General Geology and Paleontology of the Harsha 7.5' Quadrangle

Patrick K. Spencer
Department of Geology
Whitman College
Walla Walla, Washington 99362

Submitted to:

State of Washington
Department of Natural Resources
Division of Geology and Earth Resources
Eric Schuster, State Geologist

INTRODUCTION

Reconnaisance surficial geological mapping was conducted in the Harsha 7.5' quadrangle. The purpose of the mapping project was to recognize and map the extent of documented or suspected pre-Fraser age catastrophic glacial flood deposits and/or loess, and as an secondary goal, to map the distribution of any other surficial deposits or bedrock encountered in the map area.

Deposits of pre-Fraser age loess have not been studied extensively in southeastern Washington. Pre-Fraser age catastrophic outburst flood deposits have been recognized in several places in the southeastern Washington region (McDonald and Bussacca, 1989; Vrooman and Spencer, 1990). Generally, study of these and related deposits has just begun.

Fraser-age (latest Pleistocene) catastrophic glacial outburst flood deposits are well-known in the region surrounding the Harsha quadrangle, and also occur within the map area. These have been related to late Wisconsin damming of glacial Lake Missoula in western Montana, and periodic bursting of the ice dam. In the Walla Walla Valley and surrounding area, these deposits are known as the Touchet Beds for exposures along the banks of the Touchet River south of the map area.

The Touchet Beds (ca. 13 Ka on the basis of the presence of Mt. St. Helens set "s" tephra within some exposures) were deposited as a slackwater facies of the outburst flood as water backed up against the Horse Heaven Hills at Wallula Gap, the only outlet for water entering the Columbia Plateau region. In the type area of the Touchet Beds, the deposits are characterized by multiple, rhythmically deposited sand to silt graded beds. Contacts between individual beds are generally erosional. Features which help to identify the Touchet Beds in the Walla Walla Valley include the graded, stratified character of the beds, an abundance of clastic dikes, and the presence of numerous pebbles and cobbles of lithologies exotic to the region.

The debate over the precise origin of the Touchet Beds, whether they are the result of a single or few flood events, or multiple events separated in time by periods of exposure, has been going on for over sixty years. Bretz (1925, 1969, other papers) originally suggested the single flood hypothesis, and his work is echoed by many geologists even today. The opposing school of thought, pioneered by Waitt (1980, other papers) and supported by Spencer (1989) holds that the Touchet Beds were deposited by as many as forty to seventy distinct flood episodes, with each event separated in time by up to 100 years. During these intervals, the areas affected were exposed to erosion, deposition of eolian sediment, establishment of vegetation, and colonization by rodents and other vertebrate animals. The primary evidence in support of the multiple-flood hypothesis consists of the presence of suspected eolian sediment capping each individual rhythmite in the Walla Walla Valley (Waitt, 1980). In addition many exposures of Touchet Beds include fossil rodents in remarkably good

condition (Spencer, 1989), indeed, articulated rodent fossils have been found in one exposure (Spencer, unpubl. data). In the Sanpoil Arm of Glacial Lake Columbia, Waitt (1984) has documented Touchet Bed-like rhythmites occurring between deposits including as many as seventy varve-couplets, suggesting seventy annual cycles of deposition between flood events.

Whatever the ultimate outcome of the debate, and to this author the matter is effectively settled, the Touchet Beds comprise a distinctive sequence of deposits that are widespread in the southeastern Washington region.

Other surficial deposits in the Harsha quadrangle include the loosely-defined Palouse Formation. This unit includes fine sand and silt of eolian origin, which blankets the gently rolling topography of the physiographic region known as the Palouse Hills. The Palouse Soil was originally named for deposits of very fine sand up to 250 feet in thickness and covering the basaltic bedrock. The formal designation of the Palouse Formation was never established, probably because the unit could never be adequately characterized in terms of age.

Based on studies conducted for this report, it is apparent that the informal "Palouse Soil" is wide-ranging, both in terms of its geographic distribution and its age. About the only thing which can be stated with certainty about the unit is that it does indeed overlie the Columbia River Basalt. This report will document exposures of eolian silt which pre-date the late Pleistocene Touchet Beds and those which post-date the same unit. The "event" which laid down these deposits of loess apparently began well back in the Pleistocene and continues today.

In at least one outcrop within the map area deposits of stratified silt and fine silt forming rhythmically deposited couplets are found, which are overlain by eolian deposits and ancient pedalfers (iron-rich soils) and pedocals (Ca-rich soils). This section (the McFeely Road section- see figure 2) displays features suggesting deposition by processes similar to those that deposited the Touchet Beds, including clastic dikes, graded beds, exotic lithologies, and fossils. A preliminary report on these deposits is found in Laddish and Spencer (1991).

Underlying the Columbia Plateau, and exposed in several stream and road cuts within the map area is the Miocene Columbia River Basalt Group. Work by geologists at Westinghouse-Hanford and Battelle have detailed the stratigraphy and relationships of individual formations, members and flows within this thick and extensive unit. In the map area, flows belonging to the Frenchman Springs Member of the Wanapum Formation crop out in several places.

CRITERIA FOR RECOGNITION OF PRE-FRASER AGE SEDIMENTARY DEPOSITS

In order to recognize and characterize sedimentary deposits of pre-Fraser age in the Harsha quadrangle, several objective criteria were established as having some bearing on the problem. Generally, the deposits have not been subdivided, with the exception of separating out the late-Pleistocene Touchet Beds. The reasons for this are many, and include the overall uniformity in appearance of the loess sequence, the tacit assumption that the Touchet Beds represent the deposits of the only catastrophic glacial outburst flood, and a general lack of interest in the details of the surficial geology of the region.

1) Tephra age: the outcrop on McFeely Road preserves a thin, continuous tephra horizon which has not been previously analyzed. The same or a similar tephra occurs north of the Ayers Grade summit west of McFeely road. Identity of the tephra is important, since at the two localities it occurs in different sediment types (McFeely: stratified silts; Ayers: massive loess with caliche). Electron microprobe studies (currently in progress) may help to identify the chemical fingerprint, and thus the source and age of the tephra. This will allow us to establish the precise age of the stratified sediment on McFeely Road, and also allow correlation with different sediment units in the Harsha quad.

2) Age estimates based on stage of caliche development and number of caliche horizons: numerous outcrops studied expose one or more well-developed caliche horizons. In the case of the McFeely outcrop, these caliches occur stratigraphically above the stratified sediments (3 caliches). At Ayers Grade and numerous other localities, caliche occurs within unstratified loess deposits. Clearly recognizable at each of these localities is the Holocene loess cover and modern soil. Absent at all of these localities are sediments related to the Touchet Beds (late Pleistocene: ca. 17-12.5 Ka). The Touchet Beds are not known to be overlain by caliche in any stage of development; apparently, they are simply too young.

Studies of caliche horizons forming soils, and which are datable, indicate that caliche forms over periods of time ranging from 5,000 to 40,000 years, with well-developed laminar caliche at the long end of these estimates. Any site which contains at least one well-developed, laminar caliche horizon must pre-date the Touchet Beds, and thus be pre-Fraser in age.

3) Fossils: fossil rodents and molluscs have been recovered from the Ayers Grade and McFeely Road exposures. The material is not plentiful, but preservation is good. The mammals are identical to mammals now living in the region, at least based on the few specimens recovered. Similarly, the molluscs represent living species. The fossil material is of little use in age determination, although it might be useful in paleoenvironmental evaluations.

4) Stratigraphic Position and Elevation: the elevation of the top of the late-Pleistocene Touchet Beds can be objectively established. Generally, these deposits are confined to low-lying stream valleys. In addition, where observed in outcrop, the Touchet Beds are overlain by a maximum of about 1 meter of latest Pleistocene and Holocene loess. This latest Pleistocene deposit of loess can also be observed in exposures at higher elevations where the Touchet Beds were not deposited. Thus, any significant thickness of loess must be at the youngest equivalent in age to the Touchet Beds, and based on other criteria discussed above, may be considerably older.

GENERAL GEOLOGY: HARSHA QUADRANGLE

Bedrock Geology:

The bedrock geology in the Harsha Quadrangle consists entirely of the Frenchman Springs Member of the Wanapum Formation of the Columbia River Basalt Group. Exposures are confined primarily to eroded stream valleys and deep road cuts or old topographic highs on the basalt surface. Within the Harsha Quadrangle, basalt exposures are found along the highway for about 2 km west of the junction of Highway 125 and Ayers Road, for about 1 km east of the same junction, and in a quarry about 1/2 mile north of the junction. Additional exposures are found south of the junction along the Burlington Northern railroad grade along Harvey Shaw Road, and in a few scattered outcrops in the northern and eastern part of the map area.

For the most part, the exposures consist of one or a few distinct flows exhibiting the features now considered to be typical of the Columbia River Basalt Group: columnar jointing and vesiculated upper flow surfaces. Most of the basalt is deeply weathered, suggesting a long period of weathering prior to deposition of any significant sediment cover.

Surficial Deposits:

Vast areas of the Columbia Plateau, including the map area in the Harsha Quadrangle, are covered with medium brown to gray brown silt which is assigned to the Palouse Formation. The Palouse Formation is poorly defined, but generally includes all such windblown deposits on the Columbia Plateau.

In the map area, the cover of loess ranges in thickness from a meter or less to deposits up to a few tens of meters in thickness as measured in roadcuts. The true thickness is highly variable due to the topography of the underlying basalt surface. Typical exposures of loess, particluarly in thicker sections, display one or more caliche horizons; these will be discussed in more detail below.

The loess is locally fossiliferous. The fossil remains consist of small mammals, occurring as articulated skeletons and

scattered limb bones and cranial material (the mammals), and complete, well-preserved gastropods. The most productive sites discovered to date are located along the Ayers Road in the SW quarter of sec. 30, T10N, R35E, and along McFeely Road to the east of Ayers Road, in the NE quarter of sec. 32 and the SE quarter of sec. 29, T10N, R35E.

Caliche: At certain exposures in the "Palouse Loess," well-developed, thick caliche horizons occur. These range from faint nodular horizons with abundant root casts to thick, laminar caliche. They reflect a period of stability at the soil surface and extensive deposition of carbonate at the water table.

The number of caliche horizons at a given site ranges from none at sites in the Holocene portion of the Palouse Formation to as many as seven distinct horizons in some of the thicker sections (see Figure 1: Idealized Stratigraphic Column for the Ayers Road Section). In some exposures, the caliche is distinctive enough that it can be used with confidence as a marker horizon. For example, at the Ayers Road locality there is a distinctive double caliche, representing two episodes of soil formation with an indeterminate amount of silt removed by erosion between them. This same horizon, or one identical in most respects, is found farther north along Ayers Road in scattered outcrops.

Touchet Beds:

Graded, stratified sediments assigned to the late Pleistocene Touchet Beds are exposed in several places within the Harsha Quadrangle. For the most part, these occur along the valley of the Touchet River. In addition, they can be found extending up some of the tributary valleys a short distance, but are not generally found above an elevation of about 1100 feet: mostly, they are confined to elevations below 1000 feet.

The Touchet Beds are distinctive and easily distinguishable from the Palouse Formation. Generally, the Touchet Beds are stratified, graded beds are common, rocks of exotic lithology (glacial erratics) are present. The unit also contains an abundance of clastic dikes. No exposures of the Touchet Beds are known to have caliche developed to any significant extent: the time since their deposition is apparently insufficient.

Other Stratified Sediments:

In one exposure along McFeely Road in the SE quarter of sec. 29 and the NE quarter of sec. 32, T10N, R35E, a peculiar sequence of vaguely stratified sand, silt and clay occurs. This sequence is overlain by approximately 3 meters of Palouse Silt, with at least one, and possibly three well-developed caliche horizons occurring above the stratified sediment.

The section here consists of Columbia River Basalt overlain in an erosional trough by vaguely stratified sand-silt (clay)

couplets. Grain size analyses show a general fining-upward trend within each couplet. Contacts between couplets are erosional. Locally there are small channel-like features developed, which are filled with coarse-grained fragments of basalt and caliche. Associated with these channel features are rare, small fragments of exotic lithology, including mostly quartz, but also small igneous intrusive fragments.

At three points within the rhythmically deposited sediments are iron-rich horizons with well-developed root casts. These apparently represent soil surfaces developed under oxidizing conditions, such as might be found in a shallow impoundment of water. Associated with these iron-stained horizons are well-preserved gastropod fossils.

DESCRIPTION OF MAP UNITS

Pre-Quaternary Units:

Mv_{wfs}: Miocene volcanic rock. Basalt of the Frenchman Springs Member of the Wanapum Formation of the Columbia River Basalt Group of middle Miocene age. Dark gray to black, massive, dense to vesicular basalt. Exposures along Touchet River and in several roadcuts and quarries within the Harsha Quadrangle. Most exposures within the map area are deeply weathered, suggesting long periods of exposure. Where present along stream valleys, as in the Touchet River Valley, exposures are fresh.

Unconformity

Ql_{pf}: Quaternary loess. Eolian silt of pre-Fraser age assigned to the broadly defined Palouse Formation. Medium gray to gray-brown, fine to medium grained silt of eolian origin. Massive, moderately well-sorted, locally containing small, angular fragments of basaltic colluvium in slopewash channels. Where well-exposed, displaying one or more well-developed caliche horizons, suggesting long periods of development of desert soil, and indicating highly variable ages of the unit as a whole within the Pleistocene. These silts are locally fossiliferous, preserving the remains of small mammals and gastropod molluscs.

> Caliche: moderately to very well-developed nodular to laminar calcium carbonate enriched pedocal horizons. Root casts locally well-developed, caliche impregnated.

Unconformity

Qp_{cf}: Pleistocene catastrophic glacial outburst flood deposits. Vaguely stratified, rhythmically bedded, coarse silt to fine silt couplets. Beds on the order of 5-8 cm in thickness; contacts between couplets erosional, scoured. Flame structures weakly developed in some couplets. Clastic dikes present in lower part of unit. Rare, small clasts of exotic lithology, chiefly vein quartz and plutonic rock fragments. At the single exposure of this unit along McFeely Road, graded, stratified intervals are

approximately 1-1.5 meters thick, separated by moderately oxidized horizons containing abundant root casts, also oxidized, and suggesting development of soils underwater, in a localized impoundment. Fossiliferous, containing the remains of rare small mammals and abundant gastropod molluscs. Tephra horizon preserved in upper graded, stratified interval. At McFeely Road outcrop, the graded, stratified intervals are overlain by massive silt of the Palouse Formation (Ql_{pf}) exhibiting at least one and possibly as many as three moderately to well-developed caliche horizons.

These are distinguishable from the late Pleistocene Touchet Beds (Qp_{tb}, see below) based on finer grain size, weakly developed stratification, elevation, and on the presence of caliche units higher in the section.

Qp_{tb}: Pleistocene Touchet Beds. Glacial outburst flood deposits originating at glacial Lake Missoula. In the map area, these are slackwater deposits laid down as floodwaters backed up against the Horse Heaven Hills to the south. Graded, stratified beds consisting of basal sand layers grading upward into fine silt. Erosional, scoured contacts. Frequently capped by eolian silts deposited between flood episodes. Exotic lithologies common to abundant, generally coarser than those in unit Qp_{cf}; clastic dikes common to abundant. The Touchet Beds are locally fossiliferous. Within the map area, a single locality has produced fossil seeds of the genus Lithospermum (Family Boraginacea). Can be distinguished from the older glacial outburst flood deposits (unit Qp_{cf}) on the basis of texture, elevation, and the absence of caliche developed on top of the Touchet Beds.

Ql: Quaternary loess, undifferentiated. Eolian silts assigned to the broadly defined Palouse Formation. Fine to medium grained massive silt. Widely distributed within the map area. Generally found capping roadcut exposures; thickness up to about 1 m. Locally includes portions of unit Ql_{pf}; these are impossible to distinguish as a result of extensive agricultural development of large areas in the map area.

Qal: Late Pleistocene and Holocene alluvium consisting of floodplain and channel deposits of the Touchet River in the southern 1/3 of the map area, and small tributary streams elsewhere in the map area. Locally contains alluvial fan sediments, colluvium, and accumulations of colluvial tephra of ?Mazama age.

Faunal Listing:

Fossils were recovered from several localities in the Harsha Quadrangle. Remains of several species of rodent, gastropod molluscs, and plant remains are represented in the collection.

Generally, preservation is good. The rodents are represented by cranial and post-cranial elements; often these are found together, suggesting that the remains were at least partially articulated. The samples are small, generally a few individuals belonging to a single species, making statistical analysis, and thus species determination, difficult.

Gastropods molluscs are represented by at least three species. Preservation is excellent, suggesting in situ fossilization.

The Kingdom Plantae is represented by the seeds of one representative of the Family Boraginacea (Lithospermum ruderale). Preservation is excellent, with some of the seeds showing evidence of having been fossilized in the process of germination. Seeds are found in concentrations of many dozens in distinctive pockets, suggesting concentration by rodents and other seed-eating organisms.

LOCALITY	TAXA PRESENT
	MAMMALIA
Ayers Road Loc. HA-1	HA-001 Geomyidae (Thomomys townsendii) HA-002 Spermophilis (S. townsendii) HA-003 Cricetidae (Voles) HA-004 Rodentia (femur) HA-005 Spermophilis (S. townsendii) HA-006 Spermophilis (S. townsendii) HA-007 Spermophilis (S. townsendii) HA-008 Cricetidae (Voles) HA-009 Lagomorpha (Rabbits and Hares) HA-010 Geomyidae (T. townsendii) HA-011 Rodentia (skull, no molar) HA-012 Spermophilis (S. townsendii) HA-013 Geomyidae (T. townsendii) HA-014 Spermophilis (S. townsendii)
	MOLLUSCA
	HA-050 Gastropoda (pupiform) HA-051 Gastropoda (pupiform)
	PLANTAE
	HA-070 Lithospermum ruderale HA-071 Lithospermum ruderale

McFeely Road HA-2	MAMMALIA
	HA-015 Geomyidae (Thomomys townsendii) HA-016 Rodentia (femur, various)
	MOLLUSCA
	HA-052 Gastropoda (pupiform) HA-052 Gastropoda (Viviparus sp.) HA-052 Gastropoda (Valvata sp.) HA-053 Gastropoda (Valvata; Viviparus)
Ayers Road	MAMMALIA
SE corner, sec. 19 HA-3	HA-017 Spermophilis (S. townsendii) HA-018 Rodentia (2 species?, postcra.)

Biostratigraphy

The mammal taxa occurring as fossils from localities in the Harsha Quadrangle are long ranging forms, two of which are still living. Spermophilis townsendi (Tonwsend's ground squirrel) ranges from the Late Invingtonian through the Holocene (roughly 1 Ma to the present. Thomomys townsendi (Townsend's pocket gopher) ranges from the early Rancholabrean through the Holocene (roughly 700 Ka to the present). As a result of the generally long geologic ranges, and the uncertaintly of species identification owing to the paucity of material, the fossils are of little utility in subdividing or characterizing the strata studied for this report, at the present time.

If additional material is collected, and there is every reason to believe that there is much more material to be had, and objective criteria can be applied in age determination of the strata (for example, dating of the tephras), perhaps a biostratigraphic scheme can be developed, whereby distinct loess accumulations can be characterized by their fossil content. For the present, it is sufficient to know that there exists at least the potential for collection of much more fossil material.

Gastropod taxa found in the Harsha Quadrangle likewise are long ranging forms; at least two of them are still living, although not in the area. One of the gastropods has not been identified, primarily because the literature delaing with molluscs from the Palouse Hills is non-existent. Ultimately, with additional collection and establishment of objective criteria for age determination, the gastropods may be incorporated into a biostratigraphic scheme.

GEOLOGIC HISTORY OF THE HARSHA QUADRANGLE

Pre-Pleistocene: The oldest event recorded within the Harsha Quadrangle is extrusion of the Miocene age Frenchman Springs Member of the Wanapum Formation of the Columbia River Basalt Group. In the map area, these are exposed in roadcuts and quarries, and along the walls of the Touchet River Valley, where their topographic expression is that of vertical cliffs up to about 60 feet in height.

The textural character of these flows consists of dense to vesicular, dark gray to black basalt. Locally, these are deeply weathered to a crumbly, brown to reddish brown incipient soil, reflecting a long period of exposure prior to burial by younger sediment units. During this period of exposure, rivers and streams sculpted the basalt into the typical topography of the greater Palouse Hills region, that of rolling hills and broad valleys. Concurrent uplift of the basaltic topographic surface resulted in many of the larger drainages, in particular the drainage of the Touchet River, becoming incised.

Pleistocene: Subsequent to weathering of the Frenchman Springs Member, a long period of eolian deposition ensued. This event is recorded in exposures of loess in various places within the map area.

Deposition of the loess was apparently cyclic, with periods of active eolian deposition alternating with periods of stability and relatively little sediment accumulation. These periods of stability are reflected in the sediment record by well-developed horizons consisting of well-indurated eolian silt cemented by calcium carbonate. The stage of development of the caliche suggests extensive periods of stability and soil formation, however the duration of each event of soil formation can only be estimated.

These caliche horizons provide a meachanism for estimating the minimum age of outcrops in which they are observed. The maximum age of these outcrops cannot be guessed at, since data on the rates at which the eolian sediment was deposited is not available. Very generally speaking, however, outcrops at which one caliche horizon is represented might have a minimum age of 20,000 years, while those with three or more caliches would have an estimated minimum age of in excess of 60,000 years. The Late Pleistocene (Fraser age; ca. 17-12.5 Ka) Touchet Beds are not known to have caliche developed to any significant extent. While not accurate, the presence of caliche allows the deposits containing them to be assigned a pre-Fraser age, and the presence of multiple horizons of caliche suggests that eolian deposition may have been proceeding for a considerable portion of the late Pleistocene.

Within the loess interval, an event of fluvial deposition is recorded which is apparently related in some way to catastrophic glacial outburst flooding. These vaguely stratified sediments,

found in only one outcrop in the map area, exhibit features similar in many respects to the latest Pleistocene Touchet Beds, including clastic dikes, rhythmic stratification, graded beds, and rare pebbles of exotic lithology. Their age is established as pre-Fraser based on the presence of well-developed soil horizons occurring stratigraphically above the deposits; determination of the precise age of these deposits awaits geochemical characterization of the tephra found within the sequence. Whether these sediments represent a direct record of catastrophic flooding, or reworking of flood sediments deposited elsewhere, cannot be determined with certainty. Elsewhere in the region, suspected outburst flood deposits are represented by reworked flood sediment (Vrooman and Spencer, 1990; Spencer, unpubl. data). Following deposition of these suspected outburst flood deposits, eolian deposition resumed.

The latest Pleistocene Touchet Beds were deposited by catastrophic glacial outburst floods resulting from the failing of an ice dam near Missoula, Montana. These deposits were laid down as water backed up against Wallula Gap on the Oregon-Washington border, forming a hydraulic dam. The deposits are widespread in southeastern Washington, primarily in lower-lying stream and river valleys. In the map area, they are confined to the valley of the Touchet River and a single outcrop in the west-central part of the map area, in Winnett Canyon.

Subsequent to deposition of the Touchet Beds, eolian deposition resumed, accompanied by latest Pleistocene and Holocene fluvial deposition, alluvial fan deposition, and colluviation. Within this interval, the last eruption of Mt. Mazama took place, spreading a blanket of tephra throughout the region. Some of this tephra is preserved in slopewash channels within the Holocene alluvial and colluvial sediments.

FUTURE WORK

Much additional work needs to be done in this and other areas in the surrounding region.

1) Paleontology: Fossils, both mammals and molluscs, are apparently widespread in the region, in deposits of eolian silt and glacial outburst flood deposits. Additional collections in the greater eastern Washington region may in the future allow for development of a biostratigraphic scheme useful in recognizing loess and flood deposits of wide-ranging ages. In addition, the fossils may prove useful in extending the known geologic and geographic ranges of these taxa.

2) Pre-Fraser age glacial outburst flood deposits: the presence in the map area of glacial outburst flood deposits pre-dating the latest Pleistocene Touchet Beds lends support to the idea that the Missoula Floods were only the latest episode of such processes. Additional mapping and study in adjacent areas may

reveal that these deposits are more widespread than is currently documented.

3) Pre-Fraser age loess deposits: recognition of the presence in the loess sequence of well-developed caliche horizons makes possible very rough estimates of the antiquity of these sediments. Further study in adjacent areas may reveal additional exposures of pre-Fraser age loess, and combined with other evidence (biological and physical), may make regional correlation of these sediments possible.

4) Tephra-chronology: the occurrence of ash beds within the loess and flood sequences may provide a useful tool in absolute age determination, and may in turn help to establish ages of fossil sequences, and aid in attempts at regional correlation.

References Cited

Bretz, J H., 1925. The Spokane Flood beyond the Channeled Scabland. J. Geology, v. 33, pp. 97-115, 236-259.

Bretz, J H., 1969. The Lake Missoula Floods in the Channeled Scabland. J. Geology, v. 77, pp. 505-543.

Laddish, Katherine M. and Spencer, Patrick K., 1992. Characteristics of pre-late Wisconsin stratified and unstratified sediment, Palouse Hills, southeastern Washington. Geol. Soc. America Abstracts with program, v. 24, no. 5, May, 1992.

McDonald, E.V. and Busacca, A.J., 1988. Record of pre-late Wisconsin giant floods in the Channeled Scabland interpreted from loess deposits. Geology, v. 16, no. 8, pp. 728-731.

Spencer, Patrick K., 1989. A small mammal fauna from the Touchet Beds of Walla Walla County, Washington: Support for the multiple-flood hypothesis. Northwest Science, v. 63, no. 4, pp. 167-174.

Vrooman, Amanda and Spencer, Patrick K., 1990. Pre-late Wisconsin catastrophic glacial flood deposits in the Walla Walla Valley, southeastern Washington. Geol. Soc. America Abstracts with program, v. 22, no. 3., Feb. 1990.

Waitt, R.B., Jr., 1980. About forty last-glacial Lake Missoula Jokulhlaups through southern Washington. J. Geology, v. 88, pp. 653-679.

Waitt, R.B., Jr., 1984. Periodic jokulhlaups Pleistocene glacial Lake Missoula--New evidence from varved sediment in northern Idaho and Washington. Quaternary Res., v. 22, pp. 46-58.

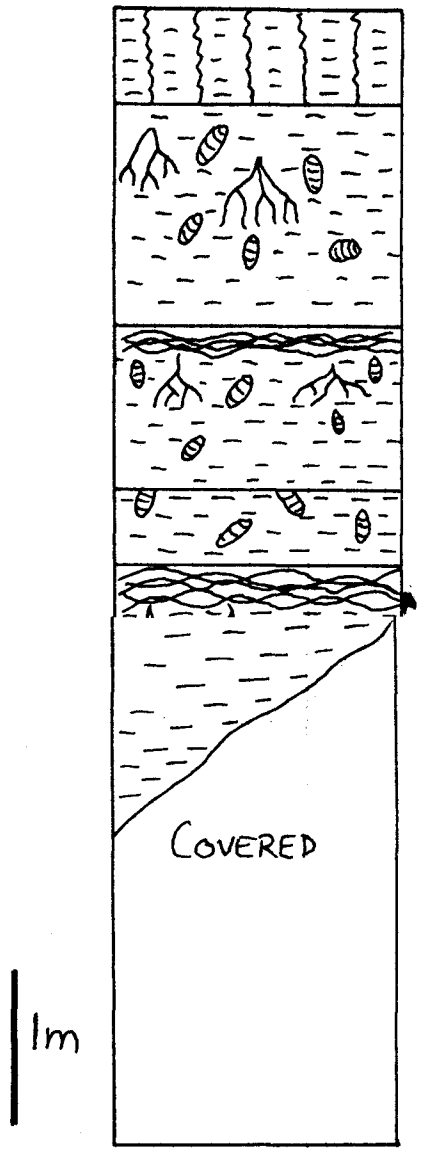


Figure 1.

MEASURED SECTION: TOP OF AYERS GRADE

HOLOCENE: Massive, columnar jointed sandy Silt of eolian origin. Palouse Formation.

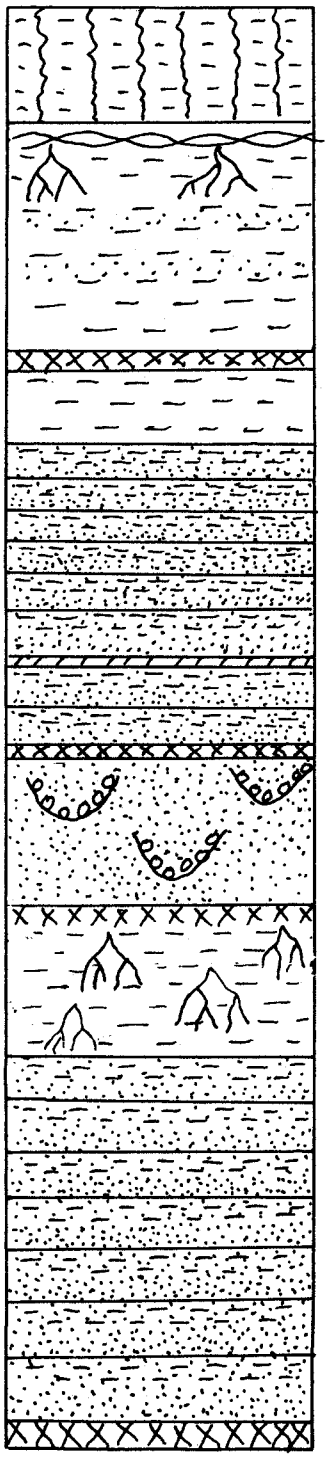
PLEISTOCENE: Massive sandy Silt of eolian origin. Root casts locally common, sparce nodular Caliche.

PLEISTOCENE: Massive sandy Silt of eolian origin. Root casts locally common to abundant. Nodular Caliche sparce, grading upward to laminar Caliche.

PLEISTOCENE: Massive sandy Silt of eolian origin. Locally sparce nodular Caliche.

PLEISTOCENE: Massive sandy Silt of eolian origin.

Figure 2.
Idealized Stratigraphic Column
McFeely Road Locality



HOLOCENE: Massive sandy Silt of eolian origin. Weakly columnar jointed.

PLEISTOCENE: Massive to weakly stratified silt and fine sand. Caliche coated root casts common to abundant. Scattered pebbles of exotic lithology; rare fossil gastropods. Moderately developed laminar caliche in upper third of unit.

PLEISTOCENE: Massive fine sandy Silt of eolian origin. Upper part of unit is severely oxidized.

PLEISTOCENE: Rhythmically stratified beds of fine sand grading upward into silt. Contacts distinct, erosional. Beds range in thickness from 4-10 cm.

PLEISTOCENE: Thin, continuous Tephra.

PLEISTOCENE: Stratified fine to coarse grained Sand with scattered pebbles. Occur as lenticular beds with erosional bases, gradational within each bed. Pebbles consist of angular basalt and caliche. Severely oxidized at top of unit.

PLEISTOCENE: Massive sandy Silt of eolian origin. Extensively rooted, root casts caliche coated. Upper portion severely oxidized. Gradational with underlying unit.

PLEISTOCENE: Rhythmically stratified beds of fine sand grading upward into silt.Contacts distinct, erosional. Flame structures locally common. Beds range in thickness from 4-10 cm.

25 CM

Base of section severely oxidized. CRB not exposed.