.2	4.0	±	0.2
Lu (ppm)	0.43	±	0.02	0.40	±	0.02	0.39	±	0.03	0.45	±	0.02	0.39	±	0.02	0.63	±	0.02	0.58	±	0.02	0.61	±	0.02
W (ppm)	1.1	±	0.4		<	2.506570816	9	±	5	7	±	5	10	±	5		<	17.6357193	18	±	8	19	±	10
Au (ppm)	0.002	±	0.001	0.004	±	0.002	0.005	±	0.003	0.006	±	0.002	0.007	±	0.003	0.007	±	0.003	0.006	±	0.002	0.008	±	0.003
U (ppm)	1.1	±	0.2	0.7	±	0.3	1.5	±	0.4	1.7	±	0.4	1.4	±	0.4	1.5	±	0.4	1.9	±	0.4	2.5	±	0.5
La/Yb	7.889943083			7.412624541			8.267274759			7.155773714			7.527883565			5.317728195			7.095876095			6.489520277		

NeutronActivation

	1u66209.ufo			1u66210.ufo			1u66211.ufo			1u66212.ufo			1u66213.ufo			1u66214.ufo			1u66215.ufo			1u66216.ufo		
	BLM 1-7			**BLM 6-2**			**BLM 7-2**			**BLM 8-3**			**BLM 8-6**			**BLM 8-9**			**BLM 6-2 >50M**			**BLM 6-2 <50M**		
Na2O (%)	0.151	±	0.006	0.846	±	0.007	1.257	±	0.007	0.850	±	0.007	0.88	±	0.02	0.61	±	0.02	3.92	±	0.02	1.55	±	0.01
K2O (%)	0.5	±	0.3	0.5	±	0.3	1.0	±	0.3	0.6	±	0.3	1.6	±	0.8		<	1.544540882	2	±	1	1.4	±	0.8
As (ppm)	17.1	±	0.5	18.9	±	0.5	21.3	±	0.5	8.3	±	0.4	10.2	±	0.8	5.8	±	1.0	105	±	1	19.6	±	0.6
Br (ppm)	0.7	±	0.3	4.1	±	0.7	2.2	±	0.4	3.5	±	0.6	1.3	±	0.4	1.4	±	0.6	1.2	±	0.4	0.8	±	0.3
Ba (ppm)	203	±	45	177	±	38	316	±	37	178	±	31	570	±	44	349	±	48	196	±	20	270	±	26
La (ppm)	42.7	±	0.3	22.3	±	0.2	29.1	±	0.2	25.3	±	0.2	29.5	±	0.2	51.2	±	0.4	9.7	±	0.1	11.2	±	0.1
Sm (ppm)	5.89	±	0.03	5.42	±	0.02	7.18	±	0.03	5.07	±	0.02	7.45	±	0.03	10.75	±	0.05	2.07	±	0.02	2.27	±	0.02
Yb (ppm)	2.2	±	0.1	2.7	±	0.1	3.5	±	0.1	2.3	±	0.1	4.5	±	0.1	2.3	±	0.1	1.02	±	0.06	2.01	±	0.09
Lu (ppm)	0.36	±	0.02	0.47	±	0.02	0.55	±	0.02	0.38	±	0.02	0.75	±	0.02	0.38	±	0.02	0.19	±	0.01	0.35	±	0.01
W (ppm)		<	2.252485037	3	±	1	2	±	1	2	±	1	6	±	3	6	±	3		<	3.102603912	3	±	1
Au (ppm)	0.005	±	0.002	0.005	±	0.001	0.003	±	0.001	0.004	±	0.002	0.007	±	0.002	0.008	±	0.002	0.003	±	0.001	0.003	±	0.001
U (ppm)	1.0	±	0.3	1.7	±	0.2	1.5	±	0.2	2.0	±	0.2	1.4	±	0.2	1.3	±	0.3	0.8	±	0.2	1.3	±	0.2
La/Yb	19.57633679			8.363354957			8.276299413			10.95152751			6.611536492			22.65613843			9.521036212			5.589486154		

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Instrumental Neutron Activation Analysis

Project Number 1662

Sample #	BLM 15-2		BLM 15-3		BLM 15-6		BLM 4-3		Uncertainty
OSU #	166201	error2	166202	error	166203	error	166204	error	
FeO (%)	6.48 ±	0.02	7.30 ±	0.0	6.93 ±	0.0	6.72 ±	0.01	5%
Na2O (%)	1.724 ±	0.003	2.319 ±	0.009	3.12 ±	0.05	1.06 ±	0.03	3%
K2O (%)	0.63 ±	0.06	0.9 ±	0.2	1.9 ±	0.5	1.1 ±	0.3	15%
Sc (ppm)	21.58 ±	0.03	22.42 ±	0.03	19.84 ±	0.02	18.75 ±	0.02	3%
Cr (ppm)	89.0 ±	0.6	89.1 ±	0.7	85.5 ±	0.3	103.4 ±	0.4	10%
Co (ppm)	17.5 ±	0.10	20.9 ±	0.12	21.00 ±	0.06	14.45 ±	0.06	5%
Ni (ppm)	24 ±	13	67 ±	11	43 ±	5	28 ±	5	12%
Zn (ppm)	70 ±	2	79 ±	2	89 ±	2	62 ±	1	15%
As (ppm)	8.6 ±	0.2	9.5 ±	0.4	8.8 ±	1.8	30.0 ±	2.0	5%
Sb (ppm)	0.87 ±	0.09	0.75 ±	0.07	0.62 ±	0.04	0.16 ±	0.03	5%
Rb (ppm)	17 ±	2	18 ±	2	22 ±	1	22 ±	1	10%
Cs (ppm)	1.66 ±	0.08	2.04 ±	0.09	1.71 ±	0.04	1.42 ±	0.05	5%
Sr (ppm)	307 ±	34	435 ±	46	472 ±	35	106 ±	17	12%
Ba (ppm)	354 ±	59	441 ±	54	458 ±	39	283 ±	37	10%
La (ppm)	19.1 ±	0.1	17.2 ±	0.2	16.9 ±	0.2	18.5 ±	0.3	3%
Ce (ppm)	39.5 ±	0.4	36.3 ±	0.4	33.9 ±	0.2	36.6 ±	0.2	7%
Nd (ppm)	23.7 ±	0.9	21.8 ±	1.0	18.8 ±	0.6	19.8 ±	0.6	12%
Sm (ppm)	5.07 ±	0.02	4.69 ±	0.03	4.40 ±	0.04	4.74 ±	0.04	5%
Eu (ppm)	1.76 ±	0.03	1.50 ±	0.03	1.42 ±	0.02	1.41 ±	0.02	5%
Tb (ppm)	0.91 ±	0.04	0.87 ±	0.04	0.76 ±	0.03	0.82 ±	0.05	5%
Yb (ppm)	2.8 ±	0.1	2.6 ±	0.2	2.5 ±	0.3	2.7 ±	0.2	5%
Lu (ppm)	0.43 ±	0.02	0.42 ±	0.01	0.37 ±	0.01	0.41 ±	0.01	5%
Zr (ppm)	140 ±	38	180 ±	35	131 ±	20	223 ±	21	10%
Hf (ppm)	4.75 ±	0.07	4.24 ±	0.07	4.12 ±	0.04	6.88 ±	0.06	5%
Ta (ppm)	0.60 ±	0.04	0.54 ±	0.03	0.51 ±	0.02	1.05 ±	0.03	5%
Th (ppm)	3.25 ±	0.05	2.87 ±	0.05	2.73 ±	0.02	3.95 ±	0.03	5%
U (ppm)	0.6 ±	0.1	0.7 ±	0.3	0.6 ±	0.2	1.6 ±	0.2	7%
Au (ppb)	2 ±	1	4 ±	2	5 ±	3	6 ±	2	10%
Ir (ppb)	<	3					<	1	10%

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Sample #	BLM 4-5		BLM 4-10		BLM 1-5		BLM 1-3		Uncertainty
OSU #	166205	error	166206	error	166207	error	166208	error	
FeO (%)	7.01 ±	0.02	7.26 ±	0.0	6.64 ±	0.01	7.20 ±	0.01	5%
Na2O (%)	1.27 ±	0.04	1.17 ±	0.06	0.75 ±	0.06	0.82 ±	0.07	3%
K2O (%)	0.7 ±	0.3	1.1 ±	0.4	1.4 ±	0.4	1.3 ±	0.3	15%
Sc (ppm)	19.35 ±	0.02	19.58 ±	0.03	15.53 ±	0.02	16.53 ±	0.02	3%
Cr (ppm)	78.4 ±	0.5	106.6 ±	0.7	60.0 ±	0.4	68.6 ±	0.4	10%
Co (ppm)	12.02 ±	0.07	16.6 ±	0.10	20.81 ±	0.08	18.24 ±	0.06	5%
Ni (ppm)	31 ±	7	31 ±	11	23 ±	6	22 ±	5	12%
Zn (ppm)	69 ±	1.866	66 ±	2.328	80 ±	1.677	80 ±	1.557	15%
As (ppm)	29 ±	2	45 ±	3	31 ±	2	34 ±	3	5%
Sb (ppm)	0.35 ±	0.04	0.53 ±	0.07	0.39 ±	0.04	0.91 ±	0.05	5%
Rb (ppm)	23 ±	2	22 ±	2	30 ±	2	28 ±	1	10%
Cs (ppm)	1.59 ±	0.07	1.00 ±	0.09	1.34 ±	0.05	1.42 ±	0.05	5%
Sr (ppm)	166 ±	25	122 ±	33	110 ±	18	109 ±	16	12%
Ba (ppm)	319 ±	38	302 ±	42	322 ±	35	289 ±	45	10%
La (ppm)	17.9 ±	0.2	19.9 ±	0.3	25.6 ±	0.3	26.2 ±	0.4	3%
Ce (ppm)	35.8 ±	0.3	38.1 ±	0.4	45.0 ±	0.3	45.6 ±	0.3	7%
Nd (ppm)	20.5 ±	0.8	22.4 ±	1.1	22.3 ±	0.7	25.5 ±	0.7	12%
Sm (ppm)	4.21 ±	0.04	5.38 ±	0.05	5.15 ±	0.05	5.54 ±	0.05	5%
Eu (ppm)	1.32 ±	0.02	1.61 ±	0.03	1.18 ±	0.02	1.28 ±	0.02	5%
Tb (ppm)	0.63 ±	0.05	1.02 ±	0.04	0.93 ±	0.03	1.02 ±	0.10	5%
Yb (ppm)	2.4 ±	0.1	3.8 ±	0.2	3.7 ±	0.1	4.0 ±	0.2	5%
Lu (ppm)	0.37 ±	0.03	0.61 ±	0.04	0.58 ±	0.02	0.61 ±	0.02	5%
Zr (ppm)	205 ±	29	239 ±	42	322 ±	31	372 ±	32	10%
Hf (ppm)	6.25 ±	0.07	7.93 ±	0.09	11.64 ±	0.09	12.22 ±	0.09	5%
Ta (ppm)	0.94 ±	0.03	1.22 ±	0.04	1.53 ±	0.04	1.63 ±	0.05	5%
Th (ppm)	3.90 ±	0.04	3.56 ±	0.05	5.03 ±	0.03	5.32 ±	0.03	5%
U (ppm)	1.0 ±	0.2	1.8 ±	0.3	1.7 ±	0.3	1.5 ±	0.3	7%
Au (ppb)	7 ±	3	7 ±	3	6 ±	2	8 ±	3	10%
Ir (ppb)	<	2	<	1			<	1	10%

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Instrumental Neutron Activation Analysis

Project Number 1662

Sample #	BLM 1-7		BLM 6-2		BLM 7-2		BLM 8-3		Uncertainty
OSU #	166209	error	166210	error	166211	error	166212	error	
FeO (%)	7.91 ±	0.0	6.65 ±	0.0	5.95 ±	0.0	6.42 ±	0.0	5%
Na2O (%)	0.151 ±	0.006	0.846 ±	0.007	1.257 ±	0.007	0.850 ±	0.007	3%
K2O (%)	0.5 ±	0.3	0.5 ±	0.3	1.0 ±	0.3	0.6 ±	0.3	15%
Sc (ppm)	23.98 ±	0.02	18.39 ±	0.02	16.45 ±	0.02	17.37 ±	0.02	3%
Cr (ppm)	11.3 ±	0.4	117.9 ±	0.5	104.1 ±	0.7	154.5 ±	0.5	10%
Co (ppm)	26.70 ±	0.09	10.51 ±	0.05	50.6 ±	0.16	8.49 ±	0.05	5%
Ni (ppm)	31 ±	11	33 ±	8	22 ±	9	34 ±	9	12%
Zn (ppm)	120 ±	2.285	57 ±	1.397	55 ±	2.042	57 ±	1.383	15%
As (ppm)	17.1 ±	0.5	18.9 ±	0.5	21.3 ±	0.5	8.3 ±	0.4	5%
Sb (ppm)	0.43 ±	0.05	0.26 ±	0.03	0.37 ±	0.05	0.57 ±	0.04	5%
Rb (ppm)	16 ±	7	16 ±	1	29 ±	3	20 ±	2	10%
Cs (ppm)	1.06 ±	0.06	1.75 ±	0.05	2.06 ±	0.07	2.31 ±	0.06	5%
Sr (ppm)	65 ±	24	77 ±	17	170 ±	29	115 ±	24	12%
Ba (ppm)	203 ±	45	177 ±	38	316 ±	37	178 ±	31	10%
La (ppm)	42.7 ±	0.3	22.3 ±	0.2	29.1 ±	0.2	25.3 ±	0.2	3%
Ce (ppm)	63.2 ±	0.4	47.7 ±	0.3	63.2 ±	0.4	44.6 ±	0.3	7%
Nd (ppm)	32.1 ±	1.0	24.9 ±	0.9	31.3 ±	1.2	23.9 ±	0.9	12%
Sm (ppm)	5.89 ±	0.03	5.42 ±	0.02	7.18 ±	0.03	5.07 ±	0.02	5%
Eu (ppm)	1.57 ±	0.02	1.54 ±	0.02	2.20 ±	0.03	1.37 ±	0.02	5%
Tb (ppm)	0.92 ±	0.04	0.79 ±	0.10	1.08 ±	0.10	0.73 ±	0.09	5%
Yb (ppm)	2.2 ±	0.1	2.8 ±	0.3	3.5 ±	0.1	2.5 ±	0.2	5%
Lu (ppm)	0.32 ±	0.04	0.43 ±	0.03	0.55 ±	0.02	0.38 ±	0.02	5%
Zr (ppm)	213 ±	28	302 ±	30	295 ±	35	296 ±	28	10%
Hf (ppm)	6.06 ±	0.08	8.83 ±	0.07	8.36 ±	0.08	9.94 ±	0.10	5%
Ta (ppm)	0.94 ±	0.03	1.25 ±	0.04	1.09 ±	0.04	1.07 ±	0.03	5%
Th (ppm)	2.60 ±	0.04	4.54 ±	0.03	4.71 ±	0.05	5.94 ±	0.04	5%
U (ppm)	0.4 ±	0.2	1.3 ±	0.1	1.3 ±	0.1	2.1 ±	0.1	7%
Au (ppb)	5 ±	2	5 ±	1	3 ±	1	4 ±	2	10%
Ir (ppb)	<	2	<	2					10%

Oregon State University

Radiation Center

Instrumental Neutron Activation Analysis

Project Number 1662

Sample #	BLM 8-6		BLM 8-9		BLM 6-2 >50M		BLM 6-2 <50M		Uncertainty
OSU #	166213	error	166214	error	166215	error	166216	error	
FeO (%)	6.45 ±	0.0	7.34 ±	0.0	7.54 ±	0.0	4.31 ±	0.04	5%
Na2O (%)	0.88 ±	0.02	0.61 ±	0.02	3.92 ±	0.02	1.55 ±	0.01	3%
K2O (%)	1.6 ±	0.8	<	1.545	2 ±	1	1.4 ±	0.8	15%
Sc (ppm)	15.52 ±	0.02	21.97 ±	0.02	4.00 ±	0.01	10.60 ±	0.04	3%
Cr (ppm)	187.1 ±	0.7	111.1 ±	0.5	58.6 ±	0.6	130.4 ±	1.6	10%
Co (ppm)	20.92 ±	0.09	26.83 ±	0.09	23.8 ±	0.14	8.8 ±	0.2	5%
Ni (ppm)	52 ±	12	59 ±	10	14 ±	10	0 ±	0	12%
Zn (ppm)	55 ±	1.74	68 ±	1.747	22 ±	2.027	31 ±	5	15%
As (ppm)	10.2 ±	0.8	5.8 ±	1.0	105 ±	1	19.6 ±	0.6	5%
Sb (ppm)	0.53 ±	0.05	0.53 ±	0.04	0.77 ±	0.04	0.48 ±	0.04	5%
Rb (ppm)	18 ±	2	8 ±	1	8 ±	3	18 ±	3	10%
Cs (ppm)	1.19 ±	0.06	0.67 ±	0.05	0.60 ±	0.07	0.93 ±	0.17	5%
Sr (ppm)	158 ±	29	182 ±	24	285 ±	32			12%
Ba (ppm)	570 ±	44	349 ±	48	196 ±	20	270 ±	26	10%
La (ppm)	29.5 ±	0.2	51.2 ±	0.4	9.7 ±	0.1	11.2 ±	0.1	3%
Ce (ppm)	50.7 ±	0.4	117.1 ±	0.6	20.9 ±	0.4	23.7 ±	0.9	7%
Nd (ppm)	28.6 ±	1.3	52.3 ±	1.4	10.4 ±	1.3	8.4 ±	1.2	12%
Sm (ppm)	7.45 ±	0.03	10.75 ±	0.05	2.07 ±	0.02	2.27 ±	0.02	5%
Eu (ppm)	2.23 ±	0.03	2.95 ±	0.04	1.93 ±	0.03	0.82 ±	0.04	5%
Tb (ppm)	1.38 ±	0.07	1.02 ±	0.04	0.34 ±	0.03	0.33 ±	0.06	5%
Yb (ppm)	4.5 ±	0.1	2.8 ±	0.1	1.4 ±	0.1	2.0 ±	0.1	5%
Lu (ppm)	0.73 ±	0.04	0.38 ±	0.02	0.22 ±	0.02	0.35 ±	0.01	5%
Zr (ppm)	470 ±	42	212 ±	29	84 ±	25	460 ±	145	10%
Hf (ppm)	13.60 ±	0.11	5.34 ±	0.07	2.53 ±	0.08	15.20 ±	0.37	5%
Ta (ppm)	1.18 ±	0.04	0.63 ±	0.03	0.32 ±	0.03	1.22 ±	0.12	5%
Th (ppm)	4.36 ±	0.04	3.07 ±	0.04	2.05 ±	0.05	2.93 ±	0.10	5%
U (ppm)	1.0 ±	0.2	0.5 ±	0.2	0.7 ±	0.1	0.9 ±	0.1	7%
Au (ppb)	7 ±	2	8 ±	2	3 ±	1	3 ±	1	10%
Ir (ppb)			<	2	<	2	<	2	10%

Oregon State University

Radiation Center

Instrumental Neutron Activation Analysis

Project Number 1662

Sample #	SRM1633A		ALLENDE		SRM278		CRB-1		Uncertainty
OSU #	166217	error	166218	error	166219	error	166221		
FeO (%)	12.07 ±	0.0	31.17 ±	0.1	1.91 ±	0.01	11.84 ±	0.0	5%
Na2O (%)	0.250 ±	0.002	0.520 ±	0.004	4.800 ±	0.008	3.29 ±	0.02	3%
K2O (%)	2.40 ±	0.09	0.20 ±	0.08	3.7 ±	0.2	2.6 ±	0.6	15%
Sc (ppm)	40.12 ±	0.05	12.80 ±	0.05	5.32 ±	0.02	31.89 ±	0.03	3%
Cr (ppm)	194.8 ±	1.4	3681.0 ±	8.4	8.1 ±	0.6	11.4 ±	0.7	10%
Co (ppm)	42.8 ±	0.24	636 ±	1.68	3.01 ±	0.07	34.7 ±	0.15	5%
Ni (ppm)	147 ±	21	13995 ±	140	20 ±	8	31 ±	15	12%
Zn (ppm)	221 ±	5.55	111 ±	11.37	51 ±	2.247	131 ±	3.267	15%
As (ppm)	144.9 ±	0.9	1.6 ±	0.4	3.8 ±	0.4	1.3 ±	1.0	5%
Sb (ppm)	2.48 ±	0.23	0.46 ±	0.21	2.03 ±	0.14	0.16 ±	0.05	5%
Rb (ppm)	128 ±	5	26 ±	12	128 ±	3	47 ±	4	10%
Cs (ppm)	9.97 ±	0.23	0.00 ±	0.00	5.13 ±	0.12	0.95 ±	0.10	5%
Sr (ppm)	854 ±	81.7	922 ±	137.2	43 ±	26.46	292 ±	45.72	12%
Ba (ppm)	1251 ±	123	200 ±	138	1042 ±	139	713 ±	158	10%
La (ppm)	82.1 ±	0.4	0.9 ±	0.1	28.9 ±	0.3	25.1 ±	0.5	3%
Ce (ppm)	166.8 ±	1.0	8.5 ±	1.5	63.8 ±	0.5	49.4 ±	0.5	7%
Nd (ppm)	78.4 ±	2.4	6.9 ±	3.4	27.4 ±	1.3	25.6 ±	1.4	12%
Sm (ppm)	16.96 ±	0.06	0.38 ±	0.03	5.31 ±	0.03	6.34 ±	0.06	5%
Eu (ppm)	3.62 ±	0.07	0.12 ±	0.05	0.85 ±	0.03	1.87 ±	0.04	5%
Tb (ppm)	0.00 ±	0.00	0.17 ±	0.11	1.14 ±	0.05	0.00 ±	0.00	5%
Yb (ppm)	7.7 ±	0.3	0.6 ±	0.3	3.7 ±	0.3	3.1 ±	0.4	5%
Lu (ppm)	1.18 ±	0.06	0.09 ±	0.06	0.68 ±	0.05	0.52 ±	0.07	5%
Zr (ppm)	257 ±	56	244 ±	142	283 ±	31	187 ±	38	10%
Hf (ppm)	7.44 ±	0.13	0.31 ±	0.17	8.74 ±	0.10	4.94 ±	0.08	5%
Ta (ppm)	1.83 ±	0.09	0.34 ±	0.17	1.31 ±	0.06	0.75 ±	0.04	5%
Th (ppm)	24.82 ±	0.15	0.46 ±	0.16	12.50 ±	0.09	5.72 ±	0.07	5%
U (ppm)	9.8 ±	0.4	<	0.847	4.9 ±	0.3	1.7 ±	0.5	7%
Au (ppb)	8 ±	2	101 ±	7	7 ±	3	9 ±	6	10%
Ir (ppb)	<	5	810.00 ±	6.56			<	3	10%

C1 Chondrite Normalization

Sample	BLM 15-2	BLM 15-3	BLM 15-6	BLM 4-3	C1 chondrite Lit. Values1
Cs	6.71	8.24	6.93	5.74	0.247
Rb	5.59	5.83	7.35	7.08	3.04
K	7.10	10.27	20.95	12.68	0.0889
Th	81	72	68	99	0.0399
U	55	68	59	149	0.0107
Sr	29.54	41.87	45.42	10.19	10.40
Ba	117.93	146.91	152.58	94.32	3.00
La	61.18	55.02	54.07	59.32	0.312
Ce	48.58	44.59	41.74	45.04	0.813
Nd	39.38	36.11	31.12	32.77	0.603
Sm	25.73	23.80	22.34	24.04	0.197
Eu	23.78	20.32	19.14	19.07	0.074
Gd*	21.28	20.06	18.06	#NUM!	0.260
Tb	19.36	18.41	16.24	-	0.047
Yb	13.25	12.25	11.72	13.08	0.210
Lu	13.25	12.87	11.31	12.75	0.0323
Sc	2.80	2.91	2.58	2.43	7.7
Zr	28.58	36.70	26.77	45.48	4.9
Hf	30.26	26.99	26.24	43.81	0.157
Ta	29.23	26.21	24.66	51.10	0.0205

C1 Chondrite Normalization

Sample	BLM 4-5	BLM 4-10	BLM 1-5	BLM 1-3	C1 chondrit
0					Lit. Values1
Cs	6.45	4.05	5.44	5.74	0.247
Rb	7.45	7.16	9.84	9.28	3.04
K	8.06	11.96	16.13	14.75	0.0889
Th	98	89	126	133	0.0399
U	97	167	163	143	0.0107
Sr	15.94	11.71	10.62	10.47	10.40
Ba	106.38	100.72	107.27	96.42	3.00
La	57.46	63.88	81.98	83.85	0.312
Ce	44.02	46.85	55.32	56.10	0.813
Nd	33.92	37.22	37.01	42.37	0.603
Sm	21.37	27.33	26.15	28.11	0.197
Eu	17.86	21.73	15.93	17.33	0.074
Gd*	15.73	23.49	21.77	23.66	0.260
Tb	13.50	21.78	19.86	21.70	0.047
Yb	11.34	17.95	17.82	19.20	0.210
Lu	11.30	18.91	18.08	18.95	0.0323
Sc	2.51	2.54	2.02	2.15	7.7
Zr	41.83	48.71	65.75	75.88	4.9
Hf	39.82	50.54	74.11	77.85	0.157
Ta	45.89	59.62	74.44	79.37	0.0205

C1 Chondrite Normalization

Sample	BLM 1-7	BLM 6-2	BLM 7-2	BLM 8-3	C1 chondrite
0					Lit. Values10
Cs	4.27	7.08	8.33	9.35	0.247
Rb	5.18	5.28	9.68	6.66	3.04
K	5.28	5.72	11.41	6.20	0.0889
Th	65	114	118	149	0.0399
U	38	121	117	198	0.0107
Sr	6.25	7.42	16.32	11.04	10.40
Ba	67.78	58.87	105.17	59.39	3.00
La	136.94	71.59	93.23	81.19	0.312
Ce	77.68	58.64	77.70	54.91	0.813
Nd	53.18	41.28	51.85	39.68	0.603
Sm	29.92	27.51	36.44	25.73	0.197
Eu	21.16	20.76	29.67	18.45	0.074
Gd*	22.51	19.76	26.86	18.33	0.260
Tb	19.53	16.75	23.06	15.48	0.047
Yb	10.39	13.45	16.74	11.67	0.210
Lu	9.92	13.44	17.11	11.76	0.0323
Sc	3.11	2.39	2.14	2.26	7.7
Zr	43.51	61.62	60.15	60.49	4.9
Hf	38.62	56.27	53.22	63.32	0.157
Ta	45.71	60.79	52.93	52.10	0.0205

C1 Chondrite Normalization

Sample	BLM 8-6	BLM 8-9	BLM 6-2 >50M	BLM 6-2 <50M	C1 chondrite
0					Lit. Values10
Cs	4.82	2.73	2.43	3.76	0.247
Rb	6.03	2.61	2.57	5.99	3.04
K	18.25	-	20.08	15.81	0.0889
Th	109	77	51	74	0.0399
U	95	50	61	86	0.0107
Sr	15.24	17.53	27.44	-	10.40
Ba	190.05	116.39	65.24	89.96	3.00
La	94.67	164.07	31.18	35.98	0.312
Ce	62.40	144.09	25.70	29.11	0.813
Nd	47.45	86.73	17.20	13.98	0.603
Sm	37.83	54.57	10.51	11.52	0.197
Eu	30.18	39.83	26.11	11.14	0.074
Gd*	31.98	29.55	8.17	8.32	0.260
Tb	29.41	21.75	7.20	7.07	0.047
Yb	21.27	13.26	6.65	9.56	0.210
Lu	22.71	11.84	6.80	10.85	0.0323
Sc	2.02	2.85	0.52	1.38	7.7
Zr	95.93	43.19	17.11	93.91	4.9
Hf	86.65	34.03	16.13	96.81	0.157
Ta	57.78	30.85	15.74	59.55	0.0205

APPENDIX G

SOIL AND WATER CONDUCTIVITY

Appendix G Soil and Water Conductivity

Site	Date	F mg/l	Cl mg/l	NO2 mg/l	Br mg/l	NO3 mg/l	PO4 mg/l	SO4 mg/l	cond uS/cm	Anions mNormality	conductivity uS/(cm.mN)
5 B-2 Trench 1 #2	?	0.056	2.561	0	0.023	0.252	0	2.746	28.3	0.137	207
10 Site 1 #3 grey clay	1/25/2002	0.02	82.492		0.089	0.543		42.474	335.7	3.220	104
3 B-4 Trench1 #4	?	0.122	39.16					37.6	257.4	1.893	136
3 BLM Trench 1 #5	3/11/2002	0.174	50.563	0	0.024	0.59	0	26.065	266.2	1.986	134
6 Trench 2 #2	?	0.051	0.453			0.224		0.912	14.1	0.038	370
2 Trench 2 #3	?	0.136	2.972	0	0	0.105	0	1.301	23.6	0.120	197
2 Trench 2 #4	?	0.852	1.37			4.64		3.253	64.9	0.226	287
9 Trench 2 #5	?	0.115	1.044	0	0	3.431	0	1.456	55.4	0.121	457
4 Site 2 #3 proj. 1135	?	0.117	3.05			0.68		1.388	26.4	0.132	200
5 Braeburn Cr. Bedrock	?	0.043	0.0356			0.047		0.258	29.2	0.009	3,107
7 Pine Forest Rd Rock Flow	?	0.045	1.93			0.32		0.486	14.2	0.072	197
7 Braeburn Cr. Soil Profile@Willamette	?	0.582	0.747	0.043	0	5.291	0.034	2.05	74.8	0.181	412
6 Greyish Nodules Breaburn Cr.	?	0.053	0.301					0.594	69	0.024	2,918
10 Braeburn Cr. soilprofile@Willamette 58"	?	0.641	3.694	0.026	0	0.366	0	2.708	38.5	0.201	192
4 Braeburn@Willamette 70"	?	0.196	0.65			5.497	0.105	2	130	0.161	807
5 Oxbow West 20"	?	0.045	0.884			0.104		1.277	16.3	0.056	293
10 Eugene 675 Sand St@frnt Skinner Butte	?	0.207	1.074					2.289	28.9	0.089	325
9 Jean Ct. 4.8-5.3'	2/2/2002	0.012	1.758					3.865	22.3	0.131	171
8 Oxbow West@Dayton 20"	3/22/2002	0.105	1.103			0.024		0.634	13.6	0.050	271
2 Headwtrs of Ama S. of Martin	2/12/2002	0.046	2.635			0.01	0.008	2.21	79.3	0.123	645
8 Braeburn Cr/Upper Zone	?	0.165	0.675	0	0	0.356	0	2.741	180.3	0.091	1,991
4 Braeburn Crk.@brookside	?	0.397	9.319	0	0	0	0.36	1.518	53.6	0.323	166
2 Braeburn Cr.@Brookside ln midslope	?	0.08	2.72	0	0	0.89	0.045	2.341	47.9	0.145	331
7 Amazon? Sequence@Greenhill diversion chnl.	?	0.837	0.586			2.854	0.038	0.627	54.4	0.120	452
6 Tugman Cr.	2/10/2002	0.029	3.513					11.808	194.2	0.346	560
4 Grass seed field near J.City	2/12/2002		2.145			6.5		14.96	168	0.477	352
3 Dexter	11/15/2001	0.022	0.911			0.023		0.476	55	0.037	1,482
6 Irish bend Upper layer	?	0.043	1.185	0	0.028	0.328	0	3.334	23.5	0.111	212
5 Irish Bend 10-12' from surface	?	0.454	3.35			0.016		2.854	42.6	0.178	239
9 Irish Bend-Paleosol	?	0.638	1.041			0.028	0.243	0.663	46.9	0.082	570

		F	Cl	NO2	Br	NO3	PO4	SO4	cond	Anions	conductivity
Site	**Date**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**uS/cm**	**mNormality**	**uS/(cm.mN)**
BLMst-1-1 Baily Hillu -0-6.5 "	12/13/2002	0.039	1,451	0.004		0.109	0.012	0.74	21.5	40.893	1
BLMst-1-2 Baily Hillu -6.5-17.5"	12/13/2002	0.005	0.608			1.441	0.155	0.64	11.2	0.057	196
BLMst-1-3 Baily Hillu-17.5 - 30.5"	12/13/2002	0.009	0.522	0.004		0.035	0.002	0.439	9.46	0.025	378
BLMst-1-4 Baily Hillu-30.5-35"	12/13/2002	0.03	0.83			0.012		1.671	12.6	0.060	210
BLMst-1-5 Baily Hillu-35-38"	12/13/2002	0.015	0.638			0.004	0.001	1.235	10.9	0.045	245
BLMst-1-6 Baily Hillu-38-53.5"	12/13/2002	0.005	0.843			0.003	0.004	1.54	11.9	0.056	212
BLMst-1-7 Baily Hillu-53.5-67"	12/13/2002	0.009	0.818			0.004	0.003	1.475	10.3	0.054	189
BLMst-2-1 Baily Hillm -0-7 "	12/13/2002	0.003	1.096			0.014		0.879	18.4	0.050	371
BLMst-2-2 Baily Hillm - 7-11.5 "	12/13/2002	0.004	0.593			0.004	0.007	0.302	8.9	0.023	380
BLMst-2-3 Baily Hillm -11.5-21 "	12/13/2002	0.006	0.546			0.02	0.007	0.379	10.1	0.024	420
BLMst-2-4 Baily Hillm -21- 25 "	12/13/2002	0.008	0.522			0.003		0.254	7.0	0.020	342
BLMst-2-5 Baily Hillm -25-36 "	12/13/2002	0.013	0.577			0.013	0.004	0.544	7.4	0.029	259
BLMst-3-1 Baily Hillt -0-7 "	12/13/2002	0.012	1.563			0.001		1.572	31.9	0.077	412
BLMst-3-2 Baily Hillt -7- 21 "	12/13/2002	0.036	0.577			0.007		0.692	15.9	0.033	487
BLMst-3-3 Baily Hillt - 21- 30 "	12/13/2002	0.048	0.522			0.009	0.004	0.694	14.4	0.032	451
BLMst-3-4 Baily Hillt - 30-43"	12/13/2002	0.06	1.147			0.003	0.011	2.709	19.2	0.092	208
BLMst-3-5 Baily Hillt - 43-51"	12/13/2002	0.119	0.727			0.003	0.142	1.757	15.1	0.066	227
BLMst-3-6 Baily Hillt - 51-56"	12/13/2002	0.068	0.707			0.003	0.03	1.265	11.6	0.051	230
BLMst-3-7 Baily Hillt - 56- 61"	12/13/2002	0.069	0.537			0.003	0.026	0.475	8.2	0.029	280
BLMst-3-8 Baily Hillt -61-67"	12/13/2002	0.103	1.323			0.029	0.217	0.912	13.4	0.067	201
BLMst-3-9 Baily Hillt 67-72.5"	12/13/2002	0.477	0.483			0.005	0.019	0.309	23.8	0.046	522
BLMst-4-1 Wil.Cr. S.18th 0-9"	12/13/2002	0.06	2.058			0.75	0.003	0.918	104.3	0.092	1,129
BLMst-4-2 Wil.Cr. S.18th 9-15"	12/13/2002	0.021	0.685					1.01	11	0.041	265
BLMst-4-3 Wil.Cr. S.18th 15-26"	12/13/2002	0.051	1.743			0.001		0.288	12.4	0.058	215
BLMst-4-4 Wil.Cr. S.18th 26-37"	12/13/2002		20.027					0.144	91.6	0.567	162
BLMst-4-5 Wil.Cr. S.18th37-46"	12/13/2002	0.008	137.657		0.088		0.004	0.282	471	3.885	121
BLMst-4-6 Wil.Cr. S.18th 46-50"	12/13/2002	0.021	126.353		0.081		0.005	0.16	430	3.565	121
BLMst-4-7 Wil.Cr. S.18th 50-56 "	12/13/2002	0.036	124.658		0.08		0.004	0.375	426	3.522	121
BLMst-4-8 Wil.Cr. S.18th 56-63.5 "	12/13/2002	0.05	156.914		0.098	0.003	0.077	0.484	410	4.436	92
BLMst-4-9 Wil.Cr. S.18th 63.5-67"	12/13/2002	0.37	120.501		0.085		0.002	0.752	525	3.431	153
BLMst-4-10 Wil.Cr. S.18th 67-77"	12/13/2002	0.284	133.895		0.094	0.029	0.01	0.947	491	3.808	129

		F	Cl	NO2	Br	NO3	PO4	SO4	cond	Anions	conductivity
Site	**Date**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**uS/cm**	**mNormality**	**uS/(cm.mN)**
BLMst-4-11 Wil.Cr. S.18th 77-85"	12/13/2002	0.277	138.77		0.093	0.004	0.007	0.961	467	3.945	118
BLMst-4-12 Wil.Cr. S.18th 85-95"	12/13/2002	0.374	64.751		0.031	0.005	0.005	1.073	466	1.867	250
BLMst-5-1a Wil.Cr. N.18th 0-6"	12/13/2002	0.036	2.094			0.074		1.923	22.5	0.102	220
BLMst-5-1b Wil.Cr. N.18th 0-6"	12/13/2002	0.045	3.357					1.497	28.4	0.128	222
BLMst-5-2 Wil.Cr. N.18th 6-11"	12/13/2002	0.09	0.798			0.258		0.757	11.53	0.047	245
BLMst-5-3 Wil.Cr. N.18th 11-14"	12/13/2002	0.187	0.761			0.035		1.31	10.87	0.059	184
BLMst-5-4 Wil.Cr. N.18th 14-20"	12/13/2002	0.107	3.859			0.014		1.223	25.9	0.140	185
BLMst-5-5 Wil.Cr. N.18th 20-29"	12/13/2002	0.057	28.28	0.018	0.02	0.004		3.034	124.7	0.864	144
BLMst-5-6 Wil.Cr. N.18th 29-36"	12/13/2002	0.063	104.427		0.088	0.022	0.013	17.694	413	3.315	125
BLMst-5-7 Wil.Cr. N.18th 36-47"	12/13/2002	0.092	46.916		0.047		0.005	12.449	214	1.586	135
BLMst-5-8 Wil.Cr. N.18th 47-61 "	12/13/2002	0.273	37.89		0.041	0.024	0.034	9.064	406	1.272	319
BLMst-5-9 Wil.Cr. N.18th 61-75 "	12/13/2002	0.517	56.854		0.06	0.072		7.673	259	1.790	145
BLMst-5-10 Wil.Cr. N.18th 75-82 "	12/13/2002	0.367	37.937		0.036	0.036	0.013	6.316	179	1.221	147
BLMst-6-1 Wil.Cr. S.11th 0-5"	12/13/2002	0.035	0.607			0.035		1.944	15.8	0.060	263
BLMst-6-2 Wil.Cr. S.11th 5-23"	12/13/2002	0.044	2.682			0.002		2.108	22.8	0.122	187
BLMst-6-3 Wil.Cr. S.11th 23-32"	12/13/2002	0.06	47.505		0.06	0.081		10.754	209	1.567	133
BLMst-6-4 Wil.Cr. S.11th 32-40"	12/13/2002	0.067	83.501		0.109	0.071		23.099	340	2.839	120
BLMst-6-5Wil.Cr. S.11th 40-48"	12/13/2002	0.083	145.698		0.179	0.08		31.381	551	4.766	116
BLMst-6-6 Wil.Cr. S.11th 48-53"	12/13/2002	0.069	193.761		0.23	0.054		40.091	672	6.301	107
BLMst-6-7 Wil.Cr. S.11th 53-71"	12/13/2002	0.065	179.93		0.209	0.054		25.198	618	5.600	110

APPENDIX H

CONDUCTIVITY OF SOD REMOVAL TREATMENT

"Top" soil samples from BLM sites.

S-0 ash grove
S-1 farmed
S-2 scraped 2002
S-3 scraped 1998
S-4 double scraped 2000, 2002
"Island" undisturbed in scraped field
Upland field, unplowed

Feb 6 soil samples

	F	**Cl**	**NO2**	**Br**	**NO3 ***	**PO4**	**SO4**	**cond**	normality	specific cond	
S-0	0.291	1.445	0.079	0.196	0.035	0.004	0.260	116.0	0.0663	1,751	
"	0.284	1.432	0.046	0.181	0.036	0.000		116.0	0.0591		with time going up
"	0.288	1.432	0.048	0.181	0.045	0.007		116.0	0.0597		lst measurement
S-0 AVG	**0.288**	**1.436**	**0.058**	**0.186**	**0.039**	**0.004**	**0.260**	116.0	0.0653	1,777	
									-		
S-1	0.132	1.893	0.017	0.115	0.090	0.002	0.320	59.3	0.0702	844	
"	0.146	1.867	0.007	0.111	0.090	0.010		59.3	0.0635		
S-1 AVG	**0.139**	**1.880**	**0.012**	**0.113**	**0.090**	**0.006**	**0.320**	59.3	0.0702	845	
									-		
S-2	0.039	0.397	0.028	0.000	1.469	0.005	1.930	18.1	0.0779	232	
"	0.050	0.400	0.036	0.000	1.744	0.014		18.1	0.0431		
"	0.052	0.378	0.033	0.015	2.038	0.009		18.1	0.0474		
S-2 AVG	**0.047**	**0.392**	**0.032**	**0.005**	**1.750**	**0.009**	**1.930**	18.1	0.0829	218	
									-		
S-3	0.058	0.772	0.025	0.057	0.566	0.030	4.435	20.8	0.1282	162	
"	0.101	0.813	0.026	0.092	0.606	0.087		20.8	0.0415		
S-3 AVG	**0.080**	**0.793**	**0.026**	**0.075**	**0.586**	**0.059**	**4.435**	20.8	0.1311	159	
									-		
S-4	0.028	0.648	0.013	0.010	0.114	0.000	5.541	18.7	0.1374	136	
"	0.012	0.642	0.013	0.006	0.172	0.000		18.7	0.0218		
"	0.068	0.646	0.017	0.009	0.683	0.004		18.7	0.0334		
S-4 AVG	**0.036**	**0.645**	**0.014**	**0.008**	**0.323**	**0.001**	**5.541**	18.7	0.1412	132	
	F	**Cl**	**NO2**	**Br**	**NO3**	**PO4**	**SO4**				

* Nitrate decreased over 2 days once supernate was removed from soil and filtered.
Later measurements llisted on top for each sample.

March 12 soil samples

	F	**Cl**	**NO2**	**Br**	**NO3**	**PO4**	**SO4**	cond	normality	specific cond
S-0 (ss2)	0.06	1.013	0.021		0.045		0.183	179.4	0.0367	4,890
S-1 (ss1)	0.028	1.104	0.02		0.02		0.772	16.7	0.0494	338
S-2 (ss3)	0.022	0.391	0.013		0.278		0.813	10.7	0.0339	316
S-3 (ss4)	0.021	0.548	0.013		0.322		0.559	9.4	0.0337	278
S-4 (ss5)	0.016	0.443	0.014		0.194		1.465	11.1	0.0473	234
Island (ss6)	0.108	1.65	0.014		0.039		0.208	153.2	0.0574	2,668
Upland (ss7)	0.043	0.772	0.01		0.013	0.007	0.403	51.3	0.0330	1,555
blank	0	0.028	0	0	0	0	0	0.2	0.0008	254

April 7 runoff

	F	**Cl**	**NO2**	**Br**	**NO3**	**PO4**	**SO4**	cond	normality	specific cond
S-0 ro	0.009	0.383			0.006	0.008	0.621	46.2	0.0245	1,888
S-1									-	
S-2 ro	0.019	4.722			0.015		3.003	58	0.1968	295
S-3										
S-4 ro	0.027	0.814	0.002		0.08		2.644	31.1	0.0808	385
Island									-	
Upland	0.037	1.889			0.003	0.01	3.081	124.2	0.1196	1,038

Normalized soils feb 6

	F	**Cl**	**NO2**	**Br**	**NO3 ***	**PO4**	**SO4**	**cond**	normality	specific cond
S-0	0.291	1.445	0.079	0.196	0.035	0.004	0.260	116.0	0.0663	1,751
"	0.284	1.432	0.046	0.181	0.036	0.000		116.0	0.0591	
"	0.288	1.432	0.048	0.181	0.045	0.007		116.0	0.0597	
S-0 AVG	**0.288**	**1.436**	**0.058**	**0.186**	**0.039**	**0.004**	**0.260**	116.0	0.0653	1,777
S-0/S-0	1	1	1	1	1	1	1	1	1	1
S-1	0.132	1.893	0.017	0.115	0.090	0.002	0.320	59.3	0.0702	844
"	0.146	1.867	0.007	0.111	0.090	0.010		59.3	0.0635	
S-1 AVG	**0.139**	**1.880**	**0.012**	**0.113**	**0.090**	**0.006**	**0.320**	59.3	0.0702	845
S-1/S-0	0.483198	1.308888	0.208092	0.607527	2.327586	1.636364	1.230769	0.511207	1.074964	0.475557
S-2	0.039	0.397	0.028	0.000	1.469	0.005	1.930	18.1	0.0779	232
"	0.050	0.400	0.036	0.000	1.744	0.014		18.1	0.0431	
"	0.052	0.378	0.033	0.015	2.038	0.009		18.1	0.0474	
S-2 AVG	**0.047**	**0.392**	**0.032**	**0.005**	**1.750**	**0.009**	**1.930**	18.1	0.0829	218
S-2/S-0	0.163384	0.272685	0.560694	0.026882	45.26724	2.545455	7.423077	0.156034	1.269714	0.12289
S-3	0.058	0.772	0.025	0.057	0.566	0.030	4.435	20.8	0.1282	162
"	0.101	0.813	0.026	0.092	0.606	0.087		20.8	0.0415	
S-3 AVG	**0.080**	**0.793**	**0.026**	**0.075**	**0.586**	**0.059**	**4.435**	20.8	0.1311	159
S-3/S-0	0.276362	0.551752	0.442197	0.400538	15.15517	15.95455	17.05769	0.17931	2.007345	0.089327
S-4	0.028	0.648	0.013	0.010	0.114	0.000	5.541	18.7	0.1374	136
"	0.012	0.642	0.013	0.006	0.172	0.000		18.7	0.0218	
"	0.068	0.646	0.017	0.009	0.683	0.004		18.7	0.0334	
S-4 AVG	**0.036**	**0.645**	**0.014**	**0.008**	**0.323**	**0.001**	**5.541**	18.7	0.1412	132
S-4/S-0	0.125145	0.449292	0.248555	0.044803	8.353448	0.363636	21.31154	0.161207	2.161892	0.074568