Possible Limiting Age for Soil Mounds In the Kittitas Valley, Washington

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Introduction:

Patterned ground features such as soil mounds, stone-nets, and stone-polygons have been described in the Kittitas Valley, WA and throughout much of the western United States. Proposed origins of the mounds fall into either depositional or erosional explanations for the mound initiation. There have been more than thirty explanations given for the formation of soil mounds (see Washburn, 1988 for a brief review of proposed origins), which include periglacial processes, pocket gophers, solifluction, and seismic activity. For further reading on the distribution and possible origins of soil mounds and other patterned ground features see: Berg, 1990; Cox, 1984; Cox and Allen, 1987; Fosberg, 1965; Fryxell, 1964; Kaatz, 1959; Malde, 1961; Malde, 1964; Washburn, 1956; Washburn, 1988; Waters and Flagler, 1929; Wilson and Slupetzky, 1977.

This study was undertaken to provide a limiting age for the formation of soil mounds in the Kittitas Valley. Mounds in the Kittitas Valley and elsewhere are quite distinct in the landscape and are often found in association with periglacial patterned ground features such as stone-nets and stone-polygons (see Washburn, 1956; and Washburn, 1980 for a review of patterned ground features). If the origin of the soil mounds in the Kittitas Valley are associated with the periglacial conditions, then by knowing the when they formed can provide insight into the climatic conditions at that time. While determining a limiting age for the genesis of the mounds may not explicitly clarify the process of mound formation, it can potentially provide another piece of evidence about the timing and environment under which mounds form.

Study Area:

The Kittitas Valley is located in central Washington on the east slope the Cascades. The valley is drained by the Yakima River, which has cut two high-relief canyons at both its entrance to and exit from the valley. Structurally, the valley is located in the Kittitas Valley Syncline, and is bound by ridges of folded Columbia River Basalts. Elevation ranges between ~450m in the valley floor and 1500m + on the adjacent ridges. The local geology is dominated by the Grande Ronde Member of the Columbia River Basalt group (CRB's) and is overlain by Tertiary alluvium and/or Quaternary alluvial and eolian deposits.

The high relief between the valley bottom and the ridges has created a pronounced climatic and ecological gradient. Riparian communities of Black Cottonwood, willows, and sedges dominate the area surrounding the Yakima River. The city of Ellensburg is located in the valley bottom and generally receives less than 25cm of winter-dominant precipitation, and has a seasonal average temperature range of -3.5^{o} C in January and 20^{o}C in July (NOAA, 1993). The adjacent hill slopes have thick (1m+) deposits of alluvial and eolian silts and are dominated by grassland and sagebrush communities. These lower hill slopes of the valley are generally used for irrigated pasture and hay production. The intermediate hill slopes are mantled with relatively thin eolian silt and are dominated by a sagebrush-bunchgrass complex. The thin, rocky soils have limited the use of the intermediate slopes to grazing and some dryland agriculture. The upper slopes of the ridges to the North and West are covered with Ponderosa Pine and sagebrush. Assuming an Environmental Lapse Rate of -3.5^{o}C per 1000m increase in elevation, the ridges have a seasonal average temperature range of -7^{o}C in January and 16.5^{o}C in July. Precipitation in the higher elevations is assumed (given the presence of Ponderosa Pine) to be higher than in the valley due t the effect of orographic precipitation.

Methodology:

Three soil mound features were described based on soil and sedimentological characteristics in the September 1998. The three mound sites (Thorp Prairie, Manastash Creek, and Ellensburg North) were chosen based on slope, accessibility, and underlying geology. Given that mounds are generally found on flat to shallow slopes and grade into soil stripes as slope increases (Katz, 1959), the three mounds selected were located on flat slopes. The initial reasoning for choosing mounds with different underlying geology was that Katz (1959) and Washburn (1980) suggest that mound formation requires an impermeable layer beneath the surface such that the overlying soil may become saturated. The impermeable layer can be composed of solid bedrock, or of a frozen substrate.

Each mound was described from a 1m x 1m soil pit located near the apex of the mound. The soil was described in the field based on color, texture, structure, and presence of characteristics such as soil carbonate, and bioturbation. Soil samples were taken from each horizon and for later particle-size analysis in the lab. Samples for Thermoluminescence (TL) dating were also taken from each site. Appropriate locations for TL sampling were based in criteria such as a lack of carbonate accumulation, lack of bioturbation, lack of pedogenic clay, and distance from regolith or other solid rock material. Sampling was done by pounding ~100cm length of 2" PVC into a suitable location, then the pipe with the encased sample was removed and the ends were covered in tin foil and duct tape.

Results:

Ellensburg North Site- The Ellensburg North site is located on a high terrace of Tertiary sidestream alluvium approximately 11 km North of Ellensburg (see Figures 1 and 2). The mound lies at ~655 m on a 1.3 degree West-facing slope. The mound is slightly elliptical, and is significantly larger than the other two sites (measuring ~25 m along the long axis). Furthermore, the mounds in this area have a more subtle profile than the other two sites, and the boundary between the mound and intermound areas is diffuse. Similarly, the vegetation between the mound and intermound area is uniform.

Manastash Creek Site- The Manastash Creek site is approximately 10 km southwest of Ellensburg on a south-facing slope of 2.6 degrees at ~871m elevation (see Figures 3 and 4). The site is underlain by Grande Ronde Basalt of the CRB group (Tabor et al, 1982). The mound that was examined measured ~12 m along the long axis and ~ 1 m at its peak. The mounds in this area are topographically distinct in relation to the intermound area. Rigid Sage and sparse bunch grasses dominate intermound areas, and there are many angular basalt cobbles on the surface that form stone-nets and stone-rings around the mounds. The mounds are dominated by Big Sage, Rabbit-brush, and bunch grasses and are composed of wind-blown silt. During the early spring months when ground moisture from snowmelt is still present the intermound areas are often saturated and difficult to walk over, while the mounds remain unsaturated and easily passable. Also, in winter and early spring the south side of a mound will often remain unfrozen, such that vegetation will 'green-up' a few weeks earlier than the north side.

One sediment sample taken from a depth of ~45 cm was submitted for TL dating and yielded an age of 7.8 +/- 0.7 ka.

Thorp Prairie Site- The Thorp Prairie site is approximately 17 km northwest of Ellensburg on a south-facing slope of 2.8 degrees at ~ 630m elevation (see Figures 5 and 6). The site is found on the upper slope of an end moraine deposited ~600 ka. Mounds in this area typically have a smaller diameter, but are slightly taller. The mound that was described measured ~7 m across the long axis and was slightly over a meter tall. The mound-intermound vegetation contrast was very similar to the Manastash Creek site. Also, the intermound area contained stone-nets and stone-polygons surrounding the mounds.

The soil profile at Thorp Prairie was quite different from any of the other sites that were surveyed. The upper two horizons were comparable with those of the other sites, but at Thorp Prairie there was a buried soil. The buried soil similar to the modern profile but it had a significantly more developed B-horizon. A sediment sample for TL dating was taken from ~46 cm and yielded an age of 5.6 +/- 0.5 ka.

Discussion:

The TL dates were intended to yield information about the age of the loess deposition, which would serve as a limiting age for the formation of the soil mounds. The main assumption of this theory was that the mounds were dissected from a once continuous blanket of loess. If the dates are believed to be accurate, then the mound formation (via the removal of sediment from the intermound area) was mid-to-late Holocene. This timing of formation rules out periglacial processes given the climate during the mid-to-late Holocene (see Barnosky, 1985; Mack et al, 1976; and Thompson et al, 1993). Furthermore, if the dates are believed to be accurate then some other erosional process must be responsible, given that the dates assume that the sediment was not disturbed once it was buried. The lack of strong horizonation in the soil may indicate that the loess deposition was as recent as the mid Holocene, especially when considering the lack of carbonate accumulations in two of the mounds and only a weak reaction with HCl at the Ellensburg North site.

There is also reason to suggest that the dates may not be an accurate limiting age for the mounds. First, all the mounds had evidence of bioturbation, which taken over a few millennia may have disturbed the upper layer of sediment enough to alter the TL ages. Second, there were no exposures of tephra that are found in other parts of the valley (for example see Lamb, 1997), which either indicates that tephra was not preserved at any of the sites or that the tephra has been reworked in the profile and is not identifiable through a hand lens. Without other dates to correlate with the TL dates the accuracy of these dates is unclear.

The TL dates are only a small part of the story of the mounds in the Kittitas Valley. Before a better understanding of their formation can be reached other questions need to be addressed. The distribution of the mounds throughout the valley has only been roughly mapped (see Kaatz, 1959). Accurate mapping of mounds and other related patterned ground features might clarify their relation to topography, geology, or other factors. Also, analysis of the orientations and slopes of mounds may provide information as to the erosional/depositional processes that have shaped the patterned landscape. Finally, a better understanding of the soil profile of the mounds may indicate whether the soil horizons are truncated towards the outer edge of the mounds, and therefore whether or not they are erosional.

Acknowledgements:

This research was funded by and undergraduate research grant through Central Washington University in spring 1998. TL dates were provided by Steve Forman of the Department of Earth and Environmental Sciences at the University of Illinois at Chicago. This project would not have been possible without the help of Karl Lillquist from the Department of Geography at Central Washington University who initiated this project and provided his assistance throughout.

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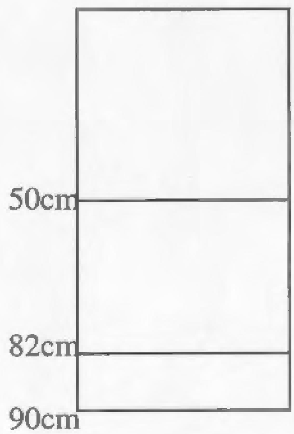
-Figure 1-
Ellensburg North Site Description



A-10YR 4/3, silt loam, hard, structurless, light bioturbation.

Bt- 10YR 4/3, silt loam, slightly hard, weak blocky structure w/cutans on ped faces, light bioturbation.

Rw- Well weathered cobbles w/ weak cutan development.

Site Description:

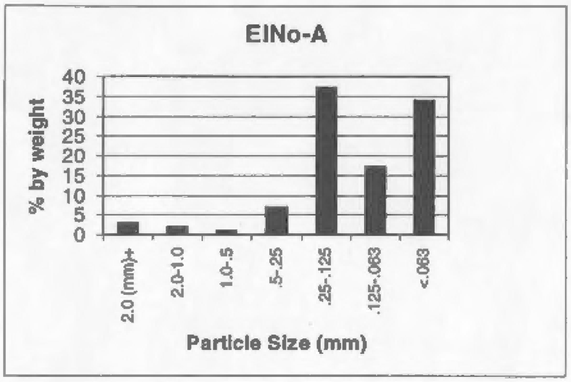
Vegetation- Bitterbrush (*Purshia tridentata*), Cheat grass (*Bromus tectorum*), Bluebunch wheatgrass (*Agropyron spicatum*), and Yarrow (*Achillea millefolium*).

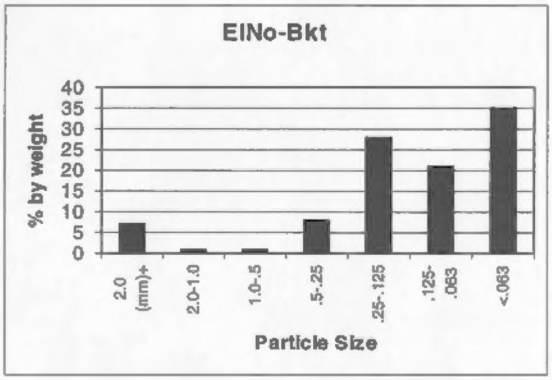
Topography- West-facing slope (1.3 degrees). ~655 m elevation.

Geology- Tertiary sidestream alluvium overlain by Quaternary loess.

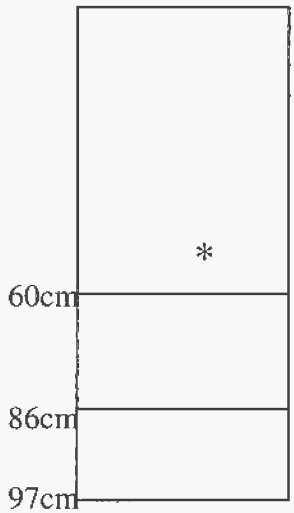
Comments- No obvious stone-ring or other periglacial feature in intermound area.

-Figure 2-
Ellensburg North Site
Particle-size Distribution





-Figure 3-
Manastash Creek Site Description



A- 10YR 6/4, silt loam, structurless, slightly hard, St. Helens ash present in upper few centimeters.

Bkt- 10YR 6/4, silt loam, weak blocky structure w/weak cutan development, hard, strong reaction w/ HCl, some bioturbation.

Rw- In place weathered basalt cobbles w/ cutans.

*-TL sample Wa-MaCr-7/9/98-TL(Bw): Luminescence Age 7.8 +/- 0.7 ka.

Site Description-

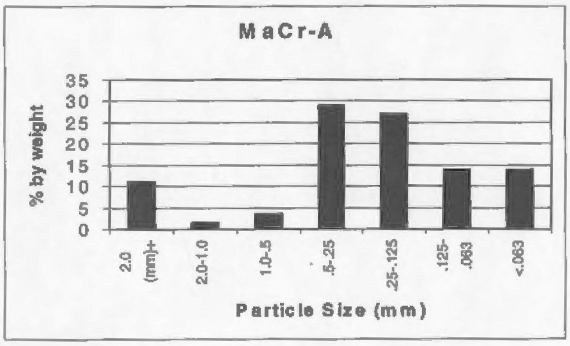
Vegetation- Mound (Big Sagebrush [*Artemesia tridentata*], Rabbit-brush [*Chrysothamnus nauseosus*], Bluebunch wheatgrass [*Agropyron spicatum*], Yarrow [*Achillea millefolium*]); Intermound (Bluebunch wheatgrass [*Agropyron spicatum*], Rigid sage [*Artemesia rigida*].

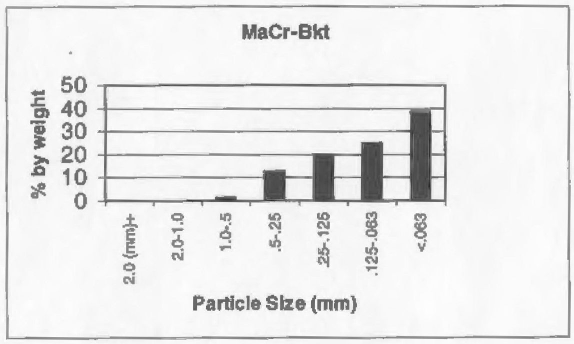
Topography- South-facing slope (2.6 degrees). ~871 m elevation.

Geology- Grande Ronde member of the CRB group overlain by Quaternary loess.

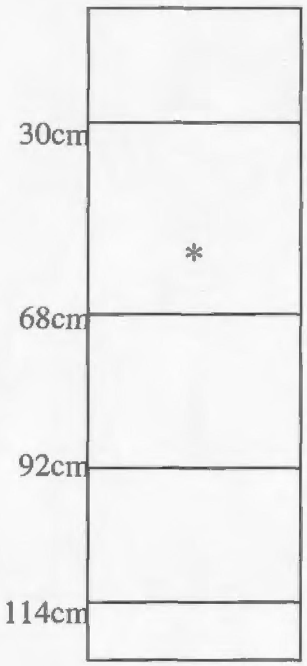
Comments- Mounds bordered by stone rings, and intermound area has stone polygons.

-Figure 4-
Manastash Creek Site
Particle-size Distribution





-Figure 5-
Thorp Prairie Site Description



A- 10YR 6/4, silt loam, slightly hard, structurless, moderate bioturbation.

Bw- 10YR 5/4, clay loam, hard, weak blocky structure, moderate bioturbation.

2A- 10YR 5/4, silt loam, hard, structurless, slight bioturbation.

2Btw- 10YR 4/2, clay loam, hard, weak-moderate blocky structure w/ cutans on ped faces.

Ct- Well weathered clast supported cobbles w/ clay loam matrix and well developed cutans.

*- TL sample WA-Th-7/23/98-TL-1 5.6 ± 0.5 ky

Site Description:

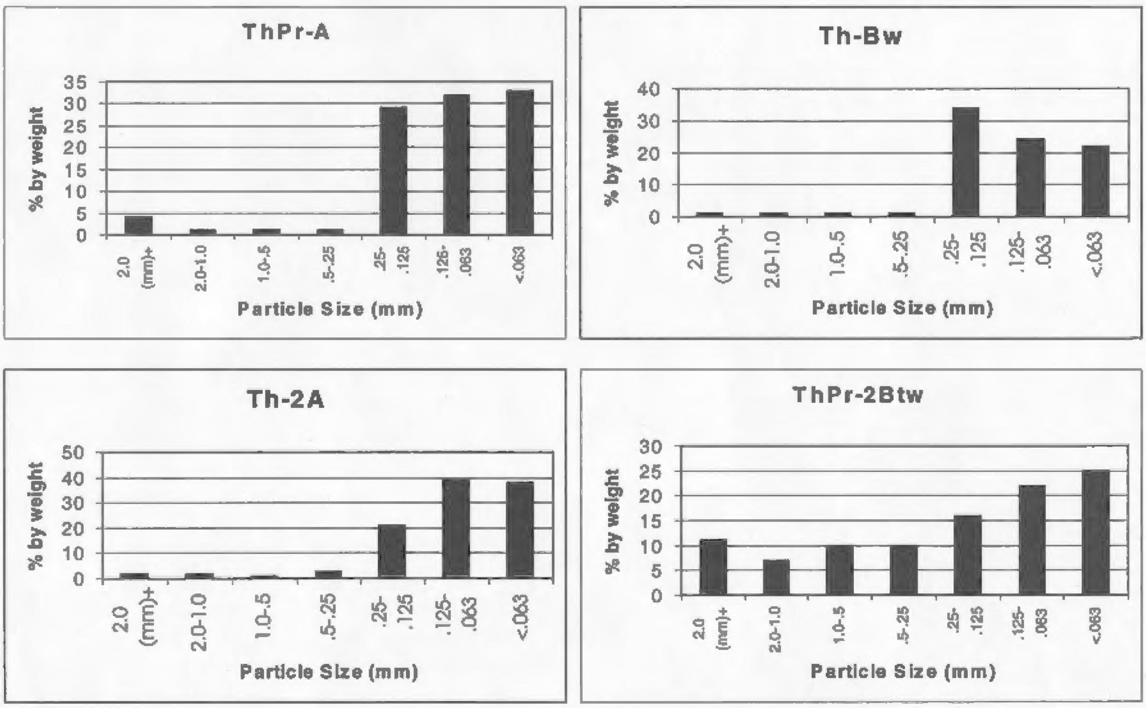
Vegetation- Mound (Big Sage [*Artemesia tridentata*], Yarrow [*Achillea millefolium*], and Rabbit-brush [*Chrysothamnus nauseosus*]); Intermound (Bluebunch wheatgrass [*Agropyron spicatum*], and Rigid Sage [*Artemesia rigida*]).

Topography- South-facing slope (2.8 degrees). ~630 m elevation.

Geology- Quaternary (~600 ka) end morraine till overlain by Quaternary Loess.

Comments- Stone-ring present around mound and stone-nets in intermound area.

-Figure 6-
Thorp Prairie Site
Particle-size Distribution



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March 21, 1999

Professor Karl Lillquist
Dept. of Geography and Land Studies
Central Washington University
Lind Hall 119
400 E. 8th Avenue
Ellensburg, WA 98926-7420

Dear Karl,

Below is a tabulation and discussion of luminescence ages for your loess samples from Kittitas Basin, Washington.

Thermoluminescence luminescence analyses were completed on the 4-11 micron polymineral fraction. The resultant blue emission is measured using 5-58 and 66-400 Corning filters. The total bleach method was used with the residual level defined by 8 hours exposure to an UV-dominated lamp. Both linear and exponential fits were used to model the additive dose response; there was no statistical difference in the generated equivalent doses from these fits. The equivalent dose was calculated from temperatures between 250 and 350 °C. The precision of analysis is very good, with dispersion in additive dose response usually ≤10%. Dose rate estimate was calculated from alpha counting to determine U and Th content (assuming secular equilibrium) and elemental analysis to provide for ^{40}K component. Moisture content of 20 ± 5 % was assumed in the final age calculation. I would gladly provide more analytical details, if needed

Table 1: Thermoluminescence age estimates for near-surface loess samples from Kittitas Basin, Washington.

Field #	Laboratory #	Equivalent Dose (Gy)	Dose Rate (Gy/ka)	Luminescence Age(ka)
Wa-MaCr-7/9/98-TL(Bw)	UIC-671	16.94 ± 0.62	2.18 ± 0.18	7.8 ± 0.7
Wa-~~MaCr~~ Th-7/23/98-TL-1	UIC-670	11.52 ± 0.17	2.07 ± 0.18	5.6 ± 0.5

I hope these TL age estimates are useful for your research.

Sincerely,

Steve Forman

Steve Forman
Associate Professor of
Earth and Environmental Sciences

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