SOIL 557 – Field Trip Guide
Western Palouse/Channeled Scabland
Fall 2012

The following information is taken from field trip guides originally prepared for the 2001 Washington Society of Professional Soil Scientist field tour and the 2001 Western Soil Science Society field tour. These guides were prepared by Alan Busacca and Paul McDaniel.

PALOUSE LOESS

The thick deposit of loess that blankets the Columbia Plateau is one of the major geologic features produced during the Quaternary Period in the Pacific Northwest. The core of this area, which is centered in eastern Washington, is called "The Palouse"(Fig. 1). The Palouse covers more than 10,000 km^2 with loess that is up to 75 m thick. Thinner and less continuous loess deposits cover an additional 30,000-40,000 km^2 in Washington, north central Oregon and northern Idaho. The loess was deposited chiefly on the gently southwest-sloping surface of the Miocene-age Columbia River Basalt. The altitude of the loess hills declines from about 800 m in northern Idaho east of the town of Moscow to about 200 m on the margin of the Pasco Basin. The surface of the basalt has warps and undulations beneath the loess. In the eastern part, island-like remnants of crystalline rocks of the Rocky Mountain system protrude as much as 450 m above the general level of the basalt and loess to create "steptoes" (buttes). Perennial streams in the Palouse flow in basalt-floored valleys.

The origin of the distinctive, steeply rolling, complex hill patterns has been the subject of considerable debate among geomorphologists and pedologists. The drainage pattern is dendritic in the eastern Palouse. This feature, along with bowl-shaped first-order drainages on north aspects caused by earthflows, implicates water, not wind, as the primary agent responsible for the classic Palouse hill shapes. The unusual hill shapes have repeatedly been called dunes in many popular accounts of the area (much to the continuing dismay of Busacca), but the loess at this position in the dust distribution system has a mean diameter of about 15-30 μm (Busacca and McDonald, 1994) and has been deposited from suspension, not saltation. A more plausible explanation is that water erosion processes have kept pace with loess deposition over the past 1 to 2 million years, shaping the hills

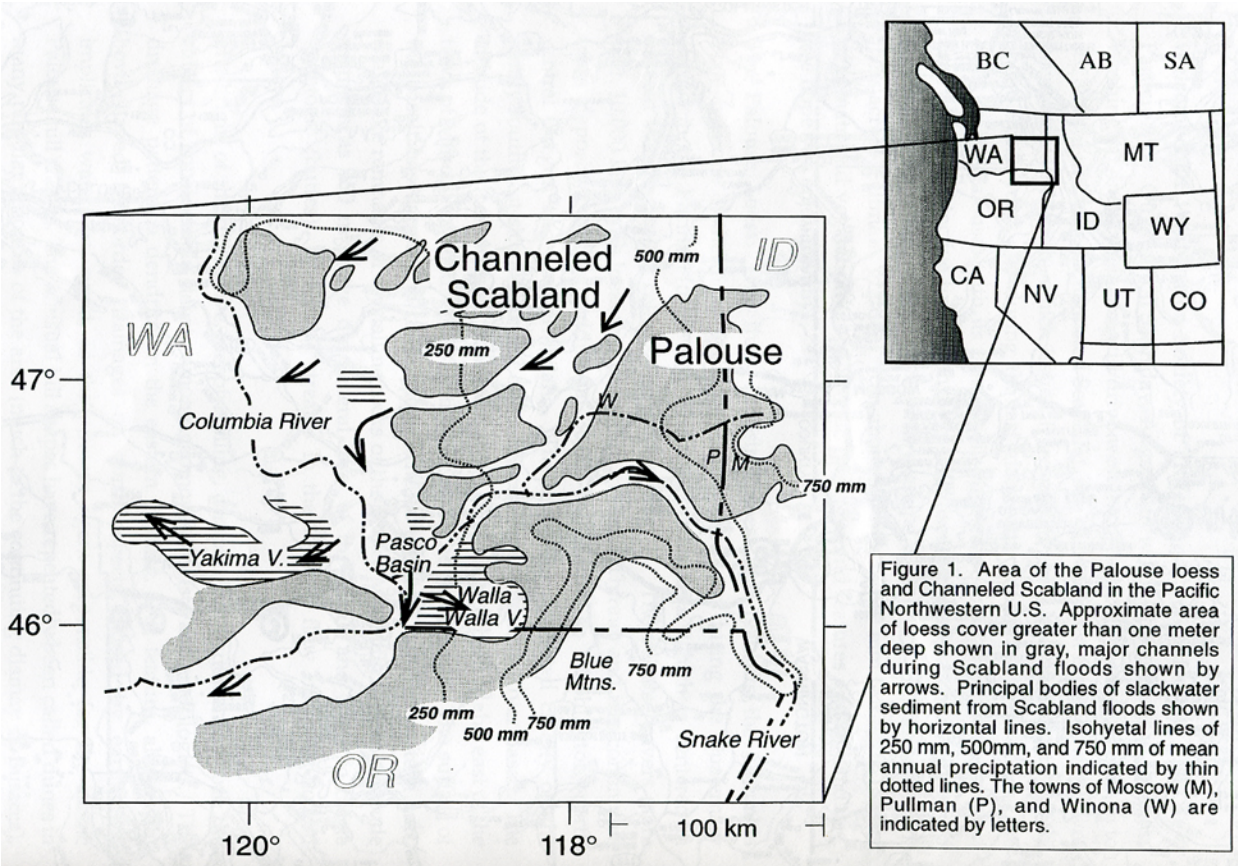

Figure 1. Area of the Palouse loess and Channeled Scabland in the Pacific Northwestern U.S. Approximate area of loess cover greater than one meter deep shown in gray, major channels during Scabland floods shown by arrows. Principal bodies of slackwater sediment from Scabland floods shown by horizontal lines. Isohyetal lines of 250 mm, 500mm, and 750 mm of mean annual preciptation indicated by thin dotted lines. The towns of Moscow (M), Pullman (P), and Winona (W) are indicated by letters.

into the rounded forms we see, continuously delivering part of the eolian mantle to perennial streams.

The bowl-shaped or "cirque-like" forms of northeast-facing slopes have resulted from nivation processes both recently and probably more actively during cold climate phases. Every winter, snow accumulates in deep drifts just to the lee (NE) of hill crests. Runoff events over frozen soil lead to sheet and rill erosion and to earthflows and mudflows that are concentrated on NE slopes. Rotational slumps also are common on NE slopes as the melting snow banks saturate the soils. The interface between the Holocene or L1 loess (McDonald and Busacca, 1992) and underlying paleo-argillic horizons forms to usual plane of failure.

The topography is distinctly trellis-like with strict alignment of loessial ridges in the southwestern Palouse. The origin of this topography has been attributed to wind (Lewis, 1960) but is not clear. Loess in the central part of the Columbia Plateau has been partly stripped away by cataclysmic outburst floods from Glacial Lake Missoula, leaving streamlined "loess islands" that range in area from 1 km^2 to more than 1,000 km^2. Two review articles (Busacca, 1989; 1991) summarize much of what had been researched and written about the Palouse between the 1880's and 1980's, including the origin of the loess, its stratigraphy, soils, and landscapes.

THE CHANNELED SCABLAND

The Channeled Scabland in eastern Washington is part of the Lake Missoula-Channeled Scabland system (Fig. 1). Cataclysmic glacial outburst floods from the repeated failure of the glacially dammed Lake Missoula created the largest floods documented on earth (Baker and Nummedal, 1978). These floods overwhelmed the Columbia River drainage system, sending up to 2500 km^3 (500 mi^3) of water across the Columbia Plateau with each outburst. The floods created in the Channeled Scabland a spectacular complex of anastomosing channels cut into southwest-dipping basalt surfaces. The floods created huge cataracts now seen as dry falls, "loess island": erosional remnants of a thick loess cover on the plateau, immense gravel bars, and ice-rafted erratic boulders at high elevations, as well as a host of other features created by the powerful erosion of loess and underlying basalt of the Columbia Plateau.

In southcentral Washington, the many paths of the onrushing floods converged on the Pasco Basin (Fig. 1) where floodwaters were slowed by the hydrologic constriction of Wallula Gap before draining out through the Columbia Gorge to the Pacific Ocean. When the floodwaters slowed at Wallula Gap, tributaries of the lower Columbia like the Snake, Yakima, and Walla Walla were inundated by water *backflooding up these valleys*, which became choked with fine sand and silt that dropped out of suspension as the floods washed into them and then drained out again. Regional patterns of the thickness and grain size of L1 and L2 loess demonstrate that the silty *slackwater sediments* from the floods were the major sediment source for these loess sheets (McDonald and Busacca, 1994).

Many already are aware that the interpretation of a giant-flood origin for the features of the Channeled Scabland, made by geologist J Harlen Bretz in journal articles beginning in 1923 (Bretz, 1923, 1925, 1928a, b, c, 1932, 1969; Bretz *et al*., 1956), precipitated perhaps *the* celebrated scientific debate in American geology. "The Spokane Flood controversy is both a story of ironies and a marvel of exposition of the scientific method. In a series of papers between 1923 and 1932, J Harlen Bretz shocked the geological community with his studies of an enormous complex of proglacial channels eroded into the loess and basalt of the Columbia Plateau, eastern Washington. This region, which he named the "Channeled Scabland", contained erosional and depositional features that were unique among fluvial phenomena. With painstaking field work, before the advent of aerial photographs and modern topographic maps, Bretz documented the field relationships of the region. He argued that the landforms could only be explained as a relatively brief, but enormous flood, which he called the "Spokane Flood." Considering the nature and vehemence of the opposition to this outrageous hypothesis, the eventual triumph of that idea constitutes one of the most fascinating episodes in the history of modern geomorphology" (Baker, *in* Baker and Nummedal, 1978, p. 3).

Bretz's ideas of giant-scale floods were in direct conflict with the uniformitarian principles that had brought geology to its modern era. Even after additional evidence was found for a source of the flood water (Pardee, 1942), it remained until 1956 (Bretz *et al*., 1956) before his ideas became widely accepted. In recent decades, researchers have estimated the hydraulics of giant flood flows and explained the origin of scabland features (Baker, 1973; Baker and Nummedal, 1978; Baker and Bunker, 1985); deduced that there were tens of last-glacial floods (Waitt, 1980, 1984, 1985; Atwater, 1986), perhaps as many as 90; documented the detailed sedimentology of backflooding (Smith, 1993); and learned that giant floods were associated with not just one but at least six or seven major glacial advances in the Pleistocene (Patton and Baker, 1978; McDonald and Busacca, 1988).

STOP 1: ATHENA SERIES SOIL PROFILE

As we travel eastward, elevation and MAP increase as a consequence of the westerly dip of the top of the CRB. MAP at this site is about 400 mm and the loess deposit here may be about 50 m thick. Soils in deep loess are dominantly Pachic and Calcic Pachic Haploxerolls of the Athena and Calouse series (Donaldson, 1980). The soils are quite typical of the Mollisols in the intermediate rainfall zone of the Palouse that have a well-expressed mollic epipedon over a prismatic or blocky cambic horizon. A well developed calcic or petrocalcic horizon also is common and is described as a Bk or Bkm horizon in soil surveys.

Until recently, there was only partial recognition that the deeper horizons of many Palouse soils, such as the petrocalcic horizon, are formed by overprinting or welding of younger carbonates into the former surface horizons of a paleosol. At this site, the mollic and cambic horizons are formed in L1 loess and the calcic and deeper horizons are part of the Washtucna Soil in L2 loess. Fortuitously, a discontinuous band of MSH set S tephra (15,000 yr BP) is preserved here at the base of the cambic horizon. As many as one-half of the upland soils in the Palouse have such welded or superimposed profiles (Busacca *et al.*, 1985), with the character of the paleosol varying from calcic to argillic to fragipan with increasing MAP (Busacca, 1989).

In this area, the cropping system is a two- or three- year wheat-fallow rotation because of low soil moisture. Nearby growers achieve 60 bu/ac yields of winter wheat in a good year. The fallow rotation is recognized as a highly susceptible to wind and water erosion and efforts are underway to replace fallow system with newly developed continuous cropping systems. In this exposure and others along this road, as much as 100 cm of post-farming overburden buries the original A horizon. The official series description of Athena (following page) illustrates typical horizonaton and morphology from the type location in NE Oregon.

LOCATION ATHENA OR+ID WA
Established Series
Rev. SHB/SBC
07/2009

ATHENA SERIES

The Athena series consist of deep and very deep, well drained soils that formed in loess mixed with volcanic ash. They are on canyon sides, hills, and plateaus. Slopes are 0 to 70 percent. The mean annual precipitation is about 17 inches and the mean annual temperature is about 50 degrees F.
TAXONOMIC CLASS: Fine-silty, mixed, superactive, mesic Pachic Haploxerolls

TYPICAL PEDON: Athena silt loam-cultivated. (Colors are for moist soil unless otherwise noted.)

Ap--0 to 8 inches; very dark brown (10YR 2/2) silt loam, dark grayish brown (10YR 4/2) dry; moderate fine granular structure; hard, friable, slightly sticky and slightly plastic; many very fine roots; many fine and very fine irregular pores; lower 1/4 inches a firm, platy and dense plow pan; slightly acid (pH 6.4); abrupt smooth boundary. (6 to 9 inches thick)

A1--8 to 15 inches; very dark brown (10YR 2/2) silt loam, dark grayish brown (10YR 4/2) dry; weak very fine subangular blocky structure; hard, friable, slightly sticky and slightly plastic; many very fine roots; many very fine pores; neutral (pH 6.7) clear wavy boundary. (5 to 9 inches thick)

A2--15 to 26 inches; very dark grayish brown (10YR 3/2) silt loam, dark grayish brown (10YR 4/2) dry; weak coarse prismatic structure parting to fine subangular blocky; hard, friable, slightly sticky and slightly plastic; many very fine roots; many very fine pores neutral (pH 6.9); gradual wavy boundary. (0 to 12 inches thick)

Bw1--26 to 39 inches; dark brown (10YR 3/3) silt loam, brown (10YR 5/3) dry; weak coarse prismatic structure parting to moderate fine and medium subangular blocky; hard, friable, slightly sticky and slightly plastic; common very fine roots; many very fine pores; neutral (pH 7.2); clear wavy boundary. (10 to 20 inches thick)

Bw2--39 to 46 inches; dark yellowish brown (10YR 4/4) silt loam, light yellowish brown (10YR 6/4) dry; weak medium and coarse subangular blocky structure; hard, firm, slightly sticky and slightly plastic; common very fine roots; many very fine and fine pores; slightly alkaline (pH 7.5); abrupt wavy boundary. (6 to 20 inches thick)

Bk1--46 to 53 inches; dark yellowish brown (10YR 4/4) silt loam, light yellowish brown (10YR 6/4) dry; weak medium and coarse subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; few very fine roots; many very fine pores; few dark gray medium and coarse sand particles; slightly effervescent with few lime veins and coatings around root channels; moderately alkaline (pH 8.2); clear wavy boundary. (0 to 10 inches thick)

Bk2--53 to 65 inches; dark yellowish brown (10YR 4/4) silt loam, light yellowish brown (10YR 6/4) dry; massive; slightly hard, friable, slightly sticky and slightly plastic; many very fine pores; few coarse and very coarse sand particles; intermittently slightly effervescent with segregated lime; moderately alkaline (pH 8.1); abrupt smooth boundary. (0 to 20 inches thick)

2R--65 inches; basalt

TYPE LOCATION: Umatilla County, Oregon; 2.5 miles southeast of Athena on the Crow Field Pendleton Branch Experiment Station in SE1/4 section 28, T.4N., R.35E.

STOP 2: MAZAMA TEPHRA IN HOLOCENE VALLEY FILL SEDIMENTS

This is a brief stop to see an excellent exposure of tephra from the climactic eruption about 7,700 cal. yr B.P. of Mount Mazama (site of today's Crater Lake in southern Oregon), which blanketed most of the northwestern U.S. and southwestern Canada in ash. In eastern Washington, the compacted thickness of the original airfall was about 20-25 cm. Here in the Holocene valley fill alluvium, this thickness is increased substantially by ash and ashy loess that was eroded from the upland slopes for several hundred to several thousand years by wind and water.

STOP 3: WINONA-1 RESEARCH ROADCUT AND WIG-1 RESEARCH DEEP DRILLING SITE

Stratigraphy of Loess and Buried Paleosols: To date the stratigraphy of loess units and buried paleosols has been developed in detail for the past 116,000 yr, most recently by the Ph.D. research of Dr. Matthew King (King, 2000). The stratigraphy has now been extended back to about a million years in a deep drill core collected on the hill summit above this roadcut (Busacca et al., 1998).

WIN-1 Roadcut: The first description of the stratigraphy of the roadcut exposure here was made by Eric McDonald in 1985 and 1986 (McDonald, 1987). The total stratigraphic thickness exposed in the roadcut is about 20 m and the sediments are all normally magnetized, which we presume to mean they were deposited during the Brunhes Normal Polarity Chron (Busacca, 1991). The oldest radiometric age measured in the roadcut exposure so far is an age of 116,000 yr on loess at a depth of 8 m. The Washtucna Soil is the prominent white petrocalcic horizon about 2 m below the land surface. The Mount St. Helens C tephra, ca. 50,000 yr, can be seen in the sandy loess beneath the Washtucna Soil. This is also a good exposure in which to see zones of carbonate cemented cicada burrows, formed during interstadial to glacial climates when this site supported a periglacial sagebrush steppe (O'Geen and Busacca, 2001).

WIG-1 Deep Drill Core: In 1996, a 38-m drill core was extracted from a site on the crest of the hill above us. The core exposed about 20 calcic paleosols and bottomed in basalt (Fig. 2; Busacca *et al.*, 1998). The magnetic polarity of the upper 28 m was found to be normal while the lower 10 m was found to be reversed. Discovery of the presence of this polarity transition, which is correlated with the Matuyama/Brunhes boundary, demonstrated that

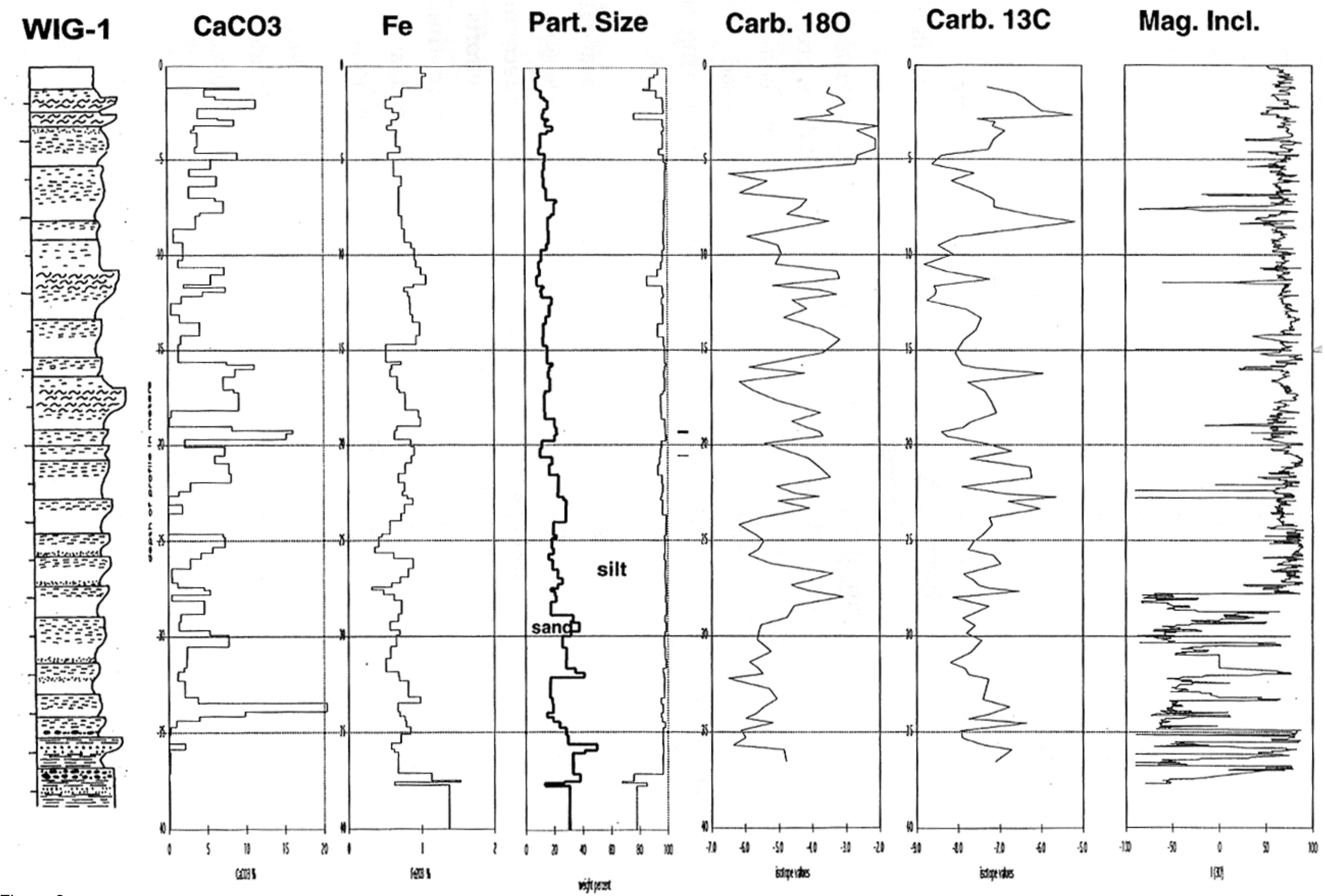

Figure 2. Schematic stratigraphic column of the WIG-1 drill core from Winona, Washington showing calcic paleosols in erosional relief. Properties plotted versus depth include pedogenic carbonates and Fe oxides, particle size, magnetic inclination, and ratios of oxygen and carbon isotopes in pedogenic carbonates. Modified from Busacca et al. (1998).

the loess at the base of the core is about 1 million years old. There are about twenty paleosols in the core. Eight or more of the 20 intervening loess units are unusually sandy and some fine upward. Loess in these units may have been derived from cataclysmic outburst floods that occurred during glacial maxima over the last 1 Myr.

STOP 4: GEOMORPHOLOGY OF FLOOD COULEES AND ORIGIN OF MIMA MOUNDS

Geomorphology of Flood Coulees: To the west, the coulee of Rock Creek was excavated by floods exploiting a NE-SW trending joint system in the basalts. The deeply eroded central part of the coulee is an example of what Baker calls an "inner channel" (Fig. 3), which forms by headward erosion of a cataract or by coalescence and deepening of basins in butte-and-basin topography as basalt columns are plucked by vertical vortices in the macroturbulent flow. The stepped surfaces in the coulee walls delineate individual lava flows that were variably resistant to erosion.

The higher, outer surfaces like the one we are standing on is an example of "butte-and-basin scabland" formed by irregular plucking of jointed basalts by floodwaters (Fig. 3).

Loess-Island Remnants: One of the very dramatic features formed by the floods are "loess islands", lozenge-shaped remnants of the original thick loess cover (Fig. 3) that have been sculpted by the flowing water. The larger remnants, which can have an area of more than 100 km^2, have Palouse-like topography.

Mima Mounds: There are good examples of "loess biscuits" or mima mounds to the right of the road: mound-and-swale microrelief formed in post-flood loess where it overlies basalt bedrock or gravel bars from giant floods. Vernal pools, seasonal ponds that fill with water in winter and dry down in late Spring through summer to reveal a succession of concentric plant zones, are found interwoven with loess mounds in bedrock channels (Crowe *et al.,* 1994). Saline-sodic soils of the Emdent series (Typic Vitraquands) occur where loess and volcanic ash mantle potholes and small undrained basins in the bedrock surface.

Many theories have been advanced in different places and by different workers to explain the origin of mima-like mounds, including nest-building activities of burrowing animals,

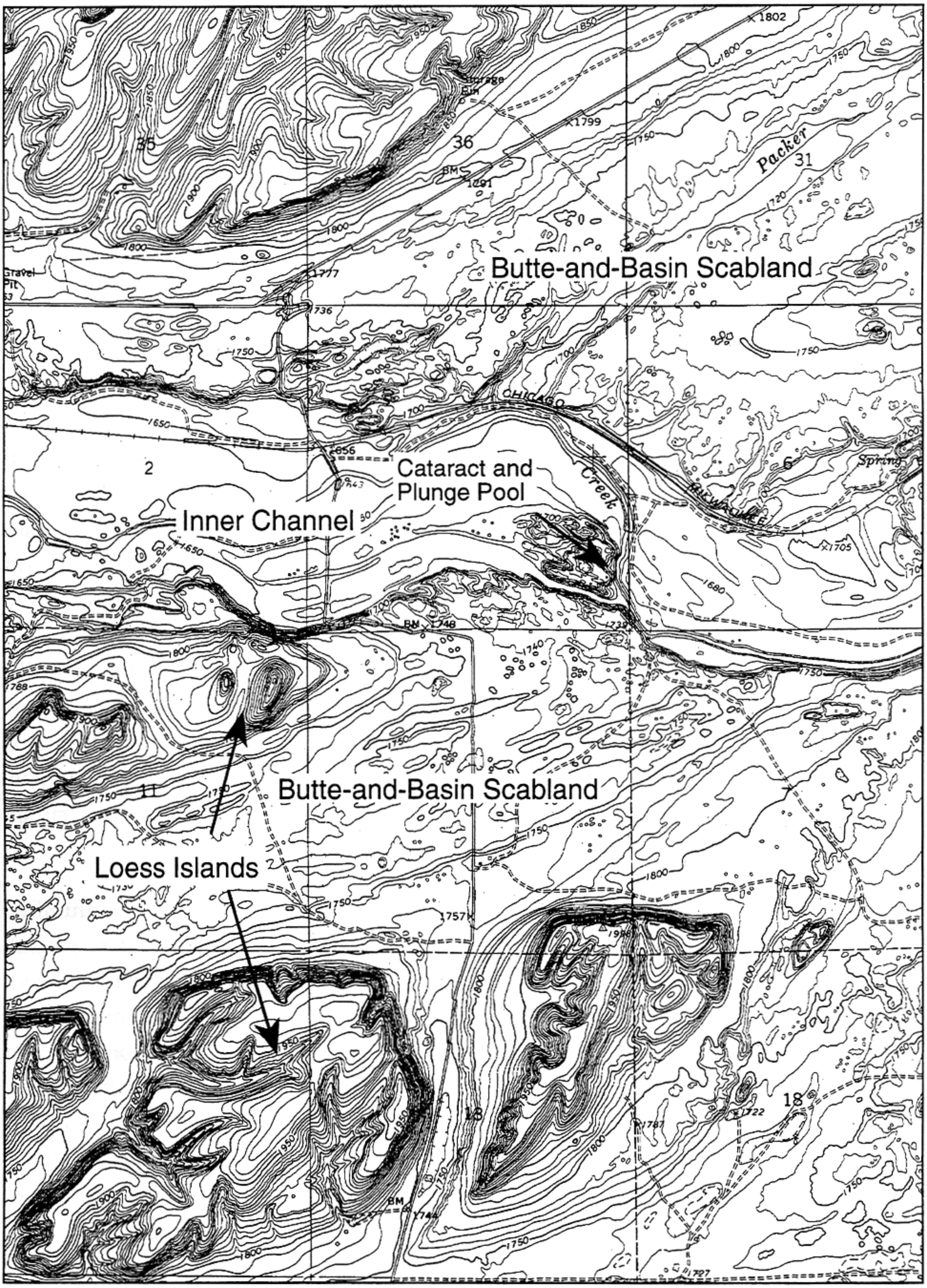

Figure 3. Image of a part of the U.S.G.S. Texas Lake 7.5' Quadrangle, a few kilometers west of La Crosse showing butte-and-basin scabland, an inner channel, and deeply eroded loess islands with numerous divide crossings. Water flow was from right to left.

periglacial processes, coppicing (dust trapping) by patchy vegetation, seismic shaking, and others. Mima mounds are common on the Columbia Plateau. They range in height from less than 1 m to 2 m and in diameter from 2 m to 10 m and more. Shallow depth to bedrock, a duripan, or a gravelly substrate appears to be necessary for their formation, as they are absent from areas with deep loess cover, even if adjacent shallow soils have prominent mounds. On steeper slopes, mima mounds can be aligned parallel to the slope into “strings of pearls” or can elongate into “super mounds” more than 30 m long.

The most commonly cited hypothesis for mounds on the Columbia Plateau is periglacial processes associated with the last glacial maximum. Indeed, nets of sorted stones can infrequently be observed in the intermound areas in some mound complexes. Complicating this explanation is the fact that mounds can be prominent on bedrock surfaces that were known to have been scoured of all surface sediment by the last glacial floods. This appears to be the case at this location. If this is true, then the loessial sediment that forms the mounds in these places began accumulating after the last floods about 12,000 years ago and long after the coldest part of the climatic minimum. Another possibility is that flood waters in some areas did not completely remove mounds formed by periglacial processes in pre-last-glacial flood loess, producing a “memory” on the landscape such that denser vegetative cover on eroded mounds led to differential trapping of dust and rebuilding of the mound complexes.

If some mounds are indeed formed entirely of post-flood loess that has accumulated during the Holocene, then differential trapping of dust may be responsible. Observations of mounds aligned along fracture systems in the underlying basalt suggests that perhaps shrubs and grasses preferentially established along theses fractures after the end of scabland flooding, causing differential trapping of dust.