



Analysis of Soils at the National Park Service Weippe Prairie Site

*Final report under Rocky Mountain Cooperative Ecosystem
Studies Unit Cooperative Agreement H1200040001*

Natural Resource Technical Report NPS/NEPE/NRTR—2011/435



ON THE COVER

Camassia quamash (Pursh) Greene at the Weippe Prairie, Idaho
Photograph by Anita Falen, University of Idaho

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Executive Summary

This project was initiated to provide baseline information about soils of the Nez Perce National Historical Park (NEPE) Weippe Prairie site. In Fall 2007, six sites representing a range in landscape position and camas density were described and sampled for a suite of chemical, physical, mineralogical analyses. In addition, equipment was installed at all six sites to monitor seasonal changes in soil moisture content at 15- and 40-cm depths, soil temperature at 15 cm, and water table levels.

Results indicate that soils of the Weippe Prairie are primarily of alluvial and lacustrine origin. Because they occupy a broad, relatively low-lying plain, they are often waterlogged during the winter and spring months. This is due, in part, to the presence of dense, slowly permeable subsoil horizons that impede drainage and help create perched water tables. Laboratory analyses revealed that these soils tend to have textures dominated by silt and clay, and are very strongly acid. Kaolin is the predominant mineral found in the clay fractions of these soils, which have also been influenced by more recent additions of volcanic ash and loess.

Hydrological monitoring indicates that all soils have water tables present for approximately 5-7 months per year. At the wettest sites, water tables are very near or above the soil surface for the majority of time during which the soils are saturated.

Results of this project do not indicate that a specific soil property is related to observed differences in camas density at the Weippe Prairie. It may be that factors such as disturbance and past management are more influential than edaphic factors in this regard. However, this project does provide site-specific, baseline information about soils of the NEPE Weippe Prairie site. This information can, in turn, be used to guide informed management strategies and contribute to a better understanding of the edaphic factors related to camas ecology in the region.

Acknowledgments

The authors gratefully acknowledge the contributions of former University of Idaho students Brooke Knutzen, Bob Brown, and John Celley for their field and laboratory contributions to this project. We also thank the National Park Service for funding, and especially Jason Lyon for his help with development of this project. The work described in this report was conducted under RM-CESU Cooperative Agreement No. H2000040001.

Introduction

Camas (*Camassia quamash* [Pursh] Greene) is a plant of considerable cultural and historical significance in National Park Service (NPS) Nez Perce National Historical Park (NEPE). Because of this, a camas monitoring protocol has been developed by the Upper Columbia Basin Network Inventory and Monitoring Program in cooperation with NEPE staff to track population status and trends (Rodhouse and Jocius, 2009). This protocol specifically targets the existing site camas populations and has been designed to provide the park with information on the health of this focal species.

Any effort to monitor and evaluate ecological trends should include careful consideration of soil resources. Soils of the NPS Weippe Prairie site have been mapped by the Natural Resources Conservation Service as part of the Soil Survey of the Clearwater Area, Idaho. However, the map scale is not suitable for site-specific interpretations, nor does the survey provide detailed soil characterization data. Therefore, as a contribution to the camas monitoring effort, NEPE has sought a better understanding of the nature and condition of soils of the Weippe Prairie site. The project described in this report was initiated in Fall 2007 to address this need and to augment ongoing camas monitoring efforts. The overall goal of the project was to assess the nature and physical condition of the soils at the NPS Weippe Prairie study site.

Specific objectives of this research were to:

- Characterize the important morphological, chemical, physical, and mineralogical properties of representative soils.
- Monitor temporal changes in soil water table levels and soil moisture content.
- Determine how the condition of the soils and available soil moisture potentially impact camas populations.

This report summarizes the information gained about soil resources at the Weippe Prairie during the course of this research project from Fall 2007 to Fall 2010.

Methods

Site Selection

In Fall 2007, 6 locations at the National Park Service Weippe Prairie Site were selected for soil sampling, laboratory characterization, and monitoring of soil moisture and water table levels. Locations were chosen to represent the range in soil drainage and camas density observed across the site (Table 1). The sampling/monitoring locations selected for this project (hereafter referred to as sites) are shown in Figure 1.

Table 1. Sampling/monitoring sites with GPS coordinates, drainage, and camas management zone.

Site	Latitude °N	Longitude °W	Drainage ¹	Camas management zone ²
1	46.348847	115.923274	poor	D
2	46.348536	115.925285	moderately well	D
3	46.348702	115.927664	somewhat poor	D
4	46.355029	115.917102	poor	B
5	46.355145	115.918249	poor	A
6	46.355411	115.919886	moderately well	A

¹ based on soil morphology and Soil Survey Staff (2008)

² after Rodhouse and Jocius (2009)

Field Sampling

At each site, a soil pit was excavated by hand. Sod was carefully removed and set aside in an effort to minimize disturbance to camas and other vegetation. Soils were described and sampled using standard methodology (Schoeneberger et al., 2002) and photographed. Bulk samples were collected from each of the genetic horizons for laboratory analyses.

Installation of Monitoring Equipment

Duplicate soil moisture sensors (Model EC-5, Decagon Devices, Pullman, WA) were installed horizontally at depths of 15 cm and 40 cm in each soil. The 15-cm depth was chosen because it represents the depth below which camas bulbs were generally not observed. The 40-cm depth was chosen because it represents the bottom of the zone containing the bulk of plant roots. A soil/air temperature sensor (Decagon Devices, Pullman, WA) was also installed at a depth of 15 cm. All sensor wiring was covered with a rodent-proof plastic sleeve. At each site, all sensors were connected to a data logger (Model Em5b, Decagon Devices, Pullman, WA) mounted on a steel fence post (Figure 2a). Soil pits were refilled and the sod saved from the excavation was replaced at the surface.

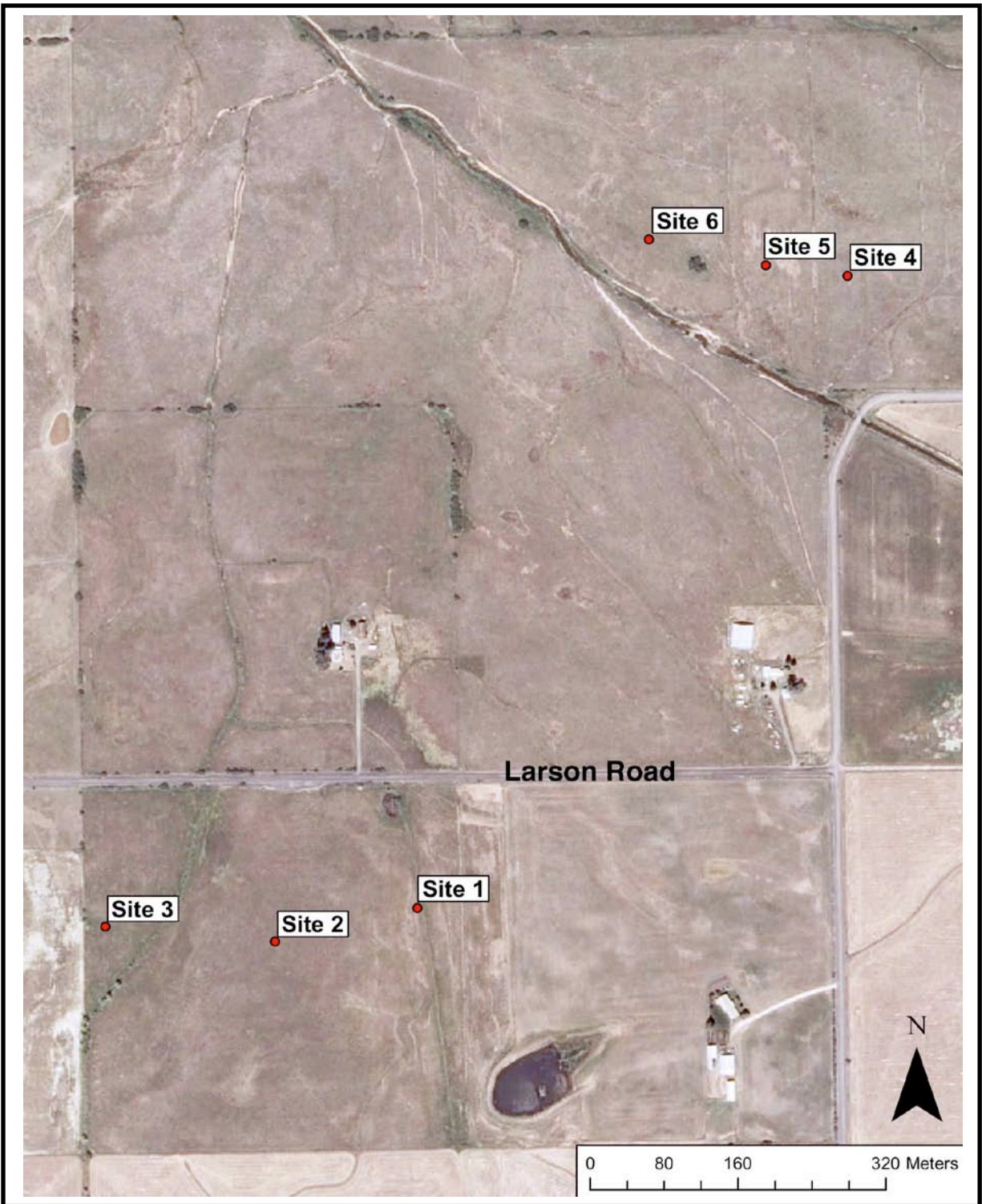


Figure 1. Location of sampling/monitoring sites at the National Park Service Weippe Prairie Site, ~3 km SE of Weippe, ID.

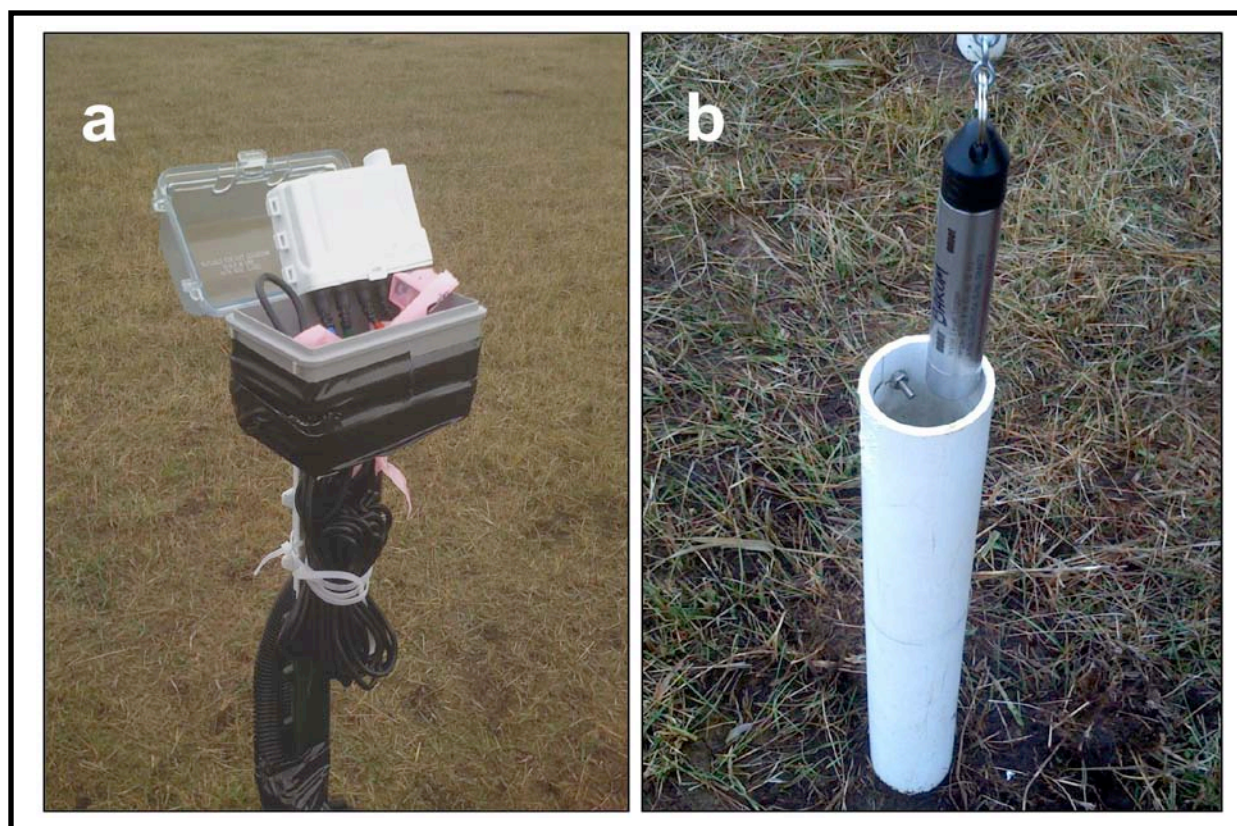


Figure 2. Monitoring equipment used at Sites 1-6. (a) Data logger connected to 4 soil moisture probes and a temperature probe. (b) Water table logger being installed in shallow well.

Shallow wells were installed at each site to allow monitoring of water tables. Wells were constructed of 2.5-inch-diameter PVC pipe. Slotted pipe was used for the below ground portion of the well; solid pipe was used for the riser. A HOBO water table logger (Model U20-001-04, Onset Computer Company, Pocasset, MA) was then inserted into each well at a depth corresponding to a hydraulically restrictive soil layer, if present, or a depth of ~75 cm (Figure 2b). Loggers were programmed to record water table levels every 12 hours. A solid well with a sealed bottom was installed at Site 3 and equipped with a well logger to monitor barometric pressure – this was used to correct all well logger readings for changes in barometric pressure and calculate water table levels. All wells were covered with a loose-fitting plastic cap to prevent entry of precipitation and evaporation losses.

Laboratory Analyses

Samples were collected from genetic horizons of the soils at each of the 6 monitoring sites. A total of 25 samples were transported back to the Pedology Laboratory at the University of Idaho where they were logged in, allowed to air-dry, and stored. Air-dried samples were then analyzed for various chemical, physical, and mineralogical properties. A detailed description of laboratory procedures used and references is contained in Appendix I.

The following physical properties were determined for all samples: bulk density; particle-size distribution (% sand, silt, and clay); textural class; and water retention at tensions of -0.03 and -0.5 MPa to simulate conditions of field capacity and wilting point. Chemical analyses performed included: pH (H₂O and NaF); organic carbon, nitrogen; exchangeable bases; exchangeable acidity, cation exchange capacity; and base saturation. For mineralogical properties, X-ray diffraction (XRD) was used to determine crystalline clay mineral components of selected horizons. Sand fractions of these horizons were observed under a polarizing microscope to determine the presence of volcanic ash and other mineral components.

Results

Soil Morphological Properties

The 6 soils described and sampled at the Weippe Prairie represent 3 NRCS soil survey map units at the Weippe Prairie Site that are contained in the Soil Survey of the Clearwater Area, Idaho (Soil Survey Staff, 2008). Sites 1, 4, and 5 are located within the Gramil-Lewhand complex; Site 2 is located within the Gramil-Reggear complex, and Site 6 is located within a Burntcreek ashy loam map unit (Soil Survey Staff, 2008). NRCS descriptions of these map units are included in Appendix II. Based on this mapping, Sites 1, 3, 4, and 5 represent the wettest parts of the landscape and wet (R009XY0181ID) or semiwet (R009XY019ID) meadow ecological sites.

The Weippe Prairie is a broad, relatively low-relief landscape that is dominated by alluvial and lacustrine sediments. These sediments have been mantled by varying amount of windblown materials, including loess and volcanic ash (Soil Survey Staff, 2008). Because of low relief and very slowly permeable subsoils, most soils at the Weippe Prairie have water tables at or near the surface at some time during the year.

Profile pictures of soils at Sites 1-6 are shown in Figures 3-8; descriptions are given in Tables 2-7. Genetic horizons are shown as well as the locations of soil moisture, temperature, and water table monitoring equipment.

All soils exhibited morphological evidence in the form of redoximorphic features that result from seasonal saturation with water (Vepraskas, 2001). These redoximorphic features include low-chroma colors and Fe concentrations and depletions. Expression of these features varies among the sites and reflects both the duration and positioning of water table within the soil profile. Horizons with low-chroma colors (i.e., horizons with 'g' designation) can be seen in Sites 1, 4, and 5, and indicate these soils are the wettest. Examples of Fe concentrations and depletions can be seen in the E/Bxg horizon at Site 4 (Figure 6, just above blue circle). Sites 2, 3, and 6 have somewhat better drainage, but nevertheless still show evidence of seasonal saturation. Sites 2 and 6 occupy marginally higher (in elevation) parts of the landscape, and this contributes to their somewhat better drainage.

An important feature of many Weippe Prairie Site soils is the presence of hydraulically restrictive subsoil horizons. These are generally dense, high-strength horizons with low porosity, and are identified in the horizon descriptions by the 'x' designation. The ability of these horizons to transmit water is rated as very low to moderately low (≤ 0.06 inch per hour) (Soil Survey Staff, 2008). Previous work in the area indicates that these subsoil horizons perch water for as much as 7 months per year (Rockefeller et al., 2004). All sites in this study except Site 6 appear to have at least a weakly expressed hydraulically restrictive subsoil horizon. These restrictive subsoil horizons were recognized by the exclusion of plant roots from the soil matrix, brittleness, abrupt textural and/or structural differences, and excavation difficulty. Sites 1, 3, 4, and 5 all occupy lower-lying areas of the landscape. It is likely that groundwater tables are also present and may work in conjunction with perched water tables to create seasonal saturation of these soils.

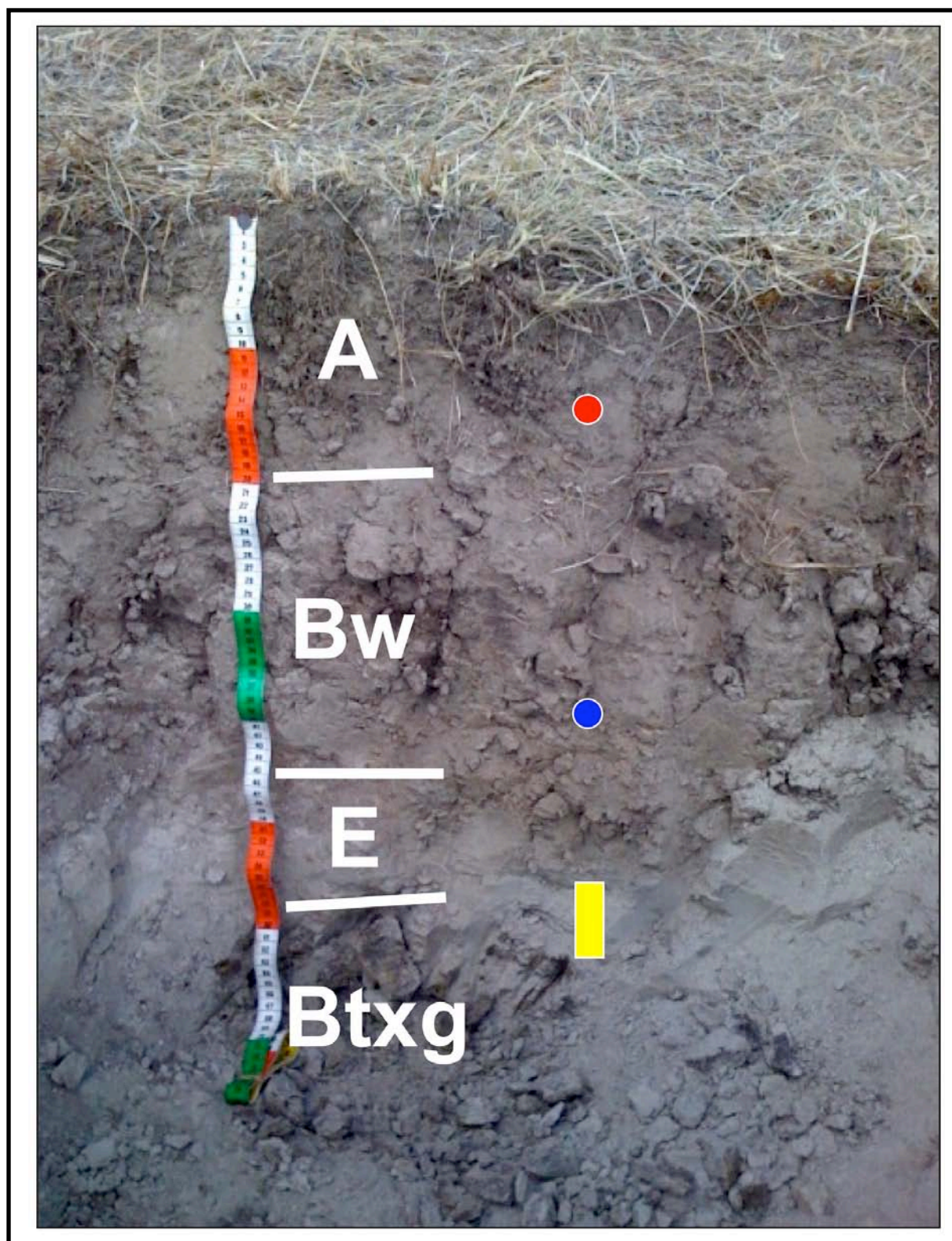


Figure 3. Site 1 (UI Pedon No. 07-ID-18167) profile and genetic horizons. Red and blue circles indicate position of soil moisture probes (15 and 40 cm); yellow rectangle indicates relative position of well logger. Each colored division on scale tape = 10 cm (4 inches).

Table 2. Site 1 morphological data – UI Pedon No. 07-ID-18167. All descriptors¹ are taken from Schoeneberger et al. (2002).

UI Lab Sample No.	Horizon	Depth (cm)	Color moist/ dry	Textural class	Structure	Consistence			Notes
						dry	moist	stickiness/ plasticity	
ID1816701	A	0-20	10YR3/2 10YR6/2	silty clay loam	strong, fine granular	hard	v firm	sl sticky/ sl plastic	most camas bulbs are contained in this horizon
ID1816702	Bw	20-44	10YR3/2 10YR6/1	silty clay loam	strong, med prismatic/ subangular blocky	hard	v firm	sl sticky/ sl plastic	faint redox concentrations/ depletions
ID1816703	E	44-58	10YR6/2 10YR8/2	silt	mod., medium subangular blocky	soft	v friable	non-sticky/ non-plastic	
ID1816704	Btxg	58-75+	10YR4/2 10YR6/2	silty clay loam	strong, coarse prismatic	extr hard	sl rigid	mod. sticky/ mod. plastic	roots restricted from ped interiors; 10YR3/2 coatings on ped faces; very difficult to dig; brittle

¹Abbreviations: v = very; sl = slightly; med = medium; mod. = moderate(ly); extr = extremely

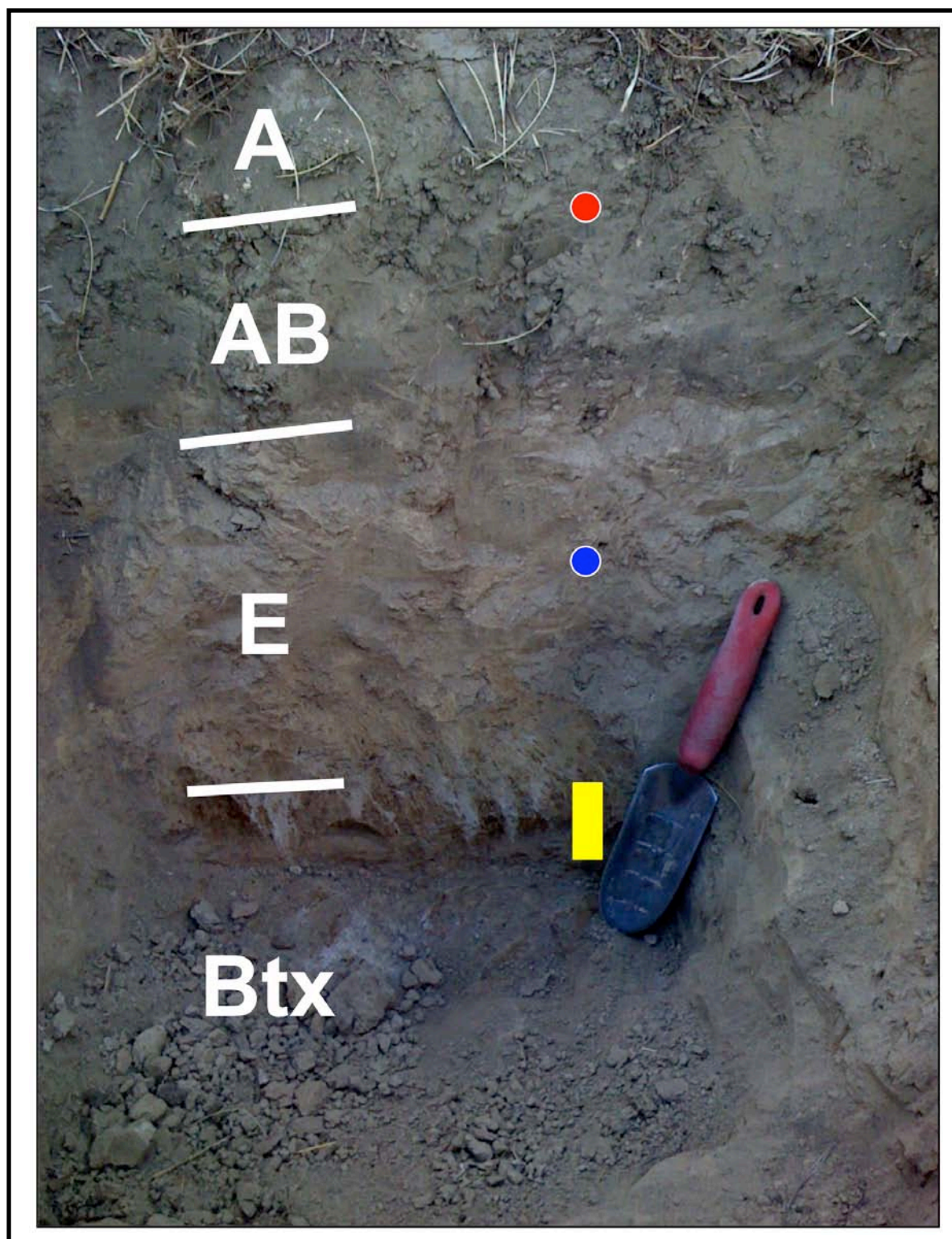


Figure 4. Site 2 (UI Pedon No. 07-ID-18168) profile and genetic horizons. Red and blue circles indicate position of soil moisture probes (15 and 40 cm); yellow rectangle indicates relative position of well logger. For scale, trowel is 30 cm (12 inches) long.

Table 3. Site 2 morphological data – UI Pedon No. 07-ID-18168. All descriptors¹ are taken from Schoeneberger et al. (2002).

UI Lab Sample No.	Horizon	Depth (cm)	Color moist/ dry	Textural class	Structure	Consistence			Notes
						dry	moist	stickiness/ plasticity	
ID1816801	A	0-10	10YR2/2 10YR5/2	silty clay loam	strong, fine/ med granular	hard	v firm	sl sticky/ sl plastic	some basalt fragments present
ID1816802	AB	10-27	10YR2/2 10YR4/2	silty clay loam	strong, fine/ med subangular blocky	mod hard	firm	mod. sticky/ mod. plastic	
ID1816803	E	27-61	10YR3/4 10YR7/4	silt loam	mod., fine/med subangular blocky	extr hard	sl rigid	v sticky/ v plastic	relatively weak E expression
ID1816804	Btx	61-81+	10YR4/6 10YR6/4	silty clay loam	mod., fine/med angular blocky/ prismatic	extr hard	sl rigid	v sticky/ v plastic	some flattened roots along ped faces; restricted from ped interiors; somewhat difficult to dig; pan features less-expressed than Site 1

¹Abbreviations: v = very; sl = slightly; med = medium; mod. = moderate(ly); extr = extremely

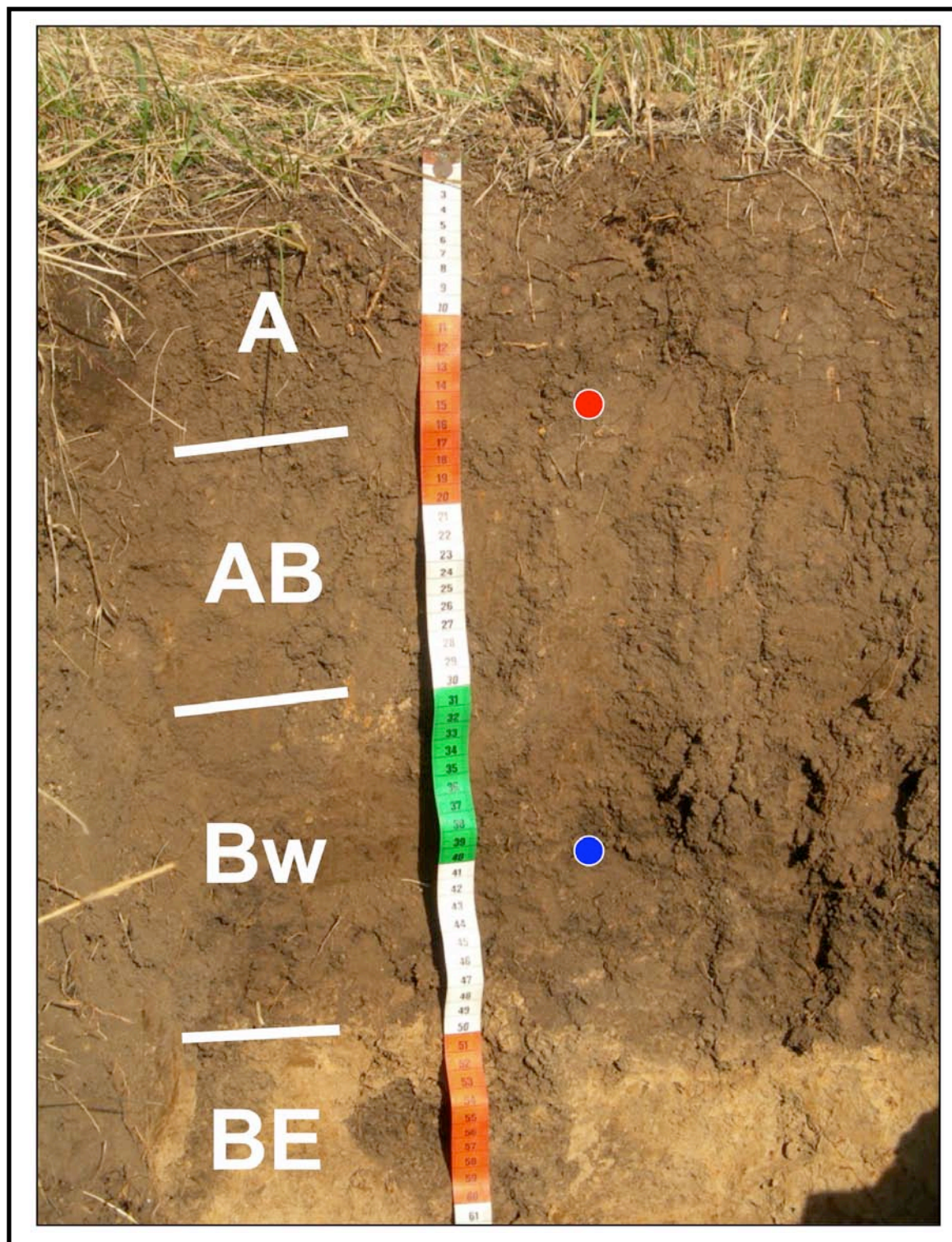


Figure 5. Site 3 (UI Pedon No. 07-ID-18169) profile and genetic horizons. Red and blue circles indicate position of soil moisture probes (15 and 40 cm); well logger is located at a depth of 92 cm and is not shown. Each colored division on scale tape = 10 cm (4 inches).

Table 4. Site 3 morphological data– UI Pedon No. 07-ID-18169. All descriptors¹ are taken from Schoeneberger et al. (2002).

UI Lab Sample No.	Horizon	Depth (cm)	Color moist/ dry	Textural class	Structure	Consistence			Notes
						dry	moist	stickiness/ plasticity	
ID1816901	A	0-16	10YR2/2 10YR4/2	silty clay	mod, v fine-med granular	sl hard	v friable	sl sticky/ sl plastic	relatively darker soil colors compared to other sites
ID1816902	AB	16-30	10YR2/2 10YR4/2	silty clay	mod, v fine-med subangular blocky	sl hard	friable	mod. sticky/ mod. plastic	few faint redox concentrations/ depletions are masked by darker colors
ID1816903	Bw	30-50	10YR3/2 10YR5/2	silty clay	strong, med subangular blocky	mod hard	firm	mod. sticky/ mod. plastic	faint redox concentrations/ depletions are masked by darker colors
ID1816904	BE	50-76+	10YR4/4 10YR6/4	silt loam	strong, coarse subangular blocky	mod hard	firm	mod. sticky/ mod. plastic	material is somewhat brittle but does not form a strongly expressed pan; many redox depletions and concentrations

¹Abbreviations: v = very; sl = slightly; med = medium; mod. = moderate(ly); extr = extremely

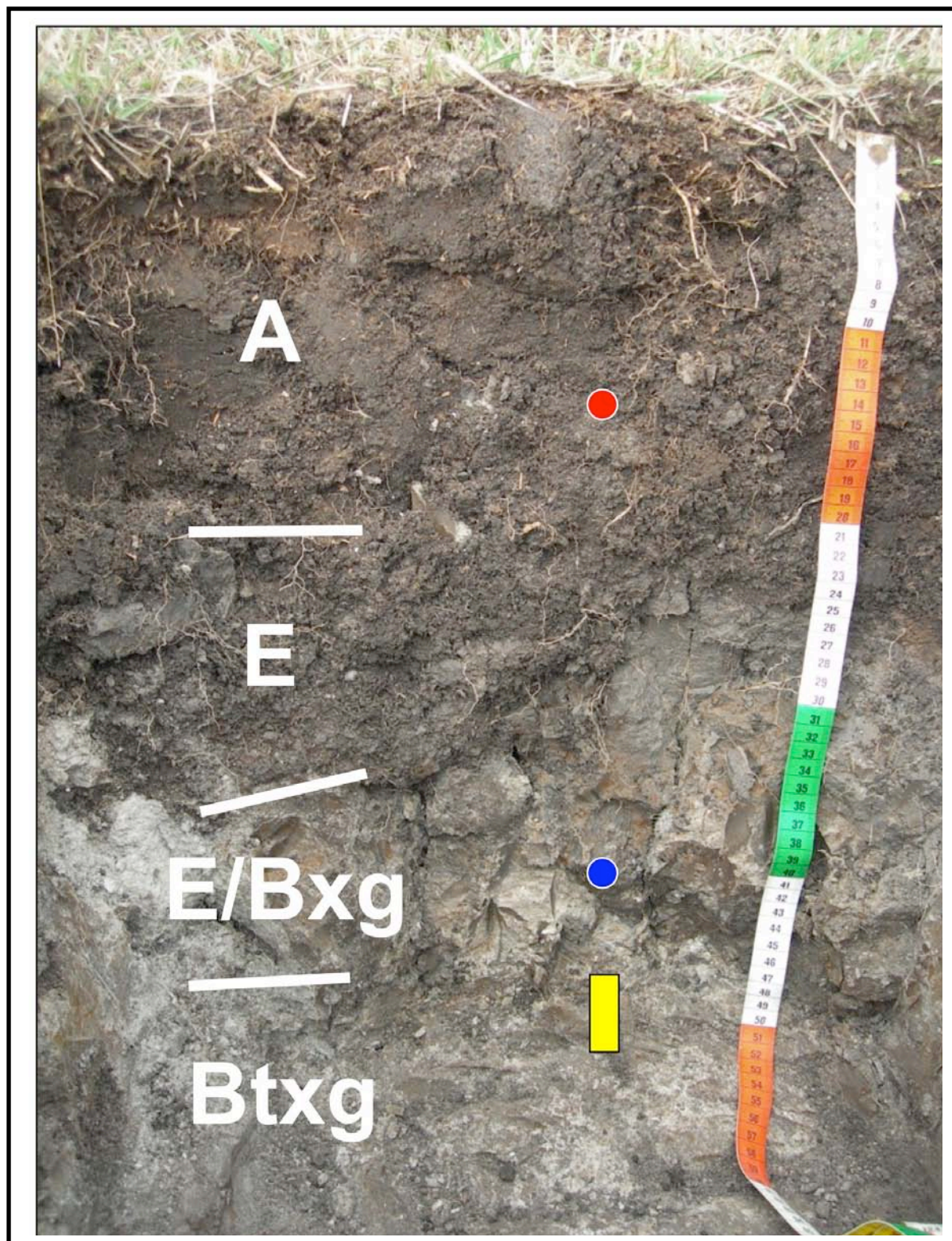


Figure 6. Site 4 (UI Pedon No. 07-ID-18170) profile and genetic horizons. Red and blue circles indicate position of soil moisture probes (15 and 40 cm); yellow rectangle indicates relative position of well logger. Each colored division on scale tape = 10 cm (4 inches).

Table 5. Site 4 morphological data– UI Pedon No. 07-ID-18170. All descriptors¹ are taken from Schoeneberger et al. (2002).

UI Lab Sample No.	Horizon	Depth (cm)	Color moist/ dry	Textural class	Structure	Consistence			Notes
						dry	moist	stickiness/ plasticity	
ID1817001	A	0-23	10YR2/2 10YR4/1	clay	strong, fine/med subangular blocky	hard	v firm	mod. sticky/ mod. plastic	
ID1817002	E	23-31	10YR4/1 10YR7/1	silty clay	strong, med subangular blocky	sl hard/ hard	friable	mod. sticky/ mod. plastic	few faint redox concentrations
ID1817003	E/Bxg	31-50	10YR4/2 10YR7/2	silty clay loam	strong, med subangular blocky	v hard	friable	mod. sticky/ mod. plastic	many redox concentrations and depletions; brittle
ID1817004	Btxg	50-65+	10YR4/2 10YR5/2	silty clay	strong, med/coarse subangular blocky	extr hard	sl rigid	v sticky/ v plastic	few clay films present on ped faces; many redox concentrations and depletions; brittle

¹Abbreviations: v = very; sl = slightly; med = medium; mod. = moderate(ly); extr = extremely

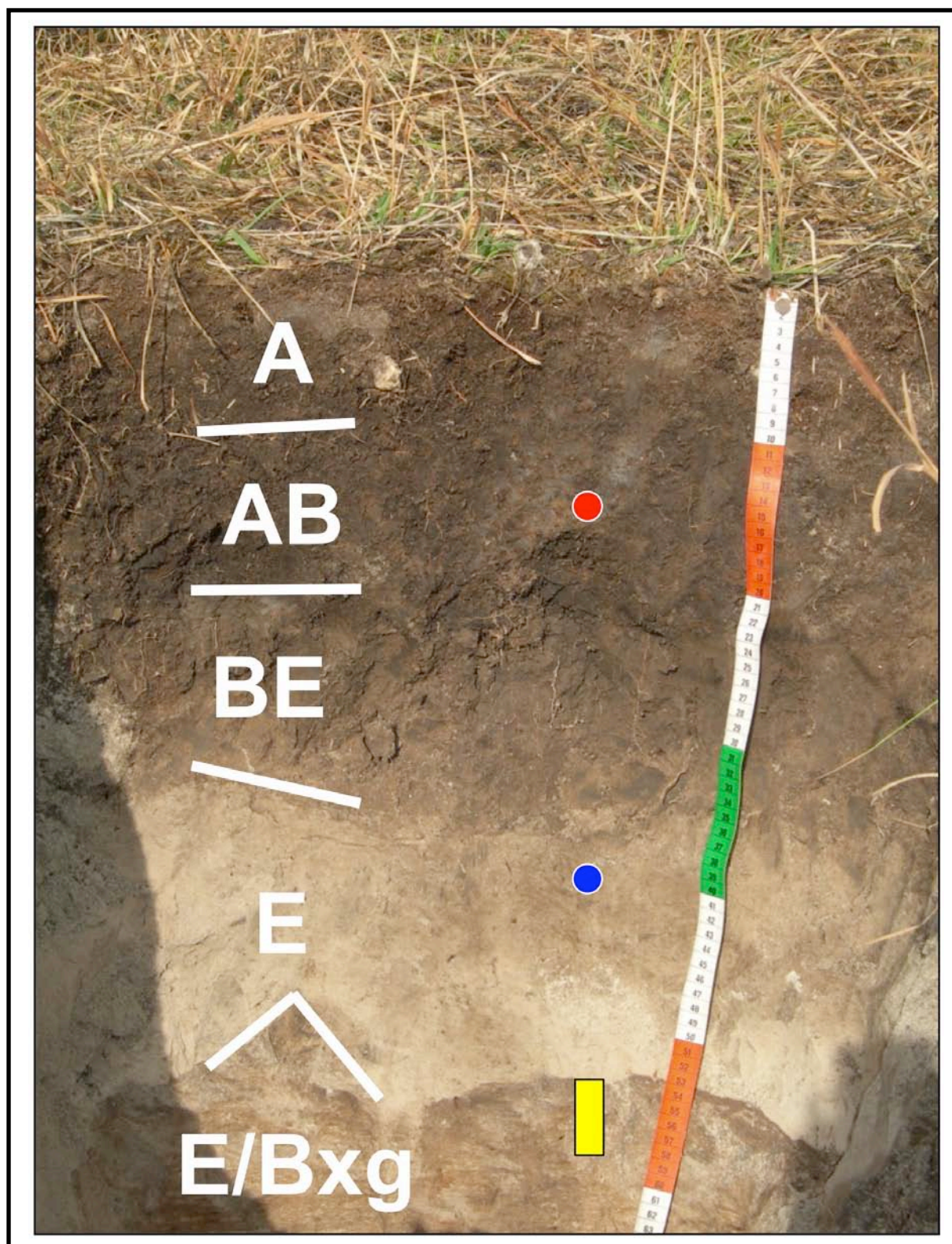


Figure 7. Site 5 (UI Pedon No. 07-ID-18171) profile and genetic horizons. Red and blue circles indicate position of soil moisture probes (15 and 40 cm); yellow rectangle indicates relative position of well logger. Each colored division on scale tape = 10 cm (4 inches).

Table 6. Site 5 morphological data – UI Pedon No. 07-ID-18171. All descriptors¹ are taken from Schoeneberger et al. (2002).

UI Lab Sample No.	Horizon	Depth (cm)	Color moist/ dry	Textural class	Structure	Consistence			Notes
						dry	moist	stickiness/ plasticity	
ID1817101	A	0-10	10YR3/1 10YR5/1	clay	mod., fine/ med granular	soft	v friable	mod. sticky/ mod. plastic	v few camas bulbs present
ID1817102	AB	10-21	10YR3/1 10YR5/1	clay	weak, fine/med subangular blocky	v hard	extr firm	mod. sticky/ mod. plastic	redox concentrations present
ID1817103	BE	21-37	10YR3/2 10YR7/1	silty clay	mod., fine/med subangular blocky	mod. hard	firm	mod. sticky/ mod. plastic	
ID1817104	E	37-54	10YR5/2 10YR8/1	silt loam	mod., fine/med subangular blocky-platy	soft	v friable	non-sticky/ non-plastic	very abrupt textural change from overlying horizon
ID1817105	E/Bxg	54-76+	10YR7/2 10YR8/1	silt loam	mod., fine/med subangular blocky	hard	firm	non-sticky/ non-plastic	pan-like, but not a true fragipan – hard, firm material, but not brittle; difficult to excavate

¹Abbreviations: v = very; sl = slightly; med = medium; mod. = moderate(ly); extr = extremely

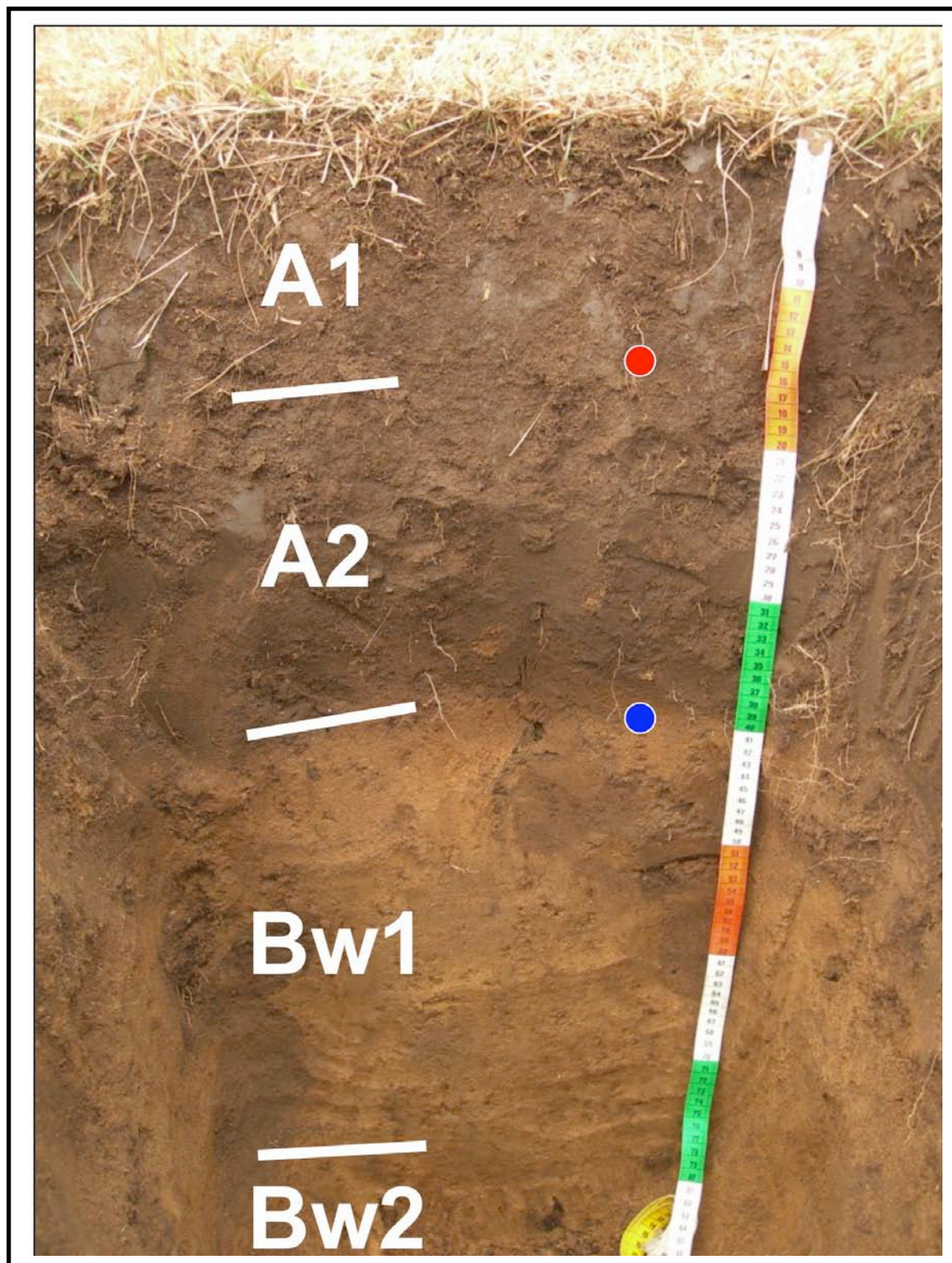


Figure 8. Site 6 (UI Pedon No. 07-ID-18172) profile and genetic horizons. Red and blue circles indicate position of soil moisture probes (15 and 40 cm); well logger is located at a depth of 92 cm and is not shown. Each colored division on scale tape = 10 cm (4 inches).

Table 7. Site 6 morphological data – UI Pedon No. 07-ID-18172. All descriptors¹ are taken from Schoeneberger et al. (2002).

UI Lab Sample No.	Horizon	Depth (cm)	Color moist/ dry	Textural class	Structure	Consistence			Notes
						dry	moist	stickiness/ plasticity	
ID1817201	A1	0-16	10YR2/2 10YR4/2	sandy clay loam	strong, fine granular	sl hard	friable	non-sticky/ non-plastic	no visible redox features
ID1817202	A2	16-40	10YR2/2 10YR4/2	sandy clay loam	mod., fine granular	mod. hard	firm	non-sticky/ non-plastic	no visible redox features
ID1817203	Bw1	40-77	7.5YR4/3 7.5YR6/4	sandy loam	mod. med subangular blocky	mod. hard	firm	non-sticky/ non-plastic	few, very faint Fe concentrations; evidence of animal burrowing
ID1817204	Bw2	77-90+	7.5YR4/3 7.5YR6/4	sandy loam	weak med subangular blocky	soft	v friable	non-sticky/ non-plastic	few, very faint Fe concentrations; black Mn oxide accumulations

¹Abbreviations: v = very; sl = slightly; med = medium; mod. = moderate(ly); extr = extremely

Soil Physical Properties

A summary of soil physical properties of the Weippe Prairie soils is presented in Tables 8 and 9. Particle-size analysis indicates silty clay loam, silty clay, and clay textures dominate the upper horizons of most of the sampled soils. These textures are typical of soils of the region that have formed in alluvium, loess, and lacustrine sediments.

Highest clay contents (up to 67%) in the Weippe soils are found at Sites 4 and 5, which are located relatively close to one another on a broad, low-lying plain. These finer textures appear to reflect a former lacustrine environment in this part of the Weippe Prairie. This interpretation is supported by the presence of diatoms in the fine sand fractions of these soils (see mineralogy section).

In contrast, Site 6 formed in coarser materials deposited in a higher-energy alluvial environment, and has sandy clay loam and sandy loam textures. These sandy textures coupled with the lack of a hydraulically restrictive subsoil horizon allows for more rapid drainage of water in this soil.

Water retention data in Table 9 illustrate the strong effect of texture on a soil's ability to provide plant-available water. Silty textures are best in this regard, as evidenced by the larger water retention differences. Soils with more clayey or sandy textures generally have lower water retention differences, making them more prone to droughtiness during the growing season. However, given the overall wet condition of the Weippe Prairie at the start of the growing season, it does not appear that water retention differences have much effect on camas density. Site 4, which is characterized by relatively low camas density, has the greatest overall water retention of any of the soils.

Bulk density values for surface horizons are generally within the range considered acceptable for plant growth and therefore likely do not limit camas growth. Subsoil bulk densities at Sites 1, 2, 3, and 6 exceed the $\sim 1.5 \text{ g/cm}^3$ threshold that restricts root growth and development (Brady and Weil, 2010). These higher bulk densities are also usually associated with perched water tables in soils of the area (Rockefeller et al., 2004). One notable exception is Site 5 – while the E/B_{xg} horizon exhibited several of the properties associated with a hydraulically restrictive horizon, the mean measured bulk density value was only 1.15 g/cm^3 . The abundance of volcanic ash in this soil (see mineralogy section) may help explain the relatively low bulk density.

Table 8. Particle-size analysis of Weippe Prairie soils.

Slite	Horizon	Depth cm	VC ¹ Sand	C ¹ Sand	M ¹ Sand	F ¹ Sand	VF ¹ Sand	Sand	Silt	Clay	Textural Class
			2-1 mm	1-0.5 mm	0.5-0.25 mm	0.25-0.10 mm	0.10-0.05 mm	2-0.05 mm	0.05-0.002 mm	<0.002 mm	
			----- % of <2 mm fraction -----								
Site 1	A	0-20	0.3	0.3	0.2	0.5	1.9	3.2	60.3	36.5	Silty Clay Loam
	Bw	20-44	0.1	0.2	0.2	0.1	4.4	5.0	65.2	29.9	Silty Clay Loam
	E	44-58	0.2	0.2	0.1	0.6	0.2	1.3	81.3	17.4	Silt
	Btxg	58-75+	0.1	0.5	0.3	0.9	4.9	6.6	57.2	36.2	Silty Clay Loam
Site 2	A	0-10	1.2	1.8	1.4	1.8	1.3	7.5	64.5	28.0	Silty Clay Loam
	AB	10-27	1.2	2.1	1.2	1.3	4.8	10.5	61.7	27.8	Silty Clay Loam
	E	27-61	1.4	2.2	1.7	2.1	3.9	11.2	64.2	24.6	Silt Loam
	Btx	61-81+	2.1	3.1	1.5	3.0	0.7	10.4	56.2	33.4	Silty Clay Loam
Site 3	A	0-16	2.2	2.0	0.9	1.2	3.1	9.4	43.1	47.5	Silty Clay
	AB	16-30	2.8	2.4	1.0	1.2	3.2	10.6	43.6	45.8	Silty Clay
	Bw	30-50	2.0	1.7	1.0	1.2	2.8	8.6	44.5	46.9	Silty Clay
	BE	50-76+	1.6	1.9	1.2	0.2	4.1	8.9	65.1	26.0	Silt Loam
Site 4	A	0-23	0.0	0.1	0.1	0.4	0.4	1.0	38.2	60.7	Clay
	E	23-31	0.0	0.0	0.1	0.5	2.2	2.8	50.4	46.8	Silty Clay
	E/Bxg	31-50	0.0	0.1	0.1	0.7	0.1	1.0	60.5	38.5	Silty Clay Loam
	Btxg	50-65+	0.0	0.1	0.4	1.2	2.2	3.9	47.9	48.3	Silty Clay
Site 5	A	0-10	0.0	0.1	0.1	0.3	0.9	1.5	31.5	67.0	Clay
	AB	10-21	0.0	0.1	0.1	0.5	1.1	1.8	32.1	66.2	Clay
	BE	21-37	0.1	0.1	0.1	0.6	4.9	5.7	52.9	41.4	Silty Clay
	E	37-54	0.1	0.2	0.1	1.7	11.8	13.8	75.2	11.0	Silt Loam
Site 6	E/Bxg	54-76+	0.0	0.0	0.1	5.4	11.6	17.1	70.3	12.6	Silt Loam
	A1	0-16	0.9	11.9	14.6	16.4	4.8	48.6	25.5	26.0	Sandy Clay Loam
	A2	16-40	0.9	12.3	16.8	16.3	4.2	50.5	25.1	24.3	Sandy Clay Loam
	Bw1	40-77	0.6	14.2	19.0	22.4	5.5	61.6	24.1	14.2	Sandy Loam
	Bw2	77-90+	1.0	17.2	25.4	27.4	5.0	75.9	12.8	11.3	Sandy Loam

¹Abbreviations: v = very; f = fine; m = medium; c = coarse

Table 9. Bulk density and water retention data for Weippe Prairie soils.

Site	Horizon	Depth	Bulk Density	Water Retention		
				-0.03 MPa	-1.5 MPa	Difference
		cm	g/cm ³	----- % by weight -----		
Site 1	A	0-20	1.03	46.9	19.6	27.3
	Bw	20-44	1.28	39.2	18.0	21.2
	E	44-58	1.33	35.6	8.6	26.9
	Btxg	58-75+	1.74	30.2	13.1	17.1
Site 2	A	0-10	1.24	33.7	14.5	19.2
	AB	10-27	1.38	32.8	12.4	20.3
	E	27-61	1.58	27.0	10.1	16.9
	Btx	61-81+	1.64	27.2	13.5	13.8
Site 3	A	0-16	1.35	34.3	20.0	14.3
	AB	16-30	1.37	32.3	18.6	13.7
	Bw	30-50	1.49	30.0	18.6	11.4
	BE	50-76+	1.65	31.0	14.6	16.4
Site 4	A	0-23	1.19	49.9	29.4	20.5
	E	23-31	1.32	65.3	29.0	36.3
	E/Bxg	31-50	1.44	54.1	28.4	25.7
	Btxg	50-65+	1.42	58.3	25.7	32.6
Site 5	A	0-10	1.13	43.4	29.8	13.6
	AB	10-21	1.20	45.1	28.7	16.4
	BE	21-37	1.28	40.7	21.6	19.1
	E	37-54	1.03	50.6	8.2	42.4
	E/Bxg	54-76+	1.15	44.5	11.0	33.5
Site 6	A1	0-16	1.17	25.6	12.6	12.9
	A2	16-40	1.44	23.1	10.5	12.6
	Bw1	40-77	1.66	14.8	6.3	8.5
	Bw2	77-90+	1.72	9.7	3.7	6.0

Soil Chemical Properties

Results of soil chemical analyses are summarized in Table 10 and 11. pH, carbon, and nitrogen data are contained in Table 10; Table 11 contains exchangeable cation and cation exchange capacity (CEC) data.

There are several important trends that may have implications for camas growth. Soil pH is considered a ‘master variable’ in that it strongly influences many chemical and biological properties and processes (Brady and Weil, 2010). All surface horizons are very strongly acid, with pH (H₂O) values ranging from 4.6-5. This reflects the relatively large amounts of exchangeable acidity found in surface horizons and relatively low base saturation percentages. As is typical, pH values increase in the subsoils.

Carbon contents of surface A horizons are relatively high for mineral soils, ranging from 3.2 to 4.5%. This is likely due to the seasonal saturation and relatively cold temperatures in the Weippe Prairie soils; both of these factors reduce organic matter decomposition rates. C:N ratios range from 11 to 15, which is typical of mineral soil A horizons (Brady and Weil, 2010).

With few exceptions, quantities of exchangeable bases (Ca²⁺, Mg²⁺, K⁺) do not vary greatly among the Weippe Prairie soils. Furthermore, quantities of these nutrients do not appear to be sufficiently low to indicate problems for plant growth. However, % base (or nonacid) saturation (i.e., percentage of total cation exchange sites occupied by bases) is relatively low in surface horizons, ranging from 18% at Site 6 to 45% at Site 4. These low values indicate that exchangeable acidity dominates the exchange complex in these soils. However, it should be pointed out that this condition is relatively common in soils of the Weippe area that have been characterized as part of the NRCS soil survey of the Clearwater Area (Soil Survey Staff, 2008).

NaF pH values provide a measure of poorly or nanocrystalline secondary minerals (Soil Survey Staff, 2010). In the Pacific Northwest, these minerals typically result from the weathering of volcanic ash (McDaniel et al., 2005). NaF pH values <~9.4 generally indicate that these minerals are not present in significant quantities, and this is the case for the Weippe soils. Examination of samples with a petrographic microscope and scanning electron microscopy indicates some volcanic glass is present (Figure 9) (see mineralogy section). The volcanic glass is most likely from the eruption of Mt. Mazama ~7600 years ago (Zdanowicz, 1999). Although it is a relatively minor constituent of the soils, its presence is recognized in the taxonomic classification of these soils. Although criteria for andic soil properties were not evaluated as part of this project, several of the soils likely qualify as *vitrandic* subgroups of Alfisols and Inceptisols (Soil Survey Staff, 2008; 2010).

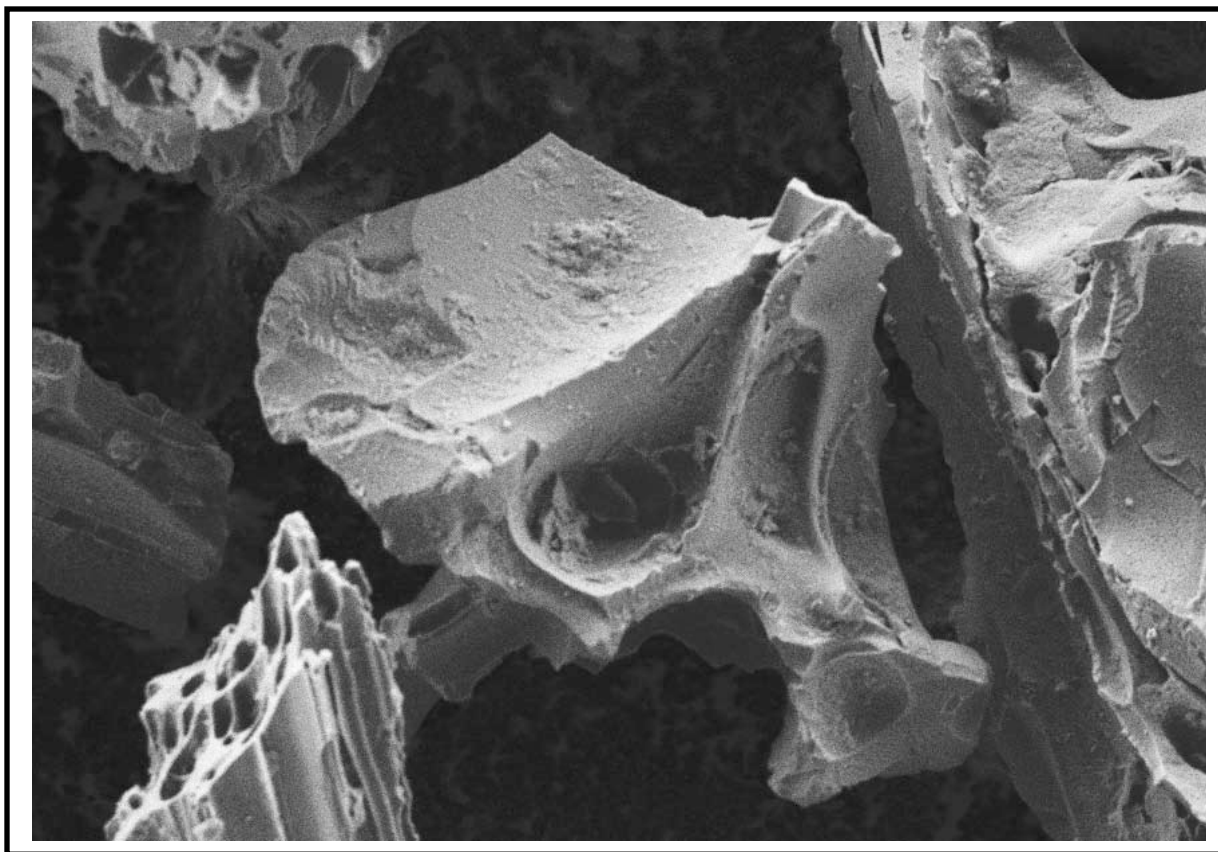


Figure 9. Volcanic glass shard (center) from the very fine sand fraction of Site 5. Shard measures ~0.1 mm across.

Table 10. pH, carbon, and nitrogen data for Weippe Prairie soils.

Site	Horizon	Depth cm	pH H ₂ O	NaF pH	Total Carbon %	Total Nitrogen %	C:N
Site 1	A	0-20	4.7	7.7	3.8	0.3	11
	Bw	20-44	5.1	7.9	1.0	0.1	8
	E	44-58	5.4	8.0	0.5	0.1	8
	Btxg	58-75+	5.5	7.9	0.3	<0.1	9
Site 2	A	0-10	5.0	7.8	4.0	0.3	15
	AB	10-27	5.1	8.0	2.8	0.2	15
	E	27-61	5.2	8.1	0.8	0.1	12
	Btx	61-81+	5.4	8.0	0.3	<0.1	10
Site 3	A	0-16	5.0	7.8	4.5	0.4	12
	AB	16-30	5.1	7.8	3.2	0.3	12
	Bw	30-50	5.2	7.7	2.5	0.2	13
	BE	50-76+	5.5	8.0	0.4	<0.1	13
Site 4	A	0-23	4.6	7.7	3.2	0.3	11
	E	23-31	4.8	7.7	1.6	0.2	10
	E/Bxg	31-50	5.1	7.8	1.1	0.1	10
	Btxg	50-65+	5.6	7.9	0.7	0.1	6
Site 5	A	0-10	4.7	7.7	3.7	0.3	12
	AB	10-21	4.8	8.0	2.7	0.2	11
	BE	21-37	5.1	8.0	1.2	0.1	10
	E	37-54	6.2	7.8	0.2	<0.1	9
	E/Bxg	54-76+	6.6	8.0	0.2	<0.1	10
Site 6	A1	0-16	4.8	7.8	3.8	0.3	12
	A2	16-40	4.9	8.3	2.2	0.2	12
	Bw1	40-77	5.5	7.7	0.4	<0.1	10
	Bw2	77-90+	5.6	7.7	0.2	<0.1	16

Table 11. Cation exchange capacity (CEC) and exchangeable cation data for Weippe Prairie soils.

Site	Horizon	Depth	Exchangeable Cations						CEC ¹	% Base sat. ²
			Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	Sum of bases	Acidity (H ⁺ + Al ³⁺)		
			----- cmol(+)/kg -----							
		cm								
Site 1	A	0-20	6.1	2.2	0.3	0.2	8.8	19.1	30	31
	Bw	20-44	6.2	2.4	0.2	0.2	9.0	11.3	29	44
	E	44-58	4.9	1.9	0.1	0.3	7.1	5.9	11	55
	Btxg	58-75+	8.3	3.5	0.2	0.3	12.3	8.0	17	61
Site 2	A	0-10	9.2	1.5	0.7	0.0	11.5	17.6	32	39
	AB	10-27	8.6	1.5	0.3	0.1	10.4	16.2	23	39
	E	27-61	6.4	1.7	0.3	0.1	8.5	9.1	15	48
	Btx	61-81+	6.6	2.4	0.2	0.2	9.4	10.0	16	49
Site 3	A	0-16	12.3	3.0	0.5	0.1	15.9	24.7	38	39
	AB	16-30	12.2	3.0	0.3	0.1	15.6	22.5	41	41
	Bw	30-50	12.7	3.7	0.3	0.1	16.8	18.5	34	48
	BE	50-76+	6.9	2.6	0.1	0.1	9.7	10.3	18	48
Site 4	A	0-23	6.9	3.5	0.4	0.2	11.0	25.6	45	30
	E	23-31	6.0	3.1	0.1	0.2	9.5	17.0	29	36
	E/Bxg	31-50	8.8	4.6	0.2	0.3	13.9	14.3	31	49
	Btxg	50-65+	10.4	5.5	0.2	0.3	16.4	9.9	29	62
Site 5	A	0-10	6.3	3.1	0.7	0.3	10.4	24.5	41	30
	AB	10-21	6.7	3.1	0.5	0.4	10.8	22.7	40	32
	BE	21-37	5.9	2.6	0.3	0.5	9.3	12.7	27	42
	E	37-54	5.3	2.0	0.2	0.7	8.1	3.9	12	68
	E/Bxg	54-76+	6.2	2.9	0.3	0.8	10.1	4.1	15	71
Site 6	A1	0-16	3.3	0.5	0.2	0.1	4.0	18.4	24	18
	A2	16-40	4.3	1.4	0.3	0.1	6.2	17.3	19	26
	Bw1	40-77	3.3	0.9	0.4	0.1	4.7	7.5	10	38
	Bw2	77-90+	3.8	1.1	0.4	0.1	5.4	4.4	6	55

¹ CEC = Cation Exchange Capacity (pH 7)² % Base Saturation = (sum of cations/sum of cations + acidity) x 100

Soil Mineralogical Properties

X-ray diffraction (XRD) patterns for all clay fractions analyzed can be found in Appendix III. XRD and sand fraction data are summarized in Table 12. Overall, kaolin is the dominant crystalline clay mineral. An abundance of kaolin, a 1:1 layer silicate, is generally indicative of more intense weathering environments (White and Dixon, 2003). It is likely that much of this kaolin formed in a warmer environment than exists today at the Weippe Prairie, such as during the Miocene. The kaolin-rich sediments have accumulated on the Prairie during the Holocene and Pleistocene (Lewis et al., 2007), and serve as the predominant parent material for the modern-day soils. Weippe Prairie soils have largely formed in these pre-weathered sediments.

In contrast, soils of the nearby Palouse Prairie region of eastern Washington and northern Idaho have formed in late Pleistocene and Holocene loess – their mineralogy is dominated by mica, vermiculite, and in some cases, smectite; kaolin is only present in minor amounts (McDaniel and Hipple, 2010). The presence of vermiculite and mica in Weippe Prairie soils suggests that there have also been additions of more recent sediment, perhaps from a similar source and timing as the Palouse loess. Windblown materials including volcanic ash and loess both appear to have influenced soil mineralogy, but to a much lesser extent than the alluvium and lacustrine deposits.

Abundant diatoms were observed in the sand fractions of soil horizons at Site 4, and a few were present in horizons at Site 5 (Figure 10). Diatoms are commonly found in shallow, freshwater environments (Monger and Kelly, 2002) and indicate that at least part of the Weippe Prairie Site was a lakebed at one time.

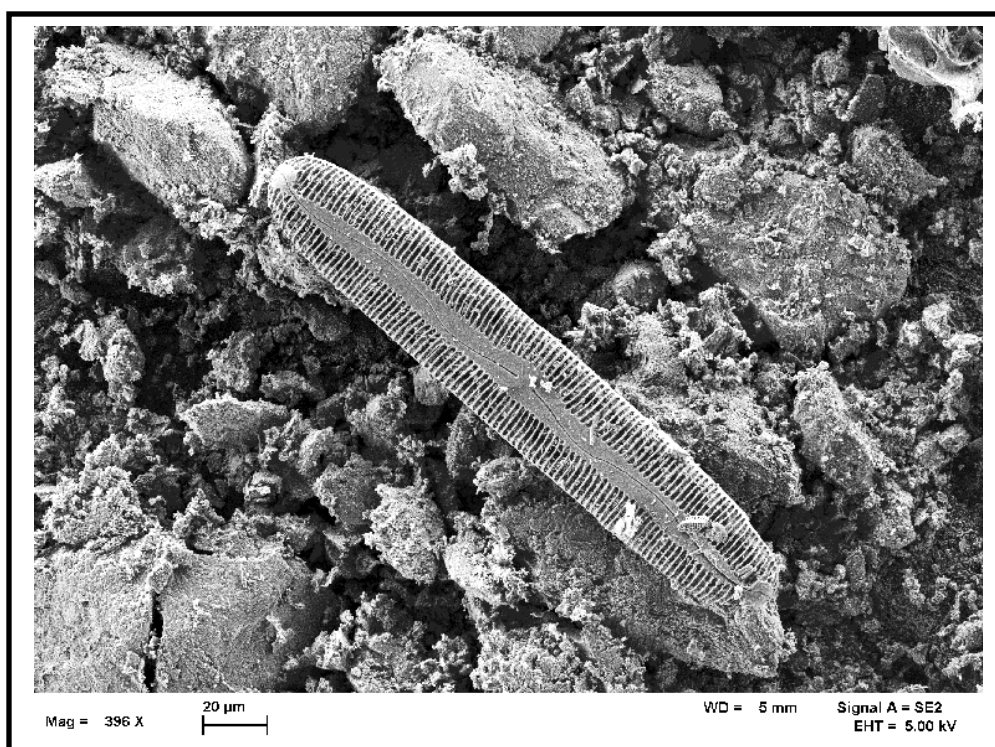


Figure 10. Scanning electron micrograph of diatom (center) from the E horizon of Site 4. Diatom is ~220 microns in length.

Table 12. Summary of mineralogical properties of Weippe Prairie soils.

Site	Horizon	Clay mineralogy	Sand fraction features
1	Bw	kaolin dominant, minor vermiculite	~5% volcanic glass
	Btxg	kaolin, vermiculite, mica co-dominant; minor smectite	~10% volcanic glass
2	AB	kaolin, vermiculite, mica co-dominant	~1% volcanic glass
	Btx	kaolin, vermiculite co-dominant; minor smectite, mica	~1% volcanic glass
3	AB	kaolin, vermiculite co-dominant; minor smectite, mica	no volcanic glass; common Fe/Mn concretions
	BE	kaolin, vermiculite, smectite co-dominant	few volcanic glass fragments
4	E	kaolin dominant; minor vermiculite, mica	no volcanic glass; 90% diatoms
	Btxg	kaolin dominant, minor vermiculite	no volcanic glass; diatoms present
5	AB	kaolin dominant, minor mica	>10% volcanic glass; abundant phytoliths; few diatoms
	E/Bxg	kaolin dominant, minor vermiculite	abundant volcanic glass
6	A2	kaolin, vermiculite co-dominant	2-3% volcanic glass
	Bw2	kaolin, vermiculite co-dominant; minor smectite, mica	Mn oxide coatings on sand grains

Soil Moisture/Temperature Monitoring

Graphs summarizing temporal changes in soil moisture and temperature at all sites over the 2007-10 monitoring period are contained in Figures 11a-16a. These graphs illustrate the overall seasonal soil wetting and drying patterns as well as several general trends that are consistent across all of the sites.

Soils achieve and maintain maximum moisture contents during the winter and spring months. The relatively flat portions of soil moisture curves seen during this period correspond to periods of saturation. As temperatures warm in late spring and evapotranspirational demand increases, moisture contents decrease rapidly over a period of 1-2 months. The exact timing of this dry-down varies somewhat, but generally begins sometime in June.

Following the rapid dry-down period, a few spikes in moisture content at 15 cm occur during the summer and fall in response to precipitation. These spikes are absent or less pronounced at the 40-cm depth, indicating that most of the growing season precipitation is lost via evapotranspiration and typically does not reach subsoil horizons. Rapid increases in soil moisture occur in the fall, depending on the timing and amount of precipitation received.

Some differences in soil moisture patterns are seen across the sites. For example, Site 4 does not dry down as much as the other sites. Even during the driest part of the summer, moisture content at 40 cm remained above 30%. In contrast, moisture content at 40 cm at Site 6 dropped to ~13%. This difference is likely due to the textures of the lower-most horizon at these sites: the Btxg horizon at Site 4 contains 48% clay while the Bw2 horizon at Site 6 contains 11% clay.

Overall, there do not appear to be significant soil temperature differences among the sites. Maximum soil temperatures of ~18-22 °C (64-72 °F) were reached during July and August. These maximum temperatures generally coincided with the rapid decline in soil moisture content.

Water Table Monitoring

Temporal changes in water table levels are shown in Figures 11b-16b for the 2008-09 and 2009-10 water years. Unfortunately, data are not available for the 2007-08 water year due to failure of the well logger used to monitor barometric pressure; although well loggers were operational, we were not able to apply the barometric correction to the readings in order to obtain water table levels.

As predicted from soil morphology, Sites 1, 4, and 5 experience the longest duration of saturated conditions (Table 13). In addition, water tables are within 15 cm of the soil surface for most of the time when a water table is present at these 3 sites. This is likely significant as most camas bulbs observed in these soils were present depths of ~5-15 cm. Sites 2, 3, and 6 experience fewer days of saturated conditions during the year. However, the biggest difference is that these sites have water table levels within 15 cm of the soil surface for considerably less time than do Sites 1, 4, and 5. In addition, water never ponded at Sites 2 and 6, and only for 4 days at Site 3.

Sites 4 and 5 were initially selected because they are in close proximity to one another and occupy similar landscape positions, but differ markedly in camas density – Site 4 supports lower densities while Site 5 supports some of the higher densities measured at the Weippe Prairie site

(Rodhouse and Jocius, 2009). A comparison of water table data in Table 13 indicates that these 2 soils both have water tables within 15 cm of the surface for a substantial period of time each year, yet ponded conditions persist at Site 4 much longer (4-5 times) than at Site 5. This difference may, in part, reflect the combined effects of microtopography and drainage ditches that are present in the area. Further investigation may be warranted to identify the conditions that result in ponding across the site.

Close examination of the moisture content and water table level graphs (Figures 11-16) shows excellent agreement between data obtained from moisture sensors and water table loggers. The ‘plateaus’ seen in moisture content readings correspond with periods when water table levels are measured at those depths. This allows information about water table levels to be reliably inferred from moisture sensor data.

Table 13. Water table data summary by site for the water years 2008-09 and 2009-10.

Site	2008-2009			2009-2010		
	Water table present	Water table within 15 cm of surface	Ponded	Water table present	Water table within 15 cm of surface	Ponded
----- Number of days -----						
1	181	152	79	196	174	70
2	166	8	0	162	2	0
3	159	11	4	172	0	0
4	191	166	140	176	169	129
5	197	151	30	198	144	27
6	172	36	0	150	10	0

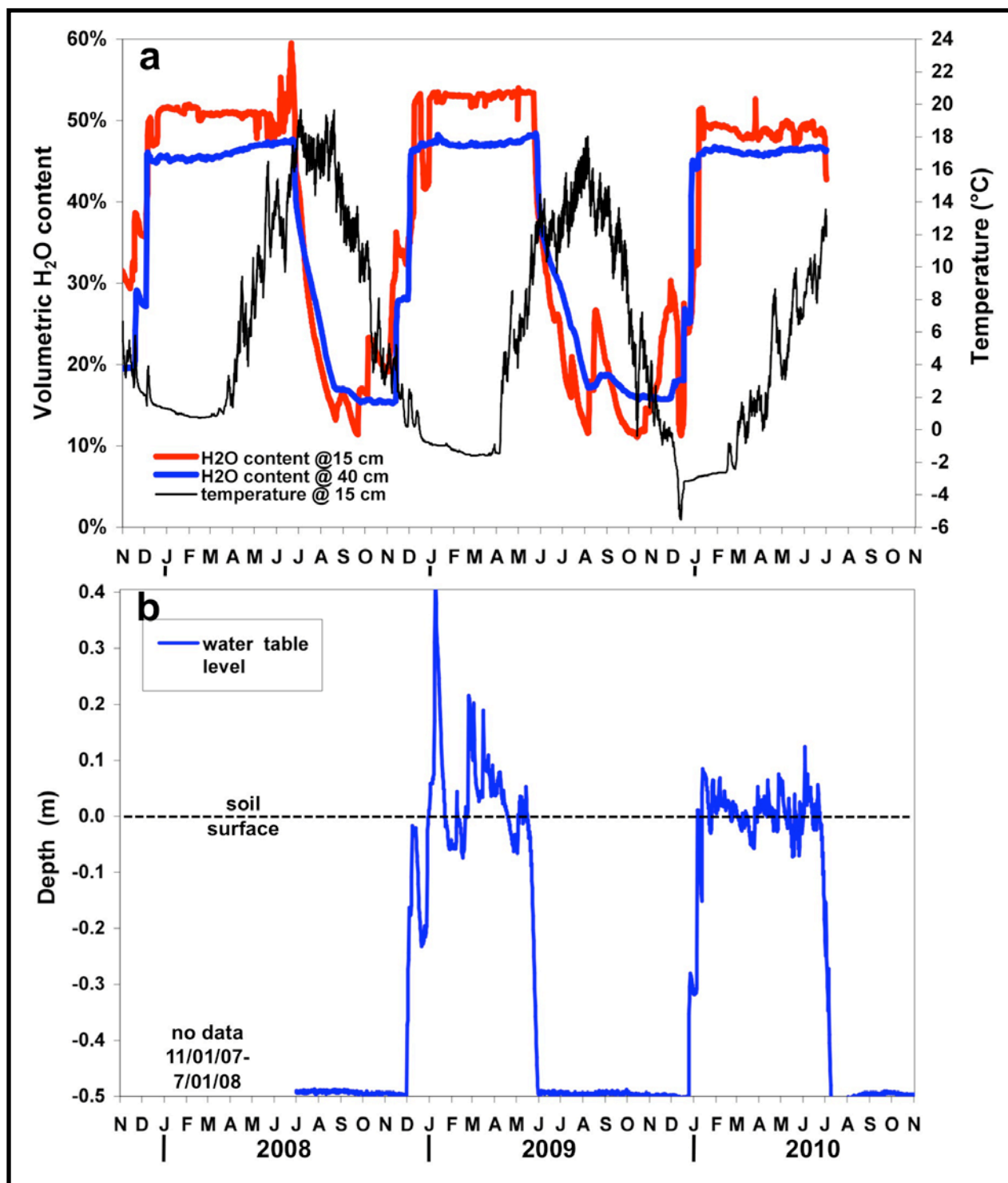


Figure 11. Hydrological data for Site 1 showing temporal changes in (a) soil moisture and temperature and (b) water table levels.

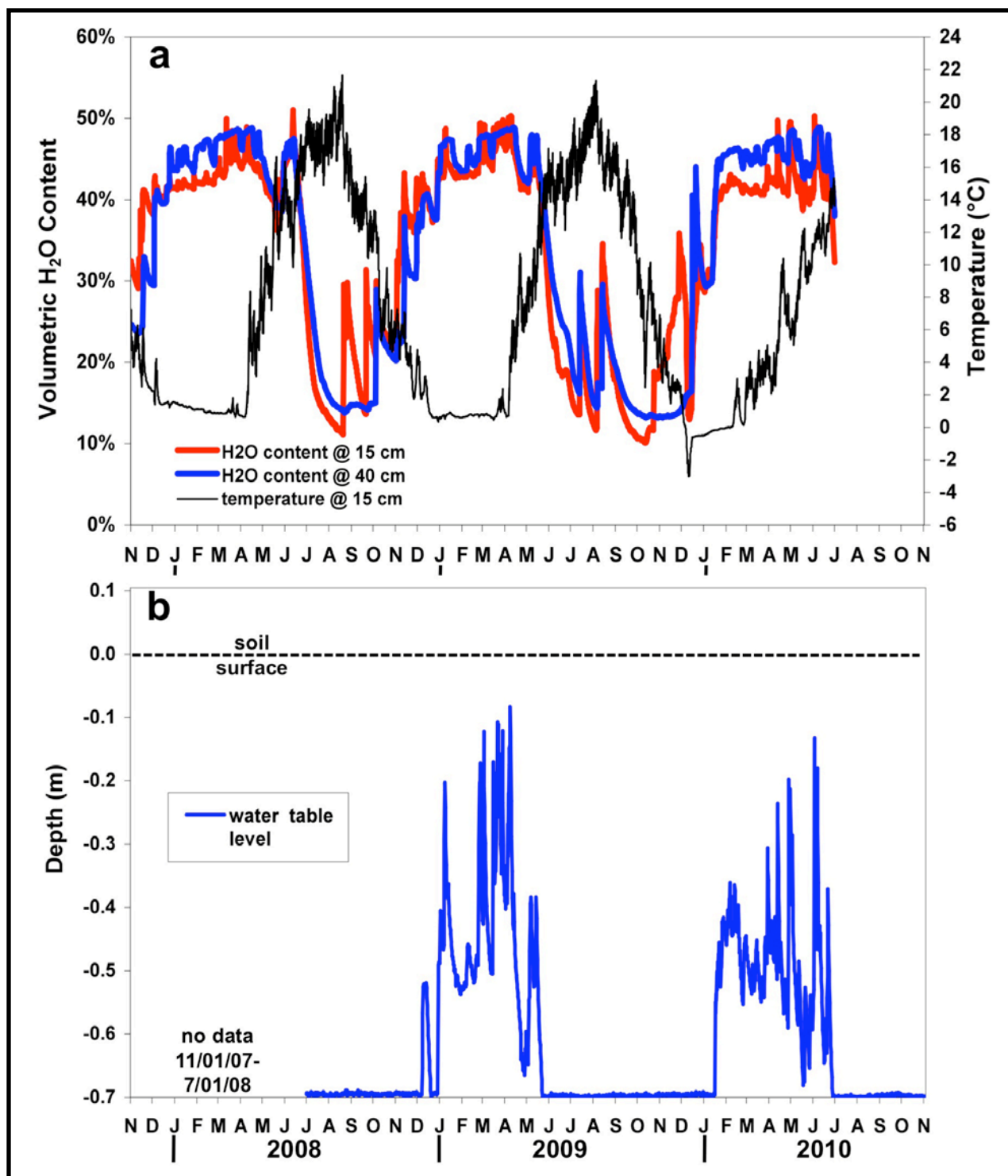


Figure 12. Hydrological data for Site 2 showing temporal changes in (a) soil moisture and temperature and (b) water table levels.

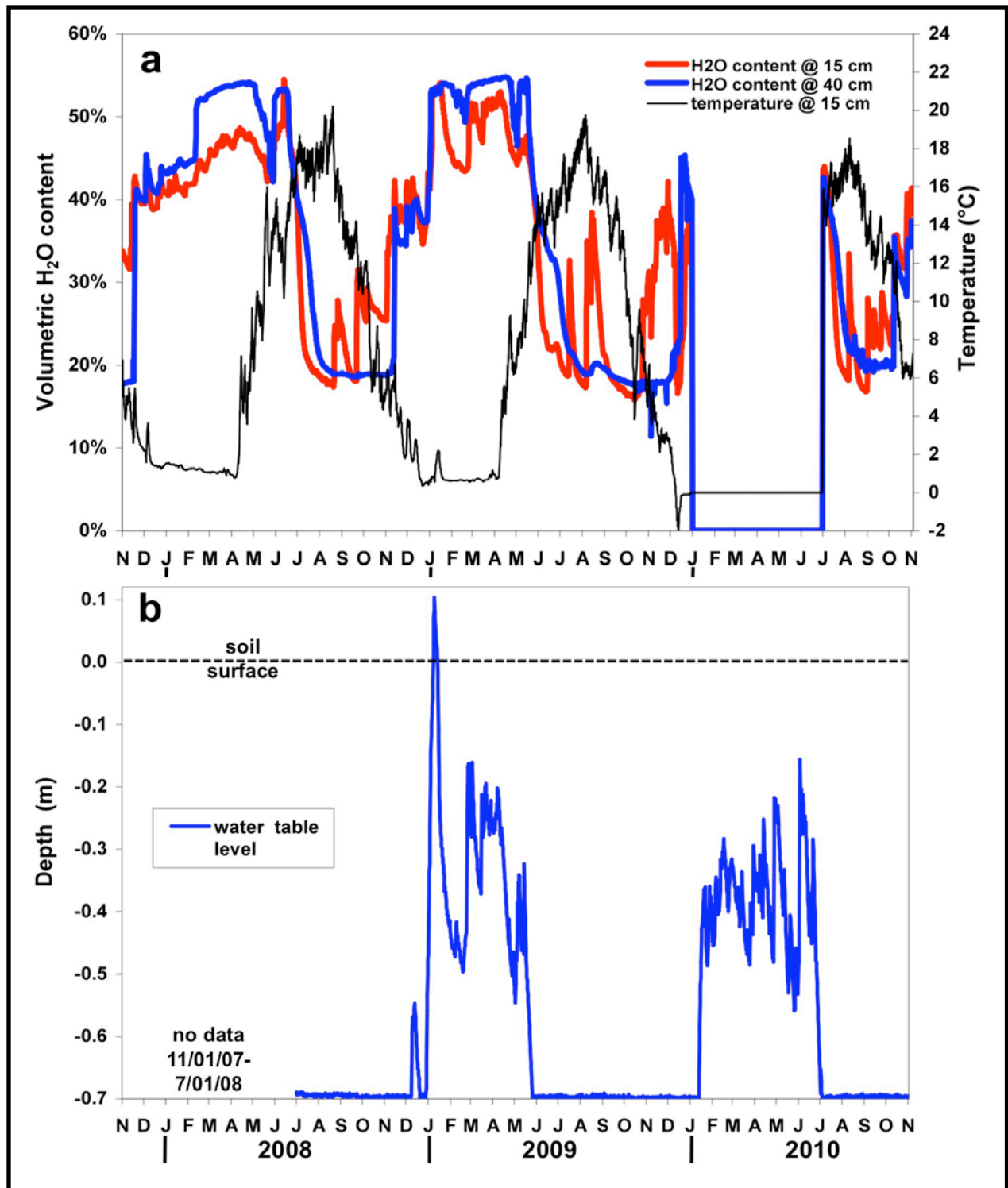


Figure 13. Hydrological data for Site 3 showing temporal changes in (a) soil moisture and temperature and (b) water table levels.

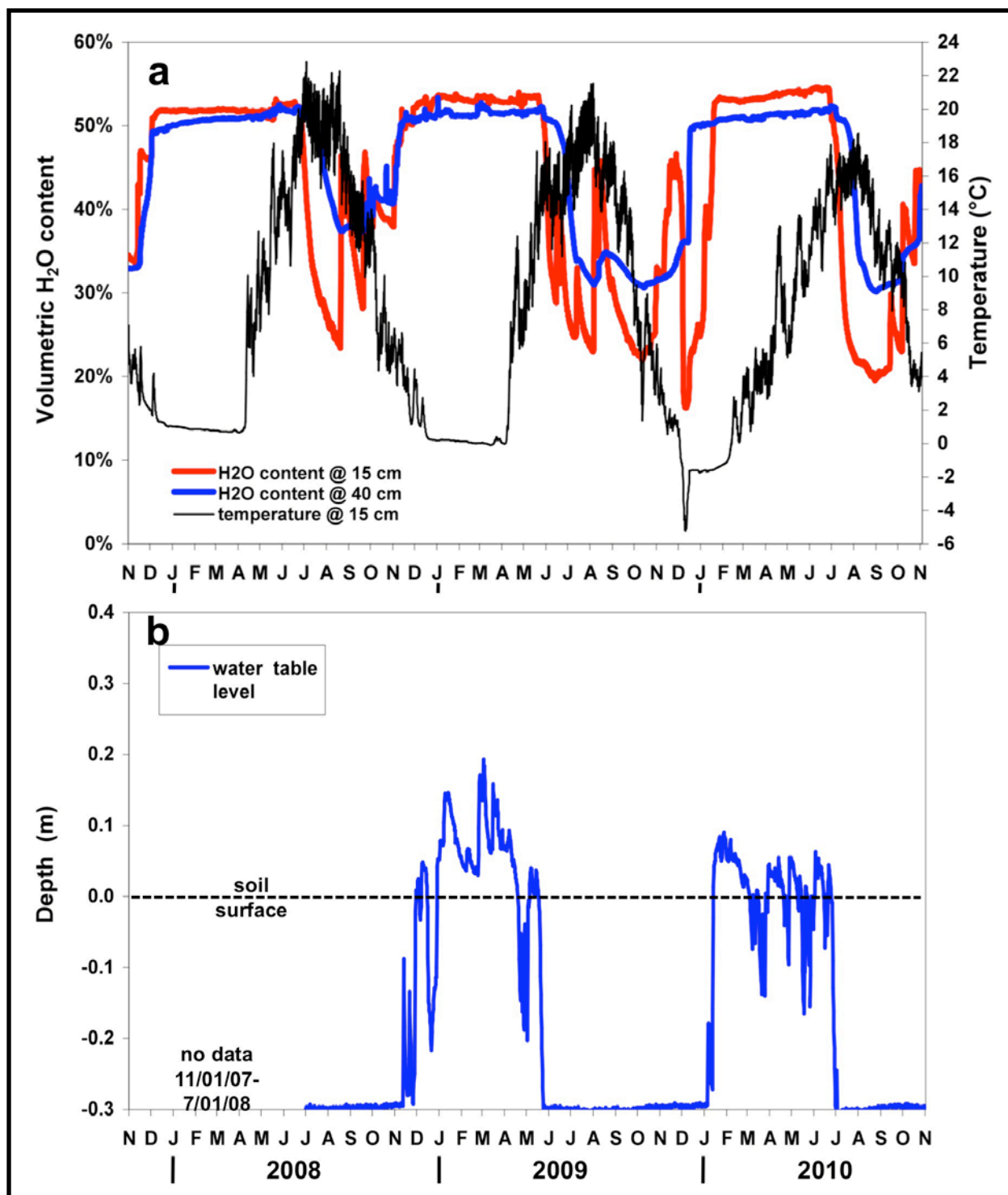


Figure 14. Hydrological data for Site 4 showing temporal changes in (a) soil moisture and temperature and (b) water table levels.

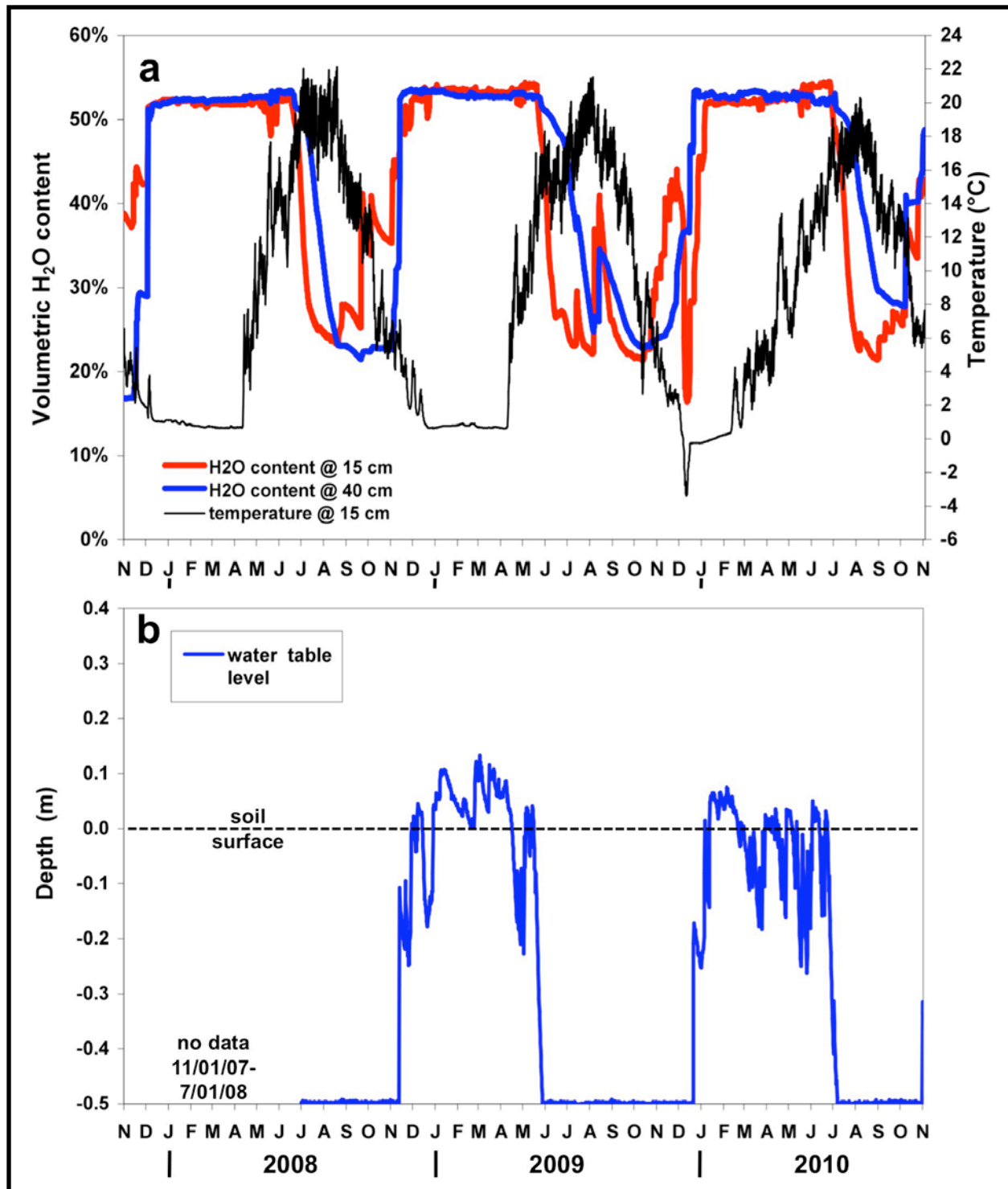


Figure 15. Hydrological data for Site 5 showing temporal changes in (a) soil moisture and temperature and (b) water table levels.

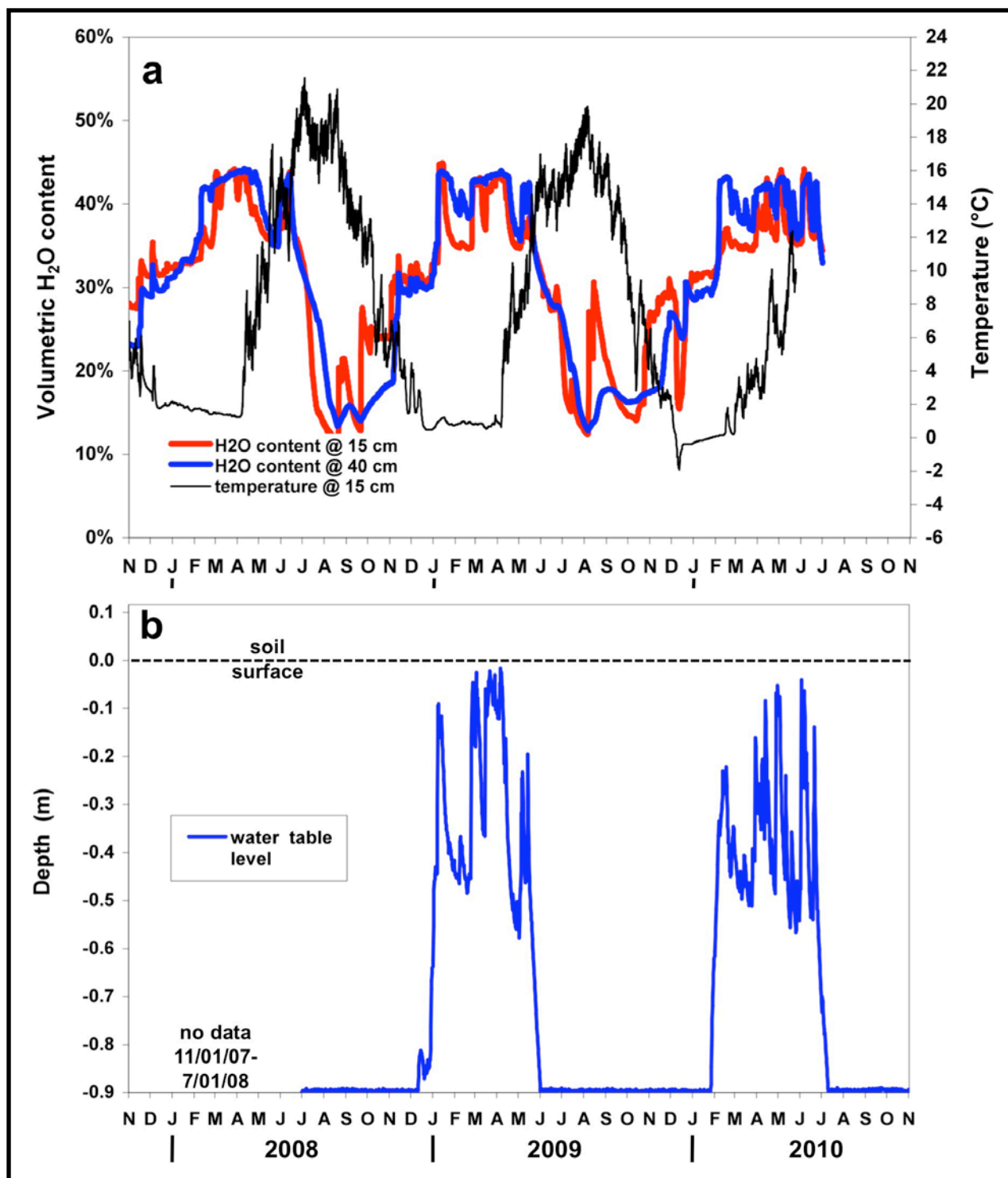


Figure 16. Hydrological data for Site 6 showing temporal changes in (a) soil moisture and temperature and (b) water table levels.

Discussion

Project efforts focused on two objectives: providing detailed soil morphological, physical, and chemical characterization data and monitoring temporal changes in soil hydrology. Sites sampled and monitored as part of this project were selected to represent a range in soil characteristics across the Weippe Prairie site that may be influential in the survival and growth of camas.

All soil profiles exhibited morphological characteristics consistent with a low-lying, alluvial/lacustrine landscape setting. They are characterized by the presence of redoximorphic features, indicating seasonal saturation with water. It is likely that the seasonal saturation of these soils is related to their ability to support camas, which is facultative wetland species (USDA–NRCS, 2010). An important feature of many Weippe Prairie site soils is the presence of a slowly permeable subsoil horizon that causes a seasonal perched water table. Because these horizons are commonly found at depths of ~0.5 m, they have a strong influence on root-zone soil-water relations.

Soils of the Weippe Prairie tend to have finer textures – silt and clay are the most abundant particle sizes. These textures are indicative of relatively low-energy depositional environments, such as those associated with slow-moving streams and lakes.

Laboratory data indicate that soil chemical properties do not differ markedly across the Weippe Prairie site. All soils are very strongly or strongly acid, a condition that affects many biological and chemical processes. Results also show that reserves of exchangeable base cations (Ca^{2+} , Mg^{2+} , and K^{+}) do not appear to be limiting for plant growth.

Kaolin is the dominant clay mineral found in the soils studied, and its presence generally indicates rather intensely weathered soil parent materials. In the case of Weippe Prairie soils, they appear to have formed mainly in pre-weathered alluvial and lacustrine parent materials. There have been additions of younger sediments such as volcanic ash and loess. Additions of these younger materials may help rejuvenate the supply of base cations in these soils and contribute to their fertility.

Hydrological monitoring confirmed the morphological evidence for seasonal wetness. All Weippe Prairie soils studied have water tables for periods in the range of 5-7 months per year. However, two major differences were observed among soils. The first difference is the relative position of the water table within the soil profile – some soils (Sites 1, 4, and 5) were usually saturated within 15 cm of the soil surface during the time when a water table was present. Water table levels at the other sites (Sites 2, 3, and 6) were typically lower in the soil profile. The second difference was ponding of water. Site 4 remained ponded for 3-4 months, while Sites 2 and 6 were never ponded. Despite these differences, there does not appear to be a consistent relationship between water tables and camas densities.

The results of this project provide valuable baseline information about soils of the Weippe Prairie site. However, they do not identify specific soil properties related to observed camas density differences. This suggests that differences in camas density at the Prairie may be due to factors such as disturbance and past management rather than edaphic factors.

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Appendix I: Laboratory Protocols

Sample Preparation

Samples collected from genetic horizons at each of the field sites were air-dried, gently crushed, and sieved to obtain the <2-mm size fraction for all laboratory analyses (Soil Survey Laboratory Staff, 2004).

Chemical Analyses

1:1 (Soil/H₂O) pH – Twenty grams of soil were weighed into a plastic container and 20-mL of triple distilled water (TDW) was added, mixed, covered, and let stand for 2-hours. pH was read using a standard pH electrode (Soil Survey Laboratory Staff, 2004).

NaF pH – The influence of volcanic ash was measured using 1M sodium fluoride (NaF) solution. One gram of soil was weighed, 50-mL of NaF solution added, and the pH read using a standard pH electrode at 2-minutes after stirring for 1-minute. A NaF pH ≥ 9.4 is a strong indicator that poorly or nanocrystalline minerals (i.e. volcanic ash weathering products) dominate the soil exchange complex (Fieldes and Perrott, 1966).

Exchangeable cations – Exchangeable cations (Ca, Mg, K, and Na) were extracted using 1 M ammonium acetate (NH₄OAc) at pH 7. Soil was weighed, ~35-mL of NH₄OAc added, placed on a hot plate for 2-hours, cooled, and extracted using a Buchner funnel apparatus with suction. Extracts were diluted and analyzed using an inductively coupled plasma (ICP) spectroscopy for Ca, Mg, K, and Na. Cation exchange capacity (CEC) at pH 7 was determined by washing the soil exchange from the exchangeable cation procedure, then removing the ammonium from the exchange using acidified sodium chloride (NaCl). The acidified NaCl solution was diluted and analyzed for ammonium using the automated AE Quickem Lachat spectrophotometer. Base saturation percent (B.S. %) was calculated using the sum of cations (pH 7) divided by the sum of cations plus acidity multiplied by 100 (Sumner and Miller, 1996).

Exchangeable acidity – Exchangeable acidity (hydrogen plus aluminum) was extracted using barium chloride (BaCl₂) and triethanolamine (TEA) at pH 8.2. Soil was weighed, ~100-mL of BaCl₂-TEA solution added and soils leached with small additions of BaCl₂-TEA solution after setting overnight using a Buchner funnel apparatus with suction. The leachate was back titrated using standardized hydrochloric acid (HCl) to a pink endpoint (Soil Survey Laboratory Staff, 1996).

Total carbon and nitrogen – Soil samples were analyzed for total carbon (C) and total nitrogen (N) by dry combustion (Nelson and Sommers, 1996) using an Elementar CNS analyzer. Samples were weighed into crucibles and placed in the automated Elementar CNS analyzer to combust at 1000 °C. C:N ratios were calculated using the total C and N data.

Physical Analyses

Bulk density – Triplicate 1-3 inch sized aggregates were collected by horizon at each of the field sites. A thin copper wire was tied around the aggregates, oven-dried, weighed, then coated with Saran F-310 lacquer at least 3 times at 15-minute intervals. Aggregate volume was obtained by

weighing in water (Blake and Hartge, 1986). Data were averaged for each horizon and reported in g/cm³.

Particle-size Distribution – Particle-size distribution was performed using sieving and sedimentation procedures (Gee and Bauder, 1986). Samples were pre-treated with sodium hypochlorite (NaOCl) to destroy organic aggregating agents (Anderson, 1963; Mikhail and Briner, 1978). Dispersion was completed using a sodium hexametaphosphate solution, mechanical shaking overnight, and sonification. The sand fraction was removed from the suspension by wet sieving and then fractionated by dry sieving. Clay and silt in suspension were stirred and aliquots removed with a pipette at predetermined intervals based on Stokes' law (Kilmer and Alexander, 1949). Aliquots were dried at 110°C and weighed. The very fine sand fraction was examined under a petrographic microscope to determine volcanic glass content and other features (Drees and Ransom, 1994). Scanning electron microscopy (SEM) was used to image special features found in the very fine sand fraction; this work was performed by Dr. Leslie Baker, Soil Chemistry Research Support Scientist.

Clay Mineralogy – X-ray diffraction analysis was used to determine the crystalline mineralogical components of clays (<2 µm diameter) saved from the particle-size analysis. Treatments included magnesium (Mg) saturation, Mg saturation and glycerol solvation, potassium (K) saturation, and K saturation-heated to 500°C (Jackson, 1975; Whittig and Allardice, 1986). Samples were oriented on glass slides and analyzed on a Siemens D5000 diffractometer instrument using Cu-K α radiation and a continuous scan rate. A formamide treatment to the Mg saturated slide was used to differentiate kaolinite from halloysite (Churchman et al., 1984; Theng et al., 1984).

Water Retention (soil water content at a given soil water tension) – Water retention is useful directly and indirectly as an indicator of other soil characteristics such as drainage, aeration, infiltration, plant available water, and rooting patterns. Soil samples were run by the pressure method (Klute, 1986). Samples were placed in retainer rings on a ceramic plate and equilibrated at 0.33 (field capacity) and 1.5 MPa (wilting point). Pressure was kept constant until equilibrium obtained; gravimetric water content of samples was then determined. The difference between 0.33 and 1.5 MPa is an estimate of plant-available water-holding capacity (U.S. Salinity Staff, 1954; Klute, 1986).

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Appendix II – NRCS Map Unit Descriptions

Map Unit Description: Burntcreek ashy loam, 0 to 3 percent slopes—Clearwater Area, Idaho

Clearwater Area, Idaho

43—Burntcreek ashy loam, 0 to 3 percent slopes

Map Unit Setting

Elevation: 3,000 to 3,350 feet

Mean annual precipitation: 30 to 40 inches

Mean annual air temperature: 38 to 44 degrees F

Frost-free period: 50 to 110 days

Map Unit Composition

Burntcreek and similar soils: 80 percent

Minor components: 3 percent

Description of Burntcreek

Setting

Landform: Drainageways, flood plains

Down-slope shape: Linear

Across-slope shape: Linear

Parent material: Mixed alluvium

Properties and qualities

Slope: 0 to 3 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Somewhat poorly drained

Capacity of the most limiting layer to transmit water

(Ksat): Moderately high to high (0.57 to 1.98 in/hr)

Depth to water table: About 7 to 19 inches

Frequency of flooding: Occasional

Frequency of ponding: None

Available water capacity: Moderate (about 8.3 inches)

Interpretive groups

Land capability (nonirrigated): 4w

Ecological site: SEMIWET MEADOW (R009XY019ID)

Other vegetative classification: grand fir/queencup beadrily (CN520)

Typical profile

0 to 7 inches: Ashy loam

7 to 11 inches: Loam

11 to 28 inches: Loam

28 to 36 inches: Loam

36 to 60 inches: Stratified very gravelly sandy clay loam to coarse sand

Minor Components

Aquandic endoaquepts

Percent of map unit: 3 percent

Landform: Drainageways

Clearwater Area, Idaho

43—Burntcreek ashy loam, 0 to 3 percent slopes

Map Unit Setting

Elevation: 3,000 to 3,350 feet
Mean annual precipitation: 30 to 40 inches
Mean annual air temperature: 38 to 44 degrees F
Frost-free period: 50 to 110 days

Map Unit Composition

Burntcreek and similar soils: 80 percent
Minor components: 3 percent

Description of Burntcreek

Setting

Landform: Drainageways, flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mixed alluvium

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water
(Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 7 to 19 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Available water capacity: Moderate (about 8.3 inches)

Interpretive groups

Land capability (nonirrigated): 4w
Ecological site: SEMIWET MEADOW (R009XY019ID)
Other vegetative classification: grand fir/queencup beadlily (CN520)

Typical profile

0 to 7 inches: Ashy loam
7 to 11 inches: Loam
11 to 28 inches: Loam
28 to 36 inches: Loam
36 to 60 inches: Stratified very gravelly sandy clay loam to coarse
sand

Minor Components

Aquandic endoaquepts

Percent of map unit: 3 percent
Landform: Drainageways

Ecological site: WET MEADOW (R009XY018ID)

Data Source Information

Soil Survey Area: Clearwater Area, Idaho
Survey Area Data: Version 4, Jan 26, 2007



Clearwater Area, Idaho

87—Gramil-Lewhand complex, 0 to 2 percent slopes

Map Unit Setting

Elevation: 3,000 to 3,200 feet
Mean annual precipitation: 30 to 35 inches
Mean annual air temperature: 38 to 44 degrees F
Frost-free period: 50 to 110 days

Map Unit Composition

Gramil and similar soils: 60 percent
Lewhand and similar soils: 30 percent
Minor components: 3 percent

Description of Gramil

Setting

Landform: Lake terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium and/or loess over lacustrine deposits

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low
to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 0 to 6 inches
Frequency of flooding: None
Frequency of ponding: Occasional
Available water capacity: High (about 10.6 inches)

Interpretive groups

Land capability (nonirrigated): 4e
Other vegetative classification: grand fir/queencup beadrily (CN520)

Typical profile

0 to 12 inches: Ashy silty clay loam
12 to 19 inches: Ashy silt loam
19 to 27 inches: Clay loam
27 to 39 inches: Clay
39 to 70 inches: Clay

Description of Lewhand

Setting

Landform: Mountain slopes
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Volcanic ash over mixed alluvium

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 13 to 19 inches to fragipan
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low
to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 0 to 2 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Available water capacity: Low (about 3.6 inches)

Interpretive groups

Land capability (nonirrigated): 4w
Ecological site: WET MEADOW (R009XY018ID)

Typical profile

0 to 8 inches: Ashy silty clay loam
8 to 12 inches: Silty clay loam
12 to 18 inches: Silt loam
18 to 32 inches: Silt loam
32 to 60 inches: Stratified silty clay to sand

Minor Components

Teneb

Percent of map unit: 3 percent
Landform: Drainageways
Ecological site: WET MEADOW (R009XY018ID)

Data Source Information

Soil Survey Area: Clearwater Area, Idaho
Survey Area Data: Version 4, Jan 26, 2007

Clearwater Area, Idaho

88—Gramil-Reggear complex, 2 to 6 percent slopes

Map Unit Setting

Elevation: 3,000 to 3,200 feet
Mean annual precipitation: 30 to 35 inches
Mean annual air temperature: 38 to 44 degrees F
Frost-free period: 50 to 110 days

Map Unit Composition

Gramil and similar soils: 50 percent
Reggear and similar soils: 40 percent

Description of Gramil

Setting

Landform: Lake terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium and/or loess over lacustrine deposits

Properties and qualities

Slope: 2 to 5 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low
to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 0 to 6 inches
Frequency of flooding: None
Frequency of ponding: Occasional
Available water capacity: High (about 10.6 inches)

Interpretive groups

Land capability (nonirrigated): 4e
Other vegetative classification: grand fir/queencup beadlily (CN520)

Typical profile

0 to 12 inches: Ashy silty clay loam
12 to 19 inches: Ashy silt loam
19 to 27 inches: Clay loam
27 to 39 inches: Clay
39 to 70 inches: Clay

Description of Reggear

Setting

Landform: Hillslopes
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Volcanic ash over loess

Properties and qualities

Slope: 2 to 12 percent

Depth to restrictive feature: 20 to 40 inches to fragipan
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low
to moderately low (0.00 to 0.06 in/hr)
Depth to water table: About 12 to 29 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Moderate (about 6.5 inches)

Interpretive groups

Land capability (nonirrigated): 4e
Other vegetative classification: grand fir/queencup beadrily (CN520)

Typical profile

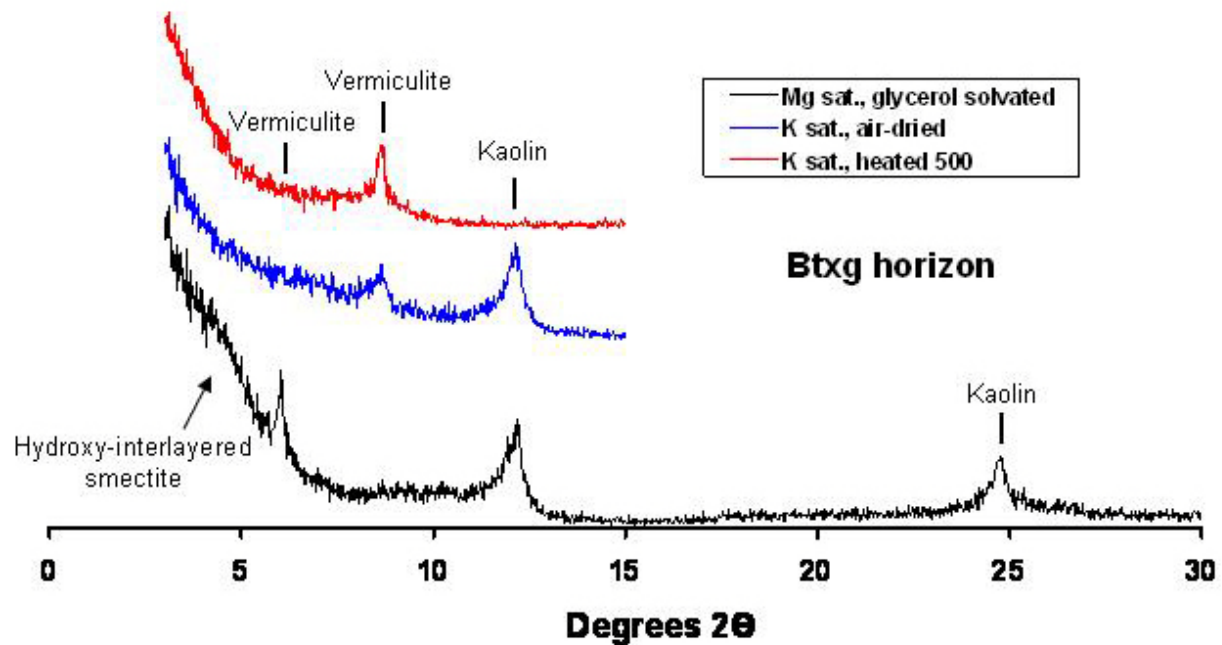
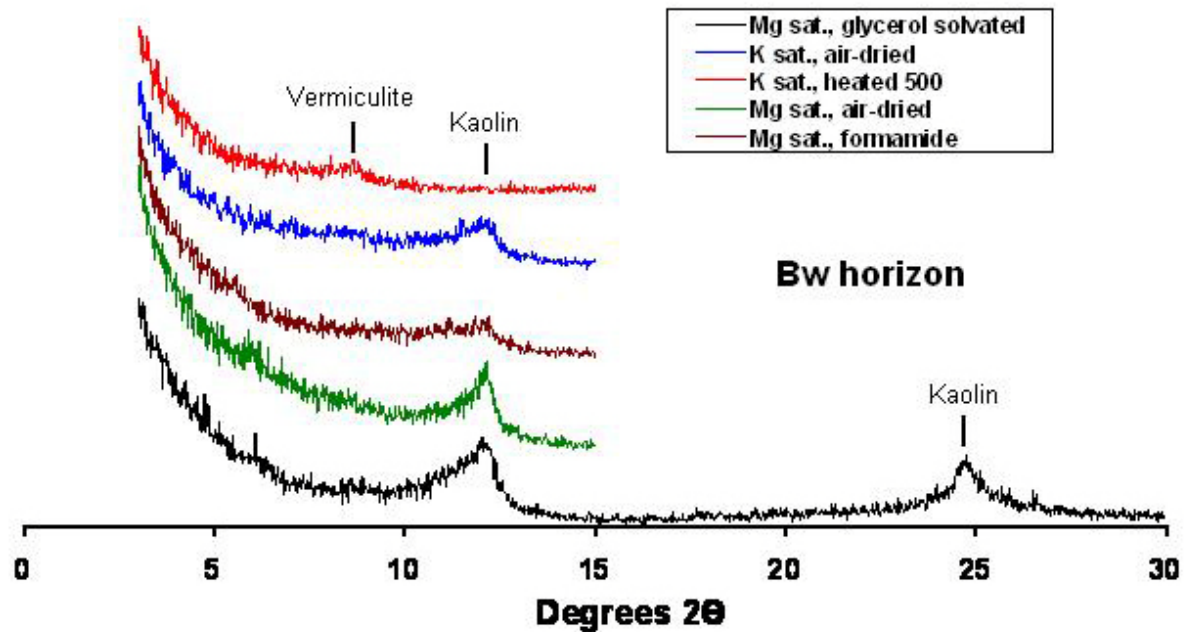
0 to 1 inches: Slightly decomposed plant material
1 to 8 inches: Ashy silt loam
8 to 13 inches: Ashy silt loam
13 to 22 inches: Silt loam
22 to 31 inches: Silt loam
31 to 60 inches: Silt loam
60 to 86 inches: Silt loam

Data Source Information

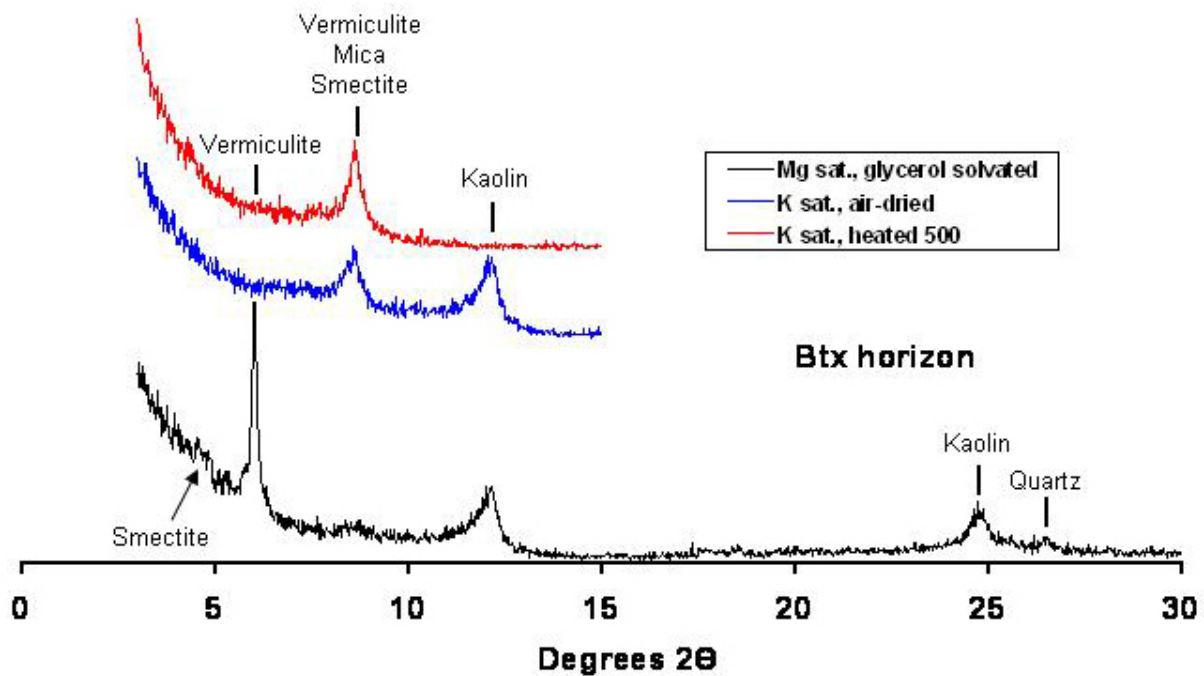
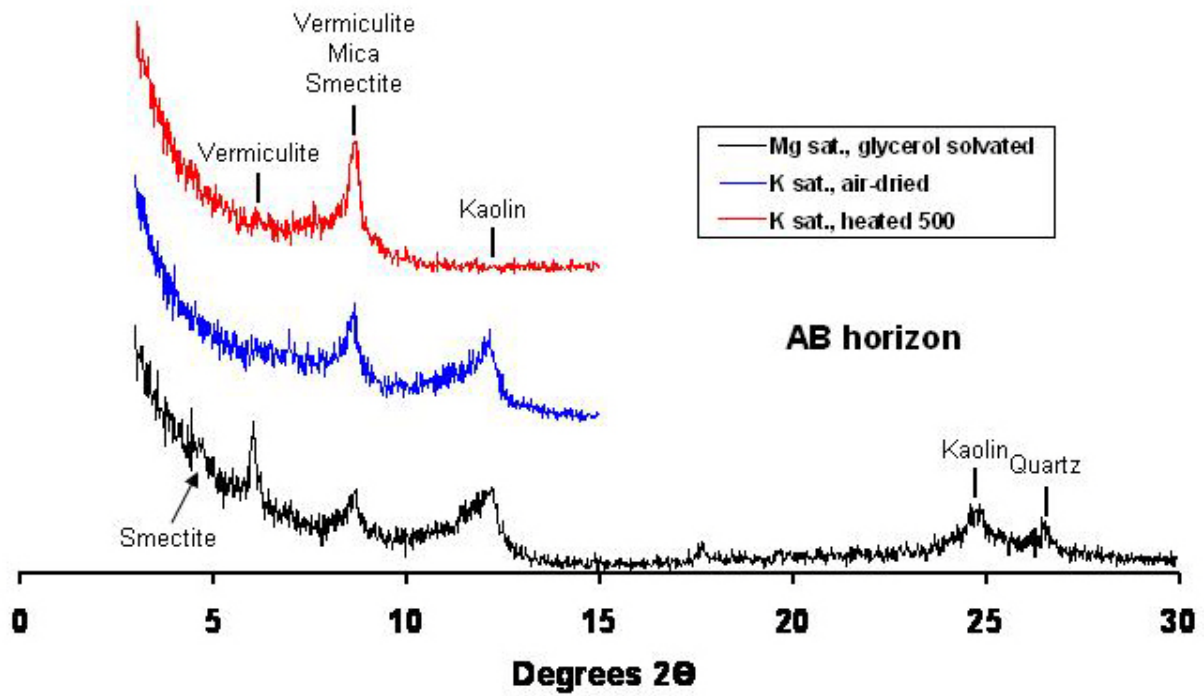
Soil Survey Area: Clearwater Area, Idaho
Survey Area Data: Version 4, Jan 26, 2007

Appendix III – X-ray Diffraction Patterns

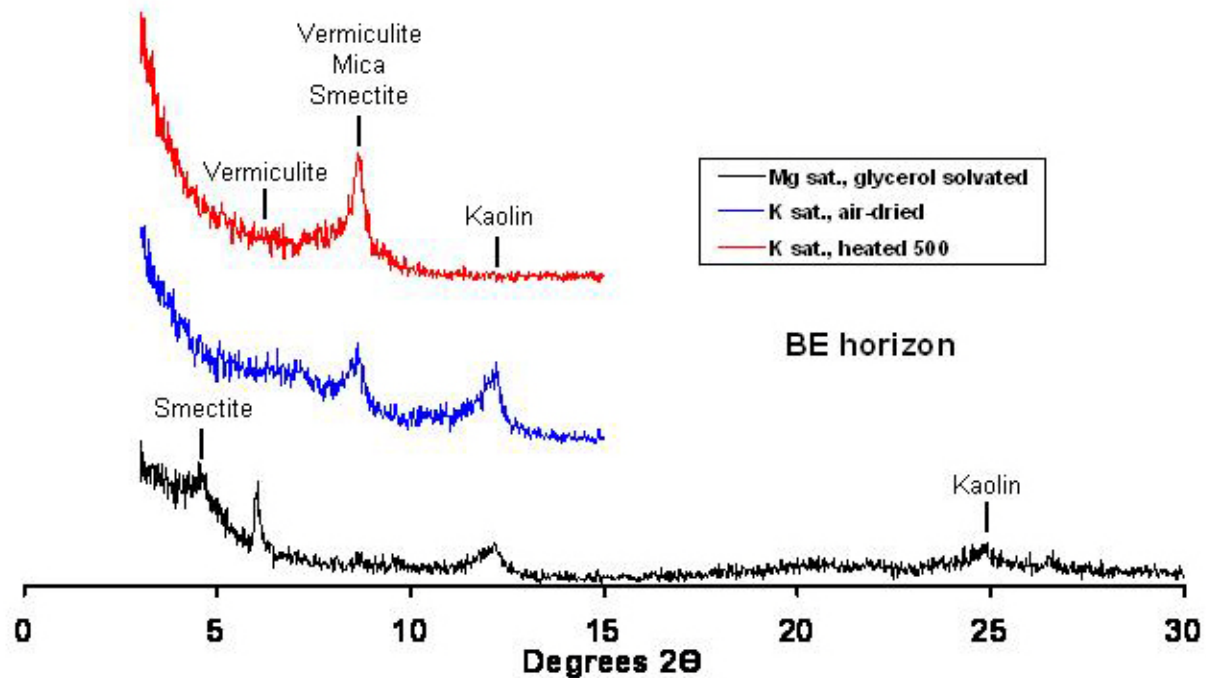
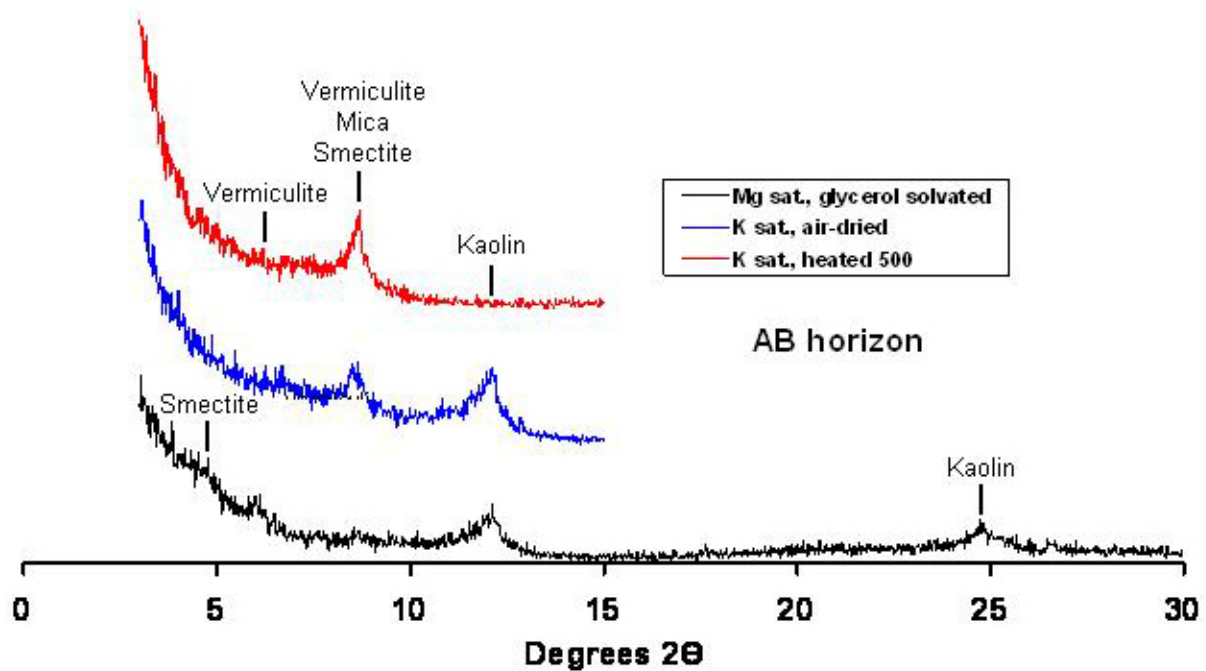
Site 1



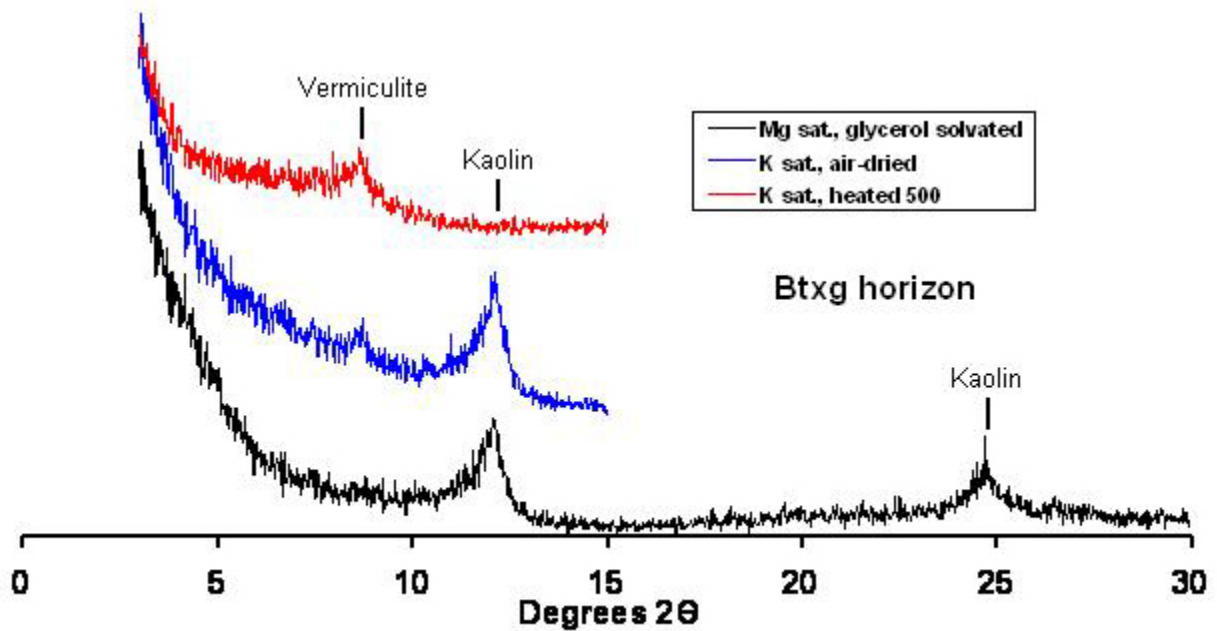
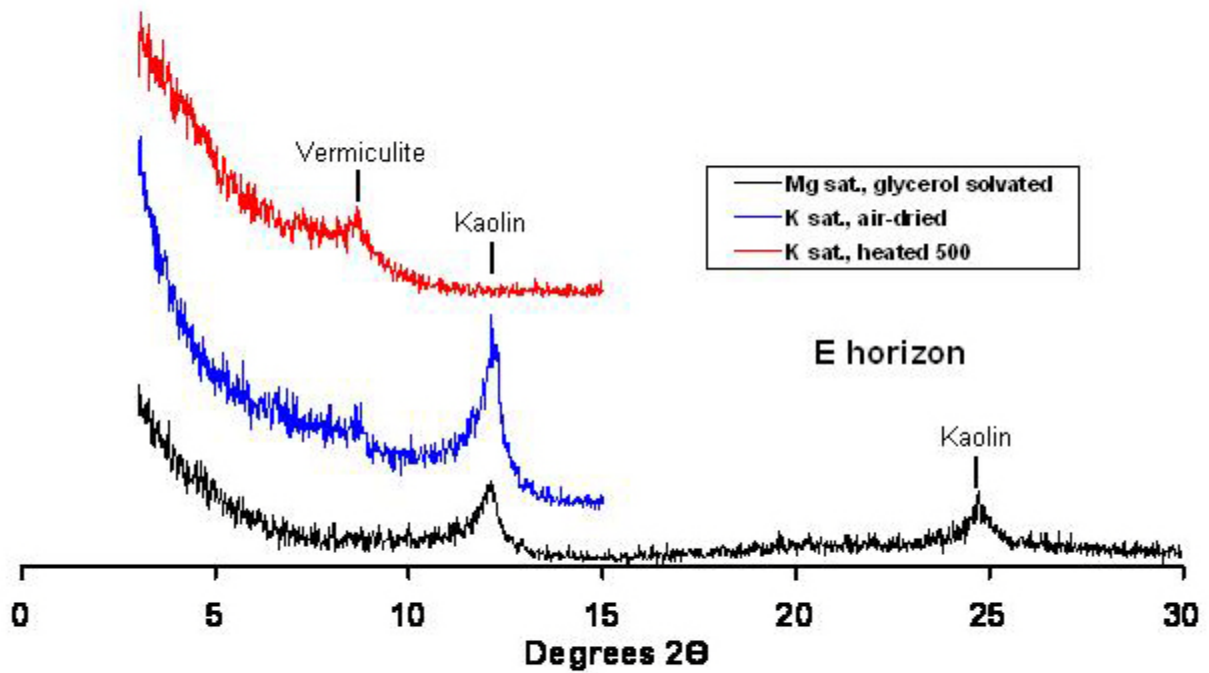
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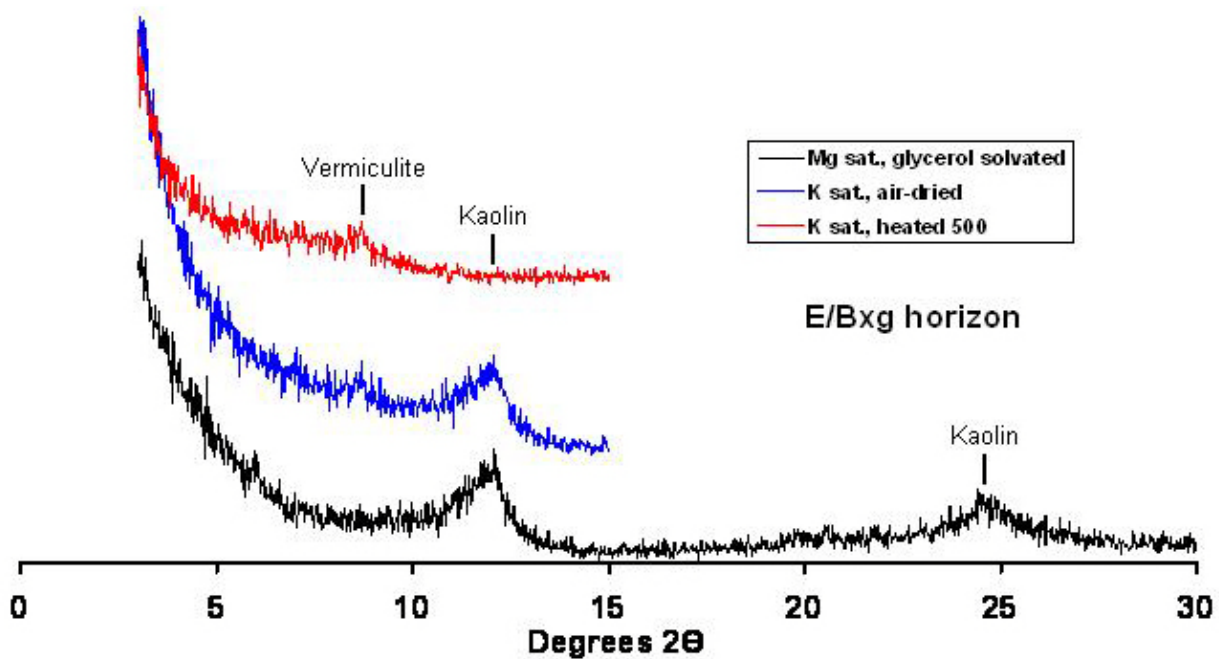
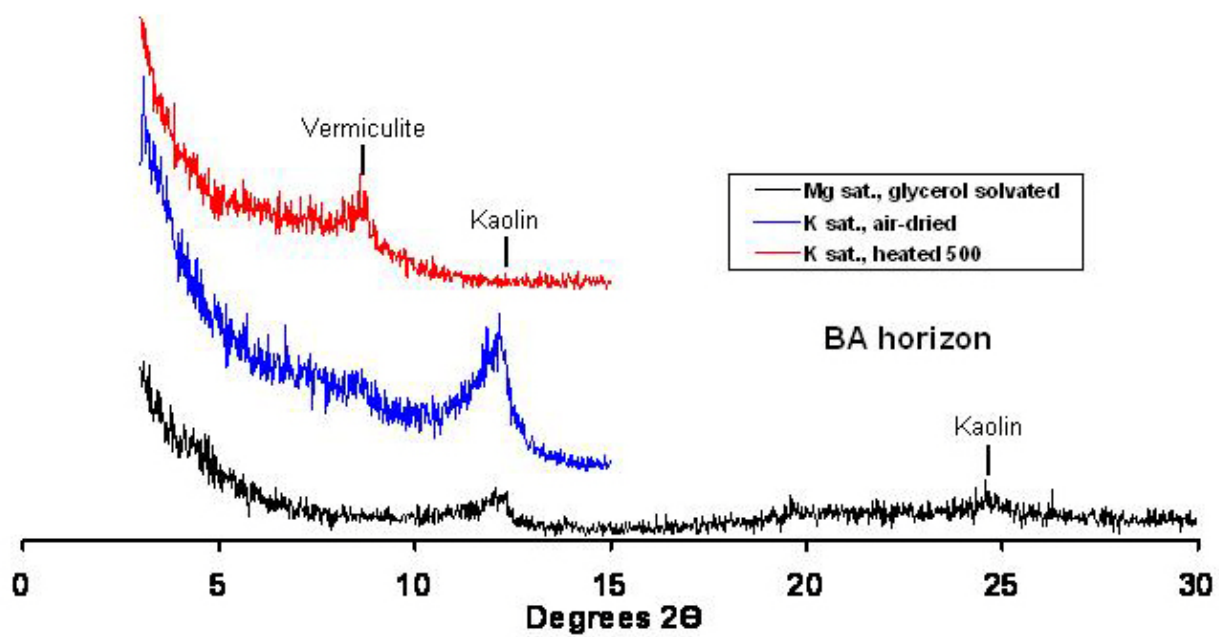
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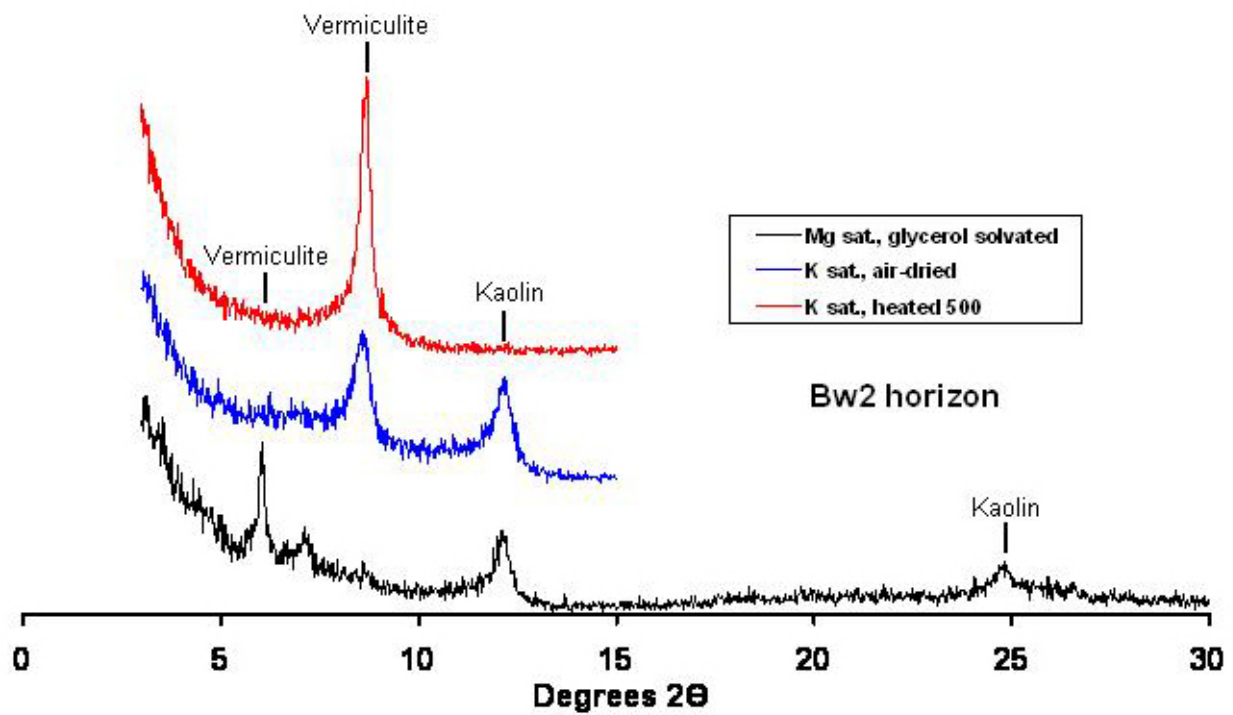
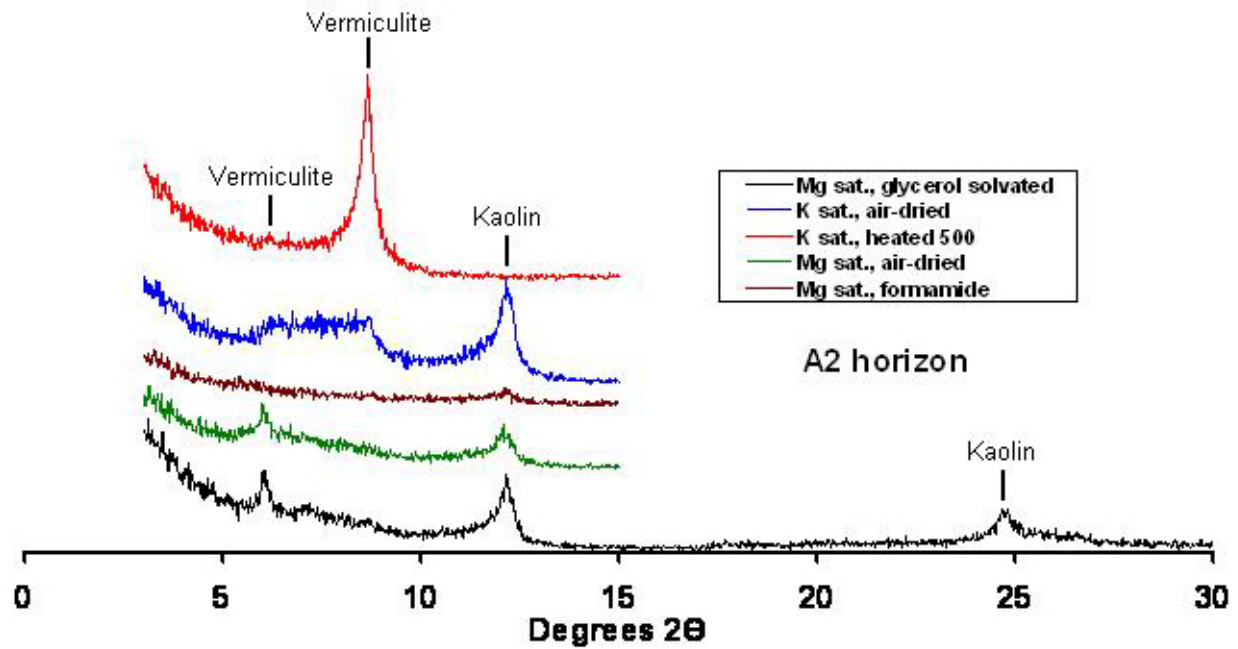
Site 4



Site 5



Site 6



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 429/106889, February 2011

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U.S. Department of the Interior



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